OUTLINE OF PRESENTATION

- Introduction: Model Background
- Key Data Sources
- Model Structure
- Key Assumptions Used in Modeling to Date
- Draft Results
- Next Steps in ROK LEAP Modeling Effort
ROK LEAP Model—Background

- Model development over the period since approximately 2001 by Dr. Kim Hoseok
  - Updated to 2010 base year by Dr. Kim
  - Dr. Kim sends his greetings to Working Group Colleagues, but could not attend due to his GGGI commitments

- Model used by Dr. Kim for a variety of studies in his positions for Korea Environment Institute and for other organizations in Korea
  - Published study on use of Landfill Gas is an example

- D. von Hippel is running ROK-LEAP for the project with input from Dr. Chung Woo-jin, Dr. Kang Jungmin
The ROK LEAP Model: Key Data Sources

- Overall: KEEI detailed energy balance tables used as “control total” source for major totals for base year (2010) supply and demand

- Residential—Driven by number of households
  - Heating: # of household by heating type from Statistics Korea
  - Activities: National Demographic Survey (NSO)

- Industrial—Driven by industrial GDP, share of GDP by subsector
The ROK LEAP Model: Key Data Sources

- Commercial/Public—Driven by building area
  - Activities: Sectoral floor space information from 2007 Wholesale & Retail Survey and 2007 Service Industry Survey
  - Recent activity, intensity, and fuel share data from Energy Consumption Survey (KEEI)
  - Some additions to Public energy use based on biomass use as reflected in KEEI 2010 Energy Balance

- Transport—Driven by number of vehicles and travel distance
  - Activities: Fuel Economy & car sales data from KEMCO, Travel distance from Road Safety Corporation, Yearbook of Construction & Transportation Statistics
  - International air travel and water freight transport from KEEI Yearbook
The ROK LEAP Model: Key Data Sources

- Transformation Module Data:
  - Yearbooks of Energy Statistics (MOCIE & KEEI)
  - Korea Electric Power Corporation
  - Korea Gas Corporation
  - Korea Coal Corporation
  - Korea District Heating Corporation
  - Long-term Electricity Sector Plan, Ministry of Knowledge Economy

- Socio-Economic Indicators and Key Assumptions
  - Statistics Korea
  - Bank of Korea
  - Households
  - Population, Persons per household, and other projections from National Demographic Survey
# The ROK LEAP Model: Demand Structure

<table>
<thead>
<tr>
<th>DEMAND SECTOR</th>
<th>SUB-SECTORS</th>
<th>ACTIVITY PARAMETERS</th>
<th>FUELS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td><strong>HEAT</strong>: By dwelling type (Traditional, coal, oil, LPG, town gas, central, district, others) <strong>APPLIANCE</strong>: 18 electric appliance types</td>
<td>Households Dwelling types Saturation of end uses (%)</td>
<td>electricity, LPG, heat, coal, kerosene, town gas</td>
</tr>
<tr>
<td>Industrial</td>
<td><strong>Agriculture &amp; Fishery</strong>, <strong>Mining Manufacturing</strong>: divided into 10 business types <strong>Construction</strong></td>
<td>Industrial sector GDP (Korean Won, or KRW) Shares of each sub-sector (%) Energy intensity (E/KRW) Fuel share (%)</td>
<td>coal, gasoline, kerosene, diesel, fuel oil, LPG, town gas, heat, electricity, naphtha</td>
</tr>
</tbody>
</table>
The ROK LEAP Model: Demand Structure

<table>
<thead>
<tr>
<th>DEMAND SECTOR</th>
<th>SUB-SECTORS</th>
<th>ACTIVITY PARAMETERS</th>
<th>FUELS</th>
</tr>
</thead>
</table>
| Commercial & Public | 11 business types: Waste management, wholesale and retail, hotel and restaurant, information & communication, real estate, scientific activities, business support, education, health and social work, art and sports, other services | Floorspace (m²)  
Energy intensity (kcal/m²)  
Fuel share (%) | electricity, LPG, fuel oil, heat, diesel, kerosene, town gas |
| Transportation      | Public, Private, and Business road vehicles, by type, size  
Mass Transit (road, rail, air)  
Freight (road, rail, water)  
International air passenger and water freight | Vehicle population  
Shares of each vehicle type and size (%)  
Energy Intensity (E/vehicle)  
Fuel share | gasoline, diesel, LPG, natural gas, electricity, fuel oil, ethanol, biodiesel |
The ROK LEAP Model: Demand Activities Assumptions

<table>
<thead>
<tr>
<th>Activity/Parameter</th>
<th>2010</th>
<th>2020</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population (million)</td>
<td>48.0</td>
<td>51.4</td>
<td>52.2</td>
</tr>
<tr>
<td>GDP Growth Rate (%)</td>
<td>6.30</td>
<td>3.66</td>
<td>2.24</td>
</tr>
<tr>
<td>Commercial floor space (million square meters)</td>
<td>412</td>
<td>548</td>
<td>728</td>
</tr>
<tr>
<td>Vehicle Population (million vehicles)</td>
<td>17.9</td>
<td>25.5</td>
<td>32.0</td>
</tr>
</tbody>
</table>
THE ROK LEAP MODEL

TRANSFORMATION STRUCTURE

- Electricity T&D
- Electricity Generation — 11 Types of power plants, including Industrial Combined Heat and Power (CHP)
- District Heat production
- Town Gas production
- LNG Gasification
- Oil Refining
- Blast Furnace Gas Production
- Coke Production

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## The ROK LEAP Model: Transformation Structure

<table>
<thead>
<tr>
<th>MODULE</th>
<th>PROCESS TYPES</th>
<th>KEY PARAMETERS</th>
<th>FUELS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity Transmission &amp; Distribution</td>
<td></td>
<td>Losses (%)</td>
<td></td>
</tr>
<tr>
<td>Electricity Generation</td>
<td>Coal steam (bituminous and anthracite)</td>
<td>System load factor (%)</td>
<td>Coal</td>
</tr>
<tr>
<td></td>
<td>Oil steam, LNG steam</td>
<td>Process shares (%)</td>
<td>Fuel oil</td>
</tr>
<tr>
<td></td>
<td>Combined cycle (gas)</td>
<td>Efficiency (%)</td>
<td>Natural gas</td>
</tr>
<tr>
<td></td>
<td>Internal combustion</td>
<td>Base year output</td>
<td>Diesel</td>
</tr>
<tr>
<td></td>
<td>Nuclear (PWR/CANDU)</td>
<td>Exogenous capacity</td>
<td>Nuclear</td>
</tr>
<tr>
<td></td>
<td>Hydro (PS/non-PS)</td>
<td>Merit order (base, intermediate, peak)</td>
<td>Hydro</td>
</tr>
<tr>
<td></td>
<td>Renewables</td>
<td>Fuel share (%)</td>
<td>Renewables</td>
</tr>
<tr>
<td>District Heating</td>
<td>Heat only boiler (HOB)</td>
<td>Efficiency (%)</td>
<td>Natural gas, fuel oil, town gas</td>
</tr>
<tr>
<td>Town Gas Production</td>
<td></td>
<td>Efficiency (%)</td>
<td>Natural gas, LPG</td>
</tr>
<tr>
<td>LNG Gasification</td>
<td></td>
<td>Efficiency (%)</td>
<td>LNG</td>
</tr>
<tr>
<td>Oil Refining</td>
<td></td>
<td>Efficiency (%)</td>
<td>Crude oil</td>
</tr>
</tbody>
</table>
THE ROK LEAP MODEL: Assumptions

Key Future Assumptions in Energy Demand

- Residential
  - Driven by number of households, and persons per household declines from ~2.8 in 2010 to 2.4 in 2030
  - Space heating—continued increase in the share of town gas and district heating, and continued slow decline in intensity per housing unit
  - Substantial increase in use of air conditioners, some increases in number of televisions, kimchi refrigerators, vacuum cleaners per household
  - The energy intensity of electric appliance use decreases at a rate sufficient to yield a 25% improvement by 2050 (or 12.5% by 2030)
THE ROK LEAP MODEL: Assumptions

Key Future Assumptions in Energy Demand

- **Industrial**—Driven by industrial GDP, share
  - Share of value added by Manufacturing falls slowly
  - Within Manufacturing, share of Chemicals decreases markedly over time, (which reduces Naptha use), “Misc Manufacturing” increases to compensate, others remain the same over time
  - All intensities slowly decline over time

- **Commercial**—Driven by building area, which rises rapidly (by 75% by 2030)
  - Fuel shares and energy intensities remain relatively constant

- **Public**—Driven by government expenditures, which rise by 75% by 2030
  - Energy intensities, fuel shares don’t change
THE ROK LEAP MODEL: Scenarios

Future Energy Paths for the Republic of Korea

- **Business-as-Usual (BAU) path**
  - Assumes generally that existing policies and currently evolving economy/energy sector trends continue
  - Attempts to reach similar fuel use, shares as in recent KEEI and Ministry of Energy projections
  - But as such is a moving target, because plans in ROK are in flux
  - Assumes continued build-out of nuclear reactors to a total of about 43 GW by 2030 (from 19 GW in 2010), but declines slowly after 2050 (not yet considered directly in LEAP)
  - Includes relatively little additional gas-fired capacity, and a slow decline in the use of gas for generation
  - Includes a considerable increase in the use of coal for generation, and of renewable energy use, but for transport (10% by 2030) and for generation (15.5 GW by 2030)
# THE ROK LEAP MODEL: Scenarios

## KEEI Projections from Late 2012; Units, Tonnes of Oil Equivalent

<table>
<thead>
<tr>
<th>Source</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
<th>2035</th>
<th>AAGR(%) (10–35)</th>
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</thead>
<tbody>
<tr>
<td>Coal</td>
<td>75.9</td>
<td>91.5</td>
<td>104.5</td>
<td>106.6</td>
<td>118.1</td>
<td>123.2</td>
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<tr>
<td></td>
<td>(28.9)</td>
<td>(30.8)</td>
<td>(30.9)</td>
<td>(29.3)</td>
<td>(30.4)</td>
<td>(30.5)</td>
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<tr>
<td>Oil</td>
<td>104.3</td>
<td>105.5</td>
<td>113.6</td>
<td>115.1</td>
<td>115.9</td>
<td>114.9</td>
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<tr>
<td></td>
<td>(39.7)</td>
<td>(35.6)</td>
<td>(33.6)</td>
<td>(31.7)</td>
<td>(29.8)</td>
<td>(28.5)</td>
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<tr>
<td>Natural Gas</td>
<td>43.0</td>
<td>45.2</td>
<td>47.5</td>
<td>55.4</td>
<td>54.6</td>
<td>59.3</td>
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<tr>
<td></td>
<td>(16.4)</td>
<td>(15.2)</td>
<td>(14.0)</td>
<td>(15.3)</td>
<td>(14.0)</td>
<td>(14.7)</td>
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<tr>
<td>Hydro</td>
<td>1.4</td>
<td>1.6</td>
<td>1.6</td>
<td>1.6</td>
<td>1.7</td>
<td>1.8</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td>(0.5)</td>
<td>(0.5)</td>
<td>(0.5)</td>
<td>(0.5)</td>
<td>(0.4)</td>
<td>(0.4)</td>
<td></td>
</tr>
<tr>
<td>Nuclear</td>
<td>31.9</td>
<td>43.9</td>
<td>56.7</td>
<td>66.9</td>
<td>79.5</td>
<td>84.5</td>
<td>4.0</td>
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<tr>
<td></td>
<td>(12.2)</td>
<td>(14.8)</td>
<td>(16.8)</td>
<td>(18.4)</td>
<td>(20.5)</td>
<td>(20.9)</td>
<td></td>
</tr>
<tr>
<td>Renewable</td>
<td>6.1</td>
<td>8.9</td>
<td>14.1</td>
<td>17.5</td>
<td>18.9</td>
<td>20.1</td>
<td>4.9</td>
</tr>
<tr>
<td></td>
<td>(2.3)</td>
<td>(3.0)</td>
<td>(4.2)</td>
<td>(4.8)</td>
<td>(4.9)</td>
<td>(5.0)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>262.6</td>
<td>296.5</td>
<td>337.9</td>
<td>363.1</td>
<td>388.6</td>
<td>403.8</td>
<td>1.7</td>
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<td></td>
<td>(100.0)</td>
<td>(100.0)</td>
<td>(100.0)</td>
<td>(100.0)</td>
<td>(100.0)</td>
<td>(100.0)</td>
<td></td>
</tr>
</tbody>
</table>
THE ROK LEAP MODEL: Scenarios

Future Energy Paths for the Republic of Korea

- **Minimum Nuclear (MIN) path**
  - Assumes reactor capacity peaks in 2025 at 35.7 GW, declines to 33 GW by 2030 (and to 25 GW by 2050)
  - To compensate for decreased nuclear capacity, MIN case includes an increase in coal-fired and combined-cycle plants in ratio of 67%/33%

- **Maximum Nuclear (MAX) path**
  - Assumes the same schedule for construction and decommissioning of existing reactors as in the BAU through 2030, but capacity continues to grow slowly through 2050
# Generation Capacity Projections (GW)

<table>
<thead>
<tr>
<th></th>
<th>2007</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antracite Coal</td>
<td>1.1</td>
<td>1.1</td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
<td>0.7</td>
</tr>
<tr>
<td>Bituminous Coal</td>
<td>19.3</td>
<td>23.1</td>
<td>28.8</td>
<td>28.8</td>
<td>29.9</td>
<td>31.8</td>
</tr>
<tr>
<td>Oil Steam</td>
<td>4.5</td>
<td>4.5</td>
<td>3.5</td>
<td>3.5</td>
<td>2.9</td>
<td>3.1</td>
</tr>
<tr>
<td>LNG Steam</td>
<td>1.5</td>
<td>0.9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Internal Combustion</td>
<td>0.3</td>
<td>0.3</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Combined Cycle</td>
<td>13.8</td>
<td>15.9</td>
<td>19.3</td>
<td>19.3</td>
<td>20</td>
<td>21.3</td>
</tr>
<tr>
<td></td>
<td>1.8</td>
<td>3.1</td>
<td>3.8</td>
<td>3.8</td>
<td>3.9</td>
<td>4.2</td>
</tr>
<tr>
<td>Nuclear</td>
<td>17.7</td>
<td>18.7</td>
<td>25.9</td>
<td>31.5</td>
<td>34.2</td>
<td>36.3</td>
</tr>
<tr>
<td>Hydro</td>
<td>5.5</td>
<td>5.5</td>
<td>6.4</td>
<td>6.4</td>
<td>6.6</td>
<td>7</td>
</tr>
<tr>
<td>Renewable</td>
<td>1.7</td>
<td>0.7</td>
<td>1.7</td>
<td>2.4</td>
<td>2.5</td>
<td>2.6</td>
</tr>
<tr>
<td>Total</td>
<td>67.3</td>
<td>73.9</td>
<td>90.1</td>
<td>96.4</td>
<td>100.9</td>
<td>107.1</td>
</tr>
</tbody>
</table>
Final Energy Demand by Sector: BAU

Demand: Energy Demand Final Units
Scenario: BAU, Fuel: All Fuels

Million Tonnes of Oil Equivalents


Residential
Industrial
Commercial
Public
Transport

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Final Energy Demand by Fuel: BAU

Demand: Energy Demand Final Units
Scenario: BAU

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Final Industrial Demand by Fuel: BAU

Demand: Energy Demand Final Units
Scenario: BAU
Final Electricity Demand by Sector: BAU

Demand: Energy Demand Final Units

Scenario: BAU, Fuel: Electricity

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Final Electricity Demand by Sector: BAU

Demand: Energy Demand Final Units

Scenario: BAU, Fuel: Electricity

- Food & tobacco
- Wood paper printing
- Non metallic
- Industrial machinery
- Instruments
- Misc manufacturing
- Textile
- Chemical petroleum
- Primary fabricated metal
- Electronic electric equipment
- Transportation equipment

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Primary Energy Requirements by Fuel: BAU
Electricity Output by Type: BAU

Transformation: Outputs
Scenario: BAU, Fuel: Electricity

- Ant. Coal
- Bit Coal
- Oil Steam
- LNG Steam
- Internal Combustion
- Combined Cycle
- CHP
- Nuclear PWR
- Hydro
- Renewable
- Pumped Storage Hydro
- Nuclear CANDU

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Electricity Output by Type: MIN

Transformation: Outputs
Scenario: MIN, Fuel: Electricity

- Ant. Coal
- Bit Coal
- Oil Steam
- LNG Steam
- Internal Combustion
- Combined Cycle
- CHP
- Nuclear PWR
- Hydro
- Renewable
- Pumped Storage Hydro
- Nuclear CANDU
Electric Capacity by Type: BAU

Transformation: Capacity
Scenario: BAU, Capacity: All Capacities

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GHG Emissions By Sector: BAU Path

One Hundred Year Global Warming Potential

Scenario: BAU, Fuel: All Fuels, GHG: All GHGs

Million Metric Tonnes CO2 Equivalent

2010 2015 2021 2027

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GHG Emissions By Scenario

Environment: One Hundred Year Global Warming Potential

Fuel: All Fuels, GHG: All GHGs

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THE ROK LEAP MODEL: Next Steps

- Work with Dr. Chung and Dr. Kang to revise BAU, MIN, MAX Cases for consistency with sources (including any new plans)
- Prepare case approximating newer (2/2013) Ministry of Energy “Target” case
- Review assumptions for all Demand, Transformation branches for reasonableness
- Detail attributes of MIN, MAX, BAU paths as needed for modeling of regional nuclear fuel cycle cooperation
THE ROK LEAP MODEL: Next Steps

- Prepare one or more “National Alternative” cases that focus more on energy efficiency, renewable energy, “green growth”

- Revise older “Regional Alternative” path that includes National Alternative attributes, and also models the inclusion of the ROK in regional energy cooperation initiatives (including with DPRK)
THANK YOU!

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