# Nuclear Power as a Viable Electrical Energy Source for Sri Lanka

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**Introduction**

For any country, low cost energy is a catalyst for economic development. In fact, modern-day economic growth of a country correlates with electricity usage. Sri Lanka, aspiring to be the wonder of Asia, must therefore look at cleaner and more economical ways of producing energy, particularly electrical energy, to fulfil the needs of the nation in the coming two decades and beyond.

Sri Lanka had been using mainly hydro-power for electricity generation, while any supplementary requirements were generated from thermal sources using diesel generating sets and steam or gas turbines. However, as the economically viable hydro-power sources were fully utilised to meet the escalating demand, more and more thermal power generation plants were planned and commissioned in Sri Lanka to meet the requirements. Figure 1 shows the share of hydro-power and thermal power in producing electricity in Sri Lanka over the past 20 years. Thermal power was particularly needed during droughts, which came on a seasonal basis annually as well as on a random basis approximately every few years. At certain periods, government funds were not invested in thermal power generation plants, and private companies were invited to invest in such plants on Build Own and Operate (BOO) basis. The result was the adding up of over 500MW of electricity, mostly based on furnace oil-driven diesel power generation plants and diesel oil-driven combined cycle power generation plants. Perhaps due to the war situation that existed during the past, these investments came to Sri Lanka at a high cost, and consequently, the electricity prices offered from these power generation plants were high. The increase of the average oil prices during the last several decades made the thermal power (based on oil) almost unaffordable from social, industrial and commercial points of view. Therefore, it is very necessary to consider medium- and long-term thermal power generating options for Sri Lanka by widening the fuel options to keep a sustained and secure economic growth.

**Coal Power**

During the last three decades, there have been debates, agreements, and disagreements regarding setting up of the first coal-fired power plant in Sri Lanka. Finally, a firm decision taken about four years ago enabled a coal-fired power plant which is a reality today. Coal is one of the cheapest sources of energy at least in the short-term, partly because the cost of environmental pollution is not reflected when pricing electricity generated by thermal sources.

The first 300MW of the 900MW Puttalam coal-fired power generation plant is in operation, while several other such power generation plants are being planned at Puttalam, and also at Trincomalee. However, the coal price which was about 50 US$ per tonne when the economics of coal-fired power generation plants was investigated, has now risen to more than 80 US$ per tonne. This makes the total generation cost of electricity by coal in Sri Lanka to be over 8 US Cents per kWh unit. There is no guarantee that coal prices will remain even at 80 US$ per tonne. Increase of demand for high-quality coal and environmental levies will invariably cause the prices to increase and have adverse effects on electricity prices.

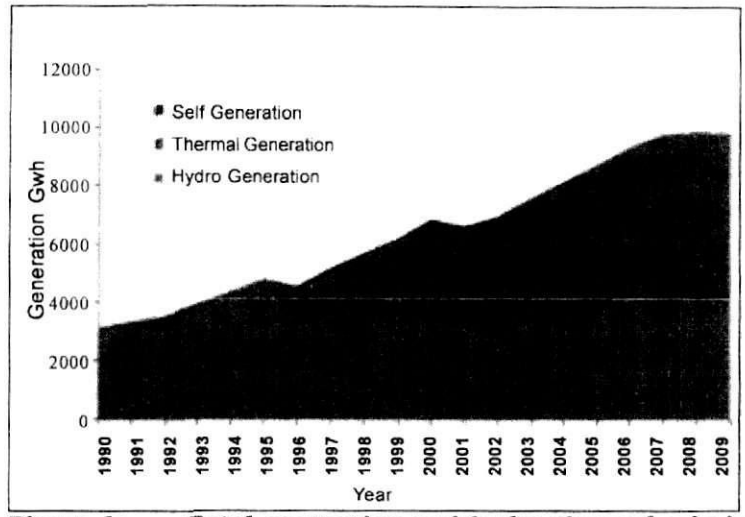


**Figure 1: Total generation and hydro-thermal mix in 20 years up to 2009**

Source: Ceylon Electricity Board, (1999, 2008)

**Renewable Energy**

Small hydro, wind, solar, biomass and other sources of renewable energy are good alternatives to produce electricity to offset burning of fossil fuels. However, as an alternative to meet the increasing demand for electricity for the modern society, renewable energy sources can presently play only a limited role due to their non-availability at economic prices as well as due to the technological barriers such as efficiency limitations. However, one cannot rule out new strides in technological improvements; especially in the efficiency of solar Photo–Voltaic (PV) technology. Such energy options may become economically competitive with conventional energy in the long-term, when used in combination with energy efficient devices such as power LEDs (Light Emitting Diodes).

**Credible Alternative**

It is in the above backdrop that the need has arisen to consider a credible alternative as a major energy source for Sri Lanka.

Figure 2 shows the predicted peak electricity demand growth for the 2010 – 2025 period and the Table 1 shows a generation expansion plan to meet the demand. The near-total dependence on imported coal may become a problem from the energy security point of view, in addition to price increases due to possible Carbon taxes on coal for environmental harm (Coal-based power generation emits Carbon Dioxide and other greenhouse gases).We also need a well-balanced energy mix or portfolio.

In terms of the above plan, by 2020, about 3000MW of power (over 50% of the total installed capacity) will be produced using coal. This plan has been drawn based on the low price of coal compared to other sources such as furnace oil and diesel. Presently, there are discussions on setting up a Liquefied Natural Gas terminal (LNG terminal) to import and distribute LNG to power generation plants. One of the major problems of LNG is the very high capital investment required to set up an LNG terminal. It has to be carefully examined whether the moderate LNG consumption (even with all the gas turbine power generation plants converted to LNG) can justify such an investment. LNG-based power generation plants too emit green house gases, though in proportion less than from coal or oil.

Global warming created by the production of Green House Gasses (GHGs), especially due to burning of coal in power generation plants is of great concern worldwide. Europe has already decided that all the coal-fired power generation plants setup after 2020 should also have 100% Carbon Capture and Sequestration (CCS); such an environmental cost component may push down the relative economics of coal-based electricity generation.

**Nuclear Power**

The moment "Nuclear Power" is mentioned, safety and security concerns are naturally raised. One cannot forget the formidable image created by the Chernobyl nuclear accident in the mid 1980s in the Russian nuclear power generation plant. It is necessary to analyse the nuclear power option today with the presently improved and operating plants which have a much higher degree of safety built-in.

**Table 1: A generation expansion scenario**

| Capacity (MW) | Fuel | Year |
|---|---|---|
| 2x300 | Coal | 2011 |
| 300 | Coal | 2012 |
| 300 | Coal | 2013 |
| 300 | Coal | 2014 |
| 300 | Coal | 2015 |
| 300 | Coal | 2016 |
| 300 | Coal | 2017 |
| 300 | Coal | 2018 |
| 300 | Coal | 2019 |
| 105 | Gas Turbine | 2020 |

Source: Ceylon Electricity Board (2010).

Today, nuclear power generation plants provide approximately 15% of the world's electricity generation. The downward trend created after the 1980s has become reversed, and in view of the global warming (due to the GHGs partly as a result of fossil fuel burning), the world has taken a fresh look at nuclear power generation plants. Several countries, including Vietnam, Bangladesh, Malaysia, Thailand, oil

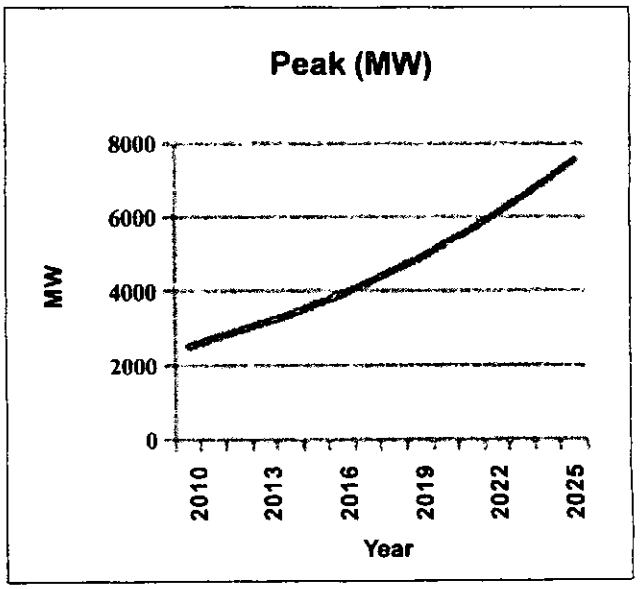


**Figure 2: Forecast peak demand**
Source: Ceylon Electricity Board (2010 ).

rich UAE and neighbouring India have revitalized their nuclear power generation programs. Some of the questions that need to get clarified on deciding whether nuclear power is suitable for Sri Lanka are as follows:

(a) Is it worth exposing Sri Lanka to the possibility of a nuclear accident?

(b) Can Sri Lanka protect a nuclear power plant from a terrorist attack?

(c) Can the Sri Lankan power system absorb power from a reasonably-sized nuclear power plant?

(d) What are the advantages and disadvantages of choosing nuclear power over coal power?

**Nuclear Technology**

Nuclear reactions can occur in two ways. The **fusion reaction** is so termed because two smaller nuclei react to form a bigger nucleus while releasing a large amount of energy arising from the loss of mass during the reaction (In terms of Einstein's equation $E=mC^2$ mass and energy are interchangeable. E stands for Energy, m is for mass and C is the velocity of light which is $3*10^8$ metres per second. Because C is very large, a small loss of mass is converted to a very large gain of energy. Tonnes of coal can be replaced by grams of Uranium). In a **fission reaction,** a large nucleus breaks down into two or more smaller nuclei, losing mass in the process. It is by fusion reactions, that energy is produced in stars (including our sun). However, fusion occurs at extremely high temperatures and is uncontrollable with today's technology. On the other hand, fission reaction is controllable and is used for electricity generation at nuclear power plants. One of the most commonly-used fission reactions is breaking down of Uranium by bombarding its Nuclei with neutrons, resulting in fission fragments such as Ba and Kr and more neutrons to continue the chain reaction. For example:

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{144}_{56}Ba + ^{89}_{36}Kr + 3\,^{1}_{0}n + Energy$$

It is noted that the above is not the usual chemical reaction, because of the presence of sub-atomic particles such as neutrons (n).

While natural as well as enriched Uranium is the most popular in nuclear power plants, Thorium is also emerging as a nuclear fuel. In fact, there is considerable research on Thorium reactors being carried out particularly in India. There is evidence of deposits of Thorium in the south-western coastal areas of Sri Lanka and Thorium and Uranium are close to Kudapandi Oya in the Balangoda area.

**Nuclear Power Technologies of the World**

The early nuclear power reactors in the 1950s favoured Uranium-fuelled and Graphite-moderated types such as Calderhall Power Plant in the United Kingdom (A moderator such as Graphite is used to slow down the neutrons; thereby the neutrons have a higher chance of interacting with Uranium nuclei to cause fission). Also the Canadian researched heavy water (with Deuterium replacing hydrogen in ordinary water) moderated and Uranium-fuelled reactors of the CANDU (Canada Deuterium Uranium) type, gained ground rapidly. Such reactors have been in satisfactory use over several decades. Boiling water reactors (BWR) which boil the water used for cooling were at times favoured. However the CANDU type gained ground over BWRs during the last decade. Figure 3 shows a typical layout of a nuclear power generation plant.

Among the other widely-used reactors is the Pressurised Water Reactor (PWR), in which the vessel housing the (Uranium) fuel rods is kept at high pressure, around160bars. Thereby the water flowing past the core is prevented from becoming steam. The heat in the pressurised water is used to generate steam in a boiler to drive a turbine coupled to an electricity generator.

Improved versions of the PWR, presently termed "Generation III or III+", have passive safety features. These features will shut down the reactor without any power, pumps or even operators in the event of an accident. Four such Plants (1000 MW each) are being built in China and the first plant is scheduled to be commissioned in year 2013.(Figure 4)

Small modular reactors, which range from 45 MW upwards and can be installed in modules, are being developed (Sally Adee and Erico Guizzo, 2010). They are not

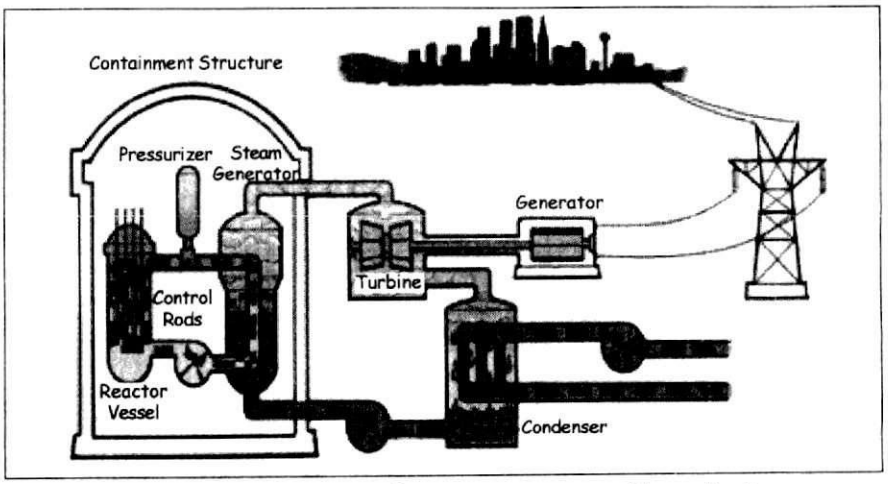


**Figure 3: Layout of a nuclear power generation plant**
Source: Priyadarshana, BMTA (2010).

**Table 2: Nuclear Status of some Countries (2006)**

| Country | Nuclear | Land Area | Population |
|---|---|---|---|
| | MW | 000, $km^2$ | Million |
| Armenia | 376 | 30 | 4 |
| Belgium | 5,800 | 31 | 11 |
| South Korea | 16,800 | 98 | 49 |
| Netherland | 482 | 42 | 16 |
| Japan | 47,000 | 378 | 127 |
| India | 3,040 | 3,288 | 1,095 |
| Pakistan | 425 | 804 | 166 |
| Russia | 21,700 | 17,000 | 143 |
| USA | 99,000 | 9,630 | 298 |

Source: Priyadarshana, BMTA (2010)

expected to be commercially proven until about year 2018. Sri Lanka has to watch these developments during the next few years.

More modern designs, termed. "Generation IV" reactors, which are "fast" reactors without a moderator, are being developed. The modular designs of these are expected to enable convenient additions of plants as and when required by demand increase in years to come. However, these reactors are still at the design stage.

While Sri Lanka may benefit from Generation III reactors in the 2030s, Generation IV is quite far from commercial operation yet. Progress of Generation III and Generation IV plants has to be keenly watched.

### Nuclear Power Technology Suitable for Sri Lanka

Depending on the size of power-generating plant and locations, there are many technological configurations used in different countries of the world. The majority of power-generating plants used in India are based on CANDU principles, and this technology has been proven over several decades as suitable for "smaller" plants of capacities of 220 MW to 900 MW range. Figure 4 shows a CANDU type power generation plant built in China. Considering the expected demand for power in Sri Lanka, the nuclear power requirement initially could be near the low-end of these "smaller" plants. Studies are currently on-going to determine admissible plant size for Sri Lanka.

### Is Sri Lanka too Small for Nuclear power?

One may argue that the mainland of Sri Lanka is only 65,000 square kilometres, and therefore, the country is too small to place a nuclear power plant. Table 2 shows the nuclear status of some countries of interest, and it can be noted that countries smaller than Sri Lanka in both population as well as land area are already hosting nuclear power plants. Therefore, it is unwise to exclude Sri Lanka from the nuclear power possibility based purely on the size of the country.

### The Capacity of the National Grid.

With the present technology, a nuclear power generation plant with a capacity in the range of 600MW to 1000MW is more economical. Even if Sri Lanka commits to build a nuclear power generation plant today, it will be another 15 years or so when the power plant is actually commissioned. By that time, probably in years 2025 to 2030, the power system capacity would have risen above 7000MW and absorbing even a 700MW nuclear power generation plant will not be a serious technical problem for the national grid.

### Risk of Nuclear Accidents

Although the safety aspects of nuclear power plants have improved considerably after Chernobyl event, it may not be prudent to rule out the possibility of an accident or a terrorist attack. In this respect, it is worthwhile to examine the present status of the nuclear power development in neighbouring India. From Figure 5, it can be seen that already nuclear power generation plants have been built at close distance from Sri Lankan soil. The distance from the Koondankulam Nuclear power plant to Colombo is only 280km.To Northern parts of Sri Lanka, it is very much close. Thus, Sri Lanka is already located in a nuclear zone.

The USA, having the largest number of nuclear power plants, is also considered as the number 1 target of the infamous Al-Qaida terrorist group. Sri Lanka too will need to plan meticulously and execute such plans and security schemes

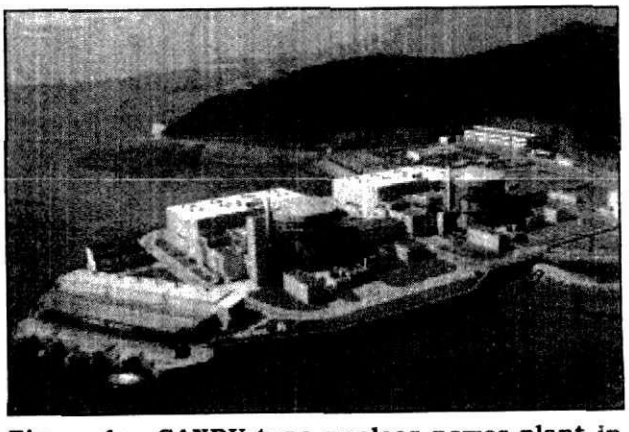

**Figure 4: CANDU type nuclear power plant in China**

Source: Priyadarshana, BMTA (2010).


**Figure 5: Nuclear power generation plants in India**

Source: Priyadarshana (2010).

to protect nuclear power generation plants as well as other strategic terrorist targets, to withstand a world plagued with modern terrorism. In fact, if a large hydro-power dam is breached by terrorists (or other acts) the flood waters will wipe out complete cities and villages and the disaster would be very heavy.

**Economics of Nuclear Power**

The long-term electricity prices will be important for a country's economic growth. The unit cost of electricity is determined by two major components. One component, generally referred to as the Capacity Cost, is based on the capital invested for setting up of the power generation plant and any other fixed costs of operation during the plant life. The second cost component, generally referred to as the Energy Cost, is the aggregate of the fuel dependent costs as well as other variable operational costs. Energy cost occurs only when electricity is generated while the capacity cost is required to return or recover the investment, whether the power generation plant is operated or not.

The calculation and comparison of electricity prices is highly complicated due to a variety of reasons, including the varying nature of capital costs, fuel prices, economies of scale, discount rates, loan interests, environmental costs, etc. As per a recent study (Priyadarshana, BMTA 2010), Table 3 shows a comparison of electricity generated from 300MW coal-based power generation plant and a nuclear power generation plant of 600MW built recently in China. The capital cost of the coal-fired power generation plant is taken as 1,500US$/kW while that of nuclear power generation plant is taken as 1,800US$/kW. An interest rate of 5% and a discount rate of 10% are assumed for both cases. Electricity prices have been calculated at current fuel prices as well as for increased fuel prices.

If $CO_2$ production is valued at 14US$ per tonne, there will be an additional 1.50 LKR cost per kWh which has to be added to the unit price tabulated for coal as an environmental cost. In case of nuclear power, the decommissioning cost as well as the cost of waste fuel handling is included in the estimation of the unit cost.

One of the notable features of nuclear power is its relatively low dependence on fuel cost increase. This is particularly important for a country's energy as well as economic stability.

**Table 3: Comparison of Electricity Cost with Rising Fuel Prices, Coal vs. Nuclear**

| At Present Cost | Unit cost of electricity | |
|---|---|---|
| | Coal LKR/kWh | Nuclear LKR/kWh |
| Current | 8.30 | 9.66 |
| 1.5 times | 10.72 | 10.06 |
| 2 times | 13.13 | 10.47 |
| 3 times | 17.96 | 11.27 |
| 4 times | 22.79 | 12.08 |

Source: Priyadarshana (2010 ).

**Conclusion**

When planning and installing new power generation facilities, Sri Lanka should look at all possible options, including renewables, fossil fuel and nuclear power. Selection of new plants should be based on economic and environmental considerations. In the future, cost of fossil fuels is likely to go up, and nuclear power may gain because nuclear power does not give out Carbon Dioxide or other green houses gases. Further, safer and modular new nuclear plant designs are now being developed and manufactured. Sri Lanka has therefore to carry out techno-economic feasibility studies taking all parameters into account, prior to deciding future generating plants.

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