U.S. Coal Plant Retirements: Outlook and Implications

Presented by

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The Brattle Group

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Emerging EPA regulations

Description of the U.S. coal fleet

Cost of compliance

Economics of retirement/retrofit decisions

Impact on gas demand and power prices
# Emerging EPA Regulations for Existing Coal Units

Potential implications of MATS and a potential replacement rule for the vacated CSAPR on coal plant retire/retrofit decisions are examined.

<table>
<thead>
<tr>
<th>Regulation</th>
<th>Status</th>
<th>Pollutant Targeted</th>
<th>Compliance Options</th>
<th>Expected Date of Compliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revised CSAPR</td>
<td>Vacated by Court</td>
<td>NO$_x$, SO$_2$</td>
<td>SCR/SNCR, FGD/DSI, fuel switch, allowance purchases</td>
<td>After 2015?</td>
</tr>
<tr>
<td>MATS</td>
<td>Final</td>
<td>HAPs (mercury, acid gases, PM)</td>
<td>ACI, baghouse, FGD/DSI</td>
<td>2015/2016</td>
</tr>
<tr>
<td>Regional Haze</td>
<td>Final</td>
<td>NO$_x$, SO$_2$, PM</td>
<td>SCR/SNCR, FGD/DSI, Baghouse/ESP, combustion controls</td>
<td>Typically in 5 years</td>
</tr>
<tr>
<td>316(b)</td>
<td>Proposed</td>
<td>Cooling water</td>
<td><strong>Impingement</strong>: Mesh screens; <strong>Entrainment</strong>: Case-by-case, may include cooling towers</td>
<td>2018</td>
</tr>
<tr>
<td>Combustion by-products (ash)</td>
<td>Proposed</td>
<td>Ash, control equipment waste</td>
<td>Bottom ash dewatering, dry fly ash silos, etc.</td>
<td>2015</td>
</tr>
</tbody>
</table>
Coal-fired capacity (316 GW) represents about 1/3rd of the total generation capacity

- Majority of coal capacity (237 GW) is owned by regulated companies (IOUs, munis/coops, etc.), and the rest (79 GW) is owned by merchant companies

Majority (93%) of the coal capacity lacks at least one major equipment (scrubber, SCR and baghouse) to control air emissions
Coal-fired capacity is largely in the eastern interconnect (~265 GW), and primarily in the RFC and SERC regions.

RFC and SERC coal fleet faces two challenges:
- Most of the capacity lacks at least one major equipment, and
- Coal is a large share of regional capacity (46% in RFC, 37% in SERC).

Most of the US merchant coal capacity is in the RFC and ERCOT regions.
Capital costs are significantly more expensive for smaller units. Retrofit costs for major equipment such as wet scrubber and SCR at a small/mid-size coal unit are comparable to cost of a new gas CC at about $1000/kW.

### CAPITAL COST OF CONTROL EQUIPMENT

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Unit Size (MW)</th>
<th>50</th>
<th>200</th>
<th>600</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet Scrubber</td>
<td></td>
<td>904</td>
<td>734</td>
<td>513</td>
</tr>
<tr>
<td>Dry Scrubber</td>
<td></td>
<td>774</td>
<td>628</td>
<td>448</td>
</tr>
<tr>
<td>DSI</td>
<td></td>
<td>42</td>
<td>39</td>
<td>39</td>
</tr>
<tr>
<td>SCR</td>
<td></td>
<td>273</td>
<td>234</td>
<td>188</td>
</tr>
<tr>
<td>SNCR</td>
<td></td>
<td>51</td>
<td>51</td>
<td>51</td>
</tr>
<tr>
<td>Baghouse</td>
<td></td>
<td>504</td>
<td>387</td>
<td>219</td>
</tr>
<tr>
<td>ACI</td>
<td></td>
<td>29</td>
<td>27</td>
<td>19</td>
</tr>
</tbody>
</table>

Source: EPA IPM 4.10 Basecase assumptions and EEI 2011 Study
Levelized Costs of Major Control Equipment

Levelized all-in (capital, FOM, VOM) cost of major control equipment for a 200 MW coal unit could be as high as $50/MWh depending on capacity factor and type of equipment.

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Capacity Factor 30%</th>
<th>Capacity Factor 70%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet Scrubber</td>
<td>$50.80</td>
<td>$22.91</td>
</tr>
<tr>
<td>Dry Scrubber</td>
<td>$43.57</td>
<td>$20.13</td>
</tr>
<tr>
<td>DSI</td>
<td>$10.10</td>
<td>$8.15</td>
</tr>
<tr>
<td>SCR</td>
<td>$15.40</td>
<td>$7.37</td>
</tr>
<tr>
<td>SNCR</td>
<td>$4.38</td>
<td>$2.48</td>
</tr>
<tr>
<td>Baghouse</td>
<td>$23.25</td>
<td>$9.98</td>
</tr>
<tr>
<td>ACI</td>
<td>$2.88</td>
<td>$1.91</td>
</tr>
</tbody>
</table>

Current energy margins (excluding capacity revenues) already low for merchant coal plants due to low gas prices, low demand growth, and new renewables:

- Current dispatch costs for an existing coal plant ~$20-35/MWh
- Low wholesale power prices in 2012 (peak):
  - PJM West: ~$40/MWh
  - Midwest (Illinois/Michigan): ~$33-35/MWh
  - Southeast: ~$30-32/MWh
Wholesale power prices in 2012

Recent power prices are low due to low gas prices and depressed load conditions.

<table>
<thead>
<tr>
<th>Hub</th>
<th>Peak Price ($/MWh)</th>
<th>Off Peak Price ($/MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mid-C</td>
<td>$22</td>
<td>$13</td>
</tr>
<tr>
<td>COB</td>
<td>$24</td>
<td>$13</td>
</tr>
<tr>
<td>NP 15</td>
<td>$32</td>
<td>$24</td>
</tr>
<tr>
<td>SP 15</td>
<td>$35</td>
<td>$35</td>
</tr>
<tr>
<td>Palo Verde</td>
<td>$30</td>
<td>$21</td>
</tr>
<tr>
<td>Four Corners</td>
<td>$34</td>
<td>$22</td>
</tr>
<tr>
<td>N. Illinois</td>
<td>$34</td>
<td>$24</td>
</tr>
<tr>
<td>SPP</td>
<td>$25</td>
<td>$19</td>
</tr>
<tr>
<td>Minn Hub</td>
<td>$32</td>
<td>$20</td>
</tr>
<tr>
<td>NYPP Zone A</td>
<td>$36</td>
<td>$27</td>
</tr>
<tr>
<td>ERCOT</td>
<td>$34</td>
<td>$24</td>
</tr>
<tr>
<td>Entergy</td>
<td>$30</td>
<td>$24</td>
</tr>
<tr>
<td>TVA</td>
<td>$31</td>
<td>$23</td>
</tr>
<tr>
<td>Southern</td>
<td>$31</td>
<td>$21</td>
</tr>
<tr>
<td>NYPP Zone J</td>
<td>$47</td>
<td>$32</td>
</tr>
<tr>
<td>Mass Hub</td>
<td>$41</td>
<td>$31</td>
</tr>
<tr>
<td>PJM-W</td>
<td>$40</td>
<td>$29</td>
</tr>
</tbody>
</table>
Forward markets show very moderate price growth, potentially improving coal plant margins.

Forwards for 2015/16 may not be reflecting impact of future coal plant retirements.
Energy Margins in PJM

Estimated energy margins for 24 GW of coal capacity (~1/3rd of total coal) in PJM were less than $10/MWh in 2011 (= margins at PJM West prices)

- Most missing key control equipment (scrubber, SCR, baghouse)
- Half (12 GW) operating at low capacity factor (< 70%)

**Assumptions**:
- $4/MWh variable O&M and the current wt. average fuel cost reported by Ventyx, Energy Velocity
- PJM West Energy Margin estimated based on 10,000 btu/kWh heat rate
- Capacity figures reflect total capacity in four quadrants defined by 70% capacity factor and PJM West margins. About 14 GW not shown due to missing data on capacity factor.
Brattle analysis of coal plant retirement exposure

A tool to analyze economics of retrofit vs. retirement for every coal unit in the U.S. under various scenarios of environmental regulation.

♦ Estimate **future capacity factor for each unit** by dispatching against projected hourly power prices

♦ Decide each year whether to retire based on comparing **15-year projected avoidable costs of retrofit against**:

  • **Revenues** from energy and capacity markets **for merchant units** (on an after-tax basis),
  
  • **Cost of replacement power** from gas CCs or CTs **for regulated units**.
Brattle coal plant retirement screening tool – details

**Hourly Energy Prices**
- Historical hourly shapes for each NERC subregion (LMPs and system lambdas)
- Recent forward prices and annual growth rates from AEO generation costs

**Hourly Dispatch of Coal Units**
- 24-hour commitment horizon
- 3 modes: off, min load, max load

**Variable Costs for Coal Units**
- AEO regional coal prices
- Unit-specific VOM and start-up costs
- Additional VOM for operating control equipment

**Energy Revenues**

**Capacity Revenues**

**All-in cost of replacement power from gas CC/CT**

**Retirement Tool**
- Merchant Unit Retire when PV(revenues) < PV(costs)
- Regulated Unit Retire when PV(coal costs) >> PV(gas CC/CT costs)

**Variable Costs**
- (fuel, VOM)

**CO₂ prices**

**CapEx for required controls (FGD/SCR/BH)**

**FOM Costs**
- (as-is and for control equipment)

Note: Dashed lines and boxes represent factors and feedback effects that are planned to be incorporated into the model.
Regulation and Market Scenarios

Regulation Scenarios

1. Lenient regulations
   - Units < 25 MW exempt
   - SNCR and ACI on all units
   - DSI and Baghouse on units in WECC and on small units (< 200 MW) in other regions
   - Wet FGD on large (>= 200 MW) units outside WECC

2. Stricter regulations
   - Units < 25 MW exempt
   - SCR on all units
   - DSI, ACI and Baghouse on units in WECC and on small (< 200 MW) units in other regions
   - Wet FGD on large (>= 200 MW) units outside WECC

Market Scenarios

1. April 2012 gas forwards
2. April 2012 gas forwards minus $1/MMBtu
3. April 2012 gas forwards plus $1/MMBtu
4. April 2012 gas forwards with $5/MWh adder to power prices in 2015 decreasing to zero by 2020
5. April 2012 gas forwards + $30/ton CO2 in 2020
Announced Coal Plant Retirements

As of January 2013, about 32 GW of coal capacity have been announced for retirements by 2021

♦ About 80% (24 GW) by 2015
♦ Most lack major environmental controls

<table>
<thead>
<tr>
<th>Year of Retirement</th>
<th>Number of Units</th>
<th>Summer Capacity (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>29</td>
<td>3,447</td>
</tr>
<tr>
<td>2014</td>
<td>48</td>
<td>6,730</td>
</tr>
<tr>
<td>2015</td>
<td>89</td>
<td>14,309</td>
</tr>
<tr>
<td>2016</td>
<td>9</td>
<td>1,138</td>
</tr>
<tr>
<td>2017</td>
<td>16</td>
<td>2,787</td>
</tr>
<tr>
<td>2018</td>
<td>5</td>
<td>991</td>
</tr>
<tr>
<td>2019</td>
<td>1</td>
<td>670</td>
</tr>
<tr>
<td>2020</td>
<td>7</td>
<td>1,653</td>
</tr>
<tr>
<td>2021</td>
<td>1</td>
<td>162</td>
</tr>
<tr>
<td>Total</td>
<td>205</td>
<td>31,886</td>
</tr>
</tbody>
</table>
### Projected Retirements by 2016 (GW)

<table>
<thead>
<tr>
<th>Market Scenario</th>
<th>Base (Recent Fwds)</th>
<th>Base Gas $-1/MMBtu</th>
<th>Base Gas $+1/MMBtu</th>
<th>Base $+5/MWh in Power Prices</th>
<th>Base $+30/ton $C_2$ in 2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retirements under EPA Regulations (GW)</td>
<td>59-77</td>
<td>115-141</td>
<td>21-35</td>
<td>61-77</td>
<td>127-149</td>
</tr>
<tr>
<td>CapEx on Retrofits and Replacement Capacity ($ Billion)</td>
<td>$126-144</td>
<td>$142-158</td>
<td>$112-139</td>
<td>$130-150</td>
<td>$156-169</td>
</tr>
</tbody>
</table>
### Projected Retrofits and Replacement Capacity by 2016 (GW)

<table>
<thead>
<tr>
<th>Regulatory Scenario</th>
<th>SCR</th>
<th>SNCR</th>
<th>Wet Scrubber</th>
<th>Baghouse</th>
<th>ACI</th>
<th>DSI</th>
<th>Total*</th>
<th>Replacement Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lenient</td>
<td>0</td>
<td>99</td>
<td>52</td>
<td>132</td>
<td>183</td>
<td>15</td>
<td>226</td>
<td>49</td>
</tr>
<tr>
<td>Strict</td>
<td>106</td>
<td>0</td>
<td>48</td>
<td>121</td>
<td>136</td>
<td>8</td>
<td>212</td>
<td>57</td>
</tr>
</tbody>
</table>
Most of the projected and announced coal retirements are in SERC (27-30 GW, 10 GW announced) and RFC (18-26 GW, 19 GW announced) reliability regions.
Projected (& announced) Coal Plant Retirements

RTO Regions

PJM and MISO have the largest projected coal retirements among RTO regions.
Overview of U.S. Gas Demand

- 2011 demand ~67 Bcf/d, non-electric demand ~46 Bcf/d
- Flat demand in past decade
- Historically, demand has grown ~1.1% per year (1990-2010)

U.S. Gas Demand

Retirement of 60 GW of coal capacity by 2016 could result in a 6 Bcf/d increase in gas demand nationwide (less with renewables).
Impact of Increased Demand on Gas Prices

♦ A recent EIA study(*) estimated the impact of a 6 Bcf/d increase in gas demand on gas prices.
  • ~15% increase in gas prices initially, and ~10% afterwards

♦ At the current gas forwards for 2015-2020 period, the estimated impact on gas prices would be $0.5-0.7/MMBtu

Impact of Retirements and Retrofits on Power Prices

- Coal retirements would likely result in higher energy prices due to:
  - Removing low-cost resources from the regional supply curve, hence dispatching higher-cost (gas) units;
  - Increased gas prices (see previous slide) making dispatch costs of gas units higher; and
  - Increased variable O&M and heat rates at retrofitted coal units

- In a recent study, we found that MISO energy prices may increase by $8/MWh in on-peak and by $4/MWh off-peak in 2017 as a result of 11 GW of coal retirements by 2016
  - Similar results in studies by MISO (+$5/MWh) and Exelon (+$3-6/MWh relative to forwards)
Questions?
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Principal

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Dr. Celebi provides expertise in electricity markets and analysis of environmental and climate policy. He has consulted primarily in the areas of electricity spot pricing and market design, and has experience in developing and analyzing climate policies, assessing generation market power, LMP modeling, and merger analysis.


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