Low Carbon Policies and Transmission Investment Analysis in a New Multi-region US Power Sector TIMES Model

International Energy Workshop
Stanford University
July 6-8, 2011
Amit Kanudia and Evelyn Wright

Username/pwd: guest/guest
Presentation Outline

• Motivation for Development of a New US Modeling Framework
• Model Design, Regional Structure, and Data
• Data Handling Approach and Techniques
• Low Carbon Portfolio Standard and Transmission Investment Analysis
The Importance of a US Regional Perspective

• Any US carbon policy will have greatly varying cost implications across regions of the country, depending on:
  – Existing electricity generation technology mix
  – Available renewable and fossil resources
  – Energy use patterns
  – New technology availability, cost, and incentives
  – State and regional climate, energy, and environmental policies

• These regional differences play some role in the political debate surrounding US carbon policy
Geography Increasingly Matters

• The cost of a transition to a low carbon energy system depends critically on geographical relationships, including those between:
  – Renewable resources, electricity loads, and transmission capacity
  – Biofuels production, transport and use
  – Captured CO2 transport and sequestration

• Following make it even more relevant for USA:
  – Diversity
  – Distances
  – Volumes
New Tools for Geographically Rich Data

• The data to support such detailed geographical analysis exists in the US

• Existing tools (bottom-up optimization) are not able to utilize this data in a resource-efficient, transparent way

• An extended Veda-TIMES framework has been developed to manage voluminous input data and analyze results data
  – Data table development using rules
  – GIS results viewer
Model Design, Regional Structure, and Data

- Motivation for Development of a New US Modeling Framework
- Model Design, Regional Structure, and Data
- Data Handling Approach and Techniques
- Low Carbon Portfolio Standard and Transmission Investment Analysis
Design Principles and Development Pathway

• Employ flexible geographic resolution driven by the native resolution of the source data in each sector

• Utilize best publicly available data
  – NEMS and IPM-EPA are major sources

• Develop new data handling tools as needed to manage data and interpret results

• Full sector model planned; power sector developed and in use for analysis
Regional Structure

• The regional structure of each of the underlying datasets is preserved to minimize “massaging” of the source data, for example:
  – *Electricity generation* is located in NERC sub-regions that represent key transmission grids and bottlenecks
    • Capacity expansion is tracked by state, to allow for state policy modeling
  – *Coal* is tracked from 30 source regions by coal type and sulfur content
  – *Electricity demand* (later end use demands) are modeled within census divisions

• Contrast with other MARKAL-TIMES models that require all supply, transformation, and demand processes to occur within a single set of regions
Electricity Generation Regions

Model Design
Regionalized Coal Supplies
End Use Demand Regions

Model Design
## Data Sources

<table>
<thead>
<tr>
<th>Sector</th>
<th>Source</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass Supply</td>
<td>AEO 2010 supply curves</td>
<td>16 supply regions</td>
</tr>
<tr>
<td>Coal Supply</td>
<td>IPM 2006</td>
<td>31 supply sources, 3 types, 6 sulfur grades</td>
</tr>
<tr>
<td>Coal Transportation</td>
<td>IPM 2006</td>
<td>Matrix of 96 coal types to 135 power plant groupings</td>
</tr>
<tr>
<td>Natural Gas (to power sector only)</td>
<td>IPM 2006 supply curves</td>
<td>Transportation markups to power regions</td>
</tr>
<tr>
<td>Existing Power Plants</td>
<td>IPM NEEDS 3.02 ARRA</td>
<td>32 NERC subregions, 15000 plants, indexed by state and county</td>
</tr>
<tr>
<td>New Power Plants</td>
<td><strong>AEO 2010/AEO2011</strong></td>
<td>Indexed by state</td>
</tr>
<tr>
<td>Renewable Potential</td>
<td>AEO 2010</td>
<td></td>
</tr>
<tr>
<td>Transmission Capacity</td>
<td>IPM 2006</td>
<td>Among 32 NERC subregions</td>
</tr>
<tr>
<td>Electricity Demand</td>
<td><strong>AEO 2010 results</strong></td>
<td>Census divisions, 4-step load curve in two seasons based on IPM data</td>
</tr>
</tbody>
</table>

*Model Design*
Data Handling Approach and Techniques

- Motivation for Development of a New US Modeling Framework
- Model Design, Regional Structure, and Data
- Data Handling Approach and Techniques
- Low Carbon Portfolio Standard and Transmission Investment Analysis
Basic Approach

• Expands the Veda-TIMES framework for managing data development, model construction and management, and analysis
• Key challenge is the immense number of trade links, e.g. 15 coal types X 30 coal regions X 30 PP regions, and 5000 coal plants with flexible inputs
  – 125,000 coal-emission-related inputs
  – 6600 trade links
  – 8000 emission-related UCs
  – 15000 existing plants and 5000 new plants
Existing Policies and Constraints

• Emissions
  – Summer NOx limit for participating states
  – Sulfur limits by plant and national cap
• State renewable portfolio standard
• Retirement
  – Existing plants retire on a plant by plant basis by age
  – Older plants are charged increasing VAROM; can make an economic decision to go out of service
• Annual build rate cost steps to prevent excessively quick run up in new capacity: nuclear, PV, wind
• Renewable potential: capacity factors and cost steps by NEMS region
Low Carbon Portfolio Standard and Transmission Investment Analysis

- Motivation for Development of a New US Modeling Framework
- Model Design, Regional Structure, and Data
- Data Handling Approach and Techniques
- Low Carbon Portfolio Standard and Transmission Investment Analysis
Power Sector Analysis: Two Policies

• Low carbon portfolio standard: 90% by 2050
  – Partial credit for gas combined cycle (50%) and coal/gas with CCS (90%)
  – Parametric scenarios with varying speed of ramping up the standard

• Investment in improved transmission grid
  – Interregional capacity expansion permitted for $100/kw
  – Test value of relieving grid bottlenecks
Scenario Definitions

<table>
<thead>
<tr>
<th>Type</th>
<th>Credit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind, Solar, Biomass, Geothermal, Hydro, Nuclear</td>
<td>1.0</td>
</tr>
<tr>
<td>Sequestration</td>
<td>0.9</td>
</tr>
<tr>
<td>Gas – Combined Cycle</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Results

With and without grid expansion ($100/kw)
Electricity generation (USA)
Reference Case [2035]

ELC generation by Region

Results

www.KanORS.com/tsviewer/FACETS
Reference Case [2020]

Coal, Gas and Hydro generation

www.KanORS.com/gistrade/FACETS
Reference Case [2020]

Can actually locate plants

Results

www.KanORS.com/gistrate/FACETS
Reference Case [2020]

ELC Trades

Results

www.KanORS.com/gistrade/FACETS
Total costs and Cum Emissions

Policy Cases

Results
ELC generation mix
Policy Case-Ref Case (2030)

ELC generation changes by Region

Results
Changes in ELC trade
Changes in ELC trade (>20 TBTU)

Policy Case-Ref Case (2035)
CO2 sequestration

Policy Case (2050)

www.KanORS.com/gistrade/FACETS
Policy Cases

ELC generation summary - 2035

Results
Policy Cases

ELC generation summary - 2050

Results
Policy Cases

Inter-grid transfer capacity

Results

<table>
<thead>
<tr>
<th>Policy Case</th>
<th>Year 2035</th>
<th>Year 2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>RPS-01</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>RPS-03</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>RPS-05</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>RPS-07</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>RPS-09</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>RPS-11</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>RPS-12</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>RPS-14</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>RPS-16</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>RPS-18</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>RPS-20</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>RPS-22</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>RPS-01</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>RPS-03</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>RPS-05</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>RPS-07</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>RPS-09</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>RPS-11</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>RPS-12</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>RPS-14</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>RPS-16</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>RPS-18</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>RPS-20</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>RPS-22</td>
<td>Y</td>
<td>Y</td>
</tr>
</tbody>
</table>

Legend:
- No GridExp
- GridExp Yes
- No Nuc + No GridExp
- No Nuc + GridExp Yes
- Ref
Electricity Prices (Summer day)
And...

• Work on building other supply and demand sectors will start soon.
• These scenarios are available on the web and one can look at many more results:

www.KanORS.com/tsviewer/FACETS
www.KanORS.com/gistrade/FACETS

Username/pwd: guest/guest