The Application of the LEAP Software Tool to Energy Sector Analysis in the Republic of Korea

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Hoseok Kim
Directions of the Study

- Applying LEAP software tool to the ROK
- Establishing a comprehensive and effective LEAP dataset for the ROK
- Assessing the properness of the application and dataset
- Projecting future energy outlook based on business-as-usual case
- Developing reasonable and meaningful alternative scenarios
- Analyzing the results and implication of the alternative scenarios
This presentation will show

- How to apply the LEAP software tool to the ROK’s energy sector.
- The structure of ROK2003: An Overview
- The obstacles and problems in the application
- Possible energy issues being analyzed based on LEAP ROK data set and ROK2003.
- Know-how might be shared with other regional working group
Organization of the Presentation

1. ROK’s Energy Policy
2. LEAP Modeling in ROK
3. LEAP ROK2003
4. Demand Sector
5. Transformation Sector
6. BAU Energy Paths
7. Obstacles and Tasks
8. Alternative Scenarios
1. ROK’s Energy Policy
Various types of energy policy give an exogenous shock to (inter)national energy system.

- Energy demand & supply
- Energy mix
- Energy efficiency
- The innovation of energy–related technology

Energy models help to foresee the impacts and to analyze the implications of energy policy.
ROK’s Energy Policy: Problems and Challenges

- Maintaining a stable energy supply for **enduring economic growth**
- **Encouraging competition** in energy market
- Reducing the dependence on oil
- Diversification of energy sources
- Establishing environment- and climate-friendly energy system for **Sustainable Development**.
- Strengthening **the long-run potential for pollution control**
- Restructuring an energy system with low GHG emissions
### Directions of ROK’s Energy Policy

- **Sustainable Energy System**
  - To stimulate energy efficiency
  - To stabilize energy supply capacity

- **Energy Technology Innovation**
  - To develop energy technologies

- **Competitive Energy Markets**
  - To privatize energy industries
  - To improve efficiency in energy market

- **Regional Cooperation**
  - To diversify energy sources
  - To stabilize energy supply and prices
2. LEAP Modeling in ROK
Previous Work

* Beijing workshop, June 2000
  * Nautilus provided support in the use of the LEAP software
  * The first national dataset for LEAP was developed.

* Berkeley workshop, February 2001
  * The first rigorous application was made.(ROK2000)
  * The conceptual and analytical understanding was elaborated in the training session.

* Berkeley workshop, January 2002
  * After the 3rd training workshop ROK2000 was completed.
    And the dataset was applied to the LFG generation issue.
Why LEAP?

* There is a huge range of models that can be used to address energy-related issues, and they are grouped into three categories: macroeconometric models, CGE models, energy-economy models.

* Energy-economy models, so called ‘bottom-up’ models, are technology based models found on engineering relationships.
Strengths and Weaknesses of Bottom-Up Approach

**Strengths of Bottom-up Approach**

- The capacity to address at a more detailed sectoral and sub-sectoral level the implications of energy policies on energy system

**Weaknesses of Bottom-up Approach**

- The models may fail to adequately capture opportunity or welfare costs of technological substitution.
- The choice of modeling platform depends on the purpose of analysis.
LEAP Modeling Platform

LEAP modeling platform

* With its flexible structures, LEAP allows the user to simulate and assess the impacts of alternative energy policies on energy system—especially technological fields, and to project the energy supply and demand situation.

* As a database, LEAP provides a comprehensive system for maintaining energy information.
Best Conditions for Applying LEAP Modeling Platform

LEAP model is most useful where:

- There is insufficient historical macro-economic data for trend analysis
- There are significant technological changes in energy sector.
- There are short-run development problems
- There is a need to disaggregate energy uses.
- There is a strong policy scheme that is shaping the national energy system.
Energy Modeling in the ROK

* Macroeconometric Models
* CGE Models
  * KEED (Korea Energy Environmental Dynamic GE Model, KEEI)
* Energy-Economy Models
  * KEEI Model, EFOM-Env (Korea Energy Economics Institute)
  * MARKAL (Korea Institute of Energy Research)
  * META-Net, LEAP (Yonsei University)
3. LEAP ROK2003: An Overview
LEAP ROK Models

* ROK1998 (LEAP v.95)
  * Highly aggregated but simple and intuitive

* ROK2000 (LEAP v.2000)
  * Highly disaggregated but complex and with uncertainties in BAU paths

* ROK2003 (LEAP v.2003)
  * Less disaggregated than ROK2000 but with reasonable and rigorous BAU paths
Determinants of Model Structure

- The purpose of analysis
- The modes of shock
- Methodological approach of the analysis
- Time horizon
- Geographical coverage
- Sectoral coverage
- Data restriction or availability
ROK Models

- The purpose is to assess the recent ROK’s energy policy scheme and its regional implication
- Shock: Policies on energy demand, supply, and technological change
- Methodology: LEAP software (scenario analysis)
- Time horizon: 2000-2015 (medium-term)
- Geographical coverage: National model
- Sectoral coverage: Energy sector
- Data availability: Quite good!
The Structure of ROK2003

- **DEMAND SECTORS**
  - Residential
  - Industrial
  - Commercial & Public
  - Transportation

- **TRANSFORMATION SECTOR**
  - Electricity Generation
  - District Heating
  - Town Gas Production
  - LNG Gasification

- **RESOURCE**
  - **SECONDARY**
    - Electricity, Town Gas
    - Natural Gas, Heat
  - **PRIMARY**
    - Coal, Gasoline
    - Diesel, Kerosene
    - Fuel oil, LPG
    - Naphtha, LNG
    - Nuclear, Hydro
Current Status of ROK2003

* Well equipped with key data, parameters, and BAU path
* Highly disaggregated in residential demand, transportation and transformation sectors
* Well structured to be applied in electricity generation and transportation analysis
* Two alternative scenarios are under developing in the climate policy context
Key Data Gaps

- Small Electricity Appliances
- Renewable Energy Uses
- Mass transit & freight: BAU path
- Air Transportation
- Heat Production of CHP
- Electricity Production of HOB
- Oil Refining Process
- Domestic Coal Mining
Key Data Sources

- Ministry of Commerce, Industry, and Energy
- Korea Energy Economics Institute
- Korea National Statistical Office
- Korea Development Institute
- The Bank of Korea
- Korea Electric Power Corporation
- Korea District Heating Corporation
- Korea Coal Corporation
- Korea Gas Corporation
4. Demand Sector
The Structure of Demand Sector

DEMAND SECTOR

RESIDENTIAL
- Cooking
- Space Heating
- Lighting
- Appliances

TRANSPORTATION
- Household Vehicles
- Mass Transit & Freight

INDUSTRIAL
- Agriculture & Fishery
- Mining
- Manufacturing
- Construction

COMMERCIAL & PUBLIC
- Commercial Sector
- Public Sector
## Energy Balance: TFE

<table>
<thead>
<tr>
<th>UNIT: 000 TOE</th>
<th>coal</th>
<th>Pet</th>
<th>LNG</th>
<th>Town Gas</th>
<th>Heat</th>
<th>Elect</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>FINAL</td>
<td>19,847</td>
<td>92,660</td>
<td>256</td>
<td>12,561</td>
<td>1,119</td>
<td>20,600</td>
<td>149,173</td>
</tr>
<tr>
<td>INDUSTRIAL</td>
<td>19,129</td>
<td>47,209</td>
<td>207</td>
<td>3,308</td>
<td>.</td>
<td>11,374</td>
<td>83,135</td>
</tr>
<tr>
<td>TRANSP</td>
<td>-</td>
<td>30,824</td>
<td>.</td>
<td>-</td>
<td>.</td>
<td>175</td>
<td>30,999</td>
</tr>
<tr>
<td>RESIDENT</td>
<td>718</td>
<td>13,487</td>
<td>49</td>
<td>9,024</td>
<td>1,097</td>
<td>7,891</td>
<td>32,414</td>
</tr>
<tr>
<td>PUBLIC</td>
<td>-</td>
<td>1,141</td>
<td>.</td>
<td>229</td>
<td>22</td>
<td>1,160</td>
<td>2,626</td>
</tr>
</tbody>
</table>

4–7 Nov. 2003

Hoseok Kim
## Final Energy Demand in 2000

<table>
<thead>
<tr>
<th>(M TOE)</th>
<th>Coal</th>
<th>Petroleum</th>
<th>Town Gas</th>
<th>Electricity</th>
<th>Heat</th>
<th>Renewable</th>
<th>Total</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial</td>
<td>19.1</td>
<td>48.2</td>
<td>3.3</td>
<td>11.4</td>
<td>0</td>
<td>1.9</td>
<td>83.9</td>
<td>56.0%</td>
</tr>
<tr>
<td>Residential &amp; Commercial</td>
<td>0.7</td>
<td>13.5</td>
<td>9.0</td>
<td>7.9</td>
<td>1.1</td>
<td>0.2</td>
<td>32.4</td>
<td>21.6%</td>
</tr>
<tr>
<td>Public &amp; Others</td>
<td>0</td>
<td>1.1</td>
<td>0.2</td>
<td>1.2</td>
<td>0</td>
<td>0</td>
<td>2.6</td>
<td>1.7%</td>
</tr>
<tr>
<td>Transportation</td>
<td>0</td>
<td>30.8</td>
<td>0</td>
<td>0.2</td>
<td>0</td>
<td>0</td>
<td>31.0</td>
<td>20.6%</td>
</tr>
<tr>
<td>Total</td>
<td>19.8</td>
<td>93.6</td>
<td>12.6</td>
<td>20.6</td>
<td>1.1</td>
<td>2.1</td>
<td>150</td>
<td>100%</td>
</tr>
</tbody>
</table>

- **Total Energy Demand**: 150 M TOE
- **Percentage Distribution**:
  - **Coal**: 13.2%
  - **Petroleum**: 62.4%
  - **Town Gas**: 8.4%
  - **Electricity**: 13.7%
  - **Heat**: 0.7%
  - **Renewable**: 1.4%
  - **Total**: 100%
Evolution from 1984 to 2002 of TFE by Sector

- Industrial
- Res & Com
- Transportation
- Public

K TOE

0 10,000 20,000 30,000 40,000 50,000 60,000 70,000 80,000 90,000 100,000

Evolution from 1984 to 2002 of TFE by Fuel
## End-Uses of Residential Sector

<table>
<thead>
<tr>
<th>END USES</th>
<th>FUEL TYPE</th>
<th>DEVICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEATING</td>
<td>COAL, GAS, HEAT, OIL, ELECTRICITY</td>
<td>Boilers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>District Heating</td>
</tr>
<tr>
<td>LIGHTING</td>
<td>ELECTRICITY</td>
<td>Incandescent bulbs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fluorescent bulbs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other bulbs</td>
</tr>
<tr>
<td>COOKING</td>
<td>LPG Town Gas</td>
<td>Town Gas Stove</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LPG Stove</td>
</tr>
<tr>
<td>APPLIANCES</td>
<td>ELECTRICITY</td>
<td>Refrigerator, Rice cooker, Air conditioner, TV, PC, Electric stove, Kimchi Refrigerator, Washing machine, Vacuum cleaner</td>
</tr>
</tbody>
</table>
## Residential Sector

<table>
<thead>
<tr>
<th></th>
<th>Cooking</th>
<th>Heating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Town gas</td>
<td>51.3</td>
<td>37</td>
</tr>
<tr>
<td>LPG</td>
<td>46.3</td>
<td>6.4</td>
</tr>
<tr>
<td>Oil</td>
<td>0.9</td>
<td>3.4</td>
</tr>
<tr>
<td>Electricity</td>
<td>0.4</td>
<td>Electricity</td>
</tr>
<tr>
<td>Coal</td>
<td>0.2</td>
<td>Coal</td>
</tr>
</tbody>
</table>
Industrial Sector

- The share of GDP of industrial sector is 44.5%. It is expected to decrease to 40.6% in 2020.
- The construction activity will increase to 3.5% in 2020 to meet the increasing demand for floor space driven by economic growth.

<table>
<thead>
<tr>
<th></th>
<th>Share(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agri&amp;Fish</td>
<td>5.04</td>
</tr>
<tr>
<td>Mining</td>
<td>0.18</td>
</tr>
<tr>
<td>Manufact.</td>
<td>92.16</td>
</tr>
<tr>
<td>Construct</td>
<td>2.62</td>
</tr>
</tbody>
</table>
## Commercial & Public Sector

<table>
<thead>
<tr>
<th></th>
<th>2000</th>
<th>2010</th>
<th>2020</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Use</td>
<td>K TOE</td>
<td>13,558</td>
<td>20,900</td>
<td>27,399</td>
</tr>
<tr>
<td>Floor Space</td>
<td>M m²</td>
<td>473</td>
<td>725</td>
<td>928</td>
</tr>
<tr>
<td>Energy Intensity</td>
<td>K TOE/M m²</td>
<td>28.66</td>
<td>28.82</td>
<td>29.53</td>
</tr>
</tbody>
</table>
### Transportation Sector

<table>
<thead>
<tr>
<th>Household</th>
<th>Vehicle Population</th>
<th>Fuel Use (Ktoe)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cars</td>
<td>7,671,000</td>
<td>9,042</td>
</tr>
<tr>
<td>SUV</td>
<td>522,000</td>
<td>972</td>
</tr>
<tr>
<td>Bus</td>
<td>1,284,000</td>
<td>2,542</td>
</tr>
<tr>
<td>Truck</td>
<td>2,254,000</td>
<td>5,268</td>
</tr>
<tr>
<td>Sum</td>
<td>11,731,000</td>
<td>17,824</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MassTran &amp; Freight</th>
<th>Vehicle Population</th>
<th>Fuel Use (Ktoe)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taxi</td>
<td>232,243</td>
<td>1,927</td>
</tr>
<tr>
<td>Bus</td>
<td>69,170</td>
<td>2,138</td>
</tr>
<tr>
<td>Truck</td>
<td>235,791</td>
<td>2,815</td>
</tr>
<tr>
<td>Marine</td>
<td>1,827</td>
<td>6,191</td>
</tr>
<tr>
<td>Rail</td>
<td>7,297</td>
<td>492</td>
</tr>
<tr>
<td>Sum</td>
<td>546,328</td>
<td>13,616</td>
</tr>
</tbody>
</table>
5. Transformation Sector
Transformation Sector

- **Electric Generation**
  - Coal, Fuel Oil
  - Diesel, Natural Gas
  - Hydro
  - Nuclear

- **Town Gas Production**
  - LPG
  - Natural Gas

- **District Heating**
  - Natural Gas
  - Town Gas
  - Fuel Oil

- **LPG Gasification**
  - LNG
## Energy Balance: Transformation

<table>
<thead>
<tr>
<th>UNIT: 000 TOE</th>
<th>coal</th>
<th>Pet</th>
<th>LNG</th>
<th>Town Gas</th>
<th>Heat</th>
<th>Elect</th>
<th>Hydro</th>
<th>Nuclear</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRIMA RY</td>
<td>42,911</td>
<td>100,280</td>
<td>18,924</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1,402</td>
<td>27,241</td>
<td>192,888</td>
</tr>
<tr>
<td>Electricity</td>
<td>23,064</td>
<td>6,042</td>
<td>5,403</td>
<td>108</td>
<td>-</td>
<td>809</td>
<td>22,910</td>
<td>1,402</td>
<td>27,241</td>
</tr>
<tr>
<td>Heat</td>
<td>-</td>
<td>331</td>
<td>436</td>
<td>120</td>
<td>-</td>
<td>355</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Town Gas</td>
<td>-</td>
<td>312</td>
<td>12,387</td>
<td>-</td>
<td>12,520</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>179</td>
</tr>
</tbody>
</table>
# Data on Generation Facilities

<table>
<thead>
<tr>
<th>Facility</th>
<th>Efficiency (%)</th>
<th>Capital Cost (K KRW/kW)</th>
<th>O&amp;M Cost (KRW/kW)</th>
<th>Output Share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>39.25</td>
<td>920</td>
<td>32,628</td>
<td>38.7</td>
</tr>
<tr>
<td>Oil</td>
<td>37.45</td>
<td>800</td>
<td>21,612</td>
<td>7.4</td>
</tr>
<tr>
<td>LNG</td>
<td>35.68</td>
<td>-</td>
<td>-</td>
<td>0.6</td>
</tr>
<tr>
<td>Internal</td>
<td>37.2</td>
<td>1,154</td>
<td>69,840</td>
<td>0.1</td>
</tr>
<tr>
<td>Combined</td>
<td>44.15</td>
<td>505</td>
<td>16,536</td>
<td>9.5</td>
</tr>
<tr>
<td>Hydro</td>
<td>N.A.</td>
<td>617</td>
<td>12,024</td>
<td>1.2</td>
</tr>
<tr>
<td>Nuclear</td>
<td>N.A.</td>
<td>1,346</td>
<td>41,544</td>
<td>42.4</td>
</tr>
</tbody>
</table>
Electric Generation by Fuel

Trend of Electric Generation

- Internal
- Combined
- LNG
- Oil
- Coal
- Nuclear
- Hydro

0 50000 100000 150000 200000 250000 300000

GWh


4-7 Nov. 2003  Hoseok Kim
Non-Electricity Transformation

- District heating
- Town gas production
- LNG gasification process
6. BAU Energy Path
Assumptions of BAU Path

- GDP: 4.9% annual growth rate for the years 2000-15
- Population: 0.6% annual growth rate
- Households: 1.5% annual growth rate
- Residential
  - Expansion of town gas use and district heating
  - Disappearance of LPG and coal uses
- Industrial
  - Decrease of the share of industrial GDP
  - Decrease of manufacturing and increase of construction
- Commercial & Public
  - Increase of floorspace in commercial and public sector
Electricity Generation Capacity
- Stable maintenance of nuclear
- Expansion of CHP
- Reduction of coal and oil generation
- Increase of LNG gasification facilities
- Expansion of district heating area
- Enlargement of town gas-using households
Major Demographic Data Outlook
GDP Outlook
Final Energy Demand: BAU

ROK2003v1 Nov: Net final energy demand in final energy units: demand
Scenario: BAU, Fuel: All Fuels

million tonnes of oil equivalent

Years


Residential
Industrial
Commercial & Public
Transportation
Energy Supply of Transformation Sector

ROK2003v1Nov: Outputs: transformation
Scenario: BAU, Fuel: All Fuels

Please refer to the diagram for detailed information on energy supply trends from 2000 to 2020.
Imports of Primary Energy: BAU
Electricity Generation: BAU

ROK2003v1Nov: Electricity Generation: BAU
Scenario: BAU, Fuel: All Fuels

- Coal
- Bti Coal
- Oil Steam
- LNG Steam
- Combined Cycle
- Internal Combustion
- Nuclear
- Hydro

Years

Million tonnes of oil equivalent
0 2 4 6 8 10 12 14 16 18 20 22 24 26
Global Warming Potential: Demand: BAU
Global Warming Potential: Transformation : BAU
## Examining the Results: TFE & TPES

<table>
<thead>
<tr>
<th>(Mtoe)</th>
<th>2000</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Res</td>
<td>16.7</td>
<td>22.0</td>
</tr>
<tr>
<td>Ind</td>
<td>80.7</td>
<td>139.2</td>
</tr>
<tr>
<td>Com</td>
<td>13.6</td>
<td>23.7</td>
</tr>
<tr>
<td>Trp</td>
<td>31.4</td>
<td>42.0</td>
</tr>
<tr>
<td>Sum</td>
<td>142.3</td>
<td>226.9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>(Mtoe)</th>
<th>2000</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>33.5</td>
<td>53.1</td>
</tr>
<tr>
<td>Oil</td>
<td>99.2</td>
<td>149.5</td>
</tr>
<tr>
<td>LNG</td>
<td>23.1</td>
<td>39.6</td>
</tr>
<tr>
<td>Hydro</td>
<td>0.2</td>
<td>0.5</td>
</tr>
<tr>
<td>Nuc</td>
<td>7.2</td>
<td>11.8</td>
</tr>
<tr>
<td>Sum</td>
<td>163.2</td>
<td>254.5</td>
</tr>
</tbody>
</table>
Projected TFE in 2015: 226.9 Mtoe
- MOCIE’s outlook: 231.7 Mtoe
  - Accounts for 97%

Projected TPES in 2015: 254.7 Mtoe
- MOCIE’s outlook: 288.4 Mtoe
  - Accounts for 88.3%

**BAU paths describe ROK’s energy system quite well.**
7. Obstacles & Tasks

* Cost data availability
* Technology–specific emission factors rather than Tier I
* Maintaining consistency between assumptions employed in BAU scenario
* Updating the dataset and upgrading the model structure
* Applying the model to other policy alternatives
* Integrating with a top–down model.
8. Alternative Scenarios

- Introduction and expansion of Natural Gas Vehicle (NGV)
- Introduction and expansion of LFG generation
- Expansion of compact household vehicles
- Introduction of ‘fuel cell’
- Changes in energy/environmental technology
- Structural change in electricity sector
- Various regional cooperations
Future Work

* Developing future energy scenarios
* Collecting and supplementing missing data
* Trying plausible structural modifications
* Updating the dataset (2000→2001)
* Disaggregating major (sub)sectors