TIMES model for the Reunion Island: Addressing reliability of electricity supply

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### Power sectors: a period of changes

1. **Numerous challenges:**
   - Constraints on carbon emission
   - Depletion of fossil fuels
   - Population densification
   - Forecast huge investments in power sectors
   - Liberalization of electricity markets

2. **The need to improve energy efficiency:**
   - Electricity efficiency is severely disadvantaged by the efficiency of the Carnot cycles

3. **Fossil fuels = 66% of the world net electricity production**

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In this context, renewable and distributed energy sources are attractive alternatives for power generation.
Benefits

1. The overall efficiency improves:
   - Renewable energy sources decrease electrical losses at production level
   - Distributed generation decrease electrical losses at transmission and distribution levels

2. High shares of renewable and distributed energy sources are expected:
   - In centralized scheme, e.g. Desertec concept
   - In distributed architecture with smartgrids concept
Spread of renewable and distributed energy sources

Challenges

1. **Design of energy policies**
   - To promote renewable and distributed sources
   - Incentives’ system

2. **Major technological issues**
   - Intermittency
   - **Reliability of electricity supply**: the capability of the power system to withstand sudden disturbances
Why focusing on the Reunion Island?

1. Blessed with high renewable energy potentials
2. Small, weakly-meshed and isolated power system
3. Binding target in 2030: 100% renewable sources in power generation
Long-term planning tools: the MARKAL/TIMES models

- **Inputs:**
  - Exogeneous demand
  - Available technologies
  - Domestic resources
  - Energy prices

- **Outputs:**
  - Optimal technologies
  - Optimal timing of investments
  - Global cost
  - Emissions

- Technological models driven by energy demand
- Minimization of the global discounted cost of the energy system
The electricity sector in 2008

- **Electricity production:** 2 546 GWh

### Installed capacities

- **Thermal units (76%):**
  - 476 MW
  - Fuels: coal, fuel oil, sugarcane bagasse

- **Hydroelectricity (20%):**
  - Dams: 109.4 MW
  - Run-of-the-river: 11.6 MW

- **Others (4%):**
  - Wind: 16.8 MW
  - Solar PV: 10 MW
  - Municipal Waste: 2 MW

- **Hydroelectricity:**
  - Dams: 109.4 MW
  - Run-of-the-river: 11.6 MW

- **Sugarcane bagasse:** 10.31%

- **Wind:** 0.53%

- **Solar:** 0.42%

- **Municipal waste:** 0.03%

- **Coal:** 50.55%

- **Hydroelectricity:** 13.30%

**Source:** BPPI - EDF SEI 2009
Existing power plants

Evolution of residual capacities

- Coal & Bagasse units
- Coal units
- Diesel (Port Est)
- Diesel
- Combustion turbines
- MSW - Landfill Gas
- Solar PV
- Wind
- Run-of-the-river
- Dams
General hypotheses

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Steam Coal</td>
<td>$2008/t</td>
<td>41.22</td>
<td>120.59</td>
<td>91.05</td>
<td>104.16</td>
<td>107.12</td>
<td>109.4</td>
</tr>
<tr>
<td>Crude Oil</td>
<td>$2008/bbl</td>
<td>34.3</td>
<td>97.19</td>
<td>86.67</td>
<td>100.00</td>
<td>107.50</td>
<td>115.00</td>
</tr>
<tr>
<td>Heavy fuel oil</td>
<td>€2008/t</td>
<td>-</td>
<td>196</td>
<td>174</td>
<td>201</td>
<td>216</td>
<td>231</td>
</tr>
<tr>
<td>Distillate fuel oil</td>
<td>€2008/hl</td>
<td>-</td>
<td>47</td>
<td>42</td>
<td>48</td>
<td>51</td>
<td>55</td>
</tr>
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</table>

Electricity:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growth rate</td>
<td>%</td>
<td>3.4</td>
<td>2.6</td>
<td>2.4</td>
</tr>
<tr>
<td>Consumption</td>
<td>GWh</td>
<td>2 546</td>
<td>3 110</td>
<td>3 500</td>
</tr>
<tr>
<td>Power</td>
<td>MW</td>
<td>408</td>
<td>520</td>
<td>595</td>
</tr>
</tbody>
</table>

Sources: International Energy Agency, Electricité de France

$1$ 2008 real term prices
## Renewable energy potentials

<table>
<thead>
<tr>
<th>Energy sources</th>
<th>Current levels</th>
<th>Potentials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass</td>
<td>260 GWh</td>
<td>400 GWh</td>
</tr>
<tr>
<td>Hydropower</td>
<td>121 MW (553 GWh)</td>
<td>177 MW until 2012, 268 MW afterwards</td>
</tr>
<tr>
<td>Wind</td>
<td>16,8 MW</td>
<td>50 MW</td>
</tr>
<tr>
<td>Solar PV</td>
<td>10 MW</td>
<td>160 MW</td>
</tr>
<tr>
<td>Ocean Thermal Energy Conversion</td>
<td>–</td>
<td>10 MW in 2020, 100 MW in 2030</td>
</tr>
<tr>
<td>Wave Energy</td>
<td>–</td>
<td>30 MW (by 2014)</td>
</tr>
<tr>
<td>Geothermy</td>
<td>–</td>
<td>30 MW</td>
</tr>
<tr>
<td>Storage Capacities</td>
<td>–</td>
<td>1 MW in 2009, 10 MW</td>
</tr>
</tbody>
</table>
Scenarios specification

- Potentials for renewable energy sources are set at their maximum values.
- Scenarios are built around 3 assumptions:
  - Fossil fuel imports: No limit, Limit on coal, Limit on all fossil fuels
  - Demand: Standard, Low
  - Sugarcane bagasse potential: Standard, High
## Results: calibration for the year of reference (2008)

<table>
<thead>
<tr>
<th>Energy sources</th>
<th>Model (%)</th>
<th>EDF (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>56.90</td>
<td>50.55</td>
</tr>
<tr>
<td>Fuel Oils <em>(Distillate and Heavy)</em></td>
<td>9.06</td>
<td>13.30</td>
</tr>
<tr>
<td>Sugarcane bagasse</td>
<td>10.21</td>
<td>10.31</td>
</tr>
<tr>
<td>Hydroelectricity</td>
<td>21.71</td>
<td>24.86</td>
</tr>
<tr>
<td>Wind energy</td>
<td>1.19</td>
<td>0.53</td>
</tr>
<tr>
<td>Solar energy</td>
<td>0.41</td>
<td>0.42</td>
</tr>
<tr>
<td>Municipal waste</td>
<td>0.52</td>
<td>0.03</td>
</tr>
<tr>
<td>Production</td>
<td>2 547 GWh</td>
<td>2 546 GWh</td>
</tr>
</tbody>
</table>
Business as Usual

\[
\{ \text{Imports: No limit} / \text{Demand: Standard} / \text{Bagasse: Standard} \}
\]
Limits on coal imports

\[ \{ \text{Imports: Limit on coal} / \text{Demand: Standard} / \text{Bagasse: Standard} \} \]
Limits on fossil fuel imports

\{\textbf{Imports:} Limit on fossil fuels / \textbf{Demand:} Standard / \textbf{Bagasse:} Standard\}
Lower demand

\{\textbf{Imports:} Limit on fossil fuels / \textbf{Demand:} Low / \textbf{Bagasse:} Standard\}
Higher sugarcane bagasse potential

Imports: Limit on fossil fuels / Demand: Low / Bagasse: High
Remembering the issues

Challenges with renewable and distributed energy sources

1. Design of energy policies
   - To promote renewable and distributed sources
   - Incentives’ system

2. Major technological issues
   - Intermittency
   - **Reliability of electricity supply**: the capability of the power system to withstand sudden disturbances
Economical plausibility

Design of the incentives’ system

Costs and levels of investments in the different scenarios:

<table>
<thead>
<tr>
<th>Limit on imports</th>
<th>No limit</th>
<th>On coal</th>
<th>On fuel oils</th>
<th>Demand</th>
<th>Standard</th>
<th>Low</th>
<th>Bagasse</th>
<th>Standard</th>
<th>High</th>
<th>Relative total costs$^1$</th>
<th>Relative investment costs$^1$</th>
<th>Demand satisfied</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td>1.32</td>
<td>8.19</td>
<td>yes</td>
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<td></td>
<td></td>
<td>X</td>
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<td>1.24</td>
<td>6.30</td>
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<td></td>
<td>X</td>
<td></td>
<td>1.10</td>
<td>5.24</td>
<td>no</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>0.98</td>
<td></td>
<td>yes</td>
</tr>
</tbody>
</table>

What are the required level of subsidies to favour these investments?

$^1$Deducing the salvage costs
Reliability of electricity supply

- It is the capability of a power system to handle load fluctuations
- It mainly relies on:
  - Voltage management, with the electromagnetic coupling energy
  - Frequency management, with the kinetic and spinning reserves
- With renewable and distributed energy sources:
  - Levels of reserves decrease
  - Production fluctuations are more frequent
- At which cost the proposed power systems can be operated reliably?
Conclusions

- Renewable energy sources may cover power generation in 2030
- The model can be further developed: loadcurve, bagasse industry, scenario prices, carbon constraints
- Good case study to address economical and technological issues in the TIMES models:
  - Incentives’ system
  - Reliability of electricity supply