ASSESSMENT OF THE QUALITY OF INDIANA COALS FOR INTEGRATED GASIFICATION COMBINED CYCLE (IGCC) PERFORMANCE

FINAL REPORT TO THE CENTER FOR COAL TECHNOLOGY RESEARCH
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By
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The scoping study preceding this project:

1) Identified properties of Indiana coals that are of major importance for IGCC performance (moisture, heating value, mineral matter properties, char reactivity, sulfur, chlorine, etc);

2) Analyzed the availability of data on coal properties needed to assess IGCC performance;

3) Identified the areas in which more data are needed to adequately assess coal performance for IGCC; and

4) Provided a preliminary assessment of Indiana coals for IGCC. (Mastalerz et al, 2005; 2008)
Status of data availability before the project started

One of the main recommendations of that study was the necessity to generate more data on mineral matter characteristics.
Following that earlier evaluation and recommendations, the main objectives of this study were to:

1) Perform new analyses and integrate them into a coal quality database

2) Map various coal quality parameters;

3) Using several IGCC-important parameters, grade the coals with regard to their suitability for IGCC; and

4) Combine coal quality information with the availability of the coal for surface and underground mining.
Project components

- New data collection
  - Mineral matter (ash) composition
  - Ash melting point and slag viscosity
  - Chlorine content of coal
  - Other (Hg, petrographic composition)

- Data integration and evaluation of the coals for IGCC
<table>
<thead>
<tr>
<th>ILLINOIS</th>
<th>INDIANA</th>
<th>W. KENTUCKY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal Member or Bed</td>
<td>Coal Member</td>
<td>Coal Member or Bed</td>
</tr>
<tr>
<td>McLeansboro Group</td>
<td>McLeansboro Group</td>
<td>McLeansboro Group</td>
</tr>
<tr>
<td>Patski Fm.</td>
<td>Patski Fm.</td>
<td>Patski Fm.</td>
</tr>
<tr>
<td>Shellum Fm.</td>
<td>Shellum Fm.</td>
<td>Shellum Fm.</td>
</tr>
<tr>
<td>No.7</td>
<td>No.7</td>
<td>No.7</td>
</tr>
<tr>
<td>Danville</td>
<td>Danville</td>
<td>Danville</td>
</tr>
<tr>
<td>Jamestown</td>
<td></td>
<td>VII</td>
</tr>
<tr>
<td>Herrin</td>
<td>Hymera</td>
<td>Herrin</td>
</tr>
<tr>
<td>Springfield</td>
<td>Bucktown</td>
<td>Vb</td>
</tr>
<tr>
<td>No.6</td>
<td>No.6</td>
<td>Vb</td>
</tr>
<tr>
<td>Houchin Creek</td>
<td>Houchin Creek</td>
<td>Houchin Creek</td>
</tr>
<tr>
<td>Survant</td>
<td>Survant</td>
<td>Survant</td>
</tr>
<tr>
<td>No.5</td>
<td></td>
<td>IV</td>
</tr>
<tr>
<td>Colchester</td>
<td>Colchester</td>
<td>Colchester</td>
</tr>
<tr>
<td>Dekoven</td>
<td>Seelyville</td>
<td>Colchester</td>
</tr>
<tr>
<td>Davis</td>
<td></td>
<td>IIIa</td>
</tr>
<tr>
<td>No.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caseyville Group</td>
<td>Caseyville Group</td>
<td>Caseyville Group</td>
</tr>
<tr>
<td>Tradewater Fm.</td>
<td>Tradewater Fm.</td>
<td>Tradewater Fm.</td>
</tr>
<tr>
<td>No.4</td>
<td>No.4</td>
<td>No.4</td>
</tr>
<tr>
<td>Willis</td>
<td>Minshall / Buffaloville</td>
<td>(Mining City)</td>
</tr>
<tr>
<td>Reynoldsburg</td>
<td>Upper Block</td>
<td>Empire</td>
</tr>
<tr>
<td>Gentry</td>
<td>Lower Block</td>
<td>Lead Creek/Dunbar</td>
</tr>
<tr>
<td></td>
<td>Shady Lane</td>
<td>Elm Lick</td>
</tr>
<tr>
<td></td>
<td>Mariah Hill</td>
<td>(Ice House)</td>
</tr>
<tr>
<td></td>
<td>Blue Creek</td>
<td>Foster</td>
</tr>
<tr>
<td></td>
<td>Pinnick</td>
<td>Amos</td>
</tr>
<tr>
<td></td>
<td>St. Meinrad</td>
<td>Bell</td>
</tr>
<tr>
<td></td>
<td>French Lick</td>
<td>Battery Rock</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nolin</td>
</tr>
<tr>
<td>No.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Informal name

Coal beds analyzed
Summary of available and restricted coal resources for main economic coal beds in Indiana (Mastalerz et al., 2004). Values are in billion short tons.

<table>
<thead>
<tr>
<th>Coal bed</th>
<th>Original</th>
<th>Mined-out</th>
<th>Remaining</th>
<th>Restricted for mining</th>
<th>Total available (Remaining - Restricted)</th>
<th>Available as % of original</th>
<th>Available for surface mining</th>
<th>Available for underground mining</th>
</tr>
</thead>
<tbody>
<tr>
<td>Danville</td>
<td>6.55</td>
<td>0.36</td>
<td>6.19</td>
<td>5.33</td>
<td><strong>0.83</strong></td>
<td><strong>13.89</strong></td>
<td>0.35</td>
<td>0.52</td>
</tr>
<tr>
<td>Hymera</td>
<td>5.53</td>
<td>0.55</td>
<td>4.98</td>
<td>4.10</td>
<td><strong>0.87</strong></td>
<td><strong>17.47</strong></td>
<td>0.15</td>
<td>0.81</td>
</tr>
<tr>
<td>Springfield</td>
<td>13.31</td>
<td>1.31</td>
<td>12.00</td>
<td>4.65</td>
<td><strong>7.35</strong></td>
<td><strong>61.25</strong></td>
<td>0.82</td>
<td>6.94</td>
</tr>
<tr>
<td>Houchin Creek</td>
<td>5.92</td>
<td>0.0022</td>
<td>5.92</td>
<td>5.56</td>
<td><strong>0.36</strong></td>
<td><strong>6.08</strong></td>
<td>0.18</td>
<td>0.17</td>
</tr>
<tr>
<td>Survant</td>
<td>8.47</td>
<td>0.31</td>
<td>8.17</td>
<td>6.86</td>
<td><strong>1.31</strong></td>
<td><strong>16.03</strong></td>
<td>0.22</td>
<td>1.10</td>
</tr>
<tr>
<td>Colchester</td>
<td>5.14</td>
<td>0.001</td>
<td>5.14</td>
<td>4.95</td>
<td><strong>0.19</strong></td>
<td><strong>3.70</strong></td>
<td>0.11</td>
<td>0.10</td>
</tr>
<tr>
<td>Seelyville</td>
<td>14.61</td>
<td>0.33</td>
<td>14.28</td>
<td>7.68</td>
<td><strong>6.60</strong></td>
<td><strong>46.22</strong></td>
<td>0.30</td>
<td>6.30</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>59.53</strong></td>
<td><strong>2.8632</strong></td>
<td><strong>56.68</strong></td>
<td><strong>39.13</strong></td>
<td><strong>17.54</strong></td>
<td><strong>30.95</strong></td>
<td><strong>2.13</strong></td>
<td><strong>15.94</strong></td>
</tr>
</tbody>
</table>
### Data availability for selected coal properties for selected Indiana coal beds.

<table>
<thead>
<tr>
<th></th>
<th>DANVILLE</th>
<th>HYMERA</th>
<th>SPRINGFIELD</th>
<th>SEELYVILLE</th>
<th>LOWER BLOCK</th>
</tr>
</thead>
<tbody>
<tr>
<td>M [weight %, ar]</td>
<td>1.9</td>
<td>28.2</td>
<td>11.3</td>
<td>253</td>
<td>0.8</td>
</tr>
<tr>
<td>A [weight %, dry]</td>
<td>4.9</td>
<td>41.1</td>
<td>13.0</td>
<td>255</td>
<td>6.8</td>
</tr>
<tr>
<td>S [weight %, dry]</td>
<td>0.33</td>
<td>7.62</td>
<td>2.65</td>
<td>163</td>
<td>1.20</td>
</tr>
<tr>
<td>Heat. Value [Btu/lb, dry]</td>
<td>7651</td>
<td>17314</td>
<td>13050</td>
<td>253</td>
<td>2520</td>
</tr>
<tr>
<td>FC [weight %, dry]</td>
<td>32.0</td>
<td>58.2</td>
<td>48.4</td>
<td>131</td>
<td>11.7</td>
</tr>
<tr>
<td>VM [weight %, dry]</td>
<td>26.9</td>
<td>46.1</td>
<td>39.1</td>
<td>131</td>
<td>15.6</td>
</tr>
<tr>
<td>Slag viscosity temp. [°F]</td>
<td>2156</td>
<td>2900</td>
<td>2559</td>
<td>30</td>
<td>2150</td>
</tr>
<tr>
<td>Cl [weight %]</td>
<td>0.01</td>
<td>0.10</td>
<td>0.03</td>
<td>25</td>
<td>0.02</td>
</tr>
<tr>
<td>SiO₂ [weight %]</td>
<td>31.0</td>
<td>60.0</td>
<td>48.3</td>
<td>34</td>
<td>17.00</td>
</tr>
<tr>
<td>Al₂O₃ [weight %]</td>
<td>14.0</td>
<td>26.0</td>
<td>20.9</td>
<td>34</td>
<td>9.10</td>
</tr>
<tr>
<td>Fe₂O₃ [weight %]</td>
<td>3.5</td>
<td>37.0</td>
<td>16.3</td>
<td>34</td>
<td>4.60</td>
</tr>
<tr>
<td>CaO [weight %]</td>
<td>0.5</td>
<td>10.0</td>
<td>2.9</td>
<td>34</td>
<td>0.43</td>
</tr>
<tr>
<td>MgO [weight %]</td>
<td>0.6</td>
<td>1.7</td>
<td>1.2</td>
<td>34</td>
<td>0.37</td>
</tr>
<tr>
<td>SiO₂/Al₂O₃</td>
<td>1.75</td>
<td>2.73</td>
<td>2.31</td>
<td>34</td>
<td>1.60</td>
</tr>
<tr>
<td>Fe₂O₃+CaO [weight %]</td>
<td>4.01</td>
<td>38.50</td>
<td>19.26</td>
<td>34</td>
<td>5.12</td>
</tr>
<tr>
<td>Silica ratio*</td>
<td>0.44</td>
<td>0.92</td>
<td>0.71</td>
<td>34</td>
<td>0.28</td>
</tr>
<tr>
<td>AFTR INIT. [°F]</td>
<td>2095</td>
<td>2540</td>
<td>2275</td>
<td>12</td>
<td>-</td>
</tr>
<tr>
<td>AFTR SOFT. [°F]</td>
<td>2155</td>
<td>2610</td>
<td>2375</td>
<td>12</td>
<td>-</td>
</tr>
<tr>
<td>AFTR HEM. [°F]</td>
<td>2210</td>
<td>2665</td>
<td>2436</td>
<td>12</td>
<td>-</td>
</tr>
<tr>
<td>AFTR FINAL. [°F]</td>
<td>2250</td>
<td>2735</td>
<td>2502</td>
<td>12</td>
<td>-</td>
</tr>
<tr>
<td>AFTO INIT. [°F]</td>
<td>2340</td>
<td>2705</td>
<td>2535</td>
<td>12</td>
<td>-</td>
</tr>
<tr>
<td>AFTO SOFT. [°F]</td>
<td>2370</td>
<td>2730</td>
<td>2570</td>
<td>12</td>
<td>-</td>
</tr>
<tr>
<td>AFTO HEM. [°F]</td>
<td>2395</td>
<td>2765</td>
<td>2594</td>
<td>12</td>
<td>-</td>
</tr>
<tr>
<td>AFTO FINAL. [°F]</td>
<td>2415</td>
<td>2795</td>
<td>2626</td>
<td>12</td>
<td>-</td>
</tr>
</tbody>
</table>

*(100SiO₂/[SiO₂+Fe₂O₃+CaO+MgO])
Evaluation of the coals has been divided into three groups:

1) Evaluation based on basic coal quality parameters such as heating value, moisture content, ash yield, and sulfur content;

2) Evaluation of the ability of coal and coal char to gasify (reactivity); and

3) Evaluation of slagging based on mineral matter characteristics.
<table>
<thead>
<tr>
<th>Facility</th>
<th>Company</th>
<th>Location</th>
<th>Feedstock</th>
<th>Capacity</th>
<th>Gasifier technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Willem Alexander Centrale</td>
<td>Nuon</td>
<td>Buggenum, The Netherlands</td>
<td>Coal/biomass</td>
<td>253 MW</td>
<td>Shell</td>
</tr>
<tr>
<td>Wabash River</td>
<td>SG Solutions</td>
<td>Terre Haute, IN</td>
<td>Coal/pet coke</td>
<td>260 MW</td>
<td>ConocoPhillips</td>
</tr>
<tr>
<td>Polk Power Station</td>
<td>Tampa Electric</td>
<td>Mulberry, FL</td>
<td>Coal/pet coke</td>
<td>250 MW</td>
<td>GE Energy</td>
</tr>
<tr>
<td>Puertollano</td>
<td>ELCOGAS</td>
<td>Puertollano, Spain</td>
<td>Coal/pet coke</td>
<td>320 MW</td>
<td>Prenflo</td>
</tr>
</tbody>
</table>
Coals best suited for IGCC (slagging gasifiers)

- Low ash content – below 12%

- Low ash fusion temperature (reducing) of <1400°C (2552°F) – guarantees smooth slag flow

- Slag viscosity of <25Pa.s (250 poise) at 1400°C (2552°F) - guarantees smooth slag flow

- A low temperature of critical viscosity <1400°C (2552°F)

- Low or no limestone flux requirements
Coals best suited for IGCC (slagging gasifiers)

- SiO$_2$/Al$_2$O$_3$ ratio of about 2 – minimizes flux requirements and avoids slag crystallization

- Fe$_2$O$_3$ +CaO content in ash $> 15\%$ - gives a chance for zero flux requirement

- A silica ratio ($\frac{100\text{SiO}_2}{[\text{SiO}_2 + \text{Fe}_2\text{O}_3 + \text{CaO} + \text{MgO}]}$) of $<70$ – also minimizes flux requirements
Suitability of selected parameters suggested for Indiana coals.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Optimal</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ash content (%)</td>
<td>less than 12.5</td>
<td>12.5% ash considered less suitable</td>
</tr>
<tr>
<td>SiO&lt;sub&gt;2&lt;/sub&gt;/Al&lt;sub&gt;2&lt;/sub&gt;O&lt;sub&gt;3&lt;/sub&gt;</td>
<td>1.9-2.2</td>
<td>&lt;1.9 and &gt;2.2 considered less suitable</td>
</tr>
<tr>
<td>Silica ratio</td>
<td>less than 0.70</td>
<td>&gt;0.70 considered less suitable</td>
</tr>
<tr>
<td>Fe&lt;sub&gt;2&lt;/sub&gt;O&lt;sub&gt;3&lt;/sub&gt; + CaO (% in ash)</td>
<td>15-35</td>
<td>&lt;15 and &gt;35 considered less suitable</td>
</tr>
<tr>
<td>Slag viscosity T (°F)</td>
<td>less than 2550</td>
<td>&gt;2550 considered less suitable</td>
</tr>
</tbody>
</table>
Map of southwestern Indiana showing the extent of the Springfield Coal Member, the Pennsylvanian System, and distribution of the Springfield coal surface and underground mines.

- **Extent of Springfield coal**
- **Extent of Pennsylvanian System**
- **Active surface mines**
- **Active underground mines**
- **Mined out areas by surface mining**
- **Mined out areas by underground mining**

**Springfield Coal – Extent, mines, and mined out areas**
Evaluation based on basic coal quality parameters such as heating value, moisture content, ash yield, and sulfur content.

Heating value influences generation capacity – higher heating value – higher capacity and efficiency.
Moisture content influences gasifier efficiency – higher moisture – lower efficiency.
Ash content influences gasifier efficiency – higher ash – lower efficiency. It also influences flux addition rates.

Optimal - less than 12.5%
Required - less than 25%
Sulfur content can cause corrosion of heat exchanger surfaces and also influences operating costs (higher sulfur – higher costs).
Springfield Coal – Chlorine content

Forming HCl can poison gas cleaning system catalysts and can cause corrosion.

Required - <0.4%
Preferred - <0.2%
Springfield Coal – Mercury content

Map of southwestern Indiana showing the mercury content (ppm, whole coal basis) of the Springfield coal.
Evaluation of the ability of coal and coal char to gasify (reactivity)

Char reactivity influences carbon conversion (higher reactivity – higher conversion) and oxygen consumption. A range of reactivities can be used.
Springfield Coal – O/C ratio

Map of southwestern Indiana showing the O/C value (daf basis) of the Springfield coal.

- Less than 0.15
- 0.15 to 0.20
- 0.20 to 0.25
- 0.25 to 0.30
- 0.30 to 0.35
- 0.35 to 0.40
- 0.40 to 0.45
- 0.45 to 0.50
- Greater than 0.50

Data points

Map scale
- 0
- 10 miles
- 1:1,000,000

Higher ratio – Higher reactivity
Evaluation of slagging based on mineral matter characteristics.

Springfield Coal – SiO₂/Al₂O₃

– minimizes flux requirements and avoids slag crystallization

Optimal: 1.9-2.2
Springfield Coal – silica ratio

minimizes flux requirements

Optimal: less than 0.70

\[
\frac{100\text{SiO}_2}{\text{SiO}_2 + \text{Fe}_2\text{O}_3 + \text{CaO} + \text{MgO}}
\]
Springfield Coal – $\text{Fe}_2\text{O}_3 + \text{CaO}$

Map of southwestern Indiana showing the $\text{Fe}_2\text{O}_3 + \text{CaO}$ of the Springfield coal.

Optimal: 15-35

Legend:
- Less than 15 and greater than 35
- 15 to 35 - optimal
- Data points

Map scale:
- 0 - 10 miles
- 1:1,000,000
Optimal: less than 2550
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Optimal</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ash content (%)</td>
<td>less than 12.5</td>
<td>12.5% ash considered less suitable</td>
</tr>
<tr>
<td>SiO$_2$/Al$_2$O$_3$</td>
<td>1.9-2.2</td>
<td>&lt;1.9 and &gt;2.2 considered less suitable</td>
</tr>
<tr>
<td>Silica ratio</td>
<td>less than 0.70</td>
<td>&gt;0.70 considered less suitable</td>
</tr>
<tr>
<td>Fe$_2$O$_3$ +CaO (% in ash)</td>
<td>15-35</td>
<td>&lt;15 and &gt;35 considered less suitable</td>
</tr>
<tr>
<td>Slag viscosity T (°F)</td>
<td>less than 2550</td>
<td>&gt;2550 considered less suitable</td>
</tr>
</tbody>
</table>
Maps showing suitability of the Springfield Coal for IGCC

- **OPT** – optimal
- **LS** – less suitable

- Ash content less than 12.5 % (OPT)
- Ash content greater than 12.5 % (LS)
- Slag viscosity temp. less than 2550 °F (OPT)
- Slag viscosity temp. greater than 2550 °F (LS)
- SiO$_2$ to Al$_2$O$_3$ ratio from 1.9 to 2.2 (OPT)
- SiO$_2$ to Al$_2$O$_3$ ratio less than 1.9 and greater than 2.2 (LS)
Maps showing suitability of the Springfield Coal for IGCC

OPT – optimal
LS – less suitable

- $\text{Fe}_2\text{O}_3 + \text{CaO}$ from 15 to 35 (OPT)
- $\text{Fe}_2\text{O}_3 + \text{CaO}$ less than 15 and greater than 35 (LS)
- Silica ratio less than 0.7 (OPT)
- Silica ratio greater than 0.7 (LS)
Maps showing grading of the Springfield Coal for IGCC and availability for surface mining.
Combination of grading and availability for underground mining of the Springfield Coal

Map of the Springfield Coal showing combination of the grading of the coal for IGCC and availability of the coal for underground mining.

- Grade 1 (optimal)
- Grade 2 (less optimal)
- Grade 3 (the least optimal)
- Springfield Coal available for underground mining
- Springfield Coal underground mines
Map of southwestern Indiana showing the extent of the Danville Coal Member, the Pennsylvanian System, and distribution of the Danville coal surface and underground mines.

- Extent of Danville coal
- Extent of Pennsylvanian System
- Active surface mines
- Active underground mines
- Mined out areas by surface mining
- Mined out areas by underground mining

Map scale
0 10 miles
1 : 1,250,000

Danville Coal – Extent, mines, and mined out areas
Maps showing suitability of the Danville Coal for IGCC

- **OPT** – optimal
- **LS** – less suitable

Legend:
- Ash content less than 12.5 % (OPT)
- Ash content greater than 12.5 % (LS)
- Slag viscosity temp. less than 2550 °F (OPT)
- Slag viscosity temp. greater than 2550 °F (LS)
- SiO₂ to Al₂O₃ ratio 1.9 to 2.2 (OPT)
- SiO₂ to Al₂O₃ ratio greater than 2.2 (LS)
Maps showing suitability of the Danville Coal for IGCC

OPT – optimal
LS – less suitable

Yellow: $\text{Fe}_2\text{O}_3 + \text{CaO}$ from 15 to 35 (OPT)
Red: $\text{Fe}_2\text{O}_3 + \text{CaO}$ less than 15 and greater than 35 (LS)
Silica ratio less than 0.7 (OPT)
Silica ratio greater than 0.7 (LS)
Maps showing grading of the Danville Coal for IGCC and availability for surface mining.
Combination of grading and availability for underground mining of the Danville Coal
Map of southwestern Indiana showing the extent of the Hymera Coal Member, the Pennsylvanian System, and distribution of the Hymera coal surface, and underground mines.

Map scale

0 10 miles
1 : 1,250,000

Hymera Coal – Extent, mines, and mined out areas
Maps showing suitability of the Hymera Coal for IGCC

- **OPT** – optimal
- **LS** – less suitable

- Ash content less than 12.5 % (OPT)
- Ash content greater than 12.5 % (LS)
- Slag viscosity temp. less than 2550 °F (OPT)
- Slag viscosity temp. greater than 2550 °F (LS)
- SiO₂ to Al₂O₃ ratio from 1.9 to 2.2 (OPT)
- SiO₂ to Al₂O₃ ratio less than 1.9 and greater than 2.2 (LS)
- No data
Maps showing suitability of the Hymera Coal for IGCC

OPT – optimal
LS – less suitable

- Yellow: Fe$_2$O$_3$ + CaO from 15 to 35 (OPT)
- Dark red: Fe$_2$O$_3$ + CaO less than 15 and greater than 35 (LS)
- Red: Silica ratio less than 0.7 (OPT)
- Dark red: Silica ratio greater than 0.7 (LS)
- Grey: No data
Maps showing grading of the Hymera Coal for IGCC and availability of the coal for surface mining.
Combination of grading and availability for underground mining of the Hymera Coal
Seelyville Coal – Extent, mines, and mined out areas

Map of southwestern Indiana showing the extent of the Seelyville Coal Member, the Pennsylvanian System, and distribution of the Seelyville coal surface and underground mines.

- **Extent of Seelyville coal**
- **Extent of Pennsylvanian System**
- **Active surface mines**
- **Active underground mines**
- **Mined out areas by surface mining**
- **Mined out areas by underground mining**

Map scale

0 - 10 miles

1 : 1,250,000
Maps showing suitability of the Seelyville Coal for IGCC

- OPT – optimal
- LS – less suitable

- Ash content less than 12.5 % (OPT)
- Ash content greater than 12.5 % (LS)
- SiO$_2$ to Al$_2$O$_3$ ratio from 1.9 to 2.2 (OPT)
- SiO$_2$ to Al$_2$O$_3$ ratio less than 1.9 and greater than 2.2 (LS)
- Fe$_2$O$_3$ + CaO from 15 to 35 (OPT)
- Fe$_2$O$_3$ + CaO less than 15 and greater than 35 (LS)
Maps showing grading of the Seelyville Coal for IGCC and its availability for surface mining.
Combination of grading and availability of the Seelyville Coal for the underground mining.
The overall objective of this study was to evaluate Indiana coals for use in IGCC technologies. Specific aims included: 1) generating new analyses on coals and integrating them into a coal quality database; 2) mapping various coal quality parameters; 3) using several IGCC-important parameters, grading the coals with regard to their suitability for IGCC; and 4) combining coal quality information with the availability of the coal for surface and underground mining. Four coal beds are targeted in this study: the Danville, Hymera, Springfield, and Seelyville Coal Members.

This study includes an analysis of coal properties that are of major importance to IGCC technology and requirements with regard to these properties in all three types of gasifiers: fixed-bed, fluidized-bed, and entrained flow. The properties identified as having major impact on gasification process are, among others, heating value, moisture content, and ash content. An updated database of coal properties important for IGCC is available with the final report.
Summary and conclusions

• Assessment of Indiana coals for IGCC is accomplished based on the analysis of: 1) basic coal quality parameters such as heating value, moisture content, ash yield, and sulfur content; 2) ability of coal and coal char to gasify (reactivity); and 3) mineral matter characteristics.

• Basic coal quality characteristics such as heating value, moisture content, and ash content indicate that Indiana coals are a good feedstock for gasification. High sulfur content of the majority of Indiana coals does not create a problem because in IGCC plants sulfur is transformed into sulfuric acid and high purity elemental sulfur, both profitable products. Chlorine content in the coals studied is usually well below the IGCC-preferred 0.2% level, except some areas in the Springfield coal, where at places is a little higher but still below 0.3%. Chlorine content below 0.4% is required for gasification.
• Since no direct reactivity measurements were available, coal/char reactivity proxies such as fuel ratio (a ratio of fixed carbon and volatile matter) and O/C ratio were used to evaluate reactivity. The analysis indicates that the Danville Coal and the Springfield Coal will be more reactive than the Hymera Coal. Reactivity of coal/char is more important in gasifiers with two-step char conversion, such as the one used at Wabash Valley Gasification Plant, than in one stage gasifiers where gasification is a faster process.

• Mineral matter characteristics are very important in entrained-flow slagging gasifiers. Entrained-flow slagging gasifiers are the most common gasifier types in IGCC technologies worldwide, including the US and, therefore, evaluation of mineral matter properties and prediction of its behavior in the gasifier is of fundamental importance.
Summary and conclusions

- Grading of coals for IGCC was accomplished by mapping the distribution of selected parameters, overlying the maps, and outlining the areas with the best characteristics (Grade 1) and less desirable characteristics (Grade 2 and 3). Maps of coal grading were combined with maps of availability for the surface and underground mining. In the Danville Coal, the best coals (Grade 1 and 2) available by surface mining methods occur in Warrick, Pike, and northern Vigo Counties. The coal available by underground methods is dominantly of Grade 3, except in northern Pike County where there is coal of Grade 2. In the Hymera Coal, most of the coal available both for surface and underground mining is represented by Grade 3 and 2. In the Springfield Coal, the best coal for IGCC available by surface methods occur in Pike and Warrick Counties and there are large areas of excellent quality coal (Grade 1 and 2) available by underground methods. In the Seelyville Coal, Pike, Vigo, and Warrick Counties contain Grade 1 and 2 coals available for surface mining and coals of Grade 1, 2, and 3 are available for underground mining in several counties.
Summary and conclusions

For Indiana coals, we recommend two main blending strategies if improvement in slagging characteristics is required: a) blending low SiO$_2$/Al$_2$O$_3$ coals (<1.6) with high SiO$_2$/Al$_2$O$_3$ coals to yield of SiO$_2$/Al$_2$O$_3$ of 1.0-2.2; and b) blending high flux (Fe$_2$O$_3$+CaO) coals with a lower flux coals to yield Fe$_2$O$_3$+CaO content about 15-20%.

Although the evaluation of Indiana coals presented in this report is particularly suitable for entrained-flow slagging gasifiers, generated data and coverages can be valuable for other coal-processing technologies as well. By concentrating on the evaluation based on mineral matter characteristics, but including evaluation of the coal/char reactivity as well as analysis of coal quality parameters, this study can be used to guide the selection of coals for other gasification technologies as well as other clean coal technologies.
Associated Maps


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