ISLAMIC UNIVERSITY OF TECHNOLOGY
(The Organization of Islamic Cooperation)

STUDY ON
ROOPPUR NUCLEAR POWER PLANT (RNPP)

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Declaration

We hereby declare that the study report has not been submitted elsewhere for obtaining any degree or diploma or certificate or for publication and as such is accepted for fulfilling the requirement of Degree of Bachelor of Science in Electrical and Electronic Engineering.

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Abstract

This study was undertaken to study on 'Rooppur Nuclear Power Project (RNPP)' as a part of power crisis in our country. Day by day population is increasing and also power demands are also increasing. Government is trying to meet up the power crisis in Bangladesh by taking various steps but it's still not satisfactory to ensure uninterrupted quality power supply to the electricity consumers. Nuclear power is desirable in Bangladesh, due low per capita fossil fuel reserves and socio- economic realities. Nuclear power will diversify the primary energy sources required for energy conservation as well as it will reduced pressure on the traffic system as fuel requirement of nuclear power plant is very low.

The purpose of this paper is to introduce nuclear energy, prospect of nuclear energy in Bangladesh, need of nuclear power plant and other necessary steps ot establish a safe , efficient and economically and socially beneficial nuclear power plants.

Acknowledgements

At first every respect to the greatest Almighty Allah to give us the opportunity to do this work with patience for the last one year. This undergraduate thesis

“Study on Rooppur Nuclear Power Plant (RNPP)” is the result of our one year continuous hard work and effort and by far the most significant accomplishment in our life. This would be impossible without continuous support and appreciation of many people.

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Chapter 1

INTRODUCTION

Electricity is the most prospective in basis of economic growth of a country and constitutes one of the vital infrastructural inputs in socio-economic development .The world faces a surge in demand for electricity that is determined by powerful forces as population growth, urbanization, industrialization and the rise in the standard of living.

Bangladesh, with its 160 million people in a land mass of 147,570sq km. In 1971, just 3% of Bangladesh's population had access to electricity. Today that number has increased to around 50% of the population –still one of the lowest in the world, but this access often amounts to just a few hours each day. Bangladesh claims the lowest per-capita consumption of commercial energy in South Asia, but still there is a significant gap between supply and demand. Bangladesh's power system depends on fossil fuels supplied by both private sector and state-owned power system. After system losses, the countries per installed capacity for electricity generation can generate 3,900-4300 Megawatts of electricity per day; however, daily demand is near 6,000 Megawatts per day. In general, rapid industrialization and urbanization has propelled the increase in demand for energy by 10% per year. What further aggravates Bangladesh's energy problems is the fact the country's power generation plants are dated and may need to be shut down sooner rather than later.

There was no institutional framework for renewable energy before 2008; therefore the renewable energy policy was adopted by the government. According to the policy an institution, Sustainable & Renewable Energy Development Authority (SREDA), was to be established as a focal point for the promotion and development of sustainable energy, comparison of renewable energy, energy efficiency and energy conservation. Establishment of SREDA is still under process. Power division is to facilitate the development of renewable energy until SREDA is formed.

While the power sector in Bangladesh has witnessed many success stories in the last couple of years, the road that lies ahead is dotted with innumerable challenges that result from the gaps that exist between what's planned versus what the power sector has been able to deliver. There is no doubt that the demand for electricity is increasing rapidly with the improvement of living standard, increase of agricultural production, progress of industries as well as overall development of the country.

Chapter 2

POWER GENERATION ALTERNATIVES

Electricity generation in Bangladesh is mainly fueled by either primary energy sources such as coal and natural gas or the renewable energy sources like hydroelectric power and solar power. Here, in this section we will discuss the electricity generation alternatives in the view of Bangladesh.

2.1 Coal

Coal is the most widely used fuel in Bangladesh as well as in the whole world for electricity generation purpose. A handful amount of coal reserves around the world has given it a huge popularity.

Bangladesh has significant coal reserve. Coal reserves of about 3.3 billion tons comprising 5 deposits at depths of 118-1158 meters have been discovered so far in the north-western part of Bangladesh. The name of these deposits are-Barapukuria, Phulbari and Dighipara coal field in Dinajpur district, Khalashpir in Rangpur district and Jamalganj in Joypurhat district. Out of which 4 deposits (118-509 meters) are extractable at present. The depth of Jamalganj coal deposit is 640-1158 meter with 1053 Million Tones in-situ coal reserve where production may not be viable by present day's technology due to the depth of the deposits. Possibilities of extraction of Coal Bed Methane (CBM) need to be explored from this coal deposits. Government is actively reviewing law to be applicable for Exploration and Production of Coal Bed Methane. So far, only Barapukuria coal field is under production.

The main drawbacks of coal based power plants are-

- ❖ Low efficiency
- ❖ High Transportation cost
- ❖ Higher emission of GHGs

Table below shows major coal fields and reserves in Bangladesh.

Coal field (district)	Year of discovery	Discovered by	Depths of coal seam (in meter)	No. of coal seam	Reserve (million ton)	Status
Jamalganj (Joypurhat)	1962	SVOC	640-1158	7	1053	Mining not feasible economically
Barapukuria (Dinajpur)	1985	GSB	118-509	6	303	Underground mine started production
Khalashpir (Rangpur)	1989	GSB	257-451	8	147	Undeveloped
Dighipara (Dinajpur)	1995	GSB	250	7	200	Undeveloped
Phulbari (Dinajpur)	1997	BHP	152-246	1	380	Open pit mine feasibility study undertaken in 2004

Source Petrobangla; Geological Survey of Bangladesh

2.2 Natural Gas

Natural Gas is one of the most important of natural resources. Our country has huge natural gas.

Bangladesh natural gas production began in 1960 from the Chattak Filed. There is much uncertainty and debate about the level of natural gas reserves in Bangladesh. Estimates from Petrobangla put net proven reserves at 15.3 Tcf as of mid-2004.

Petrobangla has approximately 20 natural gas fields nationwide, half of which are active. The main fields include.

- Bibiyana (discovered by Unocal in Block)
- Titas (Second largest natural gas field in the countries)
- Habiganj
- Kailastilla
- Rashipur
- Jalalabad
- Sangs off shore natural gas field.

Other possible natural gas field include Shaldanadi, Fenchuganj, Feni, Kumta and Shahbajpur.

- UNOCAL announced in March 2003 that it would begin development of the Moulavi Bazar field in Block 14.
- Shahbazpur, discovered by Petrobangla subsidiary BAPEX in 1995, is estimated to contain 330-400 of recoverable natural gas.

In our country invented may gas field. Some of being gas field are described below.

2.2.1 Jalalabad Field:

This is the biggest gas field in Bangladesh.

- ❖ Unocal started natural gas production form the Jalalabad Field on Block 13 in February 1999.
- ❖ At a production rate of 80-100 million cubic feet of natural gas per day.
- ❖ Jalalabad supplies approximately 12 percent of the countries gas demand.
- ❖ The field contains an estimated 1.6 Trillion cubic feet of gas- in place.

2.2.2 Bibiyana Field:

- ❖ Unocal discovered the Bibiyana gas field on block 12 in 1998.
- ❖ The report concluded that Bibiyana is a world class accumulation of natural gas.
- ❖ The Bibiyana field is estimated to hold as much as 5.5 trillion cubic feet (TCF) of recoverable reserves of natural gas and 30.7 million bevels (MMBBIS) of condensate.
- ❖ The 3-D seismic survey is the first time this technology has been used in Bangladesh and provides a move accurate reserve appeasement then 2-D seismic surveys.

2.2.3 Moulavi Bazar Field:

- ❖ Unocal has signed a natural gas purchased and sales agreement with Petrobangla to develop the Moulavi Bazar Field.
- ❖ Unocal expects to produce 70 to 100 million cubic feet of gas per day from the field beginning in the first quarter 2005.
- ❖ Unocal discovered the Moulavi Bazar field on block 14.
- ❖ The Moulavi Bazar # 3 wall set a record for drilling time and low cost.

The drawbacks for which natural gas is not considered as a good choice of fuel for electricity generation are given below

- ❖ Mainly the produced gases are used to feed the energy demand of the nation. Now a days it is very popular as vehicle driving fuel.

- ❖ Mixture of methane and other alkanes with a lesser Percentage of Carbon di Oxide, Nitrogen and hydrogen sulfide. Thus purification process is a difficult and costly job.

- ❖ Transportation is difficult. Therefore generation cost is high.
- ❖ Using natural gas as a fuel emits an enormous amount of GHGs.

2.3 Oil

Bangladesh Petroleum Exploration & Production Company Ltd (BAPEX) has determined, through a seismic survey, presence of around 150 million barrels of oil in old gas fields of Kailashtila and Haripur in Sylhet.

Around 700 barrels a day could be produced from the two fields under Sylhet Gas Field Company Ltd. Roughly, seven barrels equal to a ton. Which is not so attractive to be extracted.

OIL RESERVE		
Field	total reserve (million barrels)	producible (minimum)
Kailashtila	110	44
Haripur	44	17

No less than 40 percent of this small reserve could be commercially produced. The U.S. Energy Information Administration provides data for Bangladesh from 1988 to 2014. The average value for Bangladesh during that period was 0.03 billion barrels with a minimum of 0 billion barrels in 1988 and a maximum of 0.06 billion barrels in 1999.

2.4 Renewable energy:

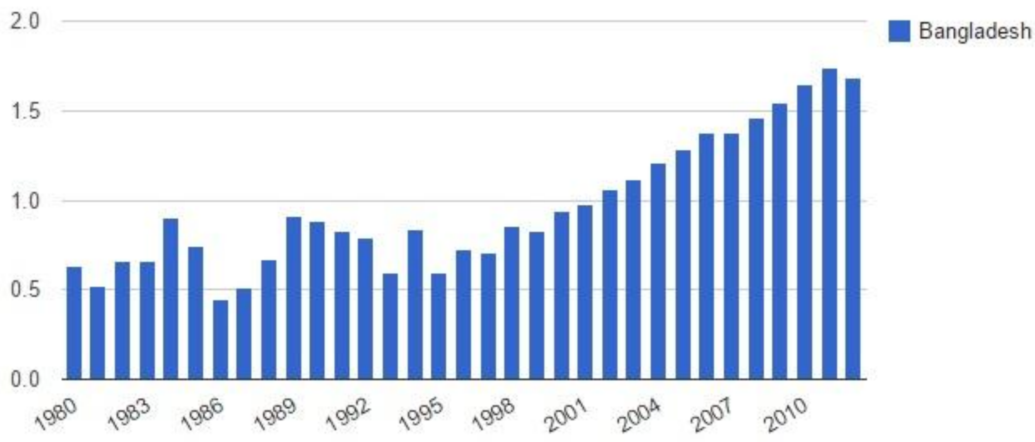
Bangladesh is currently using two forms of nuclear energy. These are hydroelectric power and solar power.

2.4.1 Hydroelectric Power

Hydroelectric power, the power generated using the gravitational force of water flow is the most widely used form of renewable energy around the world. This method of electricity generation is used in near 150 countries.

Kaptai Dam is on the Karnaphuli River at Kaptai, 65 kilometers (40 mi) upstream from Chittagong in Rangamati District, Bangladesh. It is an earth-fill embankment dam with a reservoir (known as Kaptai Lake) water storage capacity of 6,477,000,000 m3 (5,250,989 acre·ft). The primary purpose of the dam and reservoir was to generate hydroelectric power. Construction was completed in 1962. The generators in the 230 MW Karnaphuli Hydroelectric Power Station were commissioned between 1962 and 1988. It is the only hydroelectric power station in Bangladesh.

The U.S. Energy Information Administration provides data for Bangladesh from 1980 to 2012. The average value for Bangladesh during that period was 0.96 billion kilowatt-hours with a minimum of 0.45 billion kilowatt-hours in 1986 and a maximum of 1.74 billion kilowatt-hours in 2011.



The crucial drawbacks of hydroelectricity are given below:

- Damages ecosystem which disturbs nature.
- Creates siltation and flow shortage which causes river dry out.
- Methane emission from reservoirs which affects the ozone layer and commits global warming.

2.4.2 Solar Power

Solar power is the conversion of sunlight into electricity, either directly using photovoltaic (PV), or indirectly using concentrated solar power (CSP). Concentrated solar power systems use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam. Photovoltaic convert light into electric current using the photovoltaic effect.

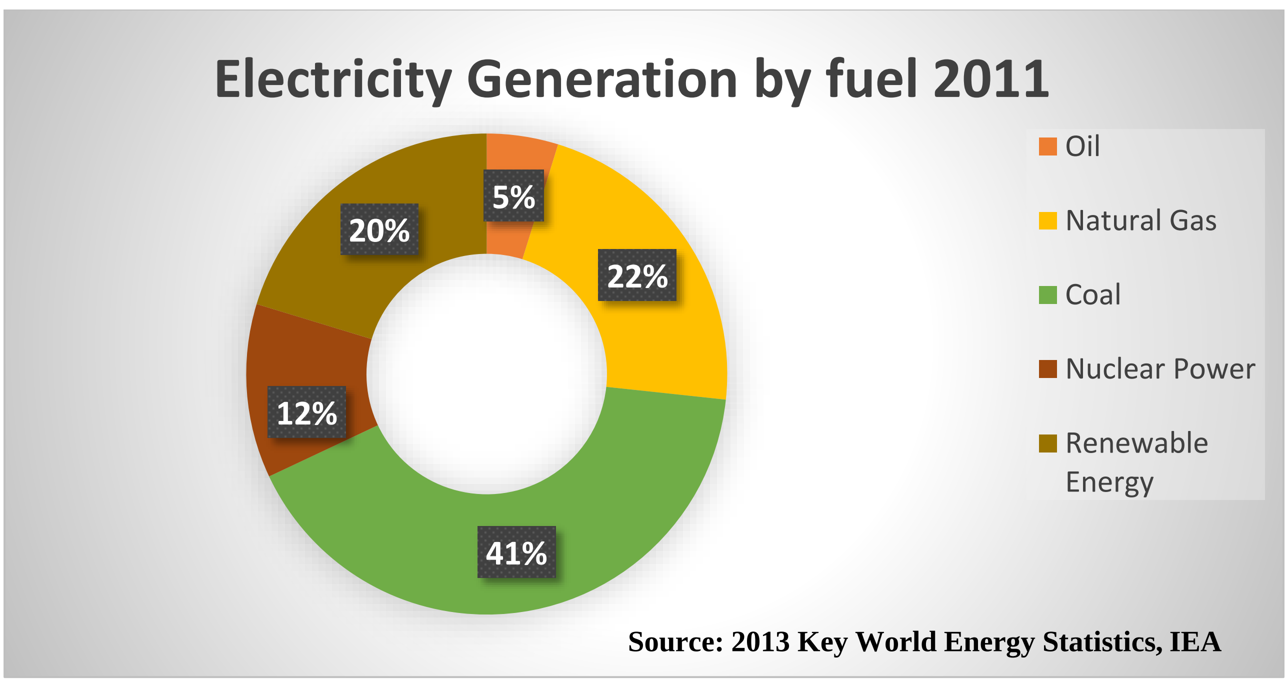
Bangladeshi Government has already launched "500 MW Solar Power Mission" to promote the use of Renewable Energy to meet the increasing demand of electricity. The government has installed the biggest solar power plant on the rooftop of the Bangladesh Bureau of Statistics building in Dhaka. The plant with a 200 kwp (kilowatt peak) generation capacity, equivalent to lighting up 5,000 bulbs of 40 watts, will meet a significant portion of the building's demand for electricity, which has been installed at a cost of more than 2.93 crore taka.

Solar power also has some drawbacks in mass electricity generation

- ❖ This method is not so popular for commercial generation of electricity.
- ❖ Used for small and medium sized applications.
- ❖ Very low efficiency makes it a lower ordered choice.
- ❖ Unreasonably expensive equipment needed for electricity generation, which makes it rather unwanted.

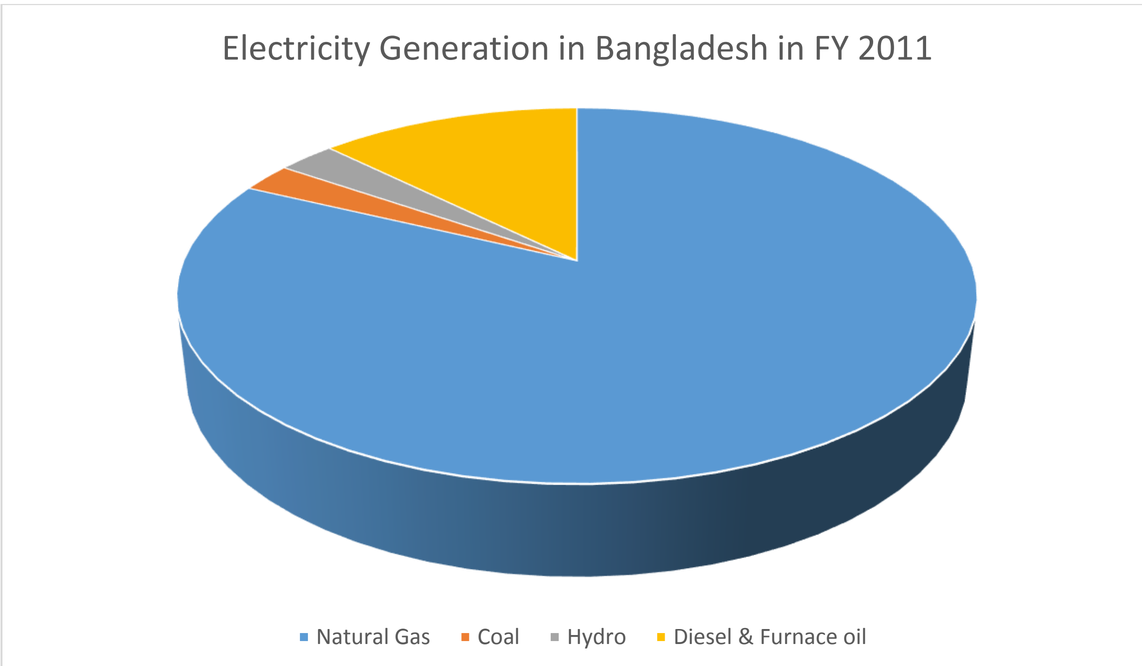
2.5 World Power Status

Now we want to take a glance at the worldwide situation of fuel used for electricity generation. The data here has been achieved for the year of 2013.



2.6 Bangladesh power status

Now if we take a look at the national scenario we can see that we are lagging behind because of not adapting the modern technology of nuclear power. As we are already not rich of oil production we must sooner or later start generation of electricity using nuclear power.



Chapter 3
NUCLEAR POWER

In this chapter, we will briefly discuss about the basics of nuclear power, nuclear fuel, nuclear reactors, how it contributes to electricity generation, how the wastes are managed. Also in the end of the chapter, a small history on the major nuclear accidents have been discussed.

3.1 What is Nuclear Power?

Nuclear power is energy contained in atoms. This energy can be released as heat from a chain reaction in a radioactive element such as uranium. Nuclear power stations use this heat to produce steam, which drives turbines to generate electricity.

There are two types of reaction in which this energy can be released. Fission and fusion.

In fission reaction, the fissile material is split into fission fragments, neutrons and substantial heat energy approximately 190 MeV.

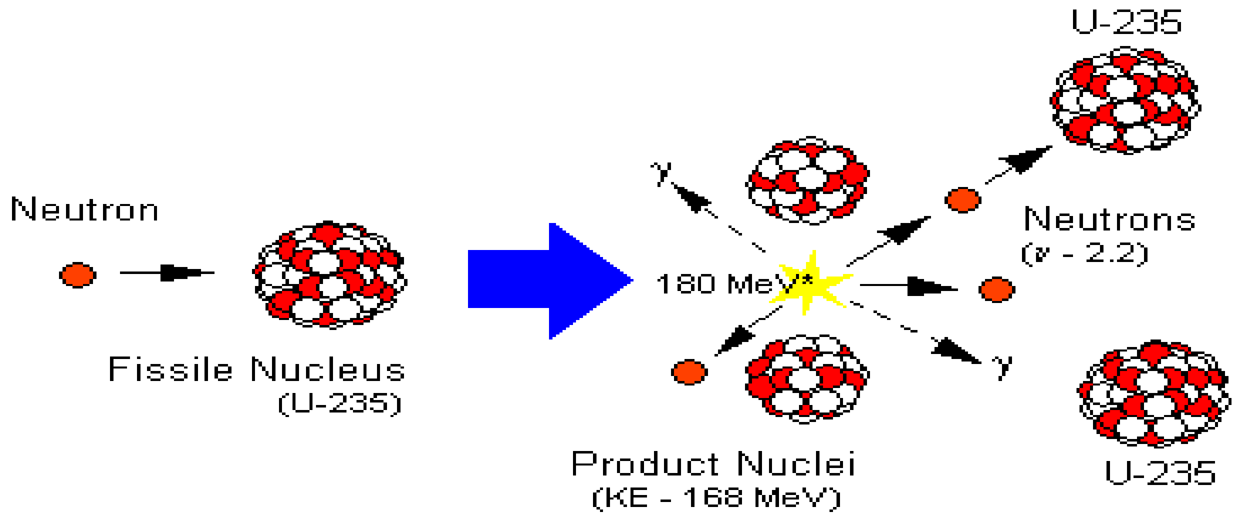


Figure: Fission Reaction

Let’s consider the following fission reaction –

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{139}_{56}Ba + ^{94}_{36}Kr + 3\ ^{1}_{0}n$$

Here, uranium is split into two lighter nucleus after being hit by a neutron and releases about 190 MeV energy.

In fusion reaction, two light atomic nuclei collide and join together to form one heavy nucleus and release heat energy. The released energy varies from 3.27 MeV to 18.35 MeV.

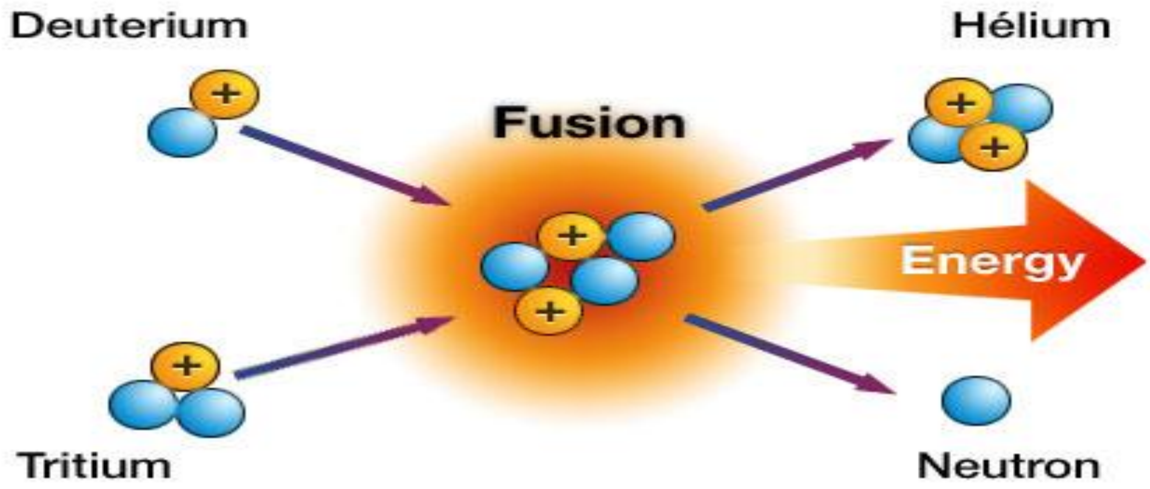


Figure: Fusion Reaction

Examples of fusion reactions are given below -

$$\text{D-D:}\quad {}^2_1\text{H} + {}^2_1\text{H} \rightarrow \begin{cases} {}^3_1\text{H} + {}^1_1\text{H} + 4.03\ \text{MeV} \\ {}^3_2\text{He} + {}^1_0\text{n} + 3.27\ \text{MeV} \end{cases}$$

$$\text{D-T:}\quad {}^2_1\text{H} + {}^3_1\text{H} \rightarrow {}^4_2\text{He} + {}^1_0\text{n} + 17.59\ \text{MeV}$$

$$\text{D-}^3\text{He:}\quad {}^2_1\text{H} + {}^3_2\text{He} \rightarrow {}^4_2\text{He} + {}^1_1\text{H} + 18.35\ \text{MeV}$$

3.2 Nuclear fuel & fuel cycle:

The driving material that produces nuclear energy through fission or fusion is called nuclear fuel. It can be the fuel itself or physical objects composed of the fuel material. Some of the examples would be Oxide fuel, Metal fuel, ceramic fuels, liquid fuels. Nuclear fuel contains heavy fissile elements that are capable of producing huge amount of heat energy when struck with neutrons.

Uranium-235 is the only nuclear fuel available in nature that undergoes fission. It is called fissile fuel. In natural uranium it consists of only 0.71% by weight. The rest of the uranium is normally uranium-238 and some traces of uranium-234. Normally uranium-238 does not undergo fission but if they are converted to plutonium-239 through neutron absorption they can again produce heat energy through fission. Thus uranium-238 is called fertile fuel. Another fissile fuel is Thorium-232, also available in nature which can be converted to Thorium-233 through same process.

The nuclear fuel cycle is the series of industrial processes which involve the production of electricity from nuclear fuel in nuclear power reactors. It consists of steps in the *front end*, which are the preparation of the fuel, steps in the *service period* in which the fuel is used during reactor operation, and steps in the *back end*. If spent fuel is not reprocessed, the fuel cycle is referred to as an *open fuel cycle*; if the spent fuel is reprocessed, it is referred to as a *closed fuel cycle.*

The steps in fuel cycle are exploration, mining, milling, conversion, enrichment, fuel fabrication, electricity generation, spent fuel storage, reprocessing and high level waste storage.

Nuclear fuel-uranium mine is first explored. Then there are three ways to mine uranium; open pit mines, underground mines and in situ leaching where uranium is leached directly from the ore. The concentration of uranium in the ore could range from 0.03% to 20%. Then mined uranium is crushed and chemically treated to separate the uranium. The result is a ‘yellow cake’ of uranium oxide (U_3O_8). In yellow cake uranium concentration is raised up to 80%. As natural uranium consists only -71% of uranium-235, enrichment of uranium-235 is necessary. Yellow cake is converted into uranium hexafluoride (UF_6) gas and then enriched. However enriched uranium cannot be directly used in nuclear reactors as it does not withstand the high temperatures or pressure. So it is converted into uranium oxide (UO_2) to achieve high density and stability. They are packed in long metal tubes to form metal fuel rods.

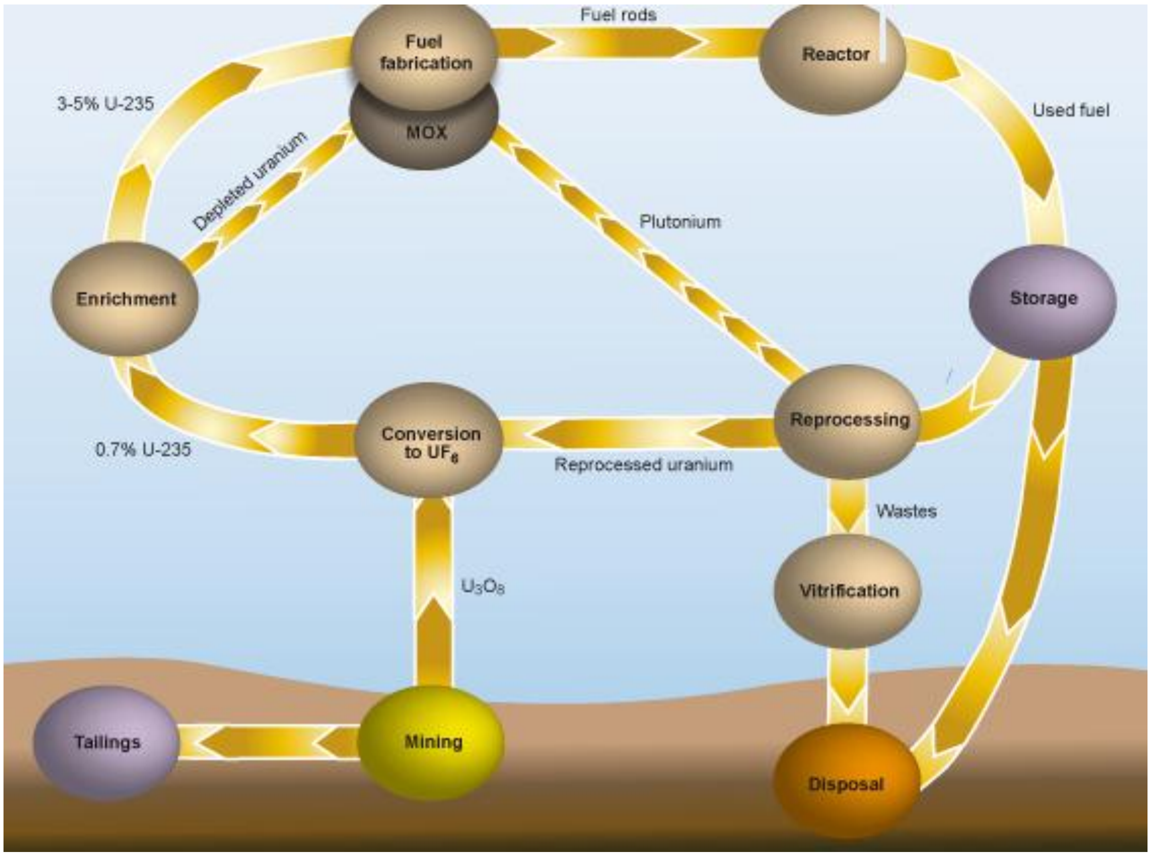


Figure: Nuclear Fuel Cycle

Once the fuel is loaded in reactor, controlled fission can occur and produce heat energy (190 MeV). Refueling is needed in 12-18 months. After few years the fuel becomes unable to split into atoms. It is then referred as spent fuel. Spent fuel is highly radioactive. So it is stored at nearby cool water pool for 20-40 years. Then either is reprocessed to get unused plutonium and uranium and recycled or directly disposed.

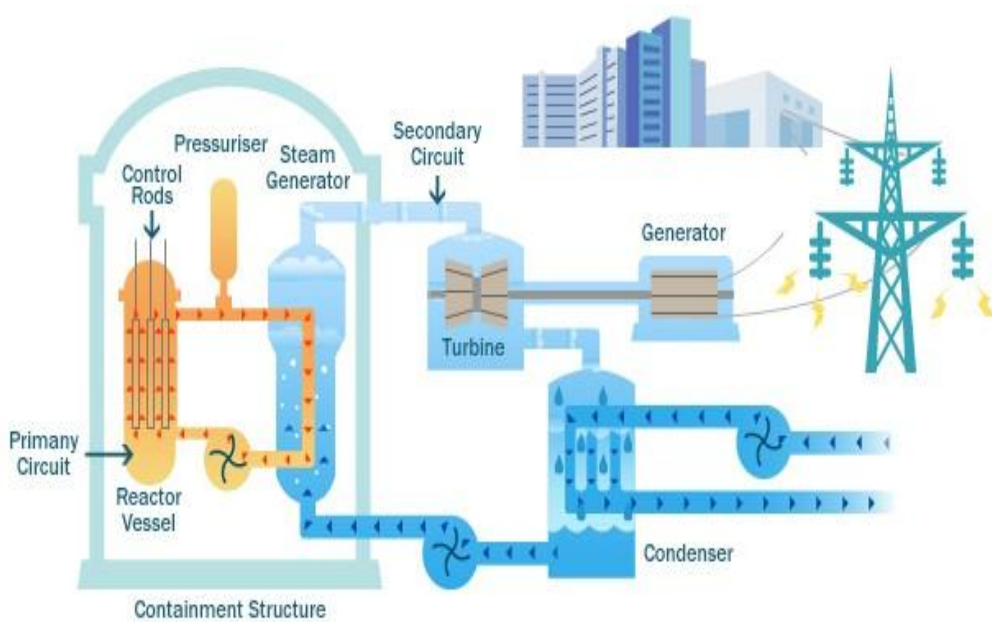
3.3 Nuclear Reactors

Fission reaction which is responsible for releasing huge amount of heat energy takes place inside reactor core. Reactors can be classified based on fuel, moderator and coolant, type of reaction. Reactors can be light water, heavy water or graphite water based on moderator. Light water reactor can be divided into pressurized water reactor and boiling water reactor. If moderator slows down fission neutrons it is called thermal reactors and if fast neutrons are used for fission it is called fast neutron reactor. Based on type of fuel reactors are classified as natural uranium fueled and enriched uranium fueled reactors.

3.3.1 Pressurized Water Reactor (PWR)

This is the most common type. PWRs use ordinary water as both coolant and moderator. The design is distinguished by having a primary cooling circuit which flows through the core of the reactor under very high pressure, and a secondary circuit in which steam is generated to drive the turbine. In Russia these are known as VVER types.

A PWR has fuel assemblies of 200-300 rods each, arranged vertically in the core, and a large reactor would have about 150-250 fuel assemblies with 80-100 tons of uranium.



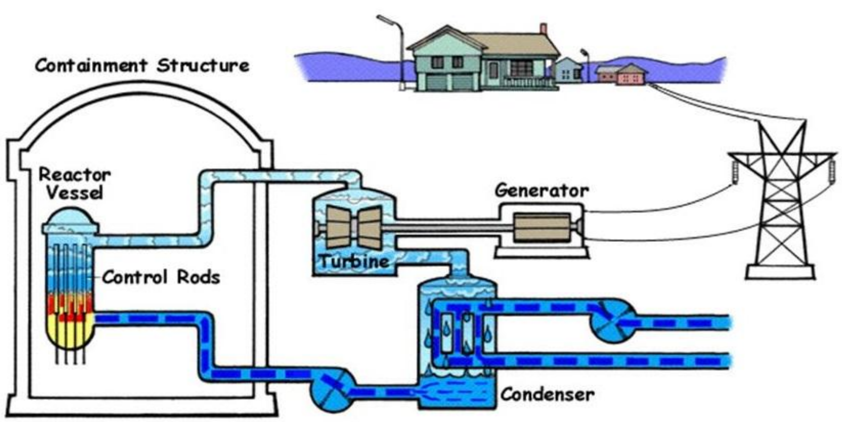
Water in the reactor core reaches about 325°C. It must be kept under about 150 times atmospheric pressure to prevent it from boiling. Pressure is maintained by steam in a pressurizer. In the primary cooling circuit the water is also moderator.

In the secondary circuit water boils in the heat exchangers which are steam generators. The steam drives the turbine to produce electricity. Steam then moves through condenser and returned to the heat exchangers in contact with the primary circuit.

3.3.2 Boiling Water Reactor (BWR)

It is the second most common reactor. It has many similarities to PWR, except that there is only a single circuit in which the water is at lower pressure (about 75 times atmospheric pressure) so that it boils in the core at about 285°C. BWR has one single water loop unlike PWR.

The steam passes through drier plates above the core and then directly to the turbines, which are thus part of the reactor circuit. Since the water around the core of a reactor is contaminated radioactive particles, it means that the turbine must be shielded and radiological protection provided during maintenance. The cost of this tends to balance the savings due to the simpler design. Most of the radioactivity in the water is very short-lived.

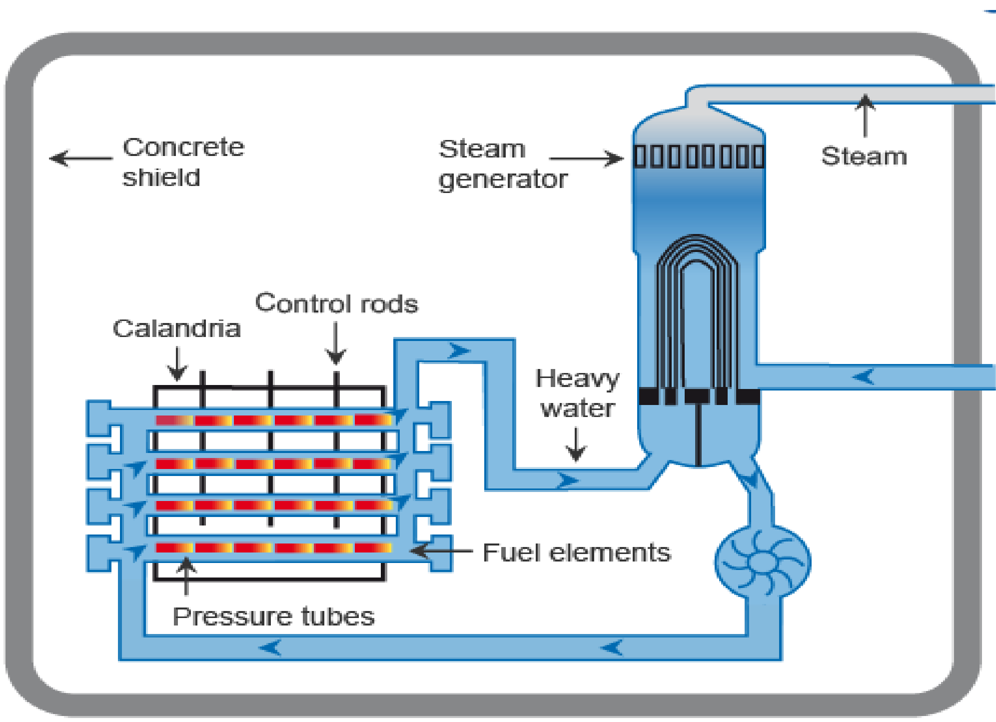


A BWR fuel assembly comprises 90-100 fuel rods, and there are up to 750 assemblies in a reactor core, holding up to 140 tons of uranium.

3.3.3 Pressurized Heavy Water Reactor (PHWR or CANDU)

The PWHR are advanced model of PWRs. This are used mainly in Canada, more recently in India. PHWRs generally use natural uranium (0.7% U-235) oxide as fuel. Moderator used is heavy water (D_20)

The moderator is in a large tank called a calandria, penetrated by several hundred horizontal pressure tubes which form channels for the fuel, cooled by a flow of heavy water under high pressure in the primary cooling circuit, reaching 290°C. As in the PWR, the primary coolant generates steam in a secondary circuit to drive the turbines. The pressure tube design means that the reactor can be refueled without shutting down, by isolating individual pressure tubes from the cooling circuit. It is also less costly to build. But the tubes have not proved as durable.

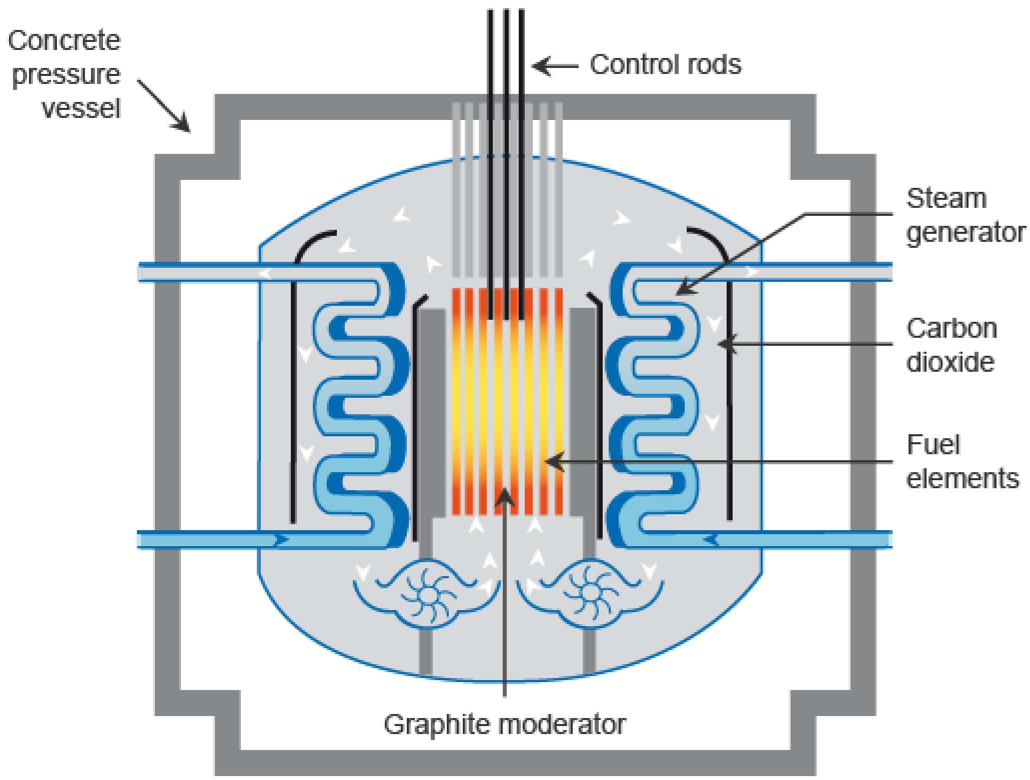


A CANDU fuel assembly consists of a bundle of 37 half meter long fuel rods plus a support structure. Control rods penetrate the calandria vertically, and a secondary shutdown system involves adding gadolinium to the moderator. The heavy water moderator circulating through calandria vessel also yields some heat.

CANDU reactors may run on recycled uranium, or a blend of this and depleted uranium left over from enrichment plants.

3.3.4 Advanced Gas Cooled Reactor (AGR)

These are the second generation of British gas-cooled reactors, using graphite moderator and carbon dioxide as primary coolant. The fuel is uranium oxide pellets, enriched to 2.5-3.5%, in stainless steel tubes. The carbon dioxide circulates through the core, reaching 650°C and then past steam generator tubes outside it, but still inside the concrete and steel pressure vessel. Control rods penetrate the moderator and a secondary shutdown system involves injecting nitrogen to the coolant.



The AGR was developed from the Magnox reactor, also graphite moderated and CO_2 cooled.

3.3.5 Light water graphite-moderated reactor (RBMK)

This is a Soviet design, developed from plutonium production reactors. It employs long vertical pressure tubes running through graphite moderator, cooled by water, which is allowed to boil in the core at 290°C. Fuel is low-enriched uranium oxide made up into fuel assemblies 3.5 meters long. With moderation largely due to the fixed graphite, excess boiling simply reduces the cooling and neutron absorption without inhibiting the fission reaction, and a positive feedback problem can arise, which is why they have never been built outside the Soviet Union.

3.3.6 Advanced reactors

Several generations of reactors are commonly distinguished. Generation I reactors were developed in 1950-60s and only one is still running today. They mostly used natural uranium fuel and used graphite as moderator. Generation II reactors use enriched uranium fuel and are mostly cooled and moderated by water. Generation III are the Advanced Reactors evolved from these, the first few of which are in operation in Japan and others are under construction and ready to be ordered. They are developments of the second generation with enhanced safety. There is no clear distinction between Gen II to Gen III.

Generation IV designs are still on the drawing board and will not be operational before 2020 at the earliest, probably later. They will tend to have closed fuel cycles and burn the long-lived actinides now forming part of spent fuel, so that fission products are the only high-level waste. Of seven designs under development, 4 or 5 will be fast neutron reactors. Four will use fluoride or liquid metal coolants, hence operate at low pressure. Two will be gas-cooled. Most will run at much higher temperatures than today’s water-cooled reactors.

3.3.7 Fast neutron reactors (FNR)

Some reactors (only one in commercial service) do not have a moderator and utilize fast neutrons, generating power from plutonium while making more of it from the U-238 isotope in or around the fuel. While they get more than 60 times as much energy from the original uranium compared with the normal reactors, they are expensive to build. Further development of them is likely in the next decade.

Chapter 4

BANGLADESH POWER STATUS

4.1 History & trend of power Development in Bangladesh

In 1947, power generation and distribution of this part of the country were in the hands of some private companies. The power supply to then 17 provincial districts was within the township in a limited way. The generation voltage was 400 volts. Power used to be supplied to most of the districts during nighttime only. Only exception was Dhaka City where power used to be supplied by two 1500 kW generators and the generation voltage was 6600 volts and this was the highest supply voltage. There was no long distance transmission lines. In aggregate the generation capacity of the country was 21 MW. The generation capacity of the power utility companies together was only 7 MW and there was no transmission system.

In 1948, Electricity Directorate was created in order to plan and improve power supply situation.

In 1959, Water and Power Development Authority (WAPDA) was created and the power sector really started working satisfactorily.

In 1960, Electricity Directorate was merged with WAPDA. At that time relatively higher capacity plants were built at Siddhirganj, Chittagong and Khulna. At the same time Kaptai dam was under construction under Irrigation department. Unit size of Kaptai was 40 MW, which for that time was considered to be a large power plant.

Side by side construction of Dhaka-Chittagong 132 KV transmission line was in progress. Construction of Kaptai dam and commissioning of Dhaka-Chittagong 132 KV transmission line in the year 1962 may be taken as milestone of power development of this country.

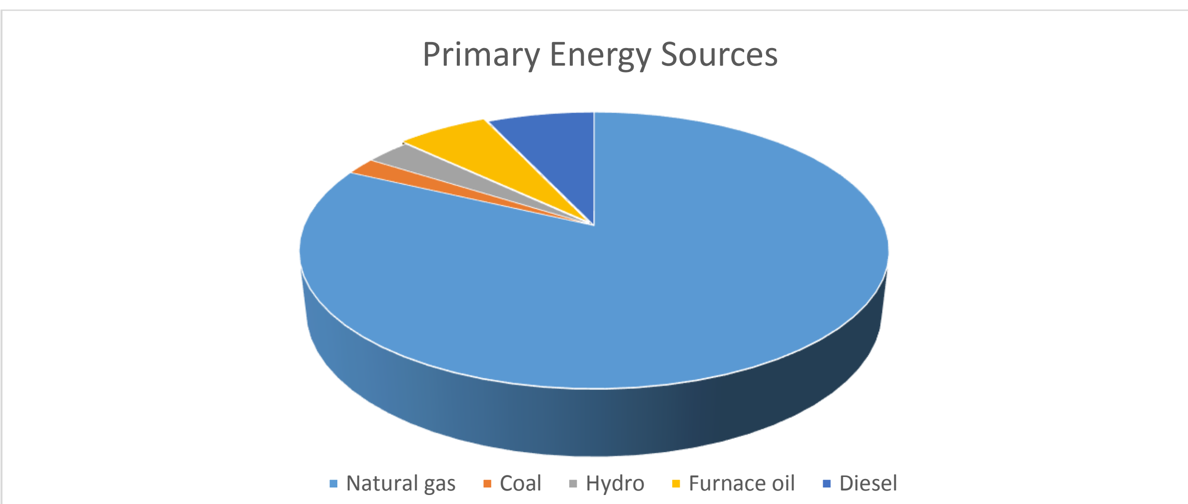
In 1972, after the emergence of Bangladesh through a bloody War of Liberation as an independent state, Bangladesh Power Development Board (BPDB) was created as a public sector organization to boost the power sector.

The Government created Rural Electrification Board (REB) in October 1977.

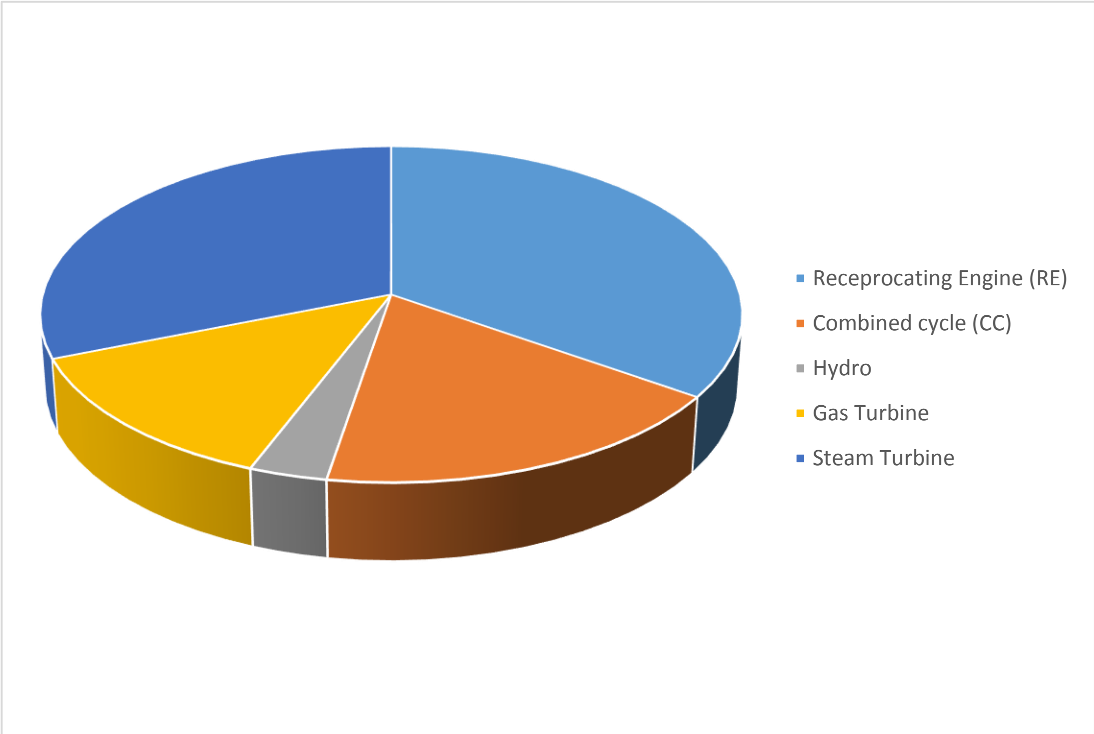
Later in 1991 Dhaka Electric Supply Authority (DESA) now DPDC was created basically to operate and develop distribution system in and around Dhaka and bring about improvement of customer service, collection of revenue and lessen the administrative burden of BPDB.

As on June-2012, in FY 2011-2012, BPDB has total installed capacity of 8716 MW at 120 units (BPDB 4910 MW at 60 Unit and IPP, SIPP & Rental at 60 units) of Power Plants located at different parts of the country. The main fuel used for power generation is indigenous gas. Total 16,012 Gwh gross energy was generated in the public sector power plant under BPDB. In addition, total 18,196 Gwh of energy was purchased by BPDB from Independent Power Producers (IPP, SIPP & Rental) in the private sector. The maximum demand served during peak hours is 6350 MW in August 04, 2012. The transmission network is 8616 ckt km long comprising 230, 132 and 66 KV lines. The total numbers of grid sub-stations are 114 and the total capacity is 17,717 MVA as on June-2011.

4.2 Electricity produced by Primary energy sources in Bangladesh



4.3 Power status of Bangladesh Generation capacity (plant type)



4.4 Power sector, generation & distribution

- Electricity Growth : 7.20 % in FY-2011 (Av. 7 % since 1990)
- Generation Capacity : 7119 MW (Oct., 2011)
- Total Consumers : 12.5 Million
- Transmission Lines : 8,600 km
- Distribution Lines : 2,78,000 km
- Per Capita Generation : 252 kWh(incl. Captive)
- Access to Electricity : 50 %

4.5 Primary fuel supply scenario

- **Gas:** No significant gas discovery in recent years.

- **Coal:** Near term option; Indigenous or Imported; Base Load.

- **Oil:** Volatile market; High price; for peaking duty.

- **LNG:** Necessary to ensure secure and reliable gas supply.

- **Nuclear:** Safe technology; No pollution; Expected to be future Base Load option.

4.6 Future development forecast

4.6.1 Short term:

- Rental Power plant mostly diesel generator based.
- Leased for one or two years.

4.6.2 Mid-term:

- Power plants leased for a short period of time.
- Maximum 5-7years depending on demand.

4.6.3 Long term:

Power System Master Plan (up to 2030)
Study completion: February 2011

- **Findings:**

- Generation capacity requirement by 2021: 24,000 MW
- Generation capacity requirement by 2030: 39,000 MW
- Coal based generation capacity by 2030: 20,000 MW
- Coal and Nuclear for base load power requirement
- Cross Border Trade with neighboring countries

Chapter 5

NUCLEAR POWER IN BANGLADESH

5.1 Why Nuclear Power in Bangladesh?

- In early 1960's there was no indigenous energy source in the western zone.
- Two separate electric grids for two zones of Bangladesh without any interconnection.
- All gas reserves were in the eastern zone only.
- Due to depletion of natural gas, we are now becoming increasingly dependent on expensive imported liquid fuel and coal.
- Unless new gas fields are discovered, present gas reserves cannot sustain more than 6,000 MW of electrical power at present and may be completely depleted in 12-15 years.
- Due to absence of a coal policy, we are deprived of a maximum of 15,000 MW of electrical power.

5.2 Prospects of Nuclear Power in Bangladesh

- In view of the shortage of indigenous energy resources, nuclear power has become an attractive alternative source of energy in Bangladesh. It can supply up to 25% of the peak demand.
- It is advisable to have a long-term program for nuclear power for economic and technical reasons.
- We should, therefore, plan for 4 more reactors, besides two at Rooppur, to be operative by 2030 in Chittagong and Khulna regions.

5.3 Rooppur Nuclear power plant:

- Proposed in 1961 and plan approved in 1963.

- ❖ Lots of discussion took place with Canadian, Swedish and Norwegian govt. but no real progress seen.
- ❖ Belgian govt. was convinced but after liberation war they showed no further interest.
- ❖ Discussion with USSR in 1974.
- ❖ In 2009, Russian and Bangladeshi govt. signed a mou and proposed a two Nuclear reactor based power plant with a capacity of 1000Mw each.
- ❖ Two vver-1000 reactors were the preliminary plan which was replaced by two vver-1200 due to safety issues.
- ❖ First ever nuclear power plant in Bangladesh costing up to US$6 billion.

5.4 MOU with Russia

Bangladesh and Russia signed a memorandum of understanding (MoU) in May 2009 for setting up nuclear power plants in Bangladesh. Since then, the two countries signed several agreements for setting up a two-unit nuclear power plant at Rooppur with a capacity of 1,000 megawatts each. The deals do not include any time schedule or the cost of the project.

Russia will assist in the development of nuclear energy infrastructure in Bangladesh

Russia will supply Bangladesh with nuclear materials and provide services in the field of nuclear fuel cycle in accordance with national legislations of the two states and international treaties to which both Bangladesh and Russia are parties

The MoU also includes terms for cooperation in education, training, updating skills of administration, scientific and technical persons and radioactive waste management.

5.5 ECNEC sanction

On April 02, the Executive Committee of the National Economic Council (ECNEC) approved the first phase of a 2,000-megawatt nuclear power project at Rooppur at a cost of Tk 5,242 crore without specifying the total cost of the project.

It is very unusual for ECNEC to approve the first phase of a project involving a huge amount of Tk 5,242 crore without knowing the total cost of the project. Will it be possible to control the cost of the project if approval is given by phases?

Russia will provide Tk 4,000 crore ($500 million) as hard term loan for the first phase but the country is likely to provide around $6 billion for the second phase the tentative implementation schedule of which is 2017 to 2022.

5.6 Manpower Development

5.6.1 Present man power in rooppur NPP:

About 55 with 28 professionals -

- Project Planning & Contract Negations: 7

- Siting and Development: 9

- Nuclear Technology: 7

- International Coordination & HRD: 5

5.6.2 Proposed workforce:

In the OS, category-wise distribution of 1048 Technical

Workforce has been proposed as follows:

- ❖ Qualified Professionals : 513 (49%)
- ❖ Technicians/ Technologist: 325 (31%)
- ❖ Craftsman : 210 (20%)
- ❖ TOTAL: 1048 (100%)

5.6.3 Status of Nuclear HRD programme:

- BAEC has a good number of professionals in various branches of

Nuclear technology;

- The Core Manpower for preparatory activities of the Rooppur Nuclear Power project is available in BAEC;

- A dedicated group of professionals is working for the regulatory body;

- Fresh professionals for Rooppur NPP and the nuclear regulatory body will be available from the General Universities, Universities of Engineering and Technology and Technical Institutions from their annual output;

- A training Institute under BAEC has been established to train the professionals in the field of nuclear technology. Presently this institute offers fundamental courses on nuclear technology to the junior professionals of BAEC.

- The Government has taken initiatives to strengthen infrastructure for education and research in nuclear science and technology and major universities have been instructed in this regard.

- A couple of universities in the country are taken initiatives to open nuclear engineering courses, mostly in the post-graduate level.

- Dhaka University has started Nuclear Engineering department for graduate and post graduate level.

Chapter 6

NEED OF ROOPPUR NUCLEAR POWER PLANT

Compared to other available alternatives, nuclear power is still the safest and the cleanest form of energy. In terms of fatalities, it has the lowest fatality rate per unit of energy. Nuclear reactors produce practically no greenhouse gases. The world is, therefore, likely to depend on nuclear power, like it did during the last fifty years, for generation of electricity for a long time to come.

In this chapter we will discuss why we need a Nuclear Power Plant, Rooppur Nuclear Power Plant (RNPP) to be precise, on the soil of Bangladesh. We will first identify the reasons or problems behind our supporting RNPP then show how a nuclear power plant can solve those problems or fit on those conditions.

6.1 Increase in Power Demand

Per capita generation of electricity in Bangladesh is now about 276KWh. In view of the prevailing low consumption base in Bangladesh, a high growth rate in energy and electricity is essential for facilitating smooth transition from sustenance level of economy to the development threshold. The average annual growth in peak demand of the national grid over the last three decades was about 8.5%. It is believed that the growth is still suppressed by shortage of supply. Desired growth in generation is hampered, in addition to financial restraints, by insufficiency in supply of primary energy resources. The strategy adopted during the energy crisis was to reduce dependence on imported oil through its replacement by indigenous fuel. Thus almost all plants built after the energy crises were based on natural gas as fuel. Preference for this fuel is further motivated by its comparatively low tariff for power generation.

6.2 DEMAND FORECAST:

In the Power System Master Plan (PSMP) -2010 demand forecast was made based on 7 % GDP growth rate. The electricity development is required to be accelerated to increase access and attain economic development. The adoption scenarios of the power demand forecast in this Master Plan are as shown in the figure below.

The figure indicates three scenarios; (i) GDP 7% scenario and (ii) GDP 6% scenario, based on energy intensity method, and (iii) government policy scenario.

FY	Government Policy Scenario		Comparison GDP (7%) Scenario		Comparison GDP (6%) Scenario	
	Peak Demand (MW)	Generation (GWH)	Peak Demand (MW)	Generation (GWH)	Peak Demand (MW)	Generation (GWH)
2010	6454	33922	6454	33922	6454	33922
2011	6765	35557	6869	36103	6756	35510
2012	7518	39515	7329	38521	7083	37228
2013	8349	43882	7837	41191	7436	39084
2014	9268	48713	8398	44140	7819	41097
2015	10283	54047	9019	47404	8232	43267
2016	11405	59945	9705	51009	8680	45622
2017	12644	66457	10463	54994	9165	48171
2018	14014	73658	11300	59393	9689	50925

2019	15527	81610	12224	64249	10255	53900
2020	17304	90950	13244	69610	10868	57122
2021	18838	99838	14249	75517	11442	60640
2022	20443	109239	15344	81992	12056	64422
2023	21993	118485	16539	89102	12713	68490
2024	23581	128073	17840	96893	13416	72865
2025	25199	137965	19257	105432	14167	77564
2026	26838	148114	20814	114868	14979	82666
2027	28487	158462	22509	125209	15848	88156
2028	30134	168943	24353	136533	16776	94053
2029	31873	180089	26358	148928	17768	100393
2030	33708	191933	28537	162490	18828	107207

Table: Demand Forecast (scenario)
Source: Power System Master Plan (PSMP) Study Team

6.3 Long term power solution

Below we have the record generation of past few years. If we compare with the table above we will realize the difference between demand and supply for the corresponding years.

- Maximum generation in 2014 : 7418.00 MW as on 18/07/2014
- Maximum generation in 2013 : 6675.00 MW as on 12/07/2013
- Maximum generation in 2012 : 6350.00 MW as on 04/08/2012
- Maximum generation in 2011 : 5174.00 MW as on 23/11/2011

- Maximum generation in 2010 : 4698.5 MW as on 20/08/2010
- Maximum generation in 2009 : 4296 MW as on 18/09/2009

We can see from the chart that the supply is always lagging behind the demand and Bangladesh needs more supply medium as only 50% if its population are having the privileges of electricity. Still the supply is not par the demand. That's why load shedding occurs.

Now if we consider the coal based power system what Bangladesh has now, then the maximum generation capacity from coal based power plants by 2030 will be approximately 20000MW. Whereas the forecasted demand is around 39000MW. So by the looks of it we are going to have a shortage of almost half the demand. Which also calls for the need of a nuclear power plant as the other fuels available are not so attractive choices.

Also using coal as a fuel for electricity generation is not cost efficient. If we look at the power generation from per unit fuel we will easily understand this phenomena. There is a huge difference in per unit power generation between coal and nuclear power system. Moreover the transport cost, mining cost and other utility costs make are the main drawbacks for coal based power plants. Coal and other fossil fuel based power plants also emits a huge amount of greenhouse gases which pollute our surroundings.

So we think, even if we have the opportunities to buy electricity from the neighboring countries at a cheaper rate than RNPP for a period of time in the future, even then we should build a nuclear power plant for the sake of long term power solution.

6.4 Availability of primary resources

Bangladesh is not renowned for its primary resources. Only a handful amount of coal and natural gas mines have been found where most of them are not extractable. Comparing with the other countries which is really nothing. The figures below depicts the history of Bangladesh in the last three decades in the regards of primary energy resources and the electricity generation.

Petroleum (Thousand Barrels per Day)		Previous Year				Latest Year
	History	Bangladesh	Asia & Oceania	World	Rank	Bangladesh
Total Oil Production	(1980-2013)	5.45	9,077	89,755	95	4.79
Crude Oil Production	(1980-2013)	4.67	7,731	75,956	79	4.00
Consumption	(1980-2013)	113.64	28,976	89,128	72	118.66
Estimated Petroleum Net Exports	(1980-2013)	-108.19	-19,898	--	176	-113.87
Refinery Capacity	(1980-2012)	33	24,875	88,097	92	33
Proved Reserves (Billion Barrels)	(1988-2014)	0.03	45	1,646	76	0.03

Figure: Oil production

Natural Gas (Billion Cubic Feet)		History	Previous Year				Latest Year
		History	Bangladesh	Asia & Oceania	World	Rank	Bangladesh
Production	i	(1980-2012)	710.18	17,008	116,255	28	772.03
Consumption	i	(1980-2012)	710.18	22,220	116,395	34	772.03
Net Export/Imports(-)	i	(1990-2012)	0.00	-4,825	--	64	0.00
Proved Reserves (Trillion Cubic Feet)	i	(1980-2014)	6.49	521	6,846	44	9.34

Figure : Natural gas production

Coal (Million Short Tons)		History	Previous Year				Latest Year
		History	Bangladesh	Asia & Oceania	World	Rank	Bangladesh
Production	i	(1980-2012)	0.992	5,529	8,444	46	1.102
Consumption	i	(1980-2012)	2.011	5,482	8,285	60	2.205
Net Export/Imports(-)	i	(1980-2012)	-1.019	-39	--	45	-1.102

Figure : Coal production

Electricity (Billion Kilowatthours)	History	Previous Year: Bangladesh	Previous Year: Asia & Oceania	Previous Year: World	Previous Year: Rank	Latest Year: Bangladesh
Net Generation	(1980-2011)	40.24	7,682	20,254	57	42.41
Net Consumption	(1980-2011)	35.93	7,060	18,501	55	37.88
Installed Capacity (GWe)	(1980-2011)	5.86	1,903	5,086	71	6.36

Figure : Electricity generation

Total Primary Energy (Quadrillion Btu)	History	Previous Year: Bangladesh	Previous Year: Asia & Oceania	Previous Year: World	Previous Year: Rank	Latest Year: Bangladesh
Production	(1980-2011)	.773	148	505	59	0.784
Consumption	(1980-2011)	1.004	190	507	57	1.018
Energy Intensity (Btu per 2005 U.S. Dollars)	(1980-2011)	2,276	7,821	7,401	170	2,164

Carbon Dioxide Emissions (Million Metric Tons of CO_2)	History	Previous Year: Bangladesh	Previous Year: Asia & Oceania	Previous Year: World	Previous Year: Rank	Latest Year: Bangladesh
Total from Consumption of Fossil Fuels	(1980-2012)	59.21	14,310	32,155	54	63.50

Figure : Energy production/consumption & Carbon Dioxide emission

By studying these figures one can simply identify the current condition of Bangladesh in the respect of natural resources and not to add that these are not been used properly. Moreover we don't have the luxury to buy these resources from other countries. The reserves we have are more likely to be decreased in the upcoming years. So we need another fuel in order to supply our energy demand. Nuclear fuel fits in this position perfectly.

6.5 Climate

There are two types of harmful gases released through burning fuels. These have some serious effects on the environment. Greenhouse gases causes global warming and exhaust gases causes damage of ozone layer which in turn too contributes in global warming. These gases also have a heavy impact on climate and weather of the globe, causing acid rain, global warming etc.

6.5.1 Greenhouse Gases:

The greenhouse effect is a process by which thermal radiation from a planetary surface is absorbed by atmospheric greenhouse effect, and is re-radiated in all directions. Since part of this re-radiation is back towards the surface and the lower atmosphere, it results in an elevation of the average surface temperature above what it would be in the absence of the gases.

By their percentage contribution to the greenhouse effect on Earth the four major gases are:

- water vapor, 36–70%
- carbon dioxide, 9–26%
- methane, 4–9%
- ozone, 3–7%

Fossil fuels are mainly fermented organic bodies over a long period of time. Thus they contain a lot of carbon in their molecular foundation. Which in turn pollutes the environment and causes greenhouse effect when burnt as fuel. So they are not an appreciable choice as far the fueling of a power plant is concerned.

6.5.2 Exhaust Gases:

Exhaust gas or flue gas is emitted as a result of the combustion of fuels such as natural gas, gasoline/petrol, diesel fuel, fuel oil or coal. According to the type of engine, it is discharged into the atmosphere through an exhaust pipe, flue gas stack or propelling nozzle. It often disperses downwind in a pattern called an exhaust plume.

These exhaust gases are one of the crucial reasons of not choosing fossil fuels and petroleum oils as fuel for electricity generation. But a huge amount of exhaust gases are being released to nature making the surroundings vulnerable to live in. On the contrary nuclear fuel releases no such gases. So it is a better option for fuel than the others.

6.6 Lower generation cost:

The lower generation cost of nuclear fuel makes it a very popular choice around the globe. As a fuel for electricity generation it has the highest efficiency known to mankind. Per fission of Uranium produces around 200MeV energy whereas fossil fuel has a range of 3.7-18.4MeV per unit generation.

Moreover the cost of fuel is quite less when nuclear fuel is concerned. In June 2010, the spot price was close to $92/kgU (2010).The highest seen spot price was $354/kgU recorded in year of 2008. Fossil fuels are far more costly than Uranium, including the mining costs and transportation costs. Also transporting fossil fuels is a messy job to do.

6.7 Why nuclear fuel is a better fuel option:

- ❖ In a nuclear fuel based power plants fuel is loaded for minimum 15years which means the refueling will be due after one and a half decades of primary fueling.

- A nuclear reactor has a lifetime 60years. Whereas fossil fuel based boiler is expected to give full service for 40years. And later that period their efficiency climbs down to an unwanted level.
- Nuclear fuel has higher efficiency than the fossil fuel or hydro or solar based electricity generation.
- Lower transportation cost of nuclear fuel makes it an attractive choice for electricity generation.
- Nature possesses the Uranium of which only around .7% are Uranium-235. 99% Uranium-238 and others are Uranium-234 of the natural Uranium. Only unranium-235 can be used in nuclear reactors.

Chapter 7

KEY ISSUES OF RNPP

Specific road map is necessary for the implementation of a nuclear power plant. Bangladesh and Russia had already signed a Memorandum of Understanding (MOU) in 2009 and Rosatom, the Russian state owned company had already signed three contacts. Fourth contact signing is awaiting confirmation. Before implementing such a huge project various things have to be checked to be over sure.

In this chapter, we shall discuss about the key issues concerning Rooppur Nuclear Power Plant (RNPP) and their different aspects.

7.1 Waste management at RNPP

According to IAEA a nuclear reactor of 1000 MW (e) produces 30 tons of high level waste where 1000 MW (e) coal fueled reactor produces 30000 tons of ash. It is clearly visible how less waste is produced by nuclear power plant. Managing of nuclear waste is also straightforward and quite simple. But even though the wastes produced are little they are radioactive. So their isolated storage and disposal where they cannot be exposed posing significant danger has to be confirmed. As it has been discussed before, we know that three types of wastes are produced from a nuclear fuel cycle-

- High level waste
- Intermediate level waste
- Low level waste.

Bangladesh Atomic Energy Commission (BAEC) has the necessary experience to handle both Intermediate and low level waste. Since 1986 they have been managing wastes with the construction of TRIGA 3 MW research reactor at Atomic Energy Research Establishment (AERE) at Savar. So there should be no major concern. The major problem lies in handling High level waste where Bangladesh lack experience and technology.

Russia is going to take care of the spent fuel produced from the reactors at RNPP. Available information say that, ROSATOM will take back the spent fuel in properly shielded containers. Then they will reprocess it in Russia and sent back the unused uranium and plutonium. All Bangladesh has to do is ensure that it gets the full credit for the unused uranium and plutonium that are inside the spent fuel before reprocessing. Russia however will charge Bangladesh for transporting, handling and reprocessing.

Even if Russia doesn't take back the spent fuel, it will be stored near the power plant. Obviously a safe location will be ensured. Future generation of nuclear reactors might have the feature of using spent fuel as a fuel without reprocessing. As it contains unused uranium and plutonium the demand of spent fuel will be ever-rising and a huge market will thus open. So management of high level waste is also no issue.

7.2 Safety of RNPP

We are all informed about the catastrophic accident that occurred on April 26, 1986 at Chernobyl Nuclear Power Plant (unit 4) now in Ukraine, then in the Soviet Union. Since the proposed reactor at RNPP is going to be built by Russia, many have questioned the wisdom of building a Russian reactor when they have such a taint in their history.

The normal answer would be 'YES' but that definitely would not satisfy curious minds. A little deliberation is needed.

First we have to know why Chernobyl disaster occurred. The main reason behind the accident was design fault and serious operational error. Chernobyl had RBMK reactor operating. The Soviet-designed RBMK is a pressurized water-cooled reactor with individual fuel channels using graphite as its moderator.

The combination of graphite moderator and water coolant is found in no other power reactor in the world. As the Chernobyl accident showed, several RBMK's design characteristics – in particular, the control rod design and a positive void coefficient – were unsafe. Positive void coefficient is like a steam bubble that forms inside the coolant channel. With it the reactor power will continue to rise, without any external control, leading to an unstable condition.

At the time of accident at Chernobyl, The reactors were used for conduction an experiment by some engineers. Those engineers lacked the knowledge on reactor physics and engineering.

A nuclear reactor generates substantial heat even after shutdown due to a high level of radioactivity inside the core. All power reactors are provided with normal and emergency core cooling system. When conducting an experiment these are shutdown. As a result power surge damaged the core, releasing highly radioactive substances. High pressure caused a pipe to explode, followed by more explosions. Eventually radioactivity leaked to the atmosphere. There was however no nuclear explosion, only conventional explosion.

Rooppur will have pressurized water reactors (PWR) of generation-III type which are more reliable, tasted and better. The core consists of slightly enriched uranium as fuel and water as both moderator and coolant, a combination that makes the void coefficient negative. A negative feedback stabilized a system. If void are formed in the core for any rise in power level, the negative void coefficient will bring the power down. No power surge, like the one in Chernobyl unit 4, is possible in a PWR.

A PWR reactor incorporates multiple barriers to prevent the leakage of radioactive substances. The first one is ceramic fuel pellet, second one is a sealed metal tube called the cladding that contains the fuel pellets, third barrier is the closed primary cooling water system that circulates through the core and carries the heat to the steam generator.

Besides the reactors at Rooppur will have containment buildings. This is the last line of defense that contains radioactivity in case all other barriers fail. The reactors at Chernobyl had no containment building.

Rooppur will select highly trained engineers for reactor maintenance and operation. Only the license holders will be allowed to operate the reactor. Some of them have built, commissioned and operated reactors in Pakistan, South Korea and Romania. There will be no permission for any kind of experiment. As a member of World Association of Nuclear Operators (WANO) Bangladesh is obliged to maintain safety standards.

Improved design, better safety standards and reliable operation will ensure the safety of RNPP to the point where an accident will be highly unlikely under any circumstances.

7.3 Site clearance

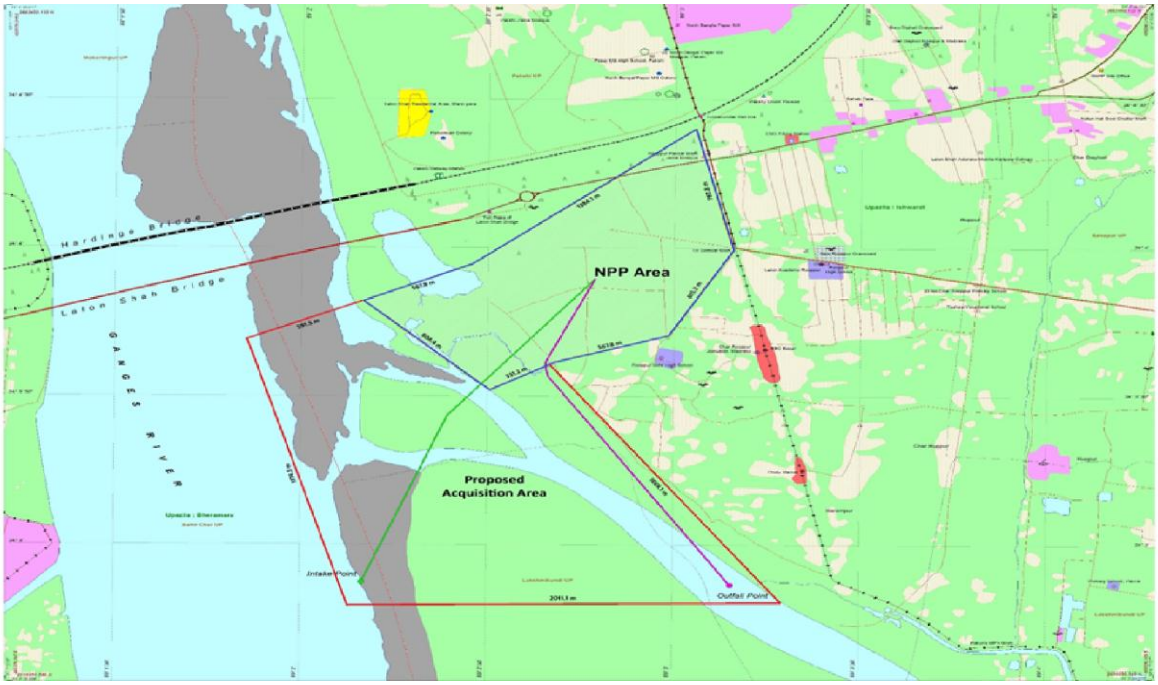


Figure: Rooppur Nuclear Power Plant site

7.4 Feasibility study

Feasibility report of any project shows its compatibility; gives an idea whether it will be feasible to run the project or not. Rooppur Nuclear power plant cannot turn into reality unless it has a trustworthy feasible report. No trustworthy feasible report has been made yet by the Bangladeshi govt. earlier it was said that around \$1.5 to \$3 billion would complete the job, but recently it has been estimated that around minimum \$6 billion will be needed to install the project with latest technology and safety features[9].

The reason for such a rise overnight was given that following the Fukushima incident safety regulations have changed to some extent and it will cost more to procure the latest VVER technology which has enhanced safety features.

For the groundwork of RNPP Bangladesh borrowed $500 million from Russia to complete the job. Rosatom, the Russian state owned company now wants an additional $55 million to complete the study[10]. So an increase in total budget is inevitable. Rosatom has showed its interest to sign the fourth deal worth $45.9 million.[11] It has failed to complete all five components under the third contract: (i) a geo-technical study of the RNPP, (ii) the environmental impact of the project, (iii) the engineering design, (iv) the technical reports on these issues, and (v) evaluation of all components. According to the officials they have not yet given the reports for the latter two.

According to the master plan of Bangladesh Power Development Board (BPDB) by 2023 around 10% of the total electricity would be produced from nuclear power plant. If we introduce VVER-1200 instead of VVER-1000 it will produce 1200 MW total producing 2400 MW which would still be less than 10% of the total demand then.

As per the deal, Bangladesh is to repay the amount for groundwork in 12 years, with a grace period of 5 years and final construction would be repaid in 28 years, with a grace period of 15 years, according to the science and technology ministry.[12]

So if the total budget exceeds far more, which is very much likely, who will take the responsibility for the extra cost that was not predicted before. It is thus high time a proper feasibility report is made to make the long awaited dream of nuclear power come to reality.

7.5 Environmental impact

While conventional thermal plants burn fossil fuels for the production of electricity, a nuclear power plant obtains its energy from a physical process, the fission of the uranium atom. This means that nuclear plant does not send into the atmosphere any greenhouse effect gasses (carbon, sulphur, nitrogen oxides and others) nor other combustion products, such as ashes, that might contribute to the climate change, the acidification of rains, and the contamination of large cities, the destruction of the ozone layer or the greenhouse effect. As to the “emissions” from the cooling towers, so frequently used as a symbol of the contamination produced by nuclear power plants, they are only water steam.

Nuclear Power is better in terms of soil occupation too. Where in Solar and Wind required soil area is between 20 to 50 km^2 and 50 to 150 km^2 respectively, nuclear only occupies about 1 to 4 km^2 soil.

The only environmental impact results from nuclear fuel cycle, operation and accidents.

Although a nuclear power plant emits no greenhouse gas, during the fuel cycle uranium has to be mined, processed and transported. These releases some CO_2 in the process. However these emissions are negligible in comparison with fossil fuel based plants.

The main problem lies in the operation and accidents. Since a nuclear power plant is different and complex from other conventional power plants, its operation need to be safe and secure. Otherwise significant amount of radioactivity might leak into the atmosphere which in turn will cause fatal health problems and environmental hazard. Operational fault or design fault or due to natural calamity accidents might occur at nuclear power plant rendering the environment vulnerable. Serious accidents include core meltdown, release of large amount of fission products etc.

Rooppur in this respect will be quite compatible with the environment as enough security measures are assured in the reactors to be built. Advanced pressurized reactors will ensure protection against emergency malfunction and containment buildings will ensure safety against natural calamities. So the environmental impact will be negligible.

7.6 Terrorism

RNPP is going to be the first ever nuclear power plant in the history of Bangladesh. This cannot be overlooked by potential terrorist threat. Fissile materials and nuclear weapons are highly valuable and priced in both local and international black market. Getting an ounce of fissile materials can prove to be fatal in fallen to the wrong hands. Furthermore in military conflict, nuclear plants automatically become the primary target.

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 heavily trained force. For security plan the whole zone is divided in to three zones.

- Owner controlled
- Protected area
- Vital area

Protected area is restricted to authorized personnel only with strengthen security barriers. Only plant employees and monitored visitors are allowed inside of it. Vital area is further restricted with additional security and barriers. NRC requires specialized trained and skilled professionals to handle the security. They provide multiple steps to ensure the physical security of a nuclear power plant which includes intruder detection, intruder alarm, threat assessment, armed response etc. Besides this NRC requires that within an approximately 10 mile Emergency Planning Zone (EPZ) operator maintains security alarm.

Bangladesh can follow their guidelines and form special taskforce with civil and defense high officials who will be responsible for the job. They can also plan an Emergency Planning Zone for higher security.

7.7 Liability

In a nuclear power plant many engineers and plant operators work day and night. Outside the plant people may live. In Bangladesh's case it is not practical at all to evacuate every single people within 30 km radius area. So there will neighbors. For any kind of malfunction or accident these people living inside and outside will be exposed to radiation. Many might die, some will live their rest of the life with major health problems. The most serious scenario is where future generation will be affected. Although the probability of such an accident is very low, necessary measures and laws have to be made for emergency case.

According to the constitution of People's Republic of Bangladesh it is stated that, government holds the full responsibility for the evacuation, compensation and rehabilitation. They are also responsible for any radiation exposed beyond the safety limit. The authority is to take care of the workers' health problem due to overdose of radiation. It has been clearly stated that for a government owned power plant, the government is to take full authority over death of any of its worker due to radiation.

Adequate laws that state these rights of depreciated people need to be made clear and visible. Confirmation and implementation of such laws will show the firm standing of the government beside the people of Rooppur and dismiss any kind of potential protest that might result.

Chapter 8

RECOMMENDATIONS

Based on the different aspects of Rooppur Nuclear Power Plant and their implementation we have had a few recommendation. In this section, the recommendations are explained briefly.

We believe this will surely enhance the whole RNPP project, help building future nuclear reactors and strengthen our future nuclear policy.

8.1 VVER-1200 Instead of VVER-1000

According to the available information Russia is going to build two 1000 MWe VVER-1000 reactors. These are the modified versions of PWR. According to the master plan of the Bangladesh Power Development Board (BPDB) the peak power demand of the country will be nearly 22,000 MW by 2023. Under these circumstances we can easily integrate a 1200 MWe nuclear power plant which would be still less than 10% of the total peak demand.

So the question rises whether we should stick with the plan to build VVER-1000 reactors or move to the plan where VVER-1200 is proposed.

VVER-1200 reactors are the improved versions of VVER-1000. Customized VVER-1000 reactors are often given different names which creates confusion. Concerns have been spoken about the safety of VVER-1000 reactors at various places. Contracts for a total of 11 reactors were cancelled for failure to meet the European safety measures.

After thorough evaluation of the safety systems of the VVER-1000/412 reactors now under construction in Kudankulam (KK) in India, the Atomic Energy Regulatory Board (AERB) recommended 17 modifications after the Fukushima accident in 2011. It added a passive heat removal system, a containment building to withstand impact of an aircraft crash, a hydrogen recombiner and a core catcher to contain the molten core in the event of a severe core meltdown. All modifications mentioned above are the specifications of VVER-1200 reactors.

VVER-1200 reactors produce 1200 MWe power, have higher efficiency (36.56%) and have longer core lifetime. Lower per unit cost and shorter period of construction also make it attractable. They have enhanced safety against earthquakes with passive emergency core cooling system, double containment and core damage frequency of 1x10-7. The core damage frequency is a measure of probability that indicates probability of accident. 1x10-7 means that a core accident is possible in 10 million reactor years.

VVER-1200 reactors are designed to meet both US and European safety standards.

By all means they are more economic, safe and environment friendly. In this perspective we should conduct a feasibility study regarding which one is the best option. We should definitely should the one that is more reliable, long lasting, safe and economic. So it is strongly recommended that we consider building VVER-1200 instead of VVER-1000 at Rooppur Nuclear Power Plant.

8.2 Ensuring best use of spent fuel

There will be a gigantic market for spent fuel in the future. Spent fuel contains fissile materials such as uranium, plutonium and even thorium which can be further used as a fuel after recycling. There are mainly two reasons why spent fuel should be reprocessed –

- ❖ Extracting fissile materials
- ❖ Reduce the volume of high level storage

Spent fuel contains fissile materials such as plutonium, uranium within it. Fissile materials can be again used as a fuel through proper recycling. If we can make the best use of our spent fuel and use it as a fuel after recycling not only out generation per unit cost will reduce but it will also strengthen the security for nuclear fuel. Russia will however take back the spent fuel from Rooppur nuclear power plant to Russia and transport back the unused plutonium and uranium after reprocessing and recycling.

Another point is the reduction of high level waste. As of now there is no permanent disposal facility for high level waste. The permanent disposal of high level storage has been some concern as it impacts the most to environment out of all radioactive wastes. Bangladesh, as expected do not have the sufficient ground or technology for such storage of high level waste. As Russia is going to take back the spent fuel, they will take care (storage and disposal) of the high level waste. However they are going to charge Bangladesh for transporting, handling and reprocessing.

Bangladesh has to ensure that it gets the full credit for the unused plutonium and uranium present in the spent fuel. This will definitely be costly. So it will be intelligent to start considering building a reprocessing plant in the future. Building a reprocessing plant will reduce the cost for transporting, handling and it will ensure minimum high level waste to dispose of. So the overall cost will decrease. This will help building further nuclear power plants which is also a consideration of

Bangladesh govt. But even if they did start constructing one, they have to maintain the international laws that are available to ensure nuclear non-proliferation.

8.3 Developing skilled manpower

One of the major requisite to operate nuclear power plant is to have skilled manpower. This is one sector in which Bangladesh lack very much. Operation of a nuclear power plant is slightly different from normal conventional power plant. A slight mistake in operating reactor can lead to catastrophic results such as core meltdown, exposure to high dose of radiation.

For now, according to the Memorandum of Understanding (MOU) between Bangladesh and Russia; Russia will send their skilled engineers for the operation of rooppur nuclear power plant. This might compensate for a short period of time but will prove unfeasible in the long run as these foreign engineers will charge more salary, take back our currency. It also shows the lack of expertise in nuclear field.

To make RNPP a feasible project and to further develop our nuclear power sector, it is recommended that we sent our young engineers abroad for higher study and start training them early. After they finish their training, they are to return to the country and offer mandatory service. In order to prevent them from going abroad for job purpose, they should be paid a handsome wage including other facilities such as residential, insurance, educational facilities. Dhaka University has opened a new department – Department of Nuclear Engineering in 2012. Another renowned university American International University of Bangladesh (AIUB) have opened MSc. In nuclear power engineering. However this is not enough. According to the MOU with Russia, a few students are going there for higher study. Bangladesh government should send more students which will benefit both party. It is to be noted that, in the early stage of Rooppur nuclear project in 1960 the then Pakistan government sent few people abroad for higher study. Although they finished their training in time, the project was not on the run any more. Some of these engineers stayed in Bangladesh, took job on Bangladesh Atomic Energy Commission (BAEC). The rest went abroad and built, commissioned and operated reactors in South Korea, Romania, Argentina and Pakistan.

8.4 Site mapping

A nuclear power plant involves a good amount of area. Because of the potential danger that it poses to the environment and habitat in case of any accident a huge area is allocated so that even in the worst case scenario it is possible to evacuate people living nearby the plant.

According to the international law the radius of a nuclear power station is to be 30 km. The area is divided into 3 circular zones. Zone-1 (reactor area) is a circular area of 3.14 Sqr Km. Only the people who operate the reactors are allowed inside this area. Zone-2 (security area) is 5 km away from the center and is 78.5 Sqr. Km. so around 200 people can live inside this region. Zone-3 (Planning disaster area) is 30 km away from the center. In the developed countries this 30 km area is free of population. Less population guarantees safe evacuation from the area. More people will consume more evacuation time.

Bangladesh is a densely populated country with only 1,47,570 Sqr. Km. So it will not be realistic if they chose to have the total 30 Km area free of population. It thus becomes necessary to modify the law a little bit to their relevance. An example would be our neighboring country India. They have changed a few regulations and adjusted as they have the same problem of large population like Bangladesh.

8.5 Raising public awareness

Nuclear power plant incorporates the lives of the people living within and outside the power plant. A large number of local have to leave their permanent land and move to other place for the construction. Those who live nearby the power plant live with the risk of exposure to radiation. It is therefore their right to know about the consequences that might occur in case of an accident.

Although unlikely but even a properly shielded and safe nuclear plant can undergo any type of accident. Maybe because of natural calamity or operational error. In case any of these happens radiation will quickly leak into the atmosphere rendering the environment and public vulnerable to danger.

In order to let the people of the country know more about such aspects of nuclear power and also its benefits, a nuclear energy information centre has been opened at the Bangabandhu Sheikh Mujibur Rahman Novotheatre at Bijoy Sarani in Dhaka since October 1, 2013. However as of today it failed to attract general public for knowledge. Though an information centre has been built, there is no sign of any such thing near the plant in Rooppur where it is needed the most.

People of the Rooppur have the most right to know about what they will be living with. Accident can not only endanger their daily life but also growth of future generation. So it is their right to know about the consequences so that they can be prepared mentally and physically for any kind of adversary.

We will see that Russia itself has around 17 nuclear information centre. Construction of many new information centre using foreign technology is also underway in Turkey, Belarus, and Vietnam. Those countries have given spreading consciousness the proper priority.

Chapter 9

Conclusion

Nuclear power is unavoidable to ensure long term power demand of Bangladesh as well as to ensure energy sustainability. But nuclear power is deep and complex power supply source with multidisciplinary expertise. It has both national and international involvements too. Since Bangladesh has already signed all international agreements/Treaties/Conventions/Protocols e.g. Nonproliferation Treaty (NPT), comprehensive Test Ban Treaty (CTBT), Safeguards and Waste Management Conventions and Protocols. There is no bar to get bilateral as well as international cooperation.

Government has to make the project development process transparent and accountable by following national and international applicable laws, codes and standards. The RNPP authority as such must complete the feasibility report, site clearance report and environmental reports as early as possible as per the applicable Bangladesh Atomic Energy Regulatory Authority (BAERA) Regulations following applicable regulatory guides, codes and standards, before starting the construction of the project. Complete, as per the law Preliminary Safety Analysis Report (PSAR) and get these documents cleared by the BAERA before fuel loading and the Final Safety Analysis Report (FSAR) and cleared by BAERA before starting economic operation.

Government should build VVER – 1200 instead of VVER- 1000. Government must ensure the transfer of all Russian plant documents specifications in understandable language (English).

Government has to ensure serious study and considerations on the key nuclear related issues e.g. continued supply of nuclear fuel, nuclear safety, nuclear safeguards, waste management, environment management, nuclear liability and disaster management etc.

Government must develop adequate numbers of qualified and skilled manpower in all relevant fields of nuclear power so that BAEC, BAERA and also the project development authority can discharge the responsibilities effectively and efficiently.

The Indian, South Korean and Japanese nuclear power development history may help in formulating the manpower development roadmap and implementing the RNPP.

There is no dearth of inherent talents in Bangladesh, Bangladesh can do what others (like South Koreans, Japan, India) could do. What is needed: real commitment, dedication and transparent, accountable good governance of the Roopur Nuclear Power Project.

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