In 2002, the CEB released its first national Integrated Electricity Plan (IEP), covering the period 2003-2012, with a view to guiding Mauritius towards a more stable electricity future, thereby supporting the continued socio-economic development of the country. The cornerstones of the IEP 2003-2012 were to optimise the use of the existing power system, ensure least-cost capacity expansion, encourage customers to participate in energy efficiency and conservation, and provide for continued private sector opportunities in the electricity sector.

During the past decade, we have, to a large extent, implemented the various strategies that were enumerated in the IEP, while taking on board the demands of the ever changing business environment. It is also worth noting that the Government’s vision to make Mauritius a sustainable island (Maurice Ile Durable) has posed new challenges for the utility.

The new Integrated Electricity Plan covering the period 2013-2022, which I am pleased to present, gives an overview of CEB’s broad strategies to address the energy challenges of Mauritius, both short-term and long-term. The primary objective of the IEP 2013-2022 is to create a sufficiently broad energy portfolio to safeguard the country against energy security concerns and price instability, while being sensitive to environmental imperatives.

Through this IEP, the CEB takes a renewed commitment to be a privileged partner in moving Mauritius into its new phase of development. Working together and through constructive partnerships with all stakeholders, we will do our best to ensure that the demand for reliable, affordable and sustainable energy is effectively and efficiently met.

S. K. Thannoo
General Manager
Electricity is unquestionably an intrinsic element of our daily lives. Round the clock, almost all our activities, in one way or another, depend on electricity supply. Today, our country’s dependence on electricity has reached new extremes. Just imagine the consequences of a relatively short power outage – our country’s economic activities, social life and vital essential services grind to a halt – to observe the extent to which we are dependent on electricity.

As in most developing countries, electrification of the Republic of Mauritius has undeniably been a major pace-setter, enabling its social and economic progress. Indeed, the development of the power system, and the power sector at large, has been driving the economic growth of our country.

However, conscious of the fact that our country, as at today, has limited known exploitable energy sources, we will continue to depend largely on energy import to meet our daily electricity requirements. In this respect, CEB reiterates that it must continue to plan intelligently so as to ensure secure, reliable, affordable and sustainable electricity supply for the future.

By formulating this second Integrated Electricity Plan (IEP) 2013–2022, using in-house expertise only, CEB asserts its readiness to guide the strategic development of its core businesses, which will attempt to guarantee the long-term stable electricity future of the country. The IEP 2013–2022 will enable the CEB to plan carefully the allocation of our country’s power systems resources so as to effectively balance the supply and demand of electricity for the coming decade, through least-cost investment, while diligently meeting emerging challenges, such as compliance with environmental norms and increasing the share of renewable energy.

This Plan is a unique document; in the sense that the CEB is among just a few public entities – not to say the only one – that formulates such a 10–year integrated planning and updates it on an annual basis, so as to steer its investment plans judiciously. This highly regarded publication is an invaluable piece of information for government, investors, business partners, NGOs, academia, customers and the society at large.

Through this strategic plan, we humbly invite all our stakeholders to unify their efforts with us to develop constructively the Mauritius and Rodrigues power systems. By sharing this Plan with you, we hope to foster a two-way exchange of information that will ensure a better electricity future for the Republic of Mauritius.

M. S. Mukoon, MIEM, RPEM
Manager, Corporate Planning & Research
# List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>AGOA</td>
<td>African Growth Opportunity Act</td>
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<tr>
<td>AMI</td>
<td>Advanced Metering Infrastructure</td>
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<td>AMR</td>
<td>Automatic Meter Reading</td>
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<td>APR</td>
<td>Automatic Price Review</td>
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<td>AVC</td>
<td>Automatic Voltage Control</td>
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<td>BSP</td>
<td>Bulk Supply Point</td>
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<tr>
<td>CCGT</td>
<td>Combine Cycle Gas Turbine</td>
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<td>CEB</td>
<td>Central Electricity Board</td>
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<td>CEL</td>
<td>Consolidated Energy Limited</td>
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<td>CEMS</td>
<td>Continuous Emissions Monitoring System</td>
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<td>CFL</td>
<td>Compact Fluorescent Lamp</td>
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<tr>
<td>CO₂</td>
<td>Carbon Dioxide</td>
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<tr>
<td>COP</td>
<td>Coefficient Of Performance</td>
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<td>CPI</td>
<td>Consumer Price Index</td>
</tr>
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<td>CPP</td>
<td>Continuous Power Producer</td>
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<tr>
<td>CTBV</td>
<td>Compagnie Thermique de Belle Vue. Also known as ‘Terragen Ltd’</td>
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<td>CTDS</td>
<td>Compagnie Thermique Du Sud. Also known as ‘Omnican Thermal Energy Operations (St Aubin) Limited’</td>
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<td>CTSav</td>
<td>Compagnie Thermique De Savannah. Also known as ‘Omnican Thermal Energy Operations (La Baraque) Limited’</td>
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<td>CUF</td>
<td>Capacity Utilisation Factor</td>
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<td>CWA</td>
<td>Central Water Authority</td>
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<td>DCA</td>
<td>Department of Civil Aviation</td>
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<td>DG</td>
<td>Distributed Generation</td>
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<td>DSM</td>
<td>Demand Side Management</td>
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<td>DST</td>
<td>Daylight Saving Time</td>
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<td>EEMO</td>
<td>Energy Efficiency Management Office</td>
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<td>EIA</td>
<td>Environment Impact Assessment</td>
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<td>EIP</td>
<td>Environment Improvement Plan</td>
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<td>ELUAT</td>
<td>Environment and Land Use Appeal Tribunal</td>
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<td>EM</td>
<td>Environment Manual</td>
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<td>EMMP</td>
<td>Environment Management and Monitoring Plan</td>
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<td>EMS</td>
<td>Environment Management System</td>
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<td>EPA</td>
<td>Environment Protection Act</td>
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<td>EPS</td>
<td>Environmental Policy Statement</td>
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<td>EPZ</td>
<td>Export Processing Zone</td>
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<td>ESP</td>
<td>Environment Supply and Purchase Agreement</td>
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<td>ESA</td>
<td>Environment Sensitive Area</td>
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<td>ESAP</td>
<td>Energy Strategy Action Plan</td>
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<td>ESC</td>
<td>Energy Supply Cost</td>
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<td>ESPA</td>
<td>Energy Supply and Purchase Agreement</td>
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<td>GAC</td>
<td>Grid Absorption Capacity</td>
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<tr>
<td>GDFCF</td>
<td>Gross Domestic Fixed Capital Formation</td>
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<td>GDP</td>
<td>Gross Domestic Product</td>
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<tr>
<td>GEF</td>
<td>Grid Emission Factor</td>
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<td>GHG</td>
<td>Greenhouse Gas</td>
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<tr>
<td>GIS</td>
<td>Geographical Information System</td>
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<tr>
<td>GWh</td>
<td>Gigawatt hour</td>
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<tr>
<td>HFO</td>
<td>Heavy Fuel Oil</td>
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<tr>
<td>HV</td>
<td>High Voltage</td>
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<td>Hz</td>
<td>Hertz</td>
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<tr>
<td>IAEA</td>
<td>International Atomic Energy Agency</td>
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<td>ICT</td>
<td>Information &amp; Communication Technology</td>
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<td>IEC</td>
<td>International Electrotechnical Commission</td>
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<tr>
<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>IEEE</td>
<td>Institute of Electrical &amp; Electronics Engineers</td>
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<td>IEP</td>
<td>Integrated Electricity Plan</td>
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<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
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<td>IPP</td>
<td>Independent Power Producer</td>
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<td>ISO</td>
<td>International Organisation for Standardisation</td>
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<tr>
<td>kV</td>
<td>kilovolt</td>
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<td>kW</td>
<td>kilowatt</td>
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<tr>
<td>kWh</td>
<td>kilowatt-hour</td>
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<tr>
<td>LDC</td>
<td>Load Duration Curve</td>
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<td>LED</td>
<td>Light Emitting Diode</td>
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<td>LNG</td>
<td>Liquefied Natural Gas</td>
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<tr>
<td>LRM</td>
<td>Long Run Marginal Cost</td>
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<tr>
<td>LSDG</td>
<td>Large-Scale Distributed Generation</td>
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<tr>
<td>LTE</td>
<td>Long Term Energy Strategy</td>
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<tr>
<td>LV</td>
<td>Low Voltage</td>
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<tr>
<td>MDI</td>
<td>Maximum Demand Indicator</td>
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<tr>
<td>MEPU</td>
<td>Ministry of Energy and Public Utilities</td>
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<tr>
<td>MOESD</td>
<td>Ministry Of Environment and Sustainable Development</td>
</tr>
<tr>
<td>MOFED</td>
<td>Ministry Of Finance and Economic Development</td>
</tr>
<tr>
<td>MID</td>
<td>Maurice Ile Durable</td>
</tr>
<tr>
<td>MOA</td>
<td>Ministry Of Agriculture</td>
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<tr>
<td>MRU</td>
<td>Meter Reading Unit</td>
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<tr>
<td>MSD</td>
<td>Medium Speed Diesel</td>
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<tr>
<td>MSDG</td>
<td>Medium-Scale Distributed Generation</td>
</tr>
<tr>
<td>MTA</td>
<td>Multilateral Trade Agreement</td>
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<tr>
<td>MV</td>
<td>Medium Voltage</td>
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<tr>
<td>MVA</td>
<td>Megavolt Ampere</td>
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<tr>
<td>MVAR</td>
<td>Megavolt Ampere Reactive</td>
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<tr>
<td>MW</td>
<td>Megawatt</td>
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<tr>
<td>MYRP</td>
<td>Multi-Year Regulatory Period</td>
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<td>NES</td>
<td>National Environmental Standards</td>
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<tr>
<td>NGOs</td>
<td>Non-Governmental Organisations</td>
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<tr>
<td>NO</td>
<td>Oxides of nitrogen</td>
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<tr>
<td>NPDP</td>
<td>National Physical Development Plan</td>
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<tr>
<td>O&amp;M</td>
<td>Operation &amp; Maintenance</td>
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<tr>
<td>PECR</td>
<td>Public, Educational, Charitable &amp; Religious</td>
</tr>
<tr>
<td>PPA</td>
<td>Power Purchase Agreement</td>
</tr>
<tr>
<td>PPI</td>
<td>Producer Price Index</td>
</tr>
<tr>
<td>PV</td>
<td>Photovoltaic</td>
</tr>
<tr>
<td>QA/QC</td>
<td>Quality Assurance/Quality Control</td>
</tr>
<tr>
<td>RCM</td>
<td>Reserve Capacity Margin</td>
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<tr>
<td>REMP</td>
<td>Renewable Energy Master Plan</td>
</tr>
<tr>
<td>RFP</td>
<td>Request For Proposal</td>
</tr>
<tr>
<td>RRA</td>
<td>Rodrigues Regional Assembly</td>
</tr>
<tr>
<td>R-Squared</td>
<td>Coefficient of Determination in Statistics</td>
</tr>
<tr>
<td>RTA</td>
<td>Regional Trade Agreement</td>
</tr>
<tr>
<td>SADC</td>
<td>South African Development Communities</td>
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<tr>
<td>SAP</td>
<td>System Application Product</td>
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<tr>
<td>SCADA</td>
<td>Supervisory Control And Data Acquisition</td>
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<tr>
<td>SIPP</td>
<td>Small Independent Power Producer</td>
</tr>
<tr>
<td>SO</td>
<td>Sulphur dioxide</td>
</tr>
<tr>
<td>SSD</td>
<td>Slow Speed Diesel</td>
</tr>
<tr>
<td>SSDG</td>
<td>Small-Scale Distributed Generation</td>
</tr>
<tr>
<td>T&amp;D</td>
<td>Transmission and Distribution</td>
</tr>
<tr>
<td>TOU</td>
<td>Time Of Use</td>
</tr>
<tr>
<td>UNDP</td>
<td>United Nations Development Programme</td>
</tr>
<tr>
<td>UNFCCC</td>
<td>United Nations Framework Convention on Climate Change</td>
</tr>
<tr>
<td>URA</td>
<td>Utility Regulatory Authority</td>
</tr>
<tr>
<td>VAD</td>
<td>Value Added to Distribution</td>
</tr>
<tr>
<td>WMP</td>
<td>Waste Management Policy</td>
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<tr>
<td>WRU</td>
<td>Water Resources Unit</td>
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<tr>
<td>WTG</td>
<td>Wind Turbine Generator</td>
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<tr>
<td>XLPE</td>
<td>Cross Linked Polyethylene</td>
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Executive Summary

CEB produced and released the first Integrated Electricity Plan (IEP) in 2002 with the objective of increasing stakeholders’ confidence in its capability to ensure reliable, affordable and sustainable electricity supply for Mauritius and Rodrigues. Without a doubt, after ten years, CEB has lived up to that promise.

As the IEP 2003–2012 is phasing out, CEB has prepared the second IEP (Master Plan or the Plan) for the period 2013–2022, with the aim of guiding Mauritius and Rodrigues towards an even more stable electricity future. Similar to the previous IEP, the cornerstones of this Master Plan also are: to optimise the use of the existing power system, to keep electricity prices as low as possible through least-cost capacity expansion, to encourage our customers to participate in Demand-Side Management (DSM), and to provide for continued Private Sector opportunities in the electricity sector. These renewed commitments of the CEB will be made, while giving due consideration to emerging challenges, such as protection of the environment and maintaining grid stability with the increasing share of renewable energy sources.

Taking into account opportunities and challenges, the IEP 2013-2022 embraces a set of values which frame its underlying philosophy. The philosophy of the Plan implies that the CEB shall continue to exist as a competitive organisation for the benefits of the country; electricity will be available at the lowest possible cost; CEB will effectively balance the demand-supply of electricity for the coming decade; and electricity services development will be in line, as far as is economical, with influential national strategies, such as the Maurice Ile Durable (MID) and Government’s Long-Term Energy Strategy (LTES) 2009-2025. In addition, with the setting up of the expected Utility Regulatory Authority (URA), CEB will continue to forge ahead under the same corporate principles by ensuring strict compliance with the regulator’s issued policies.

A review of the IEP 2003–2012 reveals that, despite a slightly lower growth rate in annual demand (4.5% compared to 5.0% forecasted), most of the planned actions, to keep the power system responsive to the social and economic conditions in Mauritius and Rodrigues, were accomplished, or are being implemented. Some key achievements include:


- The commissioning of new more efficient engines for a total capacity of 6.3 MW, in addition to the installation of 1.28 MW Wind Turbine Generators at Grenade and Trèfles, in Rodrigues.

- The upgrading and reinforcement of the electricity network. Besides continuous improvements of the transmission and distribution networks, new substations namely Amaury, Dumas, Sottise, Union Vale and Anahita, were constructed and commissioned.
- The upgrading of the SCADA at the Despatch Centre in Curepipe to a state-of-the-art technology. The more advanced system is now enabling the CEB to better monitor load flow in its networks and operations of its power stations and substations island-wide.

- The distribution of one million Compact Fluorescent Lamps (CFLs) to CEB’s customers. This initiative is still contributing in curtailing the growth rate of the evening peak demand. Based on a set of assumptions, it was estimated that the CFLs project had reduced the evening peak by approximately 14 MW and is contributing in saving about 12.3 GWh of electricity annually.

- The introduction of Automated Meter Reading (AMR) System. To date, around 60% of the CEB’s largest customers, who account for 30% of its annual revenue, have already moved onto the AMR platform.

- The promotion of renewable energy sources to produce electricity under the SSDG project. As at today, around 473 individual projects, which will culminate to about a total capacity of 4.8 MW in Mauritius and 200 kW in Rodrigues, are under consideration and partly implemented.

The integrated planning approach, adopted by the CEB, has indeed strengthened its capability to respond to its customers’ needs, while contributing to its financial soundness. With these positive outcomes, the CEB is now endeavours to move forward in the same spirit.

Based on an estimated 3.43% annual growth rate in electricity demand (Base-Case scenario), the IEP 2013–2022 shows that new additional resources will be needed. The total investment, in order to sustain the Mauritius power system development in the short and medium terms, has been estimated to be of the order of MUR 18 billion. Seventy-two percent (72%) of the financing will be required in the short term, which includes a provision of about MUR 5 billion for the development of renewable energy projects.

Out of the total investment, 70% will come from private investors, and the remaining from the CEB. The major share of the capital injection will go towards generation capacity expansion, either for ‘needs-based additions’ or for ‘opportunity-based additions’.

**IN SHORT, THE IEP 2013–2022 REVEALS THAT:**

- The electricity demand in Mauritius in the Base-Case scenario will be around 3196 GWh in 2022. A rather conservative stance in the forecast has been taken for the reasons stated in Section 4.2.3. On average, the increase in energy demand will be around 78 GWh annually, compared to 80 GWh recorded for the period 2002-2012. Under the High-Case scenario, the annual average growth could be around 160 GWh.

- By the end of the 10-year planning period, the forecasted peak power demand will reach 574 MW under the Base-Case scenario and could be as high as 702 MW under the High-Case scenario. The 574 MW are equivalent to an annual average increase of 14.4 MW for the period 2013–2022.

- Geographically, the demand distribution will not change drastically, as determined by the spatial load forecast.

- Besides the addition of a 100 MW power plant (CT Power) in 2015/2016 which, technically, is ideal in the West, two new firm generation capacity of 50 MW each will be required in 2017 and 2021 respectively. With the coming into operation of new power plant(s), the old, and less efficient, Pielstick engines at the Saint-Louis Power Station will be progressively retired.
CEPT, in keeping with Government policy, will accommodate renewable energy facilities, such as the 29.4 MW Curepipe Point (Plaine Sophie) Wind Farm, 10 MW distributed Solar PV Farms and small (micro/mini) hydro plants, among others. In this regard, CEB has already embarked on the project to increase the water storage capacity of the Sans Souci Dam by some 30%. This development, accompanied by the impounding of waters at River Canard, although modestly, will contribute to increase electricity generation from hydro. As recommended by the consultant, the Phase One of the project, which involves the increase of the height of the dam’s spillway from 240 metres to 243 metres, will be completed in 2014. In addition, CEB is also expecting to commission the Midlands Dam hydro project early 2013.

CEPT will also facilitate the penetration of renewable energy projects so as to be in accordance with the Ministry of Energy and Public Utilities (MEPU) upcoming ‘Renewable Energy Master Plan’ and the Energy Strategy Action Plan (ESAP) 2011-2025. This will include CEB’s active participation in the development of a Wind Atlas, study to increase energy production from ‘bagasse’, study to use cane residues for electricity production, setting up of a pilot plant for handling and feeding cane residues and the setting up of a 20 MW Wind Energy System every 3 years as from 2017 and a 10 MW Solar Energy System every 3 years after 2013.

As the pressures to shift technology in order to diversify primary energy sources, with the expectation to benefit from lower long-run marginal costs, and to promote more environment-friendly power station operations increase, the need for alternative power generation will be required. In this respect, CEB has set the objective to conduct a comprehensive pre-feasibility study for the use of Liquefied Natural Gas (LNG). LNG is an ideal substitute for fossil energy sources. If feasible, as an option, CEB will consider the development of LNG power plant as future base-load facilities. In anticipation, among other considerations, for this potential project, CEB has already made a strategic land acquisition in the harbour area at Bain des Dames. The site can be developed for the progressive installation of LNG generating units, as per eventual recommendations that would be made by an international consultancy firm.

Save for the hidden cost to the environment, which is normally not included in the cost of operations of fossil-fuels-based generation, the cost of generation of renewable energy technology is comparatively higher than that of conventional sources of power generation. The main reasons for the high costs are the relatively significant initial investment and the very low capacity utilization factor of renewable energy projects. Given these constraints, the financial risks are in fact much higher in RE projects.

As things stand today, renewable energy generation will continue to be more expensive compared to oil- or coal-based electricity generation in the medium term, unless the environmental costs associated with fossil-fuels-based generation are quantified and factored into the average system generation cost of conventional technologies. However, estimating environmental costs is in fact highly challenging in practice. CEB, besides not having the necessary resources and being an electricity producer, it is not appropriate for it to determine the environmental costs associated with its electricity production activities. The Ministry Of Environment and Sustainable Development (MOESD), which possesses the necessary environmental accounting tools and competences, is more apt to determine the environmental costs of electricity generation from fossil fuels.

In similar vein, to ensure completeness in costs analysis and accounting, while the MOESD shall endeavour in determining the environmental costs of conventional electricity generating engines, it requires that the opportunity cost of the massive investments made in the fossil-fuels-based technologies, which are required to back up the operations of the RE technologies, be also assessed equitably.

For the purpose of this IEP, a small (micro/mini) hydro plant is defined as a hydro power plant having a capacity below 1 MW.
In embracing the least-cost policy, given the current state-of-affairs, renewable technologies being intermittent in nature will always be the second best alternative for the CEB. Economically speaking, the higher cost of electricity produced from renewable energy sources should normally be translated into higher cost of electricity, unless it is subsidized by the Government through the MID fund.

In working towards the long term energy security of the country, as implausible as it may appear, nuclear technology is a generation option to substitute fossil-fuels-based generation in Mauritius. As a matter of preparedness, through the MEPU, CEB will initiate the process to seek technical assistance from the IAEA for preliminary research on future nuclear technology. In this regard, during the planning period, with the assistance of the IAEA, a roadmap for the possible implementation of this option will be defined so as to ascertain its economic viability. It is worth highlighting that this preparatory process in itself may cover a period of at least 10 to 15 years.

The transmission network’s reliability, in the short term, will be reinforced with the commissioning of a new 66 kV transmission line and a substation in the South-West at Case Noyale as a priority; the commissioning of a new 66 kV line from Belle Vue substation to Sottise substation; the laying of two new high-capacity underground cables to maximise power evacuation from Fort Victoria Power Station to Saint-Louis substation; the commissioning of La Tour Koenig and Riche Terre substations; and the upgrading of other existing substations.

In the long term, the expansion of the transmission network will involve the construction of new substations in the regions of Trianon; the Airport and Goodlands; the construction of a new substation for the Neotown project (depending on the development of the Neotown Mixed-Use project); the upgrading of La Chaumière substation; the construction of a new transmission line from FUEL substation to Anahita substation.

Despite the demand growth, the need to move to 132 kV transmission voltage will not be required until 2022.

Main 66 kV transmission network as well as distribution network having serviced, both rural and urban areas, for over half a century will require systematic replacement. In addition, where necessary, the consolidation/replacement of HV steel lattice towers will also be addressed so as to enhance their physical integrity and to provide more security during cyclones.

To accommodate medium- and large-scale renewable energy projects, system enhancements will be required to preserve the stability of the grid. The enhancements will include: the improvement of frequency regulation through modernisation of generators’ control; the implementation of automatic voltage control at substation level; dispersing upcoming renewable energy projects geographically; the use of weather simulation software to determine the day-ahead level of renewable energy capacity that can be integrated into the grid; and the possible use of large-scale battery energy storage system.

Furthermore, to promote the integration of larger renewable energy projects, CEB will expedite the development of a Grid Code including the Feed-In Tariff for Medium-Scale Distributed Generation (MSDG). This development is in accordance with the Energy Strategy Action Plan (ESAP) 2011-2025 of the MEPU.

According to some experts in the field of renewable energy, the maximum amount of variable renewable energy (RE) that can be safely integrated in an insular power system is about 15% to 20% of the prevailing load demand. This level of RE integration, however, is intrinsically dependent on
the availability of fast-responding conventional generating engines, which is critical so as to regulate the system frequency. To increase level of RE integration above the threshold, as per the experts, installation of battery energy storage system (BESS) becomes inevitable.

- Modernisation of the electricity network will be dependent on the development and implementation of the long-outstanding Geographical Information System (GIS); the development of a Grid Code for the medium and high voltage networks; and laying the foundation for the development of the ‘Mauritius Smart Grid’. The ambition to build the ‘Mauritius Smart Grid’ is also part of the Government’s Energy Strategy Action Plan 2011-2025.

- CEB will continue to undertake necessary actions to remain in compliance with environmental regulations and to further promote its environment stewardship. In this respect, it will implement an all-encompassing Environment Management System (EMS) and will consolidate its Environmental Reporting Programme (ERP).

- The Rodrigues’ system necessitates a deeper examination. Based on actual estimates, Rodrigues’ electricity demand is expected to grow annually by 2.1% and 1.5% for the periods 2013–2017 and 2018–2022, respectively. The forecasted peak demand will reach 8.83 MW by 2022, that is, 38% higher than the peak of 6.39 MW recorded in 2011. To satisfy future demand, a new engine of 2.5 MW will be required by 2018 following the commissioning of the 2.5 MW engine at the Pointe Monnier Power Station in 2012.

- Rodrigues’ operation is costly to the CEB. In order to study the possibility of minimising the costs of operation in Rodrigues, CEB will undertake a comprehensive study of the system in 2013, as a priority. The study will have as objectives, among others, to assess option(s) to reduce the abnormally-high network losses in the Rodrigues’ system, evaluate alternatives to the electrical heating of oil for used-on-works, examine the cost-benefit of potential DSM initiatives and explore the possibility of higher integration of RE from wind and solar with/without storage batteries. Higher RE integration can assist in reducing operation costs, abating CO₂ emissions and increase the island’s energy autonomy.

- Further exploiting renewable energy sources is an alternative being seriously contemplated for Rodrigues. To optimise and increase the share of renewable energy sources in Rodrigues, CEB is already assessing the possibility of using Modern Control Systems, which are expected to improve the system’s responsiveness and by extension the grid stability (service quality).

- In complement with the supply side, CEB will give special consideration to potential Demand-Side Management (DSM) initiatives, which can contribute towards the least-cost expansion of the power system in Mauritius and Rodrigues. In this regard, CEB will work in close collaboration with other stakeholders to implement DSM activities, such as promoting the use of efficient lighting, efficient appliances and equipment, offering Time-Of-Use tariff, and facilitating further DSM actions through the gradual deployment of its Smart Metering Strategy.

- While formulating the Plan, it is essential to consider the appropriateness of the electricity tariff which will accompany the development of the power systems. Electricity tariff is the key revenue-generating source of the CEB. A re-alignment of the prevailing electricity tariff structure to move towards a cost-reflective tariff model is warranted in the short term. This shall be accomplished with a revenue-neutral objective, in the first instance.
The IEP 2013–2022 has been prepared on the basis of a set of assumptions. It reflects CEB’s appreciation of the current outlook for electricity demand and supply. It is to be understood that this Plan is merely a snapshot in time. The fundamentals of the Plan that give rise to the 10-year outlook will, assuredly, change over time. As new information becomes available, the Plan will be updated accordingly and will be communicated to stakeholders.

The Plan is available to the public from the CEB and on its website at [www.ceb.intnet.mu](http://www.ceb.intnet.mu)
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Why Moving towards Higher Transmission Voltage?

The electricity transport system is one of the most critical links between the power generation sources and the consumers. As a power system expands, consideration is also paid to the need for enhancing the transmission capacity with the prime objective to ensure quality, reliability and security of electricity supply.

CEB, as a caring service provider, will continue to unleash necessary efforts so as to sustain the development of its electricity transport system!
Despite intensifying challenges, the Central Electricity Board (CEB), by adhering to its corporate mission, as defined in the CEB Act 1964, and its Corporate Plan 2003–04, undertakes to pursue its development as a technically viable business partner. The main objective of the CEB remains to deliver, at all times, reliable and quality electricity supply in Mauritius and Rodrigues.

With this strategic objective high on its corporate agenda, CEB has prepared this Integrated Electricity Plan (IEP) covering the period 2013 to 2022. Like the previous IEP, the current one also focuses primarily on the CEB’s obligations to provide reliable and secure electricity services to Mauritius and Rodrigues, at the least possible cost and in a socially responsible manner.

In spite of planning uncertainties, the plan essentially presents a way forward, based on a pre-defined set of planning philosophy that underlines the raison d’être of the CEB as a national competitive electric utility.

Basically, the IEP 2013–2022 reflects CEB’s assessment of the domestic electricity market’s evolution over the coming decade, the resource requirements in electricity generation, transmission and distribution, and environmental challenges. It attempts to match harmoniously the power system supply-side with the expected growing demand.

Following this introductory chapter, the Plan is organised as follows:

Chapter 2 – paraphrases the underlying philosophy, on which the IEP 2013–2022 hinges. The planning philosophy sets the framework for the rational development of the power system in accordance with the CEB’s core values.

Chapter 3 – provides a summarised review of the IEP 2003–2012, which is now dated. The review elaborates on the CEB’s achievements with respect to what was initially planned in order to enhance the national power system.

Chapter 4 – deals with the demand forecast for the planning period. It gives a clear insight into the domestic electricity market. How the market has evolved, the dynamics of the demand profile, the need for spatial load forecast, the factors driving demand, the demand outlook for the upcoming 10 years, among other things, are discussed at length in this chapter.

Chapter 5 – discusses the Generation Plan. It defines the generation resources that the CEB intends to use so as to satisfy the country’s demand. This includes bridging any gap in terms of the size and timing of new generation additions.

Chapter 6 – elaborates on the required Transmission and Distribution (T&D) electricity system in Mauritius. It also gives the essence of CEB’s vision of a future intelligent electricity network.

Chapter 7 – sheds light on CEB’s commitments to comply with environmental regulations, while carrying out its power generation and T&D activities, including the long-term expansion of the power system.

Chapter 8 – gives a concise overview of CEB’s plan to manage demand. It proposes a few Demand-Side Management initiatives, which the CEB is willing to implement with the collaboration of other stakeholders.

Utilities, such as the CEB, cannot move forward smoothly without giving serious and close attention to the electricity tariff, which is critical and is
usually the only major source of revenues. Chapter 9 embarks on a discussion concerning the appropriate electricity tariff which would support the development of the national power system.

Chapter 10 – is devoted to the Rodrigues power system. It deals exclusively with the isolated Rodrigues’ system, as it elaborates on the island’s demand forecast and the expansion plans for electricity generation and the distribution network.

A short-term Action Plan geared to strengthening the capabilities of the power systems in Mauritius and Rodrigues is presented in Chapter 11.

Essential information and briefs on the methodologies adopted to work out this IEP is provided in the Appendices at the end of the document.

Finally, the document ends with a Glossary explaining the technical terms and words used in the document.
Why Integrated Electricity Planning?

As the power system of a country expands, it becomes more and more critical for a utility to embrace an integrated planning approach with the objective to enhance Security, Reliability, Quality, Sustainability and Affordability of electricity supply.

CEB, by embracing this philosophy, will continue to provide value-added services!
Chapter 2: Underlying Philosophy of the IEP 2013–2022

Chapter 2

UNDERLYING PHILOSOPHY OF THE IEP 2013–2022

Regardless of multiple constraints in the local electricity market and despite being the sole electricity service supplier, CEB has persistently geared its strategies to adapting to the operating conditions of a competitive market environment. This persistency stems from CEB’s underlying planning philosophy, which itself is inherently linked to the firm’s core values.

By embracing a specific planning philosophy, CEB ensures that it will continue to pursue its strategic role of supporting the national development by effectively balancing supply and demand of electricity through least-cost investment, while diligently meeting emerging challenges.

2.1 CEB STRATEGIC ROLE AND ITS NATIONAL CONTRIBUTION

Beyond the traditional definition of an electric utility, the CEB, as a dynamic organization that embraces an integrated planning approach, has been actively involved in assessing the national electricity market evolution, evaluating alternative power generation technologies and carrying out studies of the electricity network in order to secure the long-term, least-cost, electricity supply for the country.

The main goal of the CEB is to exist as a competitive organization and to be ready to meet emerging challenges resulting from changes in the power market for the benefits of its customers and the public at large.

In line with the above, with a view to effectively meeting future electricity demand, CEB will continue to formulate and evaluate electricity supply strategies based on assumptions relating to the availability and prices of fuel, market penetration rates of new technologies, new investment limits, environmental emissions, the structure of the electricity market and global economic concerns.

2.2 CEB’S LEAST-COST POLICY

CEB, being a regulated utility operating in an ever changing environment, has constantly aimed at producing and delivering reliable electricity at the lowest possible cost. The least–cost policy will remain a fundamental element of the CEB’s strategic objectives, which underpin this Integrated Electricity Plan (IEP).

Through the proposals in this present IEP, CEB strongly reiterates its commitment to target the sustainable development of the national power system at the least possible cost, while paying due attention to the socio-economic and environmental concerns of the country. Under the least-cost policy, CEB through its merit order dispatching plan has always sought to operate with the best mix of inputs in order to produce electricity. In accordance with this policy, CEB has explored, and will continue to explore strategically, opportunities to diversify the generation mix.

Through this business modus operandi, to the extent it has been, and will be possible, CEB has maintained and will uphold stable electricity prices (tariffs).

2.3 BALANCING THE 10-YEAR DEMAND-SUPPLY

In this IEP, CEB attempts to pave the way towards ensuring the delivery of safe and dependable electricity to all its customers, in both Mauritius and Rodrigues, for the coming decade. Balancing demand-supply of electricity over the next 10 years implies paying due attention to the most likely changes in electricity demand and to the transformational nature of the power system in Mauritius and Rodrigues.

In principle, CEB, in its continuous quest for security of electricity supply, will be guided by its commitment to seeking the lowest long-run marginal cost (LRMC) of supply. By aiming to minimize the LRM of electricity supply, CEB will endeavour to continue its partnership with its dedicated stakeholders, who support the achievement of its corporate objectives.

* See glossary
2.4 THE IEP 2013–2022 IN SUPPORT OF NATIONAL INFLUENTIAL STRATEGIES

By preparing and releasing the IEP 2013–2022, CEB further confirms its support for the positive social and economic development of Mauritius and Rodrigues.

The current IEP takes into account the national influential strategies discussed below. To the extent that it is economical for the CEB, the IEP 2013–2022 advocates initiatives, whether on-going or impending, under these strategies.

2.4.1 The Maurice Ile Durable (MID)* Concept and its Implications

While the redefined Maurice Ile Durable conceptual model sets the scene for a paradigm shift in the energy sector in Mauritius, the intrinsic challenges in the model call for a major rethinking of the CEB’s energy supply strategies.

In pursuing its mission, CEB recognizes the fact that considerable effort has to be made, especially to remain in line with the Maurice Ile Durable objective on energy. Hence, in aiming to deliver least-cost electricity supply, to the extent possible, CEB will also factor-in the MID objectives on energy (electricity). This, however, will be dependent, among other things, on appropriate policy mechanisms of funding sanctioned in favour of the CEB by the MID fund.

2.4.2 Government Long-Term Energy Strategy (LTES)* 2009-2025

In harmony with the LTES 2009–2025, CEB will accompany the development of its power systems by setting appropriate targets: (a) to diversify its energy mix, (b) to promote the shared goal of energy efficiency and (c) to manage demand through worthwhile demand-side management initiatives.

Shared Goals

A sustainable approach to the energy sector entails efforts to reduce the emission of Greenhouse Gas (GHG)* and the preservation of non-renewable energy resources. CEB believes that these are being, and will be, partly met through:

- the continuous tapping and integrating of the island’s renewable energy* resources in the energy mix, as will be outlined in the Renewable Energy Master Plan (REMP)*, under the framework of the long-term national energy strategy. CEB is already making allowance for this concern in its generation expansion planning*.

- the enhancement of the power system capability to allow for higher integration of renewable energy sources, while ensuring system security/stability* and taking measures to minimize energy losses along the transmission and distribution networks. CEB’s transmission and distribution network planning has been addressing, and will continue to give due attention to, this concern.

**Demand-Side Management (DSM)**

It is known that variations in the daily electricity demand cause a certain degree of sub-optimal utilisation of electricity generation assets. In our context, at times, the variability in demand requires the CEB to dispatch high-cost engines so as to meet short-duration peaks, a fact which subsequently increases the cost of producing electricity.

CEB recognizes that if nothing is done, the variations in the demand patterns will exert even higher pressure on its business operations over time and will eventually have an impact on the overall electricity tariff. As a mitigation measure, CEB in the recent past engaged in activities geared to managing the electricity demand, with a special focus on peak reduction.

In the future, along with government actions, CEB, in the interest of all stakeholders, will continue to endeavour to give due attention to DSM initiatives, as discussed in Chapter 9.

2.4.3 The Utility Regulatory Authority (URA)

For quite some time, Government has been planning the setting up of a URA. The URA will operate under the URA Act 2004 and will have as main responsibility, among others, to regulate the local power sector. CEB views positively the coming into operation of the URA.

As a forward-looking organisation, while maintaining its current corporate principles, CEB will continue to exert its strategic role even within this expected new operating environment. The IEP 2013–2022 indeed sets the CEB’s orientation so that it continues to operate as a competitive entity, purposely to meet the conditions of a regulated operating environment.

* See glossary
CEB’s COMMITMENTS ACHIEVED

- Reliability of Electricity Supply
- Quality of Electricity Supply
- Sustainable Electricity Supply
- Security of Electricity Supply
- Affordable Electricity Supply
What is the Importance of an Integrated Electricity Plan?

The achievement of an Integrated Electricity Plan is measured with respect to key objectives set by a utility. The achievements of the Plan are weighted on the delivery of secure, reliable, quality, sustainable and affordable electricity supply.

CEB, so far, has indeed lived up to that promise!
The Integrated Electricity Plan (IEP) 2003–2012 made it clear that "in Mauritius, we do not have an abundant supply of natural energy resources; therefore we must plan carefully to ensure a reliable electricity supply that is also affordable and sustainable" so as "...to guide Mauritius to a more stable electricity future."

The cornerstones of the IEP 2003–2012 were "to optimise the use of the existing power system, to keep electricity prices as low as possible through least-cost capacity expansion, to encourage our customers to participate in energy efficiency and conservation, and to provide for continued private sector opportunities in the electricity sector."

CEB prepared the IEP 2003-2012 on the assumption that by 2012, the demand for electricity would grow to about 1.6 times of its 2002 level, while, at the same time, the capability of its existing generation resources would be diminished, both in Mauritius and Rodrigues, as it would retire its older generating units. Below is an overview of the targets set in the IEP 2003-2012 and the achievements made over that planned period.

It was forecasted that by 2012, the demand for electricity would reach 2436 GWh. Table 3.1 below provides an insight into the demand evolution over the period 2002–2012.

The 0.5% (targeted 5% less actual 4.5%) shortfall in the expected growth of the electricity demand could have been the result of a combined effect of slow economic growth, energy saving and technical efficiencies*.

To accompany the forecasted annual demand, an action-plan was prepared. How far the initiatives/projects, earmarked in the action-plan, have been achieved is explained below.

It is important to point out that in response to emerging changes, which occurred during the period 2003 to 2012, new or modified initiatives/projects were thus implemented.

<table>
<thead>
<tr>
<th>INITIATIVES/PROJECTS</th>
<th>DESCRIPTION</th>
<th>ACHIEVEMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEMAND</td>
<td></td>
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</tr>
<tr>
<td>DEMAND-SIDE MANAGEMENT</td>
<td>Launch pilot project in each customer segment for time-of-use pricing.</td>
<td>A comprehensive study was carried out in 2012. The introduction of the time-of-use** tariff will be considered in the next tariff review.</td>
</tr>
<tr>
<td>ENERGY EFFICIENCY PLANNING</td>
<td>Conduct sensitization campaigns to motivate energy efficiency, conservation, and shifting demand from peak to off-peak hours. Continue to work with UNDP and stakeholders on energy efficient building design. Collaborate with other institutions to identify market barriers to energy efficiency.</td>
<td>Sensitization campaign started in 2005 with the support and collaboration of the MEPU. Much progress has been made under this item. With the setting up of the EEMO, most of the initiatives are now being handled by them.</td>
</tr>
</tbody>
</table>

* See glossary
<table>
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<tr>
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<th>DESCRIPTION</th>
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</thead>
<tbody>
<tr>
<td><strong>DEMAND</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>DOMESTIC ENERGY SAVINGS</strong></td>
<td>Continue to support Rodrigues’ pilot project for energy efficient lighting, extending project reach, if cost effective. Promote use of good quality energy saving lamps.</td>
<td>An energy savings booklet was distributed to every household for free in 2006. In total, one million CFLs were distributed in Mauritius and Rodrigues in 2008/2009.</td>
</tr>
<tr>
<td><strong>TARIFF STRATEGY</strong></td>
<td>Continue with development of 5-year tariff strategy for release in mid-2004. Develop wheeling and stand-by supply tariffs based on Cost of Supply methodology.</td>
<td>A fully-fledged tariff restructuring study was completed in 2008. Implementation has been kept on hold for the time being.</td>
</tr>
<tr>
<td><strong>NETWORK LOSSES</strong></td>
<td>Proceed with loss measurement program. Identify and implement viable loss reduction projects.</td>
<td>Started, but still in progress.</td>
</tr>
<tr>
<td><strong>GENERATION</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>NEW RESOURCES</strong></td>
<td>Issue a Request for Proposal in December 2003 for 60 MW to 70 MW of new generating capacity fired by ‘bagasse’ and complementary fuel. First 30 MW to 40 MW to be developed for the earliest in-service date in 2006 and the second 30 MW to 40 MW for January 2008.</td>
<td>Request-For-Proposal (RFP) was launched in 2003 for a 30 MW capacity power plant. ‘Compagnie Thermique Du Sud’ (CTDS) Power Plant at Saint Aubin was subsequently commissioned in 2005. CTsav coal-‘bagasse’ power station was commissioned in 2007.</td>
</tr>
<tr>
<td><strong>SAINT-LOUIS POWER STATION</strong></td>
<td>Continue with feasibility assessment for the addition of 30 MW to 40 MW of heavy fuel oil-fired units. Apply for Environmental Impact Assessment* (EIA) licence by November 2003.</td>
<td>Re-development of the Saint-Louis Power Station made. Three medium speed diesel engines of 13.8 MW each were commissioned in 2006.</td>
</tr>
<tr>
<td><strong>PORT MATHURIN POWER STATION</strong></td>
<td>Develop a retirement strategy for MWM units and spare holdings.</td>
<td>Still under consideration. Operation of the units will be minimised. They are being kept for emergency purposes.</td>
</tr>
</tbody>
</table>

* See glossary
## Generation

<table>
<thead>
<tr>
<th>Initiatives/Projects</th>
<th>Description</th>
<th>Achievements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pointe Monnier Power Station</td>
<td>Continue Phase 1 development for late 2004 in-service date. Prepare for Phase 2 development, with next new unit for late 2005 in-service date.</td>
<td>Phase 1 (2×1.9 MW) completed in 2004 and Phase 2 completed in 2012, with addition of one 2.5 MW unit.</td>
</tr>
<tr>
<td>Fort Victoria Power Station</td>
<td>Develop a retirement strategy for Mirrlees units and spare holdings.</td>
<td>Re-development of the Fort Victoria Power Station carried out. Mid-2012 saw the commissioning of 90 MW (6×15 MW) medium-speed diesel engines. The coming into operation of these new engines has enabled the retirement of the old less efficient FIAT and Mirrlees engines and would help in meeting the demand until 2014.</td>
</tr>
<tr>
<td>Renewable Technologies</td>
<td>Commission wind farm at Trèfles for supply to Rodrigues' grid starting in December 2003.</td>
<td>Completed. Four additional wind turbines were installed at Grenade in Rodrigues. The total installed wind capacity has reached 1.28 MW.</td>
</tr>
</tbody>
</table>

## Transmission

<table>
<thead>
<tr>
<th>Transformers</th>
<th>Increase power transformer capacity of Rose Hill and Combo substations in the second half of 2004.</th>
<th>Power transformer capacity of Rose Hill substation (now referred to as Ebène) has been increased from 60 to 105 MVA. Increase in transformer capacity was not necessary at Combo substation.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Add 66 kV-to-22 kV transformer at Nicolay by the end of 2005.</td>
<td>Load* growth in the region has been supplied by nearby substations. As such, the third transformer was not required.</td>
<td></td>
</tr>
</tbody>
</table>

## Transmission Backbone

<table>
<thead>
<tr>
<th>Commission Champagne-Union Vale 66 kV line by the end of 2004.</th>
<th>17.5 km line has been constructed linking Champagne and Union Vale substations and commissioned in 2003.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combo-Le Morne and Henrietta-Le Morne 66 kV lines in the second half of 2005.</td>
<td>98% of the construction completed.</td>
</tr>
</tbody>
</table>

* See glossary
## TRANSMISSION

### TRANSMISSION BACKBONE

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>TRANSMISSION</td>
<td><strong>BACKBONE</strong></td>
<td><strong>Amoury substation was commissioned in 2002. Union Vale substation was commissioned in 2008 with only one power transformer. A second transformer will be commissioned in early 2013. The proposed Le Morne substation has been relocated to Case Noyale. Delays have been caused due to right-of-way issues associated with the transmission lines.</strong></td>
</tr>
</tbody>
</table>

Begin the commissioning of the back-up 66 kV Amaury-Sottise line.  
Due to right-of-way problems and higher investment cost with undergrounding system, this proposal was revised. Instead, the back-up transmission line will be constructed from Belle-Vue.

Continue to monitor transmission system performance reliability requirements, investigating possible need to upgrade sections of line from 66 kV to 132 kV operations.  
Regular studies of the transmission network are performed in-house to ensure reliability.

### SUBSTATIONS AND BULK SUPPLY POINTS

<table>
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<tbody>
<tr>
<td>TRANSMISSION</td>
<td><strong>BACKBONE</strong></td>
<td><strong>Amaury and Union Vale in 2004, and Le Morne in late 2005.</strong></td>
</tr>
</tbody>
</table>

Commission Dumas and Sottise substations in December 2003  
Dumas and Sottise commissioned in 2003 and 2005 respectively.

Prepare to commission Beau Champ substation in 2006.  
Now known as Anahita, the substation was commissioned in mid-2009. Power transformers commissioned in 2012.

### CAPACITORS*  

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>TRANSMISSION</td>
<td><strong>BACKBONE</strong></td>
<td><strong>Install capacitor banks at Henrietta and La Chaumière substations by mid-2004.</strong></td>
</tr>
</tbody>
</table>

Implement fibre optic cables for data communications in place of microwave.  
The southern and western sections of the network are at the implementation stage.

---

* See glossary
<table>
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</thead>
<tbody>
<tr>
<td><strong>COMMUNICATION</strong></td>
<td>Establish links between 66 kV substations for tele-protection relaying®. Introduce unit protection for the short transmission lines between Dumas, Fort George, and Nicolay substations by end 2003 and between Saint-Louis, Rose Hill, and Wooton substations in 2004.</td>
<td>Only Dumas, Fort George and Nicolay have been equipped with unit protection® on their transmission lines.</td>
</tr>
<tr>
<td><strong>AND PROTECTION</strong></td>
<td>Identify property, servitudes, and rights-of-way needs to ensure availability for future substation and network development.</td>
<td>Riche Terre, La Tour Koenig and Le Morne (Case Noyale) are at implementation stage, while the Amaury, Union Vale, Beau Champ (Anahita), Sottise and associated transmission lines have been commissioned.</td>
</tr>
<tr>
<td><strong>RIGHTS-OF-WAY</strong></td>
<td>Commission new 22 kV switchboard at Rose Hill-Ebène and Saint Louis, with additional Feeders® already commissioned in 2004.</td>
<td>New 22 kV switchboard® with additional Feeders® already commissioned in 2004.</td>
</tr>
<tr>
<td><strong>MAJOR SUBSTATIONS</strong></td>
<td>Complete the replacement of the 22 kV switchboard at the Nicolay substation with extension for new feeder in 2005.</td>
<td>CEB retrofitted the 22 kV panels, instead of replacing them.</td>
</tr>
<tr>
<td><strong>NETWORK REINFORCEMENT</strong></td>
<td>Continue implementation of various projects, including undergrounding, upgrading from 6.6 kV to 22 kV, adding new feeders, and back-up supplies.</td>
<td>Various system reinforcements have been done throughout the medium voltage distribution network around the island. Conversion projects from 6.6 kV to 22 kV are in progress in the regions of Port Louis, Rose Hill, Vacos, Quatre Bornes and Curepipe.</td>
</tr>
<tr>
<td><strong>AND REFURBISHMENT</strong></td>
<td>Commission switching stations, feeders, and network reconfiguration® at Pailles, La Tour Koenig, and Riche Terre in 2004 and prepare for commissioning at Phoenix in 2006.</td>
<td>Given delays in projects, the commissioning dates for La Tour Koenig and Riche Terre have been re-scheduled for 2014. Expected industrial development in the region of Phoenix did not materialize. Upgrading of Wooton substation has enabled CEB to meet increasing demand.</td>
</tr>
<tr>
<td><strong>SWITCHING STATIONS® (IDENTIFIED FOR UPGRADING TO BSPs)</strong></td>
<td><strong>DISTRIBUTION</strong></td>
<td>Introduce AMR systems for 2,000 largest customers, starting 3-year phased program in 2004.</td>
</tr>
<tr>
<td><strong>AUTOMATED METER READING® (AMR)</strong></td>
<td><strong>See glossary</strong></td>
<td></td>
</tr>
</tbody>
</table>

* See glossary
### Chapter 3: A Review of the IEP 2003-2012
Integrated Electricity Plan 2013–2022

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</tr>
</thead>
<tbody>
<tr>
<td>DISTRIBUTION</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Commission Petite Réserve switching station in 2004, with new interconnector to Port Mathurin Power Station in 2005.</td>
<td>The construction of the switching station has been delayed due to administrative reason. It is now planned for 2015.</td>
</tr>
<tr>
<td>ENVIRONMENTAL AFFAIRS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GREENHOUSE GAS</td>
<td>Continue to monitor policy developments and offset opportunities locally and internationally.</td>
<td>Some strides have been made as part of mitigation measures, such as promoting the use of renewable energies and efficient appliances and lighting.</td>
</tr>
</tbody>
</table>

* See glossary
How much Reliable is a Power System?

The robustness of a power system reflects its ability to be ‘omnipresent’, irrespective of the time and size of the load imposed on it. By adopting an appropriate planning philosophy, a utility is capable of spurring such reliance.

CEB, in the same belief, shall continue to dimension its power system in anticipation to meet its customers’ needs so as to ensure greater reliability!
Since Independence, demand for electricity, both in Mauritius and Rodrigues, has followed an upward trend. Economic development supported by substantial on-going investments in electrification was, without doubt, the main factor fuelling the steady growth in demand for electricity.

The electricity markets in Mauritius and, to a lesser extent, in Rodrigues have, since then, evolved into more dynamic operating environments.

Within these established markets, CEB regularly conducts electricity demand assessments. Hereunder, an overview of the latest demand forecast for Mauritius, prepared in the context of this IEP, covering the period 2013–2022, is presented.

4.1 THE ELECTRICITY MARKET
This section details the CEB’s appreciation of the local electricity market.

4.1.1 Trend in Electricity Sales
Traditionally, as in many countries, electricity consumers in Mauritius and Rodrigues are predominantly categorised into three main customer groups: Residential (households), Commercial (non-manufacturing) and Industrial categories. Other minor categories include: public lighting, traffic lights and irrigation. The minor groups account for a small, but a non-negligible, share of the total electricity sales. Figure 4.1 below shows the historical share of each customer category in the growing total electricity sales in Mauritius.

The post-1990s saw an accelerated growth in demand, as shown in Figure 4.1 below. The rapid growth, most likely, was the effect of structural changes in the domestic economy. In fact, Mauritius had moved away from a mono-crop-based economy towards diversification. Industrialisation, which followed, was accompanied by heavy investments in export-oriented sectors, especially in the textile and manufacturing sector.
industries. These industries, by their very operational nature, have relatively higher electricity intensity.

The upward trend in the sale of electricity was further maintained in the years 2000. It was mainly the result of a re-engineering of the economy accompanied by bolstering strategies in the Hospitality, Commercial and Manufacturing Sectors.

With the on-going diversification, new economic sectors (ICT, Sea-Food and Financial Services) which were set up also caused the demand to grow constantly. During that period, automation, which is inextricably dependent on electricity, also started its breakthrough. All these developments jointly contributed to maintain the accelerated growth in demand.

Undoubtedly, our country’s noticeable economic progress has led to a remarkable improvement in the standard of living of the population. With higher disposable income*, households became more and more affluent. By extension, the penetration rate of electric home appliances grew rapidly leading to higher demand for electricity.

More insight into the evolution of electricity demand in Mauritius and Rodrigues are provided in Appendix A1.

4.1.2 Dynamics of the Typical Seasonal Demand Profiles
An analysis of daily demand curves reveals that electricity demand is not constant over time. It varies continuously, irrespective of the day. In Mauritius, based on seasonality, two typical demand profiles, as shown in Figure 4.2 below, are identified. The hourly values along the curves are expressed in per unit (as ratios of the highest peak).

The observed uneven hourly demand, as shown in Figure 4.2, influences the unit cost of production and the inherent technical energy losses. It is estimated that the system load factor is, on average, around 82.8% and 68.6% during summer and winter respectively. A low load factor means that the power system assets are under-utilised.

The higher demand in summer, caused mainly by air-conditioning loads, raises the system utilisation factor by about 20% compared to the utilisation in winter. This change in loading has serious implications for the required availability of generation capacity; hence, the planning of electricity production capacity.

The variability in demand not only affects the planning of generation capacity, but also influences the dimensioning of the whole power system. In effect, it dictates the daily operation of the whole power system.

It is clear that insufficient or poor understanding of the demand pattern may lead to high operational inefficiencies, particularly with regard to the dispatching order of generating engines, which may eventually cause the costs of producing electricity to rise unnecessarily.

* See glossary
The overall electricity demand pattern is not static; it evolves as changes occur in the market constituents. Increasing demand of residential customers, for instance, will raise the evening peak, while rising electricity demand in the Commercial and Industrial Sectors largely contributes to shift the day-period peaks upward. Anticipating the changes in the overall demand pattern is essential for effective decision-making concerning investments, especially in capital intensive electricity generation and transport assets.

4.1.3 Spatial Distribution of Electricity Demand

Efforts to gain maximum knowledge of the electricity market involve examining the geographical distribution of electric load. This is essential so as to manage intelligently a utility’s distributed assets associated with its transmission and distribution networks.

CEB’s substations have been strategically sited around the island, as shown in Figure 4.4 on the next page, so as to be nearer to the load centres. As the load centres keep on expanding, it becomes imperative to examine the evolution of their electricity demand and forecast the future demand, which will impact on the supplying substations’ capacity.

With the development of numerous infrastructural projects around Mauritius, it has become necessary for the CEB to enhance its current demand forecast methodology so as to predict demand on a geographical basis. Under the spatial forecast approach, the future loadings on the CEB’s substations and associated electric feeders can be projected.

For the first time, in this IEP, an attempt has been made to present the demand forecast on a spatial base, whereby the loading evolution of each CEB’s substation has been estimated. The present estimates provide pertinent input into the CEB’s network expansion planning.

4.1.4 Stochastic* Factors Influencing Electricity Demand

In a nutshell, a country’s electricity demand is simply an aggregation of demand arising from different customer categories. However, underneath a myriad of dynamic factors stealthily and continuously stimulate the demand. Figure 4.3, hereunder, illustrates the complex interactions between some of the most critical demand-driven factors, which influence the overall demand for electricity. A brief explanation of the interactions is given in the paragraphs below.

* See glossary
FIGURE 4.4: Mauritius Generation Stations and Transmission System

- IPP Thermal Power Station
- CEB Thermal Power Station
- CEB Hydro Power Station
- 66 kV-to-22 kV Substation
- 66 kV Transmission Line (Double Circuit)
- 66 kV Transmission Line (Single Circuit)
- 132 kV Transmission Line
- Operating at 66 kV (Double Circuit)
In general, demand for electricity in households is a function of disposable income and household size. A rise in disposable income usually improves households’ standard of living, which subsequently influences lifestyle. A change in lifestyle, to some extent, is reflected in more spending of disposable income on durable goods, such as home appliances. Higher penetration rates of home appliances, in turn, result in higher electricity demand. This natural tendency is also observed in Mauritius, where improvements in national wealth lead to rising demand for electricity in households. Disposable income is not the only factor explaining growth in households’ electricity demand. Growth in population, and by extension households’ size, also influences households’ demand for electricity.

In the Industrial Sector, critics do not support the theory that relative price change is necessarily an important determinant of growth in electricity consumption. In fact, the main determinants are growth in output, changes in technology and value of inputs (energy, materials and labour). Industrial output is basically a function of investment in capital goods (plant, machinery, equipment, etc.), which itself is influenced by the demand for consumer goods and the cost of capital. At a much deeper level, factors such as the exchange rate, global inflation and interest rates and world market energy costs also affect the electricity demand of the Industrial Sector.

Gross Domestic Product (GDP)*, which is a measure of the value of output produced by an economy, is a statistic made up of four components, namely: Consumption, Investment, Expenditure, and Net Exports. A change in any of these components has a direct spill-over effect on the local economy and, hence, affects the performance of economic players, such as commercial entities focusing on the local market.

The main causal factor driving electricity demand for public lighting and irrigation is public infrastructural development, triggered by government expenditure on roads, airport, schools, hospitals, etc.

As shown in the causal-loop diagram (Figure 4.3 on page 33), the price of electricity is another key factor influencing aggregate electricity demand. Electricity price is generally a function of world market energy costs, the price of electricity charged by Independent Power Producers (IPPs)* and any subsidies provided by the Government.

For this IEP, the most relevant causal elements, besides weather conditions, impacting on the local electricity demand were selected for the forecast model. Based on the above conceptual causal-loop relationships, the modelling of the independent factors influencing the annual electricity demand of the three CEB’s major customer categories was developed. Details of the forecast model are provided in Appendix A1, as part of the forecast methodology.

4.2. THE UPCOMING 10-YEARS DEMAND OUTLOOK
Based on the methodology detailed in Appendix A1, a 10-year demand forecast for the period 2013–2022 has been prepared for the purpose of this IEP and is elaborated in the following sub-sections.

4.2.1 The Forecast Methodology Adopted
While there are different forecast methods, each having its own merits and limitations, for this particular IEP, the load forecast was based on the causal effect of some basic influential factors. Factors, such as end-users consumption behaviours, economic conditions, demographic and technological evolution, which affect the utilization of electrical energy, were taken into account. Energy efficiency and demand-side management, the two emerging challenges, were also given due consideration. In short, the forecast model was primarily constructed, using some fundamental econometric* and statistical techniques. More details on the demand (load) forecast methodology are provided in Appendix A1.

4.2.2 Energy Forecast Scenarios
Given the inherent unpredictability in the forecast assumptions, the demand forecast has been prepared for three possible scenarios (Low, Base and High). The assumptions for each scenario are as follows:

(1) In the Low Scenario, the economy will be sluggish and may even stagnate until the end of the medium-term.
(2) For the Base Scenario, the growth rate of the economic sectors/sub-sectors will reflect the trend of the last decade.
(3) The High Scenario assumed a rapid economic recovery in the short term, which will impact on the economic growth in the medium to long term.

* See glossary
The final results of the overall energy forecast for the period 2013–2022, under each scenario, is given in Table 4.2 in Section 4.2.4.

4.2.3 Energy Forecast of each Customer Category

In this sub-section the energy forecast, which forms the basis for developing the IEP, for the different CEB customer categories is provided.

Residential (Households) Electricity Demand

Electricity sales to the residential category represent around 32% of the CEB total sales. Although this category will remain one of the major customer groups, its share of the total electricity sales will remain almost constant, at around 30% by the end of the forecast period.

In the Base Scenario, the forecast estimates showed that the specific consumption of a typical Mauritian household will be relatively moderate. If compared to a household in Réunion Island, in 2011, while on average a household in Mauritius had consumed 1965 kWh, in Réunion Island it was 3578 kWh. Taking into account the difference of around 82% in the consumption level and the similarities of the two sister islands, it will not be exaggerated to assume that there is a potential for higher demand for electricity in the residential sector in Mauritius.

Figure 4.5 below depicts the historical and expected future trend of electricity demand in the ‘households sector’ in Mauritius.

The line graph (Base Scenario) in Figure 4.5 shows that the residential category demand will grow by 3.01% annually over the planning period. However, under the High Scenario, the demand may reach 1285 GWh by 2022, that is, approximately 1.8 times the demand recorded in 2011.

Electricity Demand in the Commercial Category

Over the recent years, the Commercial Sector has taken the lead in the share of total electricity sales in Mauritius. The share has grown from 27% in the year 2000 to reach 36% in 2011.

The growth in total demand, partly fuelled by commercial activities, has resulted in important changes in the overall system demand profile, where the peak demand occurring during the day is now of almost the same magnitude as that of the evening peak.

Today, the CEB is not only concerned about the growth of the evening peak, but also about the daytime peaks, which are intrinsically and largely dependent on commercial and industrial activities.

Since the domestic economy will, most likely, continue to be dominated by the Service (Commercial) Sector, which includes the Tourism, ICT, Financial Services, commercial complexes, Public Services and other non-manufacturing entities, the demand forecast for the commercial category was thus been built on the premise that the sector will continue to represent the largest share in the total electricity demand of the country.

† Bilan énergétique 2011, Ile de la Réunion
Almost all, not to say all, commercial activities are carried out through capital intensive immovable infrastructures. Therefore, given the heavy investment injected in the construction of the floor spaces, it is fairly logical to assume that the investment will need to be salvaged through home-based activities. In brief, the future demand for electricity in the Commercial Sector will follow an upward trend, as depicted in Figure 4.6.

In working out the forecast, the influences of the different commercial sub-sectors, some of which drive our economic performance (Tourism, Financial Services, ICT) and others, which depend on the performance of the domestic economy (Retail, Government Services, Real Estate), were distinctively analysed. The outcomes of the analysis, in terms of the sub-categories’ electricity demand growth rates reflecting inferences made, are shown in Table 4.1 hereunder.

The industrial category was indeed the most energy intensive sector. This influence, however, has shrunk over the years. Today, the sector accounts for only 30% of the total electricity sales.

Relatively lower capital injection, as reflected in the recent Industrial Sector’s Gross Domestic Fixed Capital Formation (GDFCF)\(^*\), and international pressures, noted over the recent years, have had serious ramifications for the demand for electricity in the Industrial Sector. Based on observed trends and considering other driving factors, CEB forecasted that, unless the sector undergoes major changes, the relative demand of the sector will be further lowered to 28% of the total electricity sales by the end of the planning period.

It is necessary to point out that the effect of the phasing-out of the AGOA\(^*\) Treaty by 2015 has not been considered at this stage. Necessary adjustments will be made in time over the forecast period, as and when there is more clarity on the sector’s development.

As depicted in Figure 4.7 on the next page, the compounded annual demand growth rate in the Industrial Sector will be around 2.60% for the period 2012–2022, lower than the historical annual growth rate of 3.36%. The 2.60% growth rate can however, rise up to 3.35% under the high-case scenario.

\(^*\) See glossary
Electricity Demand From Minor Customer Groups

The minor customer category includes sugar factories, street lighting accounts, pumping for irrigation purposes and CEB’s own consumption. These electricity end-users account for approximately 3% of the total electricity sales.

Based on factors mentioned in the forecast methodology (Appendix A1, Section: Sales Forecast of Minor Customer Categories), CEB estimated that the share of electricity sales for the minor customer category will not be higher than the 3% for the future. Over the planning period, the electricity demand of the minor customer categories will, therefore, grow negligibly, as illustrated in Figure 4.8.

4.2.4 Summary of the Electricity Forecast 2013–2022

Table 4.2 summarises the 2013–2022 electricity forecast for Mauritius under the three scenarios (Low, Base and High).

Considering the Base scenario, as shown in Table 4.3, on page 39 contrary to the annual compounded growth of 4.28% for the period 2001–2011, it has been estimated that the demand for electricity will grow on average by 3.43% (compounded growth) annually for the period 2011–2022.

---

**TABLE 4.2: Electricity (GWh) Forecast 2013–2022**

<table>
<thead>
<tr>
<th>YEAR</th>
<th>LOW</th>
<th>BASE</th>
<th>HIGH</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>2313</td>
<td>2416</td>
<td>2505</td>
</tr>
<tr>
<td>2014</td>
<td>2362</td>
<td>2497</td>
<td>2613</td>
</tr>
<tr>
<td>2015</td>
<td>2408</td>
<td>2587</td>
<td>2775</td>
</tr>
<tr>
<td>2016</td>
<td>2452</td>
<td>2686</td>
<td>2990</td>
</tr>
<tr>
<td>2017</td>
<td>2495</td>
<td>2787</td>
<td>3180</td>
</tr>
<tr>
<td>2018</td>
<td>2538</td>
<td>2869</td>
<td>3390</td>
</tr>
<tr>
<td>2019</td>
<td>2580</td>
<td>2951</td>
<td>3543</td>
</tr>
<tr>
<td>2020</td>
<td>2618</td>
<td>3033</td>
<td>3703</td>
</tr>
<tr>
<td>2021</td>
<td>2656</td>
<td>3113</td>
<td>3826</td>
</tr>
<tr>
<td>2022</td>
<td>2694</td>
<td>3196</td>
<td>3994</td>
</tr>
</tbody>
</table>
### TABLE 4.3: Historical Versus Forecast Growth Rate in Total Electricity Demand

<table>
<thead>
<tr>
<th>PERIOD</th>
<th>RATE OF GROWTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001–2006</td>
<td>5.05%</td>
</tr>
<tr>
<td>2006–2011</td>
<td>3.51%</td>
</tr>
<tr>
<td>2001–2011</td>
<td>4.28%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PERIOD</th>
<th>LOW</th>
<th>BASE</th>
<th>HIGH</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011–2016</td>
<td>2.15%</td>
<td>4.03%</td>
<td>6.29%</td>
</tr>
<tr>
<td>2016–2022</td>
<td>1.58%</td>
<td>2.94%</td>
<td>4.94%</td>
</tr>
<tr>
<td>2011–2022</td>
<td>1.84%</td>
<td>3.43%</td>
<td>5.55%</td>
</tr>
</tbody>
</table>

The estimated comparative lower growth rate of 3.43% can be explained by a number of factors, such as:

- The heightened importance attached to energy efficiency and savings;
- The penetration of substitutes (Solar Water Heaters & SSDGs);
- The reduction in the marginal propensity to consume* of households;
- The saturation in the development of commercial complexes;
- The potential increase in prices of energy sources;
- The structural changes in economic activities, where investments will be more concentrated in less energy intensive sectors.

It would not be unrealistic, in fact, to assume that the very inertia in the prevailing and expected economic conditions by itself, coupled with changes in lifestyles, may trigger the above influences.

The above-mentioned compounded annual growth rate of 3.43% represents the combined forecasted growth in the electricity demand of the different customer categories, as shown in Table 4.4 below.

### Table 4.4: Compounded Annual Growth Rate

<table>
<thead>
<tr>
<th>PERIOD</th>
<th>RESIDENTIAL</th>
<th>COMMERCIAL</th>
<th>INDUSTRIAL</th>
<th>OTHERS</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Historical</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001–2006</td>
<td>3.34%</td>
<td>6.91%</td>
<td>5.07%</td>
<td>5.97%</td>
<td>5.05%</td>
</tr>
<tr>
<td>2006–2011</td>
<td>3.31%</td>
<td>6.50%</td>
<td>1.46%</td>
<td>-4.78%</td>
<td>3.51%</td>
</tr>
<tr>
<td>2001–2011</td>
<td>3.32%</td>
<td>6.71%</td>
<td>3.25%</td>
<td>0.45%</td>
<td>4.28%</td>
</tr>
<tr>
<td>Forecast</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2011–2016</td>
<td>3.44%</td>
<td>5.23%</td>
<td>3.16%</td>
<td>4.35%</td>
<td>4.03%</td>
</tr>
<tr>
<td>2016–2022</td>
<td>2.66%</td>
<td>3.56%</td>
<td>2.51%</td>
<td>1.54%</td>
<td>2.94%</td>
</tr>
<tr>
<td>2011–2022</td>
<td>3.01%</td>
<td>4.31%</td>
<td>2.81%</td>
<td>2.80%</td>
<td>3.43%</td>
</tr>
</tbody>
</table>

* See glossary

In a more favourable scenario, arrived at on the assumptions that the international economy may experience a greater acceleration in its expansion and a re-engineering of the local economic pillars would follow, the demand for electricity annually may grow by 5.55% (compounded growth rate under the High-Case Scenario) during the planning period.

### 4.2.5 Peak Demand (MW) Forecast

Peak demand forecast is usually very problematic. It is even more challenging for small-sized power system, such as the CEB. A degree of accuracy of 95% in the estimation may not be sufficient, given the relatively high investment risks implied in power generation and power transport projects. Peak demand evolution is, in fact, the key factor which guides the kind, and size, of investments (base, semi-base or peak) in power generation and the dimensioning of the whole transmission network.

Several methods can be used to estimate the peak demand. However, whichever method is used, the most important concern for the CEB is to ensure the highest accuracy possible.

Using loadings data on electric feeders obtained from measurement exercises, estimated typical customer consumption profiles, information on the electricity market size and estimated overall losses; the annual peak demand for the period 2013-2022 has been calculated. Table 4.5, on next page, shows the resulting peak demand estimates for the planning period.
As shown in Figure 4.9 below, over the recent past, the peak demand in the system has occurred during the summer period extending from November to March of the next year. Given the trend in economic activities and weather conditions, future system peak demand will continue to occur in the summer season. It is rather obvious that in the event of a new higher peak demand not being recorded in November or December in the current year, it will, with a high probability, occur early the following year.

The variation in the peak power demand is not only a matter of weather conditions, but is equally dependent on the level of activity of the different electricity end-users. CEB, for a long time, has been seriously concerned about the growth in the peak power demand. A DSM strategy was even formulated to control the growth of the peak demand.

For planning purposes, the peak demand forecasted is not only assumed to be equivalent to the energy forecast (active demand), but more specifically, a function of the cumulated loads in the system and the latent demand*.

Being strongly dependent on weather conditions, the latter requires an effective long-term weather forecast, which unfortunately is difficult to make with high accuracy.

4.2.6 CEB’s Substations’ Loadings
Unlike previous demand forecast exercises, the forecast, which has been prepared for this IEP, includes a geographical distribution of the future growth in electricity demand in Mauritius. Using available information and data, a typical summer load profile for each CEB substation has been developed. It is projected that the future loadings on the CEB’s substations will be as shown in Table 4.10 on next page. The trend in the substations’ loadings reflects only the normal growth. Loadings of upcoming major projects, which may impact on the substations’ capacities, have been worked out outside the model. The reason is simply that the peak demand of a particular major project may not necessarily coincide with the supplying substation’s peak loading.

### TABLE 4.5: Estimated Peak Demand (MW)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>LOW</th>
<th>BASE</th>
<th>HIGH</th>
</tr>
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<tbody>
<tr>
<td>2012</td>
<td>422</td>
<td>430</td>
<td>444</td>
</tr>
<tr>
<td>2013</td>
<td>431</td>
<td>447</td>
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<td>2014</td>
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<td>461</td>
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</tr>
<tr>
<td>2015</td>
<td>446</td>
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<td>506</td>
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<td>2016</td>
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</tr>
<tr>
<td>2020</td>
<td>480</td>
<td>548</td>
<td>655</td>
</tr>
<tr>
<td>2021</td>
<td>487</td>
<td>561</td>
<td>675</td>
</tr>
<tr>
<td>2022</td>
<td>493</td>
<td>574</td>
<td>702</td>
</tr>
</tbody>
</table>

* See glossary
<table>
<thead>
<tr>
<th>YEAR</th>
<th>AMAURY</th>
<th>BELLE-VUE</th>
<th>LA CHAUMIÈRE</th>
<th>COMBO</th>
<th>ÉBÈNE</th>
<th>FORT GEORGE</th>
<th>FUEL*</th>
<th>HENRIETTA</th>
<th>NICOLAY</th>
<th>SOTTISE</th>
<th>SAINT-LOUIS</th>
<th>UNION VALE*</th>
<th>WOOTON</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>11</td>
<td>30</td>
<td>28</td>
<td>11</td>
<td>32</td>
<td>56</td>
<td>22</td>
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<td>2006</td>
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<td>2007</td>
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<td>2009</td>
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* The figures for the Union Vale and FUEL substations include the loading on the Feme and Anahita substations, respectively. The table will be updated as and when new information becomes available.
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Diversifying Energy Sources

Aiming Least-Cost Electricity Supply

Targeting Security of Electricity Supply
How to Achieve Security in Electricity Supply?

Through diversification of energy sources, utility aims to mitigate risks of supply. By blending the energy portfolio with different sources of inputs, the objective of securing supply shall certainly be met.

CEB, by sharing this objective, will endeavour to broaden, as economical as possible, its power generation mix!
To enable countries to develop to their full potential, new power plants need to be constructed at the right time so as to meet rising electricity demand. Achieving and maintaining a reliable electricity supply is a key target for any power utility. The reliability of each generating unit largely influences the overall system’s reliability. In fact, system reliability is achieved when the available generation capacity is able to meet demand effectively at all times, even under conditions of scheduled maintenances* and forced outages*.

Capacity planning is essentially carried out for the long term, mainly because of the technical and economic lifetime of power plants. Basically, the aims of generation planning are to identify the optimal time when new capacity should be added, to determine the magnitude of new capacity and to recommend the right technology including potential siting of the new capacity.

In the following sections, the CEB’s generation plan for the period 2013–2022 is elaborated. The elaboration starts with a brief examination of the 2003–2012 generation expansion plan, proposed in the last IEP, and its achievements focussing specifically on major projects that were implemented. The second, and last, part of the discussion details the revised generation expansion plan based on the demand forecast presented in the previous Chapter.

5.1 FLASHBACK ON INTEGRATED ELECTRICITY PLAN (IEP) 2003-2012
In the IEP 2003–2012, CEB drew up its tactical plan to ensure continuous power supply to its customers. A number of important power expansion projects were implemented as a result. The main topics pertaining to generation planning covered in the IEP 2003–2012 were:

- The relationship between utility and non-utility generation;
- The different resource options available and suitable to meet demand;
- The timing for, and appropriate size of, planned addition;
- The Generation Planning Acquisition Policy, which addressed the why, when and how new generating plant could be acquired; and
- The possibility to promote renewable energy technologies.

5.1.1 Targeted Capacity Addition
In support to the Sugar Sector Reform and with the objective of optimizing the use of indigenous energy sources – ‘bagasse’ for energy production – CEB, in-keeping with the policy of Government, set the target to accommodate the next power plant, which would operate using cogeneration (coal-‘bagasse’) technology. Based on the demand forecast presented in the IEP 2003-2012, it was thus decided that a generating unit of 32 MW would be commissioned, as and when the need for additional capacity would be required.

5.1.2 Actual Plant Commissioning
During the period of the last IEP, the following new generation projects were commissioned:

‘Compagnie Thermique Du Sud’ (CTDS)
In order to prevent potential negative impact on our country’s electricity generation capacity, CEB was called upon to launch a Request-For-Proposal (RFP) in 2003 for a 30 MW capacity plant on a fast track. Following the RFP and the ensuing negotiations, the CTDS, a pure coal-based power plant, was commissioned in 2005. This capacity addition was not in line with the target set. The reason for the deviation, however, was due to delays associated with the Sugar Sector Reform.

Saint-Louis Re-development
Based on the analysis of load duration curves* and demand pattern of forthcoming infrastructural projects,
it was resolved that a new semi-base plant capacity would be required by 2006. In this respect, CEB initiated the re-development of the Saint-Louis Power Station, whereby three medium speed diesel engines of 13.8 MW each were commissioned in 2006. This project was again a necessary diversion from the strategy to optimize ‘bagasse’ for electricity generation for the reason stated above.

‘Compagnie Thermique de Savannah’ (CTSav)
With the on-going centralization of the Sugar Sector, most of the Continuous Power Producers (CPPs)* – small-sized less efficient power plants – were required to stop operations. In order to optimize the use of the ‘bagasse’ for electricity production of those closing CPPs, it was decided that more efficient IPPs be set up. Hence, under a directive from the Government, CEB launched an RFP for a 60 to 70 MW coal-‘bagasse’ power plant. Hence, in 2007, the CTSav Power Station was commissioned, with a net export capacity of 74 MW on coal mode, and 65.5 MW on ‘bagasse’ mode.

5.1.3 Limitations of Coal-‘Bagasse’ Power Plant
The previous IEP outlined the numerous advantages that IPPs had brought to our country’s electricity generation capacity. Apart from supporting the CEB in meeting the fast-growing demand, their geographical dispersion had also helped to reduce pressure on the transmission system and improve lines’ losses. But, on the other hand, the low-efficiency spreader-stoker technology* of the IPPs has been impacting negatively on the country, both financially and environmentally.

5.1.4 Least-Cost Expansion Plan
A pre-feasibility study on the addition of new generation capacity in the long term concluded that pulverized coal technology would be the least-cost capacity expansion for Mauritius. The main advantage of pulverized-coal technology* over spreader-stoker technology is its high efficiency (32% as compared to 25%).

Following a consultancy study on the siting of power station in 2001, the Pointes-Aux-Caves site was earmarked for the setting up of a coal power plant using pulverized-coal technology. In this respect, an IPP proposal, more precisely the CT Power, was received from the Government for consideration. Despite the execution by signature of a Power Purchase Agreement (PPA)* with the CT Power on the 23rd of December 2008, the development of the project was delayed as the EIA license was not yet granted.

As an alternative to the delayed CT Power project and to ensure the least-cost expansion within a tight schedule, CEB opted for the re-development of the Fort Victoria Power Station. The latter’s re-development plan was already worked out some years back. The CEB proceeded on a fast track with a two-phase implementation. The first phase was completed in 2010 with the commissioning of two 15 MW medium-speed diesel engines. The second phase, which consisted of a further addition of 60 MW medium-speed diesel engines, was commissioned in 2012. The coming into operation of the new engines enabled the retirement of the old, less efficient, FIAT and Mirrlees engines and shall contribute in meeting demand until 2014.

5.1.5 Development in Renewable Energy (RE)
When the last IEP was published, there was little advancement in renewable energy in Mauritius, as the cost of investment was extremely high and fossil fuels, such as HFO and coal, provided relatively cheaper options for generating electricity. At that time, the share of renewable energy (consisting of only ‘bagasse’ and hydro) in the energy mix was around 23%. Discussion was also centred on the advantages and limitations of integrating renewable energy in the power system.

During the term of the IEP 2003-2012, around the year 2006, renewable energy was seriously contemplated by the Authorities. Government’s expectations on renewable energy were eventually crystallized in the Maurice Ile Durable (MID) concept. The goal of the MID is to make Mauritius a model for sustainable development and to enable people to satisfy their basic needs and enjoy a better quality of life without compromising the well-being of future generations. Energy is one of the major components among the ‘5Es’ of the MID. The MID framework basically operates on the taxation of fossil fuels to subsidize renewable energy projects and finances sustainable development projects.

Further to the above, the need to promote the development of renewable energy was additionally addressed in Government’s Long-Term Energy Strategy (LTES) 2009-2025 for Mauritius. The long-term energy strategy document is actually a white paper for the development of the energy sector up to the year 2025.
In line with Government’s objective to promote sustainable development in the context of the **Maurice Ile Durable** vision, the LTES 2009-2025 lays emphasis on the development of renewable energy, the reduction of our dependence on imported fossil fuel and the promotion of energy efficiency.

To enable and facilitate the development of renewable energy projects, as laid down in the LTES, the Negotiating Panel of the CEB was entrusted with the responsibility of considering large-scale renewable energy projects. So far, the panel has negotiated **Energy Supply and Purchase Agreement (ESPA)*** for the projects listed in Table 5.1 above.

**Targets for Renewable Energy**

In the LTES, the targets for renewable energy were defined. Table 5.2 below shows the current status for 2010 and the progressive transition to meet the target of 35% of renewable energy capacity by the year 2025.

**TABLE 5.2: Percentage Share of Energy Sources**

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<th>Fuel source</th>
<th>PERCENTAGE OF TOTAL ELECTRICITY GENERATION</th>
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<td>2010</td>
</tr>
<tr>
<td>Renewable</td>
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</tr>
<tr>
<td>‘Bagasse’</td>
<td>16%</td>
</tr>
<tr>
<td>Hydro</td>
<td>4%</td>
</tr>
<tr>
<td>Waste to Energy</td>
<td>0%</td>
</tr>
<tr>
<td>Wind</td>
<td>0%</td>
</tr>
<tr>
<td>Solar PV</td>
<td>0%</td>
</tr>
<tr>
<td>Geothermal</td>
<td>0%</td>
</tr>
<tr>
<td>Sub-total</td>
<td>20%</td>
</tr>
<tr>
<td>Non-Renewable</td>
<td></td>
</tr>
<tr>
<td>Fuel Oil</td>
<td>37%</td>
</tr>
<tr>
<td>Coal</td>
<td>43%</td>
</tr>
<tr>
<td>Sub-total</td>
<td>80%</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
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</table>

In addition to the above, CEB will also actively participate in RE projects initiated under the MEPU’s Energy Strategy Action Plan (ESAP) 2011-2025, which comprises the development of a Wind Atlas, study to increase energy production from ‘bagasse’, study to use cane residues for electricity production and the setting up of a pilot plant for handling and feeding cane residues.

As a key facilitator, CEB will also implement or assist in the implementation of other technically feasible renewable energy projects, as elaborated in the government ESAP 2011-2025. This will include the setting up of a 20 MW Wind Energy System every 3 years as from 2017 and a 10 MW Solar Energy System every 3 years after 2013.

**Assumptions**

The above-targeted energy mix is based on the assumptions that the coal and waste energy projects, approved by the Government, would be operational by 2013. New and more affordable **Photovoltaic (PV)*** technology would be also available. The targets were subject to revision in response to changes in technology and outcomes of local energy resources assessment and affordability.

**Status of Current RE Projects**

In order to meet the above targets for renewable energy, the Ministry of Energy and Public Utilities (MEPU) is currently in the process of developing a **Renewable Energy Master Plan***. The plan will provide a roadmap to reach the targets set. Meanwhile, the CEB, in line with the Government policy to promote the use of local energy resources, has already embarked on a number of renewable energy projects, as listed in Table 5.3 on the next page.

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* See glossary
5.1.6 Distributed Generations (DGs)*

Distributed generation has recently become a reality in Mauritius with the setting up of the Small-Scale Distributed Generation (SSDG)* Project. The possibility to broaden the scope of distributed generations in Mauritius is currently being studied, so as to enable connection of Medium-Scale Distributed Generation (MSDG). Related information on the SSDG and MSDG Schemes is available on the CEB website website www.ceb.intnet.mu.

Small–scale distributed generation (SSDG)

CEB, in collaboration with the MEPU, launched the SSDG project in December 2010. In this project, Small Independent Power Producers (SIPPs)* are given the opportunity to produce their own electricity from renewable sources (PV, wind or hydro) and export any surplus to the grid.

The main objective of the SSDG project is to promote distributed generation of electricity from renewable energy technologies. The SSDG project helps to reduce the use of fossil fuels for electricity generation, mitigate emission of Greenhouse Gases and decrease line losses on the Low Voltage (LV)* network. The implementation of the SSDG has required the development of a Grid Code to allow the integration of photovoltaic, wind turbine and small hydro technologies* within the grid. The Grid Code defines all the requirements relevant to the performance, operation, testing, safety and maintenance of Distributed Generation connected to CEB’s low voltage network. It also defines the rights, responsibilities and conduct of all parties involved in the process. Furthermore, the Grid Code describes the Feed-In Tariffs (FITs)* that are payable to SIPPs for the energy exported to the grid.

The first phase of the SSDG Project was opened for a total capacity of 2 MW, which was extended to 3 MW in December 2011. Out of the total capacity of 3 MW, initially 100 kW was reserved for Rodrigues. This 100 kW was subsequently increased to 200 kW.

For the 2.8 MW capacity allocated for Mauritius, 341 applications were retained out of 403 received. So far, 77 SSDGs representing a total capacity of about 714 kW have already been commissioned. For the allocated 200 kW capacity for Rodrigues, 55 applications were received. Under the first-come-first-serve

### TALBE 5.3: Status of Renewable Energy Projects

<table>
<thead>
<tr>
<th>Projects</th>
<th>Capacity (MW)</th>
<th>Status</th>
</tr>
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<tbody>
<tr>
<td>Nicolière Feeder Canal Hydro Plant</td>
<td>0.35</td>
<td>Hydro plant was commissioned in September 2010.</td>
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<tr>
<td>Midland Dam Hydro Plant</td>
<td>0.35</td>
<td>Project is currently under implementation. Commissioning is expected by the end of 2012.</td>
</tr>
<tr>
<td>Identify potential sites for mini- and micro-hydro plants</td>
<td>–</td>
<td>An RFP to seek consultancy services is expected to be launched early 2013.</td>
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<tr>
<td>Bagatelle Dam Mini-Hydro Project</td>
<td>Preliminary discussions have already started with the CWA and the WRU.</td>
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<tr>
<td>Setting of 1 to 2 MW Solar PV Farms</td>
<td>10</td>
<td>Project currently under evaluation. Solar PV farms are expected to be commissioned by 2014.</td>
</tr>
<tr>
<td>Development of a Grid Code, FIT* and Model ESA for MSDG* projects</td>
<td>–</td>
<td>The World Bank, under the MEPU’s ESAP 2011–2025, had provided CEB with a grant to undertake this consultancy exercise so as to define the framework to integrate renewable energy systems above 50 kW to the grid.</td>
</tr>
<tr>
<td>Bigara Wind Farm</td>
<td>1.1</td>
<td>Since the DCA did not give its clearance, the project was subsequently shelved in 2011.</td>
</tr>
<tr>
<td>Aerowatt Wind Farm (Revised)</td>
<td>9</td>
<td>CEB recently resumed negotiations with the promoter, but for a reduced capacity of 9 MW. Negotiation on the ESA is in progress.</td>
</tr>
<tr>
<td>Wind measurement at potential sites</td>
<td>–</td>
<td>CEB is in the process of identifying potential sites for the setting up of small wind farms similar to Rodrigues. Wind measurement masts will be installed and a feasibility study to assess sites’ wind potential will be carried out.</td>
</tr>
<tr>
<td>Solar PV Farm</td>
<td>15</td>
<td>A project proposal is under consideration.</td>
</tr>
</tbody>
</table>

* See glossary
principle, 35 applications had been retained and are currently being processed.

Another scheme, under the SSDG project, for a capacity of 2 MW has been made available for Public, Educational, Charitable and Religious (PECR) institutions. For this category, 97 applications had been received for a total capacity of about 1.2 MW. The tariff applicable for this scheme, irrespective of the renewable energy technology used, is the CEB’s Marginal Cost of Production.

Once the cumulated capacities of 5 MW SSDG are effectively connected to the CEB’s network, a study will be carried out to assess the impact of the connected SSDGs on the low voltage network. The results of the impact assessment will determine whether the low voltage network will be able to accommodate the connection of additional SSDG(s). However, connection of additional SSDG(s) will not necessarily be under the same terms and conditions of the current SSDG Schemes.

Medium-Scale Distributed Generation (MSDG)*

After the launching of the SSDG project, interests were shown by larger electricity consumers and promoters to set up renewable energy systems of capacity higher than 50 kW. Such type of RE installation will fall under the Medium-Scale Distributed Generation (MSDG) Scheme.

As in the case of the SSDG scheme, implementation of the MSDGs project will also require the development of an appropriate Grid Code and the applicable Feed-In Tariff. Normally, MSDGs will be connected mainly at Medium Voltage (MV) level. The maximum number of projects which the grid can safely accommodate will depend on the grid’s absorption capacity*. The MSDG will generally cover projects of capacity above 50 kW but lower than 4 MW.

5.2 THE 2013–2022 GENERATION EXPANSION PLAN

Based on the 10-Years load forecast, as described at length in the previous chapter, the total annual energy requirement from power stations will be around 2673 GWh in 2013 and will increase steadily to reach 3519 GWh by 2022. The resultant peak power demand is forecasted to grow at a steady rate of 2.9 % per annum. In relation to the load forecast, CEB is anticipating that an addition of 200 MW of generating capacity will be required over the planning horizon.

Using energy sales and peak power forecast as inputs, the least-cost generation expansion plan was worked out. First, the generation planning exercise had required a comprehensive examination of the existing power generation capacities. Then, adopting an appropriate planning methodology, different available generation options were assessed before selecting the best alternative(s). In the following sub-sections, a brief overview of the proposed 2013–2022 generation expansion plan is given.

5.2.1 Existing Power Plants

Hereunder, an insight into the generation park in Mauritius is given as preliminary information before assessing the future capacity requirements of the CEB to meet growing demand.

CEB’s Power Stations

In 2011, CEB had produced 1096 GWh, which was around 45% of the total electricity demand for the country. The energy was generated from the CEB’s four thermal and nine hydro power plants. Out of the four thermal power stations, three of them, namely Fort George, Saint-Louis and Fort Victoria Power Stations, operate on heavy fuel oil, while the fourth one, the Nicolay Power Station, runs on kerosene. The bar chart in Figure 5.1 on the next page shows the share of the electricity production for the period 2005–2011 by the CEB and the IPPs in Mauritius.

Fort George Power Station

The Fort George Power Station is the largest power plant owned by the CEB. It generates about 25% of the total energy generation for Mauritius. Fort George Power Station consists of 5 heavy fuel oil operated engines having a cumulated effective capacity of 134 MW. The engines at the Fort George Power Station are basically slow-speed type machines and, due to their high efficiency (typically 44.5% to 45.8%), they are operated as base-load generators throughout the year. Its annual plant load factor* is estimated to be about 55%.

Saint-Louis Power Station

The Saint-Louis Power Station, with its 5 Pielstick and 3 Wartsila engines, has a total effective capacity* of 74 MW. Its average annual plant load factor is around 30%.

* See glossary
The Pielstick engines have exceeded, by far, their normal operating life. These engines not only run inefficiently, but are also becoming problematic for the CEB in terms of environmental compliance. To remain in accordance with environmental norms, CEB is envisaging their retirement in the near future.

In respect to the retirement of the Pielstick engines, a re-development plan of the Saint-Louis Power Station was initiated and has been already completed. CEB is currently seeking to obtain the necessary EIA license for the project. According to the present generation expansion plan, the development of the project will not be contemplated during the course of this IEP.

As regards to the Wartsila engines, commissioned in 2006, they contribute to about 6 to 8% of the national electricity requirements. These engines are all medium-speed type and operate as semi-base-load generators; that is, they start their operation at seven o’clock in the morning and stop at 21:00 hours.

Fort Victoria Power Station
Since 2009, the Fort Victoria Power Station had undergone two phases of re-development. In fact, the re-development plan of the Fort Victoria Power Station was prepared back in 2004, but it was deferred as there were other power projects in the pipeline. Subsequently, due to delays in other power plant projects, the Fort Victoria re-development project was revived again on a fast-track basis so as to meet the increasing demand of the country.

In the past, the Fort Victoria Power Station had 8 Mirrlees engines providing a total output of 42 MW. Since these engines were running inefficiently and had reached the end of their useful life, which were causing adverse effect on the environment (noise and air pollution), they were retired in 2008 as part of the first phase of the re-development. The Phase-One of the re-development included the commissioning of two new Wartsila units of 15 MW each.

The second phase of the re-development was initiated in 2011, whereby four Wartsila units of 15 MW each were commissioned in 2012. In addition to the six Wartsila units, there are also two MAN engines of 8.5 MW each. All these engines are medium-speed type and contribute to meet the semi-base load.

The newly-commissioned Wartsila engines have a useful life of 25 to 30 years; this means that they can safely supply electricity to the grid until 2040, assuming no major breakdowns occur.

Today, the Fort Victoria Power Station provides a total capacity of 107 MW to the CEB’s grid and is expected to have an annual plant load factor of around 35%.

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<sup>See glossary</sup>
Nicolay Power Station

Nicolay Power Station is the only CEB’s power plant operating on kerosene. It consists of three open-cycle gas turbines with a total effective capacity of 75 MW. The plant is primarily used as a peak-lopping facility. The Nicolay Power Station has the highest running costs and, therefore, generally has a low annual plant load factor of around 3%.

Since these gas turbines have the highest marginal costs of production, they are dispatched only in exceptional cases, such as unscheduled outages and/or planned maintenance of IPPs and partial/general blackouts.

Hydro Power Plants

CEB has currently nine hydroelectric power stations in operation, with a total effective capacity of 55.8 MW. They account for approximately 9% of the island’s total effective capacity. In a good season (rainy), these stations can meet 10% to 12% of the electricity demand in Mauritius, while in a less favourable season (drought), such as in 1999, the energy produced can be as low as 2%.

CEB recently commissioned a small hydro plant having a capacity of 350 kW at the La Nicolière Feeder Canal. As at to date, this plant has generated some 1.7 GWh of electricity. Another similar project at the Midlands Dam has been planned for commissioning early 2013.

According to a recent study, the hydro potential in Mauritius has almost already reached its limit. However, it is believed that there is still room for the development of mini- and micro-hydro plants and enhancement of existing dams’ capacities. These potential hydro developments are also part of the Government’s ESAP 2011-2025. CEB has already embarked on such a project; whereby the water storage capacity of the Sans Souci Dam will be increased by some 30%. This development, accompanied with the impounding of waters at River Canard, although modestly, will contribute to increase electricity generation from hydro.

The Phase-One of the project, which involves increasing the Dam capacity from 240 metres to 243 metres, will be completed in 2014. Furthermore, CEB has recently initiated a project to identify potential sites for the installation of mini- and micro-hydro plants. The study will be completed in 2013.

5.2.2 Independent Power Producers (IPPs)

CEB is currently managing Power Purchase Agreements (PPAs) with 5 Independent Power Producers (IPPs), which operate on firm-power basis. CEB also manages an ESPA Contract with the Sotravic Landfill Gas Energy Ltd.

The largest of the IPPs is the ‘Compagnie Thermique de Savannah’ (CTSav), which was commissioned in 2007. Its net total export capacity is 74 MW. All the IPPs, with the exception of ‘Compagnie Thermique Du Sud’ (CTDS), operate on ‘bagasse’ in the crop season and coal during inter-crop season. In the ‘bagasse’ mode of operation, the IPPs export less power to the CEB’s grid, as some of the produced steam is sent to the nearby sugar factories for sugarcane production processes.

In 2011, IPPs produced 55%, equivalent to 1337 GWh, of the total electricity consumption in Mauritius. Among the IPPs, three, namely CTBV, FSPG and CEL, have ‘take-or-pay’ contracts with the CEB. The ‘take-or-pay’ principle means that the CEB shall pay for the contractual energy amount even if the energy is not dispatched, while the power plant is available. The PPAs of these IPPs include the purchase of energy on the single-part tariff model. For the other two IPPs (CTDS and CTSav), CEB negotiated for the two-part tariff model, which treats Capacity and Energy Charges as two different cost elements.

Some additional useful information on power generation assets is provided in Appendix B1.

5.2.3 Generation Planning Methodology

The present generation planning methodology adopts a deterministic approach. A demand-supply balance matrix, which forms the basis to determine the need for capacity addition, takes into consideration:

1. The updated effective capacities of existing plants; and
2. The ‘N minus 2’ criterion, that is, one of the largest generators is assumed to be on maintenance, while the second largest generator is assumed to be on breakdown.

In the demand-supply matrix, the peak demand forecast is inflated by 10% to cater for spinning reserve.
Then, the Reserve Capacity Margin (RCM)*, which determines the need for capacity addition in a particular year, is calculated as per the formula below:

$$\sum_{i=1}^{n} \text{Effective Capacity} - \text{(Capacity Out)}_{\text{Mtc}} - \text{(Capacity Out)}_{\text{Bdown}} - \frac{(\text{Forecasted Peak Power} + 10\% \text{ Spinning Reserve}) - 1}{n}$$

where,
- $n$ is the total number of generating units connected to the grid;
- $(\text{Capacity Out})_{\text{Mtc}}$ is the maximum capacity that is assumed to be unavailable due to maintenance;
- $(\text{Capacity Out})_{\text{Bdown}}$ is the largest generating unit assumed to be unavailable due to breakdown.

If the RCM is below a threshold value (say, –5%), it triggers the addition of new plant(s) in the system.

The methodology to determine the least-cost expansion plan depends on:

1. An in-depth analysis of the historical load duration curves, which dictate the technology to be adopted for future expansion; and
2. The Screening curve* analysis, which provides a way to trade-off different technologies, in terms of investment costs and operating costs.

More information on the capacity planning methodology is provided in Appendix B2.

5.2.4 Committed Additions and Retirements

Based on the present generation plan, the following will be required in the short term.

**Generation Plant Addition**

1. The next major capacity addition is a 100 MW coal plant (CT Power), which will be located in the West at Pointes-aux-Caves. The target implementation date has been set for 2015/2016.
2. Commissioning of the Midlands Dam hydro project, which has a capacity of 350 kW, early 2013.
3. The Curepipe Point (Plaine Sophie) Wind Farm project is expected to be connected to the grid by the end of 2014. This project will be the first big Wind Farm of the island, with a total installed capacity of 29.4 MW.
4. CEB has also embarked on a 10 MW Solar Photovoltaic Project, which will be interconnected on the medium-voltage network. At best, the project will consist of 5 Solar PV Farms of 2 MW each. They are expected to be commissioned by the end of 2014.
5. A 15 MW Solar PV Farm project is also under consideration.

As a pertinent information, it is worth pointing out that only the first above-mentioned generation project fall under the system’s ‘needs-based additions’, while the next four renewable energy projects fall under what is referred as the ‘opportunity-based additions.’
Generation Plant Retirements
With the commissioning of new generation plants and in meeting the objective of the least-cost expansion, CEB will progressively retire the old, and less efficient, Pielstick engines at the Saint-Louis Power Station.

5.2.5 Demand-Supply Balance
Figure 5.2 shows the matching of electricity demand with generation capacity for the planning period 2013–2022.

5.2.6 Planned Capacity Additions (2013–2022)
Following an assessment of new capacity requirements and the evaluation of alternatives, new capacity additions, as shown in Table 5.4, have been planned for the coming years.

<table>
<thead>
<tr>
<th>YEAR</th>
<th>CAPACITY (MW)</th>
<th>POWER PLANT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>50</td>
<td>CT Power</td>
</tr>
<tr>
<td>2016</td>
<td>50</td>
<td>CT Power</td>
</tr>
<tr>
<td>2017</td>
<td>50</td>
<td>New</td>
</tr>
<tr>
<td>2021</td>
<td>50</td>
<td>New</td>
</tr>
</tbody>
</table>

5.2.7 Energy Generation Forecast Methodology
Energy generation forecast is mainly carried out for budgetary purposes. It is used to prepare budget estimates for the procurement of fuels and other inputs. It also serves to determine the allocation of the amount of energy that will be purchased from the IPPs.

To estimate the energy that will be generated, the energy sales forecast is adjusted by a factor, which represents the network losses* and the energy used-on-works*. Figure 5.3 below illustrates the energy losses that are incurred from the point of generation up to customers’ premises and the energy consumed by auxiliaries* (energy used-on-works).

From the energy sales estimates, the Gross Energy Generation is calculated as follows:

\[ \text{Gross Energy Generation} = \text{Energy Sales} + \text{Used-on-Works} + \text{Network losses} \]

The allocation of energy to each power plant is subsequently made on the basis of recent trends of the load duration curve. For a better understanding, a brief on the methodology used to estimate the energy generation is given in Appendix B3.

5.2.8 Evolution of Generation Mix
In the early 2000, CEB produced most of its electricity using heavy fuel oil. As from 2005, with the commissioning of CTDS and CTSav, the share of coal in the energy mix started to increase. The share of renewable energy (hydro and ‘bagasse’) has remained almost constant over the past decade.

* See glossary
Figure 5.4 illustrates the evolution of fuel mix from 2002 to 2011.

5.2.9 Generation System Costs
From an economic point of view, it is ideal to expand a power generating plant by adding generating units, which require low capital investment and have low operating costs. In reality, this is hardly possible. When assessing the economics of power generation technologies, two key cost elements are considered:

(a) Capital Investment Costs (expressed in MUR/kW) of different available technologies. The Capital Investment Cost is the capital outlay necessary to build the power plant;

(b) Power Generation Costs (expressed in MUR/kWh), which represent the total cost of generating electricity, using specific technology. Power generation costs consist of costs associated with the initial capital investment in a power plant (fixed investment charges), fuel costs, operation and maintenance costs and taxes and insurances.

A break-down of the general categories of costs for power generation technologies is presented in Figure 5.5 below. The dashed line indicates that the fixed investment charges are a function of the capital investment costs.
Generation Costs - CEB’s Plants
The average cost of generation of CEB plants is calculated using the weighted mean of units generated for a particular year. In general, CEB generates some 40% of its electricity from HFO and about 1% from kerosene. Hence, despite gas turbines having a high running cost, the average cost of CEB’s generation is close to the cost of generation from HFO engines. The unit cost of generation for CEB’s power plants consists of costs of fuel oil, lubricating oil, labour, maintenance, depreciation, administrative, overheads and finance costs.

Generation Costs - IPP Plants
Usually, IPPs’ costs of generation are lower than CEB’s generation costs for the following reasons:

(1) IPPs operate on coal which is a cheaper fuel than HFO; and
(2) Capacity Utilization Factor (CUF)* of IPPs is above 80% as they operate mostly as base plants.

The price (tariff) of electricity purchased from an IPP is normally agreed at the PPA negotiation stage. The agreed tariff, in most cases, includes an indexation mechanism based on:

- Actual cost of fuel on the world market;
- Inflation rate;
- Exchange rate; and
- Interest rate.

System Average Cost of Generation
Since both, IPPs and CEB power plants, are solicited to meet the daily demand, their combined costs of generation are used to determine the system generation cost. The variation in the system generation cost is a function of the hourly demand profile. During the night, the generation cost is at its lowest level because only the most efficient power plants are in operation. But at peak times, the system cost is relatively higher as high running cost engines have to be operated to meet short duration system demand. The average system cost of generation also depends on:

- Seasonality;
- Days of the week;
- Maintenance of plants; and
- Breakdown of plants.

Given the influence of these factors, the system generation cost, as such, varies continuously under different scenarios.

Cost of Generation of Renewable Energy
Save for the hidden cost to the environment, which is normally not included in the cost of operations of fossil-fuels-based generation, the cost of generation of renewable energy technology is comparatively higher than that of conventional sources of power generation. The main reasons for the high costs are the relatively significant initial investment and the very low capacity utilization factor of renewable energy projects. Given these constraints, the financial risks are indeed much higher in RE projects.

However, current trends show a gradual decrease in the cost of generation of renewable technologies. Two possible reasons may explain the decreasing costs:

(1) Competition among suppliers of renewable technologies on the world market; and
(2) New improved products with higher efficiencies being offered.

While there is growing pressure to increase the use of RE technology, their high investment costs continue to inhibit their fast penetration. In our context, with the current Government declared policy and the setting up of the MID fund, it is believed that renewable technologies will make promising progress in the coming years.

However, as things stand today, it seems that renewable energy generation will continue to be more expensive compared to oil- or coal-based electricity generation in the medium term, unless the environmental costs* associated with fossil-fuels-based generation are quantified and factored into the average system generation cost of conventional technologies. Estimating environmental costs is in fact highly challenging in practice.

Besides not having the necessary resources and being an electricity producer, it is not appropriate for the CEB to determine the environmental costs associated with its electricity production activities. The Ministry Of Environment and Sustainable Development (MOESD), which possesses the necessary environmental accounting tools and competences, is more

* See glossary
apt to determine the environmental costs of electricity generation from fossil fuels.

In similar vein, to ensure completeness in costs analysis and accounting, while the MOESD shall endeavour in determining the environmental costs of conventional electricity generating engines, it requires that the *opportunity cost* of the massive investments made in the fossil-fuels-based technologies, which are required to back-up the operations of the RE technologies, be assessed equitably.

5.2.10 MID Contribution

In embracing the *least-cost policy*, given the current state-of-affairs, renewable technologies being intermittent in nature will always be the second best alternative for the CEB. As mentioned above, the cost of generating energy from renewable sources is comparatively higher than the existing firm-power generating engines. Economically speaking, the higher cost of electricity produced from renewable energy sources should normally be translated into higher cost of electricity, unless it is subsidized.

In order to promote the integration of more renewable energy technologies in the energy mix, the support of Government is strongly required so as to cover the extra costs incurred in the purchase of the higher-cost cleaner energy. As such, financing from the MID fund is more than desirable in order to promote the adoption of renewable technologies.

CEB can only afford to pay the average system cost of generation and the MID fund to cover the additional costs implied in the tariff(s) of renewable energy generation.

The graph in Figure 5.6 below depicts a case, where the MID contributions have facilitated the implementation of renewable energy projects and enabled the CEB to purchase the electricity generated.

5.2.11 Consultancy Supports in Relation to Generation Capacity Expansion

In order to fulfil its mission of securing the future electricity supply of the country, CEB will continue to solicit, where necessary, the supports of reputable consultancy firms and international agencies. Already a few studies, as listed hereunder, will be carried out with the help of international experts this year:

- Pre-feasibility study for the use of *Liquefied Natural Gas (LNG)* as an alternative to heavy fuel oil. LNG is an interesting option to enable the diversification of the country’s energy sources.
- Development of mini- and micro-hydro projects. This study will have as main objective to identify potential sites across the island, where mini- and micro-hydro generators can be installed.

The development of nuclear power for civil purposes appears to be gaining acceptance worldwide. As implausible as it may appear, nuclear technology is a generation option to substitute fossil-fuels-based generation in Mauritius. As a matter of preparedness, through the MEPU, CEB will initiate the process to seek technical assistance from the IAEA for preliminary research on future nuclear technology. In this regard, during the planning period, with the assistance of the IAEA, a roadmap for the possible implementation of this option will be defined so as to ascertain its economic viability. It is worth highlighting that this preparatory process in itself may cover a period of at least 10 to 15 years.

**FIGURE 5.6: MID Contribution Improving RE Projects’ Viability**

![Graph showing MID Contribution Improving RE Projects' Viability](image)

*See glossary*
Voltage

Time

132 kV

230/400 V

22 kV

frequency 50Hz±1.5%
Voltage 230V±6%
Does Quality of Electricity Supply Matter?

Besides reliability, electricity supply is judged by its quality. Quality of supply is intrinsically dependent on strict adherence to international standards for system design and operation with the strong involvement of all business partners.

CEB, in its commitment, shall continue to invest so as to perfect the quality of electricity supply!
The Mauritius electricity network is made up of the Transmission and Distribution (T&D) systems, which are wholly owned and operated by the CEB. The transmission network, operating at the highest voltage of 66 kV, transports power in bulk from the main sources of generation to various 66 kV-to-22 kV substations scattered over the island.

The CEB’s distribution system supplies electricity at lower voltages from its substations to various customers’ premises through 22 kV-to-415 V and 6.6 kV-to-415 V distribution transformers. As at the end of 2011, the CEB’s T&D assets were worth around Rs 6.9 billion, reflecting the massive investment made in the electric network over the years.

Given the size and importance of the network, it is imperative to ensure its proper management. Above all, the planning of the network is critical so that the CEB can support continuously the long-term social and economic developments of Mauritius and Rodrigues. The key objective of the electricity network planning is to determine the upgrading and expansion requirements of the electric network in order to guarantee the quality and reliability of electricity supply for the nation and the economic players.

6.1 THE PRESENT TRANSMISSION AND DISTRIBUTION NETWORK

In a power system, the T&D network is the lifeblood of the system. In this section, a short conspicuous exposé on the evolution of the CEB’s T&D network is presented.

6.1.1 The CEB Transmission Network

Figure 4.3 in Chapter 4 illustrates the Mauritian transmission network, which consists of sixteen major substations and 300 kilometres of single-circuit transmission lines. The transmission network is made up of a mix of underground cables and overhead lines. Overhead lines, which form around 94% of the network, greatly predominate because of their practicality and lower costs. Although they are more costly, underground cables are generally installed in places where there are environmental, or other, concerns.

The supporting structures of overhead lines, transmission-line towers and concrete poles are designed, among other standard design criteria, to withstand tropical cyclones having wind speeds within the range of 150 to 280 kilometres per hour. Part of the CEB’s transmission network has also been built for operation at 132 kV, when the need arises.

In fact, in 1996, the final report for the project on ‘Assistance in Generation and Transmission Planning’ recommended introducing the 132 kV system voltage while retaining the 66 kV network as a sub-transmission network. The recommendation was based on the assumption that all new generation units would be centralised in the region of Port Louis. It was thus anticipated that the existing 66 kV transmission capability would reach its limit during peak demand periods and, consequently, would require transmission voltage upgrade to 132 kV by 2007. In the light of that recommendation, the 132 kV double-circuit transmission lines were built.

However, moving towards the higher transmission voltage level would require additional investment in 132 kV-to-66 kV power transformers, protective relays, 132 kV gas-insulated switchgears and training of the CEB’s technical staff. Space requirement for the installation of the 132 kV equipment was already catered for at the Saint-Louis, Ebène, Amaury, Wooton, Dumas and the future L’Avenir substations, which would form part of the 132 kV transmission network backbone.

* See glossary
Subsequently, by adopting the decentralised generation expansion approach, CEB took the strategic decision to defer the upgrading of the transmission network to 132 kV. Under this new approach, new power stations - the CTDS and the CTsav Power Plants in the South, FSPG and CEL Power Stations in the East and the CTBV Power Plant in the North - were constructed to meet the increasing power demand.

6.1.2 Distribution Network

Today, CEB delivers electricity to approximately 422,000 customers across the island through its distribution system, which operates at medium voltages of 22 kV and 6.6 kV and low voltages of 230 V single-phase and 400 V three-phase. As at 2011, CEB had approximately 8,450 kilometres of electric distribution lines. The breakdown of the line length, in terms of different voltages and types of cable, is shown in Figure 6.1.

The distribution network consists of overhead lines and underground cables. In town centres, such as Port Louis, Curepipe, Vacoas, Quatre Bornes and Rose Hill, and where access to the construction of an overhead network is not practical, underground cables are used.

Traditionally, the flow of electricity in the distribution network was uni-directional from the CEB’s substations to its customers. Since 2011, the distribution system has undergone a major change as customers are henceforth able to generate their own electricity and export the excess to the distribution network.

This change in the distribution network structure presents new challenges for the CEB, in terms of the planning, design and operation of the network.

To meet some of these challenges, CEB, after having elaborated the SSDG’s Grid Code, is now in the process of developing a grid code for its 22 kV network. These changes are considered as stepping-stones towards the setting up of a future Smart Grid. A brief on the proposed Grid Code and the conceptual Mauritius Smart Grid is given in Section 6.6.2 and Section 6.6.3 respectively.

6.2 POWER SYSTEM MODELING AND PLANNING

As an electric network grows in dimension, its complexities and vulnerabilities also increase, albeit more than proportionately. Assessing the impact of challenges on the CEB’s power system requires the use of appropriate analysis tools.

6.2.1 Power System Analysis Tools

CEB carries out detailed system studies (power system modelling and analysis) using a licenced state-of-the-art simulation software. The software is used to its full capability to plan the national electric network so as to ensure quality and reliable electricity supply for the present and the future. The main functionalities of the software used for system planning exercises are shown in Figure 6.2.

6.2.2 Power System Modelling

Power system analysis and studies generally start with the formulation of appropriate mathematical models of the existing generation, transmission and distribution systems. These models, which form the foundation of simulation processes, are made up of mathematical equations representing the technical characteristics of each component of the power system. In fact, the said characteristics are usually obtained from, either manufacturer’s datasheets, and/or through test and field measurements.

CEB, on its own, developed the generation and transmission (power system) models of Mauritius and

* See glossary
Rodrigues, which were initially used to perform only power flow and short circuit analyses. In order to enhance the power system model, in 2009, CEB sought consultancy services to develop comprehensive models of control systems (voltage and frequency) of all power plants in Mauritius.

Similarly, comprehensive control systems models of Rodrigues’ power plants were developed by in-house experts. The enhanced power system models now also enable transient stability analysis.

Today, CEB has mathematical models of its power systems which are more realistic. With these enhanced models, the level of confidence is substantially boosted when performing analysis and planning studies. Using these models, CEB is now able to assess better the potential impact of disturbances and integration of variable renewable power sources on the frequency and voltages of the power systems. The present developed power system models had enabled the following advanced system studies:

- Re-development of the Fort Victoria Power Station to accommodate six new generation units;
- System Impact Studies for the wind power integration of 29.4 MW at Plaine Sophie and 9 MW at Plaine des Roches;
- System Impact Studies for the wind power integration of 1.28 MW in Rodrigues;
- Re-development of the Saint-Louis Power Station for addition of 4 to 6 generating units;
- Interconnection of a 100 MW Power Plant at Pointe aux Caves;
- Interconnection of major loads, for example Bagatelle Mall, Cargo Freeport Zone at Plaisance, Highlands City, Jin Fei, Neotown, amongst others;
- Reactive Power Compensation; and
- Transmission Voltage Upgrade.

With the increasing number of connected distributed generation projects (SSDGs & MSDGs), CEB is extending the above system modelling approach to improve its distribution network planning. However, extending this approach will require, upstream, the implementation of a Geographical Information System (GIS) of the whole electricity network. The GIS will be a support to the nascent Spatial Load Forecast. The value added of a GIS is discussed further in Section 6.6.1.

6.2.3 Network Planning Process
The flowchart in Figure 6.3 on the next page illustrates the network planning process.

Basically, network planning is the process of ensuring reliable flow of electricity at high voltage from generation sources to various substations and, ultimately, to end-users, after stepping down to low voltage level. The process of network planning is mainly dependent on inputs from the Load Forecast and Generation Planning.

Using data from the SCADA of the System Control Centre, the process starts by validating the transmission model so that it reflects the actual network operating conditions.

To assess the impact of load growth and/or new generation units on the transmission network, inputs from the Spatial Load Forecast and Generation Expansion Plan are used. Using these inputs, simulations of the transmission network for each planning year are performed so as to identify abnormal conditions, such as overloading, low and high voltage conditions.

System reinforcements are then developed to overcome these abnormalities and simulations are performed again in order to validate the proposed reinforcements. In case more than one solution is technically feasible, the least-cost one is proposed for implementation.

6.2.4 Planning Criteria
In general, planning criteria are technical boundaries, defined in a Grid Code, within which an electrical system should operate so as to ensure the reliability and quality of electricity supply.

Transmission Planning Criteria
The reinforcements of the transmission system are guided by several factors, amongst others:

- Power transfer requirements;
- Location and size of new major loads;
- Location and size of new generation units;
- Location and size of renewable generation sources;
- Expected retirement of existing generation units;
- Least-cost expansion of network, while minimising transmission losses; and
- Environmental constraints.

* See glossary
FIGURE 6.3: Network Planning Process

Start with network model

Validate transmission network model

Set planning year

Update transmission network model

10-years Generation Expansion Plan

10-years Load forecast

– System Peak
– Substation Forecast

Perform system studies:
– Load flow analysis
– Fault analysis
– Stability analysis

Any abnormal system condition?

Yes

Formulate System reinforcement

Incorporate system reinforcement in model

Perform system studies

Abnormal system conditions still present?

Yes

Are there any alternative solutions?

Yes

Perform financial analysis to determine least-cost option

No

Formulate alternate system reinforcement

No network upgrade

No

Preparation of report

End

* See glossary
‘N minus 1’ Minimum Standard Security Criterion
As best practice, the transmission system is designed with built-in redundancy. To ensure security of supply, CEB has adopted the ‘N minus 1’ criterion, which ensures continuity in supply in the event of failure of any one transmission line and/or main power transformer.

Distribution Planning Criteria
CEB has adopted the following criteria to perform distribution planning:

- The distribution network is designed in such a manner that all spur lines* with load above 100 Amperes and 22 kV feeders have a back-up supply.
- Keep the number of switching operations* to a minimum so as to enable fast restoration of supply.
- Ensure feeder’s loading under normal conditions is limited to 50% of conductor nominal current rating.
- The voltage limit should be within statutorily prescribed limits under normal conditions. Voltage regulation at the nominal value of 230 V for single-phase supply and 400 V for three-phase supply should be within ± 6%.
- Adopt the closed busbar* configuration at 22 kV in CEB’s substation so as to satisfy the ‘N minus 1’ security criterion. This requires operating the tap changers* on parallel transformers in the Master-Slave configuration* in order to ensure that all tapping is carried out in unison.

6.3 TRANSMISSION NETWORK EXPANSION PLAN
Transmission planning assesses network expansion alternatives; it deals with uncertainty and determines large investments for the long term. New power plants, large-scale integration of renewable energy sources and upgrade of transmission voltage level also drive the transmission planning.

6.3.1 CEB Transmission Network as at 2012
As described in Chapter 3 on the review of IEP 2003-2012, a number of network expansion projects were undertaken so as to further improve the CEB’s transmission network reliability.

The current status of the transmission network, including the proposals made in the IEP 2003-2012, is schematically shown in Figure 6.4 on the next page.

6.3.2 Location of Favourable Injection Point
For both economic and technical reasons, it is more than desirable to have generation power plants distributed over the island, instead of having them centralised in a particular area. In general, the following problems arise with centralisation:

a) Lack of flexibility in operating a network;
b) Increase in transmission losses; and
c) Huge investment required when the need for upgrading to higher voltages arises.

Today, as illustrated in Figure 4.3 in Chapter 4, the western part of Mauritius is the only region that has minimal generation facilities. The present generation expansion plan makes mention of capacity requirements of 50 MW in 2015 and another 50 MW in 2016. To meet these capacity requirements, the company (Mauritius) CT Power Ltd will construct a 100 MW pulverised-coal power plant at Pointe aux Caves in the West.

For this new 100 MW generation capacity, power injection will be made at La Chaumière substation. This will require the CEB to upgrade La Chaumière substation and to lay two 132 kV underground cables which will connect La Chaumière substation with the Ebène substation. This network expansion project is essential so as to relieve the Saint-Louis–Ebène transmission lines, which may otherwise reach their limits at 66 kV in the medium term given the current and expected major developments taking place in the centre of the island.

Based on the generation expansion plan, 50 MW new generation capacity has been proposed for the year 2017 and another 50 MW for the year 2021. Based on the assumption that the total 100 MW generation capacity will be sited in the same location, transmission studies were carried out to determine the most favourable injection point(s).

Five scenarios, based on geographical location, were analysed for the possible injection points and the results were ranked in the order of lowest capital investment required for the interconnection facilities*. The analysis showed that the western region is the most favourable injection point, followed by the East, North, Port Louis Area and the South regions successively.

* See glossary
FIGURE 6.4: Schematic Diagram of the Transmission Network for Year 2012
6.3.3 The 2013-2015 Transmission Expansion Plan

To overcome present network constraints, following system studies, a transmission expansion plan for the period 2013-2015 has been developed.

Figure 6.5 on the next page shows the proposed changes in the transmission network for the short term. This short-term network expansion plan, as detailed in the following sub-sections, is already at its implementation stage, except for the upgrading of the Wooton and Belle Vue substations.

Case Noyale Substation

The substation, which was earmarked in the previous IEP for construction at Le Morne in 2005, will now be constructed at Case Noyale, due to non-availability of land at Le Morne. This new substation will be interconnected to the transmission network by two new transmission lines from the Combo and Henrietta substations.

Numerous problems were, and are still being, encountered in the acquisition of the right-of-way for the erection of the transmission line from the Combo substation. The delay in the construction of the substation has exacerbated the low voltage and reliability problems in the southwest region of Mauritius.

As a short-term solution, CEB is using the 66 kV transmission line from Henrietta as a 22 kV distribution line. Given the current situation, the construction of the Case Noyale substation is thus a top priority for the CEB.

Belle Vue to Sottise 66 kV Line

The Sottise substation, commissioned in 2005, is fed by a single 66 kV transmission line. In case of outage of this 66 kV line, the Sottise substation can only, and partially, be supplied by the present 22 kV feeders from the Belle Vue substation. This state-of-affairs does not satisfy the CEB’s ‘N minus 1’ security criterion.

In the previous IEP, it was planned that a second transmission line from the Amaury substation passing through Goodlands to the Sottise substation be constructed so as to improve the reliability of the network. Due to right-of-way problems and high costs associated with an alternative underground cable, that proposal was revised.

Accordingly, it was decided instead to construct the second transmission line from the Belle Vue substation. The project is in progress and shall be completed in 2014.

Saint-Louis–Fort Victoria Lines

Fort Victoria Power Station is connected to the Saint-Louis substation through four oil-filled cables, which were commissioned in the 1970s. Following the recent re-development of the Fort Victoria Power Station, whereby the generating capacity has been increased up to 107 MW, CEB has taken the decision to lay two additional copper XLPE (Cross-Linked Polyethylene)* cables of higher capacity so as to improve reliability and maximise power evacuation towards the Saint-Louis Power Station.

Riche Terre Substation

The construction of the Riche Terre substation was initiated to supply the Jin-Fei project as well as to relieve the Nicolay substation, which has already reached its secured capacity level. Due to delays in the Jin-Fei project, the commissioning of the substation has been rescheduled for 2014.

Ebène Substation

The 66 kV Ebène substation is being upgraded to increase its transmission and short-circuit rating so as to remain within safe operational limits. This upgrade shall be completed by the end of 2014.

Wooton Substation

Similar to the Ebène substation, the Wooton substation will also need upgrading in order to increase its transmission and short-circuit rating. This upgrade is proposed for completion before the end of 2015.

Belle Vue Substation

The 66 kV busbar at Belle Vue substation has already reached its limits in terms of short-circuit capacity and, therefore, an immediate attention is most warranted.

La Tour Koenig Substation

This substation was earmarked in the previous IEP to meet the anticipated load growth in the La Tour Koenig region and Coromandel Industrial Zone. As the load growth was not significant enough to trigger its construction as planned, the commissioning of the substation has been rescheduled for 2014.

* See glossary
**FIGURE 6.5: Schematic Diagram of the Transmission Network for the Period 2013-2022**

Note: Schematic diagram does not include the next 2 x 50 MW Power Plants, which have been planned for 2017 and 2021, as the siting(s) of the power plants are yet to be determined.
6.3.4 Proposed Transmission Expansion Plan 2016 and Beyond

From 2016 and beyond, CEB will have to implement the following projects so as to maintain reliable electricity supply. The proposed upgrade/expansion of the transmission network, as depicted in Figure 6.5 on the previous page, is detailed hereunder.

New Substation in the Region of Trianon

A new substation will be required to serve the growing loads in the regions of Reduit, Highlands and Trianon. It will not only ensure electricity supply to new developments but will also help to alleviate the Wooton substation and the Ebène substation, which will be reaching their loading limits by 2017. In this regard, two possible locations – Reduit and Highlands – have been identified for this new substation. Land acquisition procedures have accordingly been initiated.

Airport Substation

A new substation will be required by 2019 in the region of the SSR Airport. This new substation will supply the New Cargo Freeport Zone at Plaisance and, by extension, will relieve nearby substations and cater for the load growth in the region of Le Chaland and Plaisance. Consequently, the existing transmission line between Champagne and Union Vale Substations will be re-routed, passing through the new Airport substation.

Goodlands Substation

In the previous IEP, a substation was proposed in the region of Goodlands so as to cater for major industrial development, which in fact did not materialise. As such, there was no need for the construction of the Goodlands substation during the period 2003-2012. Recent market surveys, however, indicate that there is now the prospect of major commercial and land development in the northeast region. In this context, a new substation may be required in the region of Goodlands by the end of the planning period.

Anahita Substation

Presently, Anahita substation is fed by one 66 kV transmission line from FUEL substation. A second transmission line, as a back-up supply from Champagne substation, would have been ideal to improve the reliability of supply. Facing major topographical constraints, this option, however, does not appear to be cost-effective. It is more appropriate that the second transmission line be constructed from the FUEL substation.

6.3.5 Upgrading of Transmission Network

In general, fault level is largely affected by the addition of generation units. The location of the two 50 MW generation capacities, which will be required in 2017 and 2021, will dictate the need for upgrading CEB’s related substations.

As regard to the 66 kV transmission infrastructures, CEB will consolidate/replace its old 66 kV Steel-Lattice Towers in order to further improve the physical integrity of the transmission infrastructure. This action will contribute towards the objective of ensuring more security of electricity supply during cyclonic season.

6.3.6 Reactive Power Compensation

As in the case of the above-mentioned new substations (La Tour Koenig, Riche Terre, Case Noyale and others), system studies show that 22 kV reactive power compensation will also be required at the Nicolay substation and additional capacitor banks will be required at the Amaury, La Chaumière, Sottise and Wooton substations.

The proposed reactive power compensation will contribute towards minimising the reactive power flow along the transmission network and reducing power loss and voltage drop. The proposed additions will be progressively required depending on the individual substation’s load growth.

La Chaumière Substation

According to the Load Forecast, La Chaumière substation will be nearing its limits in terms of secured transformer capacity by 2022. In this respect, the substation will be upgraded to accommodate an additional 66 kV-to-22 kV transformer in anticipation of load growth in the western region.

Neotown Substation

The Neotown project at Les Salines in Port Louis is a new mixed-use land development having a declared load of around 70 MVA. To meet this load (demand), CEB is planning to construct a 66 kV-to-22 kV substation at Les Salines, which will be supplied by two 66 kV underground cables from the Fort Victoria Power Station. This development will necessitate the construction of a 66 kV substation at the Fort Victoria Power Station. However, the construction of the substation will depend on major milestones in the implementation of the Neotown Project.
6.3.7 Transmission Voltage Upgrade
A network simulation exercise has revealed that maintaining operation of the grid at the current 66 kV voltage level will not be problematic for the transmission of the upcoming 200 MW power generation over the period 2013-2022. This finding, however, holds only if the 200 MW generated power originate from at least two different power plants, each having a capacity not exceeding 100 MW.

Under such a scenario, by the end of the planning period, some of the CEB’s transmission lines will be reaching 50% loading under normal conditions and 100% loading under emergency conditions. To prevent overloading, planning to upgrade the transmission lines to 132 kV voltage level will start when loading condition has reached 40% under normal conditions. As per current load forecast, the planning exercise will, most likely, begin a few years before 2022.

In case the upcoming 200 MW power generation is centralised, the requirement to upgrade the interconnection facility (transmission lines, switchgears, power transformers, etc.) at 132 kV voltage level will be required by 2017.

Notwithstanding the above, it is recommended that all new and existing transmission lines, which would be required for the interconnection of future planned power plant(s) with either the Saint-Louis, Dumas, Amaury, Wooton or Ebène substations, be designed at voltage level of 132 kV. The transmission lines so designed will enable power transmission of the ultimate capacity of the future planned power plant(s).

6.3.8 Summary of the Impact on Existing, New and Future Substations
With respect to the above proposed transmission expansion projects, the loadings on existing, new and future substations are expected to evolve over the planning period. Table 6.1 below summarises the impact on these substations.

6.4 DISTRIBUTION NETWORK EXPANSION PLAN
Presently, the distribution network is supplied from sixteen substations purposely sited in specific locations over the island, as illustrated in Figure 6.6 on the next page. From each substation, feeders†, operating in radial configuration*, are extended outwards to supply customers within a delimited service area. The back-up security for each feeder is provided by a second feeder, either from the same or another substation.

The distribution network expansion plan is mainly guided by inputs from the spatial load forecast and construction of new substations as proposed in the transmission plan in Section 6.3.

For the purpose of this IEP, CEB has adopted a standard planning technique so as to delimit the region to be supplied by each substation. The approach to determine a service area boundary (delimitation of regions) is based on costs of feeders, electric network losses’ costs and service interruption exposure. The result of this exercise is shown in Figure 6.6 on the next page.

### TABLE 6.1: Impact of the Transmission Plan on Existing, New and Future Substations’ Loadings (MW)

<table>
<thead>
<tr>
<th>Year</th>
<th>Ebène</th>
<th>Highland Trianon†</th>
<th>Wooton</th>
<th>Henrietta</th>
<th>Case Noyale†</th>
<th>Combo</th>
<th>Belle Vue</th>
<th>Riche Terre†</th>
<th>Nicolay</th>
<th>Fort George</th>
<th>Fort Victoria†</th>
<th>Saint Louis</th>
<th>La Tour Koenig†</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>44</td>
<td>37</td>
<td>39</td>
<td>9</td>
<td>36</td>
<td>29</td>
<td>28</td>
<td>40</td>
<td>49</td>
<td>–</td>
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<tr>
<td>2013</td>
<td>45</td>
<td>39</td>
<td>41</td>
<td>13</td>
<td>36</td>
<td>30</td>
<td>35</td>
<td>40</td>
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<td>–</td>
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<tr>
<td>2014</td>
<td>46</td>
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<td>33</td>
<td>13</td>
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<tr>
<td>2015</td>
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<td>30</td>
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<td>2018</td>
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<td>46</td>
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<td>22</td>
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<tr>
<td>2019</td>
<td>36</td>
<td>36</td>
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<td>47</td>
<td>32</td>
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<tr>
<td>2020</td>
<td>37</td>
<td>37</td>
<td>31</td>
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<td>49</td>
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<td>2021</td>
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<tr>
<td>2022</td>
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<td>52</td>
<td>34</td>
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</table>

†Ultimate refers to the maximum designed generation capacity of a particular power plant.

*See glossary.
6.4.1 Distribution Network Expansion Plan 2013-2015
In response to the demand forecast, described in Chapter 4, and to ensure long-term reliable electricity supply in Mauritius, the following proposals were/are made, as part of the short-term distribution plan, in the context of this IEP.

Port Louis Area
The distribution network in the Port Louis area, with around sixty distribution feeders, is one of the densest networks in Mauritius. The new 11 kV-to-22 kV Fort Victoria substation in the Port Louis area will be fully operational in 2013.

With this new network setup, loads will be redistributed among the substations (Fort George, Nicolay, Fort Victoria and Saint-Louis substations) supplying the Port Louis area. The redistribution of power flow will help to further reduce distribution losses and ensure the reliability and quality of supply*.

In accordance with the previous IEP, to improve the network covering the Plaine Verte region, the conversion of the 6.6 kV feeders from Nicolay substation, which is currently under implementation, is expected to be completed by the end of 2014.

The North
For the northern area, the following will be required:

(1) One additional feeder from Belle Vue substation to supply major projects, which are under development, along the northern motorway.

(2) With the commissioning of the second 66 kV transmission line from Belle Vue substation to Sottise substation, the present 22 kV interconnector between Sottise and Belle Vue substations will no longer be required. The 22 kV interconnector will thus be split into two 22 kV feeders from Belle Vue and Sottise substations respectively. These two proposed feeders will be used to match the expected increase in load in the region of Pointe aux Cannoniers and Goodlands.

According to load forecast, the loading on Amaury substation will continue to increase and, consequently, the present transformer capacity at that substation will need to be upgraded to 2 x 36/45 MVA.

The South
It is expected that the areas in the vicinity of Plaisance and Le Chaland will undergo major development in the coming years. Therefore, a new 22 kV feeder from the Union Vale substation will be required to supply these regions in the short term.

The Southwest
As mentioned earlier, with the construction of a new 66 kV-to-22 kV substation at Case Noyale, a completely new set-up of distribution feeders, will be available to serve the regions of La Mivoie, Case Noyale, Le Morne and La Prairie.

The East
The eastern regions, mainly Bel Air, Trou d’Eau Douce, and Beau Champ, are presently supplied from the FUEL and Ferney substations. Following the commissioning of the Anahita 66 kV-to-22 kV substation, new 22 kV feeders from the substation are being erected to share the load in these regions. A redistribution of load will thus relieve the FUEL and Ferney substations. This configuration will enhance the network reliability and help in reducing distribution network losses.

The Centre
In line with the objective to reduce distribution line losses, the on-going conversion of 6.6 kV networks to 22 kV in the regions of Quatre Bornes, Rose Hill, Vacoas and Curepipe should continue.

To serve upcoming mixed-use land developments in the regions of Côte d’Or and Highlands, two new feeders from Wooton substation will need to be erected.

The West
With the rapid development in the West, one new feeder from La Chaumière substation will be required to serve upcoming loads at Médine and Flic en Flac. The new feeder will improve the power quality during abnormal network configuration.

6.4.2 Long-Term Distribution Network Expansion Plan (Year 2015 Onwards)
Below is a description of the long-term distribution network expansion plan for the period 2015-2022.

Port Louis Area
The previous IEP had earmarked the region of La Tour Koenig for the construction of a new substation. The

* See glossary
substation, which is currently under construction, will not only supply the targeted industrial zone of La Tour Koenig, but will also supply via new outgoing feeders the regions of Pointe aux Sables, Petite Rivière and Coromandel, among others. With this new set-up, the importance of the Coromandel switching station will be studied.

Upon full operationalization of the Fort Victoria substation, the importance of Line Barracks and La Poudrière switching stations in the electricity distribution network will need to be redefined.

In the long term, with load growth in the centre of Port Louis, either a third power transformer with new 22 kV outgoing feeders at Nicolay substation or a new substation at Chateau d’Eau will be required so as to ensure the ‘N minus 1’ security criterion.

The North
With the expected commissioning of the Riche Terre substation, part of the growing load in the northern areas will be catered for. The Riche Terre substation will supply some localities (Balaclava, Terre Rouge, Bois Marchand, Baie du Tombeau and Riche Terre) presently supplied by the Belle Vue, Nicolay, Fort George and Sottise substations. Consequently, these substations will be relieved.

The South
The feeders from the new proposed Airport substation will be configured to provide back-up for the Union Vale substation and to meet load growth in the region.

The Centre
Towards the end of the planning period, the Wooton substation, which serves the regions from Curepipe to Rose Belle, Phoenix and Providence, will no longer satisfy the ‘N minus 1’ criterion, in terms of power transformer capacity. Consequently, by the year 2020, a third 36/45 MVA power transformer will be required so as to cater for the normal load growth in the aforementioned regions.

6.4.3 Upgrading of Distribution Network
As part of its operational plan, CEB will continue to progressively replace its old wooden and circular concrete poles, especially those which have been in service for more than half a century. This on-going project is in line with the CEB’s goal to ensure reliability of supply.

In addition, to reduce hazards associated with the network, CEB will gradually replace bare 22 kV wires by insulated cables, wherever and whenever mandated, and continue the exercise of insulating LV lines so as to enhance safety and reliability.

6.5 GRID INTEGRATION OF RENEWABLE ENERGY (RE) SYSTEMS
In its Long Term Energy Strategy (LTES), Government has set the targets to promote renewable energy in the energy mix of Mauritius. Integration of renewable energy into the utility grid can either be at the transmission level or at the distribution level, depending on the capacity of the generation plant.

Large-scale variable renewable energy generation, such as Wind and Solar Farms, is connected to the transmission system. Medium- and Small-scale distributed generation are normally connected to the medium-voltage or low-voltage distribution systems respectively.

While the integration of firm renewable energy sources, such as ‘bagasse’, hydro and biomass, does not pose technical challenges or constraints, the time-varying nature of wind and solar power presents challenges with respect to system stability, security, operation and power quality. These challenges are of particular concern for a small-sized and insular power system, such as for the CEB, which is characterised by a small number of generating units, low spinning reserve and low system inertia.

6.5.1 System Constraints for Variable Renewable Energy (RE) Integration
Two main aspects, namely frequency and voltage, are considered for the integration of variable renewable energy, as discussed below.

Frequency Aspects
As per regulatory requirements, CEB has to maintain the supply frequency within ±0.75 Hz of the nominal value 50 Hz so as to ensure the safe and reliable operation of electrical equipment and appliances.

For planning purposes, CEB uses the limit of ±0.5 Hz for system frequency deviation to ensure system sta

1 ‘Firm renewable energy source’ in this context means constant power output from a renewable energy generation plant.

2 ‘Time-varying’ in this context means varying power output from a renewable energy generation plant over time.

See glossary
bility, security and the reliability of supply. The limit of ±0.5 Hz caters for the condition, whereby a generator trip* coincides with the minimum system frequency, caused by a sudden drop in time-varying renewable energy generation, to help in minimising the extent of load shedding and the risk of total system breakdown.

Under normal operating condition, by ensuring system frequency within the stated limits, power generation safely matches system demand. The frequency band of ±0.5 Hz about the nominal value of 50 Hz enables safe system control during the mismatch between instantaneous demand and supply. The mismatch is due to the inherent delays of the generating units to follow the varying load demand.

During system operation with no time-varying renewable energy source, the frequency deviation is around ±0.1 Hz about the nominal value. With the integration of time-varying renewable energy, this frequency deviation inevitably increases. It is even more pronounced during the low demand conditions, when the system inertia is low and the amount of spinning reserve is less. The frequency deviation limits of ±0.5 Hz is thus used to determine the maximum capacity of time-varying renewable energy which can be safely integrated in the CEB’s system, as shown in Figure 6.7 below.

In Figure 6.7 below, $X_1$ and $X_2$ represent the maximum level of variable renewable energy (MW) that can be safely integrated in the Mauritius Power System during minimum and maximum load (demand) conditions respectively, while maintaining the system frequency within ±0.5 Hz of the nominal value of 50 Hz. $X_1$ and $X_2$ are determined by the level of demand and the amount and quality (response time of the generation system) of spinning reserve.

Generally, in our context, the minimum demand conditions occur between midnight and six o’clock in the morning, when solar energy source is not available. On the other hand, the maximum demand conditions occur during the daytime. Usually, during the daytime period both solar and wind power can be tapped off. Given these specific conditions, it is therefore possible to optimise the integration of time-varying renewable energy through a mix of wind and solar power technologies.

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**FIGURE 6.7: Impact of RE Integration on the System Frequency**

<table>
<thead>
<tr>
<th>System frequency (Hz)</th>
<th>Maximum system frequency – Low demand conditions</th>
<th>Maximum system frequency – High demand conditions</th>
<th>Minimum system frequency – High demand conditions</th>
<th>Minimum system frequency – Low demand conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>50.8</td>
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<tr>
<td>50.6</td>
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<td>49.2</td>
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</tbody>
</table>

* See glossary
However, due to the intermittent nature of these RE sources, the full capacity of the RE technologies can seldom be optimised. One possible solution to the inherent disturbances of the variable RE is the use of energy storage system, as far as it is economical.

In addition to the above, it is possible to further integrate time-varying renewable energy while maintaining the system frequency within the required limits, if the amount of spinning reserve is increased. Although it is technically possible to do so, such an option is not usually financially viable. Increasing the spinning reserve beyond 10% to 15% will result into operating the generating units at lower efficiencies, hence, increasing their cost of operations.

Voltage Aspects
As per regulatory requirements, CEB needs to maintain a voltage of 230 V ± 6% at customers’ terminals. Renewable energy-based generators are operated in the power factor control mode and their interconnections to Low-Voltage (LV) network or Medium-Voltage (MV) network inevitably lead to rise in voltage, as shown in Figure 6.8 below.

For operating voltage requirements:
- Maximum RE Farm capacity that can be interconnected to a low-voltage feeder is 50 kW. This type of RE installation falls under the Small-Scale Distributed Generation (SSDG) Scheme.
- Depending on the location and specific feeder’s absorption capacity, maximum RE Farm capacity that can be interconnected to existing medium-voltage (22 kV) feeders is 2 to 4 MW. Connection of such RE installation requires a prior detailed system study under the Medium-Scale Distributed Generation (MSDG) Scheme.
- Depending on the technology and the substation’s absorption capacity, RE Farms of capacity above 4 MW up to 10 MW can be connected through dedicated 22 kV line to the CEB’s 22 kV busbar.

![FIGURE 6.8: Voltage Profile for different level of Distributed Generation Integration](image)

* See glossary
• RE Farms of capacity more than 10 MW have to be connected to the CEB’s 66 kV substation busbar system.

In addition to the voltage rise, the variable power output from the RE farms leads to fluctuation in voltage along the low-voltage and medium-voltage feeders. As a mitigation measure, advanced automatic voltage control will be required for power transformers and capacitor\textsuperscript{*} banks in substations.

The interconnections of the variable renewable energy installations of different capacity are illustrated in Figure 6.9 hereunder.

6.5.2 International General Guidelines on Optimal Variable RE Integration

According to some experts\textsuperscript{1} in the field of RE, the maximum amount of variable renewable energy that can be safely integrated in an insular power system is about 15% to 20% of the prevailing load demand. This level of RE integration, however, is intrinsically dependent on the availability of fast-responding conventional generating engines, which is critical so as to regulate the system frequency. Regulating the power system frequency is the most fundamental requirement to ensure reliable and quality electricity supply. To increase level of RE integration above the threshold, as per the experts, installation of battery energy storage system (BESS) becomes inevitable.

\textsuperscript{1}Parsons Brinckerhoff Africa (PB Power) in the Wind Integration Study for Mauritius and International Renewable Energy Agency (IRENA).

\textsuperscript{*} See Glossary.
Given the above and in the absence of reliable and sufficient information, while taking into account upcoming RE projects in Mauritius, it is difficult at this stage to determine the optimal level of RE technology that can be integrated in the local power system. Therefore, to facilitate the integration of future RE projects, CEB upstream will perform technical system studies so as to assess their feasibilities and to determine their interconnections’ requirements.

6.5.3 System Enhancement to Allow Higher Integration of Renewable Energy (RE)
Given the current state-of-affairs, CEB’s actual power system will not be able to accommodate the targeted amount of RE capacity as set in the Government’s LTES 2009-2025. However, to enable higher penetration of renewable energy sources, CEB, as part of its research work, shall investigate on the possibility to:

- Enhance the system frequency regulation via modernisation of the governing system*
- Implement Automatic Voltage Control* at substation levels;
- Reduce power output variability by encouraging geographical dispersion of renewable power plants;
- Curtail power output from renewable energy sources during periods of low system demand;
- Use weather simulation software to determine the day-ahead generation from RE Farms to assist in dispatching, hence ensuring a better quality of supply; and
- Use large-scale battery energy storage system to help in ensuring stable power supply.

Recognising the improvement that the GIS can bring to its planning and forecasting activities, CEB has already initiated the process of studying the implementation of the GIS. Upon successful implementation of the GIS, System Planning simulation software will be interfaced with the proposed GIS system so as to enable the conduct of detailed technical studies of the distribution system. In the same vein, CEB will also use the GIS for asset management. The result would be a geographical database of each component of its electric system, IT system and power plants, among others.

6.6 MODERNIZING THE NATIONAL ELECTRICITY NETWORK
In its strategic quest to modernise the national electricity network, CEB has already kick-started discussions on a few key elements of today’s high-tech power system. These include: the building of a Geographical Information System (GIS) of the electric network; developing a transmission and medium-voltage grid code; and laying the foundation (roadmap) for a future smart-grid.

6.6.1 Geographical Information System
The Geographical Information System (GIS) – a computer-based system – will store virtual information relating to the physical aspects of the CEB’s network. It will permit the viewing, understanding, questioning, interpreting and visualizing of data in many ways that reveal relationships, patterns and trends in the form of maps, reports and charts. These capabilities of the GIS will assist in load forecasting and transmission and distribution planning activities, as illustrated in Figure 6.10 below.

**FIGURE 6.10: Geographical Information System Interaction**

![GIS Information System Interaction Diagram]

* See glossary
ration projects, CEB is finding it necessary to develop appropriate Grid Codes. Likewise, a Grid Code for the low-voltage network was developed in 2010 for the SSDG project.

A transmission Grid Code will be specifically relevant for large-scale Wind and Solar Farms that will be connected to the transmission network. For example, based on the network operating characteristics, it will establish the responsibilities of large-scale Wind and Solar Farms to support the grid during, and after, disturbances. The MV distribution network Grid Code on the other hand will cater for issues that arise in the areas of protection and operation with the connection of distributed generation. CEB will start the development of a Transmission and MV Distribution Grid Code in 2013.

6.6.3 Smart Grid Technology
First introduced in the late 1990s, the term ‘Smart Grid’ in the power system sector describes a new concept of interactions between the stakeholders of an electric utility. In fact, ‘Smart Grid’ means adding IT intelligence in the network so as to allow more efficient and accurate grid management.

The known benefits of Smart Grid are numerous: peak load curtailment; demand response; automatic call centre; remote metering; automatic response upon fault detection and higher capability to integrate diverse renewable energy sources, amongst others.

With its on-going projects, such as the deployment of smart meters* (elaborated in Section 10.3) which is one of the main components to build a smart grid, CEB is already attempting to advance on this smart journey, but shall do so cautiously.

In fact, in accordance with the Government’s Energy Strategy Action Plan 2011-2025, supports of experts to conduct research and studies are being envisaged so as to enable the CEB, in the coming years, to confirm the feasibility of building the ‘Mauritius Smart Grid’.

However, it is to be recognized that development of most Smart Grids around the world is still at their embryonic stages.

Generally, the implementation of such a grid is planned on an incremental basis spanning over several years. For instance, the South Korean’s roadmap for the implementation of a national smart grid has been phased over 20 years. Therefore, it goes without saying that the building of the ‘Mauritius Smart Grid’ will not be for tomorrow, given our limited resources.

1More information on the South Korean roadmap can be obtained at www.smartgrid.or.kr/10eng4-1.php
* See glossary.
Is Sustainable Power System Development a Concern?

Green isn’t a colour, it's a way of life. Likewise, power system development is not made in vacuum. Today, the challenge is beyond meeting demand. Satisfying demand needs to be made with endless care to the environment.

CEB, by adhering to this goal, will continue to plan the national power systems with due diligence!
In the IEP 2003-2012, CEB set the ground-work for achieving environmental sustainability\textsuperscript{*} in electricity activities, in both Mauritius and Rodrigues, through the reduction of Greenhouse Gases (GHGs)\textsuperscript{*} emissions and environment protection. In this respect, over the life of the last IEP, CEB has made some good progress, such as promoting renewable energy technologies, conducting demand-side management (DSM) activities and retiring less efficient generating units.

7.1 OVERVIEW OF CEB’S CONCERNS FOR THE ENVIRONMENT

Based on the latest generation planning outlook, the future energy mix in the electricity generation, in both Mauritius and Rodrigues, will still be largely dominated by fossil fuels. The environmental impact of the electricity generation activities will thus be as significant as it is today.

Recognizing its responsibility and being bound to protect the environment as per standing regulations, CEB is committed to promote further the sense of Environment Stewardship\textsuperscript{*}. This will contribute to ensure that all its activities are carried out in an environmentally friendly and sound manner. In other words, while fulfilling its strategic role, CEB will steadfastly ensure due diligence and compliance with existing environmental legislation.

CEB currently produces most of its electricity from its four thermal power stations, namely Saint-Louis, Fort Victoria, Fort George using HFO, and Nicolay Power Station using kerosene as fuel. Some of its generating units, such as the old Pielstick diesel engines at the Saint-Louis Power Station, have already reached the end of their lives and are becoming less and less efficient. These engines have been already earmarked for progressive retirement at the earliest possible date. The retirement of these old units will contribute to lower emissions of noxious gases and reduce vibrations and noise levels.

In pursuing its environmental stewardship and strategic roles, CEB has recently invested in 90 MW of new generation diesel engines in replacement of the old Mirrlees and FIAT units at the Fort Victoria Power Station. This high investment is contributing significantly to improving the overall environmental impact of the power station on the immediate surroundings. It is worth mentioning that during the last Environmental Impact Assessment (EIA)\textsuperscript{*} exercise, the modelling of emissions was performed in view of future possible generation expansion at the site. Based on the current generation technology and prevailing environmental standards, the EIA exercise has ruled out any further addition at this location.

CEB’s current generation from renewable energy is from its nine hydro power stations, which contribute about 4% of the total electricity generation in Mauritius. To further exploit this clean energy source, CEB intends to promote the installations of mini- and micro-hydro power plants. Hydro power stations generally have low environmental operation risks but can carry a few serious ecological risks. For example, the construction of large hydro power plants, in most cases, calls for the flooding of large portion of protected flora for water storage and dam building.

With regard to the development in renewable energies, besides hydro, CEB has already implemented two small-sized Wind Farms in Rodrigues, and it has launched the SSDG Project mainly for the installation of solar PV. In Mauritius, some 77 GWh of wind energy is expected from the 29.4 MW Curepipe Point (Plaine Sophie) and the 9.0 MW Plaine des Roches (Aerowatt) Wind Farms. An additional 16 GWh is also expected from the distributed 10 MW Solar PV Farm project. Despite requiring huge investment of about Rs 4 billion, these renewable energy projects will reduce only around 7% of our national CO\textsubscript{2} emissions. Hence, other mitigating actions are also being envisaged.

\textsuperscript{*} See glossary
As coal is becoming an integral element in our energy mix, there is more concern raised about its impact on the environment. In addressing this matter, CEB will strictly require that any new coal power plant adopts at least pulverized-coal technology, or better. In this respect, CEB hopes to reduce CO₂ emissions by at least 20%. Otherwise, such an amount of reduction in emissions would not be realized if power expansion continued with the spreader-stocker technology, similar to that of existing IPPs.

In order to reduce future levels of emissions from coal and HFO, CEB has initiated studies to investigate the potential use of Liquefied Natural Gas (LNG) for electricity generation in the years to come. LNG is relatively cleaner compared to coal and HFO. However, some factors, such as the high cost of the infrastructure and the risks associated with storage and transport of LNG, will need to be considered before introducing this new technology in Mauritius.

To meet the goals of sustainable development in the Energy Sector, while adhering to future environmental norms, CEB will strengthen its commitment to a better environment stewardship in all its activities. Efforts will be made to ensure that the CEB’s operations comply with international environmental standards, such as the ISO 14001. This commitment implies strengthening actions in the field of environmental monitoring, heat loss recovery and waste management.

7.2 ENVIRONMENTAL LEGISLATION APPLICABLE TO THE ELECTRICITY SECTOR

The Environment Protection Act (EPA) 2002 provides the legislative and administrative framework for the protection and preservation of the environment. Power generation activities have to abide by all the provisions of the EPA.

The key elements of the Act include the requirements for EIA and the formulation of National Environmental Standards for air, noise, effluent discharge, hazardous waste, etc. The EPA 2002 also promotes environmental stewardship, greater transparency and public participation in EIA process.

7.3 ENVIRONMENTAL IMPACT ASSESSMENT (EIA)

The preparation and submission of EIA report is mandatory for power generation and transmission activities under the EPA 2002. EIA report provides a mechanism to inform the Ministry of Environment and Sustainable Development (MOESD) of any proposed project, its potential impacts and how these environmental impacts would be addressed by the project developer, prior to securing the EIA licence.

According to the proposed generation plan in this IEP, there are several EIAs that will be required for the forthcoming years, as highlighted in the following sub-sections.

7.3.1 Environmental Impact Assessment in Connection with Future Power Projects

In connection with the power system development, EIA licences will need to be obtained for the following projects:

- Re-development of the Saint-Louis Power Station
- New Coal Power Plant
- New Hydro Power Projects
- New Wind Farms

Re-development of the Saint-Louis Power Station
In connection with the re-development of the Saint-Louis Power Station, an EIA report was prepared and submitted in 2012. The re-development of the Saint-Louis Power Station will bring a significant improvement in the environmental impacts of the power station on the neighbouring residential area. The project is scheduled to be implemented in a progressive manner so as to phase out the old Pielstick engines.

New Coal Power Plant
As per existing legislations, the construction/operation of a coal power plant is conditional on obtaining an EIA licence in due form. Therefore, it is imperative that project promoters secure the necessary EIA licence(s) and clearances prior to the start of the construction/operation of such a power plant.

New Hydro Power Projects
One of the objectives of Government is to promote new micro- and mini-hydro power plants around Mauritius. In line with this objective, CEB has already initiated a feasibility study to identify potential sites for the development of micro- and mini-hydro power projects.

New Wind Farms
CEB is currently investigating the possibility of setting up wind farm projects in Mauritius. In this regard, studies are being undertaken internally to identify potential sites. Any future wind farm project, upstream, will require the submission of an EIA report, prior to its implementation.
### 7.3.2 Activities to Secure an EIA Licence

Obtaining the EIA licence is mandatory under the current law for any new power generation project. The most important step in securing an EIA licence is to prepare the EIA report and submit same to the MOESD for consideration. The guidelines for preparing an EIA are as follows:

- **Selection of an EIA Consultant:** Small-scale projects can be implemented by constituting a team within the CEB, while for large-scale projects and where advanced assessment techniques are required, consultancy services are necessary. Selection of consultant(s) is usually done through tendering process.

- **Preparation of an EIA Report:** Following a comprehensive study of the project, the EIA team/consultant will prepare an EIA report for submission to the MOESD for consideration. The EIA study involves a compulsory public consultation meeting, whereby all stakeholders are informed of the project and are provided with the opportunity to make representations.

- **Review of the EIA document by the MOESD:** The EIA committee of the MOESD will then review the EIA report and decide on whether an EIA licence can be granted or not. If required, the EIA consultant and the project owner will have to provide additional information and/or clarification.

- **Issuance of the EIA licence:** Within a time-line of 90 days, from the date of submission of the EIA report, the MOESD will consider whether the EIA licence can be granted or not. In case an EIA is not granted by the MOESD, the promoter can have recourse to the *Environment and Land Use Appeal Tribunal (ELUAT)* for review, as per the current law.

Table 7.1 below gives brief information on projects which had required EIAs.

### 7.3.3 EIA in Connection with the Electricity Network Expansion

Within the scope of the EPA 2002, new high-voltage transmission line mounted on towers require an EIA licence. EIA report(s) for the high-voltage transmission lines must be prepared by an EIA consultant. Other minor transmission and distribution lines require only clearances from relevant authorities and stakeholders.

Very often, development of new transmission and distribution lines are regarded as infringements on

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**TABLE 7.1: Summary of EIA Conducted at the CEB**

<table>
<thead>
<tr>
<th>DATE OF SUBMISSION OF THE EIA REPORT</th>
<th>PROJECT</th>
<th>STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>Re-development of Saint-Louis Power Station</td>
<td>Project completed in the year 2006 with the installation of three diesel engines of capacity 13.8 MW each.</td>
</tr>
<tr>
<td>2005</td>
<td>Re-development of Fort Victoria Power Station</td>
<td>First phase of the project completed in September 2010 with the installation of two diesel engines of 15 MW each. Second phase of the project completed in July 2012 with the installation of four diesel engines of 15 MW each.</td>
</tr>
<tr>
<td>July 2006</td>
<td>Pointe Monnier Power Station Phase 2 and Phase 3</td>
<td>The Phase 2 of the extension consisting of the commissioning of one 2.5 MW generating unit was completed in December 2012.</td>
</tr>
<tr>
<td>July 2007</td>
<td>Construction of a Wind Farm at Grenade in Rodrigues</td>
<td>Project completed in 2010 with the installation of four 275 kW Wind Turbine Generators (WTGs).</td>
</tr>
<tr>
<td>August 2009</td>
<td>Construction of a mini-hydro power plant at Midlands Dam</td>
<td>EIA licence was obtained in 2010. The commissioning of the plant has been scheduled for early 2013.</td>
</tr>
<tr>
<td>July 2012</td>
<td>Re-development of the Saint-Louis Power Station</td>
<td>EIA report has been submitted to the MOESD. The issuing of the licence is awaited to enable further development of the project.</td>
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* See glossary
party properties (right-of-way issues), especially in the urban regions and in Environment Sensitive Areas (ESAs). ESAs are identified in the National Physical Development Plan (NPDP)* of the Government of Mauritius.

To avoid potential encroachment in this respect, CEB is planning to map its entire transmission network on a GIS. The GIS will also take into consideration the mapping of the ESAs into the transmission network so as to ensure that expansion of the transmission network does not adversely impact on the ESAs. Whenever and wherever possible, CEB will also consider the possibility of laying underground transmission lines in order to avoid potential negative impact on the environment.

7.4 ENVIRONMENT MONITORING AT THE CEB
CEB, as a responsible organisation, endeavours to comply not only with the EPA but also with the many regulations, which are directly and indirectly related to the EPA. By complying with the EPA and its regulations, CEB, in relation to its power generation activities, has to submit data regularly on air quality and noise levels to the MOESD and also reports on the overall environmental performance of its power stations.

In its commitment to ensure effective environment monitoring, CEB has equipped the new generation units, recently installed at the Saint-Louis Power Station and Fort Victoria Power Station, with Continuous Emissions Monitoring Systems (CEMS)*. The CEMS continuously monitors the levels of pollutants emitted from the power stations’ stacks.

Furthermore, a hand-held flue gas analyser* is regularly used to measure the concentration of air emissions from CEB’s thermal power plants. Where necessary, CEB resorts to third party’s services in order to verify the levels of emissions. In addition to the above, two noise-level meters are used to conduct noise surveys and ad-hoc monitoring of power plants.

Results of analyses indicate that emissions from CEB’s power stations are within the local standards. To meet environmental standards, among other things, CEB has set the condition that the sulphur content in the HFO, used in the power stations, be strictly limited to 3%. This measure ensures a reasonable level of sulphur dioxide emissions from the current generation technologies.

There is also a need to ensure sufficient dilution of sulphur dioxide, emitted by the thermal power plants, in the atmosphere. For this, stack of generating unit is required to be of appropriate height, as determined by air dispersion simulation models*. In line with recommendations of consultant(s), stacks of new generating units installed were built in order to ensure sufficient dilution of sulphur dioxide.

Noise level is an important parameter for compliance with environmental standards. When new power generation units are being installed, noise mitigation measures are taken into account. This is usually done by including acoustic norms in the design of engines’ rooms. CEB has made it mandatory that noise mitigation be undertaken when a new engine is installed.

As per measurements, the noise levels in CEB’s power plants generally comply with environmental standards. However, it is to be recognized that with age, at times, the noise emitted from old engines, such as the Pielstick engines at the Saint-Louis Power Station, is outside their limits. As a priority in the generation plan, CEB will retire these engines in the coming years so as to also ensure environmental compliance.

7.5 CEB’s COMMITMENT TO CLIMATE CHANGE
The Government of Mauritius has signed the UNFCCC (United Nations Framework Convention on Climate Change) convention and, hence, must adhere to the guidelines of the convention. Power generation is a major source of GHGs representing about 40% of the national emissions.

CEB has the obligation to compute and submit the national GHG emissions for electricity generation on an annual basis. This activity is done in collaboration with other stakeholders, and also in line with the IPCC (Intergovernmental Panel on Climate Change) guidelines. To enhance its measurement accuracy, CEB is already engaged in conducting in-house research activities to determine local emission factors for its power generation.

7.5.1 The Climate Change Act and its Impact on Electricity Generation
The Government of Mauritius will soon enact the Climate Change Act to regulate many forthcoming projects so as to mitigate their impact on Climate
This Act will set up the institutional and legislative framework to tackle Climate Change by promoting clean technologies with low-carbon footprint.

With regard to the above, CEB has already considered, in anticipation, some renewable energy projects in its current generation plan, with special focus on GHG emissions. Along with the Energy Efficiency Management Office (EEMO), CEB will also forge ahead with its Demand-Side Management initiatives through sensitization campaigns to encourage saving and judicious use of electricity.

7.5.2 Future Emission Compliance
Over the next decade, in the context of a rapid dynamic economic environment, Mauritius will need to enforce its power plant emission regulations. In addition to CO2 emissions, SO2 and NOx are also considered as sources of air pollution.

Within the current EPA regulations, the Government is considering revising downward the sulphur content in HFO, diesel and coal. Regulations on the Air Emission Standard to limit air pollution emissions are also under review. The new emission standard will come into force in 2013, with detailed guidelines for measurement methods, monitoring frequency and the modelling of air emissions and stacks’ heights.

7.5.3 Formulation of the Grid Emission Factor (GEF)*
The Grid Emission Factor (GEF) is a measure of the GHG emission per unit of electricity produced. It is basically the amount of CO2 emission per kWh of electricity generated expressed in kg/kWh. The GEF is usually computed annually and depends on the energy mix of the country.

The MOESD has proposed to set up a methodology to calculate the GEF annually. As a main stakeholder, CEB has the responsibility to calculate and update the GEF. In this respect, a tool for the GEF calculation will be developed in collaboration with the MOESD and other stakeholders.

7.5.4 Greenhouse Gas (GHG)* Emission Scenarios
The future generation mix has been outlined in Government’s LTES 2009-2025. Figure 7.1 (a, b), which follows, show the generation mix and the resultant GHG emissions under different scenarios.

As shown in the figure, by increasing renewable energy potential, there will be a significant decrease in the GHG emissions.

As indicated in Figure 7.1(b) on the next page, by implementing in combination all renewable energy projects, the level of CO2 emissions will not exceed 2500 Gigagrams.

FIGURE 7.1 (a): Energy Mix Evolution 2000-2040
7.6 ENVIRONMENT ACTION PLAN
Managing the intricacies involved in carrying out power generation and transmission activities, while complying with environmental legislations, necessitates reliable, accurate and readily available information and a structured approach to managing environmental impacts. To meet these objectives, as elaborated in the following sub-sections, CEB has prepared an environment related action-plan, which will be operationalized shortly.

7.6.1 Implementation of an Environment Management System (EMS)
Power generation activities have a profound effect on our environment; hence, it is essential to set up a mechanism to ensure that the CEB is taking all necessary measures to mitigate and control environmental impacts. In this respect, CEB will build an EMS, which is a structured and organized approach to managing environmental impacts.

Advantages of EMS:
- It leads to consistent and comprehensive environmental management.
- It provides standard procedures and mechanisms designed to support continual improvement.
- It provides a framework for an organization to meet its environmental goals and objectives.
- It instils confidence in addressing all environmental issues.
- It is flexible and adaptable.
- It encourages prevention of pollution.

Implementing an EMS will: enhance legal compliance; increase employee environmental awareness; improve operating efficiencies; improve public/stakeholder perception and promote fundamental understanding of the root causes of any legal non-compliance incident.

EMS has been designed to encourage organisations to adhere to environmental stewardship through a concerted approach, by taking into account all the environment aspects and the impact of activities.

The internationally accepted EMS standard, ISO 14001, will be adopted by the CEB and requirements for the accreditation will be prepared for further implementation, if the need arises. So far in Mauritius, the ISO 14001 is regarded as a voluntary standard.
However, at international level, especially in developed countries, the ISO 14001 has become a mandatory tool in environmental assessment and control.

ISO 14001 will definitely improve the environmental image of the CEB and foster sustainability in electricity generation, while showing that the CEB cares for the environment. CEB is already engaged in most of the groundwork activities leading to the ISO 14001. These will be further consolidated with the setting up of a comprehensive EMS.

**Short-Term Objectives of the EMS are:**

1. **To Implement an Environmental Policy at the CEB**
   An Environmental Policy Statement (EPS) sets out the goals and principles, which guide an organisation in putting its environmental commitments into practice. It is a declaration of commitment to the environment and to continual improvement of environmental practices. The CEB’s EPS will provide a unifying vision of environmental principles that will guide the actions of management and employees. It spells out to suppliers, customers, shareholders, directors and the community at large where the Company stands with regard to environmental matters.

2. **To Prepare an Environment Manual (EM) for the CEB**
   One of the greatest benefits of an EM is that everything pertaining to environmental management is recorded and can easily be verified. The proposed EM will outline the requirements of applicable laws and how the CEB plans to meet them. It will help to ensure that environmental issues are properly and consistently addressed within the CEB.

3. **To Prepare an Annual Environment Improvement Plan (EIP)**
   There are many activities and incentives that can promote environmental awareness and care. The CEB will prepare an annual EIP, detailing activities that will be undertaken during a year with the aim of strengthening its employees’ concerns for the protection of the environment.

**Long-Term Objective of the EMS**

The long-term objective of the EMS will be to seek accreditation to ISO 14001. ISO 14001 is a formal recognition that a particular company has adopted an EMS. CEB will seek the help of a consultant to set up its EMS.

**7.6.2 Preparation of an EIA Manual**

CEB will prepare documented guidelines on Principles of EIA Best Practice that will provide widely-agreed guidance to all departments at the CEB, which are involved in applying EIA processes. The Principles of EIA Best Practice are designed primarily for reference and are used by those professionally involved in the EIA. The aim is to promote an effective practice of EIA, which is consistent with the institutional and process arrangements that are in force in Mauritius.

**7.6.3 Environmental Reporting Programme (ERP) at the CEB**

The EPA 2002 stipulates that data on environmental parameters be submitted on a regular basis. CEB will consolidate its ERP to ensure that the data are being compiled and reported accordingly.

It is also proposed to prepare a Waste Management Policy (WMP) that will further enhance the preparation of waste audit and the integration of waste management principles in the proposed EMS for the CEB. The WMP will look into the waste disposal aspects and the re-use and recovery of wastes.

**CEB’s ERP will include the following:**

- **Environment Management and Monitoring Plan (EMMP)**
  The EMMP will form part of the formal annual submission of the environmental performance of the power generation activities of the CEB to the MOESD.

- **Industrial Waste Audit**
  The Industrial Waste Audit Act was enacted in 2006. This law made it mandatory for waste generating companies to submit regularly the amount of wastes generated, whilst explaining how they are handled and disposed of. CEB will continue to submit its waste audit reports and will also prepare a WMP to foster the concept of reduction and re-use of wastes in all its operations.

- **Environment Database for Power Generation Activities**
  In order to report on the environmental impacts of its power stations, CEB must update its database on the environmental parameters. The regular monitoring proposed in this IEP will generate large amount of data, which must be subject to a QA/QC system*

* See glossary
of data management. This will ensure confidence in, and commitment to, the ERP. The following will be necessary for future operations:

**Fuel quality and Air Emissions**
In order to adhere to some environment regulations, it is important to use fuel of good quality, with special regard to the sulphur content. In fact, the fuel quality dictates the quality of the flue gas emission and the measures that need to be taken to mitigate its adverse environmental effect. The fuel quantity is equally important in the preparation of the GHG forecast for the country.

Stack emissions from thermal power stations are major source of air pollution in Mauritius. An estimated 40% of the GHGs is mainly contributed by coal and heavy fuel oil used to produce electricity. The recent generation units of the CEB are equipped with **Continuous Emission Monitoring System (CEMS)***. The data produced gives an indication of the amount of polluting gases that are emitted from the stacks.

The commitment of the CEB will be to monitor the emission from its thermal power plants and ensure that they are complying with the Air Quality guidelines. CEB will also contract out the analyses of Ambient Air Quality in regions, where power generation plants are located, as part of its obligations of the forthcoming Air Quality Regulations.

**Noise**
Noise is a major problem associated with power generation activities. It has a direct impact on the people living in the surrounding areas of power plants. CEB will need to collect reliable measurements of noise levels in its power plants on a continuous basis.

**Water and Effluent Quality Measurement Data**
The quantity of Waste Water Discharge from thermal power plants is an important parameter to be monitored, if waste waters are discharged into our rivers, stream and the sea.

As a matter of fact, CEB thermal power stations consume a lot of water for cooling purposes. Hence, a continuous monitoring plan will be set up to ensure that these data are being recorded effectively.

**Modelling Tools**
Nowadays, there is a lot of modelling software that can be used to study and predict the impact of electricity generation on the environment.

CEB will use the software listed in Table 7.2 below, amongst others, to compute GHG emissions, calculate GEF, predict pollutant levels including air emission and noise levels and calculate emissions’ reduction of renewable energy technologies.

<table>
<thead>
<tr>
<th><strong>TABLE 7.2: Simulation Software</strong></th>
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<tbody>
<tr>
<td><strong>Software</strong></td>
</tr>
<tr>
<td>RETScreen</td>
</tr>
<tr>
<td>Homer</td>
</tr>
<tr>
<td>Air Quality Model</td>
</tr>
<tr>
<td>Message</td>
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* See glossary
How will the Rodrigues’ Power System Evolve?

The development of the Rodrigues’ power system is not an exception. Modernising the system will call for ingenuity. There is a need to ‘think outside the barrel’. Diversifying the energy sources and adopting a sustainable power system development approach are plausible answers.

CEB, in this quest, will explore all possible avenues!
Electricity services delivery of Rodrigues' branch, as part of the CEB’s assets portfolio, has been, and is still, relatively costly. So far, CEB’s investments in Rodrigues have not been optimal in terms of financing the cost of operations. Due to this serious concern, while formulating this IEP, CEB has paid special attention to its Rodrigues' activities.

Unlike the consistent growth in electricity demand in Mauritius, the demand growth in Rodrigues, during the past five years, has been relatively slow. In fact, despite frequent announcements made by the local authorities regarding infrastructural developments on the island, a more or less stalemate condition has been observed. It is felt that this situation may even persist in the near future, if there are no major improvements of the local economy.

On the one hand, due to the sluggishness of the economy, CEB has not been, and is not, able to benefit from any potential economies of scale, neither in the electricity production nor in the electricity transport activities. This observation is confirmed by the lower system load factor of about 60% in Rodrigues, compared to approximately 70% in Mauritius. On the other hand, the mounting cost of operations, associated with the isolated nature of the Rodrigues’ electric system, makes the financial situation of CEB’s undertakings in Rodrigues extremely difficult.

However, it is recognised that there exist prospects for improvements. The Budget Speech 2013, recently delivered by the island’s Chief Commissioner, explicitly goes in this direction. Section 8.1 below provides an overview of the upcoming social and infrastructural projects in Rodrigues, which most likely will influence the local electricity demand.

The inferences made in the discussion below, regarding the evolution in the electricity demand in Rodrigues, were based on information sourced and interpreted from available documents, released lately by the Rodrigues Regional Assembly (RRA).

### 8.1 EXPECTED CHANGES IN THE SOCIAL AND ECONOMIC ENVIRONMENT

Alongside its intrinsic dependence on Mauritius, as per general consensus, Rodrigues internally requires a revamping of its economic activities with the hope of boosting up its economic growth. It is indeed with this specific objective that the RRA has proposed, as part of its Budget 2013, the following developmental projects. These projects will most likely impact on the medium- and the long-term electricity demand in Rodrigues.

#### Airport Development

The authorities in Rodrigues have for some time been contemplating the extension of the current 1280 metres-long runway at Sir Gaëtan Duval Airport. It is argued that this development will enable the landing of larger airplanes, which, in turn, will:

- promote regional flights in Rodrigues;
- attract more tourists and encourage many of the prospective promoters to invest in their hotel development projects; and
- facilitate the mobility of people and resources to further promote economic development of Rodrigues.

In the Budget 2013, the RRA has therefore proposed to accelerate the process for the extension of the airport infrastructure. With this perspective, it is reasonable to assume that the development of the airport will, as a catalyst, create new demand for electricity supply.

#### Developments in Sea Ports

As mentioned in the Budget Speech 2013, some developments in sea-port services are expected in the coming years; these will include the construction of a new port at Pointe L’Herbe and a Marina at Baie
aux Huitres. These projects, by default, will imply new demand for electricity.

**Water Reforms**

According to the local authorities, water supply deficiency has been a long-outstanding problem in Rodrigues. The local authorities expect that the Central Government will continue to support the development of the Water Sector in Rodrigues. Amongst the water development projects, the installation of new desalination plants in 2013 will be of interest to the CEB.

Contrary to a former desalination project, where two 1500 m$^3$ desalination plants would have been constructed, it is being planned for 2013 to install two desalination plants of only 500 m$^3$ capacity each, which most likely will require the CEB to provide electricity supply for their operations.

CEB foresees that the enhancement of the water system in Rodrigues will have a multiplying effect on the island’s electricity consumption. With a higher volume of water availability, there may be a heightened interest in water-dependent electric appliances, such as washing machines and water pumps, as well as the setting up of new water-related industrial activities. These kinds of development will surely influence the electricity demand in Rodrigues.

**Communications – Fibre Optic Cable to enhance ICT Development**

By nature, Rodrigues is remotely located. It is believed that its remoteness, however, can be eliminated through rapid communication and connectivity. In this respect, some developments were initiated recently; for example, the construction of an ICT Academy at Camp du Roi, which is considered as a landmark achievement in the ICT Sector in Rodrigues. By itself, this project will add to the current electricity demand, as it will shortly start operation.

More importantly, it is expected that the implementation of the Fibre Optic Cable project, which was initiated in 2010 by the Ministry of Information Technology, will create new opportunities, such as attracting investments and creating employment in the field of ICT (Call Centres, Business Process Outsourcing, Disaster Recovery Centres, etc.). These developments, by their very nature, are dependent on electricity. Hence, it is reasonable to assume that demand for electricity, especially in the Commercial Sector, will tend to increase in the near future.

**Social Development Programmes**

As announced in the Budget Speech 2013, Government will construct three hundred low-cost houses soon. Construction of new houses means additional demand for electricity supply. It seems also that social housing development will be a recurrent concern for the local authorities.

In addition to the above, several other social projects are being planned for 2013 and the years after. These include, among others:

(a) The construction and renovation of schools and colleges;
(b) The construction of a complex for ‘Sports de Combat’ and renovation of sports infrastructures, such as the Malabar gymnasium and the Grande Montagne Sport Complex stadium;
(c) The renovation of cultural and community centres;
(d) The extension and renovation of the Pointe La Gueule Prison; and
(e) Improvements in health-related infrastructures.

### 8.2 Trend in Electricity Consumption

Although the overall electricity demand in Rodrigues for the period 2006-2011 has grown by an average of 1.7% annually, which is far below the 7.6% annual growth rate during the comparative previous period, the compounded growth rate in the specific consumption of the main customer categories were all negative. Table 8.1 shows the evolution of the growth rate in specific consumption.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>6.9%</td>
<td>3.1%</td>
<td>-0.6%</td>
</tr>
<tr>
<td>Commercial</td>
<td>6.2%</td>
<td>9.1%</td>
<td>-1.1%</td>
</tr>
<tr>
<td>Industrial</td>
<td>-9.1%</td>
<td>7.4%</td>
<td>-3.5%</td>
</tr>
</tbody>
</table>

For the period 2006-2011, the highest negative growth in specific consumption was in the Industrial Sector, where negative 3.5% was registered. This fall in the energy intensity is probably due to falling investment in industrial activities. This possible low capital injection, consequently, did not create the impetus, which
is required to bolster the social and economic conditions of the island. The end-result is the inhibited growth rate of the industrial sector’s electricity demand.

In the residential sector, the fall of 0.6% in the average consumption of electricity per household can be explained by a probable fall in the purchasing power of households in Rodrigues and a heightened emphasis on energy efficiency and savings. With respect to energy efficiency, the wide distribution of energy saving lamps on the island in 2009 continues to influence the residential category electricity consumption.

Given the intrinsic relationships between the different electricity consumer categories, where the propensity of one to consume influences the other, the Commercial Sector has also experienced a fall in the average electricity consumption per account. As shown in Table 8.1 above, a fall of 1.1% in the specific consumption of the commercial category was noted for the period 2006-2011. It is obvious that, because of the sluggishness of the economic activities in Rodrigues, the performance of the Commercial Sector was also gloomy.

Despite the above, the low growth in the electricity demand recorded in Rodrigues had a positive impact on the CEB’s financial performance. In Rodrigues, the cost of electricity supply has been relatively higher than the average electricity selling price, as shown in Table 8.2 below. Therefore, any reduction in electricity consumption will undoubtedly lower the overall costs of sales which, obviously, can be equated to lower deficit for the CEB.

Considering the total cost of supply in 2011, the average selling price should have been as high as Rs 9.13 per kWh for CEB’s operation in Rodrigues to break-even.

### 8.3 DEMAND FORECAST 2013-2022

Based on recent trends and the inferences made in section 8.1 above, the demand forecast for the period 2013-2022 has been prepared and is presented in this section.

#### 8.3.1 Energy Sales Forecast

As it can be observed in Figure 8.1 below, CEB has forecasted that the demand for electricity in Rodrigues will grow, on average, at an annual rate of 2.1% for the coming five years and at a lower rate of 1.5% for the period 2018-2022. Pending the gathering of additional data and the conduct of a comprehensive study of Rodrigues’ power system, these growth rates are believed to be reasonable at this stage.

#### TABLE 8.2: Loss on each Unit Sold Rodrigues for the Period 2005-2011

<table>
<thead>
<tr>
<th>YEAR</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Selling Price (Rs/kWh)</td>
<td>3.69</td>
<td>4.13</td>
<td>4.33</td>
<td>5.57</td>
<td>5.95</td>
<td>5.95</td>
<td>6.51</td>
</tr>
<tr>
<td>Cost of Sales (Rs/kWh)</td>
<td>4.26</td>
<td>5.74</td>
<td>6.38</td>
<td>7.50</td>
<td>8.45</td>
<td>7.21</td>
<td>7.52</td>
</tr>
<tr>
<td>Gross Loss (Rs/kWh)</td>
<td>(0.57)</td>
<td>(1.61)</td>
<td>(2.05)</td>
<td>(1.93)</td>
<td>(2.51)</td>
<td>(1.26)</td>
<td>(1.01)</td>
</tr>
<tr>
<td>Net Loss (Rs/kWh)</td>
<td>(1.51)</td>
<td>(2.41)</td>
<td>(2.82)</td>
<td>(2.89)</td>
<td>(3.66)</td>
<td>(2.44)</td>
<td>(2.62)</td>
</tr>
</tbody>
</table>

#### FIGURE 8.1: Annual Electricity (GWh) sales

![Image of Figure 8.1 showing annual electricity sales from 2000 to 2022, with historical data and forecasted values for 2013 to 2022]
The conducting of a comprehensive study of Rodrigues’ power system has been set as a priority for 2013. Upon completion of the study, CEB will be in a better position to arrive at a more accurate long-term demand forecast for the island.

In Rodrigues, residential sales account for more than 50% of the total electricity sales. As the residential category will continue to have the largest number of accounts, around 88% of the CEB’s customer-base in Rodrigues, and non-residential development will be mostly in proportion to the size of the local market, represented by the number of households, the above-mentioned share of more than 50% is expected to be maintained in the future.

In line with the RRA’s strategic goal to consolidate Rodrigues’ economy, future electricity sales, as mentioned above, will follow an upward trend. In addition to the spill-over effect of economic activities on the local households, the sales forecast has taken into account the potential growth in industrial activities geared towards exportation and the developments in the Commercial Sector focusing on tourism. Figure 8.2 below illustrates this overall view.

Over the past seven years, the Commercial Sector accounted for approximately 32% of the total electricity consumption in Rodrigues. Commercial electricity usages were mainly towards providing government services, businesses operations and tourism activities. Commercial activities in Rodrigues seem to be closely linked to households’ propensity to consume and tourism-related activities. Given this observation, it is sensible to assume that changes in the quantity of electricity consumed in the Commercial Sector will be largely dependent on these two causal factors. Unless there is a drastic change in the economic structure, the electricity consumption in the Commercial Sector will continue to move in tandem with the households and hospitality sectors’ affluence.

For the period 2005-2011, electricity sales to the industrial category had been around 8% annually. As at the end of 2011, statistics showed that the number of registered industrial electricity accounts was around 230. CEB has forecasted that the current trend will be maintained for the coming years. This is based on the assumption that future industrial developments in Rodrigues will be moderate for the following reasons:

- The local market will remain tiny;
- The remoteness of the island; and
- Possible development of low-energy intensity industrial activities.

### 8.3.2 Peak Demand Forecast
CEB estimated that the peak electricity demand in Rodrigues will grow on average by 3.5% annually over the next five years and by 1.5% over the period 2018 to 2022. According to this trend, the peak power demand will reach 8.83 MW by the year 2022;
that is, approximately 38% higher than the peak of 6.39 MW recorded in 2011. The estimated growth rates are consistent with the recent growth in the peak demand, as shown in Figure 8.3 above.

8.4 ELECTRICITY GENERATION PLAN FOR RODRIGUES

In accordance with the market assessment, an Electricity Generation Expansion Plan, covering the period 2013-2022, has been prepared for Rodrigues, as summarised in the following sub-sections.

8.4.1 The Existing Generating System

In Rodrigues, CEB caters for the total electricity needs. Diesel engines and Wind Farms are the two main technologies used for generating electricity. The thermal power plants (diesel engines) are located at Port Mathurin and Pointe Monnier, while the Wind Farms are sited at Trefles and Grenade.

The currently available effective plants capacities are shown in the Table 8.3.

The total installed wind farm capacity in Rodrigues is presently 1,280 kW and the total thermal effective capacity is 11,400 kW (includes the newly-commissioned generating unit at Pointe Monnier).

8.4.2 Energy Mix

In 2011, CEB generated a total of 33 GWh of electricity to meet the island’s electricity demand. Out of the 33 GWh, around 9% were generated by the Wind Farms,

<table>
<thead>
<tr>
<th>Power Stations</th>
<th>Units</th>
<th>Installed</th>
<th>Effective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port Mathurin</td>
<td>MWM No.1</td>
<td>500</td>
<td>400</td>
</tr>
<tr>
<td></td>
<td>MWM No.2</td>
<td>500</td>
<td>400</td>
</tr>
<tr>
<td></td>
<td>MWM No.3</td>
<td>500</td>
<td>400</td>
</tr>
<tr>
<td></td>
<td>MWM No.4</td>
<td>500</td>
<td>400</td>
</tr>
<tr>
<td></td>
<td>MWM No.5</td>
<td>500</td>
<td>400</td>
</tr>
<tr>
<td></td>
<td>MWM No.6</td>
<td>500</td>
<td>400</td>
</tr>
<tr>
<td></td>
<td>MAN No.7</td>
<td>1,000</td>
<td>900</td>
</tr>
<tr>
<td></td>
<td>MAN No.8</td>
<td>1,000</td>
<td>900</td>
</tr>
<tr>
<td></td>
<td>MAN No.9</td>
<td>1,000</td>
<td>900</td>
</tr>
<tr>
<td></td>
<td>SubTotal</td>
<td>6,000</td>
<td>5,100</td>
</tr>
<tr>
<td>Pointe Monnier</td>
<td>MAN No.1</td>
<td>1,900</td>
<td>1,900</td>
</tr>
<tr>
<td></td>
<td>MAN No.2</td>
<td>1,900</td>
<td>1,900</td>
</tr>
<tr>
<td></td>
<td>New Unit</td>
<td>2,500</td>
<td>2,500</td>
</tr>
<tr>
<td></td>
<td>SubTotal</td>
<td>6,300</td>
<td>6,300</td>
</tr>
<tr>
<td>Trefles</td>
<td>WTG 1</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>WTG 2</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>WTG 3</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>SubTotal</td>
<td>180</td>
<td>180</td>
</tr>
<tr>
<td>Grenade</td>
<td>WTG 1</td>
<td>275</td>
<td>275</td>
</tr>
<tr>
<td></td>
<td>WTG 2</td>
<td>275</td>
<td>275</td>
</tr>
<tr>
<td></td>
<td>WTG 3</td>
<td>275</td>
<td>275</td>
</tr>
<tr>
<td></td>
<td>WTG 4</td>
<td>275</td>
<td>275</td>
</tr>
<tr>
<td></td>
<td>SubTotal</td>
<td>1,100</td>
<td>1,100</td>
</tr>
</tbody>
</table>

Total Thermal: 11,400
Total Wind + Thermal: 12,680
remaining was produced from diesel and heavy fuel oil. Figure 8.4 shows the share of the energy mix in 2011.

**FIGURE 8.4: Energy Mix 2011 - Rodrigues**

8.4.3 Capacity Planning Criteria
The updated effective generation capacities, the spinning reserve margin and the ‘N minus 1’ criterion are the main determinants of the generation expansion plan.

**Effective capacities**
As in Mauritius, the effective plant capacities of Rodrigues are updated on an annual basis. The revised generating capacities are used, when carrying out the demand-supply balance.

**Spinning Reserve**
As for the power system in Mauritius, a margin of 10% is generally maintained for the spinning reserve in the Rodrigues’ system.

‘N minus 1’ Criterion
In Rodrigues, given the small number of generating units which allows better maintenance management, CEB uses the ‘N minus 1’ criterion in the demand-supply balance matrix. Under this planning approach, CEB ensures that in the event of the largest engine being out of use, mainly due to forced outage, the remaining available engines should be able to satisfy the demand.

According to records, the peak demand in Rodrigues usually occurs on the last day of December every year. With this information and to ensure preparedness in having sufficient generation capacity, CEB does not plan any engine maintenance during the month of December. By so doing, CEB is able to achieve the ‘N minus 1’ criterion.

8.4.4 Proposed Plant Addition
In February 2005, a study for extension of the Pointe Monnier Power Station was carried out. The ensuing development plan recommended a two-phase extension of the power station. Under the Phase-One, 2 units of 2.5 MW each, both operating on heavy fuel oil, would have been added. The first unit was initially planned to start operation in September 2006. The second unit was intended for commissioning in September 2007 depending on the coming into operation of the announced desalination plants. Otherwise, it would have been commissioned in September 2008 to satisfy the normal growth in demand.

Phase-Two of the project comprised 3 additional units of 2.5 MW each. Its implementation depended on the island’s load growth.

Contrary to what was planned, the acquisition of the first generating unit under Phase-One was later deferred for the following reasons:
- CEB adopted the ‘N minus 1’ criterion;
- Delayed decommissioning of the old MWM units at the Port Mathurin Power Station; and
- Accumulated delays in the installation of desalination plants by the local authority.

The commissioning of the first 2.5 MW engine under Phase-One was then rescheduled for the end of 2012, in anticipation of satisfying the projected increase in demand.

In accordance with the development plan, as and when the need arises, new generating units of 2.5 MW will be added. Generally, the construction time for such capacity engine(s) takes at least 14 months.

It is worth highlighting that the EIA licence for the full development (5 x 2.5 MW) of the Pointe Monnier Power Station had been already secured.

8.4.5 Proposed Retirements
With time, the MWM engines at the Port Mathurin Power Station have become less efficient, due to ageing, and increasingly problematic for the CEB to ensure strict compliance with environmental norms, especially in terms of noise level. The maintenance costs, in terms of sourcing of spare parts
for these engines, are also significant. Moreover, these engines have high generation costs because they use expensive light fuel to produce electricity. Hence, their uses are limited to a minimum so as to mitigate financial impact on CEB’s operation in Rodrigues. Nevertheless, CEB will keep the MWM engines in its portfolio as back-up for emergency situations. In the long run, CEB will consider their progressive retirement, as and when the need arises.

8.4.6 Demand-Supply Balance
Further to the demand forecast and the planned additions and retirements, as discussed above, the demand-supply balance, depicted in Figure 8.5 below, has been prepared while taking into account the planning criteria stated in Section 8.4.3. The demand-supply balance depicts how the CEB intends to match the 2013-2022 electricity demand in Rodrigues with the current and future generation mix.

8.4.7 Planned Capacity Addition
In accordance with the demand-supply balance, whilst respecting the threshold limit for Reserve Capacity Margin, a new generating unit of 2.5 MW will be required in 2018.

With the revised effective capacity, which includes the last generating unit of 2.5 MW commissioned in 2012, CEB will be able to meet short- and medium-term demand, unless new developments emerge. By tracking the market, CEB will anticipate potential changes and, accordingly, plan for the addition of a new 2.5 MW generating unit before 2018, if the need arises.

Within the scope of this integrated plan, consideration will also be given to the re-development of the Trêfles site, where currently three 60 kW Wind Turbine Generators (WGTs) are installed. By 2022, these WTGs will already reach the end of their service lives. This proposed re-development project will contribute to increase the energy generation from renewable sources.
8.4.8 Energy Generation Estimates
Energy generation estimates, which are essential for budget purpose, are worked out as follows:

**Energy Used-On-Works** Assumption
Compared to around 4% of energy used-on-works in Mauritius, power plants’ auxiliaries in Rodrigues consume, on average, 8% of the total energy generated annually. The relatively higher energy used-on-works is mainly due to the heating of heavy fuel using electrical means, as opposed to the steam system being used in Mauritius.

**Network Loss Assumption**
In 2011, network energy losses in Rodrigues were estimated to be around 12.4%. Based on observed trend, it has been estimated that the energy losses will reach around 10% by the end of the planning horizon.

Reduction of energy losses in Rodrigues will be subject to close analysis in the comprehensive study, which CEB intends to finalise in early 2013. Upon completion of the study, the losses’ estimates shall be reviewed accordingly.

**Gross Generation Estimates**
The similar bottom-up approach, as applied for Mauritius and described in Appendix B3, has been used to estimate the gross energy generation for Rodrigues for the planning period. The gross energy generation is equal to the sum of the energy sales forecast, the network losses’ estimate and the power plants auxiliaries’ consumptions.

The estimated energy to be generated by the different power plants is calculated, following the analysis of load duration curves, and considering the approximately 3 GWh energy produced by the existing Wind Farms.

8.5 RODRIGUES’ ELECTRICAL NETWORK EXPANSION PLAN
The Island of Rodrigues has a relatively smaller power system, with no interconnection with the mainland, Mauritius. In the following sub-sections, a snapshot of the electric network expansion plan, which will ensure safe and dependable supply in Rodrigues over the next 10 years, is presented.

**8.5.1 Rodrigues’ Distribution Network**
The Rodrigues power system consists of a 22 kV distribution network energized by two thermal power plants and two small-sized wind farms, as shown in Figure 8.6 on the next page.

There are five 22 kV feeders, namely the Cotton Bay, Oyster Bay, Malartic, Port Mathurin and Ti Reserve feeders, which are extended in radial configuration from the two thermal power plants located at Port Mathurin and Pointe Monnier. The two Wind Farms, located at Trêfles and Grenade, are connected to the Cotton Bay 22 kV feeder.

There are presently about 155 distribution transformers, with a total installed capacity of 14.26 MVA. The total length of the 22 kV distribution network is approximately 150 km, consisting mainly of 25 mm² and 50 mm² overhead conductors. Table 8.4 below gives a break-down of the network’s length by feeders.

<table>
<thead>
<tr>
<th>Station</th>
<th>Feeder</th>
<th>Total Length (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pointe Monnier</td>
<td>Malartic</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>Oyster Bay</td>
<td>34</td>
</tr>
<tr>
<td>Port Mathurin</td>
<td>Cotton Bay</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>Ti Reserve</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Port Mathurin</td>
<td>8</td>
</tr>
</tbody>
</table>

8.5.2 Network Losses
The network losses in Rodrigues were reported to be around 12.4% for the year 2011. It is mainly attributed to lightly-loaded distribution transformers (below 50%), long 22 kV distribution feeders having small cross-sectional area and long low-voltage distribution feeders (around 1 km). In order to reduce network losses, CEB will endeavour to:

- Replace under-loaded transformers by adequately sized transformers so as to achieve an efficient transformer loading condition;
- Reconfigure the low-voltage distribution feeder in order to reduce the average length to around 0.5 km;
- Upgrade the 22 kV distribution lines to 100 mm² bare conductors or 95 mm² insulated twisted cables;
- Install capacitor banks to optimise reactive power flow; and
- Construct a switching station at Petite Réserve.

* See glossary
FIGURE 8.6: 22 kV Network and Power Stations in Rodrigues

- Power Station
- Wind Farm
- Port Mathurin 22 kV feeder
- Malartic 22 kV feeder
- Oyster Bay 22 kV feeder
- Cotton Bay 22 kV feeder
- Ti Reserve 22 kV feeder
8.5.3 Distribution Network Expansion Plan
With the upgrading of the 22 kV feeders to minimize losses, as discussed in Section 8.5.2, the 22 kV distribution system will have sufficient spare capacity to satisfy power delivery during the period 2013-2022.

All new 22 kV distribution lines to be constructed will need to be of either 100 mm$^2$ bare conductors or 95 mm$^2$ insulated twisted cables.

8.5.4 Renewable Energy (RE) Integration
The Island of Rodrigues is endowed with wind power potential. The Grenade area was identified as a prominent site for the installation of Wind Turbine Generators (WTGs). The prime objective of installing WTGs in Rodrigues is to reduce its dependency on costly heavy fuel oil, which is transported from Mauritius to Rodrigues.

CEB has developed dynamic models of the Rodrigues’ power system so as to study the impact of wind power integration on the system frequency and voltage profile. With the present level of wind power integration amounting to 1,280 kW, CEB had to curtail the power output from the Grenade Wind Farm during low system demand condition so as to maintain the system frequency deviation within the range of ±0.5 Hz.

Prospects for further RE Integration
With the commissioning of the new 2.5 MW generating unit, which is equipped with modern control systems at the Pointe Monnier Power Station, in 2012, it is anticipated that the system’s response will be enhanced and that the frequency variation about the nominal value of 50 Hz will be reduced.

Once it is confirmed that the system’s response has been enhanced, CEB will plan to equip the other two 1.9 MW Pointe Monnier units with similar control system.

Following these enhancement measures, CEB expects to relax the curtailment of the power output from the Grenade Wind Farm during low system demand.

In addition to the above, CEB will undertake further studies to assess the implications of integrating more RE technologies into the Rodrigues’ power system. This will include, among others, exploring the possibility of higher integration of RE with/without storage batteries.

Besides adverse impact on the system frequency, the integration of wind power also leads to voltage rise and fluctuation along the distribution feeders to which the wind farms are interconnected. As per the regulatory requirement, CEB needs to maintain the voltage at the customers’ terminals within ±6% of the nominal value of 230 V.

Simulation results show that the maximum wind power that can be interconnected on the 22 kV Cotton Bay feeder is 1,350 kW. Today, there is a total wind turbine capacity of 1,280 kW installed at the Trèfles and Grenade Wind Farms, which are connected to the 22 kV Cotton Bay feeder. Assuming another 275 kW wind turbine generator (similar to the Grenade Wind Farm) is added, the limit of 1,350 kW will be exceeded. As such, it will not be possible to interconnect an additional wind turbine generator to the 22 kV Cotton Bay feeder.

Considering the above constraint, any new wind turbine generator, greater than 70 kW, will have to be interconnected to another 22 kV distribution feeder. This will ensure system security in the event of sudden loss of wind power generation, which may be due to the tripping of the distribution feeder to which the wind turbine generators are interconnected.

In addition, contrary to a setup where all the wind turbine generators are connected to one single distribution feeder, the resulting generation-demand mismatch will be less when the interconnection of the WTGs are made to more than one feeder. Furthermore, in case of a potential disturbance, it will be easier for the power system to recover.

As an alternative, the extension of the Port Mathurin 22 kV feeder towards the Grenade Wind Farm site will be studied in order to accommodate new wind turbine generators. This option will be further investigated in the comprehensive study, which will be conducted early 2013.

RE technologies of smaller capacities are being implemented in Rodrigues under the SSDG Project for an initial quota of 100 kW. The project is for RE installations having capacity not exceeding 50 kW. Given that SSDGs have small capacities and are dispersed throughout the island, they have consequently less impact, in terms of power output variation, on the system frequency and voltage, as compared to wind farms.
8.6 ENVIRONMENTAL CONSIDERATION IN MANAGING RODRIGUES SYSTEM

The development of a power system is mainly triggered by economic development, which in turn may have a direct or indirect impact on the environment. Today, electric utilities cannot develop their power systems, without considering the impact on the environment. In other words, power system development cannot be made in isolation.

During the recent years, CEB has given a particular attention to the environmental aspect of its development. The concern for the environment is an integral part of its power generation and system planning. Like for the Maurice Ile Durable project, CEB will also participate in the making of the Rodrigues Ile Ecologique et Durable project. From this viewpoint, as elaborated below, CEB has already been contributing to the sustainable development of the Rodrigues' power system.

8.6.1 Current Environmental Issues in Relation to Power Generation

As mentioned above, electricity demand in Rodrigues is met through the operations of two thermal power plants, using HFO and diesel, and two Wind Farms. Given the impact of its thermal power plants on the environment, CEB has already put in place measures to monitor the emissions, noise levels and the wastes that they generate.

The Pointe Monnier Thermal Power Station, for instance, prior to its inception, acquired the mandatory EIA licence. It was obtained following the conduct of a fully-fledged Environmental Impact Assessment (EIA) that stated CEB's obligations to ensure compliance with the national environmental standards.

With regard to the Port Mathurin Thermal Power Station, which has six old and less efficient MWM engines, CEB is planning to retire them progressively so as to comply with environmental regulation, especially noise level, in the future.

CEB has also been contributing to the sustainable development of Rodrigues by facilitating and introducing Renewable Energy (RE) generation technologies in the generation mix. The Wind Farms at Grenade and Trêfles, which represent around 10% of the CEB’s generation capacity today, are evidence of CEB’s commitment to environmental protection, while ensuring reliable electricity supply in Rodrigues.

Furthermore, as mentioned earlier, with the support of the Government, CEB extended the SSDG project to Rodrigues in December 2010, for an allotted quota of 100 kW, in order to promote further the penetration of RE technologies.

8.6.2 Environmental Monitoring

CEB recognises that, with the expansion of its power generation activities in Rodrigues, it will need to increase its involvement in the protection of the local environment. In this respect, it has already decided to establish a proper Environmental Monitoring Plan for Rodrigues. The main areas of monitoring will include air emissions, effluent discharges and noise levels from the two existing thermal power stations.

Accordingly, the Pointe Monnier Power Station has been equipped with a hand-held flue gas analyser to measure air emissions from the stack. Moreover, the service of the University of Mauritius was retained to conduct monitoring of stack emissions at the Port Mathurin Power Station.

To ensure that the noise level is within the prescribed limits, CEB has also made a commitment to regularly carry out noise level monitoring in the surrounding areas of its power stations.

Furthermore, the analysis of the effluent generated from each thermal power plant will be conducted on an annual basis. Where necessary, the services of accredited laboratories will be solicited to conduct other regulatory analyses.

To strengthen its commitments, CEB is also contemplating the development of a Waste Management Plan (WMP) for the thermal power plant in Rodrigues. The plan will aim at fostering the CEB’s environmental stewardship.

8.6.3 Achieving Sustainable Power Generation Development in Rodrigues

CEB envisions that Rodrigues’ objectives for sustainable development can be partly met by maximizing RE potential. One main driver to accelerate the penetration of RE technologies in Rodrigues is a workable financial mechanism. The MID funding, for example,
can bridge the incentive gaps in order to support the positive evolution of renewable technologies in Rodrigues.

**8.7 DEMAND-SIDE MANAGEMENT (DSM) PROGRAMME FOR RODRIGUES**

Based on the demand forecast prepared for this IEP, CEB believes that by managing effectively electricity demand in Rodrigues it can modestly reduce its operational and financial risks. With this expectation, the Demand-Side Management (DSM) Programme, which is currently being devised for Mauritius, will be extended to Rodrigues. DSM initiatives may include promoting the use of solar water heaters, efficient appliances and energy efficient lamps. The DSM strategy will not only contribute to improving the costs of operation of the CEB, but may equally result in lower electricity bills for the CEB’s customers in Rodrigues.

**8.8 RODRIGUES SHORT-TERM ACTION PLAN**

As part of its action-plan, CEB will conduct a comprehensive study of the Rodrigues’ power system early in 2013. The objectives of the study are to conduct a thorough assessment of the market and update the demand forecast accordingly, propose measures to reduce the cost of supply and the overall electricity losses, which are estimated to be as high as 12% today, evaluate implementable Demand-Side Management initiatives and determine to what extent the capacity of RE Technologies can be increased in the generation mix.
How High is Demand-Side Management on the Agenda?

Sustainable power system development starts well before the setting up of the physical infrastructures. It is a shift in thinking and of evaluating alternatives. The time to focus on the supply-side has already revolved. Managing demand is equally important and it deserves our closest attention, if we are serious about our core values.

CEB, by sharing this engagement, will act in the best interests of its customers by effectively balancing the demand-supply of electricity!
In working towards the least-cost expansion of the national power systems, as exemplified in this IEP, CEB has resolved that close attention be given to potential Demand-Side Management (DSM) initiatives.

As in other sectors, the rationale underlying DSM in power systems is the exact opposite of traditional supply-side philosophy. In the electricity business, a supply-side approach focuses on the construction of new generation capacity in response to increasing demand. DSM is based on the demand-side approach, that is, what can be done on the demand-side, not only to promote efficient use of energy, but also to lower and/or displace loads imposed on the power system.

As highlighted in the previous IEP, CEB had embraced the DSM concept as far back as in 2003. From mere theory, the concept was translated into real initiatives. Today, DSM has gained useful momentum and is an integral element in the planning of the CEB’s power systems.

Within the DSM framework, CEB had actively emphasized measures to manage electricity demand in households and businesses. Over the recent years, CEB, in collaboration with the MEPU, initiated and implemented a number of projects in accordance with its DSM objectives; as is elaborated briefly in the next section. Sections 9.2 and 9.3 below give some important information on the scope of the CEB’s DSM strategy and on its future DSM initiatives, respectively.

### 9.1 Recent DSM Initiatives Implemented

In its commitment to pursue its DSM strategy, CEB has implemented successfully the following initiatives.

#### 9.1.1 Efficient Lighting (One Million CFLs Distribution Campaign)

CEB successfully accomplished the distribution of a total of one million Compact Fluorescent Lamps (CFLs) in Mauritius and Rodrigues. The CFL project was launched on 1st August 2008 and lasted until April 2009. The targets set were indeed largely met, as pointed out in the Table 9.1 below.

#### 9.1.2 Daylight Saving Time (DST)*

Under a directive from the Government, CEB engaged actively in the Daylight Saving Time (DST) project. The project was launched on the 26th of October 2008 and ended on the 29th of March 2009. The post-evaluation of the project confirmed the expected benefits. The published results are reproduced in the Table 9.2 hereunder.

Despite these benefits, Government resolved not to renew the project, because of strong objections from the public.

### 9.1.3 Sensitization Campaign

The CEB’s on-going sensitization campaign, which started in 2005, has produced positive results. Over the past years, a noticeable improvement in specific

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* See glossary
consumption, especially in residential consumption, has been noted. Based on information collected, it appears that customers are becoming more and more efficient in their electricity consumption.

As part of its sensitization campaign, among other actions, CEB distributed, free of charge, a very useful Energy Saving Booklet to about 300,000 households in Mauritius and Rodrigues in 2006, and also carried out communication exercises through the different media.

9.2 THE ENERGY EFFICIENCY MANAGEMENT OFFICE (EEMO)

Following the setting up of the EEMO, the CEB revised the scope of its DSM strategy, especially with regard to energy efficiency. This is a necessary step so as to prevent potential duplication of activities which, otherwise, may negatively impact on the overall effectiveness of national energy efficiency initiatives. CEB, however, will maintain its active participation in the EEMO’s activities.

As a key stakeholder, in accordance with its DSM strategy, CEB will continue to provide technical and development supports in the national project entitled ‘Removal of Barriers to Energy Efficiency and Energy Conservation in Buildings and Industry’, being led by the EEMO. CEB is strongly convinced that initiatives falling under this project can contribute positively to the efforts to manage the ever-growing electricity demand.

9.3 PROPOSED 2013-2022 DSM INITIATIVES

As part of its commitment to ensure the least-cost development of the power system, CEB will keep on emphasizing the importance of DSM related activities. Over the next 10-years, to the extent it is feasible and viable; CEB will work toward the implementation of the following actions, which are closely in line with the Energy Strategy Action Plan (ESAP) 2011-2025 of the MEPU, so as to effectively respond to its customers’ demand.

Renew the Sale of Energy Saving Lamps

Depending on the findings of the Households Electricity Utilisation Survey, conducted in May-July 2012, the second campaign of the sale of CFLs, under similar conditions governing the first one, will be planned. In parallel with the proposed CFLs campaign, CEB intends to launch a project for the replacement of Conventional Fluorescent Tubes (T8) by Linear Fluorescent Lamps (T5).

Replacement of T8 by T5

T5 lamps (Linear Fluorescent Lamps) consume around 40% less energy than T8 lamps of similar dimension. Although the cost of a T5 tube is higher, when compared to a T8 type, the high initial cost will be fully compensated by the long life of the T5 and the benefits derived from its energy efficiency properties. Currently, a pilot study has been undertaken on one of the CEB’s premises. After the feasibility study, if the findings are positive, a project to replace all T8 tubes by T5 on the premises will be carried out. At a later date, the project will be reformulated so as to encourage all CEB’s customers to replace their T8 tubes by T5 Linear Fluorescent Lamps.

Promoting the Use of Light Emitting Diodes (LEDs) Technology

As an alternative to the above proposed sale of CFLs, CEB will study the possibility of promoting the use of LED technology. LED technology is a real source of energy saving. LED light bulbs are much more energy-efficient than conventional incandescent lights and even CFLs. They contain no mercury and have a lifespan of about 15 years. As the price of LED bulbs becomes more competitive, CEB, with the participation of other stakeholders, may launch a LED campaign at a national level.

Encourage the Replacement of Old Inefficient Refrigerators

According to a latest survey, 92% of households in Mauritius have at least one refrigerator of an average capacity of 200-300 litres. The refrigerators originated from different countries and their energy consumptions vary a lot. Most of the refrigerators of the 1990s consume far more energy than the new frost-free generation.

As a consequence of the varying power consumption, the refrigerators have different coefficient of performance (COP). Hence, for same output, different quantities of input (electricity) are required.

To encourage people to replace their less energy-efficient refrigerators - those older than ten years - an appropriate incentivised scheme will be planned. However, for the scheme to be effective, the followings are necessary:
• The full support of the EEMO and the MID Fund; and
• Enforcement of the necessary regulations in relation to the Energy Efficiency Act.

Use of Smart Power Strips
From information collected in a previous survey, an equivalent of 1.4 MW of electrical appliances was estimated to be left on stand-by mode. This unnecessary energy loss can be avoided by encouraging customers to use a Smart Power Strip. In collaboration with the EEMO, CEB will plan to launch the Smart Power Strip project on a pilot basis.

The Smart Power Strip is an intelligent power strip made of several power inlets with one control inlet. Once an appliance, say a TV, connected to the control inlet is switched off at the TV level, all other equipment, say a DVD player, satellite channel receivers, Hi-fi and so on, are switched off automatically, and power is cut off to all of them completely, thus avoiding stand-by mode power consumption or idle current.

Smart Metering
CEB has started installing smart meters on the premises of some of its important consumers, in replacement of conventional meters. This is a first step towards smart metering, which eventually will contribute to building the ultimate Smart-Grid.

For the medium term, the CEB envisages replacing all its electro-mechanical energy meters by electronic meters or, to the extent that it is viable, by smart meters. Smart meters, among other advantages, offer the possibility of monitoring electric loading on consumers’ premises. With this option, CEB may explore the possibility of engaging in load management, if need be, as part of its demand-side management strategy. More information on metering is given in Chapter 10, Section 10.3.

Time-Of-Use (TOU) Tariff*
Exploring the potential of TOU tariff in the local power system has been a recurrent debate. It is known that TOU tariff is a powerful tool to manage electricity demand and can contribute to optimising the utilisation of power generation assets. However, like most alluring business applications, the TOU tariff also has some critical implications for both the consumers and the utility.

In our context, after systematic analysis, it has been found that TOU tariff will not be an effective means to manage electricity demand, unless a comprehensive restructuring of the current electricity tariffs is pervasively accepted and made. The importance of a fully-fledged tariff restructuring and features of a modern tariff model are discussed in Chapter 10.

In general, TOU tariffs will be dependent on customers’ expected gains, which normally should be equal to a certain amount of revenue that the utility is willing to forgo. That monetary amount should at least be equal to the efficiency gains made through optimal dispatching of generation facilities under a revenue-neutral scenario.

At the CEB, efficiency gains can be generated by flattening the daily demand curves. The results of the flattening of those curves shall enable the CEB to minimise the operation of high running cost engines.

Impact of TOU on the Evening Peak Demand
The system’s evening peak is generally caused by the demand of the Residential Sector. From a recent customer survey, it was estimated that there is a potential of reducing the evening load by shifting it to the off-peak (night period), using a TOU tariff, as depicted in the typical demand curve shown in Figure 9.1 on the next page.

Impact of TOU on the Daytime Peak Period
The morning peak in the system is generally caused by the activities of the Industrial and Commercial Sectors. Figure 9.1 also shows the shift in load that can be targeted through an effective TOU tariff scheme.

Limitation of the Inclining-Block Tariff Structure
By its very specific nature, the present residential inclining-block tariff, applicable to households in Mauritius and Rodrigues, does not allow offering a single equivalent TOU tariff, which would be suitable to all CEB’s residential customers under a revenue-neutral scenario.

Figure 9.2, on page 106, shows the current distribution of the number of accounts by average selling price in the residential category. It can be observed that for every block of consumption, customers pay an average selling price which is different from another block of consumption.

* See glossary
In fact, viewed at a micro level, for every quantity of electricity consumed a consumer experiences a different average selling price. This snag is even more acute in the low usage bracket. The distribution in Figure 9.2 also shows that a large number of the residential customers pay an average selling price below the mean selling price of the category.

Taking the above into account, if no customer is to be penalized while opting for TOU tariff, the CEB will have to customize a set of TOU rates for each bracket of consumption. However, this is contrary to normal practice and is not reasonable.

**Other DSM-related Initiatives**

A lack of information and insufficient knowledge usually prevent optional DSM practices. To enhance the CEB’s DSM programme, the aforementioned communication campaign (Section 9.1.3) will be intensified and will cover such actions as:

(a) Promoting the use of sensors to control lighting;
(b) Encouraging the use of more energy-efficient lamps for public lighting; and
(c) Identifying and motivating customers, who are consuming high reactive power. This will include how, and why, to use Power Factor Correctors in electrical installations.

The communication campaign will also comprise CEB’s participation in events on energy-related activities organised by government, schools, colleges, hotels, industries and other stakeholders.
Cost Reflective

Affordable

Transparent

Stable Electricity Price

Equitable

Time-of-Use Tariff

Cost of Supply

Electricity Tariff =
Energy Supply Costs
+ Value Added to Distribution
+ Efficiency Gains
Why Cost Reflective Electricity Tariff?

Fairness, Transparency, Equity, Efficiency and Affordability are the key features of a modern Electricity Tariff Structure. These characteristics are embedded in cost-reflective electricity tariffs.

CEB, in fulfilling its strategic role, shall consider the implementation of a cost-reflective tariff structure with the support of all its stakeholders!
Chapter 10: Electricity Tariff in Perspective

Given the substantial investment that will be required to support the implementation of the projects mentioned in this IEP, CEB will need to explore all possible avenues so as to raise the necessary financial resources. Increasing financial resources usually means higher financial obligations for the CEB. In meeting future financial obligations, CEB will inevitably depend in a large measure on the electricity tariff, which is its main, not to say sole, source of revenue.

Over the years, the electricity tariff in Mauritius has evolved in an apparently haphazard manner. Today, there are twenty-two types of tariffs in the CEB’s tariff schedule.

Although the different available tariffs are not overly complex, there are, however, some inherent weaknesses in their structures, and some are even duplicative in nature. The most important weaknesses of the present electricity tariffs are that they are not cost-reflective and consist of a substantial amount of cross-subsidisation*.

In general, for electricity pricing model to be characteristically in line with international best practices, it should embrace, *inter alia*, the objectives based on the associated guidelines as elaborated in Table 10.1 below.

CEB had recognised that there were a number of weaknesses embedded in its electricity-pricing structure. A study was even carried out to resolve the inherent weaknesses. A number of changes were recommended.

However, it was acknowledged that the recommended changes should be implemented in harmony with the prevailing social and economic conditions so as to prevent potential tariff shocks. A tariff shock is a situation where significant adjustments are made to the applicable electricity tariffs, which seriously affect electricity end-users’ budgets.

The very absence of an effective tariff structure in our context thwarts, to some extent, the implementation of important actions, which can bring up substantial efficiency gains for the benefits of all electricity end-users. For instance, the benefits of implementing Time-Of-Use (TOU) tariff and quarterly billing, among others, cannot be reaped, unless the current electricity tariffs are properly restructured and implemented. In the next section, an overview of a proposed typical cost-reflective tariff model, workable for Mauritius and Rodrigues, is presented.

### Table 10.1: Objectives and Guidelines for Electricity Pricing Model

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Guidelines</th>
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<tbody>
<tr>
<td>Encourage national economic growth by</td>
<td>Price according to cost</td>
</tr>
<tr>
<td>• Efficient allocation of national resources</td>
<td>• With due regard to economic efficiency</td>
</tr>
<tr>
<td>• Electricity priced for efficient usage</td>
<td>• To foster efficient and deter wasteful use of electricity</td>
</tr>
<tr>
<td>Ensure CEB is kept financially viable</td>
<td>Encourage commercial practices at CEB</td>
</tr>
<tr>
<td>Ensure customers are treated equitably</td>
<td>Price according to cost</td>
</tr>
<tr>
<td></td>
<td>• Offer life-line provisions for qualifying customers</td>
</tr>
<tr>
<td></td>
<td>• Eliminate improper subsidies</td>
</tr>
<tr>
<td>Achieve simplicity and stability in pricing</td>
<td>Keep structure simple and comprehensible</td>
</tr>
</tbody>
</table>

* See glossary
10.1 OVERVIEW OF A PROPOSED COST-REFLECTIVE TARIFF MODEL

In 2008, assisted by an internationally-known consultant, CEB worked out a restructuring of the electricity tariffs - implementation of which is still pending - with the aim of streamlining the current tariff structure into a modern one. The restructured tariff model, if implemented, would have been in line with best international practices.

The main objectives of the CEB tariff restructuring, among other things, would have been to make the electricity tariffs cost-reflective across different sectors. The new tariff model would have included an indexation mechanism so as to prevent future tariff shocks, and would have enabled CEB to offer Time-Of-Use options.

In short, the implementation of the new tariff model would have further enforced the principles of fairness, equity and transparency in CEB’s electricity price and rates-setting. In the following sub-sections, a few salient features of the proposed tariff model are given.

10.1.1 The Tariff Development Methodology

Every tariff structure is built on a central revenue requirement methodology (rate of return, revenue-cap, price-cap, hybrid method, etc.). In the local context, CEB, in the interest of all stakeholders, will adopt a Cost of Service paradigm.

Under this approach, all costs incurred, from production to delivery points, including service costs, are apportioned to each business unit. Thereafter, where applicable, the costs are further apportioned at different voltage level. Subsequently, the costs are allocated effectively to each customer category.

Finally, the apportioned costs are translated into the unitary rates applicable to each tariff, hence making the applicable tariff totally cost-reflective. Unlike the present tariffs, in the proposed tariffs each customer will be charged the real costs that it provokes, while demanding electrical power and energy.

Through this approach, customers are given the assurance that the necessary and proper discrimination is made so as to differentiate the service conditions that each customer category creates by virtue of their supply requirements.

In simple terms, the electricity rates applicable to each customer category will vary, depending on the supply point (HV, MV, LV) and the Time-Of-Use (TOU), wherever appropriate.

10.1.2 The General Tariff Formula & Tariff Components

Basically, the proposed unbundled tariff will have two components: The first will cater for the electricity generation, energy purchase and transmission costs, and the second will cover the distribution costs, inclusive of the value added service costs, as shown in the formula below.

\[
\text{Unit Tariff Price} = \text{Unit Energy Supply Cost (ESC)} + \text{Unit Distribution and Value Added Cost (VAD)}
\]

10.1.3 Demand and Energy Losses

In addition to the Energy Supply Costs (ESC) and Value Added to Distribution (VAD) costs, both demand and energy losses will be estimated and treated as cost elements. Thereafter, these costs will be embedded into the energy charge, which will then be transferred to the tariffs.

As for the VAD costs allocation, the allocation of losses to each customer category will be dependent on the typical demand profile of the customer category.

10.1.4 Tariff Categories

Implementation of the new tariff structure will call for a re-categorisation of the existing customers into different tariff categories.

10.1.5 Tariff Model

To implement the cost-reflective tariff structure, a tariff calculation model, as an essential tool, will be regularly used to determine:

- The revenue requirements;
- The cost-reflective real rates, as a result of changes in market forces;
- The variances between the actual applicable rates and the real rates; and
- The cash flows for a period of 4 to 5 years.

10.1.6 Automatic Price Review (APR) Mechanism

To ensure tariff stability, it is recommended that a full tariff review be carried out at the end of the Multi-Year Regulatory Period (MYRP)*, where amendments to
the tariff structure itself and adjustments to the asset base can be made.

To prevent tariff shock at the end of the MYRP and to account for incremental evolution of energy costs, an APR mechanism is usually necessary. The APR, on a quarterly basis, enables a review of energy rates based on indices, such as CPI, Wages index, Producer Price Index, etc. The APR mechanism is an in-built functionality in the tariff calculation model.

10.2 IMPLEMENTATION ISSUES

Above all, the implementation of a restructured tariff model is to prevent any tariff increase; thus aiming at revenue neutrality. In reality, this is difficult and by default, there may be some collateral impact on some customer sub-categories. For example, in our case, subsidised (preferential) tariffs, such as the EPZ tariffs, will be automatically phased out upon the implementation. This may lead to tariff adjustment(s) of customers benefitting from the EPZ tariffs.

To avoid potential tariff shock*, it is advisable to stagger the implementation of the cost-reflective tariff regime over a defined time period, and, here, a two-step implementation approach is suggested. The first step is to implement the structure with revenue neutral objective and the second step is the transition from actual level of revenue to a cost-reflective regime.

The implementation of the new tariff structure will also entail investments in a new metering system. CEB is already investing in such metering technology for other purposes, as discussed in the next section.

10.3 METERING

Electric meters are unquestionably important - not to say one of the most vital - pieces of asset in a power system. Meters are the links which connect the customers with the utility. They provide essential information to both parties. Enhancement in the metering system gives a cutting edge, in terms of benefits, to a utility and its electricity customers; such as:

- providing consumers with real-time information on the electricity bill; hence they can better control their consumptions;
- providing time of use features, whereby consumers can benefit from lower rates during off-peak hours;
- encouraging efficient use of renewable sources of energy in relation to a demand response program;
- enabling efficient management of cost-reflective tariffs;
- providing built-in anti-theft mechanisms to track down fraudulent consumptions;
- enabling load sharing and load management* by limiting user consumption;
- enabling automatic connection/disconnection of electricity supply; and
- reducing operation cost, for example, by decreasing the time taken for bill settlement, which in turn improves the working capital ratio.

Above all, an advanced metering system allows the gathering of significant intelligence about the market.

Over the years, CEB has heavily invested in improving its Metering System. In the deployment of its Metering Strategy, CEB has been gradually moving away from the utilization of electro-mechanical meters, through the installation of electronic meters and, modestly, smart meters. Figures 10.1(a) and 10.1(b) on the next page show the evolution of the penetration of electronic meters, in the CEB’s power system, in comparison to the number of installed electro-mechanical meters.

In moving forward with the strategy, while adopting a systematic approach, CEB had already embarked on the next phase of its metering installation enhancement programme. As at today, major customers, categorised under CEB’s ledger billing system, have been already transferred to the so-called Automatic Meter Reading (AMR) platform. This is a critical step towards the development of an Advanced Metering Infrastructure (AMI), which CEB is ultimately aiming at in the long run so as to modernise the national power system.

AMI provides state-of-the-art technology, which consists of smart meters, a communication system and meter data management software. Despite its numerous attractive advantages, however, there is one major barrier to its widespread implementation, which is the huge investment required.

* See glossary
Chapter 10: Electricity Tariff in Perspective
Integrated Electricity Plan 2013–2022

Figure 10.1 (a): Trend in Number of Electro-Mechanical Meters Installed

Figure 10.1 (b): Trend in Number of Electronic Meters Installed
What is the Ultimate Goal?

Building the grid of tomorrow - the ‘Smart Grid’.
It is a grid that uses digital technology to further enhance reliability and security of the electric system from generation facilities through the delivery systems to electricity consumers.

CEB, while walking this path, shall accomplish this smart journey cautiously!
Considering proposals made in the previous IEP and the current market evolution, as discussed in this Plan, it is evident that the country will need to invest in new electricity resources in order to cope with future increases in demand. To guide investment, the action-plan, presented below, has been prepared. Some of the short-term actions, as described below, have already been started, while others are being strongly contemplated. Implementation of key projects to accompany the development of the CEB’s power system will require investment on the order of MUR 18 billion in the short and medium terms. Seventy-two percent (72%) of the financing will be required in the short term, which includes a provision of about MUR 5 billion for the development of renewable energy projects.

Out of the total investment, 70% will come from the private investors and the remaining from the CEB. The major share of the capital injection will be made for generation capacity expansion, either for ‘needs-based additions’ or for ‘opportunity-based additions’.

<table>
<thead>
<tr>
<th>PROJECT</th>
<th>DESCRIPTION</th>
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<tbody>
<tr>
<td>DEMAND/DSM/TARIFF</td>
<td></td>
</tr>
<tr>
<td>Planning and Forecasting</td>
<td>To facilitate targeted investments, the development of spatial load forecast has become necessary. As a priority for 2013, the spatial load forecast model will be enhanced.</td>
</tr>
<tr>
<td>Demand-Side Management (DSM)*</td>
<td>A study to assess the cost-benefits of identified DSM initiatives will be carried out so as to justify resources requirements. Accordingly, DSM activities will be planned after securing the necessary approvals and commitments.</td>
</tr>
<tr>
<td>Cost of Supply Study</td>
<td>Update the Cost of Supply Study 2003 with the scope to determine the transfer price(s) of core business units.</td>
</tr>
<tr>
<td>Tariff Restructuring and Review</td>
<td>To seek necessary support and approval in order to embark on a cost-reflective tariff structure.</td>
</tr>
<tr>
<td></td>
<td>In accordance with the Government Budget 2013, CEB will design and implement the Time-of-Use (TOU) tariff, as and when requested.</td>
</tr>
<tr>
<td>RODRIGUES</td>
<td></td>
</tr>
<tr>
<td>Cost Reduction Study</td>
<td>A comprehensive study of the Rodrigues’ power system will be conducted early 2013, with the following objectives, among others:</td>
</tr>
<tr>
<td></td>
<td>(a) To improve the financial situation in Rodrigues;</td>
</tr>
<tr>
<td></td>
<td>(b) To optimise the operations of the different generating power stations.</td>
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</tbody>
</table>

* See glossary
<table>
<thead>
<tr>
<th>PROJECT</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>POWER GENERATION PROJECTS</strong></td>
<td></td>
</tr>
<tr>
<td>New Thermal Power Stations</td>
<td>Construction of the CT Power 100 MW coal-based power plant at Pointe aux Caves. The coming into operation of the CT Power is expected in 2015/2016.</td>
</tr>
<tr>
<td>Renewable Energy</td>
<td>Already in the pipeline, the 29.4 MW Curepipe Point Wind Farm, the first of its kind in Mauritius, will start operation in 2014.</td>
</tr>
<tr>
<td></td>
<td>In line with the Government strategy to promote renewable energy projects, 10 MW distributed Solar PV Farms are expected to be operational by the end of 2014.</td>
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<tr>
<td></td>
<td>The Aerowatt Wind Farm at Plaine des Roches is also in the pipeline. The revised 9 MW Wind Energy Project will further boost the share of renewable capacity in the generation mix. The project is also planned for 2014.</td>
</tr>
<tr>
<td></td>
<td>Construction of a mini-hydro power plant at the Bagatelle Dam Project is being contemplated in the short term.</td>
</tr>
<tr>
<td></td>
<td>A large-scale Solar PV Farm of 15 MW is also under consideration for implementation in the short term.</td>
</tr>
<tr>
<td>Future Power Plants</td>
<td>To meet forecasted demand, additional capacity of 50 MW is planned for 2017.</td>
</tr>
<tr>
<td></td>
<td>A further addition of 50 MW is also planned for 2021.</td>
</tr>
<tr>
<td><strong>POWER GENERATION PROJECTS – CONSULTANCY SERVICES</strong></td>
<td></td>
</tr>
<tr>
<td>Pre-feasibility Study for LNG Usage</td>
<td>A pre-feasibility study on the possibility of using LNG will be carried out soon. The use of LNG will further enable diversifying the electricity generation mix and, at the same time, promote the use of cleaner energy sources.</td>
</tr>
<tr>
<td>Mini- and Micro-Hydro Development</td>
<td>A study will shortly be carried out to identify sites for the development of Mini-Hydro and Micro-Hydro projects.</td>
</tr>
<tr>
<td>PROJECT</td>
<td>DESCRIPTION</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>TRANSMISSION INFRASTRUCTURE</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Achieve security of supply at Sottise substation by commissioning the second Belle Vue-Sottise 66 kV feeder in 2014.</td>
</tr>
<tr>
<td></td>
<td>Maximise evacuation of power from the Fort Victoria Power Station by laying two additional underground 66 kV cables between Fort Victoria Power Station and Saint-Louis substation.</td>
</tr>
<tr>
<td></td>
<td>Commission two 132 kV underground cables between La Chaumières and Ebène substations to alleviate expected bottle-necks on Saint-Louis-Ebène transmission lines, owing to the setting up of 100 MW power generation facilities in the West.</td>
</tr>
<tr>
<td></td>
<td>Continue to monitor the transmission system’s performance reliability requirements; investigating the possible need to upgrade sections of lines from 66 kV to 132 kV operation.</td>
</tr>
<tr>
<td>Transformer</td>
<td>Increase power transformer capacity of Amaury substation to 2x36/45 MVA.</td>
</tr>
<tr>
<td></td>
<td>Operate tap changer on 66 kV-to-22 kV power transformer in the master-slave control scheme to enable 22 kV closed busbar configuration.</td>
</tr>
<tr>
<td>Reactive Power Compensation</td>
<td>Install capacitor banks at Amaury, La Chaumières, Nicolay, Sottise, Wooton substations, in accordance with load growth in the regions that they serve.</td>
</tr>
<tr>
<td>Substations</td>
<td>Expedite the commissioning of the Case Noyale substation.</td>
</tr>
<tr>
<td></td>
<td>Commission the Riche Terre and La Tour Koenig substations in 2014.</td>
</tr>
<tr>
<td></td>
<td>Reconstruction of the FUEL substation.</td>
</tr>
<tr>
<td></td>
<td>Upgrade Belle Vue, Wooton and Ebène substations by the end of 2015.</td>
</tr>
<tr>
<td></td>
<td>Upgrade La Chaumières substation to accommodate the new 100 MW power generation plant in the Western region.</td>
</tr>
<tr>
<td>Right-of-way</td>
<td>Identify property, servitudes and right-of-way needs for the construction of future substation(s) and network development.</td>
</tr>
<tr>
<td>PROJECT</td>
<td>DESCRIPTION</td>
</tr>
<tr>
<td>-------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>DISTRIBUTION NETWORK ENHANCEMENT</td>
<td></td>
</tr>
<tr>
<td>Erection of new Feeders</td>
<td>Due to load growth, new feeders will be required in the following regions: Pointe aux Canonniers, Goodlands, along Northern Motorway, Plaisance,</td>
</tr>
<tr>
<td></td>
<td>Le Chaland, Côte d’Or, Highlands, Médine, Flic en Flac, Le Morne and La Mivoipe.</td>
</tr>
<tr>
<td>Reconfiguration of Distribution Network</td>
<td>As a result of the commissioning of new substations and the upgrading of existing ones, distribution network reconfiguration will be required</td>
</tr>
<tr>
<td></td>
<td>to further reduce distribution losses and to continue ensuring reliability and quality of supply.</td>
</tr>
<tr>
<td>Conversion from 6.6 kV to 22 kV Feeder</td>
<td>Continue with the implementation of the conversion of 6.6 kV feeders to 22 kV feeders in the regions of Port Louis, Quatre Bornes, Rose Hill,</td>
</tr>
<tr>
<td></td>
<td>Vacoas and Curepipe.</td>
</tr>
<tr>
<td>SYSTEM PLANNING STUDIES</td>
<td></td>
</tr>
<tr>
<td>MSDG Grid Code</td>
<td>Establish a Grid Code including the Feed-in tariff and model ESPA for the Medium Scale Distributed Generation, as stipulated in the ESAP</td>
</tr>
<tr>
<td></td>
<td>2011-2025 of the MEPU.</td>
</tr>
<tr>
<td>Renewable Energy</td>
<td>Continue research work/studies in view of increasing the level of integration of renewable energy.</td>
</tr>
<tr>
<td>Smart Grid</td>
<td>Study the feasibility for the implementation of a <em>Mauritius Smart Grid</em>.</td>
</tr>
<tr>
<td>ENVIRONMENTAL ACTIONS</td>
<td></td>
</tr>
<tr>
<td>Environmental Management System (EMS)</td>
<td>CEB will build an EMS, which is a structured and organized approach to managing environmental impact. The ultimate goal is to obtain the ISO 14001</td>
</tr>
<tr>
<td></td>
<td>accreditation.</td>
</tr>
<tr>
<td>EIA Manual for CEB’s Power Stations</td>
<td>The aim of preparing an EIA manual in the Power Generation Sector is to promote effective EIA so as to be consistent with the institutional</td>
</tr>
<tr>
<td></td>
<td>and process arrangements that are in force in Mauritius.</td>
</tr>
<tr>
<td>Environmental Reporting Programme (ERP) at the CEB</td>
<td>The ERP will be an essential element to consolidate further the CEB’s EMMP.</td>
</tr>
<tr>
<td></td>
<td>A Waste Management Policy to strengthen CEB’s commitment for the protection of the environment will shortly be implemented.</td>
</tr>
</tbody>
</table>
APPENDICES

A1: DEMAND FORECAST METHODOLOGY

B1: USEFUL INFORMATION ON POWER PLANTS

B2: GENERATION PLANNING METHODOLOGY

B3: ENERGY GENERATION ESTIMATION METHODOLOGY

C1: NETWORK PLANNING METHODOLOGY
DEMAND FORECAST METHODOLOGY

Appendix A1

In an electric utility, the load forecast constitutes the starting point for much of the planning activity. Its accuracy and reliability are intrinsically dependent on the methodology adopted. The demand forecast methodology, elaborated in this appendix, has been used to estimate the 2013-2022 electricity demand for the Island of Mauritius. Features, model and peak estimation method of the forecast methodology are described hereunder.

Key Features of the Forecast Methodology
Having the privilege to hold primary data and information on the electricity consumption of different segments of electricity consumers, CEB has built on its knowledge of the performances of the different economic sub-sectors and its customers’ segmentation strategy to develop the forecast methodology for the IEP 2013-2022.

The methodology includes application of statistical and econometric tools and techniques, combined with facts and information collected from end-users through surveys and meetings.

The previous forecast approach, which addressed the electricity demand projections from a macro-level, has been enhanced so as to improve the forecast accuracy. The enhanced-model is now built around sub-categories of customers; hence, it adopts a micro-level approach.

Although aggregated GDP growth rates have not been used as the direct central predictor, for obvious reasons, CEB has focused on the prevailing, and expected future, social and economic conditions of the country in order to work out the demand forecast.

Using these elements, which underlie the adopted forecast methodology, estimates of the electricity requirements of the different electricity customer segments/groups were thus more objectively arrived at.

Enhanced Demand Forecast Model
The enhanced-model first takes on board the key economic players which operate in different sectors of the economy and which largely influence our country’s economic activities; that is, those whose transactional behaviours directly influence economic growth. As for other CEB’s customer categories, the major customers have been clustered into distinct groups.

At a second stage, the electricity requirements of the other sub-categories of customers, which rely closely on the performances of the major economic players, were then estimated in order to predict the total system electricity requirements for the planning period.

For the next 10-years, demographic or/and economic indicators, as independent factors, were used to estimate the electricity demand for each sector/sub-sector, using regression techniques. However, given that the demand forecast depends intrinsically on the performances of different economic sectors/sub-sectors, an assessment of the performances of different economic sectors/sub-sectors has been made upstream. For this, a simple trending method was used in the absence of long-term economic forecast.

At the outset, it is believed that the inherent momentum of the economy, driven by both government expenditures and the Private Sectors’ investments, will create the necessary impetus which will sustain economic development, under the following three possible scenarios:

1. **Low Scenario**: The economy will be sluggish and may stagnate until the end of the medium-term.
2. **Base Scenario**: The growth rate in the economic sectors/sub-sectors will reflect the trend of the last decade.
3. **High Scenario**: A rapid economic recovery in the short term will accelerate the economic growth in the medium to long term.
In general, taking into account the overall resources' (capacities') constraints of Mauritius and to avoid the risk of over-estimation, a conservative approach has been adopted, whereby results obtained from applying econometric/statistical techniques are within the range of past values.

**Peak Demand Forecast**

For this IEP, a new method of estimating the peak electricity demand has been used and is briefly described in sub-section 4.2.5. To confirm the results, the general empirical formula below was used to validate the results.

\[
P = \alpha E + \beta \sqrt{E}
\]

Where, 
- \(P\) is Peak Power, \(E\) is Energy Sent-out and 
- \(\alpha\) and \(\beta\) are coefficients.

The yearly peak demand forecast has thus been confirmed by using estimated energy sent-out, while assuming a percentage network losses for the ten-year planning horizon. Until a more robust model is developed to estimate the network losses, the simple trend-ing method has been applied in order to estimate the percentage network losses for the period 2013-2022.

**DEMAND FORECAST METHODOLOGY OF EACH CUSTOMER GROUP**

The electricity sales forecast for each customer category has been worked out as follows:

**Residential Sector Electricity Sales Forecast**

The residential sector, also referred to as the domestic consumers in the CEB’s database, has been historically categorized into three electricity tariff categories (tariffs 110, 120 and 140), based on their declared load.

For the purpose of a more accurate forecast, the residential customer group has been segmented according to consumption ranges. Essentially, this segmentation approach provides the possibility of analysing demand-triggering factors relative to each segment/sub-segments. Figure A1.1 below shows the evolution of the size of the sub-segments, in terms of number of accounts, over the period 2005-2011.

The division enables an analysis of electricity consumption with demand-driving factors such as level of income, household size, penetration of home appliances and other relevant qualitative social causes.
between population size and the number of residential electricity accounts.

TABLE A1.1: Result of Regression of Number of Accounts on Population Size

<table>
<thead>
<tr>
<th>Estimated Y = a + bx</th>
<th>Regression Res &amp; Pop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated Coefficient ‘b’</td>
<td>2.82 Estimated Coefficient “a”</td>
</tr>
<tr>
<td>Standard Deviation ‘b’</td>
<td>0.06 Standard Deviation “a”</td>
</tr>
<tr>
<td>R² of Regression</td>
<td>0.996 Standard Error of Y</td>
</tr>
</tbody>
</table>

Considering the high R² of 0.996, the number of residential accounts for the forecast period has been estimated, using the ‘Population Forecast’ prepared by the Statistics Office of Mauritius.

Assumptions

For the different scenarios, it is assumed that the number of customers in each consumption segment will evolve as depicted in Figure A1.3 below. The change in the height of the bars represents the growth rates. Customers from the lowest consumption block (specifically those in the block 76 to 150 kWh) are expected to move progressively to higher consumption bracket. This assumption is dependent on a favourable sustained economic growth, whereby GDP per capita will increase satisfactorily and there will be an improvement in the distribution of national income.

Estimating Energy Intensity (Specific Consumption)

With regard to the energy intensity of a typical Mauritian household, a regression analysis was run, using household size and an estimation of household income as independent factors, based on the following assumptions:

a) The Low Scenario assumed that the residential customers’ specific consumption will tend to decrease in the short to medium term and will eventually stabilize. Reasons behind this assumption are:

(i) For the large majority of households the real disposable income* will not grow, which is most likely to reflect a fall in purchasing power;

* See glossary
(ii) Consumers will further embrace energy-saving practice as a result of sustained DSM campaign; and

(iii) Price of electricity will impact negatively on consumption as costs of services increase.

b) In the Base Scenario, CEB presumed that the residential customers’ specific consumption will grow at a decreasing rate, as residential consumers will further embrace energy conservation and energy efficiency practices. In addition, more efficient appliances will enter the local market, and, to some extent, electricity prices may hinder the consumption level.

c) In the High Scenario, CEB assumed that the growth rate will be around 3.6% compared to 0.5% and 1.5% for the Low and Base Scenarios, respectively.

At 95% confidence interval, unlike household size, real disposable income*, as evidenced by the t-ratio 4.93 shown in Table A1.2 is the most influential factor affecting household electricity consumption.

### TABLE A1.2: Result of Regression of Residential Demand on Household Size and Real Income

<table>
<thead>
<tr>
<th>Regressands</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>T-Ratio</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>1392.20</td>
<td>534.37</td>
<td>2.61</td>
<td>0.03</td>
</tr>
<tr>
<td>Household Size</td>
<td>48.97</td>
<td>127.67</td>
<td>0.38</td>
<td>0.71</td>
</tr>
<tr>
<td>Real Income</td>
<td>0.001834</td>
<td>0.000372</td>
<td>4.93</td>
<td>0.00</td>
</tr>
</tbody>
</table>

#### Commercial Sector Electricity Sales Forecast

The CEB commercial customer category accounts for the highest income-generating sector (approximately 46%). Five types of tariffs are currently available and are applicable to Commercial Customers, namely Tariffs 215, 217, 225, 245 and 250.

The largest number of Commercial Customers is registered under Tariff 215. In 2011, it represented 96% of the CEB’s commercial customer base but accounted for only 22% of the energy consumed by the commercial category and 14% of the overall CEB’s electricity sales. Figure A1.4 below shows the segments within

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* See glossary

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**FIGURE A1.4: Segments (Size and Energy Share) in Tariff 215 Category**
Table A1.3 and Figure A1.5, which follow, show the number of accounts (size of the customer-base) and the shares of electricity consumption of commercial sub-categories operating in different economic sub-sectors, such as finance, tourism, utilities, transportation, wholesale and retail trade, recreation, food and beverage supply, health care, education and public administration, hotels, and other non-manufacturing activities. The shares of categories T245 and T250 are not shown because of their small figures.

The key point to note from the above is that a small number of customers accounts for the large portion of electricity sales in the commercial category. This vital information in fact assists in defining the CEB’s market monitoring strategy.

Using the above insight, the commercial sales forecast has been developed in two steps. First, the demand of the medium and large commercial categories, which are considered as key economic players, has been examined and projection has been made accordingly. The formulae below underlie the forecast model used to estimate the future demand of the medium and large commercial customer categories classified under Tariffs 217, 225, 245 and 250.

\[
\ln \text{CINTER}_t = \alpha + \beta_1 \ln (\text{HO}_t) + \beta_2 \ln (\text{ICT}_t) + \beta_3 \ln (\text{FI}_t) + \xi_t
\]

Where,

\( \text{CINTER}_t \) Value of Outputs of Commercial Sectors whose performance is mostly driven by international factors and which have a spillover effect on the local economy by generating income and wealth

\( \alpha \) Constant

\( \beta_i \) Coefficients

\( \text{HO}_t \) Hotels and Restaurants Annual Output Value in year ‘t’

\( \text{ICT}_t \) Communications Annual Output Value

\( \text{FI}_t \) Financial Intermediation Annual Output Value

\( \xi_t \) Error term

Using the above relationship, the electricity demand of the medium and large commercial customer categories (COMDDL), whose performances depend on international conditions, was thus determined, using the equation overleaf.
The test statistics, shown in Table A1.4, for the above expression revealed that there is a strong relationship between the electricity demand of the targeted commercial customer groups and the selected economic sub-sectors’ value of outputs.

\[
\text{Ln COMDDDL}_t = \alpha + \beta \text{Ln CINTER}_t + \xi_t
\]

Where,
\(\text{COMDDL}_t\) Annual Demand of medium and large commercial customer categories
\(\alpha\) Constant
\(\beta\) Coefficient
\(\text{CINTER}_t\) The annual Value of Outputs of Commercial Sectors whose performance is mostly driven by international factors and which have a spill-over effect on the local economy by generating income and wealth
\(\xi_t\) Error term

The second step in the demand forecast of the commercial category is about estimating the demand of those commercial customers whose business performances depend on the domestic social and economic conditions, for example small Commercial Customers registered under electricity Tariff 215. They constitute the vast majority of CEB’s commercial accounts. Their share of the total electricity sales in 2011 stood at 7.77%.

Based on the test statistics at 5% significance level, as shown in Table A1.5, it is obvious that there exists a strong correlation between the performances of both Small Local-Market Focused and Medium & Large Domestic-Market Focused Commercial Customers and the commercial sectors’ growth rate, which is driven by the key above-mentioned players (Medium and Large Commercial Accounts).

\[
\text{Ln COMDDDD}_t = \alpha + \beta \text{Ln COLO}_t + \xi_t
\]

Where,
\(\text{COMDDD}_t\) The electricity demand of Small Local-Market Focused and Medium & Large Domestic-Market Focused Commercial Customers
\(\alpha\) Constant
\(\beta\) Coefficient
\(\text{COLO}_t\) The annual performance of Small Local-Market Focused and Medium & Large Domestic-Market Focused Commercial Customers, which are dependent on the local economic performance, has been regressed on the total value of outputs of the country
\(\xi_t\) Error term

Industrial Sector Electricity Sales Forecast
The CEB’s Industrial Customers are specifically involved in manufacturing activities. By definition, the purpose of using electricity in the Industrial Sector is when there is necessarily a transformation process taking place. Industrial Customers are classified under one of the nine available tariffs (excluding the tariff for sugar factories).

In 2011, the larger share of electricity consumption in the Industrial Sector was mostly accounted for by a handful of key export-oriented economic players. This trend has prevailed historically.
Table A1.6 above provides a workable segmentation of electricity end-users in the industrial category.

As in the case of the commercial category, the linear regression technique, in two steps, has been applied to estimate the demand of the major and small manufacturing firms. In working out the short- medium- and long-term forecast of each industrial subcategory, under the three scenarios, the following assumptions were made:

**Small Industrial Customers (T315)**

Although the pool of small Industrial Customers represents around 86% of the total industrial customer base, their share of the total electricity sales of 2204 GWh in 2011 stood merely at 1.31%. For this reason, they are considered as secondary economic players. Like the Commercial Customers under Tariff 215, the small Industrial Customers are highly dependent on the prevailing economic conditions, which are strongly influenced by major income-generating key economic players.

Given the close links between them and the other economic players, the number of accounts in the T315 category is expected to evolve in step with the other industrial customer categories. The assumption under each scenario is explained in the Table A1.7.

**Medium Industrial Customers (T313, T317 & T320)**

The present forecast for the medium-size industrial customer categories is made on the assumptions elaborated in Table A1.8 which is shown on the next page.

**Large Industrial Customers (T323, T325 & T330)**

Large Industrial Customers are strong enterprises which had/have made heavy investments to start their business operations. Analysis of their consumption trends, declared loads and demand profiles indicates that most of these existing companies are operating at almost full-load capacity. CEB has estimated that growth, if sufficiently significant, in the large industrial customer category will be caused mostly by new entrants.

---

1. **MDI** stands for Maximum Demand Indicator in technical term, which is used to measure maximum demand.
2. The term ‘high voltage’ here refers to the 22 kV distribution voltage level. In general, the 22 kV voltage level is classified as medium voltage.
Short- to medium-term demand estimates of new entrants are based on official requests received from potential customers. Industrial projects are usually known 2 to 3 years in advance, before the commissioning of supply. Such information enables the CEB to arrive at accurate and reliable estimates.

As no major industrial projects have been identified for the long term, the current demand projection has assumed that electricity demand of the large Industrial Customers will grow at a decreasing rate. A decreasing trend has also been assumed so as to reflect a possible shift to other energy sources. In fact, there is already a tendency for large enterprises to invest in renewable energy sources so as to partly meet their power demand.

Industrial Customers Operating in Freeport

In the CEB’s customer database, companies involved in Freeport Operations are classified under Tariffs 340 and 350. They are considered as key economic players which generate substantial amount of revenues for the country.

The Freeport Sector has maintained a positive growth in its operations during the recent years. As Mauritius is viewed as a strategic bridge between new emerging industrialized countries (India & China) and the South African Development Communities (SADC) Countries important developments are expected in this sector in the long term.

<table>
<thead>
<tr>
<th>Table A1.8: Forecast Assumptions For Medium Industrial Customer Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scenario</strong></td>
</tr>
<tr>
<td><strong>Category</strong></td>
</tr>
<tr>
<td>T313</td>
</tr>
<tr>
<td>T317 &amp; T320</td>
</tr>
</tbody>
</table>
In the short and medium terms, based on recent consumption trends and given the present limited transactional capacity, including the geographical location of the Mauritian port, CEB has projected that the electricity demand in the Freeport Operations will grow at a decreasing rate in the Base Case Scenario. This assumption will be revised in the light of upcoming events.

Industrial Demand Modelling
The business performances of major income-generating key players (medium and large Industrial Customers) have serious implications for the local economy. Evolutions in their operations impact on the electricity requirements of other categories/sub-categories, given the linkages they have built with them.

For the major Industrial Customers, the combined value of outputs, produced by export-oriented firms in the Agricultural and Manufacturing Sectors, was used as the predictive element. Accordingly, as shown in the general equation below, a relationship was modelled. A time factor ‘TIME’ was also included in the model to cater for technological progress (advancements & efficiencies).

\[ \ln \text{IND}_t = \alpha + \beta_1 \ln \text{AHF}_t + \beta_2 \ln \text{MA}_t - \beta_3 \text{TIME}_t + \xi_t \]

Where,
- \( \text{IND}_t \): Industrial Demand for Electricity in GWh
- \( \alpha \): Constant
- \( \beta_1 \): Coefficient
- \( \text{AHF}_t \): Annual Output Value of Agriculture, hunting, forestry and fishing
- \( \text{MA}_t \): Annual Output Value of Manufacturing in year ‘t’
- \( \text{TIME}_t \): Time trend, a proxy for technical progress and technical efficiency
- \( \xi_t \): Error term

The test statistics in Table A1.9 below fully support the above modelling, whereby a high R\(^2\) was obtained.

<table>
<thead>
<tr>
<th>TABLE A1.9: Test Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>t-ratio</td>
</tr>
<tr>
<td>p-value</td>
</tr>
<tr>
<td>R-Squared</td>
</tr>
</tbody>
</table>

The R\(^2\) of 0.817 suggests that there exists a good relationship between the two groups. Hence, using the above, the number of customers in the T315 category was estimated. To ensure consistency with past values, statistical methods were used to determine the energy intensity per unit of stock for this customer group under the different scenarios. The total electricity demand forecast for the small industrial category has been calculated by finding the product of the number of customers and the energy intensity.

Sales Forecast of Minor Customer Categories
CEB’s minor customer category includes sugar factories, street-lighting accounts, irrigation accounts and its own consumption.

These electricity end-users consume approximately 3% of the total national electricity production.

Public Lighting and Traffic Lights
Public infrastructural development is an indicator of real economic progress of a country. Alongside wealth creation by private owners and enterprises, Government has the critical responsibility of ensuring that the national wealth created is effectively distributed. In response to this obligation, Government, among other things, invests so as to widen the availability of electricity-usage public goods, for example, street and traffic lightings.

CEB has noted that demand for public lighting over the years has gradually increased. The following have been identified as the triggering factors:
- Kilometres of lighted highway;
- Lighting along existing roads which were not lit before;
- Increase in number of traffic lights;
Figure A1.6 above, depicts the increasing trend in the number of accounts of public lighting. Although the number of accounts is increasing, the installed load, however, has fallen substantially over the last four years.

This has been mainly due to the wide replacement of non-efficient bulbs with energy-saving lamps by local authorities.

**Electricity for Irrigation Purpose**

CEB has been actively supporting the Agricultural Sector by providing a subsidized tariff for water pumping for irrigation purposes. A 2-Tier time-of-use tariff is presently allocated to accounts which use electricity specifically for this purpose. The number of customers in this category has also shown an upward trend. However, recently, electricity sales to this category were on a decreasing trend. This can be explained by the fact that large portions of land, previously under agriculture, have been freed for infrastructural developments. Figure A1.7 below illustrates the observation.

Based on the above and on knowledge of upcoming developments, it is expected that the share of 3% of minor customers will be maintained in the future. The demand forecast for these minor electricity end-users was based on the following assumptions:

- Sugar factories, which include mostly IPPs, will rely as usual on CEB mainly for start-up operations and in cases of breakdowns. No major increase in sales to sugar factories is expected in the future at this stage.

- Although it was forecasted that the number of street-lighting accounts would increase as a result of the construction of new roadways (Ring Road, Dream Bridge, and Terre Rouge-Verdun Road) and improvement of existing ones, demand for electricity for public lighting will, most likely, follow a logarithmic trend. The electric load will grow at a much lower rate than in the recent past, given that more efficient lighting and renewable technologies may be used.

- Demand for electricity for irrigation purposes is expected to grow slightly in response to the Food Security Development Project initiated by the Ministry of Agriculture (MoA). However, the increase may be partly offset as more lands under agriculture will be released for infrastructural (real estate) developments.

Overall, electricity demand of the minor customer categories is projected to grow negligibly over the planning period. Since the share of the minor categories is relatively small, simple statistical techniques were applied to forecast the future demand.

**SYSTEMATIC CONTINUOUS DATA COLLECTION**

A proper demand forecast requires that data be systematically gathered and evaluated. In performing these tasks for the preparation of the IEP 2013-2022, CEB has carried out the following exercises:

**Consultation with Promoters of Major Projects**

To enhance the accuracy of the 10-year electricity demand forecast, in addition to historical data and information, CEB has, on an ongoing basis, held consultation meetings with promoters of major projects. By holding such technical meetings, the level of subjectivity implied in forecast exercises is thus minimised.
Mapping of Customers on Substations
For the purpose of studying monthly demand evolution on each CEB’s substation and preparing, for the first time, a spatial load forecast, data was extracted from the SAP system, grouped by Meter Reading Units (MRUs) and then mapped out on the electric network appropriately.

In fact, each and every account was mapped out on the respective feeder, and then the monthly aggregate demand for each substation was estimated. Accordingly, a database of monthly energy delivered by each substation, for the period January 2005 to July 2012, was constructed.

In addition to the above, for each major substation, the total power supplied to the loads was computed, using the input power to the station. This has enabled validating the data collected.

Using the above-mentioned database with other relevant information from the SCADA System and data collected through feeder-loading measurements, typical load profiles of CEB’s substations were simulated. The annual peak loads, hauled by each existing substation for hot summer periods (January, February and March), were then calculated. Figure A1.8 below summarises the process.

Feeder Loading Measurement Campaign
One of the primary objectives of feeder loading measurement is to determine the load profiles of electric feeders, which can be used as an input for preparing the spatial load forecast.

CEB conducted a feeder loading measurement campaign, involving a sample of feeders, for two consecutive years. The measurements have enabled estimating the typical profile of each major customer group in the system load profile. The information thus obtained has enhanced our understanding of the demand patterns of the different customer groups. Evolution in the demand patterns usually dictates the kind of investment (base, semi-base or peak load) in power generation expansion and, by extension, in network expansion.

A Power Analyser was used for the feeder loading measurement exercise. Active, reactive and apparent powers, as well as, the power factors, were recorded.

Household Electricity Utilization Survey
Reliable and updated information is a key ingredient in effective decision-making. Holding the right information provides a cutting edge and improves corporate values. Recognizing the intrinsic value of information creates the need for an entity, such as the CEB, to conduct primary data collection, as part of its research work. CEB conducts, on a periodic basis, a national household electricity utilization survey. The survey assists in strengthening our understanding of electricity usage in households and in acquiring pertinent information to formulate Demand-Side Management (DSM) strategy.

The last survey was conducted in May-June 2012. The findings of the survey had helped to validate the residential sector demand forecast and, accordingly, to plan forthcoming DSM initiatives.
The following tables give useful information on the capacity of power generation facilities in Mauritius.

### Table B1.1: Information on CEB’s Power Plants

<table>
<thead>
<tr>
<th>Engine</th>
<th>Make</th>
<th>Year Commissioned</th>
<th>Effective Capacity (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fort George Power Station</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G1</td>
<td>Sulzer</td>
<td>1992</td>
<td>22</td>
</tr>
<tr>
<td>G2</td>
<td>Sulzer</td>
<td>1993</td>
<td>22</td>
</tr>
<tr>
<td>G3</td>
<td>Mitsui &amp; Hyundai</td>
<td>1997</td>
<td>30</td>
</tr>
<tr>
<td>G4</td>
<td>Mitsui &amp; Hyundai</td>
<td>1999</td>
<td>30</td>
</tr>
<tr>
<td>G5</td>
<td>Mitsui &amp; Hyundai</td>
<td>2000</td>
<td>30</td>
</tr>
<tr>
<td><strong>Saint-Louis Power Station</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G1</td>
<td>Pielstick</td>
<td>1978</td>
<td>5</td>
</tr>
<tr>
<td>G2</td>
<td>Pielstick</td>
<td>1978</td>
<td>5</td>
</tr>
<tr>
<td>G3</td>
<td>Pielstick</td>
<td>1979</td>
<td>5</td>
</tr>
<tr>
<td>G4</td>
<td>Pielstick</td>
<td>1979</td>
<td>5</td>
</tr>
<tr>
<td>G5</td>
<td>Pielstick</td>
<td>1981</td>
<td>5</td>
</tr>
<tr>
<td>G6</td>
<td>Pielstick</td>
<td>1981</td>
<td>5</td>
</tr>
<tr>
<td>G7</td>
<td>Wartsila</td>
<td>2006</td>
<td>13.8</td>
</tr>
<tr>
<td>G8</td>
<td>Wartsila</td>
<td>2006</td>
<td>13.8</td>
</tr>
<tr>
<td>G9</td>
<td>Wartsila</td>
<td>2006</td>
<td>13.8</td>
</tr>
<tr>
<td><strong>Fort Victoria Power Station</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G1</td>
<td>Wartsila</td>
<td>2010</td>
<td>15</td>
</tr>
<tr>
<td>G2</td>
<td>Wartsila</td>
<td>2010</td>
<td>15</td>
</tr>
<tr>
<td>G3</td>
<td>Wartsila</td>
<td>2012</td>
<td>15</td>
</tr>
<tr>
<td>G4</td>
<td>Wartsila</td>
<td>2012</td>
<td>15</td>
</tr>
<tr>
<td>G5</td>
<td>Wartsila</td>
<td>2012</td>
<td>15</td>
</tr>
<tr>
<td>G6</td>
<td>Wartsila</td>
<td>2012</td>
<td>15</td>
</tr>
<tr>
<td>G11</td>
<td>MAN</td>
<td>1989</td>
<td>8.5</td>
</tr>
<tr>
<td>G12</td>
<td>MAN</td>
<td>1989</td>
<td>8.5</td>
</tr>
<tr>
<td><strong>Nicolay Power Station</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G1</td>
<td>GE</td>
<td>1988</td>
<td>21</td>
</tr>
<tr>
<td>G2</td>
<td>GE</td>
<td>1991</td>
<td>21</td>
</tr>
<tr>
<td>G3</td>
<td>GE</td>
<td>1995</td>
<td>33</td>
</tr>
</tbody>
</table>
### TABLE B1.2: Information on CEB’s Hydro Power Plants

<table>
<thead>
<tr>
<th>Hydro Plants</th>
<th>Turbine Type</th>
<th>Year Commissioned</th>
<th>Effective Capacity (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Champagne</td>
<td>Francis</td>
<td>1984</td>
<td>30.0</td>
</tr>
<tr>
<td>Ferney</td>
<td>Francis</td>
<td>1971</td>
<td>10.0</td>
</tr>
<tr>
<td>Tamarin</td>
<td>Turgo and Pelton</td>
<td>1945-1987</td>
<td>9.30</td>
</tr>
<tr>
<td>Le Val</td>
<td>Francis</td>
<td>1961</td>
<td>4.00</td>
</tr>
<tr>
<td>Réduit</td>
<td>Francis</td>
<td>1984</td>
<td>1.00</td>
</tr>
<tr>
<td>La Ferme</td>
<td>Francis</td>
<td>1959</td>
<td>1.20</td>
</tr>
<tr>
<td>Cécile</td>
<td>Francis</td>
<td>1963</td>
<td>1.00</td>
</tr>
<tr>
<td>Magenta</td>
<td>Francis</td>
<td>1960</td>
<td>0.90</td>
</tr>
<tr>
<td>La Nicolière</td>
<td>Francis</td>
<td>2010</td>
<td>0.35</td>
</tr>
<tr>
<td>Midlands Dam</td>
<td>Francis</td>
<td>2013 (expected)</td>
<td>0.35</td>
</tr>
</tbody>
</table>

### TABLE B1.3: Information on IPPs Power Plants

<table>
<thead>
<tr>
<th>Power Plant</th>
<th>Commissioned in</th>
<th>Effective Capacity Coal Mode (MW)</th>
<th>Effective Capacity Bagasse Mode (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTSav</td>
<td>August 2007</td>
<td>74</td>
<td>65.5</td>
</tr>
<tr>
<td>CTBV</td>
<td>June 2000</td>
<td>62</td>
<td>46</td>
</tr>
<tr>
<td>CTDS</td>
<td>September 2005</td>
<td>30</td>
<td>N/A*</td>
</tr>
<tr>
<td>FSPG</td>
<td>August 1997</td>
<td>27</td>
<td>20</td>
</tr>
<tr>
<td>CEL</td>
<td>April 1998</td>
<td>22</td>
<td>11</td>
</tr>
</tbody>
</table>

*Not Applicable.
Capacity Planning Methodology

With the increasing load demand and multiple large projects in the pipeline, the CEB has an obligation to supply power to its growing customer database. Addition of new power plants requires proper planning so as to ensure the availability of enough generation capacity at the required time. Different applications are used to perform a least-cost generation expansion plan.

The current generation planning method uses a deterministic approach to predict the addition of future power plants. The Load Forecast section provides two parameters as inputs, namely Peak Power Demand and Energy Sales, which are used to perform the Demand-Supply Balance. This exercise is aimed at determining the need to add more generation capacity to the existing system. In the following sections below the generation planning methodology is explained in detail.

Effective Capacities

The most critical input, in carrying out the Demand-Supply Balance, is information on the latest Effective Capacity of each generator connected to the grid. The effective capacity of each power plant is updated on an annual basis. This exercise is very important as power plants name-plate ratings may be de-rated for the following reasons:

- **Ageing**: Fatigue of certain components in an engine which may lead to failure. So, it is necessary to lower the power output of the engine in order to maximize availability of the generator.

- **Mechanical constraints limiting power output**: Examples include the surging of turbo chargers or excessive vibrations of engines’ components if operated at name-plate ratings.

- **Electrical Constraints**: These may occur when the power transmission lines are already overloaded and cannot take all the power from a power plant.

Out of a total effective capacity of 56 MW in hydro power generation in Mauritius, only 25 MW is assumed as firm power and is used in the demand-supply matrix. Power outputs from hydro plants are dependent on rainfall and dam levels. Hence, it is not appropriate to assume full hydro capacity for planning purposes.

The Effective Capacities of IPPs are generally assumed, as mentioned in the respective PPAs. For the purpose of the Demand-Supply Balance exercise, a prudent approach has been adopted, whereby effective capacities in ‘bagasse’-mode are used rather than that in coal-mode operation. The main reason for adopting this approach is based on the fact that the system peak demand of the country usually occurs in summer, and during these periods, IPPs are using ‘bagasse’ to generate electricity.

Planned Maintenance

The second important parameter used in the demand-supply balance matrix is the planned maintenance outage, which caters for the downtime of major components, such as engines, boilers and turbines. CEB’s records show that the maximum combined capacity which can be out of service, due to planned maintenance, can be as high as 120 MW in a year. Figure B2.1 on the next page illustrates the capacity not available, due to planned maintenance, on a monthly basis for the last 3 years.

It can be noted that during the first five months in each year, there had been a reduction in the availability of generation capacities. This is due to existing IPPs’ plants being planned for maintenance in the first half of each year after continuous operation during the sugar-cane crop season. To avoid a further fall in availability of capacity, maintenance of the CEB’s generators is carried out during the second half of the year.

For the purpose of capacity planning, an average value of 60 MW is assumed for planned maintenance.
Unplanned Outages (Breakdowns)
Despite having scheduled maintenance, some engines or boiler turbine system may encounter unexpected fault which force the ceasing of their operations. Breakdowns are inherent in power plants. As good planning practice, unplanned outage should also be catered for when planning the need for additional generation capacity. It is therefore very critical to factor it into the demand-supply matrix. Generally, in the worst case scenario, the largest generator connected to the grid is assumed to be on forced outage.

In the Mauritius power system, the largest unit connected to the grid is a 37 MW boiler turbine system located at the CTSav power plant. Thus, in the demand-supply matrix, this figure is assumed as forced outage.

Spinning Reserve
Spinning reserve refers to generating capacity that can be called on in a few seconds to supply power in the event of sudden load increases or unit failures. The generator(s) for such reserve should already be in operation on spinning mode. This is essential so as to avoid the time delay required to bring up an engine to full power from a cold-start condition and synchronizing it with the system grid.

There are actually two practices adopted to cater for spinning reserve in planning. First, a spinning reserve capacity equivalent to the largest unit connected to the grid may be opted. Alternatively, a factor equal to ten percent (10%) of the prevailing load on the system can be used. In the CEB’s case, the second option is chosen as it is more in line with normal utility practice for small island systems.

Reserve Capacity Margin
The reserve capacity margin (RCM) is expressed as a percentage and is determined as follows:

\[
\text{RCM} = \frac{\left( \sum_{i=1}^{n} \text{Effective Capacity}_i - (\text{Capacity Out})_{\text{Mtie}} - (\text{Capacity Out})_{\text{Bdown}} \right) - (\text{Forecasted Peak Power} + 10\% \text{ Spinning Reserve})}{(\text{Forecasted Peak Power} + 10\% \text{ Spinning Reserve})} - 1
\]

where,
- \( n \) total number of generating units connected to the grid;
- \( (\text{Capacity Out})_{\text{Mtie}} \) maximum capacity that is assumed to be unavailable due to maintenance;
- \( (\text{Capacity Out})_{\text{Bdown}} \) largest generating unit assumed to be unavailable due to breakdown.

Usually, the RCM is kept at a threshold of minus 5%, which gives the appropriate level of confidence to meet demand. Where the RCM value falls below this
threshold, the need for additional capacity to restore supply confidence is triggered.

**Firm Capacity versus Non-Firm Capacity**

As discussed earlier, CEB is already contemplating the addition of a few power projects for the short term. However, only *firm* power generations are considered in the demand-supply balance matrix. By definition, a *firm* power plant is one whose power is available at scheduled times and at controllable levels. For instance, only one of the power projects, listed in Section 5.2.4, is classified as *firm* power plant. It is the CT Power Coal Plant.

A *non-firm* (also called variable) power plant is defined as a power plant whose capacity availability cannot be scheduled with certainty. The power supplied is typically based upon availability of renewable energy sources.

Therefore, renewable energy projects are considered as *non-firm* power and are not included in the demand-supply balance matrix. Figures B2.2(a) and B2.2(b) below illustrate the power output profile of a typical *firm* power plant and a *non-firm* power plant.

**Selection of Least-Cost Generation Addition**

While formulating a new generation plan, a number of technical, economic and new generation plant assumptions are made. First, one should know what type of technology to adopt and what capacity to install. To sort out these issues, a thorough analysis of the evolution of Load Duration Curves (LDCs) is required.

A LDC is similar to a load curve, but the demand data is arranged in descending order of magnitude. The area under the LDC gives the total energy generated for the period under study. The maximum value on the y-axis is the peak power demand. The first 1000 hours represent the peak loads registered in a given year. Figure B2.3 on the next page shows the evolution of CEB’s LDCs from 2002 to 2011.

Generally, the LDC can be subdivided into three areas, namely: base load, semi-base load and peak load. The first 1000 hours is normally assumed to be the peak load, while the position where the LDC starts to kink vertically shows the base load. The region between the peak and the base load areas is referred to as the semi-base load. These three areas are shown in the LDC (Figure B2.3 on the next page) of the year 2002.

Sustained growth in any of the three areas dictates the type of plant technology to be installed. Using historical trends and demand profiles of future load additions, the LDCs of future years can be forecasted. These LDCs show the growth in either base, semi-base or peak regions. Generally, the following rules, as described in Table B2.1, are adopted to select the best generation technology.

**Screening Curves**

After the appropriate technology has been chosen, the economic aspects of the candidate plants are analysed. The screening curve approach provides a way to view the trade-offs of the different available power

<table>
<thead>
<tr>
<th>Table B2.1: Preferred Generation Technology for each Type of Load</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Anticipated Load Growth in Load Duration Curve</strong></td>
</tr>
<tr>
<td>Base</td>
</tr>
<tr>
<td>Semi-Base</td>
</tr>
<tr>
<td>Peak</td>
</tr>
</tbody>
</table>
generation technologies, in terms of investment and operating costs.

Basically, the screening curve provides a preliminary understanding of the competitiveness of the different plants (options) at varying capacity factors. From an economic point of view, if the expected load factors of candidate plants are known, the screening curve will illustrate which options are most cost-effective to operate.

From Figure B2.4 below, it can be observed that the gas turbines have the lowest investment costs but the highest operating costs. As such, it is not financially sound to run gas turbines permanently. However, if it is operated below 10% utilization factor - that is, for peaking periods only in a year - it becomes an interesting option. Other technologies, for example coal, have higher initial investment costs but lower operating costs. Therefore, they are best suited for base load (continuous) operations.

**Capacity Sizing**

The sizing of generating units is very important in capacity expansion planning. Normally, if base plants are to be installed, they are sized according to the peak demand. A factor of 10% of the predicted system peak is used as an estimate for the unit size of a base plant.

In case a semi-base plant (medium-speed diesel) is required, generating units of 12 to 18 MW are most commonly used, as they are readily available worldwide. Moreover, these modular-sized generating units offer the advantage of dispatching the units, as and when required. It is more flexible to connect smaller-sized units for semi-base loads than adding a big generator and operating it at poor efficiency.

As far as sizing of peaking unit is concerned, it depends on how the peak load will evolve in the future. Nevertheless, units, which will be installed for this purpose, will remain available at all times for peak shaving and be synchronized to the grid in minimum time. If well-maintained, a peaking unit can offer a long operating life.

**Timing**

Another essential factor to consider, while carrying out a capacity expansion planning, is timing. Timing
ensures that new generators will be available on time to meet the forecasted peak demand. Therefore, planning to construct a power plant should be done well in advance so that demand can be met in the future. Table B2.2 below gives an idea of the construction period for each type of power plant.

<table>
<thead>
<tr>
<th>Types of Plant</th>
<th>Construction Time (Months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Turbine</td>
<td>12 to 15</td>
</tr>
<tr>
<td>Medium/ Slow Speed Diesel</td>
<td>18 to 24</td>
</tr>
<tr>
<td>Pulverized Coal</td>
<td>30 to 36</td>
</tr>
<tr>
<td>Dual-Fired Coal/Bagasse</td>
<td>24 to 30</td>
</tr>
<tr>
<td>Combine Cycle</td>
<td>30 to 36</td>
</tr>
<tr>
<td>Hydro</td>
<td>9 to 12</td>
</tr>
</tbody>
</table>
Energy generation estimates are essential for budgetary purposes. The methodology adopted to work out the energy generation estimation is detailed hereunder.

**Assumption on Network Losses**

Network loss is an essential input in gross generation estimation. It is generally expressed, as shown in the formula below, as a percentage difference between total energy sent-out from power plants and total energy sales.

\[
\text{Network Loss} = \frac{\text{Total Energy Sent Out} - \text{Total Energy Sales}}{\text{Total Energy Sent Out}} \times 100
\]

Network losses can be divided into technical and non-technical losses. Technical losses take into account both transmission and distribution losses, while non-technical losses include energy loss due to fraudulent actions. The line graph in Figure B3.1 below shows the evolution of network losses over the last decade in Mauritius.

It can be observed that the network losses of the country are continuously improving. However, there is a limit to which the system losses can be reduced. For the planning period, CEB has assumed a network loss of around 8%.

**Assumptions regarding Used-on-Works**

Power plants’ auxiliaries consume electricity, and this value is quite significant. The auxiliary consumptions of IPPs are excluded in the estimation, as CEB is concerned with their sent-out energy only. As regards to CEB’s power stations, the amount of energy used on works is generally estimated to be in the range of 3.5% to 4% of the total energy generated. CEB has assumed that the units used on works will be around 4%.

**‘Take-or-Pay’ Contracts**

CEB has Power Purchase Agreements with IPPs. In these agreements, CEB has guaranteed purchase of a minimum amount of energy. Therefore, when electricity production plan is being prepared the contractual obligations with the IPPs have to be respected. Table B3.1 below shows the IPPs with which the CEB had signed ‘take-or-pay’ contract and the corresponding minimum annual quantity of energy agreed.

<table>
<thead>
<tr>
<th>IPPs</th>
<th>(GWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTBV</td>
<td>325</td>
</tr>
<tr>
<td>FSPG</td>
<td>160</td>
</tr>
<tr>
<td>CEL</td>
<td>110</td>
</tr>
</tbody>
</table>

**Energy Generated by Renewable Sources**

Unlike capacity planning, renewable energy is taken on board in energy planning exercises. Since CEB has hydro power plants, the energy generation estimates from these power plants are based on historical data. Generally, there are dry and rainy years, but an average of 90 GWh is assumed for hydro power generation.

Given that wind and solar photovoltaic farms will be introduced soon, the forecasted annual energy generation from these sources is estimated using the capacity utilization factor (CUF). The annual energy generation can then be estimated as follows:
For upcoming wind farms in Mauritius, the typical CUF may range from 20% to 35%, depending on wind availability on the site. On the other hand, the CUF for solar PV farms may vary from 12% to 20%, depending on the insolation level at the particular site.

Energy Allocation Methodology
The area under the load duration curve (LDC) gives the total energy generated. As discussed above, there are three distinct regions under the LDC, namely, the base, semi-base and peak energy areas.

Based on an analysis of historical behaviour of LDCs, the base energy represents about 60% of the total energy generated. Likewise, the semi-base and peak energy represent about 39% and 1%, respectively. Figure B3.2 below shows the energy allocation in the 3 regions of a typical LDC.

From the energy sales, the Gross Energy Generation is calculated as follows:

<table>
<thead>
<tr>
<th>Gross Energy Generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>= Energy Sales + Used-on-Works + Network losses</td>
</tr>
</tbody>
</table>

Once the gross energy generation is calculated, it is then broken down in the base, semi-base and peak energy proportionately, as mentioned above.

The base energy is supplied mainly by all existing IPPs and the Fort George Power Station. The semi-base energy is generally provided by the medium-speed diesel engines located at the Saint-Louis Power Station and Fort Victoria Power Station. The demand for peak energy is usually met by the Nicolay Power Station and the Champagne Hydro Power Station.
Transmission and Distribution planning is the process of ensuring safe flow of electricity from generation sources to various substations at high voltage, and ultimately to end-users after stepping down to low-voltage level. The process of network planning is mainly dependent on inputs from load forecast and generation planning. The methodology adopted for transmission and distribution network planning over the planning period 2013-2022 is presented in the following sections.

Transmission Network Planning

For the transmission network planning, the following are considered:

‘N minus 1’ Security Criterion

The transmission network consists of high-voltage transmission lines and 66 kV-to-22 kV substations. The transmission plan is mainly based on the ‘N minus 1’ security criterion, which requires the transmission system to be in a position to supply the total connected load under both normal and abnormal conditions. The abnormal condition refers to the isolation during fault condition or out of service, due to maintenance of either one transmission line or one power transformer. Under the ‘N minus 1’ security criterion, the maximum loading of equipment in the transmission network is limited to 50%.

Input to the Transmission Planning Process

The transmission network plan is largely driven by the loading of the substations and the location of new generation facilities. Inputs to the planning process are thus the spatial load forecasting and generation forecast as shown in the Figure C1.1.

The generation expansion plan mainly impacts on the transmission lines and the 66 kV busbar system requirements, while load demand impacts on the 66 kV-to-22 kV power transformers, 22 kV busbar loadings, reactive power compensation requirements and the 66 kV network.

Integrating the Load Forecast

The demand forecast is usually prepared for three scenarios; namely low-case, base-case and high-case. In order to reduce the risk of over-investment in transmission facilities, the 10-year transmission network plan considers the base-case load forecast.

The daily load demand profile of the CEB’s system has three peaks referred to as: the morning peak, day peak and evening peak. The time at which a substation experiences its maximum demand depends on the predominant customer category (whether residential, commercial or industrial) connected to the substation. The forecasted system peak and substation demand correspond to the day-peak. Consequently, the loading of the substations during evening peak and morning peak over the planning period have to be estimated by scaling the substation forecast appropriately.

Integration of the New Generation Facilities

The locations of new generation facilities are provided by the generation forecast. However, if the locations are unknown, a number of scenarios are evaluated
a geographical basis and the most favourable injection points are ranked, in terms of the least-cost investment transmission facilities.

**System Initialization and Study Cases Development**

In order to perform power system studies and ultimately formulate a transmission expansion plan, a calibrated transmission model that reflects actual loading condition is required. The CEB’s transmission model was developed using the DIgSILENT Powerfactory Software. The current base-case model developed reflects the load flow condition during the system peak demand of 430 MW recorded on Wednesday 22nd February 2012 at 14:00 hours.

**Determining the Requirements for Transmission Lines and Power Transformers**

For each year of the planning period, the power system is simulated under different network set-ups and conditions to identify the least-cost network expansion solution. In this exercise, the following studies are performed:

- Load flow study to determine transmission line loadings and voltage profile. The resulted loadings guide the upgrade and/or adding of new transmission lines and power transformers so as to meet the increase in the load demand and satisfy the ‘N minus 1’ security criterion.
- Transient stability study to identify the interconnection facility requirements for both conventional and renewable generation power plants.
- Reactive power study identifies the need for reactive power compensation to maintain the voltage profile within the regulatory requirements and reduces power loss.
- Fault level study to determine the fault level at the 66 kV busbars, following the addition of generating units and transmission lines, and assess the need for busbar system upgrade.

**Reactive Power Compensation**

Reactive power compensation is required at the 22 kV busbar of the 66 kV-to-22 kV substation in order to supply the reactive power demand at the substation. Generally, the adopted approach is to provide for reactive power compensation at substations located far from power plants. Having reactive power compensation at substation helps in minimizing the reactive power flow along the transmission network and, thereby, reducing the power loss and voltage drop.

In order to determine the need for reactive power compensation, the following power factors are assumed:

- a power factor of 0.92 lagging for generating units; and
- a power factor of 0.98 lagging for medium-voltage side power transformer.

**Fault Levels**

Fault levels are largely affected by the addition of generating units and new transmission lines to the system. In this respect, fault level studies are carried out on the DIgSILENT Powerfactory Software. The standard used by the software to perform these calculations is IEC 60909.

For the purpose of this IEP, fault level studies have been performed for the year 2014, 2016 (associated with the commissioning of two new 50 MW generation units) and 2022 (end of the study period and associated with the commissioning of two additional 50 MW generating units) to identify the need for upgrading of the 66 kV busbar system at the older 66 kV-to-22 kV substations.

**Distribution Network Planning**

In preparing the distribution network plan, the following are considered:

**Planning Criterion**

The planning criterion for the medium-voltage distribution network is to have the distribution feeders loaded at 50% of their rated capacity at the instant of the peak system demand so that the distribution feeder can take up the whole load on an adjacent distribution feeder during a contingency on the supply side of that feeder. Figure C1.2 on the next page illustrates this condition.

Adherence to this planning criterion would require limiting the load on a distribution feeder, having conductors size 150 mm², to some 6 MVA under normal network conditions while ensuring compliance with the regulatory requirement of maintaining supply voltage within ±6% about the nominal value of 230 Volts at customers’ terminals.

**Distribution System Expansion**

As the loading of the medium-voltage distribution feeder approaches 50% of the rated capacity, distribu
tion network reconfiguration or initiation of a new distribution feeder is proposed to share the load growth. Given the cost implications associated with a new feeder, the load growth of the region supplied by the existing feeder is determined to ascertain the requirement for the new feeder.

Methodology to Study the Impact of Renewable Energy (RE) Integration
The integration of variable renewable energy in a power system has negative impact on the system frequency and voltage profile.

The maximum capacity of renewable energy that can be safely integrated in the system is the maximum capacity that will maintain the system frequency and voltage level within the regulated operating limits.

Limit on RE Integration due to Regulatory Requirement on Frequency
In order to assess the stability of a network, dynamic models of the frequency and voltage control systems of generation units are required. CEB’s models have been developed in the DIgSILENT Powerfactory Software, using the IEEE standard models and have been validated through field tests and measurements.

It is required to determine the maximum level of renewable energy integration sustainable for the CEB’s system, while adhering to the operational frequency limits within ±1% of the nominal value of 50 Hz and the voltage within ±6% of the nominal value.

The block diagram of the power system model, with the associated variables, in the frequency-domain is shown in Figure C1.3 on page 143.

The frequency response of the power system is different for the low-demand conditions and high-demand conditions, due to different amount of spinning reserve and system inertia. Higher load demand is associated with higher level of spinning reserve and higher system inertia, therefore, the impact of variable renewable energy on the system frequency is less.

For each of the low-demand and the high-demand conditions, the maximum level of variable renewable energy that can be integrated has been determined by increasing the level in step and determining the corresponding maximum system frequency deviation, which is caused by the variable power output from the renewable energy farms.

The maximum renewable energy integration is taken as that value which brings a maximum operational system frequency deviation of ±0.5 Hz.

Limit on RE Integration due to Regulatory Requirement on Voltage
In addition to the above, steady-state models of typical medium-voltage distribution feeders and low-voltage distributed feeders have been developed; where the electrical lines, transformers, loads and equivalent grid system have been accurately modelled. Figure C1.4 on the next page illustrates the model of distribution feeder using a lumped load approach. The
**FIGURE C1.3: Block Diagram in the s-domain for the Active Power-Frequency System**

<table>
<thead>
<tr>
<th>Generating unit 1</th>
<th>Generating unit 2</th>
<th>Generating unit N</th>
<th>Wind Farm</th>
<th>Solar Farm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Model of prime movers, governors and generators

Model of rotating parts and load demand

\[
2s \sum_{i=1}^{N} H_i S_{base,i} \]

\[
W_{pu} = P_{load}(s) - \sum P_{gen}(s)
\]

**Index identifying a generating unit**

**N**  
*Number of generating units in the power system*

**S_{base,i}**  
*Apparent power rating of the \(i\)th generator in MVA*

**P_{load}**  
*Total active power demand of the system in MW*

**P_{gen}**  
*Total active power generated in MW*

**W_{pu}**  
*Electrical angular frequency in per-unit*

**H_i**  
*Inertia constant of the prime-mover and alternator combined for the \(i\)th unit in MJ/MVA*

**s**  
*Laplacian operator*

**FIGURE C1.4: Model of Distribution Feeder using a Lumped Load Approach**

maximum level of renewable energy that can be integrated on a low-voltage feeder and a medium-voltage feeder has been determined by increasing the level of renewable energy in step until the voltage reaches the upper limit of \(\pm6\%\) of the nominal value.
**66 kV-to-22 kV Substation.** The purpose of a substation is to transform electrical energy at different voltages levels for distributing power to regional centres such as villages, industries, and commercial centres. Substations are normally sited near densely populated areas and various switchgear combinations and layouts are employed in the substation design. In Mauritius, a typical substation will transform 66 kV power to 22 kV or 22 kV power to 6.6 kV for distribution purposes.

**AGOA.** Stands for African Growth and Opportunity Act which was signed on May 18, 2000. Under this Act, the United States of America offers tangible incentives to targeted African countries to continue their efforts to open up their economies and build free markets.

**Air Dispersion Simulation Model.** A mathematical model describing how air pollutants disperse in the ambient atmosphere. Computers are used to solve the mathematical equations underlying the model.

**Automated Meter Reading.** Technology of automatically collecting consumption, diagnostic, and status data from electric meters and transferring that data to a central database for billing, trouble-shooting, and analysing.

**Automatic Voltage Control (AVC).** The automatic voltage control is found on transformers and generators. It is used to control the voltage at the terminals of the equipment.

**Auxiliaries.** These include all the components and circuits, except the engine block, involved in the generation of electricity at a power station.

**Busbar.** The common connection point of two or more electrical circuits.

**Capacitor.** It is a fundamental element of the electrical circuit along with the inductor and resistor. The capacitor is a source of reactive power (See below for reactive power).

**Capacity and Energy Charges.** Capacity Charge is the amount payable to the IPPs for the guaranteed Power Output capacity to the CEB’s grid. Energy Charge is the amount payable based on the units produced.

**Capacity Utilization Factor (CUF).** Similar to Load Factor.

**Continuous Emissions Monitoring Systems (CEMS).** A tool to generate information on combustion in industrial set-ups by monitoring the content of oxygen, carbon monoxide and carbon dioxide in flue gas.

**Continuous Power Producers (CPPs).** In Mauritius, CPPs refers to sugar factories which generate electricity from ‘bagasse’ during the crop season and export it to the CEB’s grid.

**Cross-Linked Polyethylene (XLPE).** A special type of plastic used as insulation material in medium- to high-voltage cables.

**Cross-Subsidisation.** Subsidizing the prices of electricity paid by low-usage groups from revenue generated from other end-users in different customer groups.

**Daylight Saving Time.** The practice of advancing clocks so that there is more daylight in the evenings.

**Demand-Side Management (DSM).** Methods of managing electrical resources that affect a customer’s end-use, rather than the supply, of electricity. It includes, but is not limited to, energy-efficient lighting and load control apparatus.

**Demand-Supply Balance Matrix.** A matrix used to compute the value of Reserve Capacity Margin (RCM), while taking into account the updated effective capac
Dispatching Order. It is the order of priority to start generators based on their marginal cost of production. Generally, the generator with the cheapest marginal cost of production is dispatched first followed by the more costly ones to meet demand.

Disposable Income. The amount of money left for spending and saving after income taxes have been deducted from a household’s income.

Distributed Generation (DG). Relatively small-sized generators that are connected to the distribution network.

Econometric. Application of Mathematics and Statistical methods to economic data. Described as the branch of Economics that aims to add empirical content to economic theory, by allowing theories to be tested and used for forecasting and policy evaluation.

Effective Capacity. It is the de-rated capacity of a generator, due to ageing and/or mechanical/electrical constraints inherent in the generator system.

Energy Supply and Purchase Agreement (ESPA). Similar to PPA, but applies only for the purchase of energy by a utility. Usually applies in the contracts of renewable energy projects.

Energy Used-On-Works. The energy consumed by the auxiliaries of a power plant during its operation.

Environmental Cost. It is defined as the expenditures incurred to prevent, contain, or remove environmental contamination that occurs from electricity generation. Environmental costs are the indirect costs that include the full range of costs throughout the life-cycle of electricity generation from any sources of fuel.

Environment Impact Assessment (EIA). An assessment of the possible positive, or negative, impact that a proposed project may have on the environment, while considering the environmental, social and economic aspects.

Environment Stewardship. Use and protection of the natural environment through conservation and sustainable practices.

Environment and Land Use Appeal Tribunal (ELUAT). The ELUAT was established under the Environment and Land Use Appeal Tribunal Act 2012 in order to hear appeals relating to matters that are directly or indirectly related to the environment and the manner in which land is made use of.

Environmental Sustainability. Making responsible decisions that will reduce businesses’ negative impacts on the environment. It is not simply about reducing the amount of wastes produced, or using less energy, but it is also concerned with developing processes that will lead to businesses becoming completely sustainable in the future.

Fault Analysis. The mathematical solution that enables the determination of the magnitudes and flows of electrical current that occur during a short circuit. These are required to size equipment properly so as to withstand the electro-dynamic and thermal effects of faults and determine Protection Relay settings.

Feeders. An electrical line outgoing from a substation to supply customers’ premises.

Feed-In Tariff (FIT). Pricing mechanism designed to accelerate investment in renewable energy technologies. This is achieved by offering long-term contracts to renewable energy producers, typically based on the cost of generation of each technology.

Flue Gas Analyser. An instrument that is used to measure both the efficiency of combustion and the levels of pollutant gases.

Forced Outage. Similar to Unscheduled Outage.

Gross Domestic Fixed Capital Formation (GDFCF). A statistics prepared by the Statistics Office of Mauritius to indicate the investment in specific sectors in Mauritius.
**Generation Mix.** Diversity of fuels used for power generation.

**Generator Trip.** An unforeseen stopping of a generator, due to either an internal or external fault.

**Geographical Information System (GIS).** Integrates hardware, software, and data for capturing, managing, analysing, and displaying geographically referenced information.

**Generation Expansion Planning.** Process to plan power plant projects so that enough capacity is available at the appropriate time in order to meet forecasted demand.

**Governing System.** It controls the speed and power output of the prime-mover, which may be a diesel engine, steam or hydraulic turbine.

**Greenhouse Gas (GHG).** Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, which absorb and emit radiation at specific wave-lengths within the spectrum of infra-red radiation emitted by the Earth’s surface, the atmosphere and clouds. This property causes the greenhouse effect. Water vapour ($H_2O$), carbon dioxide ($CO_2$), nitrous oxide ($NO_2$), methane ($CH_4$), and ozone ($O_3$) are the primary greenhouse gases in the Earth’s atmosphere. However, there are a number of human-made greenhouse gases in the atmosphere, such as halocarbons and other chlorine and bromine containing substances.

**Grid Absorption Capacity (GAC).** Maximum amount of variable renewable power that a grid can accommodate, without any adverse impacts on the grid’s reliability and security.

**Grid Emission Factor (GEF).** It is defined as the amount of GHGs emitted from one unit of electricity that is generated and exported to the national grid. The GEF is expressed as tons of $CO_2$ emitted per MWh of electricity produced [$tons CO_2/MWh$]. The GEF is calculated by taking into account all the generation technologies that are used in the power system and the emissions calculated based on average of each type of fuel.

**Gross Domestic Product (GDP).** Total value added from all economic activities in a country; that is, the total value of goods and services produced.

**High Voltage (HV).** It refers to systems normally operating at a voltage above 35 kVac and not exceeding 230 kVac.

**Independent Power Producers (IPPs).** Large Private Generators selling electricity to CEB.

**Interconnection Facilities.** The electrical wires, switches and related equipment that are required to interconnect an IPP to the CEB’s network.

**Landfill Gas.** Complex mix of different gases created by the action of micro-organisms within a landfill.

**Latent demand.** Demand which exists but currently inactive. It may become active under certain conditions.

**Least-Cost Policy.** Developing the power system at the least cost possible.

**Liquefied Natural Gas (LNG).** LNG is natural gas (predominantly methane, $CH_4$) that has been converted to liquid form for ease of storage or transport.

**Load.** The amount of electric power delivered or required at any specific point or points on a system. The requirement originates at the energy-consuming equipment of the consumer.

**Load Duration Curve (LDC).** A graph of system load, expressed in MW, versus hours. The value of the x-axis, being the number of hours the load is at and the y-axis shows the value in Megawatt.

**Load Factor.** The ratio of the units of electricity generated by a generating unit to that theoretically possible if the generating unit was operated at full-rated load.

**Load-Flow Analysis.** The mathematical solution that enables the determination of voltages and power flows in the power system. These are required to size equipment correctly for continuous operation and to determine the network’s upgrades and expansion.

**Load Management.** The management of load patterns in order to better utilise the facilities of the power system. Generally, load management attempts to curtail load or shift load from the peak-use periods to other periods of the day or year.
**Long-Term Energy Strategy (LTES).** A roadmap developed by the Government of the Republic of Mauritius to address the energy and environmental challenges lying ahead.

**Long-Run Marginal Cost (LRMC).** The change in the long-run total cost of producing a good or service resulting from a change in the quantity of output produced.

**Low Voltage (LV).** It refers to systems normally operating at a voltage not exceeding 1000 Vac.

**Marginal Cost.** The cost to the utility of producing the next (marginal) kilowatt-hour of electricity, irrespective of sunk (or fixed) costs.

**Marginal Propensity to Consume.** Proportion of the disposable income which individuals desire to spend on consumption.

**Medium & Large International-Market Focussed Firms.** These are commercial customers having declared electric load above 20 kVA and activities geared towards the international market.

**Medium & Large Domestic Market-Focused Firms.** These are commercial customers having declared electric load above 20 kVA and activities geared to satisfy the local market.

**Master-Slave Configuration.** Mode of operation, whereby the AVC (see above) of one transformer, selected as the ‘master’, instructs its associated transformer to perform a tap change, and then immediately afterwards instructs the other transformers, the ‘slaves’, to perform a tap change.

**Maurice Ile Durable (MID).** A federated concept to make Mauritius a world model of sustainable development.

**Medium-Scale Distributed Generation (MSDG).** Distributed generation of capacity greater than 50 kW, and not exceeding 4 MW.

**Medium Voltage (MV).** It refers to systems normally operating at a voltage above 1000 Vac and not exceeding 35 kVac.

**Merit Order Dispatching Plan.** Same as Dispatching Order (see above).

**Multi-Year Regulatory Period (MYRP).** Normally it is desirable to have a period of stable tariff in real terms. The duration that a tariff structure shall remain unchanged is usually referred as the multi-year regulatory period.

**National Environment Standards (NES).** Standards that form an integral part of the current Environmental Legislation. The NES sets limits on the emissions to the land, water and air for specific environmental parameters, which may have an impact on the environment.

**National Income.** Total value of a country’s final output of all new goods and services.

**National Physical Development Plan (NPDP).** Guidelines prepared and managed by the Ministry of Housing and Lands.

**Network Losses.** The sum of the electrical energy lost as heat in the transmission and distribution networks, due to the flow of electricity.

**Network Reconfiguration.** Switching operations with the objective of relieving heavily-loaded feeders by redistributing the excess load to adjacent feeders.

**Opportunity Cost.** The opportunity forgone for not investing in the next best project as a consequence of the fund being tied up in an actual project.

**Photovoltaic.** It is a technology to generate electricity by conversion of solar radiation into electricity. Planned Maintenance. Maintenance of power plant with prior notice.

**Power Demand.** The amount of electrical energy required at any specific point or points on a system. The primary source of demand originates at the energy consuming equipment or appliance of the consumer. Often used interchangeably with ‘Load’; however, demand is generally associated with customers’ requirements, whereas load is generally associated with the technical impact and requirements of the electric system.
Power Factor. In the field of electricity, power factor is the ratio of the active power to the apparent power.

Power Loss. The rate of loss of energy in the form of heat, due to current flowing in lines and transformers (load losses) and voltage being continuously applied on power system equipment (no load losses).

Power Purchase Agreement. Legal contract signed between an IPP and CEB. Normally the duration of such contract is 20 years.

Pulverized-Coal Technology. This technology is based on generating thermal energy in a boiler by burning powdered coal or coal dust. It is more efficient, compared to conventional coal combustion methods, as the fine coal particles provide improved combustion.

QA/QC System. Quality Assurance (QA) is the process or set of processes used to measure and assure the quality and reliability of the data. Quality Control (QC) refers to the verification and validation of the data.

Quality of Supply. This comprises both the reliability of supply and the power quality. A reliable supply has few interruptions and low durations of interruptions. A good power quality means that voltage and frequency are within the statutory limits.

Radial Configuration. The philosophy of operating the distribution network such that power flows uni-directionally from the substation to the customers.

Reactive Power. The component of power which is interchanged between the source and reactive elements to establish electrostatic and magnetic fields. The energy associated with this component is zero. Reactive power is required to meet the reactive needs of the transmission system and reactive loads, such as motor drives, fluorescent lighting, and other end uses. The unit of reactive power is the VAr and the consumption of reactive power is the VArh, similar to the unit of active power which is the kW and its consumption the kWh.

Reactive Power Compensation. The injection of reactive power into the network to provide voltage support and control, as well as to increase the power transfer capability of the transmission system.

Real Disposable Income. Disposable income adjusted for inflation.

Reliability. Electric system reliability has two components: adequacy and security. Adequacy is the ability of the electric system to supply customers at all times, taking into account scheduled and unscheduled outages of system facilities. Security is the ability of the electric system to withstand sudden disturbances, such as electric short circuits or un-anticipated loss of system facilities.

Renewable Energy. The energy obtained from natural resources such as the sun, wind, rain, waves, bio-mass, geo-thermal heat and tides that replenish themselves over short periods of time.

Renewable Energy Master Plan. A report under preparation at the level of Government, which will provide a road-map to integrate renewable energy technologies in the current energy mix, with the objective to meet the targets set out in the Long term Energy Strategy (LTES) 2009-2025.

Reserve Capacity Margin (RCM). Electric power systems need to have excess capacity to assure reliability in meeting demand in the event that a power plant breaks down or a transmission line shorts out. The amount of excess generation capacity needed for such reliability is often referred to as a reserve margin.

SCADA. Supervisory Control and Data Acquisition. This is the computerised system which monitors the status of the electric network, generating stations, and power flows and remotely controls the switchgear at substations.

Scheduled Maintenance. Similar to Planned Maintenance (see above).

Screening Curve. It is a graph having Investment Cost in the vertical axis and Load Factor (see above) on the horizontal axis. It is used to compare the competitiveness of different power generation technologies for base, semi-base or peak load.

Semi-Base Load Generators. These generators are designed to start operation in the morning and stop at night. They are generally relatively economical, when operating at load factors in the range of 20% to 70%.
**Short Circuit Level.** It is the maximum flow of electrical current during a short-circuit fault.

**Small Independent Power Producer (SIPP).** Owners of the SSDG are referred to as SIPP's.

**Small Local-Market Focussed Firms (SLMF).** For the purpose of electricity demand forecast, firms having declared load below 20 kVA have been identified and categorised as SLMF firms.

**Small (Micro/Mini) Hydro Technologies.** There are different definitions for micro- and mini-hydro power plants worldwide. In our context, the capacity of micro-, mini- and small hydro units, connected on the low voltage distribution network, are defined in the SSDG Grid Code. For the purpose of this IEP, micro/mini-hydro unit has been considered as small hydro unit. A small hydro power plant is one having a generation capacity below 1 MW.

**Small-Scale Distributed Generation (SSDG).** Renewable energy generators dispersed over the island with installed capacity less than or equal to 50 kW.

**Smart Grid.** Any combination of supporting technologies that together make the grid more reliable, secure and efficient. In practice, it is mainly the application of Information Technology to a utility’s grid.

**Smart Meters.** A meter incorporating communication facilities that enable two way communications between the meter and the central system. The communication facilities may be used to obtain time-varying information about the load and perform remote switching.

**Spatial Load Forecast.** It refers to forecasting where future electric demand will arise in addition to how much the demand will be and when it will occur.

**Spinning Reserve.** Fast-response capability held on partly-loaded, synchronized generators to compensate for any sudden change in demand, network frequency, or generator outage. CEB usually takes 10 percent of peak demand as spinning reserve.

**Spreader-Stoker technology.** A coal-burning system whereby mechanical feeders project the coal pieces into a travelling grate for combustion.

**Spur Lines.** Branch-off from the main distribution line with a total connected transformer capacity of less than 1000 kVA.

**Stability Analysis.** A numerical method to determine the variation of a generating unit's rotor position over time, following a fault on the network. The stability analysis is critical and performed at the outset of network expansion.

**Stochastic.** Means randomness. Stochastic variables have probability distributions.

**Sustainable Development.** Meeting the needs of the present generation without compromising the ability of future generations to meet their own needs.

**Switchboard.** Assembly of switchgears (see below), each with their respective protection and monitoring equipment. It receives power in bulk and distributes it in smaller amounts to feeders, transformers etc.

**Switchgears.** It comprises all the switches, switch-fuses and circuit breakers that are used to interrupt load and fault current and isolate specific items of plant.

**Switching Operations.** A sequence of switching of electrical switches for purposes, such as de-energizing and isolating a specific item of a circuit for maintenance, repairs, replacement and re-routing power through alternate paths.

**Switching Stations.** Stations that may be at distribution or transmission levels. They do not contain power transformers and operate at a single voltage level. Their functions are: to provide a connection point for several circuits; to provide alternate power paths; and to distribute power.

**System Control Centre.** Refers to CEB’s operating unit responsible for centralised dispatch of generating units and grid operation within the network.

**System Inertia.** The capacity of the power system to resist to changes in frequency, owing to variations in load demand and power generation.

**System Load Factor.** The ratio of units generated in a year to that theoretically possible at peak demand over a year.
System Security/Stability. The ability of the electric system to withstand sudden disturbances, such as electric short circuits or un-anticipated loss of system facilities.

Tap Changers. Transformers are generally equipped with tap changers, which allow the control of the terminal voltage.

Tariff Shock. A sudden high increase in tariff leading to high rise in consumers’ bills.

Technical Efficiencies. Advancement in technology resulting in higher output with the same input.

Tele-Protection Relaying. Use of Fibre Optics Communication Systems to perform system’s protection.

Time-Of-Use Tariff. A tariff offered by an electric utility, where the price of electricity depends on the time when the electricity is consumed.

Transmission line. The portion of the transmission system between two or more circuit breakers, but excluding busbars and generating circuits.

Unit protection. A protection scheme designed to protect specific equipment only.

Unscheduled Outage. An outage occurring due to an unplanned event, such as an equipment breakdown.

Waste Management. The collection, transport, processing or disposal, managing and monitoring of waste materials. The term usually relates to materials produced by human activities; and the process is generally undertaken to reduce their effects on health and the environment or aesthetics.

Wind Turbine Generator (WTG). A device that is used to convert the energy from wind into mechanical energy and further into electrical energy.
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Comments
CEB Board
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