CO₂ reduction through Energy Efficiency in Coal Fired Boilers

Jim Sutton
Today’s Coal Power Plant Market Reality

- Drive to zero emissions for coal power plants
  - Water
  - Gas
  - Combustion Residues

- Older, less efficient coal fired units shut down

- Surviving units struggle to
  - Optimize position on the dispatch curve
  - Keep pace with regulatory changes on water, air, and Combustion residues
  - Minimize impact of potential Carbon taxes or efficiency legislation
US Boiler CO₂ production intrinsically related to coal mining

US coal 1,171,809 million Short Tons

Western 634
Interior 146
Appalachian 390

Where coal of more than one age group is present, the age shown is that of the coal nearest the surface.
1 Ton of Coal = 3.7 Tons of CO2

Oxygen
Atomic Number: 8
Atomic Mass: 15.9994 amu

Carbon
Atomic Number: 6
Atomic Mass: 12.0107 amu

Wt Ratio = \frac{12 + 32}{12} = 3.7
US Coal Plants 2008 CO2 Data
Weighting typical ultimate values

<table>
<thead>
<tr>
<th>Coal Source</th>
<th>Fixed Carbon (%)</th>
<th>Higher Heating Value (Btu/lb)</th>
<th>Coal Fired in Utility Boilers (Million Tons)</th>
<th>Carbon Fired (Million Tons)</th>
<th>CO2 produced (Million Tons)</th>
<th>Heat Produced (Million Btu's)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Western</td>
<td>47%</td>
<td>8000</td>
<td>565.5</td>
<td>263.0</td>
<td>964.2</td>
<td>9.0E+09</td>
</tr>
<tr>
<td>Appalachian</td>
<td>77%</td>
<td>13650</td>
<td>347.9</td>
<td>266.5</td>
<td>977.0</td>
<td>9.5E+09</td>
</tr>
<tr>
<td>Interior</td>
<td>62%</td>
<td>11200</td>
<td>130.2</td>
<td>80.2</td>
<td>294.1</td>
<td>2.9E+09</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>1043.6</td>
<td>609.6</td>
<td>2235.3</td>
<td>2.1E+10</td>
</tr>
</tbody>
</table>

US Electricity Production: 2.0E+12 KW-hr
US CO2 Production: 2.1E+09 Tons
US Coal Thermal Energy: 2.1E+16 BTU

Net Plant Heat Rate: 10,761 BTU/kw-hr
Overall Efficiency: 31.71 %
CO2 Conversion Rate: 0.10 Ton CO2/MMBTU
CO2 Efficiency: 2.15 lbs/kwhr

Source: US EIA and Alstom Fuel databases.

CO2 in top table from fuel analysis CO2 in lower table from eia
US Coal Power Plants
Installed Base (GW) vs Age (years)

Source: Energy Velocity databases
Heat Rate Capability

- Eddystone Unit Design
- Typical Super Critical Unit
- Average of top 10 Units
- Capability of typical 2500 psig 1000/1000 Unit
- Average Heat Rate
- Typical new PC Unit

Heat Rate (BTU/KWH):
- 8210
- 8600
- 8540
- 9650
- 10800
- 8320

Heat Rate Improvement Potential:
- Heat Rate Improvement

Year:
- 1960
- 1995
- 2003
- 2004
- 2008
- 2009
National Energy Technology Laboratory (NETL) Efficiency Analysis

• “The analysis of U.S. fleet of coal-fired power plants shows a wide variation in efficiency levels but the basic message is that these levels have been largely stagnant for decades and that there is “headroom” for efficiency improvements among all plants including those that currently operate at below average, average, and above average efficiency levels. “

• Claim 10% improvement potential
Market Challenges and Potential Issues

• Making changes in plants to improve efficiency is hampered by the New Source Review provisions of the Clean Air Act, which can trigger potentially lengthy and costly regulatory proceedings when capital improvements and other changes in the plant are made.

• The lack of economic incentives to address efficiency improvements due to the presence of fuel adjustment clauses in approved electricity rates that enable power companies to “pass-through” changes in fuel costs directly to customers.

• Concerns about regulatory proceedings, combined with the lack of economic incentives, make it difficult to get management commitment for power plant efficiency programs that must compete for scarce corporate capital and labor resources. At the same time, the primary aim for power plant operators is to optimize the profitability of the units and ensure they are available to serve load.
Case Study: 760 MW Midwest Coal Boiler
Analysis of Energy losses

Design Heat Rate 8960 BTU/kWhr
As found Heat Rate 9602 BTU/kWhr

Turbine 22%
Condenser 27%
Boiler 45%
AUX Power 1%
Cycle Isolation 4%
Feedwater Heater 1%
Case Study: 8 Units (1000MWE) low sulfur fuel conversion – Power Savings from ESP Transformers

### After SIR Upgrade, Before EPOQ

<table>
<thead>
<tr>
<th>Unit 4</th>
<th>T/R</th>
<th>Size (kV/mA)</th>
<th>kV avg</th>
<th>mA avg</th>
<th>kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>4A1</td>
<td>70/800</td>
<td>56</td>
<td>579</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>4B1</td>
<td>70/800</td>
<td>57</td>
<td>594</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>4A2</td>
<td>70/800</td>
<td>51</td>
<td>743</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>4B2</td>
<td>70/800</td>
<td>51</td>
<td>734</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>4A3</td>
<td>60/1000</td>
<td>52</td>
<td>638</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>4B3</td>
<td>60/1000</td>
<td>51</td>
<td>793</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>4A4</td>
<td>60/1000</td>
<td>54</td>
<td>756</td>
<td>41</td>
<td></td>
</tr>
<tr>
<td>4B4</td>
<td>60/1000</td>
<td>50</td>
<td>828</td>
<td>41</td>
<td></td>
</tr>
</tbody>
</table>

Unit 4 Boiler Load 96.9 MW
Total Plant Capacity 1,028 MW
Stack Opacity 13%
Unit 4 Coal SO₂ Content 1.5 lb SO₂/MBtu

### After SIR Upgrade, With EPOQ

<table>
<thead>
<tr>
<th>Unit 4</th>
<th>T/R</th>
<th>Size (kV/mA)</th>
<th>kV avg</th>
<th>mA avg</th>
<th>kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>4A1</td>
<td>70/800</td>
<td>51</td>
<td>238</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>4B1</td>
<td>70/800</td>
<td>51</td>
<td>225</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>4A2</td>
<td>70/800</td>
<td>41</td>
<td>294</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>4B2</td>
<td>70/800</td>
<td>39</td>
<td>250</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>4A3</td>
<td>60/1000</td>
<td>45</td>
<td>505</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>4B3</td>
<td>60/1000</td>
<td>44</td>
<td>482</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>4A4</td>
<td>60/1000</td>
<td>46</td>
<td>511</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>4B4</td>
<td>60/1000</td>
<td>38</td>
<td>274</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

Unit 4 Boiler Load 103 MW
Total Plant Capacity 1,030 MW
Stack Opacity 13.5%
Unit 4 Coal SO₂ Content 1.0 lb SO₂/MBtu

**Total Power Savings:**

- **296 kW**
- **124 kW**
Case Study: 2 x 500 MW Boiler Combustion Optimization Tuning

- Reduce overall excess air levels with optimum adjustment of air introduction (7% reduction)
- Decrease cold air to Pulverizers (5% reduction)
- Increase Pulverized Coal Fineness (Before – 69% thru 200, After – 78% thru 200 mesh)
- Eliminate Leaks in Ductwork and Casing
- Alstom believes that optimizing existing equipment lowers CO₂ production by up to 0.5%
Summary

- US electric power production from coal results in more than 2,100 million Short Tons on CO$_2$
- Improvements in coal power plant efficiency result in a decrease in CO$_2$ emissions and improved power plant economics
- A 5% reduction in CO$_2$ / KW-hr produced appears to be feasible
- Case studies showing results for both larger projects and smaller efficiency improvements confirm the concept.
Alstom Contacts

Jim Sutton
Director, Boiler Service Products
860 285 4750
jim.sutton@power.alstom.com

Doug Kerr
Director, Asset Optimization
631 420 3251
doug.kerr@us.sigenergy.com