COAL BENEFICIATION
DRY METHODS

Rick Honaker, University of Kentucky
Gerald (Jerry) Luttrell, Virginia Tech

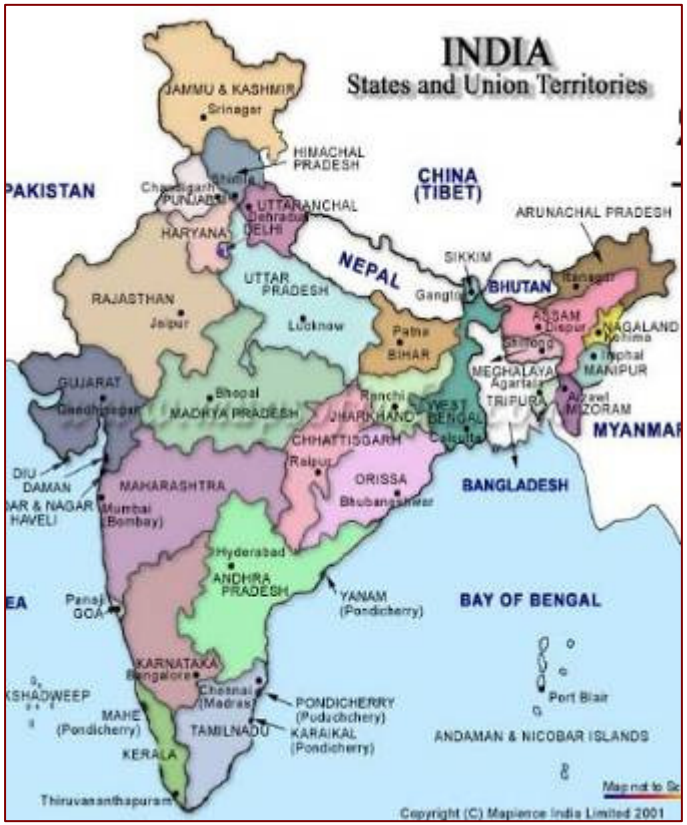
U.S.-India 6th Coal Working Group Meeting
L'Enfant Plaza Hotel
Washington D.C.
September 23, 2009

VirginiaTech
Invent the Future

India's Coal Industry

- Coal Production/Consumption
  - 4th largest coal reserve
  - 3rd largest coal producer
  - 53% of energy consumption
  - expected to double by 2030

- Poor Domestic Coal Quality
  - typically 40-50% ash
    - low thermal efficiency
    - high transport cost
    - large O&M costs
  - government mandate
    - clean to <34% if transported >1000 km or if burned in sensitive areas



VirginiaTech
Invent the Future

India's Coal Industry

- CO_2 Emissions in India
  - According to Friedman et al. (South Asian Monitor, 2009), coal is *"…the most polluting fuel in terms of greenhouse gases and already accounts for 65% of India's CO_2 emissions."*
  - According to Couch (2002), India could "*…reduce CO_2 emissions to nearly 45% of its present level using state-of-the-art technologies relating to **coal quality**, boiler/generator design, instrumentation and control, and high voltage distribution system*." (Couch, 2002)

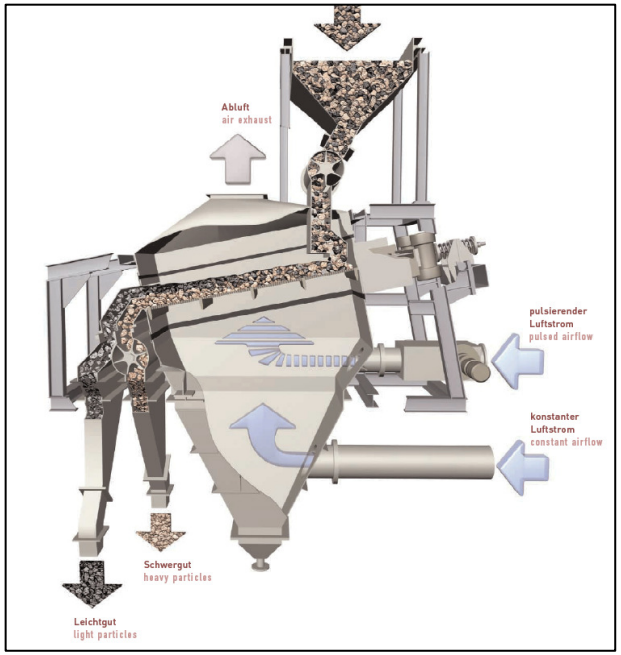
Project Description

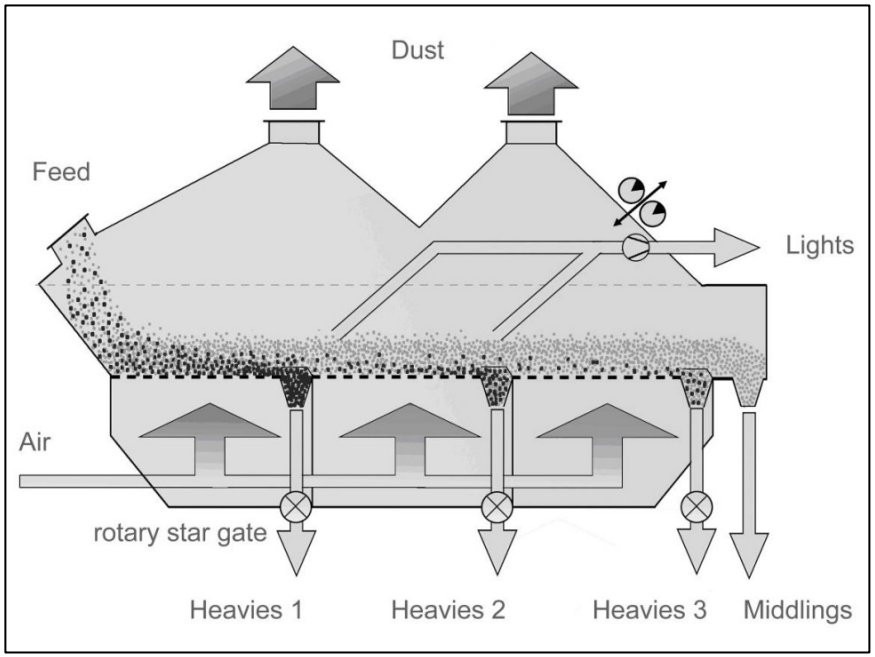
- VT and UK funded to study dry cleaning
  - Avoids adding moisture to cleaned coal
  - Easy to implement - little support structure
  - Lower cost compared to wet cleaning
  - Simple to operate and maintain

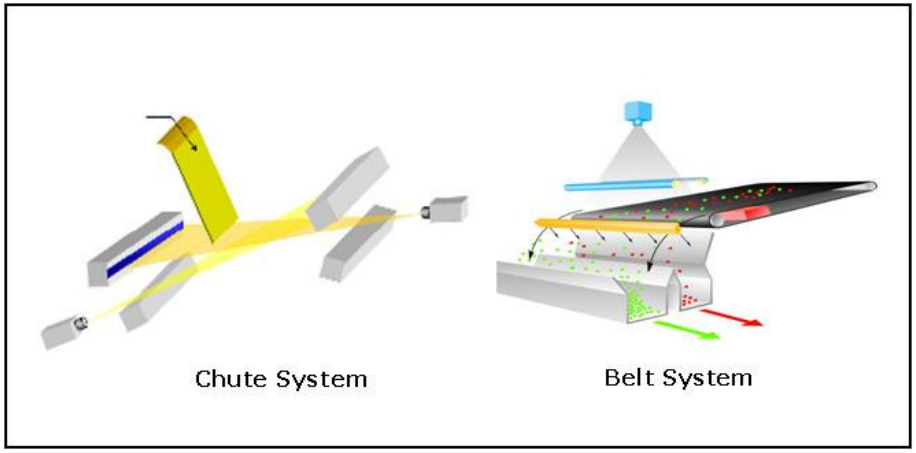
- Environmentally Friendly
  - Reduces CO_2 emissions at low cost
    - improves thermal efficiency via rock removal
  - Side benefit of reducing other emissions
    - air toxics, particulates, ash disposal, etc.
  - No fine coal impoundment required
  - Provides financial incentive for environmental control (payback via higher coal quality)

VirginiaTech
Invent the Future

Deshaling Technologies

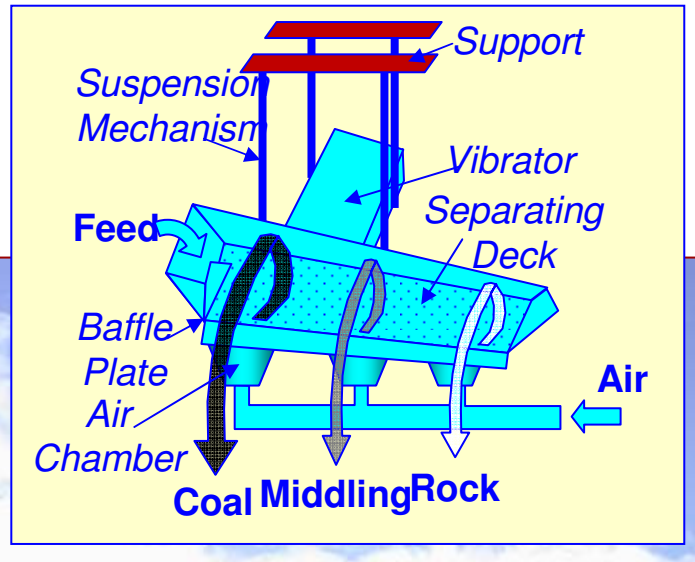






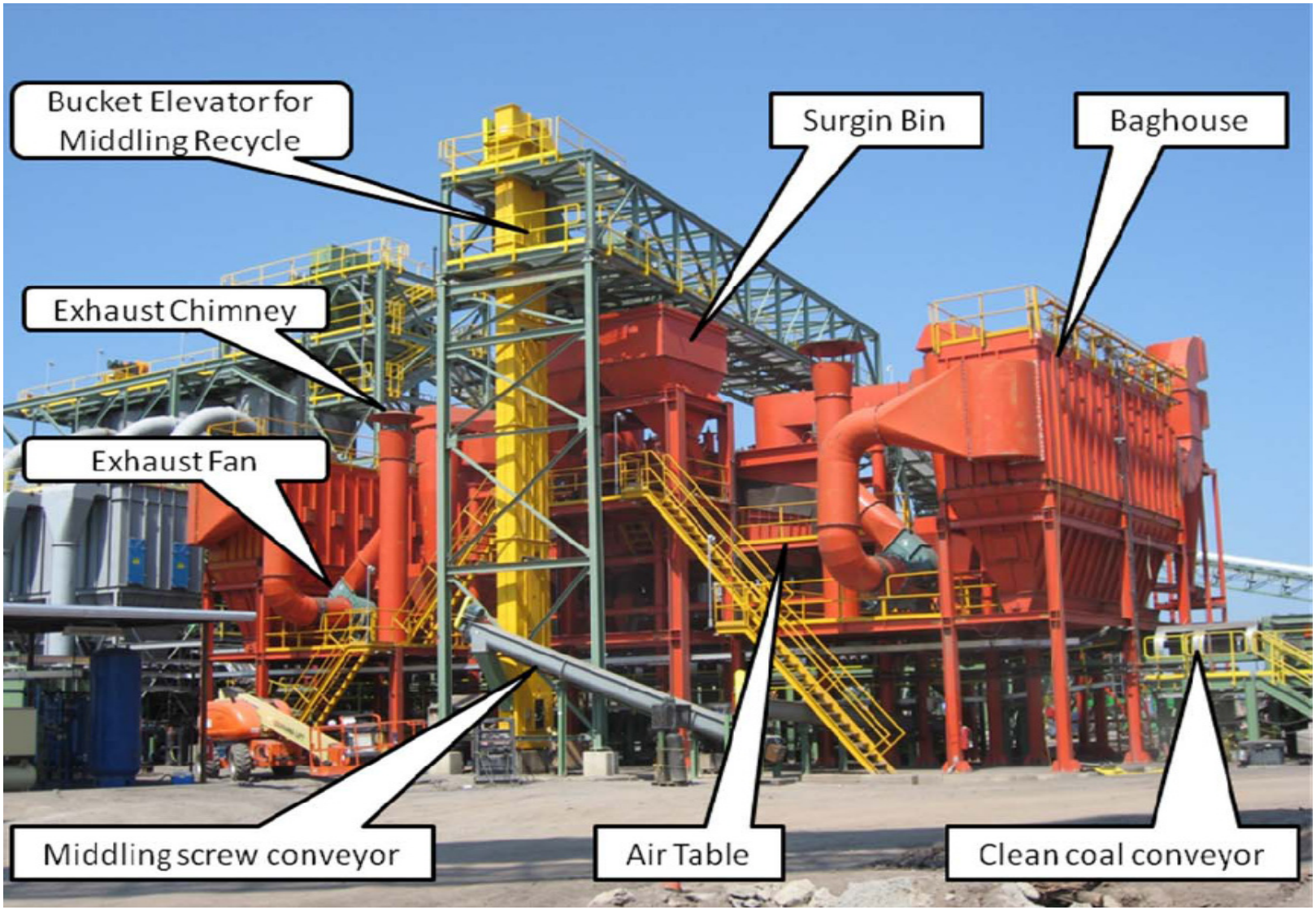
VirginiaTech
Invent the Future

Eriez Air Table



Eriez Air Table

Industrial Application



Industrial Application

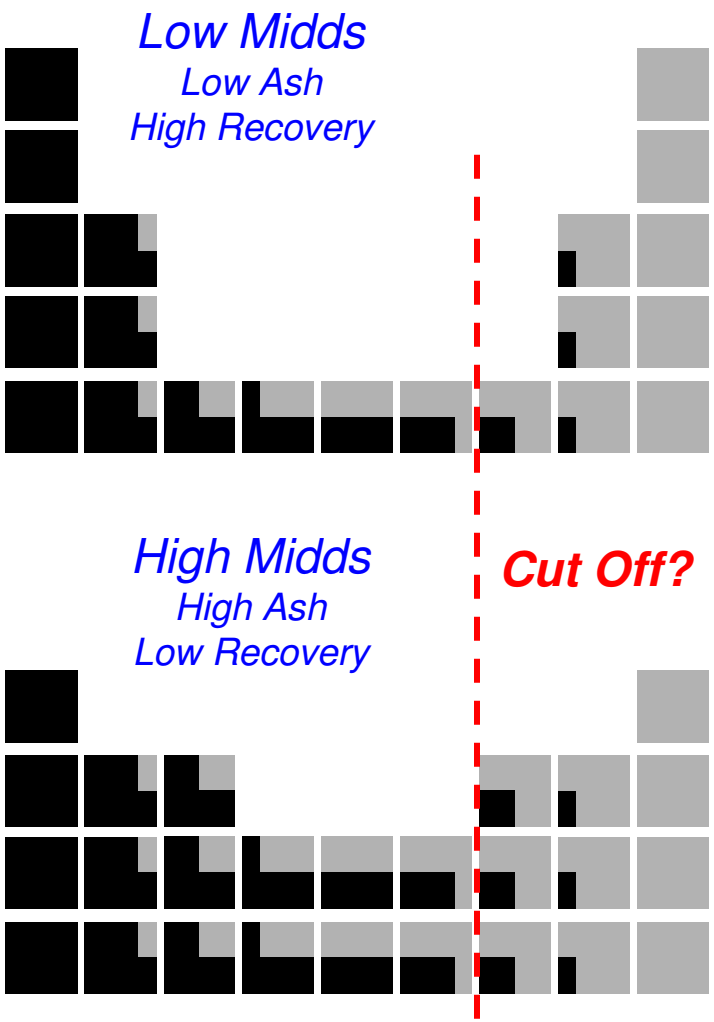
VirginiaTech
Invent the Future

Industrial Application

Test	Product Ash %	Product Yield %	% Ash Reduction	% Sulfur Reduction	% Mercury Reduction
1	4.23	85.81	33.15	28.42	65.24
2	4.84	83.16	34.27	56.76	56.13
3	4.90	83.13	32.84	47.68	67.12
4	5.03	80.66	43.13	41.51	67.66

Impetus for Deshaling?

- All coals contain “middlings” that force a trade-off between recovery and quality.
- How to clean to maintain a constant fuel cost to boiler of $2.00/MM BTU?
- Assumptions
  - Freight = $10/ton Coal
  - Evaporation = $3/ton H_20
  - Ash Handling =$20/ton Ash
  - Emissions = $200/ton SO_2
  - Other = $1.00/ton Coal



VirginiaTech
Invent the Future

Impetus for Deshaling?

Every coal particle sent to the consumer should have sufficient value to justify its shipment (i.e., high ash particles result in negative payment).

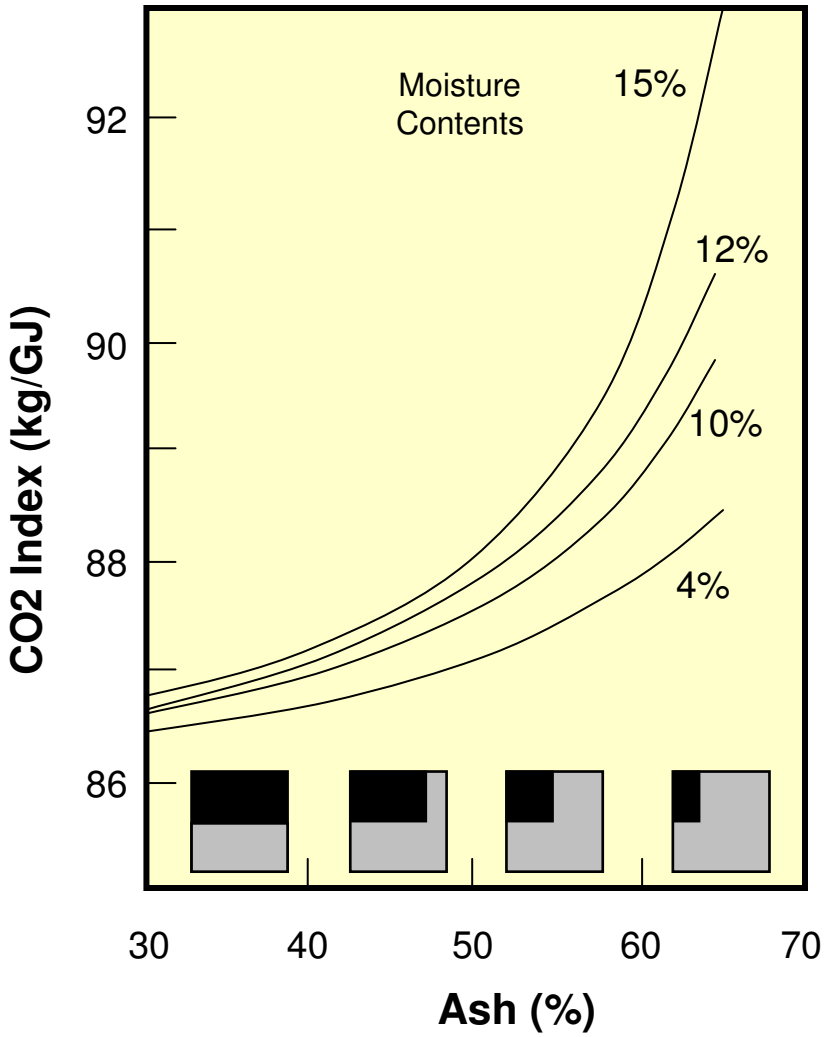
SG Class		1	2	3	4	5	6	7	8	9	10	11	12	13	Totals
Sink SG	---	**1.28**	1.30	1.35	1.40	1.45	1.50	1.55	1.60	1.65	1.70	1.80	1.90	2.00	---
Float SG	---	**1.30**	**1.35**	**1.40**	**1.45**	**1.50**	**1.55**	**1.60**	**1.65**	**1.70**	**1.80**	**1.90**	**2.00**	**3.20**	---
1/Mean SG	---	0.78	0.75	0.73	0.70	0.68	0.66	0.63	0.62	0.60	0.57	0.54	0.51	0.38	---
Mass	%, dry	**43.59**	**16.09**	**5.90**	**3.47**	**2.05**	**1.03**	**0.91**	**0.45**	**0.58**	**0.95**	**0.92**	**0.87**	**23.19**	100.0
Ash	%, dry	**3.65**	**7.83**	**13.31**	**18.90**	**24.20**	**29.45**	**33.30**	**37.37**	**41.13**	**44.59**	**51.58**	**60.35**	**87.22**	27.45
Sulfur	%, dry	**0.70**	**1.26**	**1.94**	**2.16**	**2.14**	**2.45**	**2.47**	**2.15**	**2.05**	**2.64**	**3.15**	**2.82**	**1.12**	1.15
BTU/lb	dry	**14511**	**13866**	**12960**	**12072**	**11229**	**10443**	**9707**	**9110**	**8339**	**7732**	**6498**	**4934**	**845**	10627
BTU/lb (Predict)	dry	14581	13887	12977	12049	11169	10298	9659	8983	8359	7785	6624	5168	708	10630
BTU/lb	maf	15061	15044	14950	14885	14814	14802	14553	14546	14165	13954	13420	12444	6612	14649
Cost to Boiler	$/MM BTU	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00
Freight Cost	$/MM BTU	$0.37	$0.39	$0.41	$0.44	$0.48	$0.51	$0.55	$0.59	$0.64	$0.69	$0.82	$1.08	$6.33	$0.50
Evap. Cost	$/MM BTU	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.02	$0.02	$0.12	$0.01
Ash Cost	$/MM BTU	$0.03	$0.06	$0.10	$0.16	$0.22	$0.28	$0.34	$0.41	$0.49	$0.58	$0.79	$1.22	$10.32	$0.26
SO2 Cost	$/MM BTU	($0.02)	$0.06	$0.18	$0.24	$0.26	$0.35	$0.39	$0.35	$0.37	$0.56	$0.85	$1.02	$2.53	$0.10
Other Cost	$/MM BTU	$0.04	$0.04	$0.04	$0.04	$0.05	$0.05	$0.06	$0.06	$0.06	$0.07	$0.08	$0.11	$0.63	$0.05
Coal Worth	$/MM BTU	$1.59	$1.45	$1.26	$1.11	$0.99	$0.80	$0.65	$0.58	$0.42	$0.09	($0.56)	($1.46)	($17.94)	$1.08
Cost to Boiler	$/ton	$54.27	$51.86	$48.47	$45.15	$42.00	$39.06	$36.30	$34.07	$31.19	$28.92	$24.30	$18.45	$3.16	$39.75
Freight Cost	$/ton	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00
Evap. Cost	$/ton	$0.20	$0.20	$0.20	$0.20	$0.20	$0.20	$0.20	$0.20	$0.20	$0.20	$0.20	$0.20	$0.20	$0.20
Ash Cost	$/ton	$0.68	$1.46	$2.49	$3.53	$4.53	$5.51	$6.23	$6.99	$7.69	$8.34	$9.65	$11.29	$16.31	$5.13
SO2 Cost	$/ton	($0.64)	$1.60	$4.35	$5.37	$5.48	$6.82	$7.06	$6.00	$5.80	$8.14	$10.32	$9.44	$4.00	$1.91
Other Cost	$/ton	$1.00	$1.00	$1.00	$1.00	$1.00	$1.00	$1.00	$1.00	$1.00	$1.00	$1.00	$1.00	$1.00	$1.00
Coal Worth	$/ton	$43.03	$37.60	$30.44	$25.05	$20.79	$15.54	$11.82	$9.89	$6.51	$1.25	($6.86)	($13.47)	($28.34)	$21.51

Positive Value (Recover) **Negative Value (Reject)**

VirginiaTech
Invent the Future

Impetus for Deshaling?

- Greenhouse Gas Emission
  - Ash content has a large impact on CO_2 emissions.
    - High ash reduces thermal efficiency.
  - Excess water can also reduce efficiency and increase CO_2 emissions.
    - Added advantage of dry coal cleaning.
  - Note that emissions climb rapidly >55-60% ash.
    - Also tend to be high in trace elements (Hg), particulates, etc.



VirginiaTech
Invent the Future

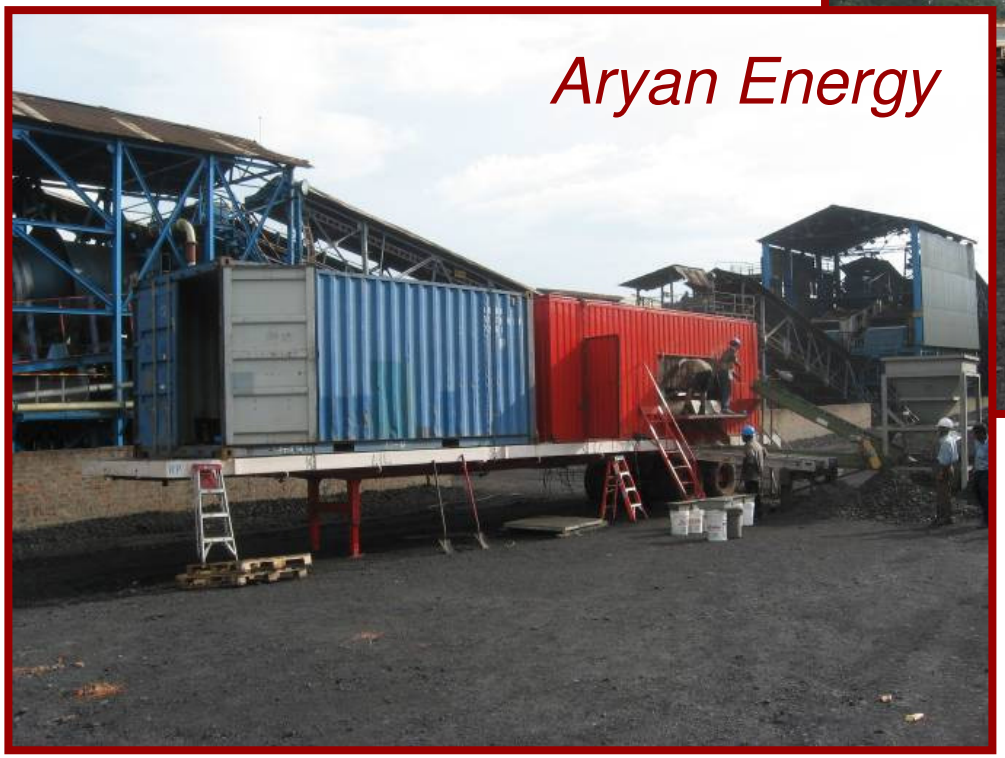
Pilot-Scale Setup

VirginiaTech
Invent the Future

Pilot-Scale Setup

Bhushan Steel & Power

Aryan Energy



VirginiaTech
Invent the Future

Pilot-Scale Testing

Typical Results

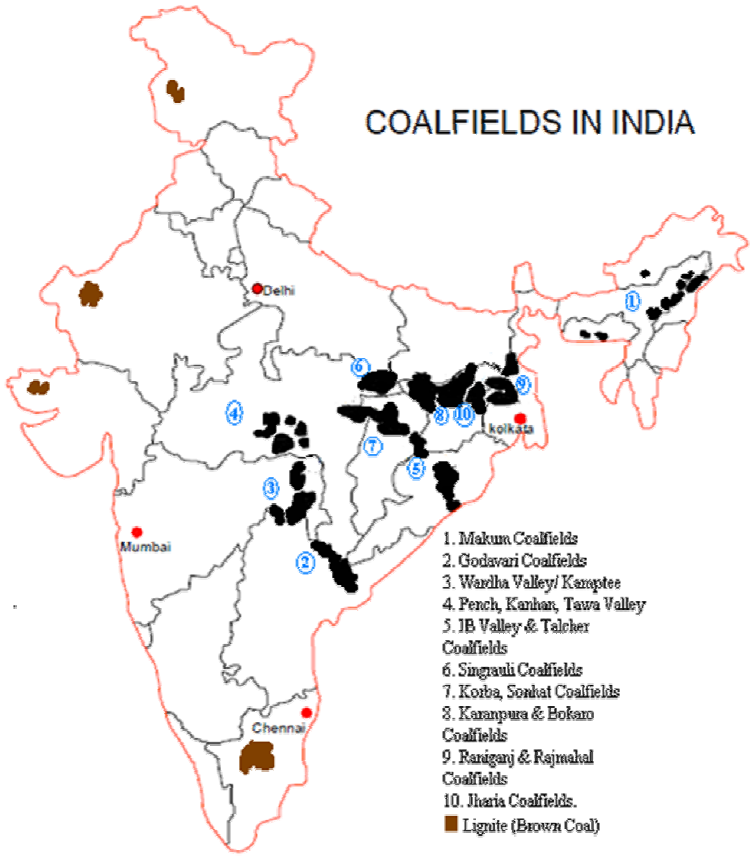
Test Run	Comb. Rejection	Reject Ash %	Reject Yield %
1	9.99	72.59	15.87
2	8.99	72.58	14.54
3	8.36	70.72	13.59
4	11.79	70.19	18.27
5	11.10	69.17	16.55
6	9.59	73.37	15.86
7	18.74	71.36	26.54
8	14.19	72.98	22.21
9	11.81	70.19	19.10
10	6.35	77.37	13.41
11	14.19	70.50	20.60
12	19.37	66.39	26.54
13	12.17	64.02	16.04
Average	**12.05**	**70.88**	**18.40**

VirginiaTech
Invent the Future

Continuing/Future Work

- Current Sites
  - Aryan Energy (Global Coal), Orissa*
  - Bhushan Steel & Power, Orissa*
- Future Sites
  - Five private companies

*Field Testing Conducted Aug '09



VirginiaTech
Invent the Future