“Nuclear Technology for socio-economic development & electricity generation in Sri Lanka context”

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World at glance........

Nuclear Power (70%)
- Electricity Generation
- Transportation
- Marine propulsion programme
- Space Shuttle programme
- Nuclear weapon programme

Nuclear Non-Power:
Radiation applications (30%)
- Nuclear Medicine
- Food irradiation & Sterilization
- Industrial applications
- Agriculture and Animal production science
- Isotope hydrology etc.

(Overview)
Nuclear Safety, Security & Safeguards
Organizational Structure

SLAEB : Promotional Body
SLAERC : Regulatory Body

SLAEB & SLAERC internationally ties with International Atomic Energy Agency (IAEA), Vienna, Austria.

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Introduction

Sri Lanka Atomic Energy Board (SLAEB) is involved in promoting the development of Nuclear Science and Technology (NST) in the fields of:

- Human Health
- Industry
- Environment
- Food & Agriculture
- Animal husbandry
- Naval & Aeronautics
- Isotopes hydrology
Key Figures:
Total electricity requirement per day: 25 – 35 GW hours

Expected electricity demand by 2032 is 6460 MW

Current growth rate of Electricity: 6 - 7 %

- Hydro power reserves are fully exploited.
- Solar and Wind energy is not practicable in large scale.
- Petroleum is expensive source for the country.
- Main option based on the coal power plants.
  Constraints: GHG Issues (CO₂, NOₓ, SOₓ emission)
- Therefore, Sri Lanka should be pay attention to Nuclear Energy.

“Sri Lanka keep option open for future developments in Nuclear Energy generation”
“Pre-feasibility study on the use of Nuclear power for Electricity Generation”

Steering committee
- Secretary, Ministry of Power & Energy
- Secretary, Ministry of Technology & Research
- Chairman, Ceylon Electricity Board (CEB)
- Chairman, Sri Lanka Atomic Energy Board (SLAEB)
- Chairman, Central Environmental Authority (CEA)
- Chairman, Geological Survey and mines Bureau (GSMB)

Core Group to assist the Steering Committee in
- Legal and regulatory requirements
- Energy planning
- Site Selection
- Nuclear Power plant Identification
- Public awareness
- Surveying for Nuclear Minerals
- Human Resource Development

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Existing levels of natural and artificial radioactivity concentrations of K-40, Ra-226, Th-232, Cs -137 and Cs -134 in marine and coastal sediment collected from selected locations in Sri Lanka have been determined after Fukushima Nuclear Power Plant (FNPP) accident took place in Japan.
Environmental Radiation Level in Sri Lanka

Atomic Energy Authority has established an on-line radiation monitoring system in order to measure environmental radiation levels continuously at different locations around the country. The system also works as a Nuclear Disaster Early Warning System.

At present 7 numbers of Remote Monitoring Stations (RMS) are installed at Colombo, Kalpitiya, Mannar, Delft, Kankasasthurai, Trincomalee and Galle. The Central Monitoring Station (CMS) of the above system was installed at the SLAEB premises.

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Present Composition of Electricity Generation

Hydro – 1355 MW
Thermal (CEB) – 863 MW
Thermal (IPP) – 820 MW
NCRE – 317 MW

IPP: Independent Power producers
CEB: Ceylon Electricity Board
NCRE: Non Conventional Renewable Energy
Nuclear Fuel Cycle

Front end: Mining and milling, Conversion, Enrichment and Fuel fabrication

Back end: Nuclear waste categorization
(Low level, Intermediate level & High level)
Nuclear fuel recycling (MOX fuel), nuclear waste transportation & Waste storage's are proceed as per the IAEA standards

Some Nuclear manufacturing companies are accepting the safe handling, transportation & storage of the nuclear waste.
e.g: Rosatom, Russia

IAEA Nuclear Fuel (LEU) Bank: Kazakhstan.
Nuclear Fuel Cycle

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Uranium Fuel Fabrication & Enrichment Process

UO₂ Pellet → Fuel Rod → Fuel Assembly

- Heating
- Autoclave with UF₆ transport container
- Pressure reduction
- Enriched UF₆
- Separation in centrifuge cascades
- Compressor
- Cooling box with transport container with enriched UF₆
- Depleted UF₆
- Compressor
- Cooling box with transport container with UF₆
Enrichment level in different conditions…..
- Nuclear Power Reactors: Enrichment level: 4-5% 
- Research Reactors: Enrichment level: 20%
- Nuclear weapons: Enrichment level: 90%

Main types of Nuclear fuel enrichment techniques
- Centrifuge Techniques
- Gaseous Diffusion Technique
- Laser Techniques (GE Hitachi based developed technique)

Main type of Nuclear waste Management technique:
Vitrified System (Convert into the glasses)
Nuclear Fission done as a chain reaction

\[
\begin{align*}
_{92}^{235}U + _{0}^{1}n & \rightarrow _{92}^{236}U \\
_{56}^{140}Ba & + _{36}^{93}Kr + 3_{0}^{1}n_0 \\
_{54}^{144}Xe & + _{38}^{90}Sr + 2_{0}^{1}n_0 \\
_{55}^{144}Cs & + _{37}^{90}Rb + 2_{0}^{1}n_0
\end{align*}
\]

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Nuclear Fusion Reaction
Two or more atomic nuclei collide at a very high speed and join to form a new type of atomic nucleus.

Fusion of deuterium with tritium creating helium-4, freeing a neutron, and releasing 17.6 MeV of energy, as an appropriate amount of mass changing forms to appear as the kinetic energy of the products, in agreement with kinetic $E = \Delta mc^2$, where $\Delta m$ is the change in rest mass of particles. e.g: ITER, Cadarache, France

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## Types of Nuclear Reactors – Fission based

### Nuclear power plants in commercial operation

<table>
<thead>
<tr>
<th>Reactor type</th>
<th>Main Countries</th>
<th>Number</th>
<th>GWe</th>
<th>Fuel</th>
<th>Coolant</th>
<th>Moderator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressurised Water Reactor (PWR)</td>
<td>US, France, Japan, Russia, China</td>
<td>265</td>
<td>251.6</td>
<td>enriched UO₂</td>
<td>water</td>
<td>water</td>
</tr>
<tr>
<td>Boiling Water Reactor (BWR)</td>
<td>US, Japan, Sweden</td>
<td>94</td>
<td>86.4</td>
<td>enriched UO₂</td>
<td>water</td>
<td>water</td>
</tr>
<tr>
<td>Pressurised Heavy Water Reactor 'CANDU' (PHWR)</td>
<td>Canada</td>
<td>44</td>
<td>24.3</td>
<td>natural UO₂</td>
<td>heavy water</td>
<td>heavy water</td>
</tr>
<tr>
<td>Gas-cooled Reactor (AGR &amp; Magnox)</td>
<td>UK</td>
<td>18</td>
<td>10.8</td>
<td>natural U (metal), enriched UO₂</td>
<td>CO₂</td>
<td>graphite</td>
</tr>
<tr>
<td>Light Water Graphite Reactor (RBMK)</td>
<td>Russia</td>
<td>12</td>
<td>12.3</td>
<td>enriched UO₂ PuO₂ and UO₂</td>
<td>water</td>
<td>graphite</td>
</tr>
<tr>
<td>Fast Neutron Reactor (FBR)</td>
<td>Japan, France, Russia</td>
<td>4</td>
<td>1.0</td>
<td>PuO₂ and UO₂</td>
<td>liquid sodium</td>
<td>none</td>
</tr>
<tr>
<td>Other</td>
<td>Russia</td>
<td>4</td>
<td>0.05</td>
<td>enriched UO₂</td>
<td>water</td>
<td>graphite</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>441</strong></td>
<td><strong>386.5</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*GWe : Capacity in thousand of megawatts*


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Light Water Reactor (LWR)

Enriched uranium used as the nuclear fuel and demineralized water (light water) used as a coolant and thermal neutron used as the moderator.

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Pressurized Heavy Water Reactor (PHWR)

Natural Uranium used as the fuel and heavy water (D2O) used as a coolant and thermal neutron used as the moderator.
Graphite moderated Gas Cooled Reactors
Fast Breeder Reactor - Fast Neutron Reactor (FBR)
Safety aspect of Modern Nuclear Power Plants

- GDCS (Gravity Driven Cooling System)
- PCCS (Passive Core Cooling System)
- ECCS (Emergency Core Cooling System)
- RHRS (Residual Heat Removal System)
- RCCV (Reinforced Concrete Containment Vessel)
- Natural air circulation system in between RCV (Reactor Containment Vessel) & RPV (Rector Pressure Vessel) etc.

e.g: Westinghouse AP 1000, GE Hitachi ESBWR, Areva EPR, Rosatom VVER 1200
**Human Resource development**

Well trained, technically sound, safety first disciplined human resources are needful in the following sectors.

**Engineering:** Nuclear, Electrical, Electronics, Mechanical, Civil, Material, Chemical, Networking etc.

**Scientific:** Nuclear Physics, Radiochemistry, Radio biology etc.

**Technical:** Control Simulators, Quality Assurance & Quality Control, Non Destructive Testing (NDT), welding techniques etc.

**Sociological:** Psychological aspect, Public perception, Signing conventions/International Treaties etc.
Environmental Impact Assessment (EIA) & Site Selection

Engineering aspects:
- Oceanography
- Hydrology
- Geology
- Seismology
- Meteorology etc.

Environmental aspects:
- Man induced events
  (Terrorist attack, Plane crash etc)
- Demography
- Land and water use
- Ecology etc.
Climate Change and Current status of Nuclear Power

In September 2012 the International Atomic Energy Agency (IAEA) announced that (07) seven newcomer countries to launch nuclear programs - Lithuania, - UAE, - Turkey, - Belarus, - Vietnam, - Poland and Bangladesh
Locations of Nuclear Power plants & seismic zones of Indian subcontinent
Bilateral Agreements – Nuclear Diplomacy

February 2015: Sri Lanka government signed a nuclear cooperation agreement with India.
- capacity building and training in peaceful application of nuclear energy
- the use of radioisotopes
- Nuclear safety
- Radioactive waste management
- Radiation safety and nuclear security.

April 2015: Sri Lanka government signed a nuclear cooperation agreement with Pakistan.

Several nuclear partnerships are proceed with Japan, Russia & Republic of Korea on HR Development
GTRI Programme: USA
Conclusion

- Electrified train system
- Indo - Sri Lanka
Common electrical grid

“Total power demand should be larger than to 6000 MW to introduce a minimum 600 MW scale nuclear power plant beyond 2030 is a viable option for the Sri Lanka context.”

Load balancing factor

Current Lack of Base load, Grid capacity & Power demand are not suite to connect the Nuclear power as a favourable candidate of the county.

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References


Thank You