Sri Lanka’s Power
Generation Expansion Planning

Eng. Buddhika Samarasekara
Chief Engineer (Generation Planning)

Transmission and Generation Planning Branch
Transmission Division
Ceylon Electricity Board
Sri Lanka

May 2017
SRI LANKA

- Total Area: 65,610 km²
- Land Area: 62,705 km²
- Population: 21.2 million
  - Urban: 18.3%
  - Rural: 81.7%
- Population Density: 338 per sqkm
- Labour Force: 8.311 million
- Unemployment rate: 4.4%
- Literacy rate: 93.3%
- Life expectancy: 72 yrs (M), 78 yrs (F)
- Monetary Unit: Sri Lankan Rupee
  (1 USD = 150 LKR at Jan 2017)

INTRODUCTION

- Gross Domestic Product: 11,839 billion LKR (Market Prices)
- GDP per capita: 3,835 US$ (Market Prices)
- GDP structure 2016
  - Agriculture: 7.1%
  - Industry: 26.8%
  - Services: 56.5%
  - Taxes less subsidies on products: 9.6%
SRI LANKAN POWER SECTOR

- Installed capacity: 4065 MW
- Peak Demand: 2483 MW
- Electricity Generated: 14249 GWh
- System Losses: 10.28%
- Elec. Consumption per Capita: 603 kWh
- Level of Electrification: 98.71%

(STATUS OF ELECTRIFICATION IN SRI LANKA JUNE - 2016)

(June 2016)
DISCUSSION TOPICS

• Generation Planning Methodology & Tools
• Scenario Analysis
• Contingency Analysis
• NDC Planning
LONG-TERM GENERATION EXPANSION PLAN

• Planning Period: 20 Years (2018-2037)

• Study Period: 25 Years (2018-2042)

• Planning Criteria:
  – **Loss of Load Probability**: Maximum 1.5%
  – **Reserve Margin**: Minimum 2.5% & Maximum 20%.

• **Unserved Energy Cost**
  
  2011 value *(Reference-PUCSL)* - 0.5 $/kWh
  
  2017 escalated Value - **0.663 $/kWh (98.07 Rs/kWh)**

• **Discount Rate**
  – 10% discount rate
STUDY PROCESS

- Preparation of Demand Forecast
- Update existing and committed generating system data
- Screen available generating technology options
- Assess the hydro system capabilities using SDDP model
- Study on Integration of Renewable Based Generation
- Formulate and prepare the generation expansion plan using WASP IV (In future Optgen-sddp Model)
- Analysis of robustness and feasibility of the plan
- Contingency Analysis
DEMAND FORECAST 2018-2042
Base Load Forecast = Time Trend Forecast + (Econometric Forecast + External Effects)

External effects of the Temperature variation and Tariff adjustments were analyzed and considered.

<table>
<thead>
<tr>
<th>Year</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Distribution Divisions (GWh)</td>
<td>14,967</td>
<td>16,171</td>
<td>17,282</td>
<td>18,704*</td>
<td>19,822*</td>
</tr>
<tr>
<td>Time Trend (GWh)</td>
<td>15,160</td>
<td>16,188</td>
<td>17,285</td>
<td>18,456</td>
<td>19,370</td>
</tr>
</tbody>
</table>

*These two figures are high due to the consideration of the demands of Megapolis Projects and other new developments. However, average 5.9% growth is forecast during 2018-2022.
LONG TERM FORECAST

Methodology

• Econometric modelling has been adopted by CEB for the PERIOD 2021-2040
• Sales figures of the past were analysed against following independent variables.

  • GDP Per Capita
  • Number of Domestic Consumer Accounts in previous year

  • Industrial Sector Gross Domestic Product
  • Previous year Electricity demand of Industrial consumer category

  • Service Sector Gross Domestic Product
  • Previous year Electricity demand in Commercial consumer category

  • Time-trend analysis
ACTUAL AND FORECAST ENERGY/PEAK DEMAND

As per Draft LTGEP 2018-2037
## Base Demand Forecast

<table>
<thead>
<tr>
<th>Year</th>
<th>Demand (GWh)</th>
<th>Net Loss* (%)</th>
<th>Net Generation (GWh)</th>
<th>Peak Demand (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>13656</td>
<td>9.92</td>
<td>15160</td>
<td>2585</td>
</tr>
<tr>
<td>2018</td>
<td>14588</td>
<td>9.88</td>
<td>16188</td>
<td>2738</td>
</tr>
<tr>
<td>2019</td>
<td>15583</td>
<td>9.84</td>
<td>17285</td>
<td>2903</td>
</tr>
<tr>
<td>2020</td>
<td>16646</td>
<td>9.81</td>
<td>18456</td>
<td>3077</td>
</tr>
<tr>
<td>2021</td>
<td>17478</td>
<td>9.77</td>
<td>19370</td>
<td>3208</td>
</tr>
<tr>
<td>2022</td>
<td>18353</td>
<td>9.73</td>
<td>20331</td>
<td>3346</td>
</tr>
<tr>
<td>2023</td>
<td>19273</td>
<td>9.69</td>
<td>21342</td>
<td>3491</td>
</tr>
<tr>
<td>2024</td>
<td>20242</td>
<td>9.65</td>
<td>22404</td>
<td>3643</td>
</tr>
<tr>
<td>2025</td>
<td>21260</td>
<td>9.61</td>
<td>23522</td>
<td>3804</td>
</tr>
<tr>
<td>2026</td>
<td>22332</td>
<td>9.58</td>
<td>24697</td>
<td>3972</td>
</tr>
<tr>
<td>2027</td>
<td>23459</td>
<td>9.54</td>
<td>25933</td>
<td>4149</td>
</tr>
<tr>
<td>2028</td>
<td>24639</td>
<td>9.50</td>
<td>27225</td>
<td>4335</td>
</tr>
<tr>
<td>2029</td>
<td>25867</td>
<td>9.46</td>
<td>28570</td>
<td>4527</td>
</tr>
<tr>
<td>2030**</td>
<td>27164</td>
<td>9.42</td>
<td>29990</td>
<td>4726</td>
</tr>
<tr>
<td>2031</td>
<td>28388</td>
<td>9.38</td>
<td>31328</td>
<td>4939</td>
</tr>
<tr>
<td>2032</td>
<td>29637</td>
<td>9.35</td>
<td>32692</td>
<td>5157</td>
</tr>
<tr>
<td>2033</td>
<td>30926</td>
<td>9.31</td>
<td>34099</td>
<td>5381</td>
</tr>
<tr>
<td>2034</td>
<td>32251</td>
<td>9.27</td>
<td>35546</td>
<td>5612</td>
</tr>
<tr>
<td>2035</td>
<td>33642</td>
<td>9.23</td>
<td>37063</td>
<td>5854</td>
</tr>
<tr>
<td>2036</td>
<td>35090</td>
<td>9.19</td>
<td>38642</td>
<td>6107</td>
</tr>
<tr>
<td>2037</td>
<td>36613</td>
<td>9.15</td>
<td>40302</td>
<td>6372</td>
</tr>
<tr>
<td>2038</td>
<td>38165</td>
<td>9.12</td>
<td>41992</td>
<td>6642</td>
</tr>
<tr>
<td>2039</td>
<td>39733</td>
<td>9.08</td>
<td>43699</td>
<td>6915</td>
</tr>
<tr>
<td>2040</td>
<td>41324</td>
<td>9.04</td>
<td>45431</td>
<td>7193</td>
</tr>
<tr>
<td>2041</td>
<td>42967</td>
<td>9.02</td>
<td>47227</td>
<td>7481</td>
</tr>
<tr>
<td>2042</td>
<td>44700</td>
<td>9.00</td>
<td>49121</td>
<td>7784</td>
</tr>
</tbody>
</table>

**5 Year Average Growth (2018-2022)**: 5.9%
**10 Year Average Growth (2018-2027)**: 5.4%
**20 Year Average Growth (2018-2037)**: 5.0%
**25 Year Average Growth (2018-2042)**: 4.8%

*Net losses include losses at the Transmission & Distribution levels and any non-technical losses. Generation (Including auxiliary consumption) losses are excluded. This forecast will vary depend on the hydro thermal generation mix of the future.*

**It is expected that day peak would surpass the night peak from this year onwards.**
GENERATION OPTIONS
EXPECTED HYDRO ENERGY POTENTIAL

Obtained using SDDP Model

Annual Total
Average

4050 GWh
FUTURE GENERATION OPTIONS - CONVENTIONAL

Candidate Hydro Plants

- Seethawaka Hydro Power Plant - 20MW / 48GWh
- Gin Ganga Hydro Power plant - 20MW / 66GWh
- Thalpitigala Hydro Power Plant - 15MW / 52.4GWh

Candidate Thermal Plants

- 35 MW Auto Diesel fired gas turbines
- 105 MW Auto Diesel fired gas turbines
- 150 MW Auto Diesel fired combined cycle plants
- 300 MW Auto Diesel fired combined cycle plants
- 300 MW Coal fired Power Plants
- 600MW Super Critical Coal fired Power Plant
- 300 MW Natural Gas fired combined cycle plants
- 600 MW Nuclear plants
SCREENING CURVES
Thermal Generation Options

Unit Cost (UScts/kWh) vs. Plant Factor (%)

- GT35 MW
- GT105 MW
- CCY150 MW
- FO Engines 15MW
- CCY300 MW
- Nuclear 600MW
- LNG 150MW
- LNG 300 MW
- SUPC 600MW
- New Coal 300 MW
SCREENING CURVES

Other Renewable Options

- Solar with battery 10MW (Solar Capital Cost = USD 1400/kW)
- Dendro 5 MW
- Solar with battery 10MW (Solar Capital Cost = USD 900/kW)
- Solar 10MW (Capital Cost = USD 1400/kW)
- Solar 10MW (Capital Cost = USD 900/kW)
- Wind 20MW
OTHER RENEWABLE ENERGY MODELLING
Inclusion of ORE in the Long Term Generation Expansion Plan

According to the estimated wind and solar resource profiles, the demand profiles were modified to reflect both capacity and energy contributions from these ORE power plants.
LOAD CURVE

Maximum Wind & Solar Contribution

Minimum Wind & Solar Contribution
Inclusion of ORE in the Long Term Generation Expansion Plan

According to the adjusted demand profiles, the Load Duration Curves (LDC) were adjusted and used as inputs for expansion studies.

LTGEP 2018-2037

- 300 LDC’S represents 25 year planning horizon instead of 25 LDC’s used in previously.
- Both Capacity and Energy Contribution taken in to consideration.
### PROJECTED DEVELOPMENT OF OTHER RE

Based on RE Integration Study 2016/17

<table>
<thead>
<tr>
<th>Year</th>
<th>Mini Hydro (MW)</th>
<th>Wind (MW)</th>
<th>Biomass (MW)</th>
<th>Solar (MW)</th>
<th>Cumulative Total NCRE Capacity (MW)</th>
<th>Share of NCRE from Total Generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018</td>
<td>344</td>
<td>144</td>
<td>39</td>
<td>210</td>
<td>737</td>
<td>13%</td>
</tr>
<tr>
<td>2019</td>
<td>359</td>
<td>194</td>
<td>44</td>
<td>305</td>
<td>902</td>
<td>14%</td>
</tr>
<tr>
<td>2020</td>
<td>374</td>
<td>414</td>
<td>49</td>
<td>410</td>
<td>1246</td>
<td>18%</td>
</tr>
<tr>
<td>2021</td>
<td>384</td>
<td>489</td>
<td>54</td>
<td>465</td>
<td>1392</td>
<td>19%</td>
</tr>
<tr>
<td>2022</td>
<td>394</td>
<td>539</td>
<td>59</td>
<td>471</td>
<td>1463</td>
<td>20%</td>
</tr>
<tr>
<td>2023</td>
<td>404</td>
<td>599</td>
<td>64</td>
<td>526</td>
<td>1592</td>
<td>20%</td>
</tr>
<tr>
<td>2024</td>
<td>414</td>
<td>644</td>
<td>69</td>
<td>581</td>
<td>1708</td>
<td>20%</td>
</tr>
<tr>
<td>2025</td>
<td>424</td>
<td>729</td>
<td>74</td>
<td>685</td>
<td>1912</td>
<td>21%</td>
</tr>
<tr>
<td>2026</td>
<td>434</td>
<td>729</td>
<td>79</td>
<td>740</td>
<td>1982</td>
<td>20%</td>
</tr>
<tr>
<td>2027</td>
<td>444</td>
<td>754</td>
<td>84</td>
<td>795</td>
<td>2076</td>
<td>20%</td>
</tr>
<tr>
<td>2028</td>
<td>454</td>
<td>799</td>
<td>89</td>
<td>900</td>
<td>2242</td>
<td>20%</td>
</tr>
<tr>
<td>2029</td>
<td>464</td>
<td>824</td>
<td>94</td>
<td>954</td>
<td>2336</td>
<td>20%</td>
</tr>
<tr>
<td>2030</td>
<td>474</td>
<td>894</td>
<td>99</td>
<td>1009</td>
<td>2476</td>
<td>20%</td>
</tr>
<tr>
<td>2031</td>
<td>484</td>
<td>929</td>
<td>104</td>
<td>1064</td>
<td>2580</td>
<td>20%</td>
</tr>
<tr>
<td>2032</td>
<td>494</td>
<td>974</td>
<td>104</td>
<td>1119</td>
<td>2691</td>
<td>20%</td>
</tr>
<tr>
<td>2033</td>
<td>504</td>
<td>1044</td>
<td>109</td>
<td>1173</td>
<td>2830</td>
<td>20%</td>
</tr>
<tr>
<td>2034</td>
<td>514</td>
<td>1114</td>
<td>109</td>
<td>1229</td>
<td>2965</td>
<td>20%</td>
</tr>
<tr>
<td>2035</td>
<td>524</td>
<td>1184</td>
<td>114</td>
<td>1283</td>
<td>3105</td>
<td>20%</td>
</tr>
<tr>
<td>2036</td>
<td>534</td>
<td>1279</td>
<td>114</td>
<td>1338</td>
<td>3265</td>
<td>20%</td>
</tr>
<tr>
<td>2037</td>
<td>544</td>
<td>1349</td>
<td>119</td>
<td>1442</td>
<td>3454</td>
<td>20.6%</td>
</tr>
</tbody>
</table>
PROJECTED DEVELOPMENT OF OTHER RE

![Bar chart showing projected development of other renewable energy sources from 2018 to 2037. The chart includes data for solar, wind, biomass, and mini hydro energy (in MW) and energy share (%).](chart.png)
FORMULATE AND PREPARE THE GENERATION EXPANSION PLAN
WASP-IV METHODOLOGY

WASP determines the Generating System Expansion Plan that meets demand at minimum cost, while satisfying certain user specified constraints for the system:

INPUT
- Load forecast
- Existing system
- Candidate units
- Constraints
  - Reliability
  - Implementation
  - Environment
  - Fuel availability etc.

OUTPUT
- Time
- Build schedule
- Generation
- Fuel consumption
- Costs
- Emissions

Cost Function Minimization Using Linear Programming Method
DETERMINATION OF NECESSARY CAPACITIES

- Annual peak load
- Minimum reserve margin
- Maximum reserve margin
- WASP optimal capacity
- New necessary capacity
- Critical LOLP
- Capacity of existing system
DISPATCH ANALYSIS
Operational Study

Long Term- Hydro Thermal Optimization (SDDP Software)

• **Optimum use of hydro resource** and the corresponding operation of thermal power plants are simulated at monthly time step.

• **Future Hydro conditions are predicted** using probabilistic methods
Operational Study

Short Term Dispatch Analysis (NCP Software)

2022 High Wind period Week Day
ANALYSIS OF BASE CASE PLAN
Robustness of the economically optimized plan was investigated by analyzing its sensitivity to changes in the key input parameters.

<table>
<thead>
<tr>
<th>Scenario/Sensitivity Study</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scenarios</strong></td>
<td></td>
</tr>
<tr>
<td>Reference Case</td>
<td>No future ORE</td>
</tr>
<tr>
<td>Fuel Diversification</td>
<td></td>
</tr>
<tr>
<td>Future Coal Power Development Permitted up to 1800 MW</td>
<td></td>
</tr>
<tr>
<td>No Future Coal Power Development Permitted</td>
<td></td>
</tr>
<tr>
<td>Energy Mix with Nuclear</td>
<td></td>
</tr>
<tr>
<td><strong>Sensitivities on Base Case</strong></td>
<td></td>
</tr>
<tr>
<td>Demand Variation</td>
<td></td>
</tr>
<tr>
<td>High Demand</td>
<td>1% higher</td>
</tr>
<tr>
<td>Low Demand</td>
<td>1% lower</td>
</tr>
<tr>
<td>Discount Rate Variation</td>
<td></td>
</tr>
<tr>
<td>High Discount</td>
<td>15%</td>
</tr>
<tr>
<td>Low Discount</td>
<td>3%</td>
</tr>
<tr>
<td>Fuel Price Escalation</td>
<td></td>
</tr>
<tr>
<td>Based on IEA forecast</td>
<td></td>
</tr>
<tr>
<td>WEO 2016</td>
<td></td>
</tr>
</tbody>
</table>

Power system planners are expected to predict the future and they have to provide decision makers with information that would facilitate making sound decisions.
COMPARISON OF ENERGY SHARE IN 2037

Reference Case
- 69% Thermal - Coal
- 15% Major Hydro
- 11% Energy Mix with Nuclear
- 1% ORE
- 4% Thermal - Oil
- 2% PSPP

Base Case
- 53% Thermal - Coal
- 14% Major Hydro
- 12% Energy Mix with Nuclear
- 10% ORE
- 2% Thermal - Oil
- 2% PSPP

Future Coal Power Development Limited to 1800 MW
- 41% Thermal - Coal
- 26% Major Hydro
- 10% Energy Mix with Nuclear
- 7% ORE
- 1% Thermal - Oil
- 2% PSPP

No Future Coal Power Development
- 56% Thermal - Coal
- 11% Major Hydro
- 11% Energy Mix with Nuclear
- 13% ORE
- 20% Thermal - Oil
- 2% PSPP

Energy Mix with Nuclear
- 34% Thermal - Coal
- 21% Major Hydro
- 19% Energy Mix with Nuclear
- 14% ORE
- 2% Thermal - Oil
- 2% PSPP
COMPARISON OF CAPACITY SHARE IN 2037

Reference Case
- Major Hydro: 47%
- ORE: 18%
- Thermal - Coal: 16%
- Thermal - LNG: 6%
- Thermal - Oil: 6%
- Nuclear: 7%

Base Case
- Major Hydro: 32%
- ORE: 15%
- Thermal - Coal: 13%
- Thermal - LNG: 5%
- Thermal - Oil: 4%
- Nuclear: 4%

Future Coal Power Development Limited to 1800 MW
- Major Hydro: 31%
- ORE: 4%
- Thermal - Coal: 32%
- Thermal - LNG: 15%
- Thermal - Oil: 4%
- Nuclear: 6%

No Future Coal Power Development
- Major Hydro: 42%
- ORE: 15%
- Thermal - Coal: 4%
- Thermal - LNG: 6%
- Thermal - Oil: 8%
- Nuclear: 31%

Energy Mix with Nuclear
- Major Hydro: 32%
- ORE: 15%
- Thermal - Coal: 13%
- Thermal - LNG: 10%
- Thermal - Oil: 4%
- Nuclear: 20%
INVESTMENT ANALYSIS
ENVIRONMENTAL IMPACT ANALYSIS
Comparison of SOx, NOx, PM & CO₂ Emissions

- **CO₂ (Million tons)**
- **SO₂ (1000 tons)**
- **NOx (1000 tons)**
- **Particulate Matter (1000 tons)**

- **Base Case Scenario**
- **Reference Scenario**
- **Future Coal Power Development Limited to 1800MW Scenario**
- **No Future Coal Power Development Scenario**
- **Energy Mix with Nuclear Scenario**
Cost Impacts of CO₂ Emission Reductions

PV Cost USD mil

CO₂ kT

Compared with Reference Case

Future Coal Power Development

Base Case Scenario

No Future Coal Power Development

Energy Mix with Nuclear

Future Coal Power Development Limited to 1300MW

Base Case Scenario

No Future Coal Power Development

Energy Mix with Nuclear

Energy Mix with Nuclear Scenario

Future Coal Power Development Limited to 1300MW

Future Coal Power Development

Base Case Scenario

No Future Coal Power Development

Energy Mix with Nuclear

Energy Mix with Nuclear Scenario

Future Coal Power Development Limited to 1300MW

 préco::19.28

Energy Mix with Nuclear Scenario

Future Coal Power Development Limited to 1300MW

Energy Mix with Nuclear

Future Coal Power Development

Energy Mix with Nuclear Scenario

Future Coal Power Development Limited to 1300MW

Energy Mix with Nuclear

Future Coal Power Development

Energy Mix with Nuclear Scenario

Future Coal Power Development Limited to 1300MW

Energy Mix with Nuclear

Future Coal Power Development

Energy Mix with Nuclear Scenario

Future Coal Power Development Limited to 1300MW

Energy Mix with Nuclear

Future Coal Power Development

Energy Mix with Nuclear Scenario

Future Coal Power Development Limited to 1300MW

Energy Mix with Nuclear

Future Coal Power Development

Energy Mix with Nuclear Scenario

Future Coal Power Development Limited to 1300MW

Energy Mix with Nuclear

Future Coal Power Development

Energy Mix with Nuclear Scenario

Future Coal Power Development Limited to 1300MW

Energy Mix with Nuclear

Future Coal Power Development

Energy Mix with Nuclear Scenario

Future Coal Power Development Limited to 1300MW

Energy Mix with Nuclear

Future Coal Power Development

Energy Mix with Nuclear Scenario

Future Coal Power Development Limited to 1300MW

Energy Mix with Nuclear

Future Coal Power Development

Energy Mix with Nuclear Scenario

Future Coal Power Development Limited to 1300MW

Energy Mix with Nuclear

Future Coal Power Development

Energy Mix with Nuclear Scenario

Future Coal Power Development Limited to 1300MW

Energy Mix with Nuclear

Future Coal Power Development

Energy Mix with Nuclear Scenario

Future Coal Power Development Limited to 1300MW

Energy Mix with Nuclear

Future Coal Power Development

Energy Mix with Nuclear Scenario

Future Coal Power Development Limited to 1300MW

Energy Mix with Nuclear

Future Coal Power Development

Energy Mix with Nuclear Scenario

Future Coal Power Development Limited to 1300MW

Energy Mix with Nuclear

Future Coal Power Development

Energy Mix with Nuclear Scenario

Future Coal Power Development Limited to 1300MW

Energy Mix with Nuclear

Future Coal Power Development

Energy Mix with Nuclear Scenario

Future Coal Power Development Limited to 1300MW

Energy Mix with Nuclear

Future Coal Power Development

Energy Mix with Nuclear Scenario

Future Coal Power Development Limited to 1300MW

Energy Mix with Nuclear

Future Coal Power Development

Energy Mix with Nuclear Scenario

Future Coal Power Development Limited to 1300MW

Energy Mix with Nuclear

Future Coal Power Development

Energy Mix with Nuclear Scenario

Future Coal Power Development Limited to 1300MW

Energy Mix with Nuclear

Future Coal Power Development

Energy Mix with Nuclear Scenario

Future Coal Power Development Limited to 1300MW

Energy Mix with Nuclear
## ENVIRONMENTAL ASPECTS
### Comparison of CO₂ Emissions from Fuel Combustion

<table>
<thead>
<tr>
<th>Country</th>
<th>kg CO₂/2010 US$ of GDP</th>
<th>kg CO₂/2010 US$ of GDP Adjusted to PPP</th>
<th>Tons of CO₂ per Capita</th>
<th>Total CO₂ Emissions (Million tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sri Lanka</td>
<td>0.23</td>
<td>0.08</td>
<td>0.81</td>
<td>16.7</td>
</tr>
<tr>
<td>Pakistan</td>
<td>0.67</td>
<td>0.17</td>
<td>0.74</td>
<td>137.4</td>
</tr>
<tr>
<td>India</td>
<td>0.92</td>
<td>0.29</td>
<td>1.56</td>
<td>2019.7</td>
</tr>
<tr>
<td>Indonesia</td>
<td>0.46</td>
<td>0.17</td>
<td>1.72</td>
<td>436.5</td>
</tr>
<tr>
<td>Thailand</td>
<td>0.64</td>
<td>0.24</td>
<td>3.6</td>
<td>243.5</td>
</tr>
<tr>
<td>China</td>
<td>1.08</td>
<td>0.53</td>
<td>6.66</td>
<td>9134.9</td>
</tr>
<tr>
<td>France</td>
<td>0.10</td>
<td>0.17</td>
<td>4.32</td>
<td>285.7</td>
</tr>
<tr>
<td>Japan</td>
<td>0.21</td>
<td>0.27</td>
<td>9.35</td>
<td>1188.6</td>
</tr>
<tr>
<td>Germany</td>
<td>0.20</td>
<td>0.21</td>
<td>8.93</td>
<td>723.3</td>
</tr>
<tr>
<td>Switzerland</td>
<td>0.06</td>
<td>0.09</td>
<td>4.61</td>
<td>37.7</td>
</tr>
<tr>
<td>USA</td>
<td>0.32</td>
<td>0.32</td>
<td>16.22</td>
<td>5176.2</td>
</tr>
<tr>
<td>Brazil</td>
<td>0.20</td>
<td>0.16</td>
<td>2.31</td>
<td>476</td>
</tr>
<tr>
<td>Australia</td>
<td>0.26</td>
<td>0.36</td>
<td>15.81</td>
<td>373.8</td>
</tr>
<tr>
<td>World</td>
<td>0.44</td>
<td>0.32</td>
<td>4.47</td>
<td>32381</td>
</tr>
</tbody>
</table>

### Total CO₂ Emissions (Million tons) from Electricity – Actual and Predicted in Scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>2014</th>
<th>2025</th>
<th>2030</th>
<th>2037</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Future Coal</td>
<td>6.79</td>
<td>5.05</td>
<td>7.68</td>
<td>12.08</td>
</tr>
<tr>
<td>Coal Limited 1800 MW</td>
<td>6.79</td>
<td>6.41</td>
<td>10.72</td>
<td>17.05</td>
</tr>
<tr>
<td>Base Case</td>
<td>6.79</td>
<td>7.41</td>
<td>11.32</td>
<td>19.25</td>
</tr>
<tr>
<td>Reference</td>
<td>☺️6.79</td>
<td>9.33</td>
<td>13.55</td>
<td>24.20</td>
</tr>
</tbody>
</table>
CONTEMPENCY ANALYSIS

Analysis of the impact of both controllable and uncontrollable risk events, which could lead to inadequacy of supply to meet the capacity and energy demand in immediate future years from 2018 to 2022.

1. Variation in Hydrology
2. Variation in Demand
3. Delays in implementation of Power Plants
4. Long period outage of a Major Power Plant

Single occurrence of these risk events were considered at first and then simultaneous occurrence of several events were analysed to identify the short term energy and capacity shortage.
INDC Submitted to UNFCCC

• DETERMINATION OF INDC’s

Business As Usual (BAU):
Only existing NCRE power plants as at 1st January 2015 were included without committed major hydro developments.

Reference Case:
Only existing NCRE power plants as at 1st January 2015 were included.

Base Case:
20% Energy share from Non-Conventional Renewable Energy (NCRE) considered from 2020 onwards.

![Graph showing CO₂ emissions reduction from INDC and National Commitment](image)
Goverments agreed a long-term goal of keeping the increase in global average temperature to well below 2°C above pre-industrial levels and to aim to limit the increase to 1.5°C.

Sri Lanka ratified in September 2016

Energy Sector INDCs which was prepared based on LTGEP 2015-2034 stated that Sri Lanka expects 4% unconditional and 16% conditional reduction of greenhouse gas emissions with compared to Reference scenario in 2030.
RECOMMENDATIONS FOR VARIABLE RENEWABLE ENERGY INTEGRATION

• Day ahead, hourly basis **Wind and Solar PV energy forecasting system**

• 24 hour (round the clock), **Renewable Energy Desk**
  Technical assistance expected from financing agencies to develop Renewable Energy Desk

• Variable Renewable Energy (VRE) **curtailment rights** to system operator
  Compensation mechanism has to be studied to future VRE plants.

• Planned **network strengthening** projects must be completed as scheduled.

• Future **base load power plants should be designed to de-load** in order
  to keep the VRE curtailment at a minimum level.

• The **ORE locations** should be prioritized based on the plant factors,
  availability and cost of transmission network and developed accordingly

• If the proposed conventional plants are not commissioned as scheduled,
  the VRE addition in the plan has to be revised accordingly. Thus it is
  proposed to review this planning methodology once in two years.
SRI LANKAN CONTEXT IN CLIMATE CHANGE

TOWARDS LOW CARBON DEVELOPMENT STRATEGY

• Amendment of National Energy Policy to absorb more ORE

• Nationally Determined Contributions (NDCs)

• Contribution from Renewable Energy

• Clean Development Mechanism

• Carbon Partnership Facility

• Fuel Quality Road Map

• Loss Reduction in Transmission & Distribution Network

• Demand Side Management & Energy Conservation
THANK YOU