State-Level Modeling of Clean Power Plan Compliance Pathways with EPRI’s US-REGEN Model

Vic Niemeyer
Senior Technical Executive
Electric Power Research Institute

RFF-EPRI Seminar on Modeling the Clean Power Plan
February 11, 2016
# US-REGEN: A Full Energy-Economy Model

<table>
<thead>
<tr>
<th>Electric Model</th>
<th>Economy Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>Crude Oil</td>
</tr>
<tr>
<td>Passenger Transport</td>
<td>Refined Petroleum</td>
</tr>
<tr>
<td>Other Transport</td>
<td>Coal</td>
</tr>
<tr>
<td>Residential</td>
<td>Natural Gas</td>
</tr>
<tr>
<td>Commercial</td>
<td>LNG</td>
</tr>
<tr>
<td>Industrial</td>
<td></td>
</tr>
</tbody>
</table>
CPP Analyses Based on 48-State Electric Model

All lower 48 states represented separately. Economy model not used.
Electric Model: Key Features

- Endogenously builds/retrofits/retires capacity in each model time period according to the economics
  - Coal (+ retrofit to gas, biomass, CCS, co-firing, heatrate improvements), Gas NGCCs, Gas Combustion Turbines, Nuclear, Hydro, Geothermal, Wind (Onshore, Offshore), Solar (CSP, PV, Rooftop PV), Diesel/Oil, Coal/Gas with CCS, new biomass

- Endogenously builds inter-state transmission if needed and economic

- We select representative hours to capture load-wind-solar correlations across the year
  - i.e. US-REGEN knows when load is high and there’s no wind!

- Based on a dataset of every unit in the country
  - Last updated July 2015
Renewable Resource Data

- Wind resource data from AWS Truepower
  - Based on 2010 meteorology

- Solar resource data from AWS Truepower
  - Separate resource for central station PV/CSP versus rooftop solar
  - Based on 2010 meteorology

- Geothermal resource data based on NREL (2009) estimates for the Western states
  - New potential additions of ~40GW by 2050 (8GW in CA)
  - Assume capacity factor improves from 50% to 80% due to technical progress
Location of Wind Resource by State

Sample Wind Resource for 80/100m Hub Heights

IN Ref Wind Resource by Capacity Factor

IN CF vs IN MW graph
Location of Central PV Resource by State

* Assumes the use of up to 1% of each state’s available land
US-REGEN vs IPM

- US-REGEN and IPM are both based on the same modeling paradigm
  - Full information, inter-temporal optimization

- Compared to IPM, US-REGEN
  - Uses 48 state-based regions vs IPM’s 60+ regions across state lines
  - Aggregates units more, but uses ~ 6 times as many representative hours to capture renewable intermittency better

- All models of this type have the same computational limitations; modelers must make tradeoffs as to what elements are important to represent the policy at hand
US-REGEN Models Four Main Compliance Pathways

- **Rate**
  - **Subcategory Rates**
    - Steam units target of 1305 lb/MWh, NGCC units target of 771 lb/MWh (2030)
  - **State Rate**
    - Steam and NGCC units target equal to the state rate
  - **Cap Existing and New Units**
    - Existing and New Steam and NGCC units emit less than the state mass target + the new source complement target
  - **Cap Existing Units Only**
    - Existing and Steam and NGCC units emit less than the state mass target

- **CPP Path**
  - Mass
Specific Features for Modeling the Clean Power Plan

- Detailed representation of ERC sources by type
  - Zero, Fossil, Gas-Shift
- Inclusion of output-based set-asides for Existing Mass path
- Endogenous energy efficiency
  - US-REGEN can endogenously build energy efficiency (that counts towards CPP compliance)
  - Current using EPA CPP proposal costs, could revisit
- Detailed renewable representation
  - US-REGEN was built from scratch to give a very detailed representation of wind and solar, and their intermittency
- Other options for coal
  - Co-firing, conversion to biomass or gas, CCS retrofits
Compliance Pathway Determines Trading Partners

- **Rate**
  - **Subcategory Rates**
    - Can trade ERCs with any other Subcategory Rate state
  - **State Rate**
    - Can trade ERCs with another State Rate state in the same compliance plan
- **CPP**
  - **Cap Existing and New Units**
    - Can trade allowances with any other Mass-Based State
  - **Cap Existing Units Only**
Caveats for Following Model Results

- All analyses preliminary
  - CPP highly complex, still testing our modeling
- Models are highly aggregated simulations but not reality
- No constraints on gas delivery
- Not forecasting
- Choices for states intended to show consequences of alternative pathways in a heterogeneous world, not speaking to what pathways states may choose
- Many uncertainties not explored here
  - Cost of EE and RE
  - Possible future additional CO2 policy/regulation
  - Ability to deploy added transmission
EEA Reference Case + 111(b)

EEA Reference Generation (US48)

- EE + Price Response
- New Solar
- Ex Solar
- New Wind
- Ex Wind
- Hydro
- Gas Turbine
- CCS Gas
- CCS Coal
- New NGCC
- Ex NGCC
- New Coal
- Ex Coal
- Other
- Geothermal
- New Nuclear
- Ex Nuclear

Scenario Load

TWh

Year
- 2015
- 2020
- 2025
- 2030
- 2035
- 2040
- 2045
- 2050

© 2016 Electric Power Research Institute, Inc. All rights reserved.
Island Results

Each state must comply relying solely on resources within its own boundary; power trading limited to that in reference case
Natural Gas Price Uncertainty Represented with EIA’s Annual Energy Outlook 2015 “High” and “Low” Paths

Average Power Producer's Gas Price (US)

High Price Path
(based on AEO2015 Ref)

Low Price Path
(based on AEO2015 HEUR)

Natural Gas Price Uncertainty Represented with EIA’s Annual Energy Outlook 2015 “High” and “Low” Paths

Average Power Producer's Gas Price (US) + NYMEX Henry Hub

High Price Path (based on AEO2015 Ref)

Low Price Path (based on AEO2015 HEUR)

Emission Rate Credit (ERC)/Allowance Prices for 2030 with Full Island Compliance (Low gas price path)

State rate/mass path based on minimum costs of island compliance (based on present value of compliance cost through 2050)

Note: for Rate states (green), prices are for ERCs in $/MWh,
For Mass states (brown) prices are for Allowances in $/metric ton
ERC/Allowance Prices for 2030 with Full Island Compliance (High gas price path)

Note: for Rate states (green), prices are for ERCs in $/MWh, For Mass states (brown) prices are for Allowances in $/metric ton
Observations

- Simple economics of rate vs mass:
  - rate compliance achieved with investment in renewables (wind) and energy efficiency, gas redispatch
  - mass compliance achieved with more gas generation
- Zero prices imply states are in compliance in 2030 (though possible need some effort to comply in other time periods)
- Low prices driven by ease of compliance, in turn driven by
  - Low price of natural gas
  - Low incremental cost of wind (in high-wind states)
  - Energy efficiency credits from existing EE programs
  - Announced/expected post 2012 coal retirements
- Many states at/near compliance for both Rate and Mass paths
National Uniform-Pathway Results

All states choose the same compliance pathway
2030 Net ERC Exports if All States Choose Sub Category Rate Path and Trade ERCs (ERC price = $10.96/MWh)

ERC exports in TWh

<table>
<thead>
<tr>
<th>Rate State</th>
<th>Rate Subcategory</th>
<th>Mass Full</th>
<th>Mass Existing</th>
</tr>
</thead>
<tbody>
<tr>
<td>VT</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

RUn Exports
2030 Net Emission Allowance Exports if All States Choose Existing Mass Path (EA price = $12.49/metric ton)

Allowance exports millions of metric tons

低天然气价格路径

MXn Exports
Trading Results Sensitive to National Mix of Pathways
2030 Mix1 ERC/Allowance Pricing with Low Gas Prices

- Allowance prices in $/metric ton
- ERC prices in $/MWh

- Rate State
- Rate Subcategory
- Mass Full
- Mass Existing
2030 Mix2 ERC/Allowance Pricing with Low Gas Prices

Allowance prices in $/metric ton

ERC prices in $/MWh

- Rate State
- Rate Subcategory
- Mass Full
- Mass Existing
Observations

- Mix scenarios are illustrative samples of many possibilities
- Assume national markets for ERCs and Allowances
- ERC price if only new-nuclear states choose Rate is low, but that price may invite other state to “go rate”
- Mix2 shows more realistic set of ERC/Allowance prices
- Many states nominally committed to mass path through existing state polices, e.g., California and RGGI states, would be in compliance with the CPP by choosing rate pathway
- Reasonable variation in future natural gas prices has greater impact on costs than the Clean Power Plan
Strategic Insights

- Key decisions for states are Rate vs. Mass, but also reliance on participation in the market
- Some states appear to have lower costs with Rate, some for Mass, no single universal lowest-cost choice
- Some states may be net beneficiaries of the CPP
- Trading creates value on both sides of the transaction
- The future matters
  - Natural gas prices
  - Renewable and EE costs
  - Market scope and depth
    - Supply/demand for ERCs and Allowances depends on individual state choices for Rate vs. Mass
Together...Shaping the Future of Electricity