

Coal Gasification & SynGas based DRI

Presented by

Rajesh Jha

Executive Director

Jindal Steel & Power Limited

Orissa, India

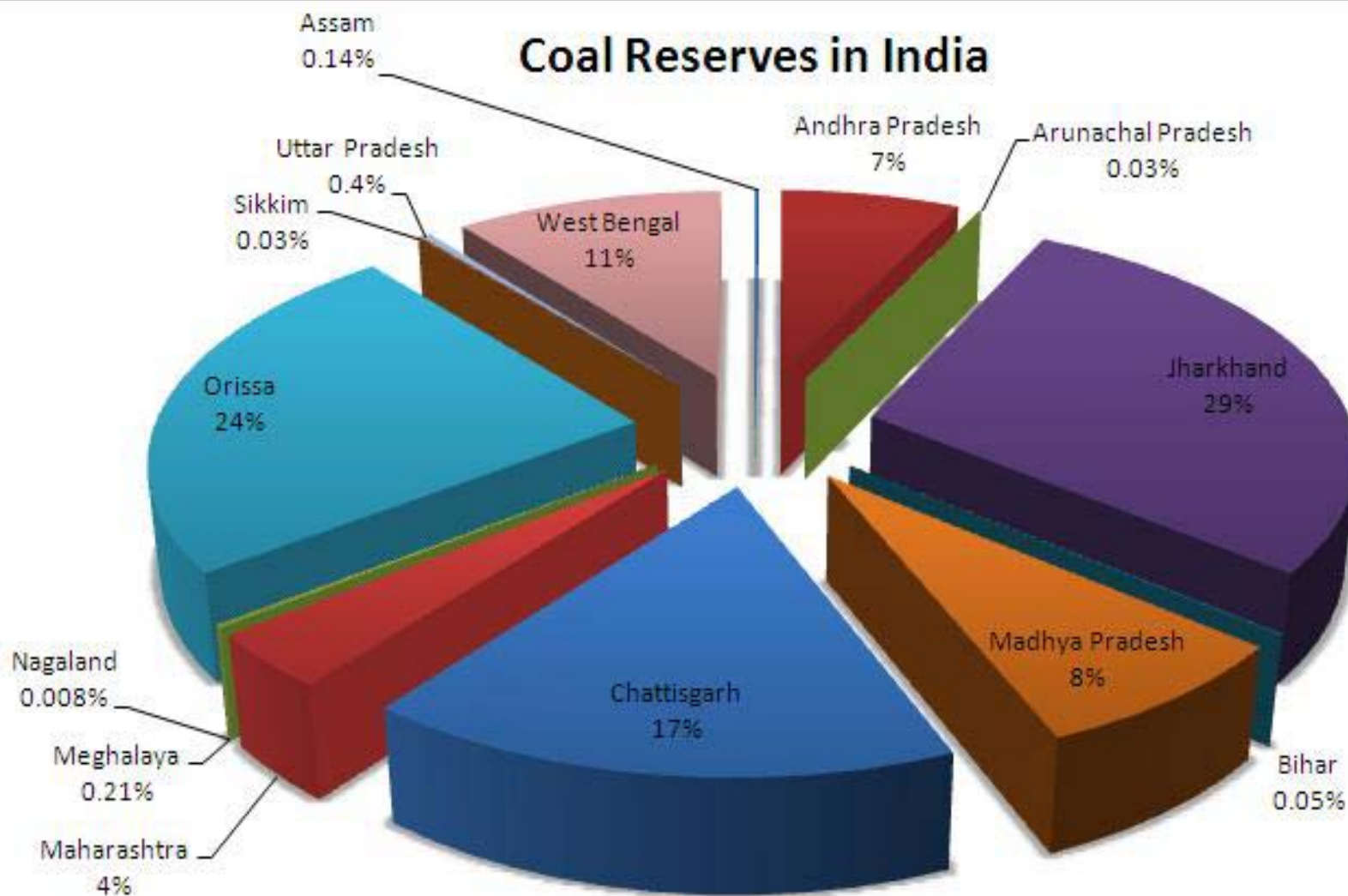
Back ground

- India is third largest producer of coal in the world*
- India has fourth largest reserve of coal in the world**
- Non Coking Coal reserves are 233.8 Billion Tons (~87%)
- Coking Coal Reserves are 33.4 (~13%) Billion Tons
- Typically Indian coal has high ash content (15-45%) & low calorific value

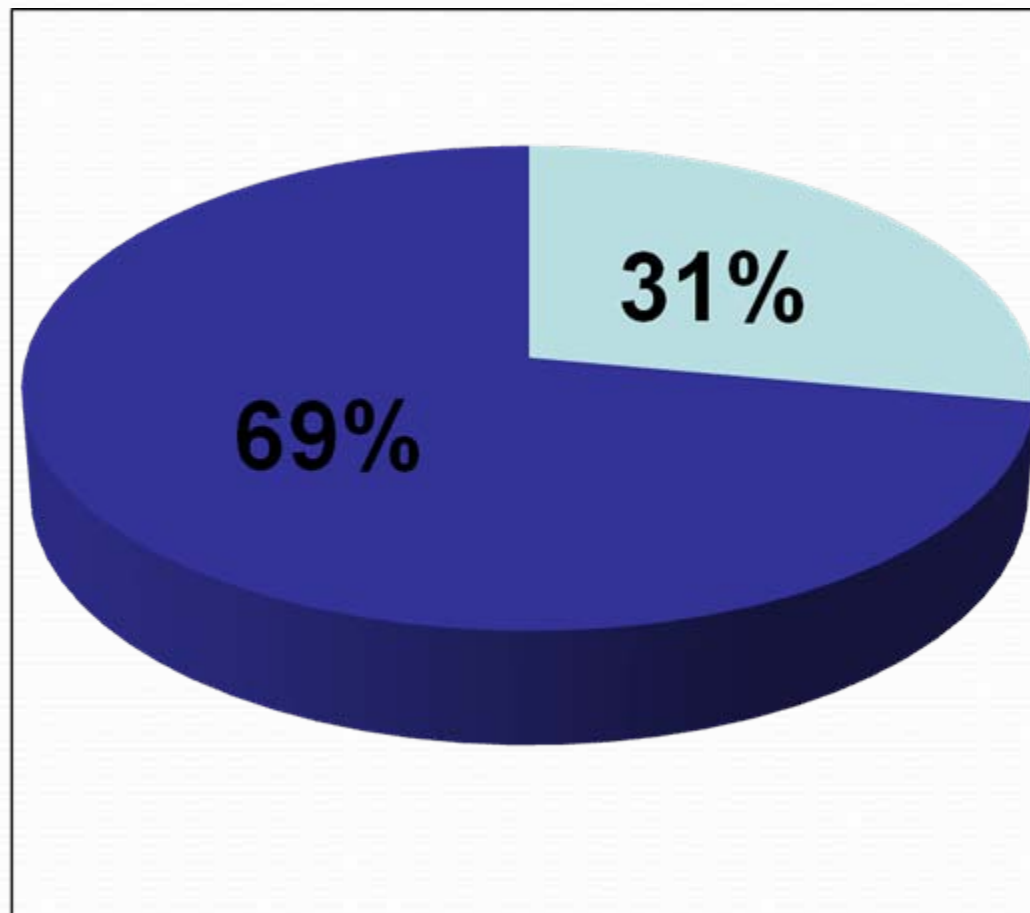
* Source: www.worldcoal.org (International Energy Agency)

** Source: www.worldcoal.org

Coal Reserves in India



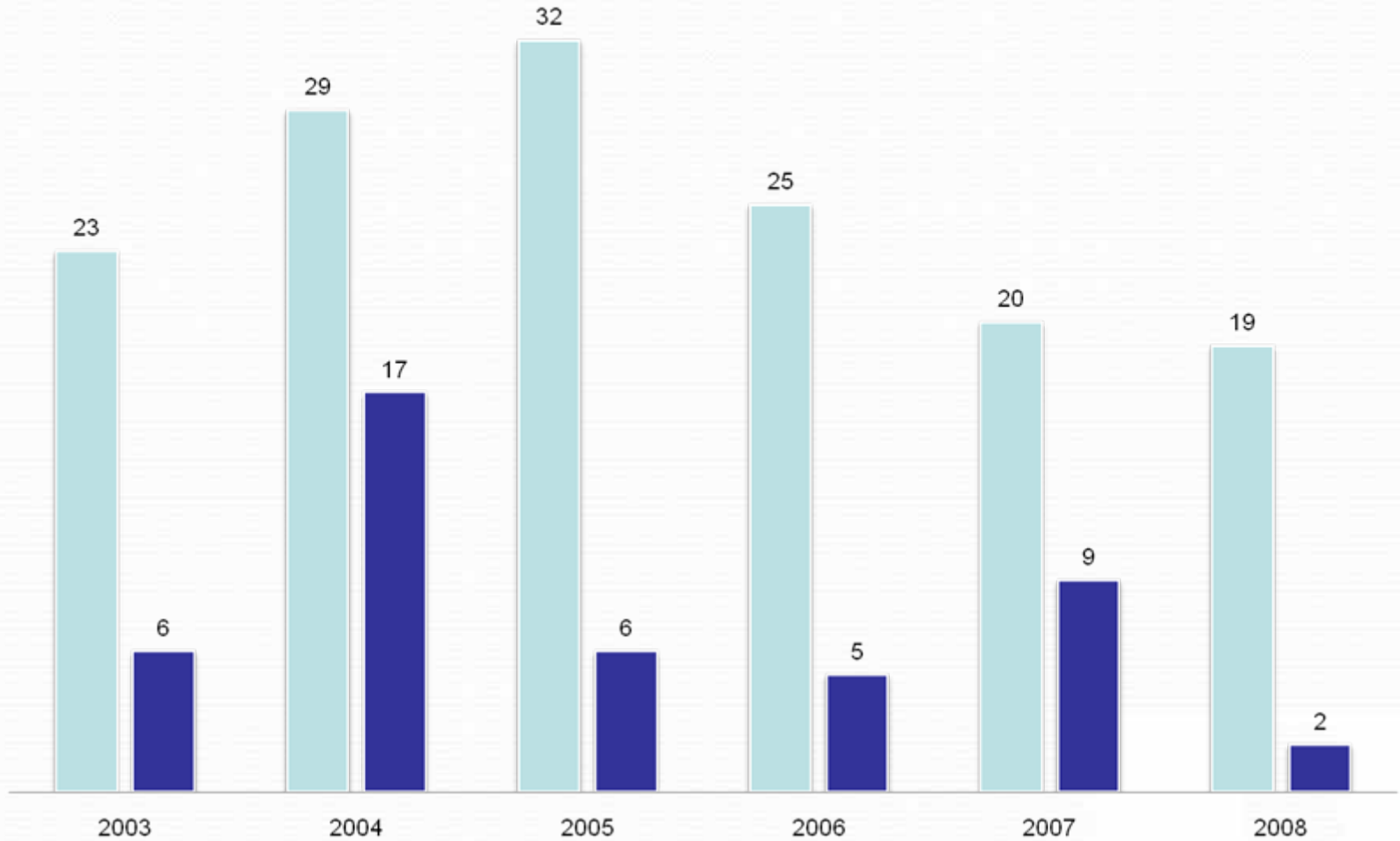
India's Share of World DRI Prodn. 2008



India 

% Growth in DRI Production

■ India ■ World



Total India DRI Production 2008 21.2 Million Tons

14.79 Million tons **Coal Based**
70%

6.41 Million tons Gas based

- Iron Oxide is converted into Iron in two ways
 - (a) Blast Furnace/Smelting reduction Route
 - (b) Direct Reduced Iron (DRI) route.
- Smelting Reduction has shown some limited success - COREX.....FINEX
 - High ash Indian coal **suitability ?**
- In India Metallurgical Coal reserves are limited. For going in Blast Furnace route, required **coking coal** needs to be **imported** – very volatile n expensive

What To Do ???

- a) India has abundant high quality iron ore
- b) Scarcity of Natural Gas
- c) India has abundant non Coking coal.
- d) Non coking coal is to be used efficiently

Coal Gasification ???

Alternatives

- There are two prevalent ways of producing Direct Reduced Iron (DRI).
 - (a) Rotary kiln based
 - (b) Gas based
- In both the processes non-coking coal can be used.

Rotary Kiln DRI Vs Gas based DRI

S No	Rotary Kiln based DRI	Gas based DRI
1	Prone to Pollution.	Clean Technology.
2	Plant size 50 – 500 TPD	1200 -6000 TPD
3	Low Capital cost	Investment required is comparatively higher
4	Energy requirement is high	Energy requirement is atleast 20% less than that of rotary Kiln
5	Not suitable for making quality steel (for flat products)	Product suits making good quality steel
6	DRI fines (-3mm) generated is ~30-40% Losses in SMS are more due to high % of fines	DRI fines (-5mm) ~5% Losses in SMS are less due to low % of fines
7	Sulfur in the Coal partly attached to DRI and partly going to atmosphere as SO ₂ causes environmental pollution	Sulfur content in DRI is in the range of 0.003-0.01%
10	Carbon in the range of 0.1 – 0.3%	Carbon in the range of 1.5-2.5%.
11	Metallization 86-90%	Metallization 92-94%

Examine Coal Gasification

Table 12. Some important features of different Coal Gasification process

	FEATURES	Fixed Bed	Fluidized Bed	Entrained Bed	
		Lurgi FBDB	Winkler	Shell	Texaco
1. a)	Pressure , Kg/cm ²	10-30	Atm	30-40	40-80
b)	Temperature deg C	1200	1100	1600	1600
c)	Gas-outlet Temp, deg C	675	~850	1370	1320
2	Type of Coal and caking coals	All ranks except coking coal	Low rank coal	All types	All types
3	Feed coal size , mm	6-50	0-9.5	-200 mesh	0-0.5
4	Moisture in feed coal , wt%	up to 18		<5	No limit
5	Maximum ash content tried, wt%	up to 40		up to 25	up to 25
6	Ash withdrawal	Dry Powder	Dry Powder	Molten Slag	Molten Slag
7	Dry gas composition , vol%				
	CO	18-20	34-36	65-66	55-57
	H ₂	39-41	40-42	30-32	33-35
	CH ₄	10-12	3-4	0.4	<0.1
	CO ₂	28-30	19-20	1-2	10-12
	S ' Compounds	~0.5	~0.5	0.4	0.3
	N ₂ and others	~0.5	1	1	0.6
8	H ₂ / CO ratio in gas	2.1	1.25	0.48	0.65
9	Calorific value of gas , kcal / Nm ³	2600-2900	2640	2980	2700
10	Cold Gas efficiency , %	>85		80-83	76-77
11	Carbon Conversion , %	93-99		>93	>99

WHY SASOL-LURGI GASIFICATION

- Well demonstrated, Proven Technology, Low risk. 101 Gasifiers in operations.
- Suited to wide variety of low grade , high ash content coal up to 40 %
- Robust and mature technology, high reliability and on line availability factors. (90 to 92 %)

- High Carbon efficiency (i.e. 95 %)
- High cold gas efficiency = 85 % because of counter current operation.
- Oxygen consumption is low

- Most suitable for steel industry, as it contains gas H_2 : $CO = 1.6: 1.8$ and CH_4 of 10 to 12 % which is a requirement of steel industry.
- Ash fusion temp of Indian Coal is high. Hence dry bottom ash is preferred.
- No coal drying & grinding. So less energy consumption and not hazardous.
- Valuable Co-Products like tar, oil, phenol, ammonia are produced.

Syngas Composition vs Reformed Gas

S No	Component	MIDREX	HYL Reformer	COREX	Syngas	ZR Scheme
1	H ₂	55	73	19	51	50
2	CO	33.5	15	38	31	15
3	CH ₄	3.1	5	1	9	25
4	CO ₂	2.6	1	35	6	3
5	H ₂ O	5	5	3	1.5	4
6	N ₂	0.8	1	4	1.5	3
7	H ₂ /CO	1.64	5	0.5	1.65	3.33

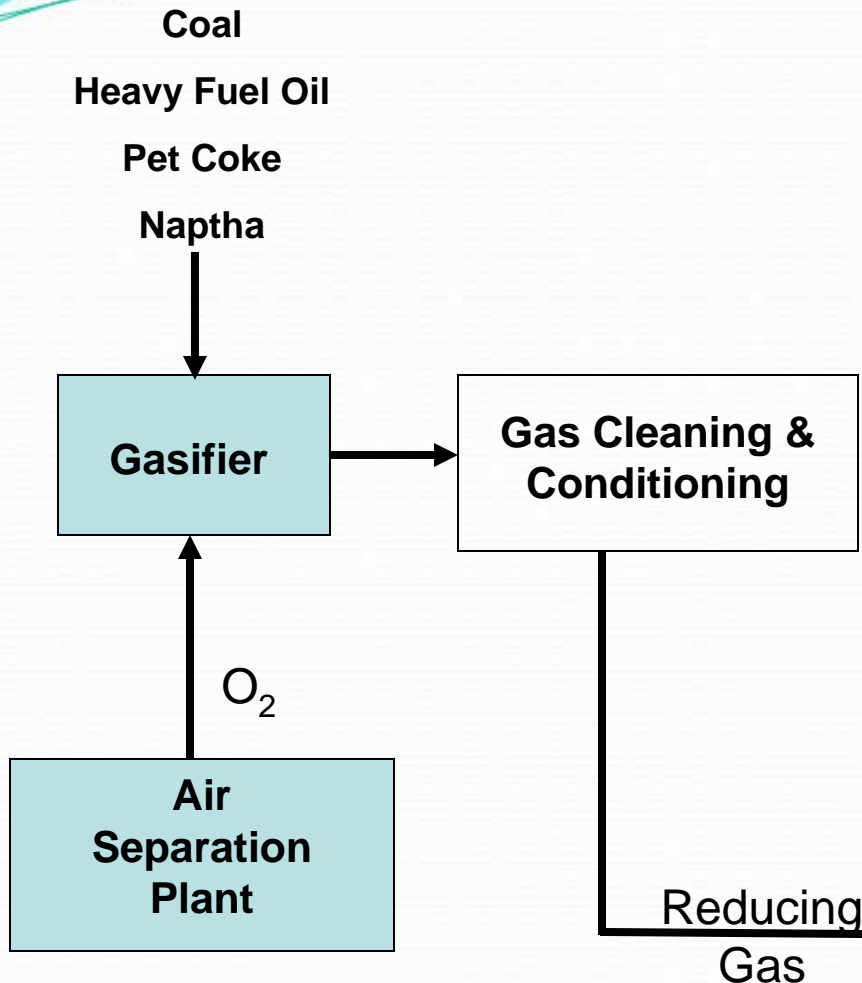
Above table shows the composition of the Reducing Gas that is being used by various processes. **Syngas from Coal Gasification looks to be quite usable.**

Inputs	Specific Consumption		
	Unit	Natural gas	Syngas
Iron ore	t/t	1.42-1.44	1.42-1.44
(Screened-3.2-mm, dry basis)			
Natural gas	Gcal/t	2.4	-
Syngas*	Gcal/t	-	2.2
Electricity	kwh/t	115	115
Oxygen	Nm3/t	15	15
Water	m3	1.5-1.8	1.5-1.8
Steam at 4.5 bar			
For Co2 removal in syngas	kg/t	-	700
Labour	man hrs/t	0.11-0.17	0.11-0.17
Maintenance	US\$	3.5	3.0

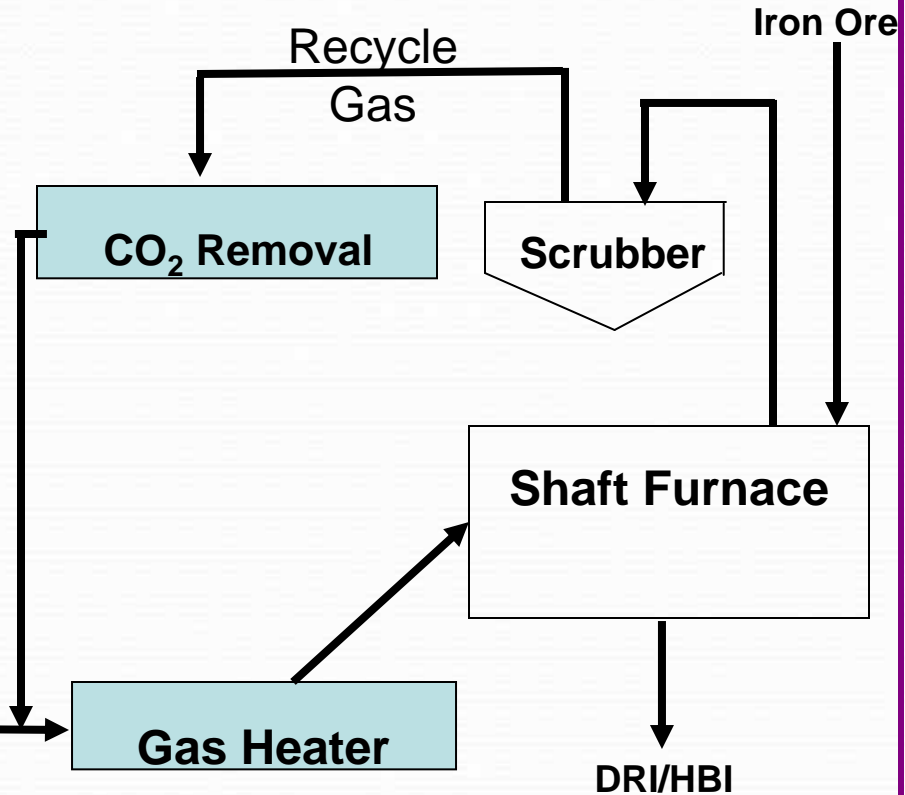


JINDAL

Process Route

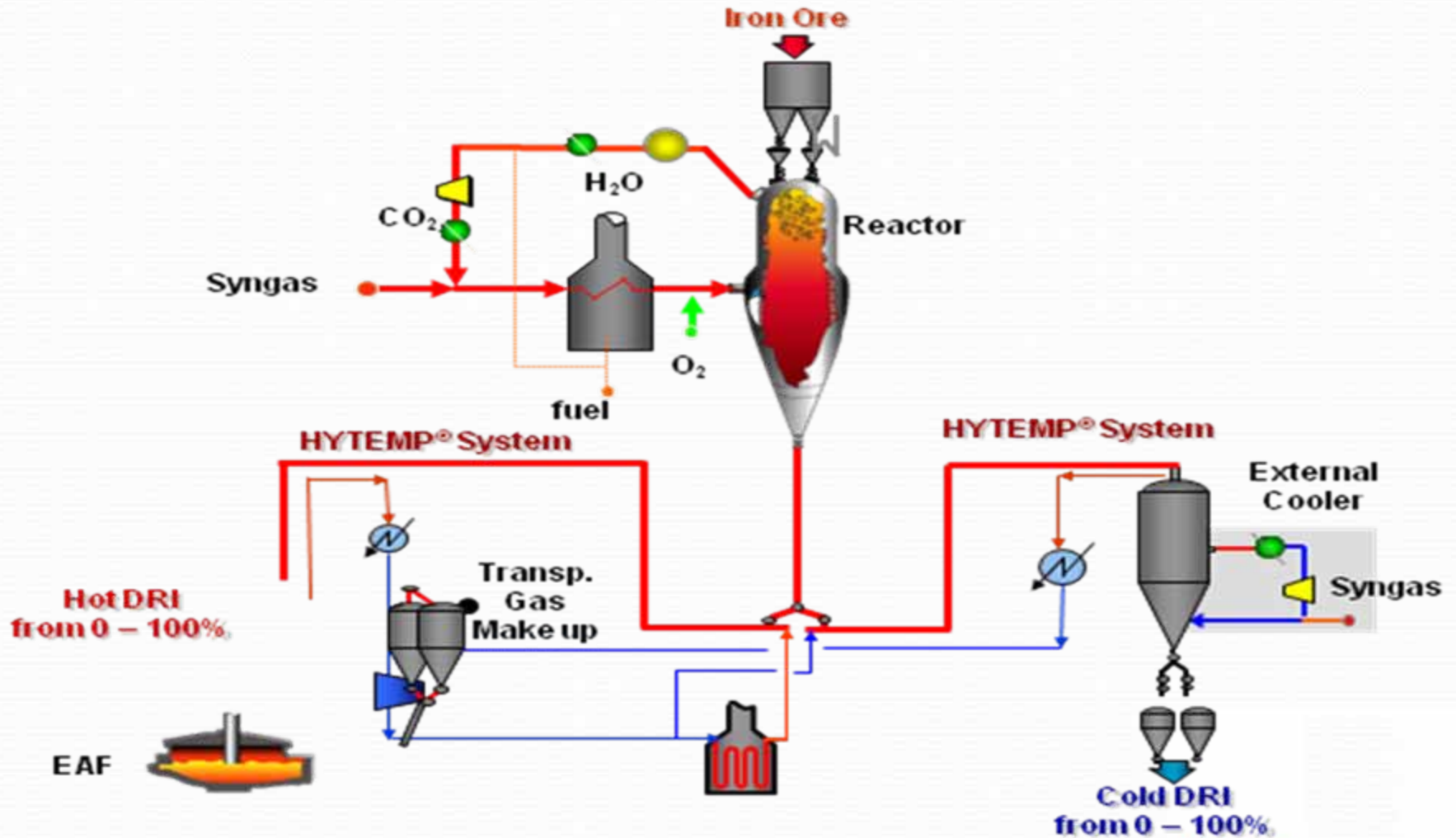


Gasification plant



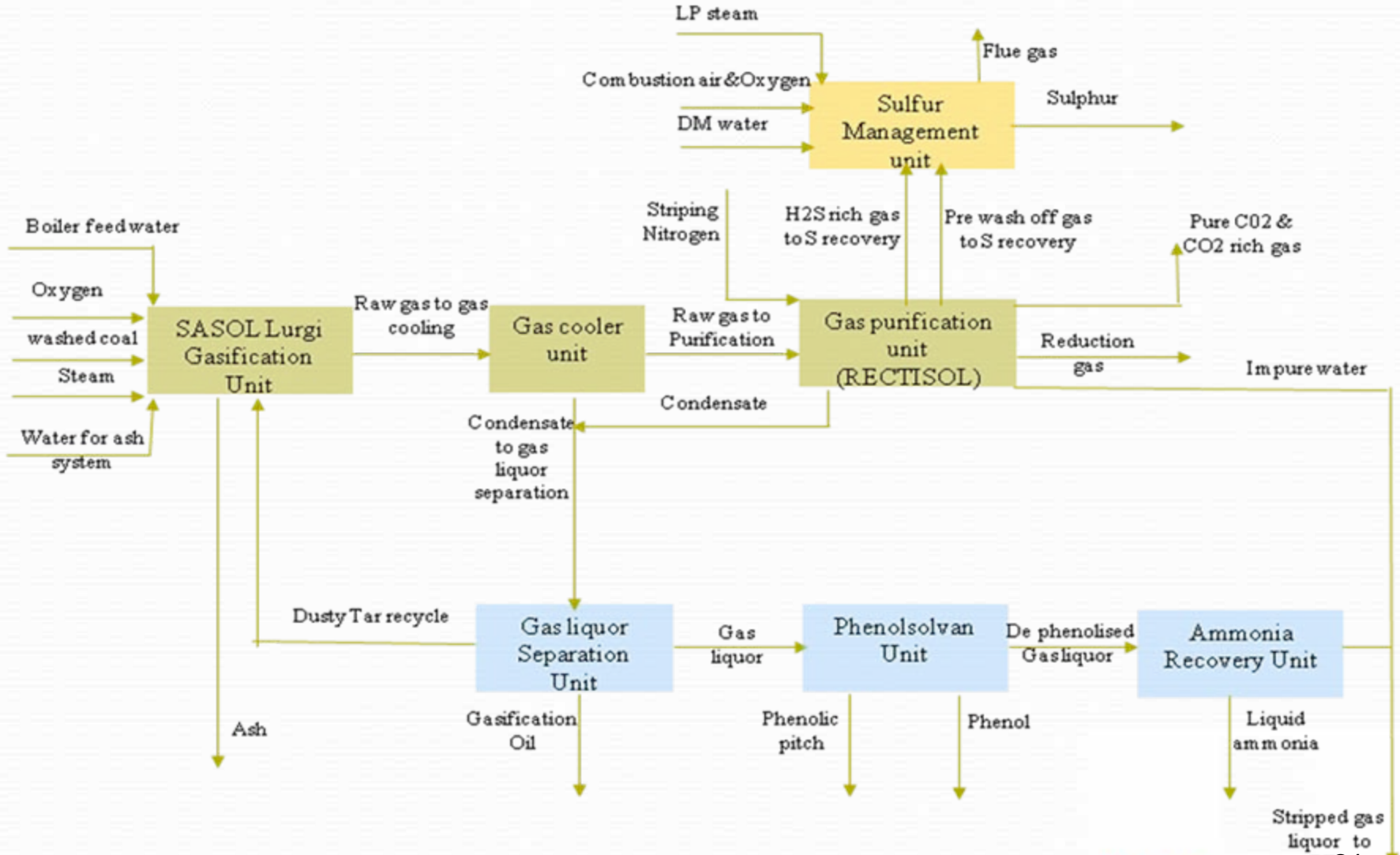
Direct Reduction Plant

Figure 2. Energiron process



- Sasol- Lurgi gasifier can use high ash coal (34-36% ash).
- 269 t/hr of coal produces 225 000 NM³/hr of syn gas.
- Adequate volume for 2.5 MTPA DRI plant
- This technology is being implemented at JSPL, Angul (Orissa) for 4 MTPA DRI plant.

Figure 1. Coal gasification process block diagram



Following tests were conducted on Coal sources to determine the suitability for Gasification Purposes:

- Proximate Analysis
- Ultimate Analysis
- Co₂ Gasification reactivity
- Particle size distribution
- Ash melting properties and ash composition
- Caking Properties under 30 kg/cm²

- Thermal Fragmentation
- Mechanical Fragmentation
- Fisher Assay
- Total Sulphur
- Heating Value
- Rank of the coal.

Table 2: Particle size distribution on sample as received (Mass% -Fraction Retained)

Fraction (mm)	Talcher 1	Talcher 2
37.5	9.7	3.0
26.5	39.0	42.5
19	25.4	30.8
13.2	11.8	11.7
9.5	5.9	4.5
6.7	3.4	2.5
4.75	1.5	1.3
3.35	0.9	0.9
2.36	0.6	0.7
1.7	0.3	0.5
-1.7	0.3	1.8
-0.5	1.2	0

Table 3: Proximate analysis **(air dried basis-mass %)**

Sample	Talcher 1	Talcher 2
% Moisture	7.5	6.4
% Volatile matter	26.3	26.2
% Fixed carbon	31.9	31.6
% Ash	34.3	35.8

Co₂ reactivity/hr 50% burn off - 5.9

Table 5. Fisher assay (mass %)

Sample	Talcher (composite)
% Tar (as received)	6.5
% Tar (dry basis)^A	7.3
% Char* (as received)	77.6
% Water (as received)	10.3
% gas (as received)	5.6

Table 6. Ash fusion properties

Sample	Initial deformation (°C)	Hemispherical (°C)	Flow (°C)
Talcher 1	1530	1590	+1600
Talcher 2	1500	1580	+1600

Higher Ash Fusion Temp – Low H₂/CO ratio

Table 7. Ash Analysis (mass %)

Sample	Talcher 1	Talcher 2
SiO ₂	66.6	66.7
Al ₂ O ₃	25.0	25.4
Fe ₂ O ₃	2.4	1.8
P ₂ O ₅	1.0	1.0
TiO ₂	1.4	1.4
CaO	1.8	1.2
MgO	0.9	0.8
K ₂ O	1.7	1.7
Na ₂ O	0.3	0.3
SO ₃	0.2	0.1

Caking properties

Talcher coal of the size $-19+2.36\text{mm}$ under pressure of inert atmosphere shows no caking tendency.

Thermal & Mechanical Fragmentation

The thermal & mechanical fragmentation tests were conducted on a composite sample.

The thermal degradation of the Talcher Coal at atmospheric pressure was 20%.

The mechanical fragmentation of the Talcher coal was determined as 32.7%.

Table 8. Ultimate analysis & heating value

Sample	Talcher	
C	Mass	76.4
H	%	5.3
N	DAF	1.9
S		0.7
O(by difference)		15.7
Lower calorific value(air dried) MJ/kg		17.3
Higher calorific value(Dry basis) MJ/kg		17.5

Inorganic and Organic Sulphur distribution

Table 9. Forms of Sulphur (mass% as received basis)

Sample	Total Sulphur	Mineral Sulphur	Organic sulphur
Talcher 1	0.46	0.08	0.38
Talcher 2	0.45	0.11	0.34

Table 10. Petrographic Composition

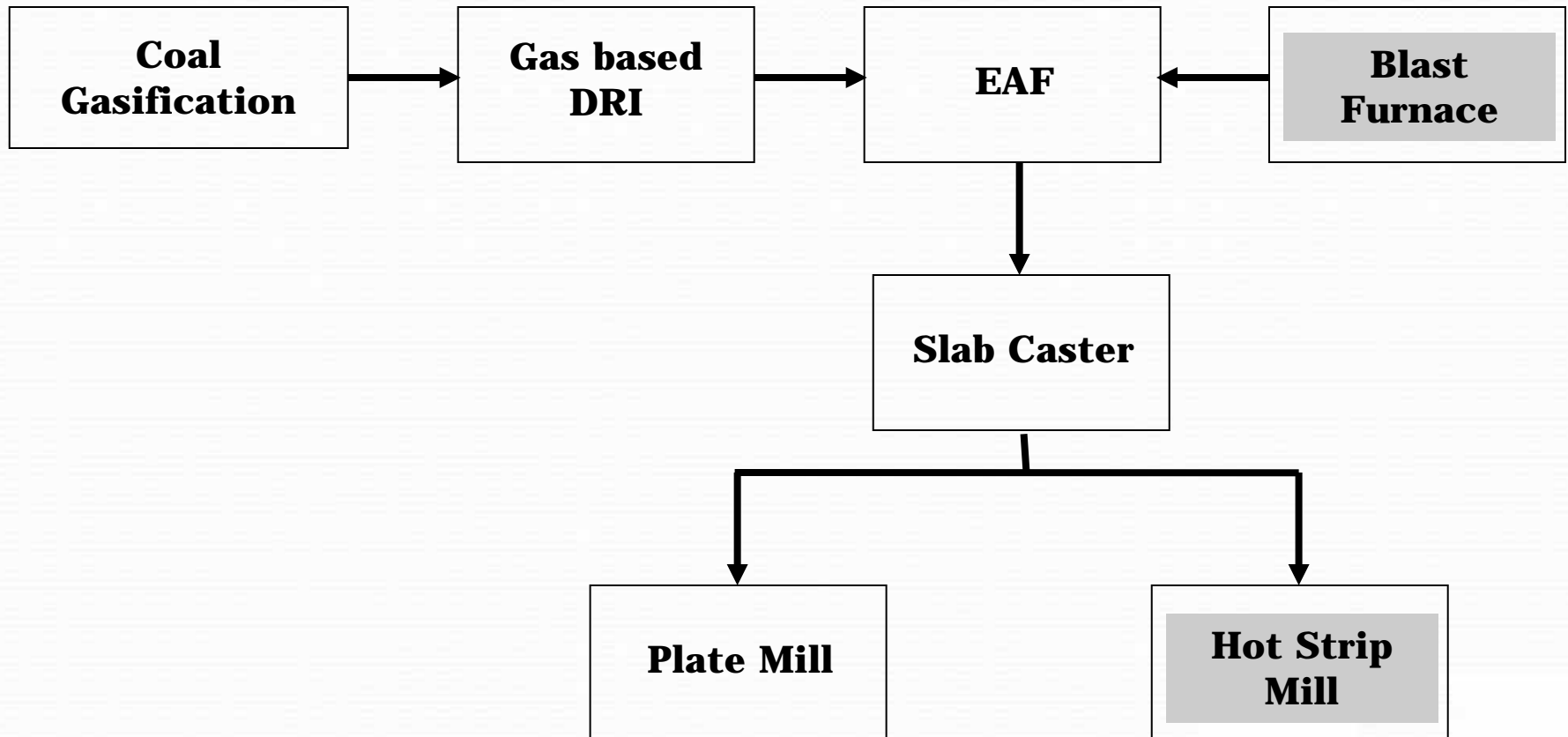
Sample	PETROGRAPHIC COMPOSITION (MASS %)			
	Vitrinite	Liptinite	Total Inertnite	Visible minerals
Talcher	49.8	2.2	15.4	32.6

Classification of Coal According To Rank

-----0.25-----0.4-----0.6-----4.0-----
Lignite Sub-bituminous Bituminous Anthracite

Talcher Coal Rank was found to be - 0.37

Process flow at Jindal Steel's Angul Project



2nd Step

Conclusion

- Right technological fit
- Lower cost base of raw material
- Market linkage at strategic process interface.
- Utilization of complete coal basket

Thank You

Thermal Fragmentation: It is measured by placing a sample with a specific predetermined size distribution into a pre heated muffle oven at 100 °C under atmospheric pressure. The coal is then heated to 700 °C (final temperature) at a rate of +/- 12 °C/min. The experiments are conducted under nitrogen with a reaction time of 60 minutes at the final temperature. The percentage thermal fragmentation of coal is given as a percentage decrease in Sauter Diameter. The smaller the percentage decrease, the better the thermal stability.

$$\% \text{ Thermal Fragmentation} = \frac{d_p \text{ before test} - d_p \text{ after test}}{d_p \text{ before test}} \times 100$$

Sauter Mean Diameter (SMD, d_{32} or $D[3,2]$) is a common measure in fluid dynamics as a way to estimate the average particle size. It was originally developed by German scientist, J. Sauter in the late 1920s. It is defined as the diameter of a sphere that has the same volume/surface area ratio as a particle of interest. Several methods have been devised to obtain a good estimate of the SMD

Cold Gas efficiency: $\frac{\text{Heating value of (CO + H}_2\text{ + C}_2\text{ to C}_6\text{)}}{\text{Heating value of Coal}} \times 100$

Carbon Efficiency: $\frac{\text{Carbon Converted}}{\text{Carbon input by Coal}} \times 100$

1) South Africa: 80 Gasifiers

2) USA: 14 Gasifiers

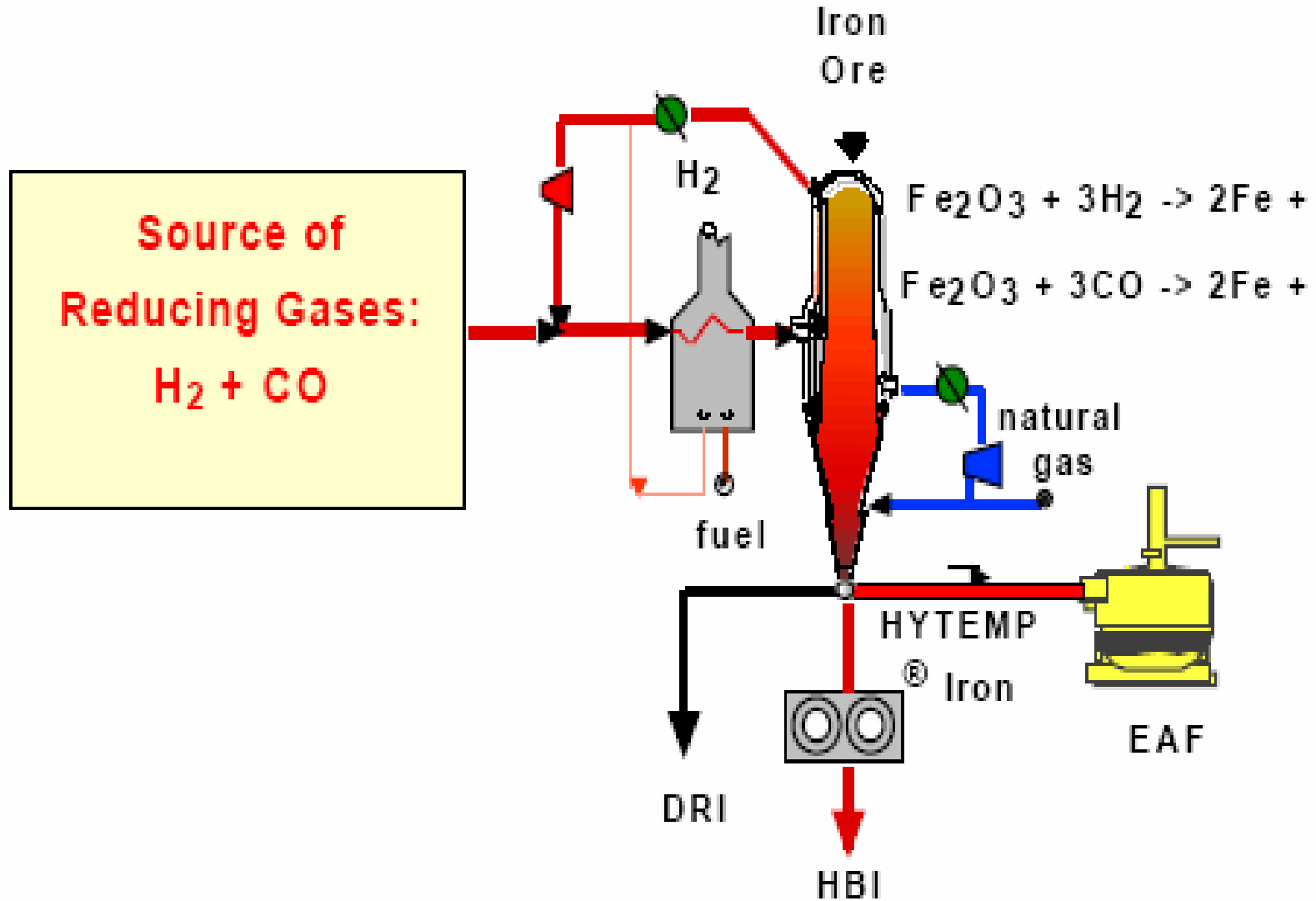
3) China: 7 Gasifiers

Total : 101 Gasifiers

DRI vs Hot Metal (BF route) comparision

S No	DRI	Hot Metal
1	Iron Ore and non-coking coal are available abundantly in India	Coking Coal is to be imported
2	Pellet Plant and Coal Gasification plants are required	Sinter plant and Coke Oven plant are required
3	Cost of production ↓	Cost of Production ↑
4	Investment required for making liquid steel ↓	Investment required for making liquid steel ↑
5	Conversion cost of DRI to liquid steel ↑	Conversion cost of Hot Metal to liquid steel ↓
6	Overall production cost from Iron Ore / Coal to Liquid steel ↓	Overall production cost from Iron Ore / Coal to Liquid steel ↑
7	Overall investment for Iron Ore / Coal to Liquid steel ↓	Overall investment for Iron Ore / Coal to Liquid steel ↑

Process Scheme for Syn Gas + DRI



Ash fusion properties and Ash composition

Ash fusion properties and Ash composition: Ash fusion properties and ash composition are given in Table-6 & Table-7. Tests are conducted under oxidizing conditions at a temperature of 1600C. Ash fusion temperature of Talcher coal is significantly high with coal displaying high ash melting point as a result a low H₂:CO ratio gas can naturally be produced. This increases the carbon efficiency by lowering the CO₂ content in the product gas.

In Talcher coal SiO₂ & Al₂O₃ contents are on higher side and CaO & Fe₂O₃ contents are relatively on lower side.

Table 11. The effect of coal quality on Gasifier performance

S.No	Parameter	Importance
1	Moisture	<ul style="list-style-type: none"> ▪ Influences gasifier efficiency ▪ Determines if process must be dry or slurry fed
2	Volatile Matter	<ul style="list-style-type: none"> ▪ Determines the extent & rate of gasification reactions
3	Heating value	<ul style="list-style-type: none"> ▪ Determines plant dimensions ▪ Influences generation capacity
4	Ash content	<ul style="list-style-type: none"> ▪ Lowers system efficiency ▪ Increases slag production & disposal cost
5	AFT (Ash Fusion Temp)	<ul style="list-style-type: none"> ▪ Influences melting ability of the coal Ash (must be solid below performance temperature)
6	Slag viscosity \approx 1400°C	<ul style="list-style-type: none"> ▪ Influences smooth slag flow between packed bed particles (viscosity must be sufficiently low)
7	Char reactivity	<ul style="list-style-type: none"> ▪ Influences the extent of carbon conversion
8	Sulur	<ul style="list-style-type: none"> ▪ May cause corrosion of heat exchanger surfaces
9	Nitrogen	<ul style="list-style-type: none"> ▪ Contributes to NO_x emissions.
10	Chlorine	<ul style="list-style-type: none"> ▪ May form HCL which can poison gas cleaning system catalysts ▪ May form HCL which can cause chloride stress corrosion.