An SG-TIMES Model for Singapore’s Electricity Sector

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Bin Su

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Table of Contents

- **Introduction**
  - Singapore energy landscape
  - Current energy efficiency policies in Singapore

- **Electricity Consumption Projection to 2030 and 2050**
  - Naturally Evolving Scenario
  - Sectoral analysis on energy efficiency improvement
  - End-use electricity consumption scenarios 2030 – 2050
  - Total electricity consumption scenarios 2030 – 2050
  - Sectoral electricity consumption scenarios 2030 – 2050
  - Total installed capacity by 2030 and 2050

- **SG-TIMES Model Structure**
  - Singapore Reference Energy System
  - Model input analysis
  - Model output analysis

- **Concluding remarks**
Singapore Energy Landscape (Electricity Sector)

Unit: GWh

Electricity Consumption 2005 - 2010

Source: EMA 2010
# Current Energy Efficiency Improvement Policies in Singapore

<table>
<thead>
<tr>
<th>Power Generation</th>
<th>Industry</th>
<th>Buildings</th>
<th>Transport</th>
<th>Households</th>
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</thead>
<tbody>
<tr>
<td><strong>Promote adoption of energy efficient technology and measures</strong></td>
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<td></td>
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<td>$10 Million EASe Scheme</td>
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<td>Accelerated depreciation allowance</td>
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<td>Investment allowance</td>
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<td>Design for Efficiency scheme</td>
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<td>Grant for Energy Efficient Technologies</td>
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<td>Building regulations</td>
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<td>Government take the lead</td>
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<td>Energy Smart</td>
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<td>Mandating Green Mark certified</td>
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<td>$20 million Green Mark Incentive Scheme</td>
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<td>Grant to upgrade Building Envelopes</td>
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<td>Residential building standards</td>
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<td>Manage vehicle usage and traffic congestion</td>
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<td>Improving and promoting the use of public transport</td>
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<td>Fuel economy labeling</td>
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<td>Green vehicle rebate</td>
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<td>Promoting fuel-efficient driving habits</td>
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<td>Mandatory labeling</td>
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<td>Minimum energy performance standards</td>
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<td>Electricity Vending System</td>
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<td>Electricity consumption tracking device</td>
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<td><strong>Research &amp; Development and Capability-building</strong></td>
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<td>Innovation for Environmental Sustainability Fund</td>
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<td>Green building R&amp;D fund</td>
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<td>Energy service company accreditation scheme</td>
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<td>Singapore Certified Energy Manager programme and Training Grant</td>
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<td><strong>Raise awareness</strong></td>
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<td>Energy efficiency seminars and workshops</td>
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<td>Energy efficiency website</td>
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<td>Public awareness programme</td>
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<td></td>
</tr>
</tbody>
</table>

# Table of Contents

- **Introduction**
  - Singapore energy landscape
  - Current energy efficiency policies in Singapore

- **Electricity Consumption Projection to 2030 and 2050**
  - Naturally Evolving Scenario
  - Sectoral analysis on energy efficiency improvement
  - End-use electricity consumption scenarios 2030 – 2050
  - Total electricity consumption scenarios 2030 – 2050
  - Sectoral electricity consumption scenarios 2030 – 2050
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- **SG-TIMES Model Structure**
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  - Model input analysis
  - Model output analysis

- Concluding remarks
Electricity Consumption Projection to 2030 and 2050 in the Naturally Evolving Scenario

- Electricity consumption projection based on the latest official estimation of 6.9 million population by 2030, followed by linear extrapolation to 2050 at about 8.7 million population
- Previous estimation was 5.9 million by 2030, and 6.7 million by 2050
Industry

• Current efficiency improvement policies
  – $10 Million dollars Energy Efficiency Improvement Assistance Scheme (EASe) by NEA and MEWR

• Relevant Industry Sectors and savings potential with the use of Best Available Technologies (BATs)(EJ/Yr, %)
  – Chemicals/Petrochemicals (1.0, 25%)
  – Cement (No data available)
  – Pulp and paper (0.3, 16%)
  – Wafer fab (N.A., 20%)

• Most relevant industrial technology systems and savings potential with the use of BATs (%)
  – Motor systems (20%)
Building

• Current efficiency improvement policies:
  – Green Mark (GM) Scheme
  – Energy Smart Building Labeling Scheme

• Prospect efficiency improvement policies:
  – Efficiency Improvements for Existing Stocks of Buildings

• GM Certification Criteria (% electricity reductions)
  – Platinum (30%)
  – GoldPLUS (25%)
  – Gold (15%)
  – Certified (10%)
Transport

- Current Mode of Transport
  - RTS Network
  - Bus
  - Taxi
  - Private Vehicles
  - Others

- Current transport policies (increase in electricity consumptions)
  - Doubling of RTS network by 2020 Electric Vehicle (EV) test bedding program
  - SMRT-BYD MOU on the distribution of BYD e6 taxi and eBus012 in Singapore

- Prospective transport policies (further increase in electricity consumptions)
  - Trolleybus
  - Tram
  - Bus Rapid Transit (BRT)
Household

• Current efficiency improvement policies
  – Minimum Energy Performance Standard (MEPS) for appliances sold in Singapore
  – Feasibility study on Electricity Vending System (EVS) scheme
  – 10% Energy Challenge to encourage household sector to reduce electricity consumption by 10%
# Sectoral Analysis on Energy Efficiency Improvement (EEI)

## Summary of Reductions from Naturally Evolving Scenario

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Industry</th>
<th>Building</th>
<th>Transport</th>
<th>Households</th>
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</thead>
<tbody>
<tr>
<td><strong>BAU Scenario</strong></td>
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<tr>
<td>2030</td>
<td>1.0%</td>
<td>3.0%</td>
<td>1738.05</td>
<td>-65.0%</td>
</tr>
<tr>
<td>2050</td>
<td>3.0%</td>
<td>6.0%</td>
<td>0.00</td>
<td>0.0%</td>
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<tr>
<td><strong>Conservative Scenario</strong></td>
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<tr>
<td>2030</td>
<td>1.5%</td>
<td>6.0%</td>
<td>1739.60</td>
<td>-65.0%</td>
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<tr>
<td>2050</td>
<td>5.0%</td>
<td>7.5%</td>
<td>52.00</td>
<td>-1.8%</td>
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<tr>
<td><strong>Optimistic Scenario</strong></td>
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<tr>
<td>2030</td>
<td>2.5%</td>
<td>12.0%</td>
<td>1806.93</td>
<td>-67.0%</td>
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<tr>
<td>2050</td>
<td>7.0%</td>
<td>15.0%</td>
<td>260.02</td>
<td>-9.1%</td>
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<tr>
<td><strong>Technical Scenario</strong></td>
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<tr>
<td>2030</td>
<td>10.0%</td>
<td>20.0%</td>
<td>2502.61</td>
<td>-110.0%</td>
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<td>2050</td>
<td>20.0%</td>
<td>30.0%</td>
<td>2996.18</td>
<td>-105.0%</td>
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</tbody>
</table>
End-use Electricity Consumption to 2050

End-Use Electricity Consumption by 2030 and 2050

- BAU Scenario
- Technical EEI Scenario
- Optimistic EEI Scenario
- Conservative EEI Scenario

Year

GWh

2010 2030 2050
Total Electricity Consumptions to 2050

Total Electricity Consumption by 2030 and 2050 (Including Energy Industry Own Use and Losses)

- BAU Scenario
- Technical EEI Scenario
- Optimistic EEI Scenario
- Conservative EEI Scenario

Year

GWh
## Total Installed Capacity by 2030 and 2050 - at 50% Capacity Factor

<table>
<thead>
<tr>
<th>Year</th>
<th>Naturally Evolving Scenario</th>
<th>BAU Scenario</th>
<th>Conservative EEI Scenario</th>
<th>Optimistic EEI Scenario</th>
<th>Technical EEI Scenario</th>
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</thead>
<tbody>
<tr>
<td>2010</td>
<td>10.1</td>
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<td>10.1</td>
<td>10.1</td>
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<tr>
<td>2030</td>
<td>15.3</td>
<td>15.5</td>
<td>15.3</td>
<td>14.9</td>
<td>14.1</td>
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<tr>
<td>2050</td>
<td>19.6</td>
<td>18.9</td>
<td>18.7</td>
<td>18.0</td>
<td>16.5</td>
</tr>
</tbody>
</table>

Singapore Total Installed Capacity at 2010 Published by the Energy Market Authority
Table of Contents

- Introduction
  - Singapore energy landscape
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  - End-use electricity consumption scenarios 2030 – 2050
  - Total electricity consumption scenarios 2030 – 2050
  - Sectoral electricity consumption scenarios 2030 – 2050
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- SG-TIMES Model Structure
  - Singapore Reference Energy System
  - Model input analysis
  - Model output analysis
- Concluding remarks
TIMES Modeling Paradigm
SG-TIMES Reference Energy System

**Primary Energy Supply**
- **Imports (e.g.)**
  - Crude oil
  - Natural gas
  - Oil products
- **Exports (e.g.)**
  - Oil products
- **Renewables (e.g.)**
  - Solar
  - Wind
  - Hydro
  - Biomass

**Process Technology**
- **Power plants (e.g.)**
  - Coal plant
  - NGCC
  - Solar
  - Wind
  - CHP
  - Nuclear
- **Fuel processing plants (e.g.)**
  - Oil refineries
  - Hydrogen production

**End-Use Technology**
- **Industry (e.g.)**
  - Machinery
  - Steam boilers
- **Transport (e.g.)**
  - Gasoline car
  - Diesel truck
  - LPG buses
- **Household (e.g.)**
  - Refrigerators
  - Water heaters
- **Services (e.g.)**
  - Air conditioning
  - Light bulbs

**Demand for Energy Service**
- **Industry (e.g.)**
  - Automotive power
  - Process steam
- **Transport (e.g.)**
  - Person-km
  - kg-km
- **Household (e.g.)**
  - Refrigeration
  - Hot water
- **Services (e.g.)**
  - Cooling
  - Lighting
SG-TIMES Reference Energy System
- the Electricity Sector

**Existing Technologies**

- **Imported natural gas** → **Natural Gas Power Plant** → **Industry Sector**
- **Imported oil** → **Oil Power Plant**
- **Others** → **Other Power Plants** → **Building Sector**

**New Technologies**

- **Imported electricity** → **Renewable Power Plant (e.g. solar PV)** → **Transport Sector**
- **Renewables (e.g. solar)** → **Renewable Power Plant (e.g. solar PV)**
- **Imported nuclear fuel** → **Nuclear Power Plant** → **Household Sector**
- **Imported coal** → **Coal Power Plant**
Technical Details on the Model Structure

- **Time Slices**
  - Weekday/Saturday/Sunday -> Day/Nite

- **Sectoral Electricity Demand**
  - Current implementation: aggregated exogenous sectoral electricity demand based on offline analysis
  - *Future implementation: Energy service demand by commodity fraction*

- **User constraints**
  - Emission reduction target
  - Maximum share of coal + HFO power
  - Maximum share/installed capacity of nuclear power
  - Minimum penetration of renewables (solar PV and wind)

- **Calibration for the base year**
Model Output Analysis

- Electricity Sector BAU Scenario (No constraints)
  - Emissions by 2030 and 2050
- Emission reduction by 30% by 2030 and 50% by 2050 from the BAU Scenario
  - No constraints on the choice of technologies
  - Fixed range of combined Coal and HFO in the mix
  - Fixed range of combined Coal and HFO, and max Nuclear installed capacity in the mix
- Each model run was based on the four demand scenarios defined earlier
  - For illustration purposes, only the BAU and Technical EEI Scenarios will be presented
Electricity Sector BAU Scenario 1/3

- Emissions

Emissions in the BAU Scenario

- BAU Scenario
- Conservative EEI Scenario
- Optimistic EEI Scenario
- Technical Scenario
Electricity Sector BAU Scenario 2/3

- Installed Capacity

![Graph of Installed Capacity (DEM-BAU)](image)

![Graph of Installed Capacity (DEM-TEC)](image)
Electricity Sector BAU Scenario 3/3

Fuel mix

Electricity Generation by Fuel Group (BAU)

Electricity Generation by Fuel Group (Technical EEI)
Electricity Sector Emission Reduction Scenario 1/3

30% Reductions by 2030 and 50% reductions by 2050

Emissions Reduction from Electricity Sector BAU

- Blue line: BAU Scenario
- Red line: Conservative EEI Scenario
- Green line: Optimistic EEI Scenario
- Purple line: Technical Scenario

Mt-CO₂
Electricity Sector Emission Reduction Scenario 2/3

Installed Capacity under No System Constraints

![Installed Capacity (DEM-BAU-TAR)](chart1)

- Coal
- Natural Gas
- HFO
- Nuclear
- Waste

![Installed Capacity (DEM-TEC-TAR)](chart2)

- Coal
- Natural Gas
- HFO
- Nuclear
- Waste
Fuel Mix under No System Constraints

Electricity Generation by Fuel Group (DEM-BAU-TAR)

Electricity Generation by Fuel Group (DEM-TEC-TAR)
Installed Capacity under Fixed Range of Coal+HFO Share in the Fuel Mix

![Bar Chart: Installed Capacity (DEM-BAU-TAR-COAHFO)]

- Coal
- Natural Gas
- HFO
- Nuclear
- Waste

![Bar Chart: Installed Capacity (DEM-TEC-TAR-COAHFO)]

- Coal
- Natural Gas
- HFO
- Nuclear
- Waste
Electricity Sector Emission Reduction Scenario 2/2
- Fixed range of Coal+HFO mix (20% - 30%)

Fuel Mix under Fixed Range of Coal+HFO share
Installed capacity under fixed range of Coal+HFO share and max Nuclear capacity (1 GW) in the fuel mix
Fuel Mix under fixed range of Coal+HFO share, and max Nuclear capacity (1 GW)
Table of Contents

Introduction
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  • End-use electricity consumption scenarios 2030 – 2050
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Concluding remarks
Concluding Remarks

• As of now
  – We have constructed an SG-TIMES model for the electricity sector
  – We have calibrated the model for the base year
  – We have obtained model run results for further analysis

• Next
  – Expanding towards an economy wide TIMES model
  – Expanding towards a multi-regional model for the ASEAN region
Thank you