Low-Carbon Electricity Pathways for the U.S. and the South

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The Future of Electric Power in the South

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Legend
State Reduction
- 10.6% - 16.2%
- 16.2% - 23.1%
- 23.1% - 29.4%
- 29.4% - 35.5%
- 35.5% - 40.6%
- 40.6% - 51.7%
- 51.7% - 71.6%
Motivation and Methodology
Research Questions

- What is the nation’s least-cost pathway for complying with the Clean Power Plan (CPP)?
- Is the least-cost compliance pathway different in the South?
- How will CPP impacts differ across regions of the South?
- Would a regional approach to compliance have merit?
- What do our results suggest for choosing between mass-versus rate-based goals?
Research Methodology

- Create region-level goals from EPA state-level goals
  - Use location of fossil-fueled plants to apportion goal shares from states to NERC regions

- Introduce various levels of carbon prices
  - Reflects direct pricing for states that choose that route or an indirect penalty on continued use of high carbon fuels, or the assumed allowance price for a metric ton of CO₂ emissions reductions for states that use trading schemes.

- Introduce assumptions of accelerated EE deployment and reduced-cost renewable generation

- Run these scenarios in GT-NEMS
  - Compare the results to EIA’s 2014 Reference case
A Range of Impacts are Examined

- CO$_2$ emissions
- Fuel mix
- End-use efficiency gains and electricity saved
- Electricity rates and bills
- Economic activity
- Other emissions from the electric power sector
Defining the “South” in GT-NEMS

Census Divisions in the South

NERC Regions in the South
The Seven Southern Regions in GT-NEMS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>NERC Sub Region Name</th>
<th>Geographic Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. TRE</td>
<td>Texas Regional Entity</td>
<td>Texas</td>
</tr>
<tr>
<td>2. FRCC</td>
<td>Florida Reliability Coordinating Council</td>
<td>Florida</td>
</tr>
<tr>
<td>12. SRDA</td>
<td>SERC Reliability Corporation - Delta</td>
<td>Mississippi Delta</td>
</tr>
<tr>
<td>14. SRSE</td>
<td>SERC - Southeast</td>
<td>Georgia &amp; Alabama</td>
</tr>
<tr>
<td>15. SRCE</td>
<td>SERC - Central</td>
<td>Tennessee Valley</td>
</tr>
<tr>
<td>16. SRVC</td>
<td>SERC – Virginia &amp; Carolinas</td>
<td>Virginia &amp; Carolinas</td>
</tr>
<tr>
<td>18. SPPS</td>
<td>Southwest Power Pool South</td>
<td>Southern Plains</td>
</tr>
</tbody>
</table>
We modify GT-NEMS to model various levels of carbon pricing starting in 2020 and applied only to the electric power sector.

- Three levels of prices are studied: $10, $20, and $30/metric tons of CO$_2$
- In 2012 dollars
- Applied in 2020 and operation through 2040

The price level needed to achieve a mass-based goal is one way to estimate compliance cost.

NEMS operates with foresight, so changes in response to the carbon price begin earlier than 2020.
(2) Updating Solar Costs

- Used “Tracking the Sun 7” report to update PV costs; by 2030:
  - $1.75/W for utility-scale PV
  - $2/W for commercial-scale PV
  - $2.50/W for residential-scale PV (2010 dollars)
- Also used the low-cost renewables side-case assumptions from EIA
From $/W_{DC}$ to $/W_{AC}$, PV Prices Increase

- Project developers oversize $W_{DC}$ versus inverter $W_{AC}$
- Average cost ratio is 1.25

**$W_{DC}/W_{AC}$ Ratio Increasing**


- Greater $W_{DC}/W_{AC}$ ratios ("Inverter Loading Ratios")
  - Boosts capacity factor and hedges risk
  - Incentivized by PPAs favoring longer hours of delivery
Utility-scale PV Prices at New Lows

- Q4 2014 cost: $1.55/\text{W}_{\text{DC}}$

- To calculate $/\text{W}_{\text{AC}}$,

$/$\text{W}_{\text{AC}} = (1.25 * $/\text{W}_{\text{DC}}$)

=$1.94/\text{W}_{\text{AC}}$

(3) Modeling an “Ambitious” Integrated High-Efficiency Case

- We employ the assumptions of EIA’s High Demand Technology Side Case
  - Advanced equipment is available earlier, at lower costs, and/or at higher efficiencies
  - Stricter building codes and greater compliance with those codes
- Stronger appliance and equipment standards
- Lower costs and extended tax credits for industrial CHP
- Increased energy efficiency in five manufacturing sectors
- Changes are introduced throughout the planning period

Note: For more information: http://cepl.gatech.edu/drupal/node/88
Results
The U.S. and South can Nearly Meet their Rate-Based Goals with the $10 Fee+EE+Solar Pathway

The $10 Fee+EE+Solar and $20 Fee+EE+Solar scenarios are called “compliance pathways”
The Compliance Pathways Cut Coal Use, Curb Natural Gas Growth and Increase EE and RE

The reference case includes naturally occurring energy efficiency
EE investment costs are included in NEMS
The Fuel Mix Transformation in the U.S.

- The low-carbon pathways cause little uptake of additional nuclear power.
- The low-carbon pathways would cause more wind, biomass, and solar PV (but not geothermal or hydro).
- There appears to be a tipping point for solar PV between the $10 and $20 price per tonne-CO$_2$.
- The growth in solar PV mostly displaces wind and natural gas.
- The growth of solar is subdued by EE; solar PV grows along with EE when a carbon price is added.
- Without the introduction of additional low-carbon policies such as those proposed by the CPP, coal generation does not decrease between 2012 and 2030.
Similar Fuel Shifting Would Occur in the South

South

- Efficiency
- Renewables
- Nuclear
- Natural Gas
- Petroleum
- Coal

Bill kWh

- 2012 Reference
- 2030 $10 Fee
- 2030 $20 Fee
- 2030 Updated Solar Cost
- 2030 $10 Fee + EE + Solar
- 2030 $20 Fee + EE + Solar
The South’s Distinct Fuel Mix Response

- Coal tends to decline more rapidly in the South
- Natural gas increases less in the South
- Nuclear power increases in the South
- The South shows proportionately more growth in renewable energy and slightly more growth in energy efficiency
- Biomass plays a greater role in the South’s renewable portfolio, rivaling the role of wind
There are Diverse Responses Across the South

- The three NERC regions with nuclear units under construction require higher carbon prices to achieve compliance.
- The tipping point between the $10Fee+EE+Solar and $20Fee+EE+Solar pathways is shown clearly in several NERC regions.
- In three of the seven southern NERC regions, coal power would decline significantly. EE and renewables grow to fill the gap in SRVC and SPPS, and natural gas also grows in SRCE.
South’s Fuel Mix

- In southern regions where coal use declines, EE, RE, and natural gas increase to fill the gap, in that order
- Natural gas, EE & renewables: competitive or complementary?

Competitive

Complementary
Compliance Pathways Increase Wind, Biomass & Solar; Hydro is Still Dominant

United States

Limited growth of geothermal and hydro
In the South, Solar Rivals Wind, Biomass, and Hydro in Two Pathways

South

- Wind
- Solar PV
- Solar Thermal
- Biomass
- Biogenic Municipal Waste
- Geothermal
- Hydro

![Diagram showing energy sources in the South over 2012 to 2030 with different fees and cost updates.](Image)
Several Regions Reach a “Tipping Point” for Solar PV with $20 Fee + EE + Solar

When $10/tonne-\text{CO}_2$ increases to $20/tonne-\text{CO}_2$ (with EE and solar), significant gains in solar PV generation occur by 2030.
Wholesale generation price, solar \$/kW, and trading may explain solar tipping

<table>
<thead>
<tr>
<th>Solar Tipping Point</th>
<th>High CT $/kW</th>
<th>Low PV $/kW</th>
<th>High Demand Growth</th>
<th>High Natural Gas prices</th>
<th>High Wholesale Prices</th>
<th>High Power Imports</th>
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</thead>
<tbody>
<tr>
<td>TRE</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>FRCC</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>SPPS</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>SRVC</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>No tipping point</td>
<td>SRDA</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
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<td>X</td>
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<td></td>
<td>SRSE</td>
<td>X</td>
<td></td>
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<td>X</td>
<td></td>
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</tbody>
</table>
Residential bills in $10Fee+EE+Solar case in 2030 are 376 TWh (24%) lower than in the Reference case forecast for 2030, saving $46 billion (in $2012).
Impacts on Residential Electricity Rates

- EIA forecasts that electricity rates will rise in the U.S. and the South over the next 15 years, even without new regulations.
- State commitment to energy efficiency and solar can support continued operation of fossil plants, while avoiding additional capital expenditures on new power generation and transmission, leading to lower rates over the long term.
EIA forecasts that household bills will rise in the U.S. and the South over the next 15 years, even without new regulations.

Smart state policies can reduce carbon emissions and also cut household electricity bills in Georgia and Alabama.
Impact on Energy Bills per Household

- Prices per cubic foot of natural gas rise because of upward market pressure from its expansion as a fuel for electric generation;
- However, natural gas bills would decline due to more efficient gas furnaces and water heaters.
Electricity Total Resource Costs Are Less Under Compliance Pathways

- Cost savings are likely due to EE reducing electricity sales
- $20Fee+EE+Solar exhibits more utility investment in solar power
GDP Grows Slightly More in the Compliance Pathways

The value of industrial shipments and exports also increase in the compliance pathways.

*Reference 2012: $13,593 billion
Rate-Based Goals are Less Costly than Mass-Based Goals, Particularly in the South

<table>
<thead>
<tr>
<th>Performance with respect to CPP goals for 2030</th>
<th>CO$_2$ Fee+EE+Solar Required to Meet the Proposed Mass-Based Goals (Existing &amp; New Units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO$_2$ Fee+EE+Solar Required to Meet the Proposed Rate-Based CPP Goals (Existing Units Only)</td>
<td>≤$10$/metric ton</td>
</tr>
<tr>
<td>≤$10$/metric ton</td>
<td>United States</td>
</tr>
<tr>
<td>$10$ - $20$/metric ton</td>
<td>SPSS</td>
</tr>
<tr>
<td>$&gt;$20$/metric ton</td>
<td>TRE</td>
</tr>
</tbody>
</table>

![Map showing regions indicated by different symbols: United States (North), South, SRCE, SRVC, SRSE (South), SPSS (Midwest), FRCC (West), SRDA (East), TRE (TRE)]
Conclusions
Conclusions

- CPP compliance can be achieved cost effectively with a combination of renewable and EE policies plus a modest price on carbon that could be expected to result from the Plan’s implementation.

- This compliance pathway would produce substantial collateral benefits including lower electricity bills across all customer classes, greater GDP growth, and significant reductions in SO$_2$, NO$_x$, and mercury emissions.

- Rate-based goals appear to be less costly than mass-based goals, particularly in the South.
For More Information

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Additional Documentation
South Regional Mass-based Outcomes

- Within the South:
  - 2 regions meet goal at between $10/ton-CO_2$ and $20/ton-CO_2$
  - 2 regions meet goal at between $20/ton-CO_2$ and $30/ton-CO_2$
  - 3 regions meet goal only at >$30/ton-CO_2$
SRSE Mass-based Outcomes

![Graph showing SRSE trends with various fees and measures](image)

- **Reference**
- **$10 Fee**
- **$20 Fee**
- **Updated Solar Cost**
- **Integrated EE**
- **$10 Fee + EE + Solar**
- **$20 Fee + EE + Solar**
- **$30 Fee + EE + Solar**
- **2012 Emission & 2030 Goal**
South Regional Rate-based Outcomes

Within the South:
- 3 regions meet goal at <$10/ton-CO_2$
- 3 regions meet goal at between $10/ton-CO_2$ and $20/ton-CO_2$
- 1 region meets goal only at >$20/ton-CO_2$
SRSE Rate-based Outcomes

- $10 Fee + EE + Solar
- $20 Fee + EE + Solar
- Blue circle = 2030 Rate-based goal

Graph showing SRSE outcomes from 2010 to 2040.
Compliance Scenarios Drive End-Use Efficiency and Renewables

Total Energy Use in Electric Power Sector

Renewable Energy Generation in Electric Power Sector

-13%
-15%
-17%
-20%

28%
17%
3%
7%

Reference
$10 Fee
$20 Fee
Updated Solar Cost
Integrated EE
$10 Fee + EE + Solar
$20 Fee + EE + Solar
$30 Fee + EE + Solar
## Renewable Energy Generation in 2030

<table>
<thead>
<tr>
<th>Abbreviation*</th>
<th>RE Generation in 2030 Ref (Billion KWh)</th>
<th>RE Generation in 2030 $10Fee++ (Billion KWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. TRE</td>
<td>33</td>
<td>37</td>
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<td>2. FRCC</td>
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<td>14. SRSE</td>
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<td>15. SRCE</td>
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<td>16. SRVC</td>
<td>16</td>
<td>43</td>
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<tr>
<td>18. SPPS</td>
<td>18</td>
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</tbody>
</table>

*Regions that tip to solar between $10 and $20 Fee in combination with EE and updated solar.
# Residential Electricity Prices and Bills

<table>
<thead>
<tr>
<th>Scenario</th>
<th>2012</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
<th>2035</th>
<th>2040</th>
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<tbody>
<tr>
<td>$10Fee+EE+Solar</td>
<td>11.88</td>
<td>12.02</td>
<td>12.78</td>
<td>12.75</td>
<td>12.83</td>
<td>12.82</td>
<td>12.76</td>
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<tr>
<td>Difference</td>
<td>0.00</td>
<td>0.09</td>
<td>0.42</td>
<td>0.38</td>
<td>0.16</td>
<td>-0.12</td>
<td>-0.53</td>
</tr>
<tr>
<td>South Reference Case</td>
<td>10.73</td>
<td>10.44</td>
<td>11.01</td>
<td>11.03</td>
<td>11.27</td>
<td>11.55</td>
<td>11.81</td>
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<tr>
<td>$10Fee+EE+Solar</td>
<td>10.73</td>
<td>10.42</td>
<td>11.34</td>
<td>11.32</td>
<td>11.34</td>
<td>11.34</td>
<td>11.31</td>
</tr>
<tr>
<td>Difference</td>
<td>0.00</td>
<td>-0.02</td>
<td>0.33</td>
<td>0.29</td>
<td>0.07</td>
<td>-0.21</td>
<td>-0.50</td>
</tr>
</tbody>
</table>

## Annual Electricity Bills per Household

<table>
<thead>
<tr>
<th>Scenario</th>
<th>2012</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
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<tbody>
<tr>
<td>U.S. Reference Case</td>
<td>1341</td>
<td>1331</td>
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<td>1349</td>
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<tr>
<td>$10Fee+EE+Solar</td>
<td>1341</td>
<td>1241</td>
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<tr>
<td>Difference</td>
<td>0.0</td>
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<td>-201</td>
<td>-267</td>
<td>-330</td>
</tr>
<tr>
<td>% Change</td>
<td>0%</td>
<td>-6.8%</td>
<td>-14.9%</td>
<td>-19.8%</td>
<td>-23.7%</td>
</tr>
<tr>
<td>South Reference Case</td>
<td>1450</td>
<td>1428</td>
<td>1478</td>
<td>1480</td>
<td>1520</td>
</tr>
<tr>
<td>$10Fee+EE+Solar</td>
<td>1450</td>
<td>1329</td>
<td>1275</td>
<td>1194</td>
<td>1163</td>
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<td>Difference</td>
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<td>-203</td>
<td>-286</td>
<td>-357</td>
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<tr>
<td>% Change</td>
<td>0%</td>
<td>-7.0%</td>
<td>-13.8%</td>
<td>-19.4%</td>
<td>-23.5%</td>
</tr>
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