Modelling for Energy Planning and Policy Analysis for Nepal

Joint TERI – ETSAP Workshop
Energy Modelling Tools & Techniques to address Sustainable Development & Climate Change

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Outline of Presentation

1) Introduction
2) Current Energy Sector Situation
3) Major Issues
4) Renewable energy resources potential
5) Modelling Framework: MAED & MARKAL
6) Future Energy Scenario Analysis
7) Major Policy Recommendations & conclusion
The world’s energy system is at a crossroads. Current global trends in energy supply and consumption are patently unsustainable – environmentally, economically, and socially. But that can – and must – be altered; there is still time to change the road we are on.

- World Energy outlook, 2008

IEA
Per Capita Primary Energy Supply in 2007

- China: 62 GJ
- India: 22 GJ
- Pakistan: 21 GJ
- Sri Lanka: 20 GJ
- Bangladesh: 7 GJ
- Nepal: 14 GJ
- Asian Average: 27 GJ

1 toe = 41.87 GJ

Per Capita Electricity Consumption in 2007

- China: 2,346 KWh
- India: 543 KWh
- Pakistan: 475 KWh
- Sri Lanka: 418 KWh
- Bangladesh: 144 KWh
- Nepal: 81 KWh
- Asian Average: 705 KWh

Key World Energy Statistics, IEA, 2009
Brief Introduction on Nepal

- Population: 28.11 million
- Per capita GDP: US$ 246
- Area: 147,000 sq km
- Length: 880 km (East-West)
- Breadth: 145 to 241 km (North–South)

Key World Energy Statistics, IEA, 2009

DOED, 2006
End-use Consumption of Energy in Different Sectors in 2005

Total consumption: 367 million GJ

Energy Consumption in 2005

Total Energy Consumption 367 million GJ
Fuelwood requirement against sustainable supply (in TJ at 5.5% GDP growth rate)


Import of Petroleum Products against Commodity Exports

2000/01 2001/02 2002/03 2003/04 2004/05 2005/06 2006/07

Commodity export in 2006/07: NR 61 billion

1 US$ = NR 73.00

Economic survey, GON, 2007/08
Monthly household life cycle costs of cooking in different fuels (based on D’sa and Murthy, 2004)

<table>
<thead>
<tr>
<th>Year</th>
<th>Kerosene</th>
<th>LPG</th>
<th>Electricity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td>180</td>
<td>465</td>
<td>605</td>
</tr>
<tr>
<td>2000</td>
<td>385</td>
<td>405</td>
<td>680</td>
</tr>
<tr>
<td>2003</td>
<td>410</td>
<td>510</td>
<td>788</td>
</tr>
<tr>
<td>2009*</td>
<td>912</td>
<td>794</td>
<td>788</td>
</tr>
</tbody>
</table>

**Economic cost**

<table>
<thead>
<tr>
<th></th>
<th>Kerosene</th>
<th>LPG</th>
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<tbody>
<tr>
<td></td>
<td>862</td>
<td>853</td>
</tr>
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</table>

Sensitivity Analysis of ratio of imports of petro products to commodity exports

Commodity exports in 2015 expected to grow at 11% as in the period 1995-2005 to the value of 139 billion NR at 2001 constant prices.


1 US$ = NR 73.00

Electricity price at NR 7.30/unit

Current LPG Price: loss of NR 87/cyl (Sept. 2009)

* At price adjustment in March 2009 (NOC, 2009)
### Sales of petro-products in 2009

<table>
<thead>
<tr>
<th>Petro-products</th>
<th>Sales in KL/MT</th>
<th>% growth from 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td>124,169</td>
<td>22%</td>
</tr>
<tr>
<td>Diesel</td>
<td>446,468</td>
<td>46%</td>
</tr>
<tr>
<td>LPG MT</td>
<td>115,813</td>
<td>24%</td>
</tr>
<tr>
<td>Kerosene</td>
<td>70,089</td>
<td>-65%</td>
</tr>
<tr>
<td>Total petro-products</td>
<td>828,022</td>
<td>14%</td>
</tr>
</tbody>
</table>

Source: NOC, 2009

### Electricity sales and expected demand in 2010

<table>
<thead>
<tr>
<th>Expected demand/sales</th>
<th>Expected demand in 2010 GWh</th>
<th>Sales in 2009 GWh</th>
<th>Deficit in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected demand/sales</td>
<td>4,018</td>
<td>2,309</td>
<td>43%</td>
</tr>
</tbody>
</table>

1 GWh = 1 million KWh (units)

Source: NEA, 2009
Load Curve on 8 March, 2009 (NEA)

Expected powercuts a day: 12 hours in dry season in 2010 (March- June)

Major Issues in energy sector

- Consumption of traditional fuels - unsustainable
- Dependence on imported petroleum products – too much
- Harnessing of the indigenous hydropower resources – very poor
- Fuel substitution - strongly needed
Energy Resources Potential

<table>
<thead>
<tr>
<th>Renewable energy sources</th>
<th>Theoretical potential MW/MWa</th>
<th>Economical potential MW/MWa</th>
<th>Utilized MW/units</th>
<th>% of utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydropower</td>
<td>83,000</td>
<td>42,000</td>
<td>688</td>
<td>1.6</td>
</tr>
<tr>
<td>Microhydro</td>
<td>50</td>
<td>10.2</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Solar PV power plant</td>
<td>9,750</td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Solar PV home system</td>
<td>122</td>
<td>3.2</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Wind Power</td>
<td>1,215</td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Biogas plant (MWa)</td>
<td>864</td>
<td>60</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Solar water heating Urban (MWa)</td>
<td>82</td>
<td>23</td>
<td>28</td>
<td></td>
</tr>
</tbody>
</table>

Based on NEA, 2009; WECS, 2006; AEPC, 2008 and author’s calculations

Methodology

- Useful Energy Demand Projection using Model for Analysis of Energy Demand (MAED) developed by International Atomic Energy Agency (IAEA), Vienna, Austria.
- Energy Supply System Analysis using ASWER MARKAL developed by Energy Technology Systems Analysis Programme (ETSAP), International Energy Agency (IEA), Paris, France.
End-use Approach for demand projection using MAED-2

Final Energy Demand in 2030
- Industrial sector
- Transport Sector
- Household Sector
- Service Sector

MARKAL Methodological Diagram

MARKAL Energy Systems Modelling Framework

Energy Mix Scenarios

Energy Resources
Process Technologies
Conversion Technologies
End-use Technologies
Demands

Establish constraints to study cases

MARKAL Energy Systems Modelling Framework

Final Energy Demand in 2030
- Industrial sector
- Transport Sector
- Household Sector
- Service Sector

Developmental scenarios in future years
Methodology

- Participatory workshops for issues identification
- Collection of data from WECS, CBS, MOF, MOF&SC, NPC, NEA, NOC, World Bank, ADB, UN, ESMAP etc.
- Analysis/Time horizon : from 2005 to 2030
- Macroeconomic indicators –
  - GDP growth rate - 4.3 percent (average)
  - GDP growth rate – 5.5 percent
  - GDP growth rate - 7.0 percent
- Demographic parameter – population growth rate: medium variant growth rate (leading from 2.23 percent to 1.74 percent in 2020 and onwards; CBS, 2003)
Scenarios (Policy Interventions at Reference Case)

- **Introduction of Clean Energy Technology at Reference Case**
  - Traditional fuels and fossil fuels replaced by electricity and/or fossil fuels.

<table>
<thead>
<tr>
<th>Sub-sector</th>
<th>2020</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial and commercial</td>
<td>Traditional and fossil fuels decreased by 20%</td>
<td>*Decreased 30%</td>
</tr>
<tr>
<td>Residential Urban</td>
<td>Fuelwood share decreased by 50%</td>
<td>*Decreased by 75%</td>
</tr>
<tr>
<td>Residential Rural</td>
<td>Fuelwood share decreased by 10%</td>
<td>*Decreased by 30%</td>
</tr>
</tbody>
</table>

*replaced by electricity, kerosene & LPG

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Scenarios - Policy Interventions at Reference Case

- **CFL Penetration**
  - Incandescent bulbs replaced by CFLs at the rate of 50 percent in 2020 and then linearly to 100 percent in 2030 industrial, commercial and residential sectors.
  - Transmission and distribution losses of electricity grid reduced from 25 percent in base year to 20 percent in 2015, and then linearly to 10 percent in 2030

*replaced by electricity, kerosene & LPG
Scenarios - Policy interventions at reference case

- **Introduction of New Transportation Technology:**
  - Ethanol and bio-diesel mixing in petrol and diesel respectively. Ethanol mix 10 percent 2020 onwards and 20 percent in 2030. Bio-diesel mix 5 percent 2020 onwards and 10 percent in 2030, and
  - Electric and hybrid cars introduced. Diesel and petrol cars to be reduced by 10 percent of reference case in 2020, 20 percent in 2025, and 30 percent in 2030.
  - Electric cars will be substituting at the rate of 5 percent in 2020, 10 percent in 2025, and 15 percent in 2030.
  - Hybrid cars will be substituting the remaining as 5 percent in 2020, 10 percent in 2025, 15 percent in 2030.

- **All combined policy measures:**
  - All combined policy measures plus wind power plant and solar water heating system introduced.
Energy consumptions in reference and combined policy cases

Fuel Mix at Reference & combined policy cases

Reference case

Combined case
Scenario Comparison

Comparison with other models
### Sustainable Energy Indicators in Reference Case Scenario

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Units</th>
<th>2005</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final energy consumption/capita</td>
<td>GJ/capita</td>
<td>15</td>
<td>16</td>
<td>18</td>
<td>21</td>
<td>23</td>
<td>26</td>
</tr>
<tr>
<td>Electricity consumption/capita</td>
<td>kWh/capita</td>
<td>67</td>
<td>67</td>
<td>123</td>
<td>183</td>
<td>297</td>
<td>423</td>
</tr>
<tr>
<td>Energy Intensity</td>
<td>GJ/1000S</td>
<td>54</td>
<td>51</td>
<td>46</td>
<td>45</td>
<td>46</td>
<td>46</td>
</tr>
<tr>
<td>Electricity Intensity</td>
<td>kWh/1000S</td>
<td>247</td>
<td>275</td>
<td>327</td>
<td>406</td>
<td>548</td>
<td>641</td>
</tr>
<tr>
<td>Energy intensity per cent</td>
<td></td>
<td>1%</td>
<td>3%</td>
<td>4%</td>
<td>7%</td>
<td>11%</td>
<td>18%</td>
</tr>
<tr>
<td>Total Energy Consumption/ value added in industrial sector</td>
<td>GJ/1000S value added</td>
<td>21.3</td>
<td>23.9</td>
<td>26.7</td>
<td>31.0</td>
<td>36.5</td>
<td>43.3</td>
</tr>
<tr>
<td>Commercial energy - value added</td>
<td>GJ/Bill Nrs</td>
<td>20.7</td>
<td>21.8</td>
<td>22.6</td>
<td>24.2</td>
<td>26.0</td>
<td>28.6</td>
</tr>
<tr>
<td>Total Energy Used/household</td>
<td>GJ/HH</td>
<td>76.1</td>
<td>81.6</td>
<td>87.6</td>
<td>95.8</td>
<td>107.3</td>
<td>123.3</td>
</tr>
<tr>
<td>Electricity used/HH</td>
<td>kWh/HH</td>
<td>177</td>
<td>261</td>
<td>372</td>
<td>536</td>
<td>774</td>
<td>1,115</td>
</tr>
<tr>
<td>Transport Energy Utilization</td>
<td>GJ/M T-km</td>
<td>1.3</td>
<td>1.9</td>
<td>1.9</td>
<td>1.9</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Transport Energy Utilization</td>
<td>GJ/M P-km</td>
<td>0.4</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Share of non-carbon energy in primary supply</td>
<td>per cent</td>
<td>1.7%</td>
<td>1.9%</td>
<td>2.5%</td>
<td>3.2%</td>
<td>4.5%</td>
<td>5.2%</td>
</tr>
<tr>
<td>Share of renewable energy in final energy consumption</td>
<td>per cent</td>
<td>2%</td>
<td>3%</td>
<td>4%</td>
<td>6%</td>
<td>6%</td>
<td>6%</td>
</tr>
<tr>
<td>Share of net import to total primary supply</td>
<td>per cent</td>
<td>10%</td>
<td>12%</td>
<td>15%</td>
<td>16%</td>
<td>21%</td>
<td>25%</td>
</tr>
<tr>
<td>GHG emission for every ton of energy production and use</td>
<td>Gg in Kg/capita</td>
<td>806</td>
<td>892</td>
<td>1,006</td>
<td>1,797</td>
<td>1,471</td>
<td>1,996</td>
</tr>
</tbody>
</table>

USD 1.00 = NR 73.00

### Sustainable Energy indicators for combined case

<table>
<thead>
<tr>
<th>Energy Indicators</th>
<th>Units</th>
<th>2005</th>
<th>2010</th>
<th>2015</th>
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</tr>
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<td>Electricity consumption per capita</td>
<td>kWh/capita</td>
<td>67</td>
<td>99</td>
<td>158</td>
<td>282</td>
<td>533</td>
<td>862</td>
</tr>
<tr>
<td>Energy Intensity</td>
<td>GJ/1000S</td>
<td>54</td>
<td>48</td>
<td>38</td>
<td>34</td>
<td>31</td>
<td>31</td>
</tr>
<tr>
<td>Electricity Intensity</td>
<td>kWh/1000S</td>
<td>249</td>
<td>313</td>
<td>444</td>
<td>663</td>
<td>1,026</td>
<td>1,382</td>
</tr>
<tr>
<td>Electricity power utilized per cent</td>
<td></td>
<td>1%</td>
<td>2%</td>
<td>4%</td>
<td>7%</td>
<td>13%</td>
<td>23%</td>
</tr>
<tr>
<td>Total Energy Consumption/ value added in Industrial sector</td>
<td>GJ/1000S value added</td>
<td>24</td>
<td>24</td>
<td>26</td>
<td>30</td>
<td>36</td>
<td>41</td>
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<td>2</td>
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<td>2</td>
<td>2</td>
</tr>
<tr>
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<td>GJ/M P-km</td>
<td>0.4</td>
<td>0.5</td>
<td>0.5</td>
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<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
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<td>6.3%</td>
<td>11.0%</td>
<td>15.9%</td>
</tr>
<tr>
<td>Share of renewable energy in final energy consumption</td>
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</tr>
</tbody>
</table>
HDI and per capita electricity consumption (ADB, 2007)

2,000 KWh per capita is needed to achieve HDI of 0.8.

Per Capita Electricity Consumption in 2007

Key World Energy Statistics, IEA, 2009
Energy Intensity

Share of Renewable Energy in Total Final Energy

Energy Intensity

Share of Renewable Energy in Total Final Energy
Net Imports to Total Energy Consumptions

[Graph showing Net Imports to Total Energy Consumptions with two lines: Reference case and Combined Policy case]

GHG Emissions in CO₂ equivalent

[Graph showing GHG Emissions in CO₂ equivalent with two lines: SCEN55BA and SCEN55CN]

12 billion NR through carbon trading (164 million USD) in 2030.

25 million tons in 2030 savings
Major Policy recommendations & conclusion

- Discourage use of fossil fuels
- Prioritize indigenous hydropower as lead energy resources
- Promote energy efficiency program
- Emphasize on renewable energy technology
- Deregulate energy sector
- Regional cooperation with SA countries
- Further improvement/development of MARKAL model and MARKAL-MACRO

Thank you!