Energy Crisis and the Need to Enhance Nuclear Energy in Pakistan

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Abstract

Energy crisis is the immense shortfall in the supply of energy resources including electricity. Due to increase in the consumption of electricity, Pakistan is facing the worst power crisis of its history. An integrated energy plan is needed to improve access to energy. The drastic increase in fuel prices recommends a decreasing dependency on fossil fuel. Nuclear energy is one of the best alternatives to fossil fuel. It is safe, economical and environment-friendly. In this paper, the generation of electricity through nuclear power plant is compared with that obtained from fossil fuel operated power plants. The study also compares the design of Advanced Passive reactors with other nuclear power plants in the World. Moreover, it is illustrated that Pakistan should acquire Advanced Passive nuclear power plants for safe, economical and high power generating capacity. The main problems which Pakistan is facing in acquiring nuclear technology are highlighted in the study. It is concluded that Pakistan should aggressively pursue civil nuclear technology to increase power generating capacity.

Introduction

Energy can be considered as prerequisite for both economic growth and a higher standard of living. Pakistan is currently caught up in the worst power crisis due to the lack of integrated energy planning & demand forecasting. Increase in the consumption of electricity in public and private sectors has given rise to the energy crisis. The gap between demand and supply of energy has drastically increased, affecting many fields of the economy. Power shortages have had a strongly negative impact on economic growth especially in the industrial sector. Many industries have been closed due to severe loadshedding and insufficient power supply. The crisis appears insurmountable unless proper understanding and appropriate implementation is undertaken on priority basis. This is high time for the government to take the power crisis seriously and to focus on electricity generation to meet the increasing demand of the electricity. The government should ensure a sustainable supply of energy resources for the economic growth. An integrated energy planning is needed to achieve a quantum jump in electricity generation to overcome the gap between demand and supply of electricity at peak hours. Developing countries like Pakistan need to invest more in energy for socio-economic development.

There is a growing consensus that nuclear power should play a role in meeting this future electricity demand. Technological developments in nuclear power generation and the experience gained in reactor construction and operation have simultaneously increased public confidence level. These technological advancements have also provided a better way to meet the increasing energy needs economically. According to July 2010 International Energy Outlook report, the projected nuclear generation capacity by region, for the year 2007 and 2035 [1], shows an increasing trend as shown in Fig. 1.

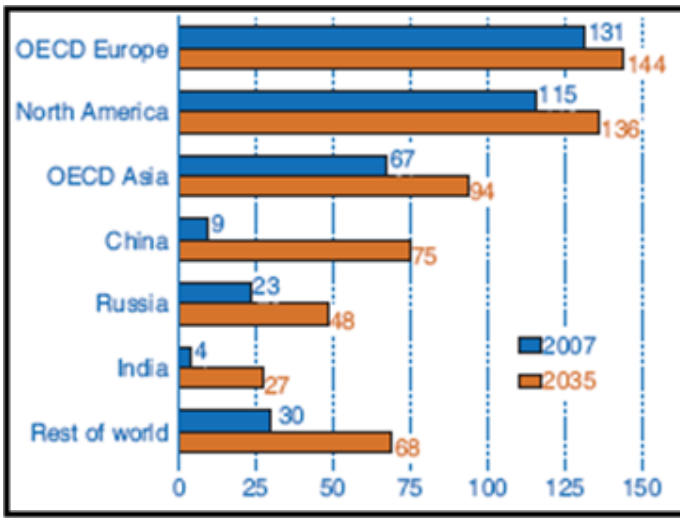

Figure 1: World nuclear generating capacity in 2007 and 2035 (gigawatts) [1]

There are numerous reasons for nuclear power to be considered a serious option. Nuclear power is a mature technology with significant potential to provide large amounts of emissions-free baseload power. Benefits from nuclear power include the abatement of greenhouse gas emissions and air pollution, as well as energy diversity. According to "World Nuclear Industry Report" [2], more than 51 new nuclear plants are under construction worldwide and additional plants are planned or under consideration. It is important that nuclear energy should expand in a way that supports global nuclear safety, security, and protection of the environment.

The whole world is thinking of a nuclear energy renaissance because of the unavailability and high

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prices of fossil fuels. The world average for nuclear energy is 16 percent which is provided by the 440 nuclear power plants in 31 different countries. The US obtains 20 percent of its electric power from nuclear energy with 104 reactors, France 76 percent with 58 reactors, Japan 25 percent with 53 reactors, South Korea 36 percent with 20 reactors, Belgium 54 percent with 7 reactors, while nuclear energy forms the lowest source of power production in Pakistan. Pakistan only produces two percent of its power through two reactors (KANUPP and CHASHNUPP at 125 MWe and 300 MWe respectively) [2]. Pakistan is a technologically advanced country with capabilities to produce fuel, but still it falls behind other countries in terms of nuclear power generation.

Nuclear power is free of pollution and has no environmental affects such as greenhouse gases or acid rain. It is cost competitive and safe, but most importantly it can provide a continuous electric supply throughout the year. This continuous supply can be achieved because nuclear plants are independent of seasonal effects. The latest nuclear plants are smaller in size and more efficient. Another advantage of nuclear power plant is that it doesn't require continuous refueling. The plants only need to be refueled once a year (except CANDU reactors), as compared to fossil fuel operated thermal power plants in which continuous refueling is needed.

Environmental Impact

Nuclear technology can be avowed as the best technology available for producing reliable, carbon-free electricity economically at base-load scale with high availability and capacity factor. In nuclear power plants nothing is burned in a conventional sense. Heat is produced through nuclear fission, not oxidation; therefore, nuclear power plants make no contribution to global warming through the emission of carbon dioxide and other greenhouse gasses. Nuclear power plants do not produce greenhouse gases such as carbon dioxide, nitrogen oxides etc., and gaseous pollutants such as sulfur oxides, acid gases or particulates, etc. Therefore, nuclear power can be presented as providing net environmental benefits over conventional thermal power plants. Fig. 2 shows greenhouse emissions from various energy sources.

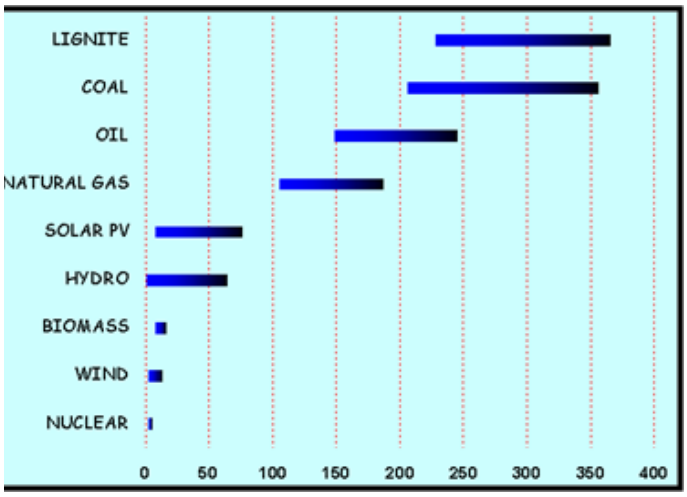

Figure 2: Greenhouse Gas Emission(gCeq / KWh) (Source: Sokolov, IAEA, 2005)

Energy-related carbon dioxide emissions are projected to rise from 30 billion metric tons in 2007 to 42 billion metric tons in 2035 under current laws and policies [1], and if the reduction of greenhouse gases emission is considered to be of higher priority, then nuclear power is the best available technology for energy generation.

In a nuclear power plant, different types of waste produced are characterized broadly into radioactive and non-radioactive waste products, which are further characterized into solid wastes, liquid wastes, gaseous wastes, spent fuel, and some process chemicals. The total volume and mass of waste produced in nuclear power plants are small, relative to the electricity produced, in comparison with waste produced in fossil fuel operated power plants. Nuclear power plants are more environment- friendly compared to fossil fuels, as the waste volume of the nuclear plant is less and well- controlled. The permanent storage of fuel and other contaminated wastes is an emerging issue as many nuclear power plants in the world are now in a decommissioning stage. The fuel storage problem can be solved by using advanced nuclear fuel recycling technologies, hence reducing the volume, heat and toxicity of used fuel. The unused energy (which is approximately 90 percent of the original amount of energy) in the fuel that remains in the fuel after use in the reactor can be recovered by fuel recycling technology.

The US Environmental Protection Agency (EPA) identifies the following average emission levels in the production of 1 MWh of electricity [3].

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TABLE 1.
Pounds of Emissions per MWH [3]

	Coal	Oil	Natural Gas	Nuclear
CO2	2249	1672	1135	0
SO2	13	12	0.1	0
NOX	6	4	1.7	0

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Cost Comparison

Due to the unavailability and drastic increase in fossil fuel prices, the power generating units across the country are producing much below their capacity. The current power crisis is grossly due to very high fossil fuel prices. There has been a global trend to shift away from oil because of its rising price. Natural energy resources have depleted and are too expensive. Due to a decline in the availability of natural resources, it is recommended to reduce dependency on fossil fuel. Alternate energy sources should be availed such as nuclear energy, fuel cell technology, hydrogen fuel, biomethanol, biodiesel, Karrick process, solar energy, tidal energy and wind energy. To date, nuclear energy is a significant alternative to fossil fuel. Other alternative energy sources, particularly renewables, will also play a part in the future energy mix, but do not replace nuclear energy because of their limited availability, high cost and intermittent nature.

Imbalanced energy mix with heavy reliance on gas 47.5% and oil 30.5% (out if which 72% is imported), is the key factor in energy crisis [4]. The energy mix is essentially imbalanced even on a worldwide comparative basis. Pakistan is currently facing millions of tons of oil shortage and is lagging behind its needs of natural gas too, and this ratio is bound to rise in the upcoming years. There is clearly adire need to plan a revised primary energy mix along with a revised electricity generation plan by source. The prices of the uranium metal are less volatile and more consistent than the fossil fuel prices. Nuclear power plants can continue to compete with fossil fuel-fired units, even supposing a several-fold increase in the price of nuclear fuel.

Although the capital cost of building a nuclear power plant is high but the nuclear fuel is low-cost, and as small amounts of fuel are required andvariations in its cost do not affect operating costs to a great extent. Therefore, nuclear energy is best suited for large-scale generating units where the initial capital costs can be spread over many hours of low-cost operation. A further important feature of nuclear power is the fact that its fuel cost amounts to 20 per cent of the electricity generation cost whereas the fuel cost of fossil fuel-fired power plants amounts to 50-70 per cent of the generation cost [5]. This makes the overall cost of nuclear electricity generation relatively stable and hence inelastic to possible future escalation of fuel prices. Fig. 3 shows the trend of US electricity production cost from 1995 to 2008, which shows that the electricity generation cost from nuclear energy is almost constant and less volatile as compared to other energy sources [6].

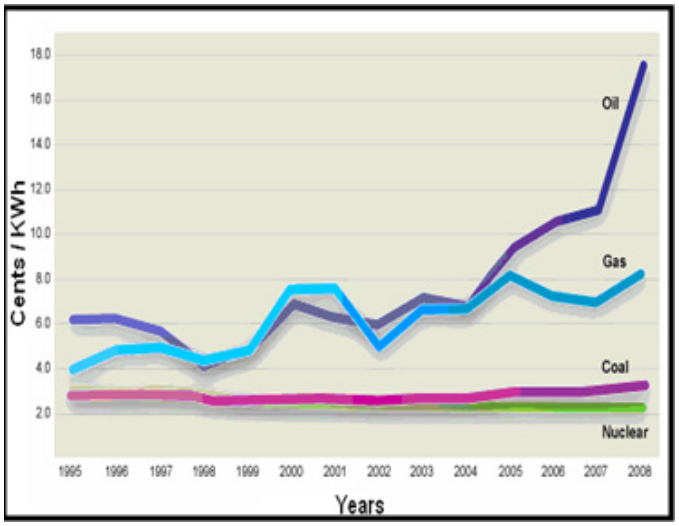

Figure 3: US electricity production cost (cents/KWh) [6]

In 2005, a study was undertaken by the Organisation for Economic Co-operation and Development in collaboration with Nuclear Energy Agency and International Energy Agency to calculate the kilowatt-hour power cost. The study was conducted under the assumption that oil prices in 2010 would hike up to US $50 per barrel. The projected generation costs are calculated with generic assumption at 5% discount rate. Economic lifetime was assumed to calculate levelised costs if different from 40 years. The study provided statistics for power generation costs for one kilowatt-hour for the three most important energy sources i.e. nuclear energy, coal and gas [5].

TABLE 2.

Cost ratios for coal, gas and nuclear power plants

	Nuclear	Coal	Gas
France	2.54	3.33	3.92
Japan	4.80	4.95	5.21
Canada	2.60	3.11	4.11
USA	3.01	2.71	4.67
Germany	2.86	3.52	4.90
Korea	2.34	2.36	4.65
Czech Rep.	2.30	2.94	4.97
Slovac Rep.	3.13	4.78	5.59

Table II shows that nuclear energy has the lowest cost per unit electricity generation. It can be evaluated that if oil prices increase with a corresponding increase in natural gas prices, as a result gas power generation costs will be much higher in comparison to nuclear power generation. It can be debated that uranium prices are also increasing and hence they will adversely affect the nuclear power generation cost but it must be noted that nuclear power plant fuel cost contribution to the overall cost of the electric production is relatively small. Thus even a huge increase in the fuel price will have a minor effect on the electricity production cost. For instance, a doubling of the uranium market price would increase the fuel cost for a light water reactor by 26 per cent and the electricity cost by about 7 per cent whereas doubling the gas price would typically add 70 per cent to the price of electricity from that source [7].

Advanced Passive Reactors

PWR (Pressurized Water Reactor) is a proven technology but the innovative advanced passive safety systems of the AP (Advanced Passive) pressurized water reactor can achieve generation costs that are economical in the current electricity market. Safety through simplicity is achieved in the AP reactors. The AP reactor design is simple, mature, safe and affordable. Simplicity is a key technical concept behind the AP reactors. It makes these reactors easier and less expensive to build, operate, and maintain. Due to the reduced number of components and bulk commodities, simplicity in design is achieved. Simplicity in procurement is achieved by standardization of components. Simplification helps reduce capital costs and provides a hedge against regulatory-driven operations and maintenance costs by eliminating equipment subject to regulation. Multiplexed I&C (Instrumentation and Control) communication reduces cables. Major reduction is done in Safety Related Pumps, Valves, Piping and Electrical Components. It has 60% fewer valves, 75% less piping, 80% less control cable, 35% fewer pumps, and 50% less seismic building volume than a conventional reactor [8].

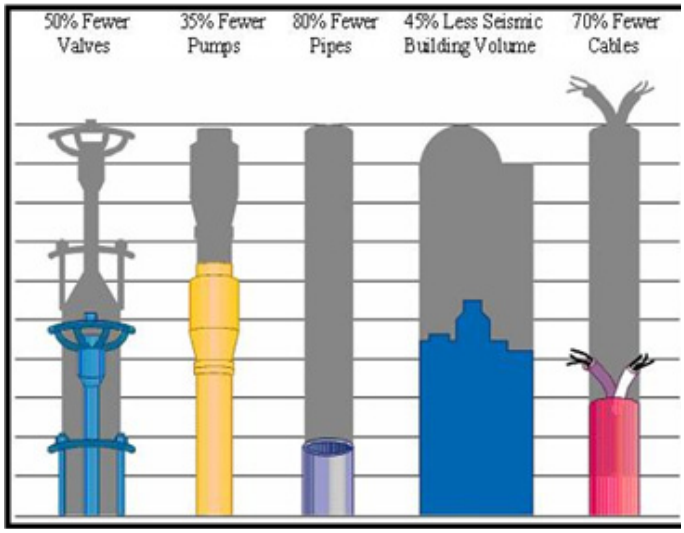

Figure 4: Major reduction in AP plants [9]

The simplification of plant systems, combined with large plant operating margins, greatly reduces the actions required by the operator in the unlikely event of an accident. The AP reactors have more than 15% margin to the DNB (Departure from Nucleate Boiling) limit for loss-of-flow accidents [10]. Containment isolation is improved due to fewer penetrations. Open penetrations have fail-closed valves. Air cooling alone prevents containment overpressure failure. A high degree of modularisation is also used for equipment, piping and valves. Extensive use of modules reduces on-site construction. The modular design is expected to reduce construction times to as little as 36 months from first concrete pour to fuel loading, with consequent reduction in capital investment and interest costs. As AP reactors have simpler and more rugged design thus making them easier to operate and less vulnerable to operational upsets. These plants have higher availability and longer operating life of typically 60 years. Reduced possibility of core melt accidents and resistance to serious damage that would allow radiological releases certifies these plants as best operating plants.

The safety systems for the AP reactors include passive safety injection, passive residual heat removal, and passive containment cooling. Passive systems do more than increase safety, enhance public acceptance of nuclear power, and ease licensing, they also simplify overall plant systems, operation and maintenance.

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No active cooling system for reactor isolation or accident mitigation is designed. The Passive Systems (Natural Circulation, Gravity) replace active systems. Safety-related systems are passive while non safety-related systems are active. These plants have passive core cooling and containment cooling system. These plants are evolutionarily safer having lower probability of accidents. Passive safety systems introduce simplicity in safety assessment. Natural circulation Heat exchanger is connected to RCS (Reactor Coolant System) for passive decay heat removal. Automatic depressurization valves are used in Pressurizer. Natural circulation of air / evaporation of water on outside surface of steel containment vessel enhance passive containment cooling. Passive containment hydrogen control is done by using passive autocatalytic recombiners. Due to larger containment diameter, laydown area inside containment is increased. Access to containment is improved and access platforms are provided for equipment maintenance and inspection. Passive systems are very reliable due to very simple designs with few components that need to function. In these plants single system/component failures are not very important because of redundancy/diversity between different passive safety features.

Key Prospects of Advance Passive Reactors

Following are some key prospects of AP reactors which show that these plants are quite beneficial as compared to other nuclear power plants [9][10][11][12].

i Core damage frequency is reduced by at least a factor of 10
ii. Simpler design with larger margins for safety
iii. Operating lifetime is 60 years
iv. Availability factor of producing power is at least 85%
v. Cheaper production of electricity
vi. Extensive use of modules reduces on-site construction time to 3 to 5 years
vii. Fuel cycle of 18 to 24 months
viii. Simplicity in Operation and Maintenance
ix. Use of proven systems and components
x. No reliance on safety grade AC power
xi. Greatly reduced dependency on operator actions
xii. Radial Reflector improves fuel efficiency

V. Constraints in Nuclear Tecnology development in Pakistan

In the current era, installation of advanced passive nuclear reactors does not have technological constraints as the development in the nuclear power plant technology has grown enough to produce safer and cheaper energy. The main hindrances in the installation of nuclear power plants are political and financial considerations and clarity of the nation's energy policy. For the developing countries, the non-availability of technology may worsen the situation, which is the case.

Pakistan is facing a number of constraints in the development of nuclear technology. One of the more contentious issues is the lack of confidence of the international community on Pakistan nuclear program. The international nuclear community is skeptical about our nuclear program. Pakistan does not have the technology to make nuclear power plants and currently no other country wants to supply nuclear plants to Pakistan due to the terrorism problem.

Pakistan is largely excluded from trade in nuclear power plants or materials because it is not a party to Non-Proliferation Treaty, which hinders its development of civil nuclear energy. Pakistan is not party to the Nuclear Non-Proliferation Treaty but does have its main civil power reactors under item-specific IAEA (International Atomic Energy Agency) safeguards. The objectives of nuclear non-proliferation, safety and security can only be served and promoted through a non-discriminatory paradigm for international cooperation in the peaceful uses of nuclear energy. Pakistan has one of the best systems of safety and security of nuclear assets and technology both on the defence and civilian side. A civilian nuclear power agreement would play an important role in easing the energy crisis of Pakistan. It is urged that the nuclear supply group should give Pakistan access to nuclear technology for peaceful uses, in a non-discriminatory manner, to meet its growing demand for energy.

Other challenging issues faced by Pakistan mainly include high capital cost and financial uncertainties. Given the current economic situation of Pakistan, obtaining the necessary capital cost for the construction of nuclear power plants will be a challenging issue because the financial situation of the government is not strong enough to support such a big project all alone.

Operating Considerations

Nuclear power plants have a high capacity factor. These plants are available to meet demand almost throughout the year because of high availability fac-

tor. Typically, availability for the latest generation of nuclear power plants ranges between 90% and 95% [13]. To operate a nuclear power plant efficiently, availability of highly trained workforce, skilled craftsmen and operators are required. Pakistan possesses more than 35 years experience of operating nuclear power plants successfully. It has highly trained manpower and a well-established foolproof safety and security culture which fully qualifies Pakistan for equal participation in civil nuclear cooperation at the international level. It would also help in addressing immediate energy problems. Pakistan has developed effective nuclear safety, security and non-proliferation measures underpinned by an extensive legislative, regulatory and administrative framework. The Pakistan Nuclear Regulatory Authority is responsible for licensing and supervision of nuclear power plants. Also, Pakistan is a country with advanced fuel cycle capability. Pakistan can provide nuclear fuel cycle services under IAEA safeguards, and can participate in any non-discriminatory nuclear fuel cycle assurance mechanism.

Conclusion

Pakistan's power shortage problem is not only impacting the living standard of its people but country's economy as-well. An integrated energy plan is needed to alleviate its power crisis. Effective project structuring, planning and implementation of identified and viable projects, is needed to overcome the energy shortage. To find out an environment-friendly source and at the same time cost-effective for electricity generation, nuclear energy at present is the best option. Nuclear power is safe, economical and environment-friendly. It is very clear that Pakistan needs to aggressively pursue ways to increase its power-generating capacity with nuclear as a best option available. All Pakistan needs is to set up at least a dozen nuclear power plants to overcome the energy deficiency. Pakistan should continue to refine and modernize its technical capabilities, and train with skills. Pakistan needs to cut back its non-development expenditures to invest in the power sector to develop the infrastructure and establish power plants using nuclear technology.

Although, a nuclear power plants is expensive to build but provide low cost service over the life of the plant, once it is in service. Nuclear fuel is the lowest-cost fuel. If reduction of greenhouse gasses emission is considered to be of higher priority, then nuclear power is the best available technology for energy generation.

Pakistan must dig out ways for self-indigenization in the nuclear field in order to reduce the capital cost of building nuclear power plants. Pakistan needs to acquire AP reactors because these reactors are safer and cheaper as compared to other nuclear power plants as discussed earlier. Also AP reactors can provide high generating capacity. Pakistan lacks the technology to build AP reactors, but a civilian nuclear power agreement with the international nuclear community can play an important role in this regard. Civilian nuclear agreement would make Pakistan more stable, more prosperous and will improve the living standard of the people. It can be concluded that a civilian nuclear agreement would be a positive achievement for Pakistan.

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