Coal in Kentucky

The eastern Kentucky Coal Field is part of the Central Appalachian Basin.

The Western Kentucky Coal Field is part of the Illinois Basin.
Kentucky Coal Production
1975 to 2015

Source: USDOE/EIA
Original Eastern Kentucky Coal Resources

64.1 BT Original resource
50.0 BT Remaining

52% 31% 12% 5%

Coal thickness
- 14 to 28 in
- 28 to 42 in
- 42 to 56 in
- > 56 in

Substantial resource base, but more than 50% is ≤ 28 inches thick

Source: Brant and others, 1980-1983, Kentucky Geological Survey
Original Western Kentucky Coal Resources

- 69% for 41 BT Original resource
- 26% for 35.4 BT Remaining

Coal thickness:
- 14 to 28 in
- 28 to 42 in
- >42 in

Fewer resources than eastern Kentucky, but mineable beds are typically thicker.

Source: Brant and others, 1980-1983, Kentucky Geological Survey
**Resources vs. Reserves**

**Resource** – the occurrence of coal, regardless of thickness, extent, quality, or mineability

**Reserve** – the occurrence of coal interpreted to be economically exploitable (mineable)

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**Eastern Kentucky**
- Resource: 9,482 million short tons
- Reserve: 5,295 million short tons
- Recoverable: 357 million short tons

**Western Kentucky**
- Resource: 18,844 million short tons
- Reserve: 8,727 million short tons
- Recoverable: 479 million short tons

**Kentucky**
- Resource: 28,326 million short tons
- Reserve: 14,021 million short tons
- Recoverable: 837 million short tons

*2015 figures in million short tons*

Source: USDOE/EIA
Underground vs. Surface Mining

Eastern Kentucky: 28.1 MM short tons

- Underground: 14,598
- Surface: 13,503

Western Kentucky: 33.3 MM short tons

- Underground: 28,780
- Surface: 4,544

Kentucky: 61.4 MM short tons

2015 figures in thousand short tons

Source: USDOE/EIA
48% of EKY’s production in 2015 was from surface mining.

- More stringent surface mining regulations
- Continued opposition from NGO’s is likely

Martin County, KY - Google Earth image

Elk repopulation program

Big Sandy Industrial Park
Stoney Fork (SF) Member
Magoffin (M) Member
Kendrick Shale (K) Member
Betsie Shale (B) Member

Conemaugh + Monongahela Formations

Middle Pennsylvanian
Breathitt Group

Upper

Major marine zones
Princess Formation
Four Corners Formation
Hyden Formation
Pikeville Formation
Grundy Formation

Major coal beds
Princess #5-10
Richardson
Skyline
Hazard #9
Hazard #8
Hazard #7
Hazard
Haddix
Taylor
Hamlin
Fire Clay/FCR
Whitesburg
Amburgy
U. Elkhorn #3
U. Elkhorn #1,2
L. Elkhorn
Manchester
Millard
Hagy
Splash Dam
Elswick

Lower Pennsylvanian

Unconformity Surface

Detailed Resource Assessment
Coal Beds

Alvy Creek Formation
Bottom Creek Formation
Pocahontas Formation

Hensley Member
Dark Ridge Member
Warren Point SS Member

NW
SE
Fire Clay Coal Bed

Original Resources

<table>
<thead>
<tr>
<th>Category</th>
<th>&gt;28 in (71 cm)</th>
<th>&lt;28 in (71 cm)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original Resources</td>
<td>2,745.2</td>
<td>1,418.3</td>
<td>4,163.5</td>
</tr>
<tr>
<td>Mined Resources</td>
<td>1,658.6</td>
<td>46.2</td>
<td>1,704.8</td>
</tr>
<tr>
<td>Remaining Resources</td>
<td>1,086.6</td>
<td>1,372.1</td>
<td>2,458.7</td>
</tr>
<tr>
<td>Remaining %</td>
<td>40 %</td>
<td>92 %</td>
<td>59 %</td>
</tr>
</tbody>
</table>

Figures are expressed as million short tons

Eble and Weisenfluh, 2012
## Upper Elkhorn #3 Coal Bed

### Original Resources vs Remaining Resources

<table>
<thead>
<tr>
<th>Category</th>
<th>&gt;28 in (71 cm)</th>
<th>&lt;28 in (71 cm)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original Resources</td>
<td>3,571.5</td>
<td>4,430.2</td>
<td>8,001.7</td>
</tr>
<tr>
<td>Mined Resources</td>
<td>1,725.1</td>
<td>57.2</td>
<td>1,782.3</td>
</tr>
<tr>
<td>Remaining Resources</td>
<td>1,846.4</td>
<td>4373.0</td>
<td>6,219.4</td>
</tr>
<tr>
<td>Remaining %</td>
<td>52 %</td>
<td>99 %</td>
<td>78 %</td>
</tr>
</tbody>
</table>

*Figures are expressed as million short tons*

Eble and Weisenfluh, 2012
The Eastern Kentucky Coalfield is a mature mining region. For the eight coal beds assessed:

Most of the resources of optimal thickness (>42 in) have been mined out, and current development is in thinner coals that require mining of additional rock, resulting in higher mining and processing costs.

For coal >28 in thick:
Original resources = 11.4 BT
Remaining resources = 5.5 BT (48 %)

More than 90 % of the coal <28 in thick remains.

For (optimal) coal >42 in thick:
Remaining resources = 1.9 BT (17 %)
## Western Kentucky Coal Beds

<table>
<thead>
<tr>
<th>Westphalian D</th>
<th>Desmoinesian</th>
<th>Middle Pennsylvanian</th>
<th>Raccoon Creek Group</th>
<th>Tradewater</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bolsovian</strong></td>
<td>Atokan</td>
<td></td>
<td>Mcleansboro Shelburn</td>
<td>Carbondale</td>
</tr>
<tr>
<td><strong>Duckmantian</strong></td>
<td><strong>Lower Morrowan</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Principle Mining Targets**
  - Western Kentucky #14 (Coiltown)
  - Western Kentucky #13 (Baker)
  - Western Kentucky #12 (Paradise)
  - Western Kentucky #11 (Herrin)
  - Western Kentucky #10 (Briar Hill)
  - Western Kentucky #9 (Springfield)
  - Western Kentucky #8 (Colchester)
  - Western Kentucky #7 (Dekovan)
  - Western Kentucky #6 (Davis)
  - Western Kentucky #5 (Wheatcroft)
  - Western Kentucky #4 (Mining City)
  - Elm Lick zone
  - Dunbar zone
  - Western Kentucky #3 (Ice House)
  - Amos/Foster zone
  - Deanefield Bell
  - Battery Rock Main Nolin
**WKY Coal Resource Summary**

Although extensive coal mining has occurred in western Kentucky, significant resources remain in the Springfield, Herrin and Baker coal beds.

Although production initially declined after the CAAA90, the increase in scrubber capacity at U.S. power plants has increased the demand for these high sulfur, but lower cost coals.

<table>
<thead>
<tr>
<th>Thickness Categories</th>
<th>Original</th>
<th>Mined-Out Total</th>
<th>Remaining</th>
<th>Percent Mined Out</th>
</tr>
</thead>
<tbody>
<tr>
<td>14-28</td>
<td>1,036.6</td>
<td>33.2</td>
<td>1,003.5</td>
<td>3</td>
</tr>
<tr>
<td>28-42</td>
<td>1,021.1</td>
<td>28.6</td>
<td>992.5</td>
<td>3</td>
</tr>
<tr>
<td>&gt; 42</td>
<td>1,762.6</td>
<td>122.9</td>
<td>1,639.6</td>
<td>7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3,820.3</strong></td>
<td><strong>1,031.784</strong></td>
<td><strong>3,635.6</strong></td>
<td><strong>5</strong></td>
</tr>
</tbody>
</table>

**Herrin**

<table>
<thead>
<tr>
<th>Thickness Categories</th>
<th>Original</th>
<th>Mined-Out Total</th>
<th>Remaining</th>
<th>Percent Mined Out</th>
</tr>
</thead>
<tbody>
<tr>
<td>14-28</td>
<td>207.2</td>
<td>2.9</td>
<td>204.2</td>
<td>1</td>
</tr>
<tr>
<td>28-42</td>
<td>569.7</td>
<td>16.9</td>
<td>552.8</td>
<td>3</td>
</tr>
<tr>
<td>&gt; 42</td>
<td>3,162.0</td>
<td>1,011.9</td>
<td>2,150.1</td>
<td>32</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3,938.9</strong></td>
<td><strong>1,031.8</strong></td>
<td><strong>2,907.1</strong></td>
<td><strong>26</strong></td>
</tr>
</tbody>
</table>

**Springfield**

<table>
<thead>
<tr>
<th>Thickness Categories</th>
<th>Original</th>
<th>Mined-Out Total</th>
<th>Remaining</th>
<th>Percent Mined Out</th>
</tr>
</thead>
<tbody>
<tr>
<td>14-28</td>
<td>1.0</td>
<td>1.2</td>
<td>9.8</td>
<td>11</td>
</tr>
<tr>
<td>28-42</td>
<td>217.5</td>
<td>12.7</td>
<td>204.8</td>
<td>6</td>
</tr>
<tr>
<td>&gt; 42</td>
<td>9,688.8</td>
<td>2,389.1</td>
<td>7,299.7</td>
<td>25</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>9,917.3</strong></td>
<td><strong>2,403.0</strong></td>
<td><strong>7,514.3</strong></td>
<td><strong>24</strong></td>
</tr>
</tbody>
</table>
Flue Gas Desulfurization (FGD)

FGD - Flue gas desulfurization (FGD, scrubbers) effectively controls the emission of $\text{SO}_2$, and several other effluents, including:

- Acid gases ($\text{HCl}$, $\text{HF}$)
- Mercury ($\text{Hg}$)
- Particulate matter (PM)

FGD decreases fuel costs: low-sulfur EKY coal is more expensive than high-sulfur WKY coal.

- As electric utilities increase the amount of FGD on coal-fired capacity, the demand for low-sulfur, compliance coal for electricity production is projected to decrease (USDOE/EIA).
Trace Element Data

<table>
<thead>
<tr>
<th></th>
<th>CaO</th>
<th>MgO</th>
<th>Na₂O</th>
<th>K₂O</th>
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</thead>
<tbody>
<tr>
<td>PRB</td>
<td>13.1</td>
<td>3.2</td>
<td>1.4</td>
<td>0.7</td>
</tr>
<tr>
<td>WKY</td>
<td>3.7</td>
<td>0.8</td>
<td>0.4</td>
<td>1.8</td>
</tr>
<tr>
<td>EKY</td>
<td>1.6</td>
<td>0.8</td>
<td>0.3</td>
<td>2</td>
</tr>
</tbody>
</table>

Average  Maximum

42  12  12  3.2  3.2  0.7
### Selenium

- Princess: 5.6 ppm
- Southwest: 5.2 ppm
- Licking River: 4.8 ppm
- Big Sandy: 4.7 ppm
- Upper Cumberland: 3.5 ppm
- Hazard: 2.8 ppm
- Western Kentucky: 2.5 ppm

**Average for all KY coals, 4.2 ppm**

### Arsenic

- Princess: 32.1 ppm
- Southwest: 31.7 ppm
- Licking River: 27.1 ppm
- Big Sandy: 23.4 ppm
- Upper Cumberland: 23.3 ppm
- Hazard: 19.7 ppm
- Western Kentucky: 16.5 ppm

**Average for all KY coals, 24.8 ppm**
### Eastern Kentucky Reserve Districts

- **Ohio**
  - Princess
  - Licking River
  - Big Sandy
  - Hazard

- **Virginia**
  - Southwest
  - Upper Cumberland

- **West Virginia**

### Coal Beneficiation

<table>
<thead>
<tr>
<th></th>
<th>Ash</th>
<th>Sulfur</th>
<th>Mn</th>
<th>Ni</th>
<th>Co</th>
<th>Cr</th>
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</thead>
<tbody>
<tr>
<td>EKY</td>
<td>11</td>
<td>1.4</td>
<td>28.6</td>
<td>15.4</td>
<td>5.8</td>
<td>16.6</td>
</tr>
<tr>
<td>WKY</td>
<td>12.3</td>
<td>3.9</td>
<td>39.4</td>
<td>22.6</td>
<td>4.3</td>
<td>18.1</td>
</tr>
<tr>
<td>Cleaned</td>
<td>7.0</td>
<td>1.0</td>
<td>16.2</td>
<td>12.1</td>
<td>2.6</td>
<td>13.2</td>
</tr>
</tbody>
</table>

---

*Kentucky Geological Survey*
<table>
<thead>
<tr>
<th>Location</th>
<th>As, ppm</th>
<th>Co, ppm</th>
<th>Cr, ppm</th>
<th>Ni, ppm</th>
<th>Pb, ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Princess 5a-9</td>
<td>Avg. = 24.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Princess 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hazard 9</td>
<td></td>
<td></td>
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<tr>
<td>Hazard 8</td>
<td></td>
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<tr>
<td>Haddix</td>
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<tr>
<td>Hamlin</td>
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<tr>
<td>Fire Clay</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Whitesburg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Amburguy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U. Elkhorn 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U. Elkhorn 1,2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L. Elkhorn</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manchester</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Millard</td>
<td></td>
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</tr>
</tbody>
</table>

Avg. = 24.8
Avg. = 5.9
Avg. = 17.3
Avg. = 16.1
Avg. = 9.0
**Met Coal** – Used to make coke, a principle component in the production of steel. Coke serves as a reducing-agent for iron ore; it is also a source of process heat. Results indicate that many eastern Kentucky coals have favorable metallurgical properties.

- Less than 10% of Kentucky coal production was used for met coal in 2015.
Sample Collection (mines, prep and power plants)

Sample Preparation (reduce material to -325 mesh)

Sample Ashing (500°C for 5 to 6 hours)

Sample Digestion (HF/HCL/HNO₃ for 10 to 12 hours)

Sample Analysis (5 to 10 minutes, via ICAP)

ICAP = Inductively-coupled argon plasma optical emission spectroscopy
Fire Clay Coal Bed
James River Coal Co., mine #90
Perry County, Kentucky
Hazard South Quadrangle
Latitude: 37.175121
Longitude: 83.157591

Total REE + Y (ppm)

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gray, silty shale roof rock, 3” sampled</td>
<td>295.9</td>
</tr>
<tr>
<td>Top Bench, 32”</td>
<td>976.6</td>
</tr>
<tr>
<td>Flint Clay Parting, 3”</td>
<td>1100.4</td>
</tr>
<tr>
<td>Bottom Bench, 16”</td>
<td>292.0</td>
</tr>
<tr>
<td>Seat Rock (covered) 3” sampled</td>
<td>1018.3</td>
</tr>
<tr>
<td>Coal average</td>
<td>1031.8 ppm</td>
</tr>
<tr>
<td>Rock average</td>
<td>283.9 ppm</td>
</tr>
</tbody>
</table>
Thank You