Cost Impacts of Drying Indonesian Low Rank Coals
Mine Site vs Power Plant

Bart Lucarelli
Roleva Energy

Topics

- Indonesia's approaching shift to low rank coals

- Comparison of cost reduction benefits of drying Indonesia's low rank coals:
  - At the mine site
  - At the power plant site

- Summary of findings

Appendix A: Overview of four coal drying technologies:

- Great River Energy's fluidized bed drying system
- Evergreen Energy's pyrolysis system
- White Energy's binderless briquetting system
- CoalTek's microwave drying system

Indonesia's ongoing shift to low rank coals

Sub-bituminous coals

- Measured: ~ 4.5 billion tonnes
- Inferred : ~ 17.0 billion tonnes
- Measured resources sufficient to last 25 years at current production rates
- But a number of Indonesia's major coal suppliers claim that they are already sold out of their sub - bituminous coals

Typical Specification

- CV : *4700 – 6000 kcal/kg*
- S : 0.3% – 0.6%
- Ash : 3.0% – 7.0%
- TM : *20.0% – 28.0%*

Low rank coals (LRCs)

- Measured: ~2 billion tonnes
- Inferred : Many more billions of tonnes
- Major producers are starting to shift production to these LRCs
- But creating a LRC market will be a slow process – unless TM of LRC can be reduced to levels of sub-bituminous coals

Typical Specification

- CV : *3800 – 4500 kcal/kg*
- S : 0.3% – 0.6%
- Ash : 3.0% – 7.0%
- TM : *36.0% – 43.0%*

Options for Selling LRCs

Low Rank Coal

	New Plants	Operating Plants
Undried	• Design can be optimized around LRC • Higher capex, O&M costs and heat rates than power plant fired on sub-bituminous coals • Higher plant costs mean coal producers must offer large price discounts for LRC • Security of supply considerations may complicate financial close process	• Adverse effects on plant heat rate & output will require coal producers to offer unacceptably large price discounts • Boiler limits on moisture content will reduce market size
Dried	• Long lead times for building new plants will significantly delay ramp up of LRC production • For new plants located in Indonesia, Philippines and Malaysia, it is cheaper for power producers to: ✓ design new plants optimized on undried LRC spec ✓ pay for extra capex and O&M costs.	***Most promising option & one reviewed for this paper*** ➢ Displace sub-bituminous coals with dried LRC in operating plants ✓ Established market for dried LRC ✓ Spec for dried LRC is similar to a sub-bituminous coal spec ✓ LRC can be phased in

Assumptions & Conversions

Approach/Assumptions

- Market Segment Considered:
  - Operating power plants optimized to run on Indonesian sub-bit coals
- Question for analysis:
  - Does it make more sense for power plant producers to procure dried or undried LRC?
- Coal producer transports coal from mines to T/S facility via trucks & barges
- Coal shipped by Panamax vessel
- 2006 price premium of $10/t for sub-bit coal over LRC
- Power plant is a subcritical 700 MW single unit plant

Useful Conversions

Kcal/Kg	GJ/tonne	MMBtu/tonne
4000	16.76	15.89
4915	20.59	19.52
5500	23.04	21.84

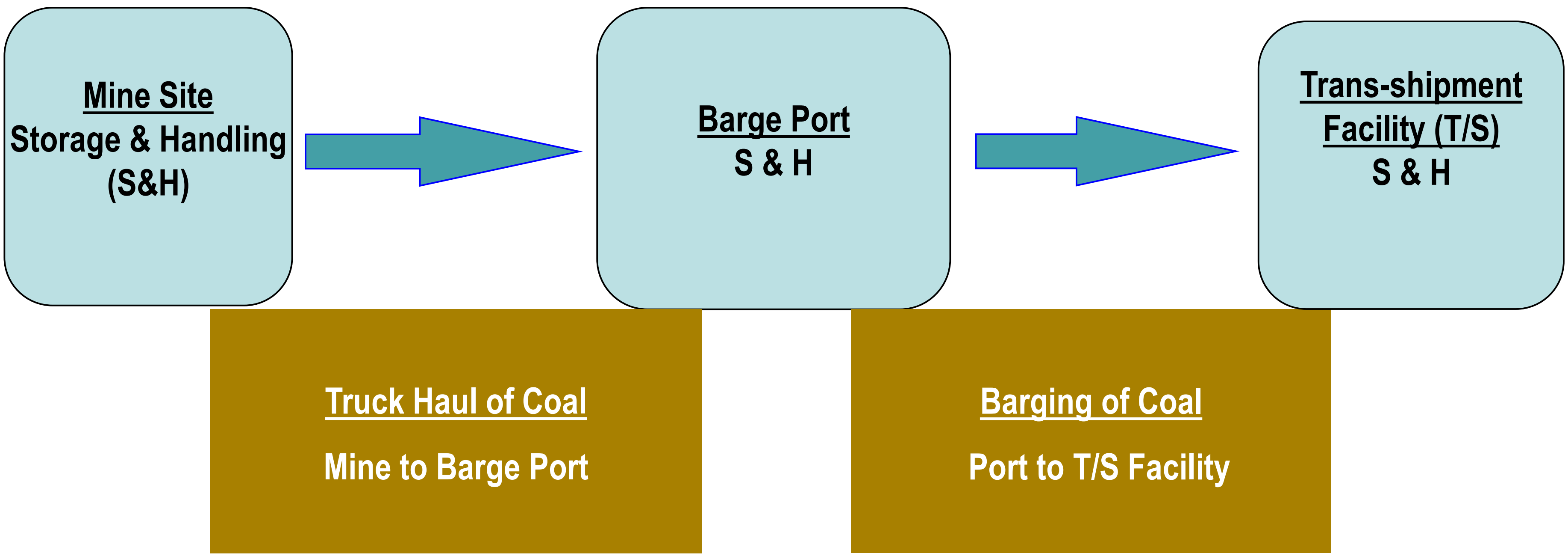
Coal Producer's Perspective

Drying LRC can increase gross revenues through

– Reduced S&H and Transport Costs

– Price Premium

Coal Producer's Perspective
Cost Savings per GJ will occur at each point in the supply chain



Indonesia's 6 largest coal producers (~70% of 2006 coal production) have very different internal transportation arrangements

Company	2006 Production (mt)	2006 Exports (mt)	Mine Site to Barge Port (km)	Barge Port to T/S Facility (km)	Remarks
KPC	35.3	34.2	13 (conveyor)	1/9 km (conveyor)	Geared/gearless
Adaro	33.5	24.7	80 (truck)	215/450 (barge)	Taboneo anchorage/IBT
Kideco	18.9	13.6	39 (truck)	58 (barge)	From TMCT to FC via 8KT -12KT barges
Arutmin	16.3	13.3	7 (truck)	15/120 (barge)	Geared vessel/ Satui Port via 3.5KT – 7KT barges to NPLCT
Berau	10.8	7.4	13 (truck)	74 (barge)	From Lati to Muara Pantai
Indominco	10.2	10.5	35 (truck)	0/9 (conveyor)	From Port to Bontang Coal Terminal

(Source: Indonesian Dept of Energy & Mineral Resources)

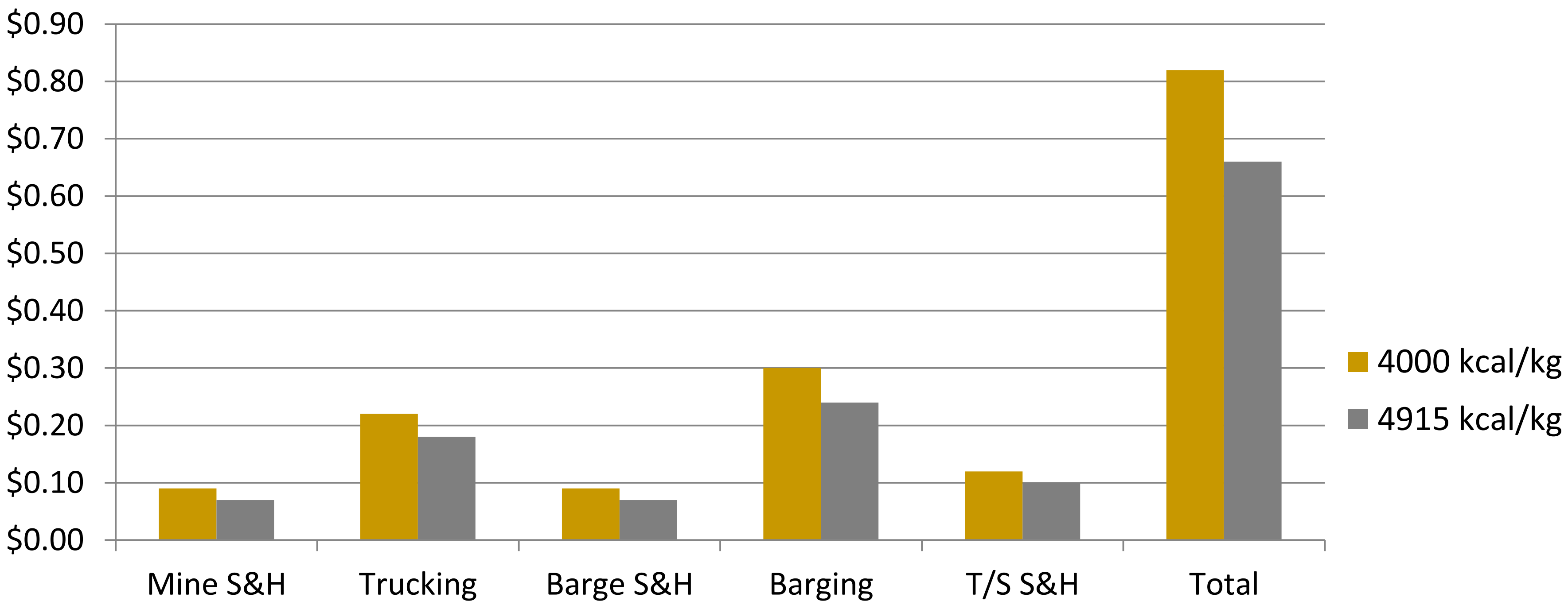
Coal Producer's Perspective
Storage, Handling and Transport Costs from Mine to T/S Facility

Activity	Location of Activity/Value Range	Cost analysis assumptions
Storage & handling (S&H)	@Mine site $1.00 - $2.00/tonne (t)	$1.50/t
Trucking	Mine to barge port/ $0.06 - $0.15/t-km 7 - 80 km haul distance	$3.75/t ($.075/t-km x 50 km)
S&H	@Barge port $1.00 - $2.00/t	$1.50/t
Barging (3KT – 12KT)	Port to T/S facility $0.01 - $0.10/t-km 1 – 450 km	$5.00/t ($0.025/t-km x 200 km; via 10KT barges)
S&H	@T/S facility $1.50 - $2.50/t	$2.00/t

Coal Producer's Perspective
Hypothetical Coal Producers Storage & Transport Costs
Raw vs Dried LRC

	Cost ($/t)			Average Cost ($/GJ)	
	Low	Average	High	LRC@38%TM	LRC@25%TM
1. Storage & handling (S&H) @ Mine site	$1.00	$ 1.50	$ 2.00	$0.09	$0.07
2. Trucking- mine site to barge port (50 km)	$3.50	$ 3.75	$ 4.00	$0.22	$0.18
3. S&H @ Barge Port	$1.00	$ 1.50	$ 2.00	$0.09	$0.07
4. Barging- Port to T/S facility (200 km)	$4.00	$ 5.00	$ 6.00	$0.30	$0.24
5. S&H T/S Facility	$1.50	$ 2.00	$ 2.50	$0.12	$0.10
Total Cost Difference	$11.00	$13.75	$16.50	$0.82	$0.66

Drying LRC from 38%TM to 25%TM will result in coal producer saving ~$0.16/GJ in S&H and transport costs ($/GJ)



Coal Producer's Perspective
Greatest value will come in form of an energy adjusted price premium

- In 2006, Indonesian sub-bituminous coals sold for ~$35/t (FOBT, 5000 kcal/kg, gar | 25%TM) vs. $25/t for LRC (4000 kcal/kg, gar | 38%TM)

or

- $1.70/GJ for dried LRC w/25%TM vs. $1.49/GJ for LRC w/38%TM = premium of $0.21/GJ for dried LRC.

- Coal producer selling 15 mt of dried LRC per year would earn additional gross revenues of $53 million per year.

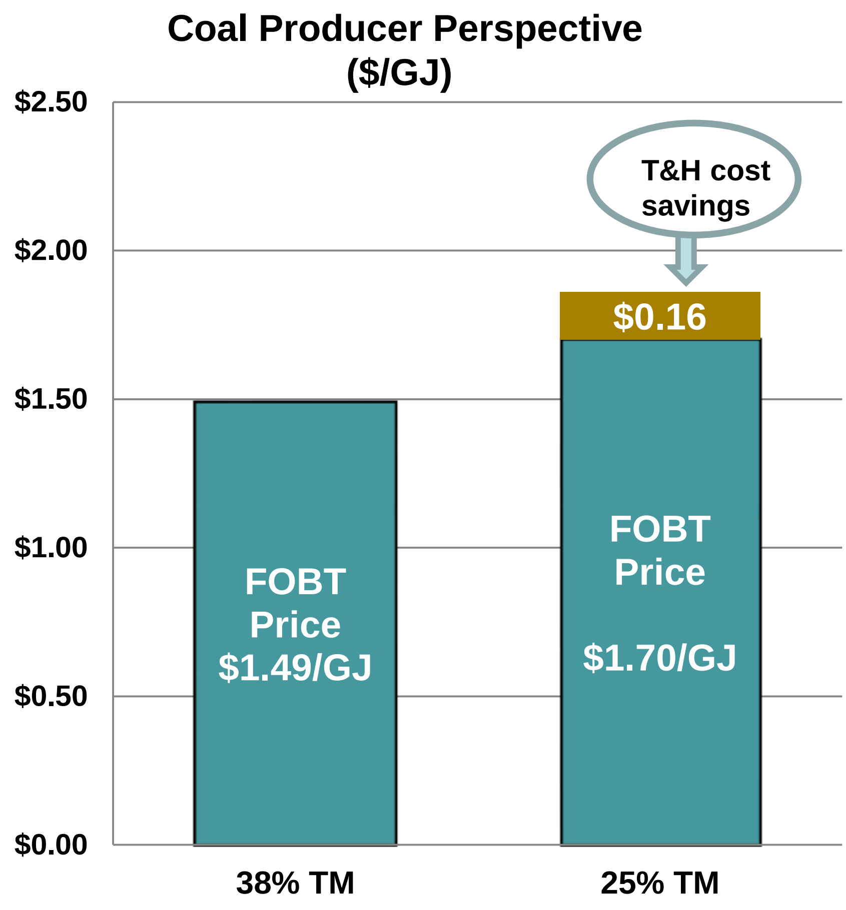
- Price premium alone would increase gross revenues by 14%.

- Current spread is around $15/t for 1 year term contract.

Coal Producer's Perspective
Drying LRC @ mine = substantial gain in gross revenues

- A coal producer with 15 mt annual output (251.7 million GJ) of LRC would *increase gross revenues by an extra $93 million per year as follows*:
  - Savings on transport & handling ~$ 40 million per year
  - Premium value for dried coal ~$ 53 million per year

- Assuming 20 year project life & 12% DF and no increase in coal prices, PV of annual revenues = $695 million.



Power Plant Owner Perspective
Comparison of Impacts from three coal supply choices for plant designed to burn Indonesian sub-bit

Undried LRC	LRC dried @ mine	LRC dried @ powerplant
✓ Lower Coal Price/ GJ	✓ Lower Shipping Costs	✓ Lower Coal Price/ GJ
✓ No Capex or O&M costs for dryer	✓ Lower S&H Costs at power plant	✓ Better control of the final product
✓ Big Increase in Heat Rate	✓ Heat Rate unchanged	✓ Slight increase in Heat Rate
✓ Lost MWs	✓ Output unaffected	✓ Output unaffected
✓ Increased O&M costs	✓ O&M Costs unchanged	✓ O&M Costs unchanged
✓ Increased emissions	✓ Emissions unchanged	✓ Emissions unchanged

Power Plant Owner's Perspective
Other Considerations

Dried LRC burned in power plant designed for undried LRC	Undried LRC burned in power plant designed for dried LRC
• Boiler hot spots may cause tube leaks • Higher temperatures in pulverizers may lead to explosions • CV of coal in any case will be limited by boiler tolerances	• Lost efficiency and output due to: – Lower inlet Air temp to mills – Need for greater air volumes • Increased moisture in flue gases will: – adversely affect ESP performance – cause corrosion • Possible mill explosions

Power Plant Owner's Perspective
If power plant owner procures and ships undried LRC to site, it will incur significant transport and S&H cost penalties

- Transport costs will vary based on:
  - Distance for round trip journey
  - Type of vessel used
    (Handymax, Panamax or Cape)
  - Term of charter
    (spot, 1 year, 3 year, 7 year, 10 year)
  - Price of Bunker C
  - State of the Vessel Market
- Sample Calculation
  - 6,300 km round trip journey
  - Panamax vessel
  - 3 yr time charter as of 9/07
  - Bunker C = $400/t
  - Range: $9.65 - $12.15/t
  - Average cost: $10.90/t

- Storage & Handling Costs will vary by:
  - Size of jetty
  - Type of unloading system: clamshell unloader or screw-type unloader
  - Length of conveyor system
  - Size of stockyard and equipment used (stacker reclaimer or just truck and shovel)
- Sample Calculation
  - Range: $ 1.50 - $2.50/t
  - Average value of $2.00/t

Power Plant Owner's Perspective
Shifting to undried LRC will also cause significant increases in plant heat rate, O&M costs and emissions

- Each tonne of undried LRC (TM 38%) will have fewer GJs than a tonne of dried LRC (TM25%)

- With undried LRC, more tonnes of coal needed to produce each MWh, leading to:
  - increased load for mills
  - Increased usage of FD and ID fans

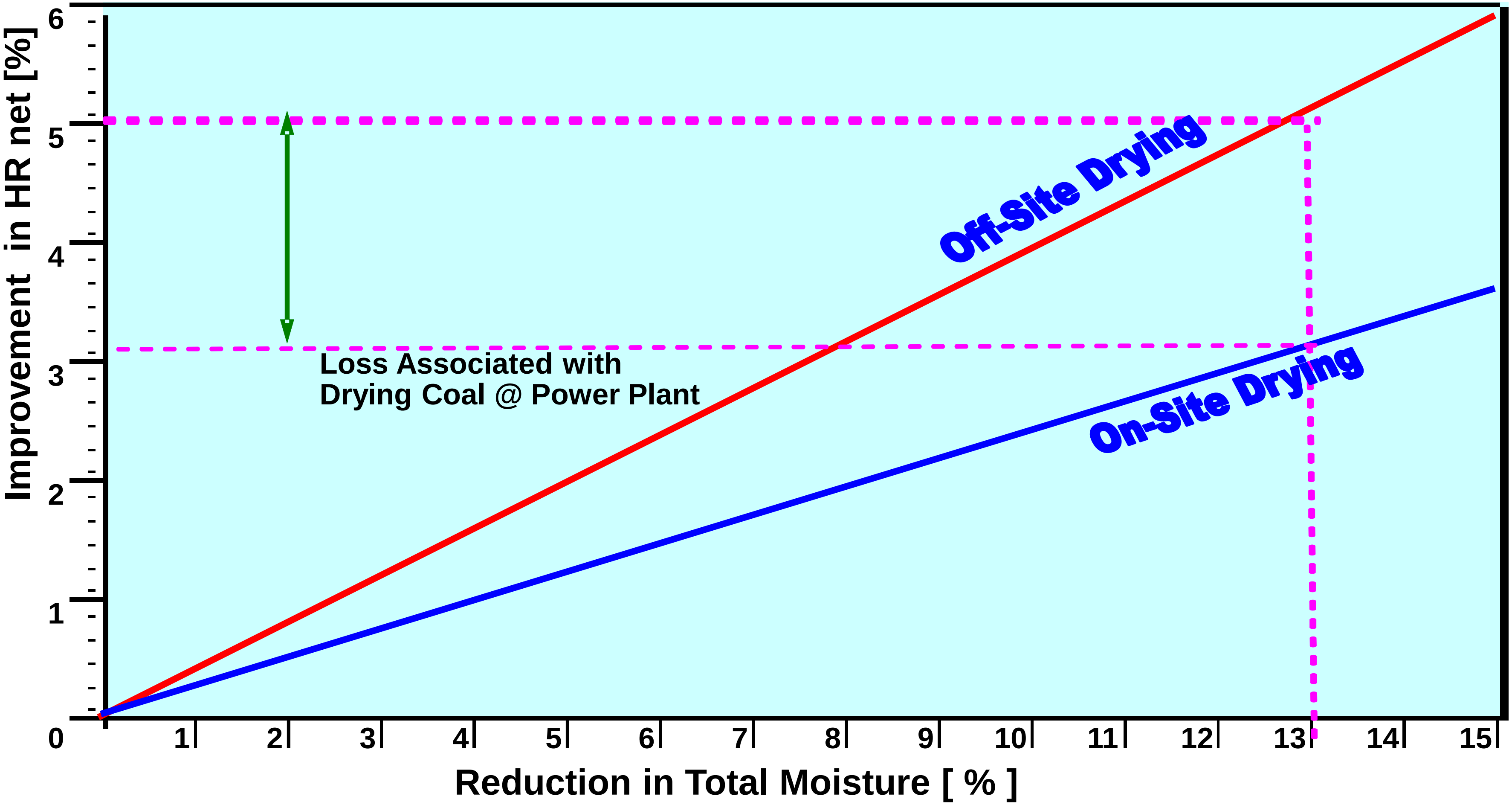
- More energy needed (per tonne of coal) to vaporize water in coal.

- Increased maintenance costs due to increased usage of pulverizers and ID and FD fans

- Significantly higher emissions of CO_2, SO_2 and NO_x emissions per MWh generated.

Power Plant Owner's Perspective

Drying LRC @ Power Plant will result in some HR deterioration compared to LRC dried at mine.



Shifting to undried LRC will cause a 5% deterioration in net plant heat rate, which is equal to paying a $10/t premium for LRC dried at mine site (Sample calc: 700 MW plant w/subcritical boiler)

	LRC @ 38% TM	LRC @ 25% TM (dried at mine site)
Coal Price ($/t, DES)	$35	$45
Heat Rate (HHV | KJ/kWh)	9,535	9,060
Capacity Factor	85%	85%
Coal Consumption (mt/yr)	2.97	2.30
Annual Coal Bill (million $)	~$104	~$104

Power Plant Owner’s Perspective
Output losses will result if plant designed to run on dried LRC is fired on undried LRC

- Running plant on undried LRC will not only cause loss in plant efficiency but reduction in MWs produced due to:
  - Pulverizer, fan and boiler capacity limits
  - Increase in aux loads
  - Waste of energy in coal to vaporize moisture in the coal.
- With new coal-fired power plants costing between $1100/KW -$1500/KW, the value of the lost MWs = significant opportunity cost.
- For example, an existing 700 MW coal-fired power station designed to run on dried LRC would lose, at a minimum, 35 MWs if it were instead fired on undried LRC.
- The value of the extra MWs at today’s EPC prices would range from $38.5 million to $52.5 million with an average value of $45.5 million.

Power Plant Owner Perspective
Delivered Coal Prices for 3 Coal Supply Options

	Cost ($/t)			Average Cost ($/GJ)		
	Low	**Average**	**High**	**LRC@38%TM (Undried)**	**LRC@25%TM (Dried @Mine)**	**LRC@25%TM (Dried @Power Plant)**
Shipping-T/S facility to power plant(6300km RT)	$9.65	$10.90	$12.15	$0.65	$0.53	$0.65
S&H- power plant site	$1.00	$ 2.00	$ 3.00	$0.12	$0.10	$0.12
Subtotal	**10.65**	**12.90**	**15.15**	**$0.77**	**$0.63**	**$0.77**
Unadjusted FOBT Prices	**$10.65**	**$12.90**	**$15.15**	**$1.49**	**$1.70**	**1.49**
Less: a) Reduced fuel bill via improved HR b) Value of “Saved” MWs					**(- $0.05)** **(- $0.13)**	**(-$0.03)** **(-$0.08)**
Delivered Coal Price ($/GJ)	**n/a**	**n/a**	**n/a**	**$2.26**	**$2.15**	**$2.15**

Power Producer Prospective
Value of Reducing Coal Moisture Content at Power Plant (PP)
(for 700 MW Subcritical Plant)

	LRC @ 38% TM	**LRC @ 25% TM (coal dried at PP site)**
Coal Price, DES ($/t)	$35	$35
Heat Rate (HHV | KJ/kWh)	9,535	9,250
Capacity Factor	85%	85%
Undried LRC Requirement (t/yr)	2.97	2.87
Coal Bill (million $) (PV @12%DF over 20 yrs)	$104 n/a	$100 $30.0 million
Saved MWs (35 MWs)	n/a	$45.5 million
PV for buying and operating dryer		$75.5 million

Summary of Power Plant Owner Perspective
Comparison of Revenue Impacts of Buying Dried LRC vs Undried LRC

LRC dried at power plant

- PV of HR Improvement = $ 30.0 million
- PV of Additional MWs = $ 45.5 million

  Gross Benefits $ 75.5 million

- Investment Decision
  - Compare PV of installing and operating coal drying system against PV of gross revenue gain
  - If PV of gross revenue gain exceeds PV of costs, investment should be made

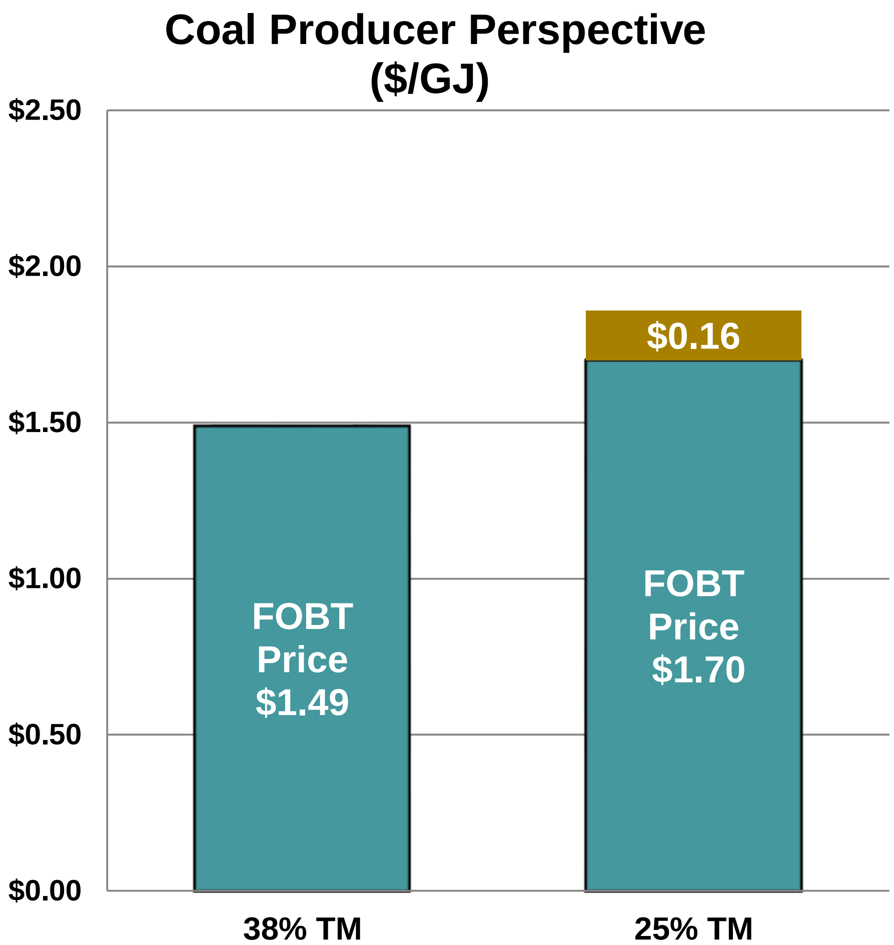
LRC dried at mine

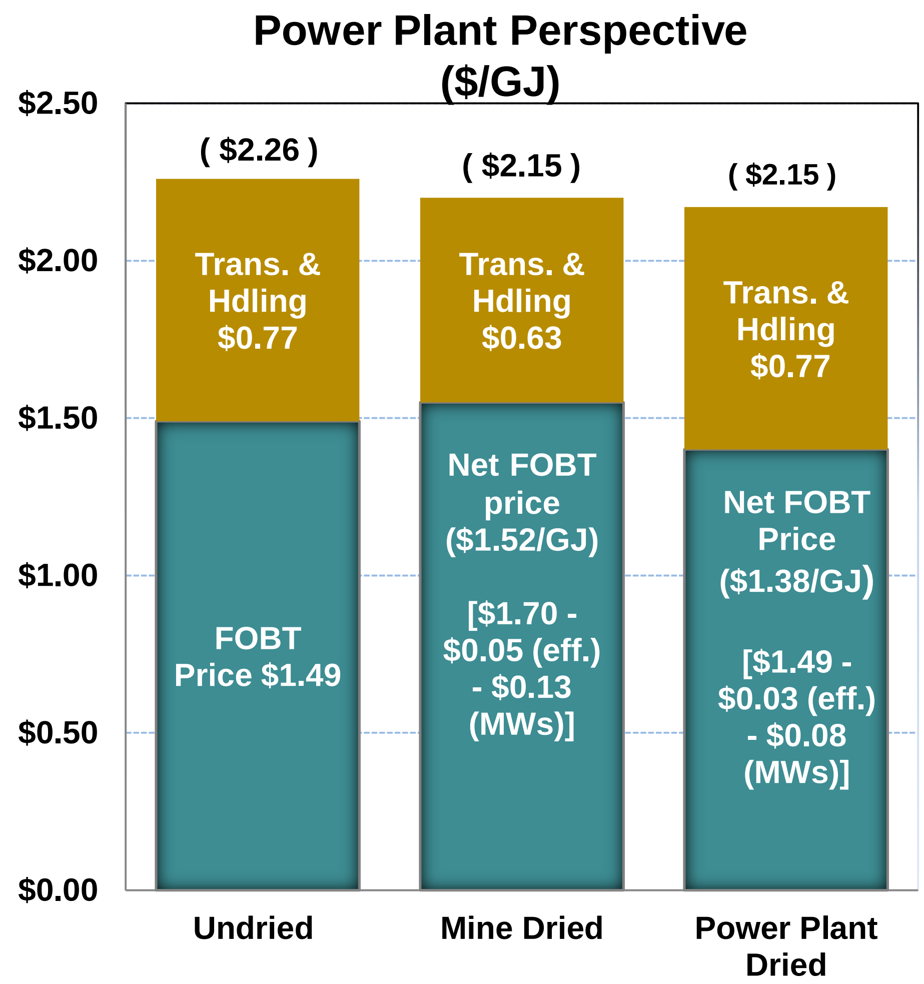
- Price Premium + $ 0.21/GJ
- Less Savings - $ 0.32/GJ
  - Transport+ S&H ($0.14)
  - Efficiency ($0.05)
  - Extra MWs ($0.13)

  Net Benefits $ 0.11/GJ

- Investment Decision
  - Proceed with purchase of upgraded coal
  - Power plant owner is likely to accrue additional O&M cost savings plus benefits from emission reductions.
  - Potential increases in coal prices may also positively impact decision to invest

Summary of Both Perspectives
Value of Coal Drying @ Mine Site vs. Power Plant





Despite large revenue potentials from coal drying, available technologies have not been widely implemented for four reasons.

1. For some technologies being proposed, drying costs at mine > savings + revenue gains:
   - Cost of fuel to generate heat and electricity for drying coal
   - Capex and O&M costs for mine site drying device.
2. Some drying technologies create changes in the physical properties of the coal, rendering the dried coal less marketable:
   - Dried coal crumbles more easily increasing % of fines
   - Potential for moisture recovery leading to lost value from drying and greater risk of spontaneous combustion.
3. Existing boilers designed for specific coal quality; dried coal exceeds specification.
4. Some technologies are still considered “unproven” by coal producers.

➢ Because of these cost & technology issues, application of coal drying technologies at either the mine site or the power plant site remains a niche application at best.

Summary

- LRC is destined to become the primary coal type mined in Indonesia by 2015 as existing reserves of sub-bituminous coal are depleted.
- High moisture content of LRC will impose transport cost penalties and performance issues on power plant owners, which will limit run-of-mine markets to the domestic market and the near-by markets of the Philippines, Malaysia and Thailand.
- Coal drying technologies can expand the market for LRC by allowing boilers, optimized to fire sub-bituminous and bituminous coals, to run on dried LRC.
- In Asia, many power plant boilers have been optimized to run on coals with TM between 20% and 25% . Moving LRC into this existing market is the preferred way forward.

Summary

- Dryer applications at the mine-mouth are intuitively preferred due to the large savings in coal handling & transport plus the greater benefits of improved efficiency and output gains.

- But other factors – cost of heat and power and effect on coal physical properties – will likely determine whether mine site or power plant provides best location.

Appendix A

Survey of Drying Technologies

Sample of technologies available for drying coal

Technology	Primary Energy Source(s)	Company
Fluidized Bed Dryer	Waste heat from condenser (~50 °C), aux load for fans and pumps	Great River Energy (USA) Lehigh University (USA)
Microwave Dryer	Power	CoalTek (USA) AMTECH (USA)
Pyrolysis System	Both heat and power from power plant	Evergreen Energy (USA)
Binderless Briquetter	Both heat and power from mine mouth power plant and/or flash dryer	White Energy (Australia)

Two other drying technologies not covered in this paper but worth mentioning

Technology	Primary Energy Source(s)	Company
UBC Process	Power & Steam	Kobe Steel
WTA Process	Power & Steam	RWE

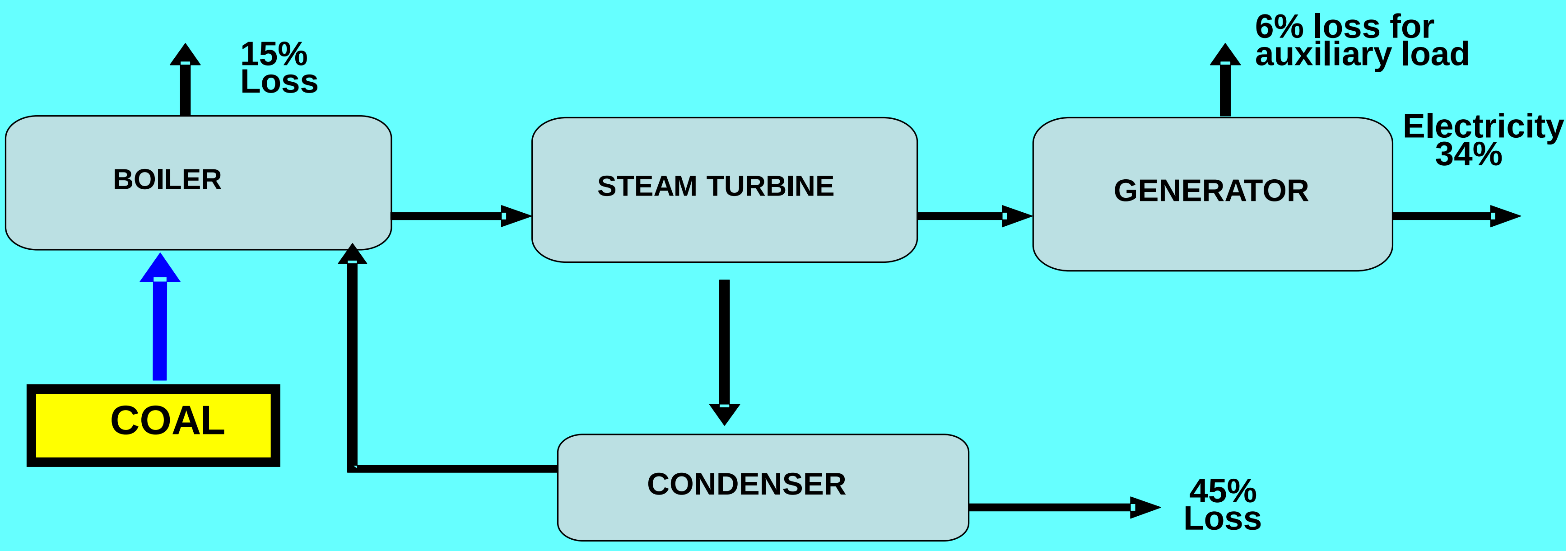
Great River Energy (GRE)
Fluidized Bed Dryer using waste heat from condenser

- Demonstration project located at GRE's Coal Creek Station, a 2 x 546 MW lignite-fired power plant in Underwood, N.D.

- Phase 1 of the project funded by US DOE in 2003 under its Clean Coal Power Initiative:
  - Prototype coal dryer demonstrated on Unit 2 of the plant between 2004 and June 2007
  - Capable of reducing the TM of 1/4 of Unit 2's annual coal requirements; TM reduced from 38.5% TM to around 29.5% TM.

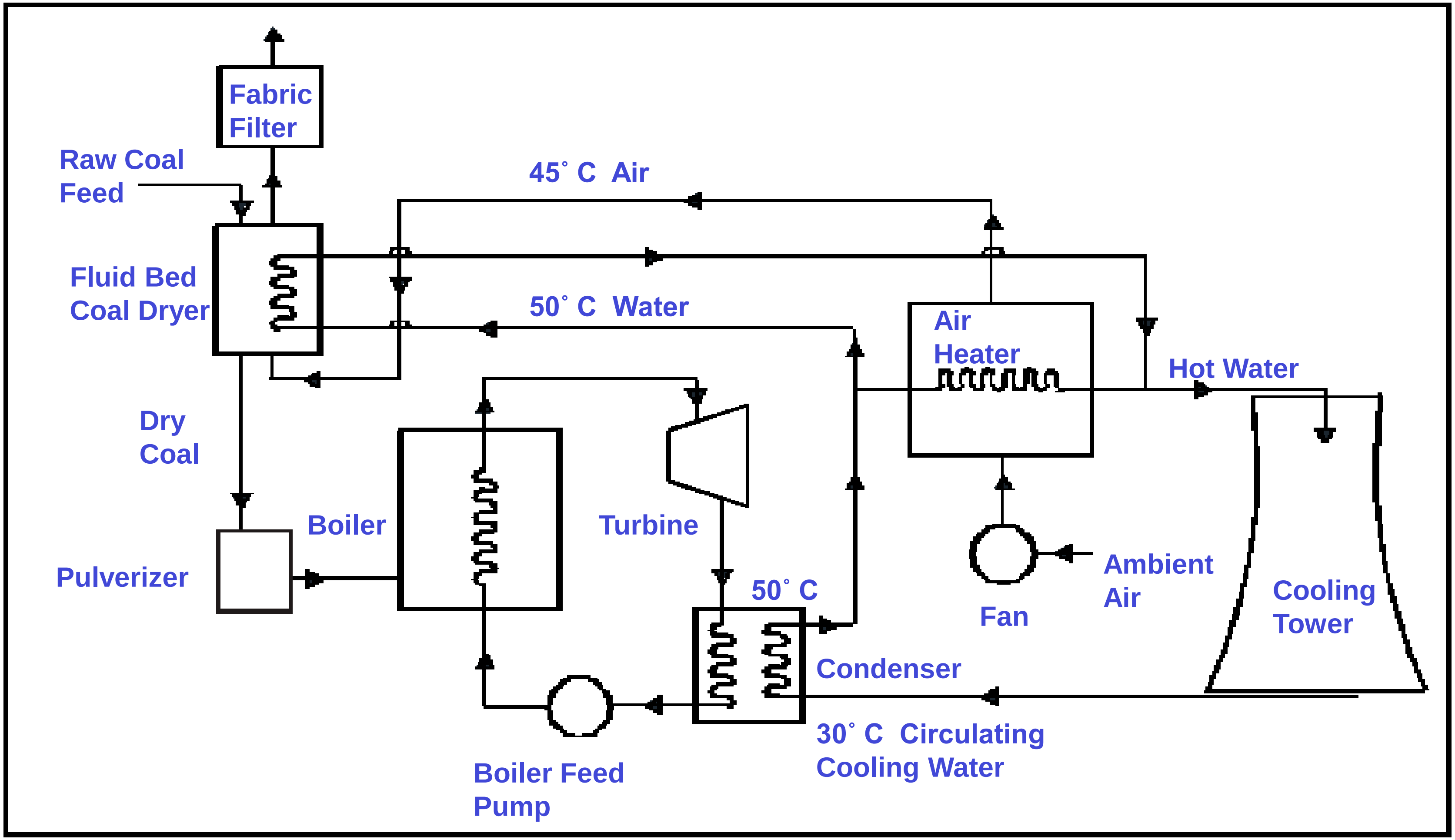
- Dryer design has won numerous engineering awards such as:
    - Lignite Energy Council's Distinguished Service R&D Award
    - EPRI's Generation Technology Transfer Award

GRE's Low Tech Drying Option
Coal-fired power plants lose around 45% of the energy in the coal through the condenser, which GRE is using to dry high moisture coals



- For cycle optimized to produce power @ 560c/160 bar steam
- Majority of losses are in the condenser: 50°c

Dated Flow Diagram of System for Drying Coal Using Hot Circulating Water From Condenser



Source: Modified from diagram obtained from: "Lehigh Energy Update: Research Demonstrates Benefits of Drying Western Coal", August 2002 (published by Lehigh University, Pennsylvania (USA)

Application of Fluidized Bed Dryer @ GRE's Coal Creek Station

- GRE has declared Phase 1 to be a complete success. Over the next two years, it plans to install dryers on both units (Phase 2).
- Work program for its Phase 2 project:
  - By March 2008, GRE will have installed 4 dryers on Unit 2, which will be capable of processing its full coal requirements (135 tons of coal/hr).
  - The Unit 2 project is being partly funded by US DOE and test results conducted during 2008 will be made available to the broader public through the US DOE Clean Coal Initiative Program.
  - By 2009, it will also install 4 dryers on Unit 1 at its own expense based on "positive prototype results and confidence we (GRE) have in the technology".
- Huge US Market for this system.
  - 100 GWs of coal-fired power plants (279 power plants) burn high moisture coals.
  - Another 100 GWs based on high moisture coal expected to be added by 2020.
- GRE subsidiary - Great American Energy- will market this technology to other power companies, pursuing both retrofit and greenfield projects.
- GRE may also sell upgraded coal to other power companies.

Main Selling Points of GRE Technology

- Uses waste heat only – steam is not taken from plant production cycles.
- Drying temperature is below volatization temperature of coal- no additional emission control equipment is required except for a baghouse to catch dust.
- For a new plant, the dryer can be incorporated into plant with relatively small impact on structural costs. O&M costs also very low.
- Dryer system can be designed to remove larger and denser particles from coal stream before it enters the pulverizers, resulting in:
  - an improved HGI
  - 8%-9% reduction in pulverizer loads
  - reduction in S and mercury in coal.

Other Selling Points of GRE Technology

- Flexible and Adaptable: Can be used with any type of coal-fired plant:
  - Coal-to-liquids
  - Activated charcoal
  - Oxyfuel
  - Supercritical & Subcritical boilers.

- New design for mine sites under consideration

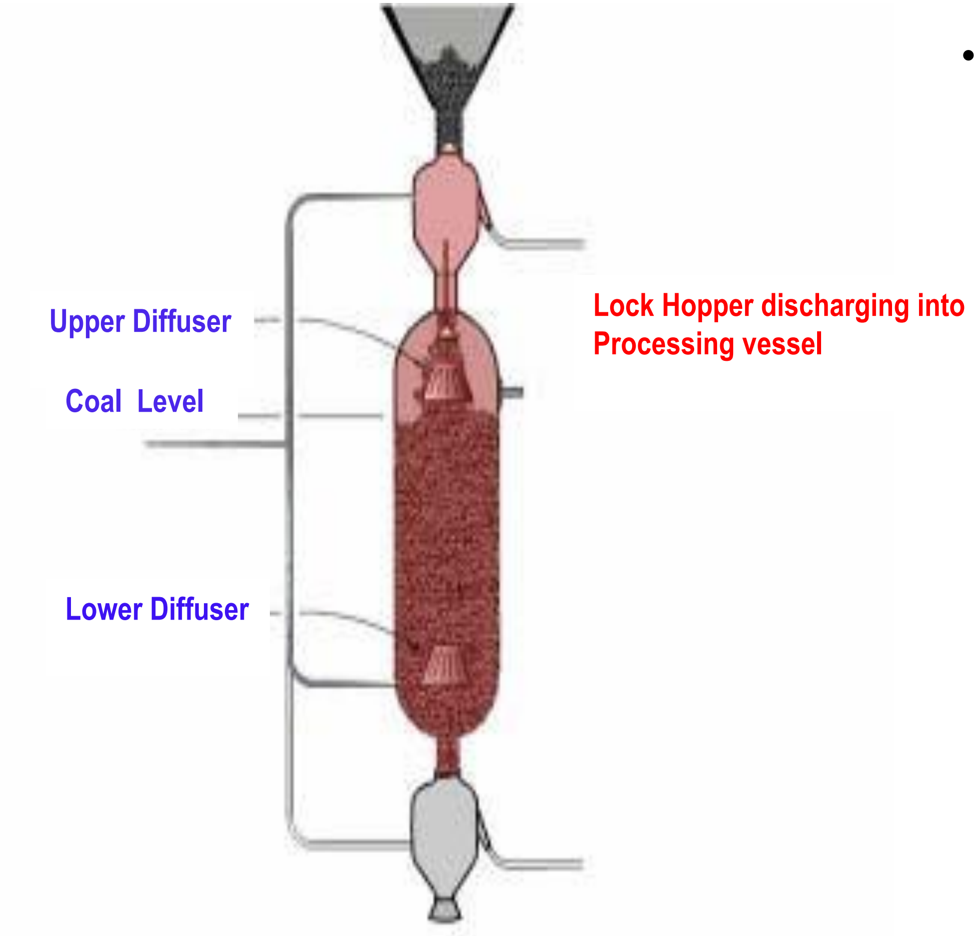
Application of Pyrolysis System for drying LRC
Evergreen Energy Inc

- Evergreen Energy (EEE) is a publicly traded US company that markets:
  - "Coal refineries" that produce upgraded sub-bituminous and lignite coals, known as K-Fuel®
  - K-Fuel® is being produced at EEE's K-Fuel® plants located in Gillette, Wyoming and Buckeye, Ohio.

- K-Fuel® produced from Power River Basin coal has 30% higher energy content and 70% lower moisture content than raw coals.

- Other benefits:
  - Emissions per kWh of SOx, NOx, and mercury are reduced due to reduced moisture plus ability of refining process to remove pyrites and high density inerts
  - CO2 emissions reduced per kWh due to higher plant efficiency that will result from burning lower moisture coal in power plant.

K-Fuel® Process



- Pyrolysis process using Sasol/Lurgi technology
  - Raw coal enters at top into pyrolysis vessel
  - Heat and pressure added, causing the coal pores to collapse and drive out both surface and inherent moisture.
  - Pressure causes tars to move to surface of coal and to seal the coal particles, minimizing chance of moisture recovery
  - Process also causes coal to undergo "decarboxylation, which increases energy density of the refined coal.

Application of Binderless Briquetters White Energy Company (WEC)

- WEC, a public company listed on the Australian stock exchange, was previously known as Amerod Resources Ltd.

- Name changed to White Energy Company in 2006 with the acquisition of a worldwide exclusive license to market binderless briquetting (BB) technology from White Energy Technology, Ltd.

- WEC's BB technology was originally developed by CSIRO of Australia in collaboration with two USA based companies, KR Komarek and TraDet Inc., and an Australian coal miner.

- In May 2007, BHP Billiton agreed to provide WEC with an A$35 million unsecured financing facility, which will be used to roll-out its BB technology in Indonesia, China, South Africa and America.

Application of WEC's Binderless Briquetters

Technology described

- Coal dried to 7%-9%TM in a flash dryer
- Dried coal passes through cyclone separators and then sent to roll briquetting machines.
- Resulting briquettes have 7%-9% TM and are reportedly:
  - Very stable, will not disintegrate during transport and storage
  - Weather resistant
  - Very dense with low tendency to reabsorb moisture = reduced spon-com risk
- Process is reported to cost 1/3 to 1/2 of traditional briquetting processes that use binders.
- WEC has in operation a 12 t/hr development plant in Western Australia and is currently constructing a 10-12 t/hr demonstration plant in the Hunter Valley.

Partnerships & JVs

Indonesia:

- JV with PT Bayan Resources (51% WEC: 49% Bayan): Plant under construction
- MOU and feasibility study with Adaro / Itochu

China:

- HOA with Datang International Power
- HOA with Shenhua International

Application of Microwave Drying System
CoalTek, Inc.

- CoalTek is a small start-up company located in Tucker, GA with a staff of 10.
- It recently raised $18 million in private equity financing with investments coming from:
  - Draper Fisher Jurveston,
  - Braemer Energy Ventures,
  - Technology Partners,
  - Element Ventures
  - Warburg Pincus.
- Funds used to build a microwave coal drying facility at a coal handling facility, located in Calvert, KY and owned by Southern Coal Handling Services (SCH)
- SCH builds and manages coal handling terminals for coal mines and power plants throughout the US. Its Calvert, KY facility can:
  - handle 10 million tons coal throughput per year
  - accurately blend up to 3 coals
  - receive coal by truck, barge or rail.

Microwave Drying System: CoalTek, Inc.

- Few technical details are provided by CoalTek on its website about the technology except to say that:
  - Its facility will have capacity to process 27 t/hr of LRC.
  - The coal can be processed to a moisture level as desired by the company ordering the coal.

Summary

- Shift to LRC will happen over the next 7-8 years:
  - LRC is destined to become the primary coal brand of Indonesia by 2015 as existing reserves of sub-bituminous coal are depleted
  - Coal drying technologies can hasten shift to LRC by allowing boilers, optimized to fire sub-bituminous and bituminous coals, to run on dried LRC.
  - In Asia, many power plant boilers has been optimized to run on coals with TM between 20% and 25% . Moving LRC into this existing market is the preferred way forward.
- Technology Assessment:
  - Dryer applications at the mine-mouth are intuitively preferred due to the large savings in coal handling & transport but other factors – cost of heat and power and effect on coal physical properties – will determine whether mine site or power plant provides best location .
  - GRE's waste heat drying system may have near term potential at power plant sites in SE Asia.
  - Binderless briquetters from WEC should have their most attractive commercial applications at mine sites. Low cost coal can be used to fire their flash dryer, product is very stable and transportation resistant. The final product is suited for plants designed to burn Australian bituminous coals, not Indonesian sub-bits.
  - Pyrolysis systems, such as the K-Fuel process, will also have their most attactive commercial applications at mine sites and offer the best potentials for US and Chinese coals, where removal of S, CL and Hg from the raw coal will add value.
  - Microwave drying has the greatest technological uncertainty attached to it.

Comments may be sent to:
bart@rolevaenergy.com