

Assessment of the quality of Indiana coal for Integrated Gasification Combined Cycle Performance (IGCC)

Progress report –September, 2007

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Project duration – July 1, 2006 – June 20, 2008

Project components:

☐ New data collection

- Mineral matter (ash) composition
- Ash melting point and slag viscosity
- Petrographic composition
- Chlorine content in coal

**☐ Data integration and updated
evaluation of Indiana coals for IGCC**

Associated maps

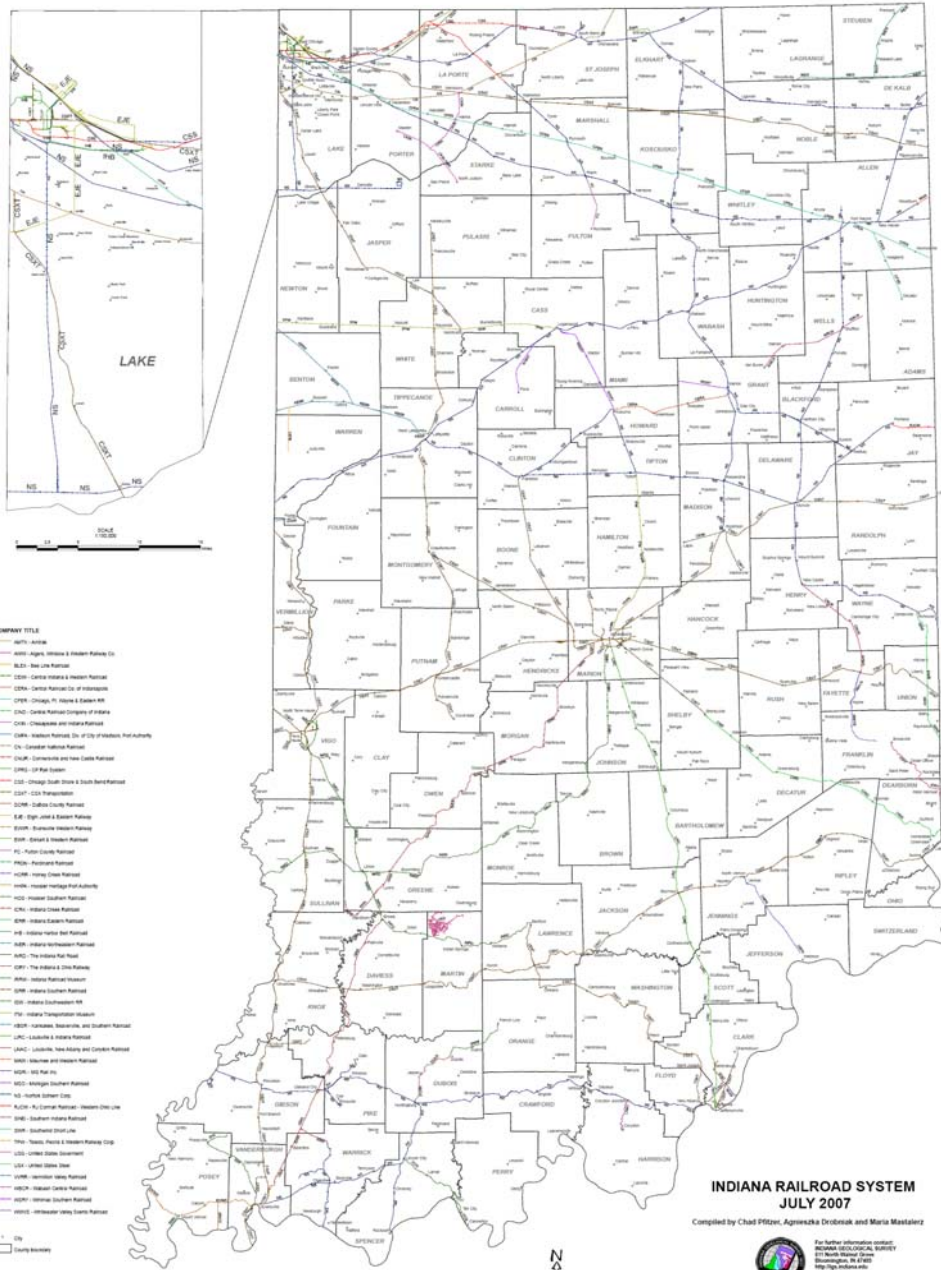
Map 1. Drobniak, A., Mastalerz, M., and Shaffer, K., 2006. **Coal Supply and Demand in Indiana**, IGS Miscellaneous Map 72

Map 2. Drobniak, A., Mastalerz, M., and Shaffer, K., 2006. **Coal, Electricity, and Gas Transportation Systems in Indiana**. IGS Open-File Study 06-03.

Map 3. Drobniak, A., Rupp, J., Mastalerz, M., and Shaffer, K., 2007. **Conceptual Carbon Management Strategies in Indiana**, Open File Study 07-01.

Recent Activities

- **Map 4 – *Railroad Map of Indiana* – including ownership**
- **Coal availability maps for the Danville and the Springfield– as a side project**



- COMPANY TITLE**
- APV - Amtrak
 - AKR - Akron, Indiana & Eastern Railway Co.
 - BLD - Beech Lake Railroad
 - CDM - Central Indiana & Western Railroad
 - CDW - Central Indiana Co. of Indiana
 - CPH - Chicago, Ft. Wayne & Eastern RR
 - CRS - Central Indiana Company of Indiana
 - CRW - Chicago and Indiana Railroad
 - CRW - Madison Railroad, Co. of City of Indiana, Port Authority
 - CRW - Greater Indianapolis
 - CRW - Indianapolis and Fort Wayne Railroad
 - CRW - UP Rail System
 - CRW - Chicago South Shore & South Bend Railroad
 - CRW - CRW Transportation
 - CRW - Dallas County Railroad
 - CRW - Elgin, Joliet & Eastern Railway
 - CRW - Evansville Railroad
 - CRW - Grand & Western Railroad
 - CRW - Hudson County Railroad
 - CRW - Indiana Railroad
 - CRW - Indiana Creek Railroad
 - CRW - Indiana Eastern Railroad
 - CRW - Indiana North Bell Railroad
 - CRW - Indiana North Eastern Railroad
 - CRW - The Indiana Rail Road
 - CRW - The Indiana & Ohio Railway
 - CRW - Indiana Railroad System
 - CRW - Indiana Southern Railroad
 - CRW - Indiana Southern RR
 - CRW - Indiana Transportation Museum
 - CRW - Indiana, Bessemer, and Southern Railroad
 - CRW - Lincoln & Indiana Railroad
 - CRW - Lincoln, New Albany and Eastern Railroad
 - CRW - Madison and Indiana Railroad
 - CRW - IRT Rail Co.
 - CRW - Michigan Southern Railroad
 - CRW - N. Indiana Central Co.
 - CRW - N. Central Indiana - Madison Street Line
 - CRW - Southern Indiana Railroad
 - CRW - Southern Indiana RR
 - CRW - Newby, Potosi & Indiana Railway Co.
 - CRW - United States Government
 - CRW - USA - United States
 - CRW - Indiana State Railroad
 - CRW - Indiana State Railroad
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**INDIANA RAILROAD SYSTEM
JULY 2007**

Compiled by Chad Pfister, Agneszka Drobnik and Maria Mastalerz



PREPARATION OF THIS MAP WAS FUNDED BY THE INDIANA CENTER FOR COAL TECHNOLOGY RESEARCH

Data collection and interpretation

- **Emphasis on mineral matter (ash) composition and slagging characteristics in order to identify the best coals for use in the leading slagging gasifiers (entrained flow gasifiers);**
- **Mapping the parameters of critical importance, and outlining the most favorable zones**

Status of data availability before the project

	Danville				Hymera				Springfield				Lower Block			
	Min	Max	Ave	n	Min	Max	Ave	n	Min	Max	Ave	n	Min	Max	Ave	n
Moisture, ar	1.9	28.2	11.2	252	0.8	23.5	10.26	135	0.5	34.7	9.91	651	0.7	27.1	13.57	156
Fixed carbon, dry	32	58.24	48.43	131	11.7	54	46.75	110	29	70.7	48.03	306	35.5	59.5	50.52	53
Volatile matter, dry	26.9	46.1	39.15	131	15.6	46.8	38.54	110	19.9	62	40.89	306	33.5	47.5	38.75	53
Ash (dry)	4.9	41.1	13	254	6.8	72.7	14.5	136	4.89	54.21	12.12	651	4.1	31	8.82	158
Btu (dry)	7651	17314	13051	252	2520	13734	12043	135	8362	20647	13229	651	9677	14726	13333	156
AFTred, init	2095	2540	2274	12	no data								1990	2800	2399	14
AFTred, soft	2155	2610	2376	12									2040	2800	2445	14
AFTred, hem	2210	2665	2435	12									2080	2800	2491	14
AFTred, final	2250	2753	2502	12									2170	2800	2551	14
Slag viscosity	2419	2900	2672	12			2460	1	2155	2900	2626	14				
Cl (%)	0.01	0.1	0.03	24	0.02	0.07	0.04	24	0.03	0.24	0.15	28	0.01	0.05	0.02	28

Current status

	DANVILLE				HYMERA				SPRINGFIELD				LOWER BLOCK			
	Min.	Max.	Ave	n	Min.	Max.	Ave	n	Min.	Max.	Ave	n	Min.	Max.	Ave	n
M [ar]	1.9	28.2	11.3	253	0.8	23.5	10.3	134	0.5	34.7	9.9	653	0.7	27.1	13.8	138
A [dry]	4.9	41.1	13.0	255	6.8	72.7	14.5	135	4.9	54.2	12.2	662	4.1	31.0	9.0	145
Btu [dry]	7651	1731 4	1305 0	253	2520	1373 4	1204 2	134	8362	2064 8	1321 4	662	9677	1470 2	1326 2	144
FC [dry]	32.0	58.2	48.4	131	11.7	54.0	46.7	110	29.0	70.7	48.0	307	35.5	59.5	52.6	93
VM [dry]	26.9	46.1	39.1	131	15.6	45.8	38.5	110	19.9	62.0	40.9	307	33.5	47.5	38.5	94
Slag Visc.	2156	2900	2559	30	2150	2900	2421	15	2150	2720	2344	40	2150	2900	2661	37
Cl [%]	0.01	0.10	0.03	25	0.02	0.07	0.04	23	0.01	0.24	0.15	30	0.01	0.06	0.02	40
SiO ₂ [%]	31.0	60.0	48.3	34	17.00	55.00	39.13	20	21.0	53.0	38.5	47	0.4	61.7	47.5	38
Al ₂ O ₃ [%]	14.0	26.0	20.9	34	9.10	28.40	18.00	20	9.2	28.0	18.2	47	16.4	34.0	25.4	38
Fe ₂ O ₃ [%]	3.5	37.0	16.3	34	4.60	41.00	22.95	20	6.5	49.0	23.1	47	3.3	47.2	14.6	38
CaO [%]	0.5	10.0	2.9	34	0.43	27.00	4.80	20	0.3	16.0	4.3	47	0.5	7.1	1.9	38
MgO [%]	0.6	1.7	1.2	34	0.37	1.50	0.85	20	0.3	1.4	0.8	47	0.3	1.0	0.6	38
SiO ₂ / Al ₂ O ₃	1.75	2.73	2.31	34	1.60	2.93	2.22	20	1.46	2.59	2.16	47	0.02	2.52	1.89	38
Fe ₂ O ₃ + CaO	4.01	38.50	19.26	34	5.12	42.00	27.75	20	7.60	53.80	27.42	47	4.80	47.66	16.51	38
Silica ratio*	0.44	0.92	0.71	34	0.28	0.90	0.58	20	0.30	0.86	0.58	47	0.02	0.92	0.73	38

*Silica ratio = SiO₂ / (SiO₂ + Fe₂O₃ + CaO + MgO)

Criteria of best suited coals for IGCC (slagging gasifiers)

- Low ash content – below 12%
- Low ash flow temperature (reducing) of $<1400^{\circ}\text{C}$ (2552°F) – guarantees smooth slag flow
- Slag viscosity of $<25\text{Pa}\cdot\text{s}$ (250 poise) at 1400°C (2552°F) -guarantees smooth slag flow
- A low temperature of critical viscosity $<1400^{\circ}\text{C}$ (2552°F)
- Low or no limestone flux requirements

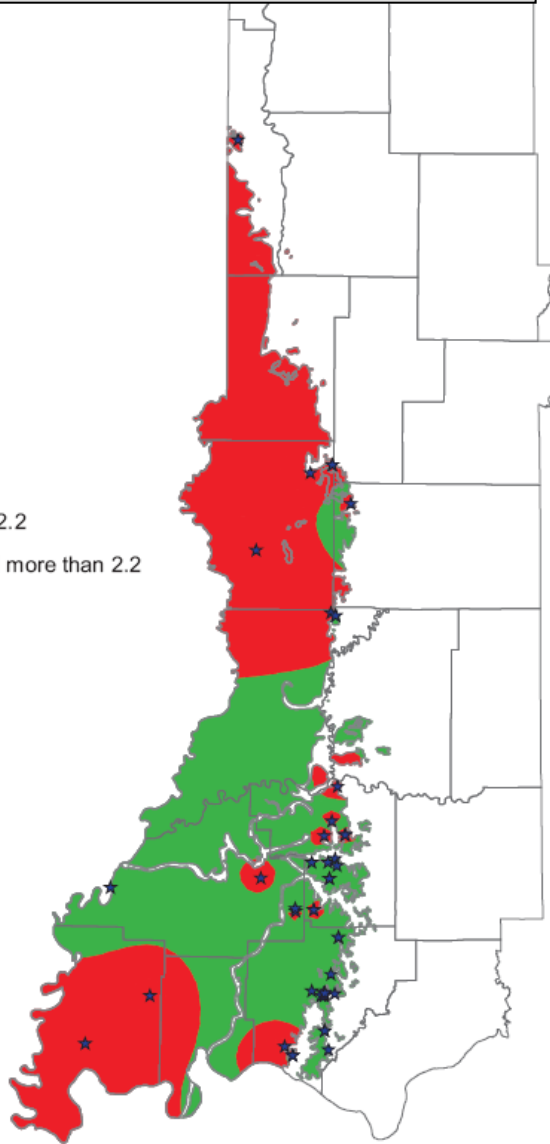
Criteria of best suited coals for IGCC

- $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratio of about 2 – minimizes flux requirements and avoids slag crystallization
- $\text{Fe}_2\text{O}_3 + \text{CaO}$ content in ash $> 15\%$ - to give a chance for zero flux requirement
- A silica ratio ($100\text{SiO}_2/[\text{SiO}_2 + \text{Fe}_2\text{O}_3 + \text{CaO} + \text{MgO}]$) of < 70 – also minimizes flux requirements

**Best for IGCC:
 $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratio of about 2**

Springfield Coal
 $\text{SiO}_2/\text{Al}_2\text{O}_3$

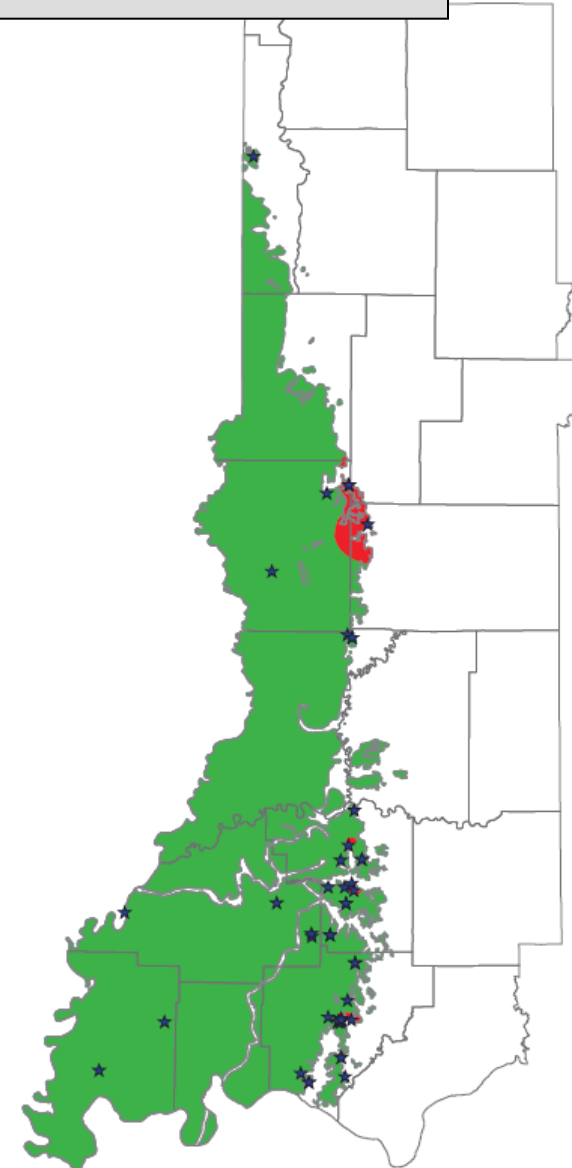
- Between 1.9 and 2.2
- Less than 1.9 and more than 2.2
- ★ Data Points



**Best for IGCC:
A silica ratio <0.7**

Springfield Coal
Silica Ratio

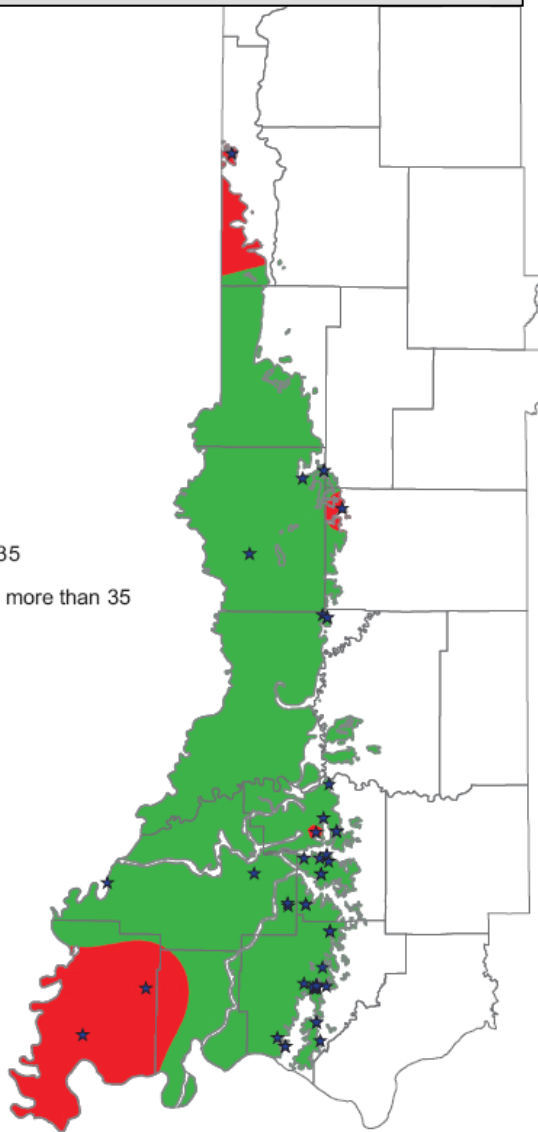
- Less than 0.7
- More than 0.7
- ★ Data Points



**Best for IGCC:
Fe₂O₃ +CaO in ash > 15%**

Springfield Coal
Fe₂O₃+CaO

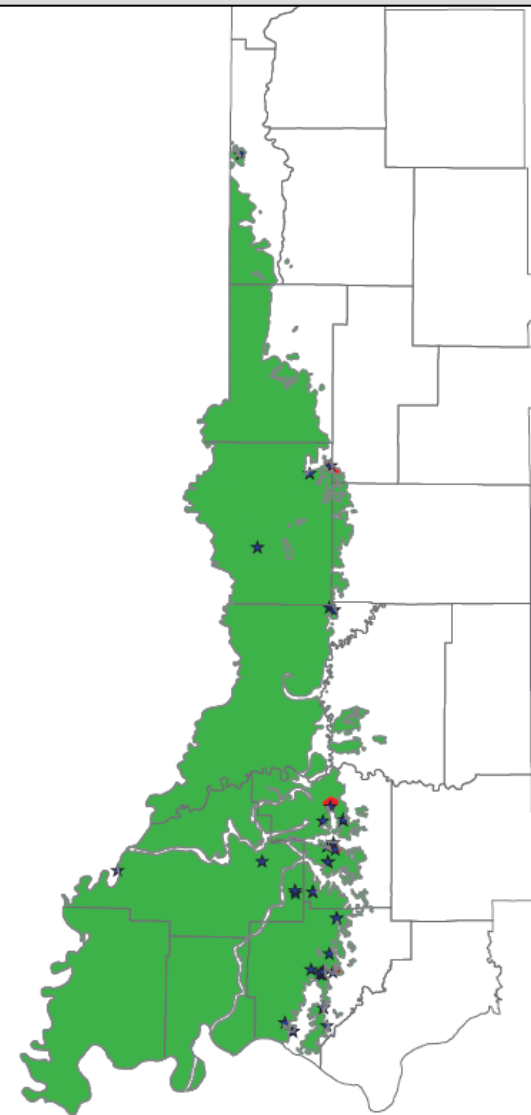
- Between 15 and 35
- Less than 15 and more than 35
- ★ Data Points



**Best for IGCC:
T of critical viscosity <2552°F**

Springfield Coal
Slag Viscosity

- Less than 2,550
- More than 2,550
- ★ Data Points



Other parameters analyzed

- Chlorine (preferable $<0.2\%$ for IGCC) – forming HCl can poison gas cleaning system catalysts and HCl can cause chloride stress corrosion
- Hg content to expand our Hg database for Indiana coals

Next steps

- **Sampling and collection of additional data will continue till the end of this year**
- **Mapping IGCC-important parameters for Danville, Hymera, and Springfield, and the Lower Block**
- **Outlining areas within these coals that are best suited for IGCC and combining this information with coal availability – January - April, 2008**
- **Final report with recommendations (outlining the most favorable coal zones and discussing opportunities for selective mining and/or coal blending to produce an optimum product). The report will also include four maps – June 2008**

Thank you

