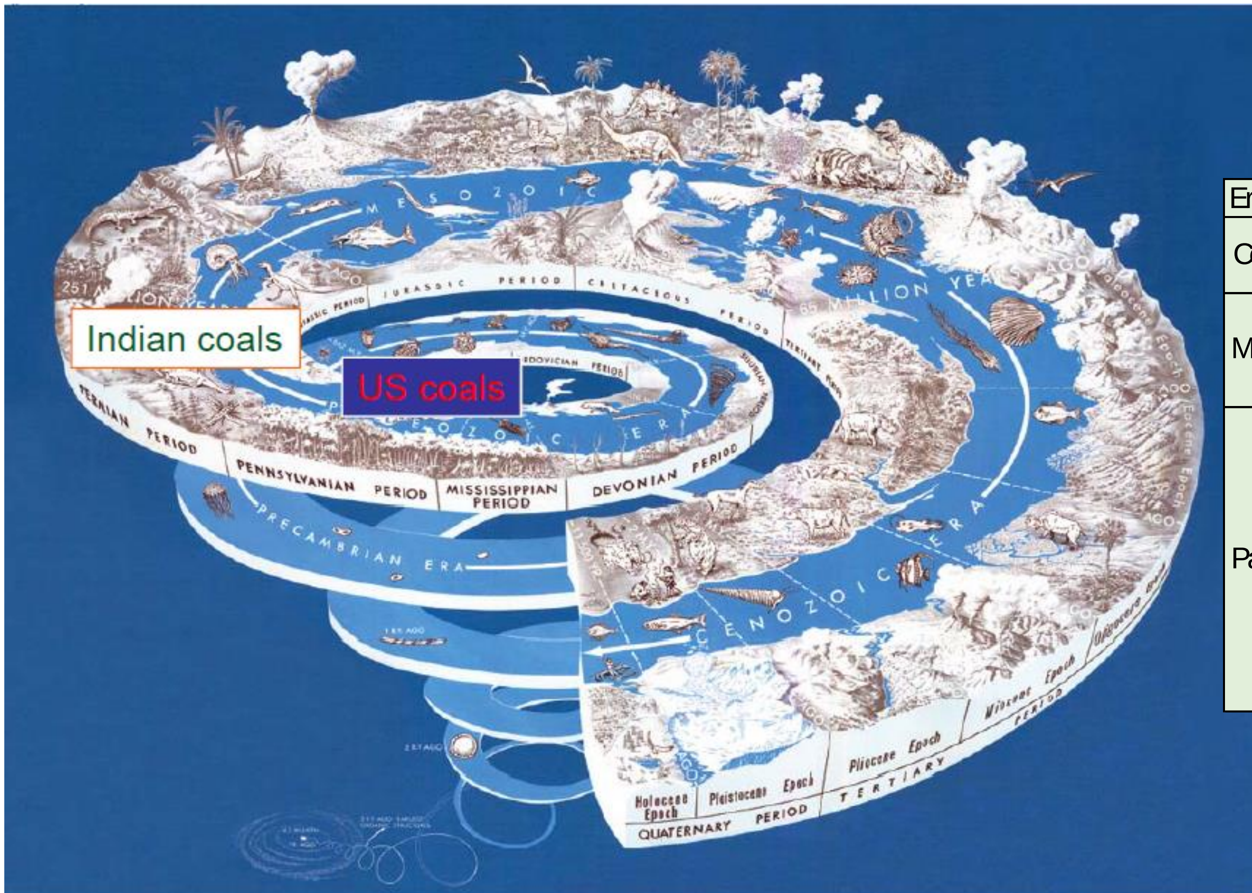
Summary of Presentation

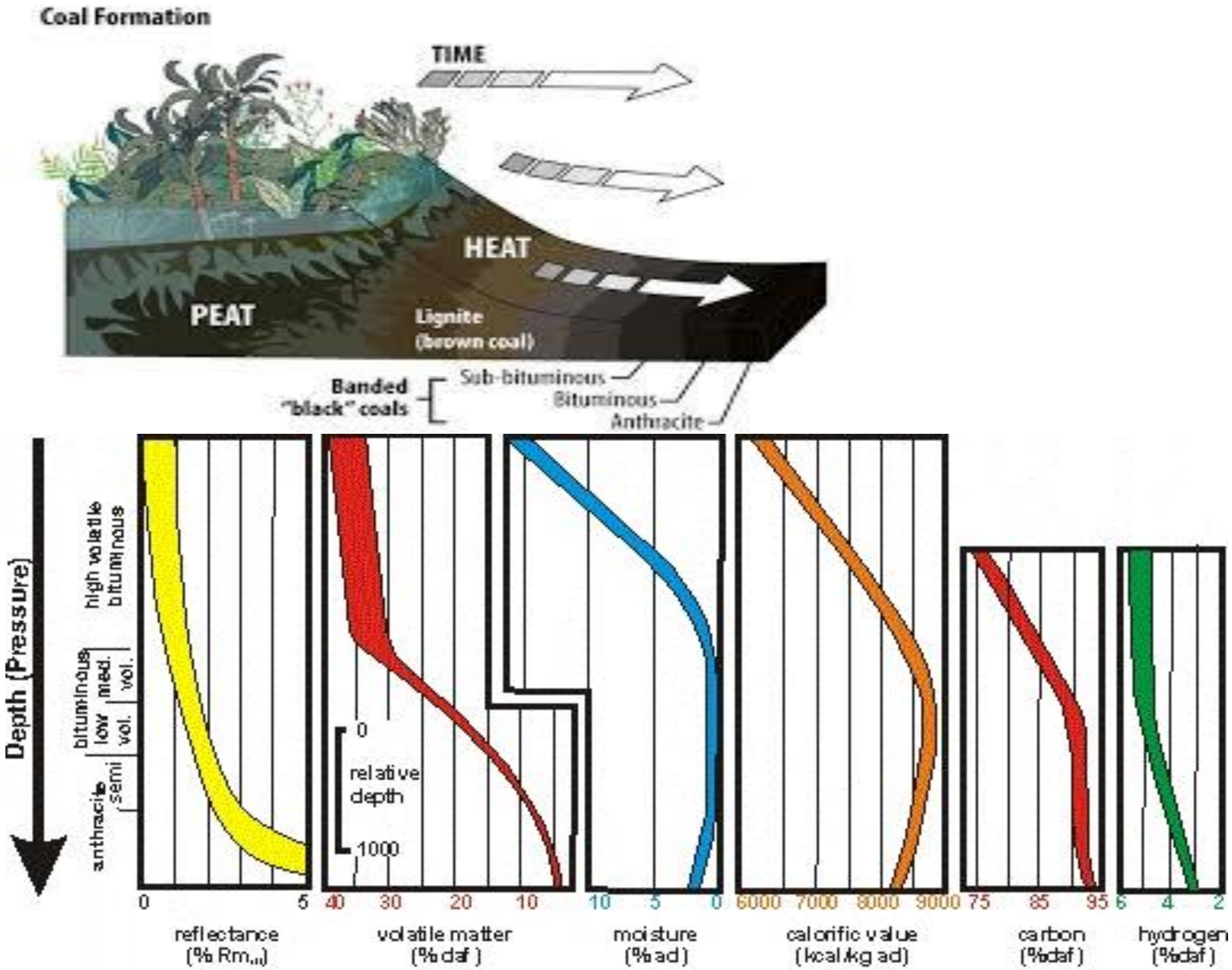
- Gasification of Coal – Primer
- Comparative Assessment of Moving, Entrained & Fluidized Bed Technologies
- Key Process Variables Involved - Fluidization
- Carbon Conversion - Concept of Net Carbon Conversion
- Concept of Recirculation & Importance of Cyclone Design
- Contribution of BHEL in Gasification Technology Development

Gasification of Coal - Origin

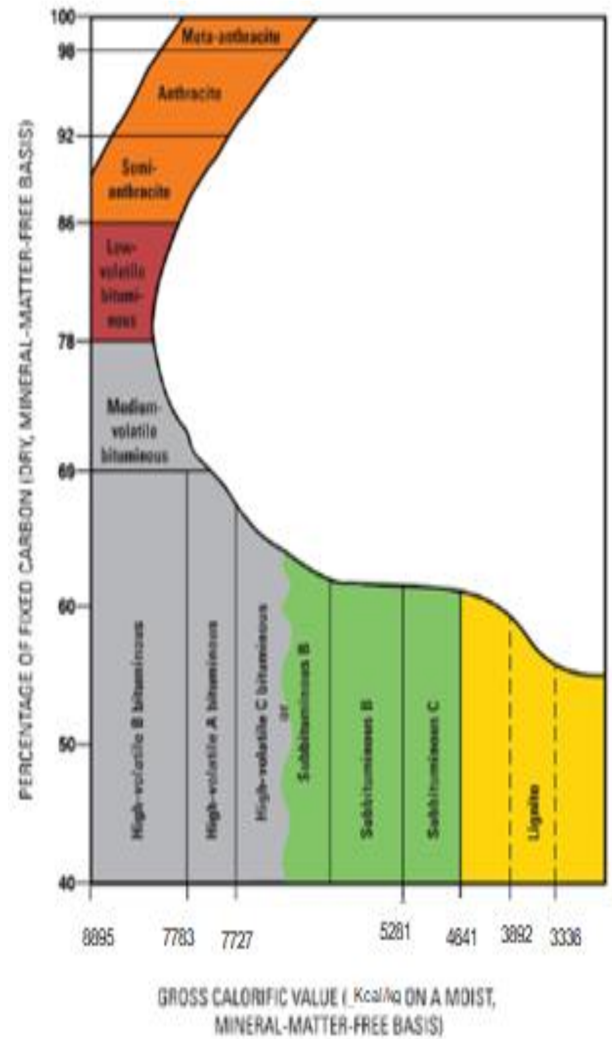


Era	Age (million years ago)	
Cenozoic	65-0	Quartenary
	65-1.8	Tertiary
Mesozoic	144-65	Cretaceous
	206-144	Jurassic
	240-206	Trassic
Paleozoic	290-248	Permian
	323-290	Pennsylvanian-Carboniferous
	354-323	Missipian-Carboniferous
	417-354	Devonian
	443-417	Silurian
	490-443	Ordovician
	530-527	Tommotian
	543-490	Cambrian

Nature of Coal

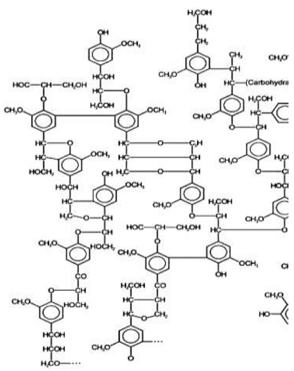


After Teichmüller & Teichmüller 1979

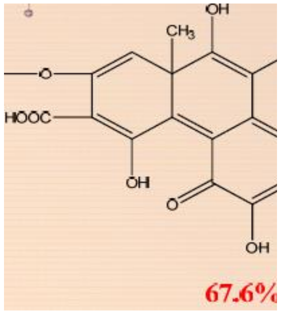


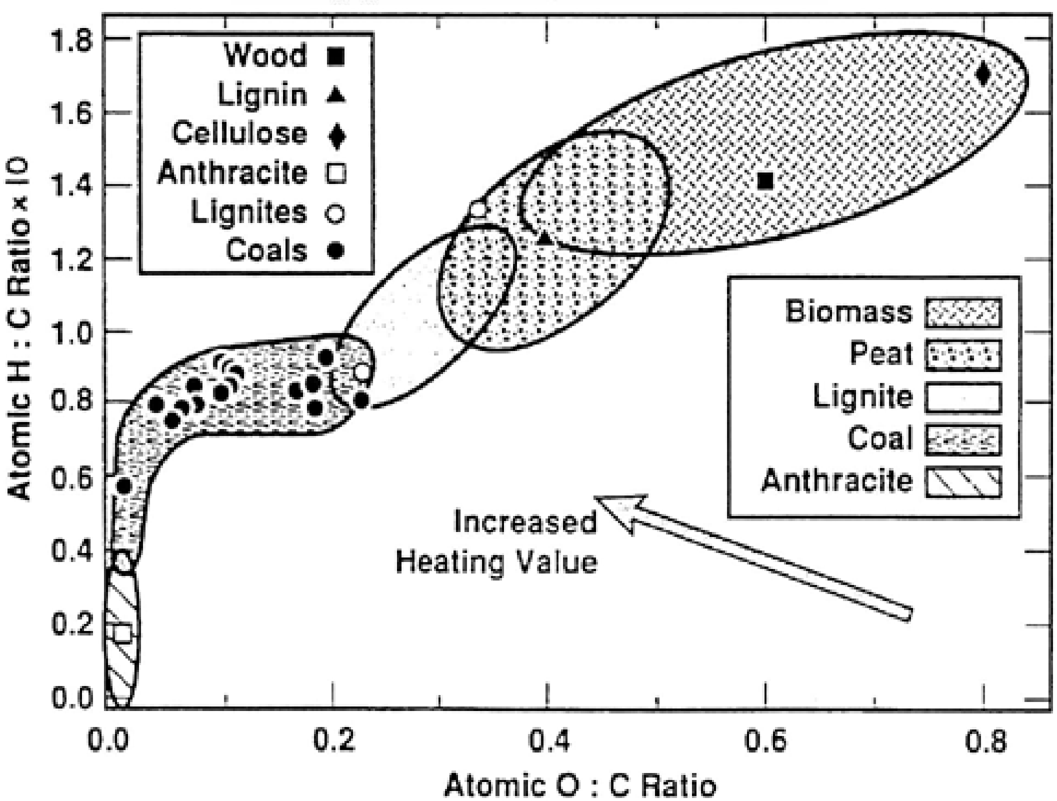
Structural Changes with Coalification

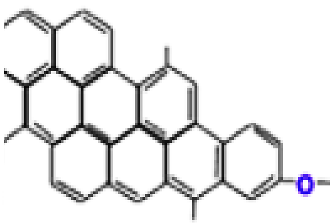
- De-hydration (loss of water molecules)
- De-alkylation (loss of alkyl group)
- Aromatization (conversion of cyclic structures to Aromatics)
- Condensation (increase cyclization)



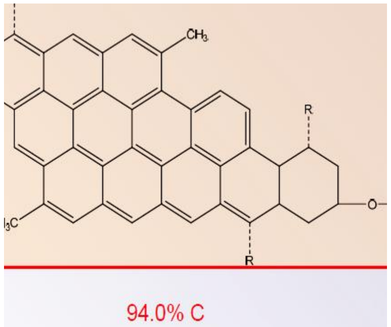
Lignit







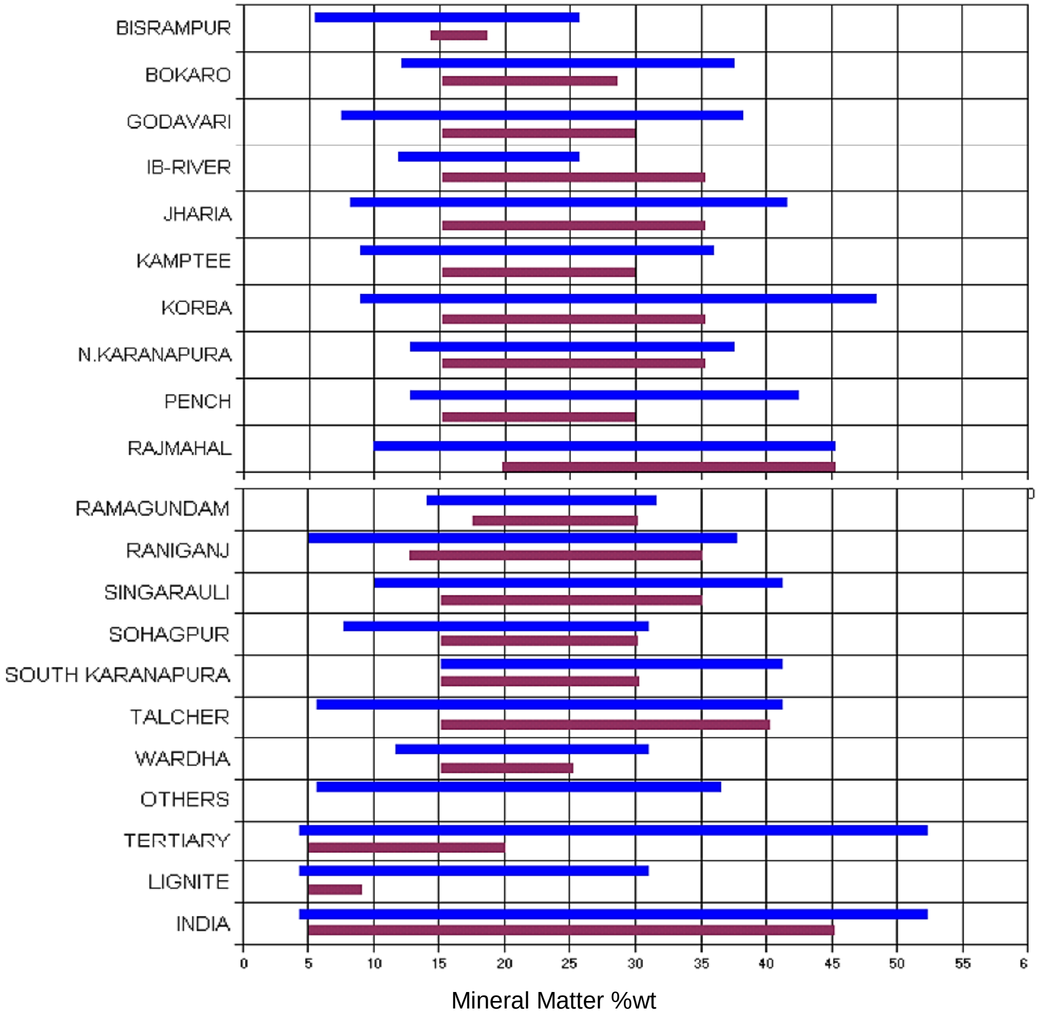
Anthracite



Gasification of Coal - Origin

	INDIAN COAL	US COAL
ERA OF FORMATION	LOWER PERMIAN 200-250 MILLION YEARS	CARBONIFEROUS (> 300 MILLION YEARS)
VEGETATION	SMALL BUSHES AND FERNS	BIG TREES WITH BIG LEAVES
DEPOSITION	SEDIMENTATION ALONG RIVER BASINS	INSITU DUE TO EARTH MOVEMENTS
MINERALS CONTENT	HIGH 25 TO 50% HOMOGENOUS MIX OF MINERALS	LOW 3 TO 12% AS FOUND IN WOOD MINERALS ARE EXTRANEOUS
WASHABILITY INDEX	30-40	70
SULPHUR CONTENT	LOW	HIGH
RANK	MAINLY SUB-BITUMINOUS TO LOW RANK BITUMIOUS	BITUMINOUS

Indian Coal Nature



Permian Gondwana Series (Fresh Water Origin)

North Eastern Coals & Lignite (Fresh Water Origin)

Miocene 25 Million Years

Eeocene 60 million Years

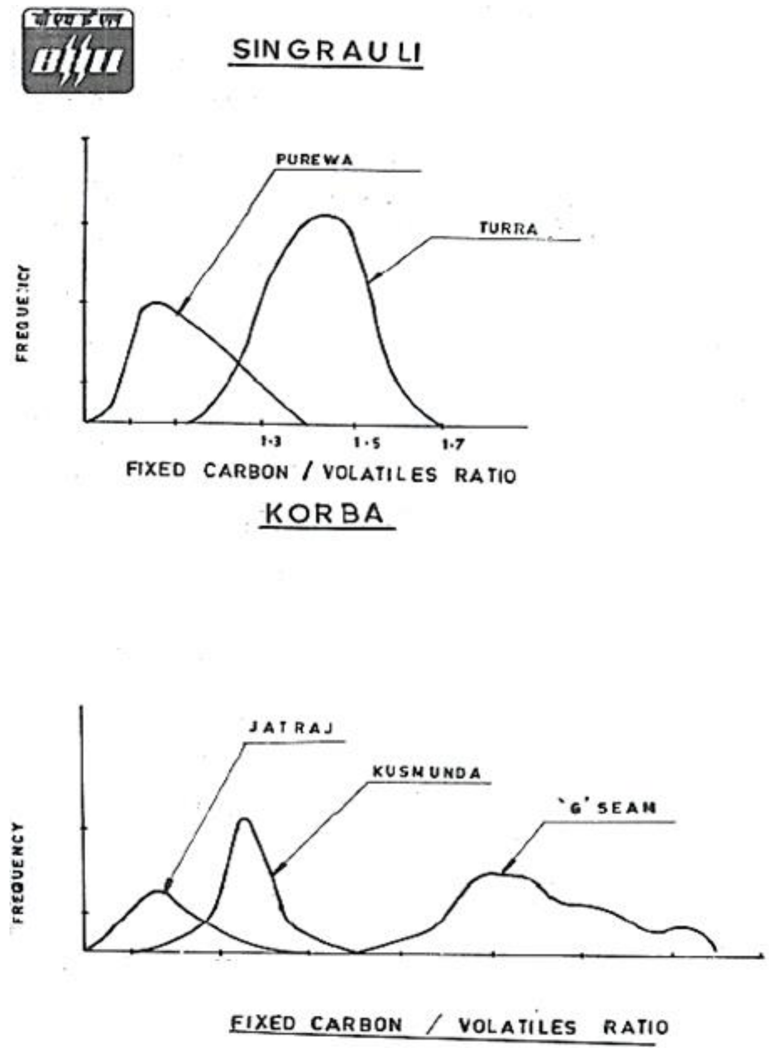
Jurassic 150 Million Years

Coastal Lignite

Gujarat & Rajasthan (Marine origin)

Neyveli & Jayamkondam(Freshwater origin)

What is the Difference ?

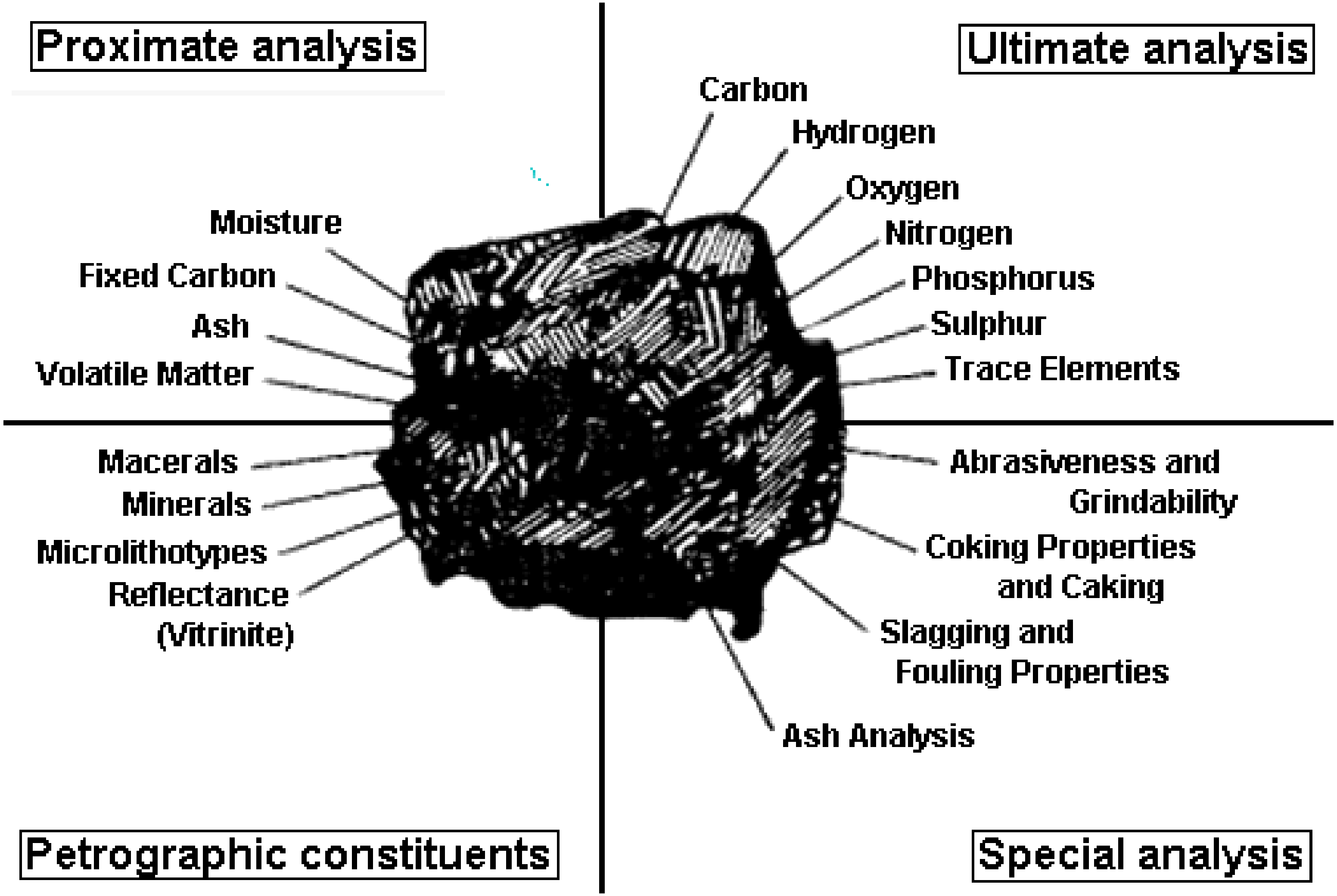


Analyzing one aspect viz Fuel ratio
(Fixed carbon to volatile matter ratio)

Spread of frequency distribution ?

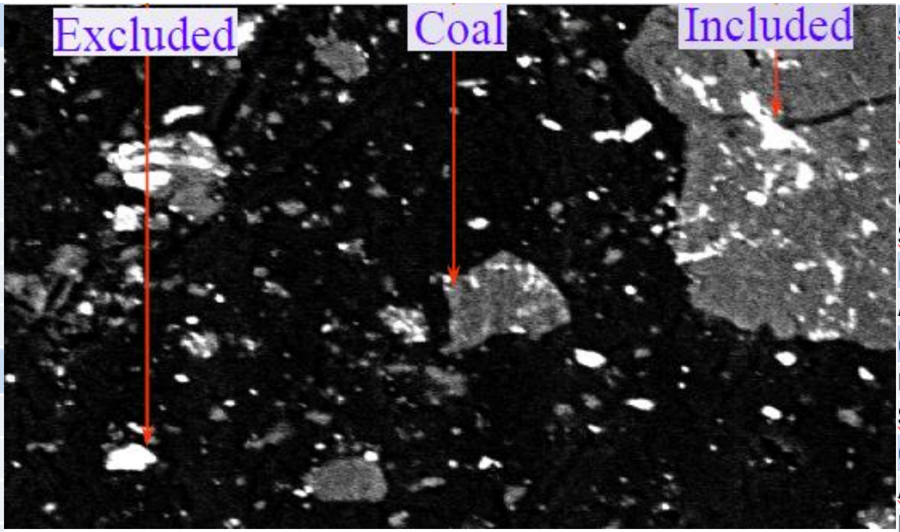
Long duration of vegetation deposition, Drift origin and bio/geochemical changes coal properties can vary significantly along the basin , along the seam
& across the thickness !

What to Analyze about Coal?



Ash ? - Mineral Matter

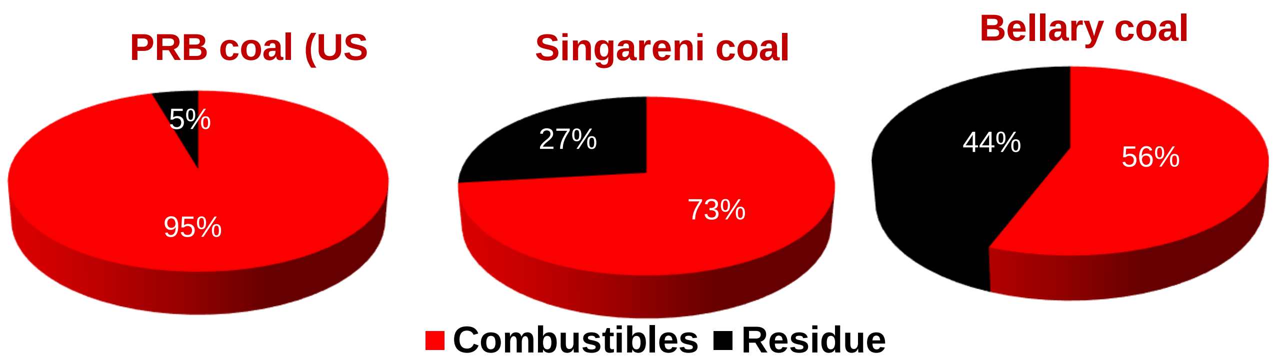
Oxides	
Quartz	SiO_2
Alumina	Al_2O_3
Hematite	Fe_2O_3
Magnetite	Fe_3O_4
Rutile	TiO_2
Periclase	MgO
Spinel	$MgAl_2O_4$
Carbonates	
Calcite	$CaCO_3$
Dolomite	$CaMg(CO_3)_2$
Ankerite	$CaFe(CO_3)_2$
Siderite	$FeCO_3$
Sulphates	
Anhydrite	$CaSO_4$
Gypsum	$CaSO_4.2H_2O$
Barite	$BaSO_4$
Alunogen	$Al_2(SO_4)3.17H_2O$
Thenardite	Na_2SO_4
Arcanite	K_2SO_4
Hexahydrite	$MgSO_4.6H_2O$
Coquimbite	$Fe_2(SO_4)_3.9H_2O$



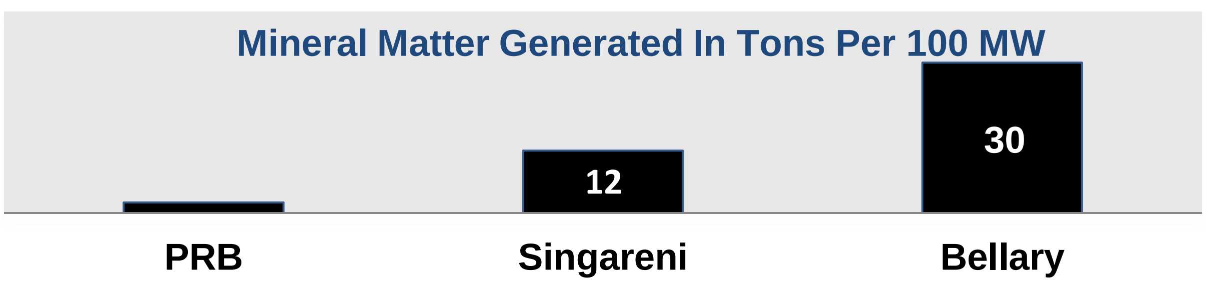
Sulphides	
Pyrite	FeS_2
Marcasite	FeS_2
Pyrohotite	FeS
Chalcopyrite	CuFeS
Galena	PbS
Sphalerite	ZnS
Phosphates	
Apatite	$Ca_5(PO_4)3(F,Cl,OH)$
Chlorides	
Halite	NaCl
Sylvite	KCl
Clay Minerals	
Aluminosilicate	Al_2SiO_5
Kaolinite	$Al_2(Si_2O_5)(OH)_4$
Illite/Muscovite	$(K, H)Al_2(Si, Al)_4O_{10}(OH)_2.nH_2O$
Montmorillonite	$(Ca, Na)(Al, Mg)_2(Si, Al)_4O_{10}(OH)_2$
Feldspar	
Albite	$NaAlSi_3O_8$
Anorthite	$CaAl_2Si_2O_8$
Orthoclase	$KAlSi_3O_8$

Major Elements !

Difference ? - Mineral Matter



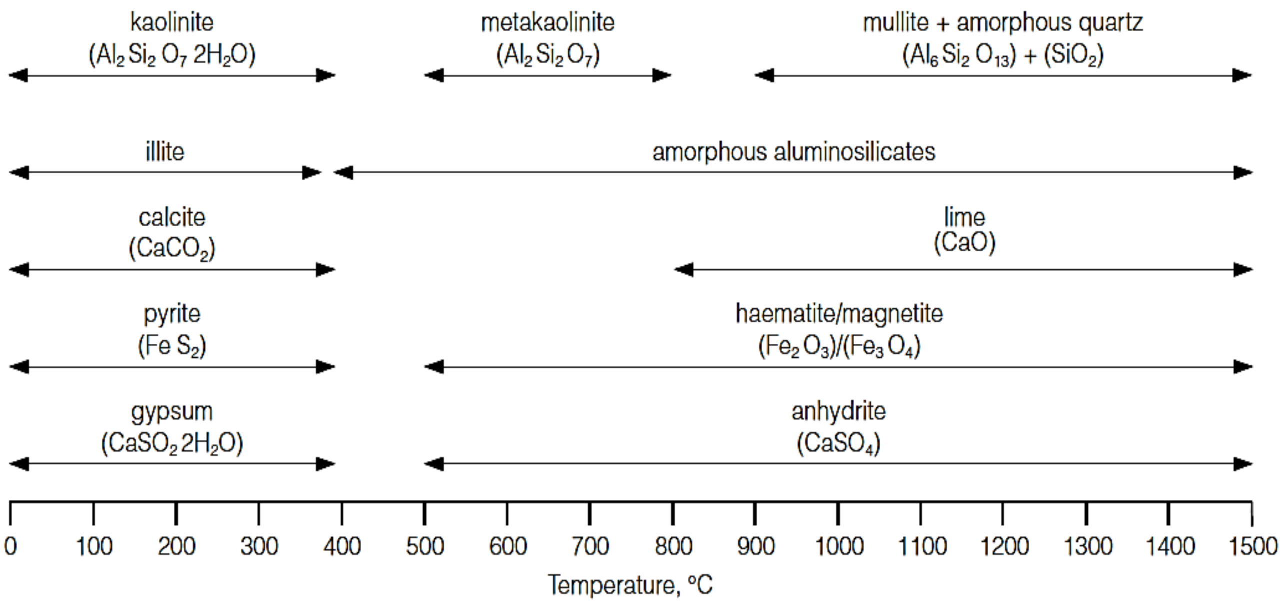
Coal	HHV (Kcal/Kg)	Mineral Matter %	Coal per 100 MW
Bellary	3340	44.13	67.74
Singareni	4885	26.80	46.32
Powder River Basin	4890	4.50	46.27

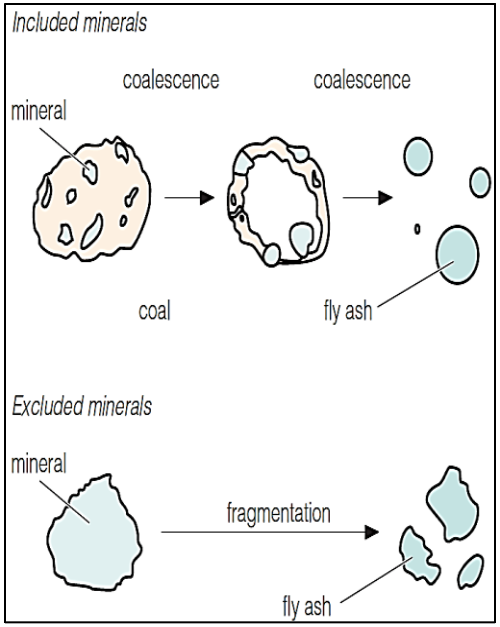


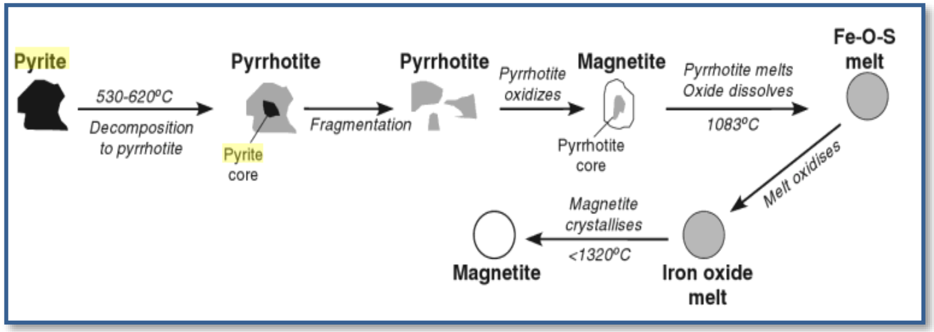
Quantity of mineral matter is almost on par with that of combustibles

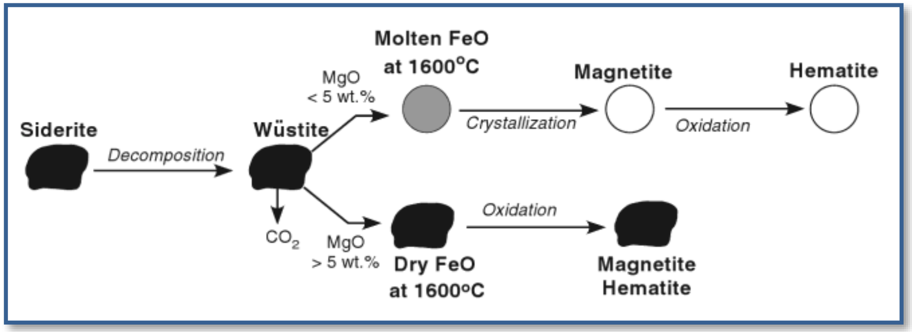
Impact on process !

How Mineral Impacts ?









How Mineral Matter Aspects Impacts ?

Sticky amorphous/glassy phase + partial crystalline phases such as CaO, $CaCO_3$, $CaSO_4$, SiO_2, etc → Hard massive build-up
Ash particle size, shape, PSD

Excluded Pyrite, Marcasite content in coal
illites/mica - clay minerals containing Fe, K or Na
Interaction of included pyrite, quartz and clays in coal
Coal fineness

SO_2 + Alkali as (K, Na) → Alkali sulfates (glue –bonds fly ash)
Sulphur+ excess air → SO_3 Sulphuric acid + fly ash → Acid smut

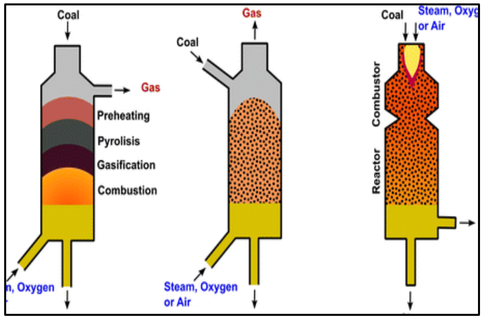
Extraneous rock fragments (Eg. Sandstone, siltstone, mudstone and carbonaceous shale) + Free aluminium silicates (Clays) → Molten agglomerates

Chlorine content, HCL
% Sulphur → Sulphuric acid
$FeS_2 + CO + H_2O \rightarrow FeS + H_2S + CO_2$

Relative higher proportions of excluded quartz, pyrites
% Ash content in coal
Quantity of quartz in the fly ash, PSD

Melting phases in ash
Coal composition, plasticity

Challenges in Indian Coal Gasification



❑ Non-coking Coal Related

- Major variation in quality of feedstock Coal between Mines
- High Ash, Low Rank, weathered / deactivated coal
- Large quantity of Coal Fines in Feedstock (Slurry Based Technologies)

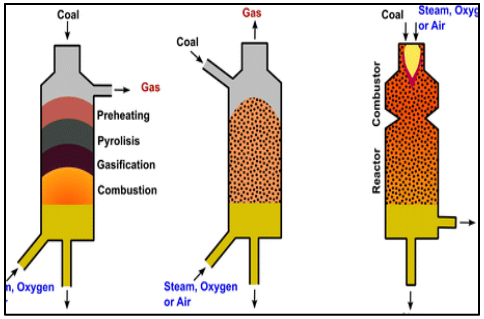
❑ Environmental Related (Slurry & Quench Technologies)

- Large quantities of Waste / Black water generation
- Costly WW Treatment Plants to meet PCB Norms for ‘Zero Discharge’

❑ Technology Related

- Suitable & proven Technology for Indian low rank Coal
- Coal Feed preparation is very critical, complex & costly
- Inexperienced Vendors vis-à-vis fabrication of critical Equipment (Gasifiers)
- Imported & Very costly Spares, still have to keep high Inventories

Challenges in Indian Coal Gasification



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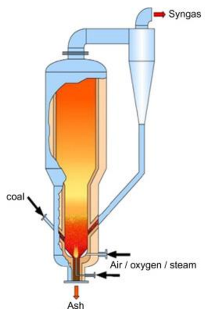
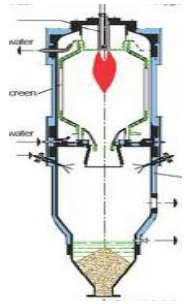
Choice of Technology

Parameters / Type	Moving bed	Fluidized bed	Entrained Flow
			
Feed coal size	5 – 30 mm	< 6 mm	<250 Microns
Mineral Matter %wt	Any	Any	<25%
Fusion temperature	Not limiting	Not limiting	< 1250 °C preferred
M Matter Removal	Dry/wet	Dry	As slag
Gas outlet temp	425 – 650 °C	900 – 1000 °C	1250 – 1350 °C
Spec. Throughput	1	2.5-3.5	3.0-3.5
Effluents	Tar & Phenols	None	Waste water

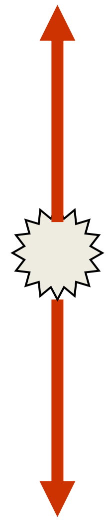
Fluidized Bed Gasification Technology

When

Buoyancy Force

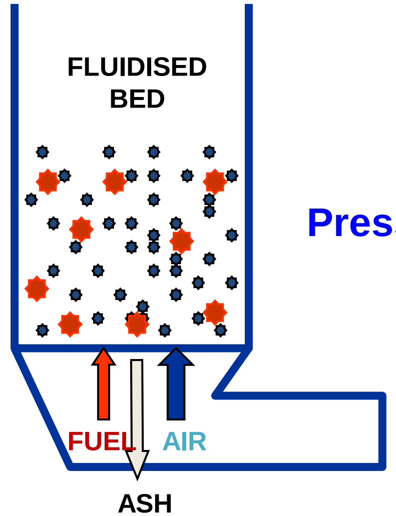
Balances

Gravity Force

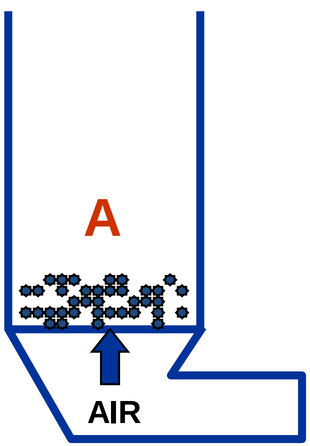


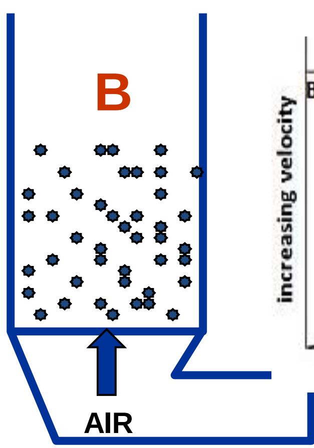
Buoyancy Force

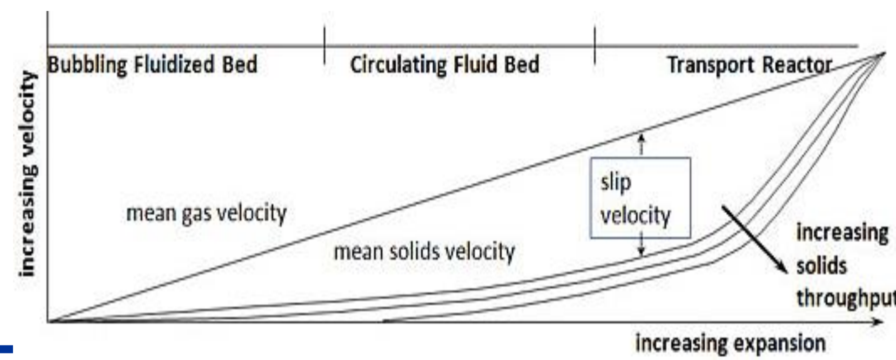
Gravity Force



Pressure drop α Bed Height





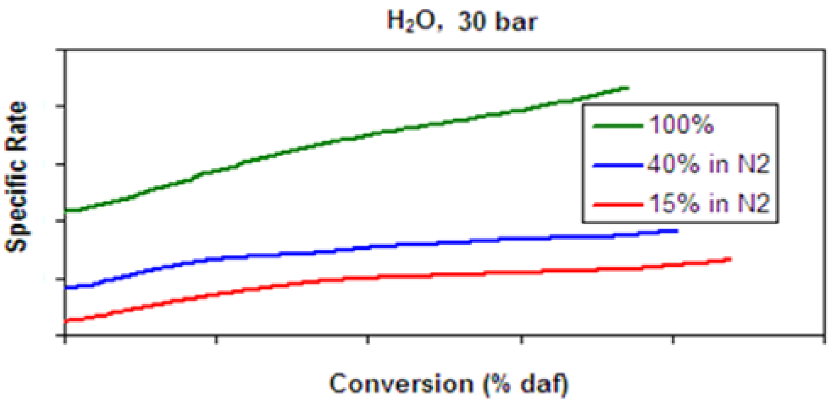


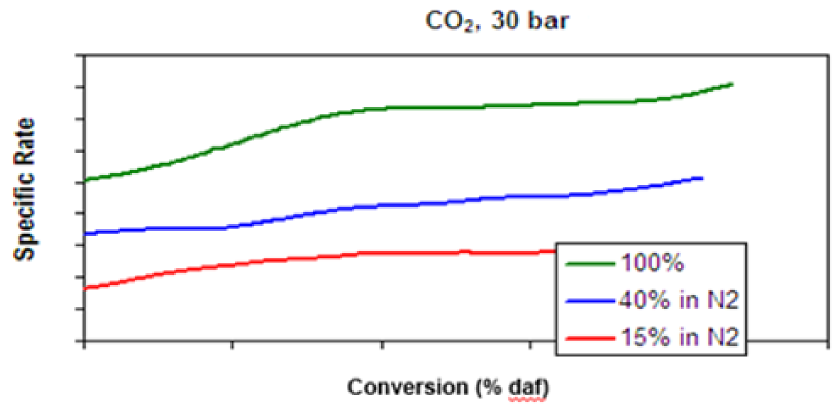
Fluidized Bed Gasification Technology

- Large variety of fuels can be handled and suitable specifically for high ash Indian coals as large fuel inventory provides safety, reliability, & stability of the process
- No requirement of pulverizing. Crushing is sufficient & Ability to accept fines
- Higher unit capacity per unit area, Better heat and mass transfer in the bed
- No tar/ phenol formation and hence easy gas cleaning
- Operates in non slagging mode with dry granular ash discharge
- Moderate gasifier temperatures :low Heat loss through bottom ash
- Technology does not involve moving parts
- Better turn down ratio
- Product composition is steady due to uniform conditions in the bed

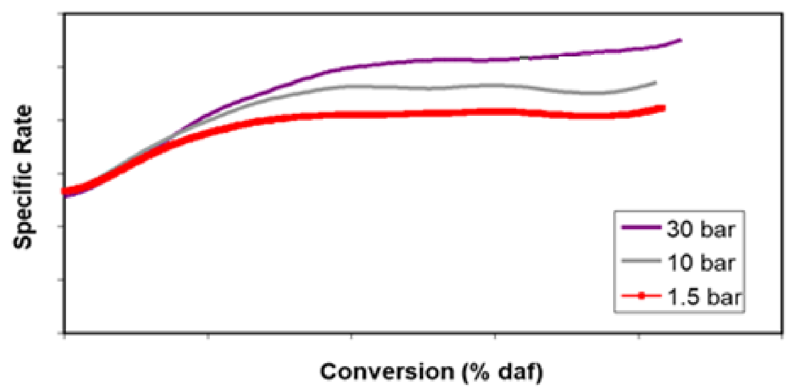
Fluidized Bed Gasification – Impact of Key Variables

Effect Of Reactant Partial Pressure On Reaction Rate



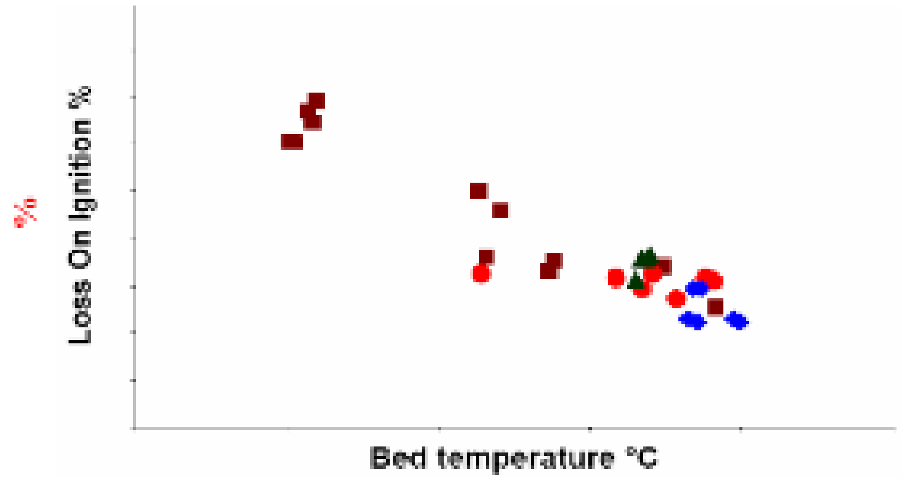


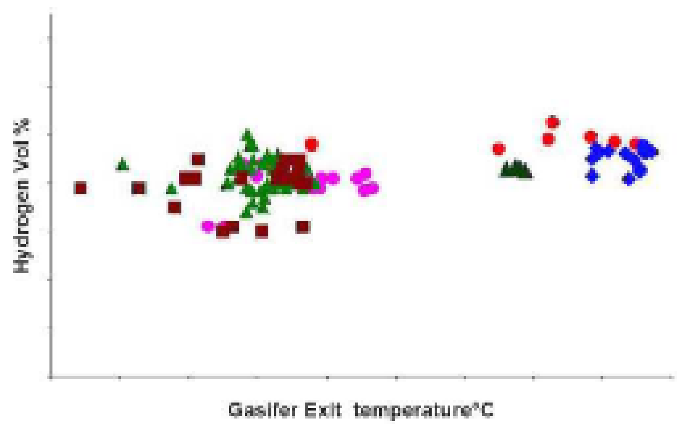
Effect Of Operating Pressure On Reaction Rate

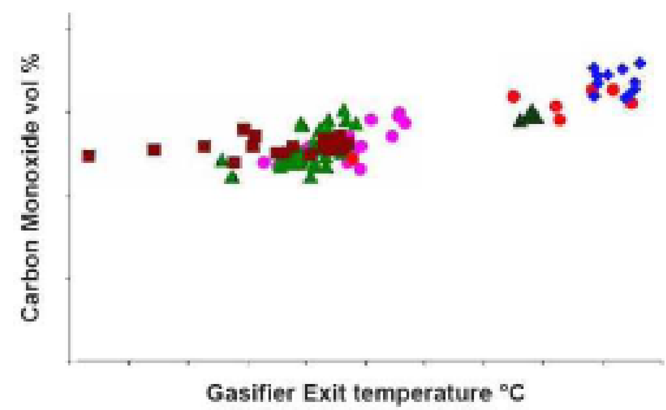


Fluidized Bed Gasification – Impact of Key Variables

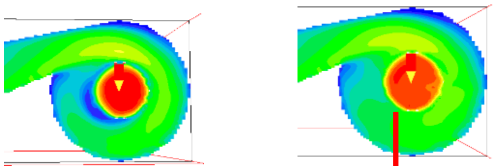
Process Temperature Optmization – to improve carbon conversion and CV

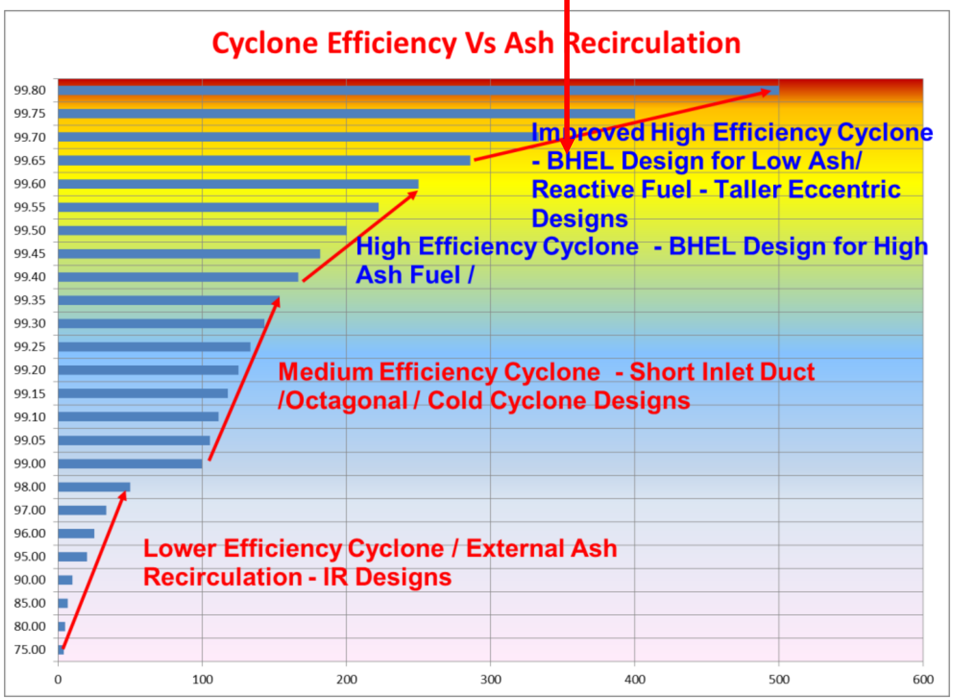






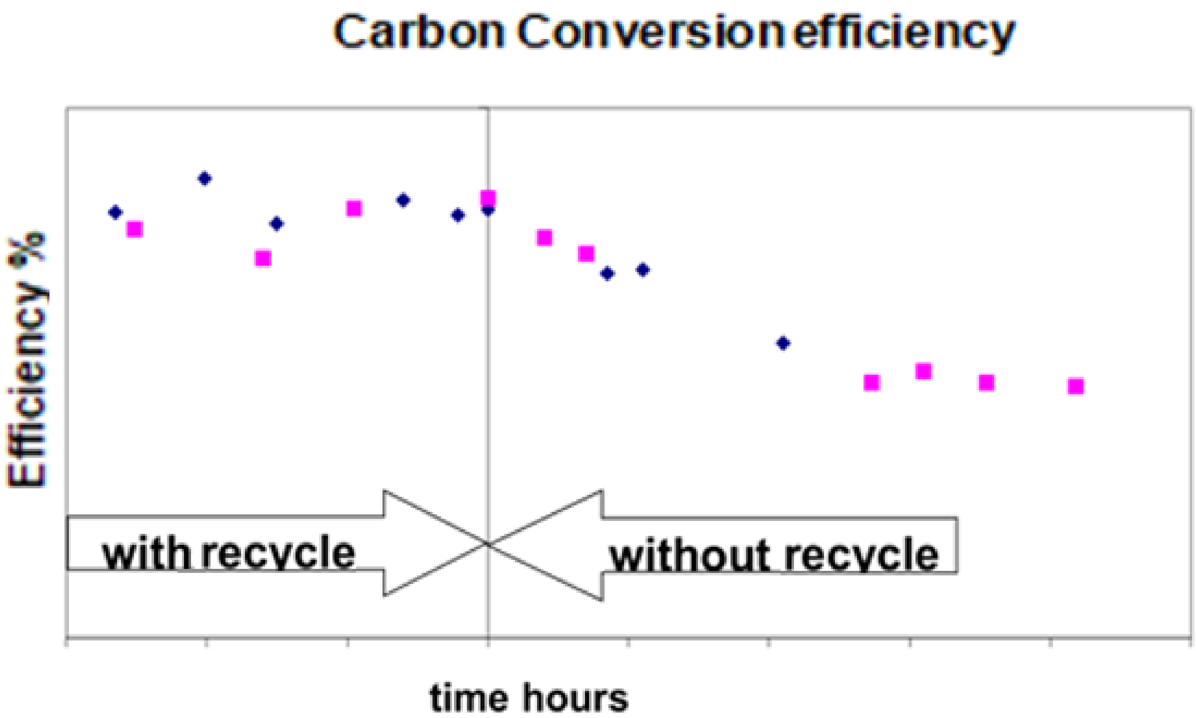
BHEL's Superior particle separation equipment





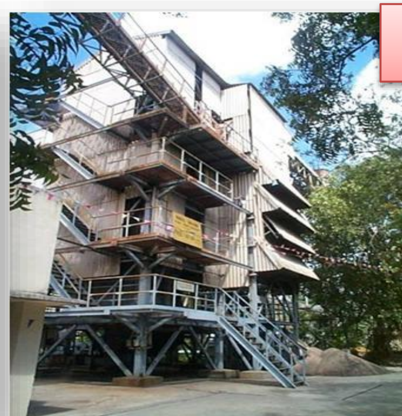
- BHEL has incorporated high efficiency cyclone separators for syngas particle separation, .
- BHEL's cyclone separators are high efficiency design with higher fractional collection efficiencies compared to standard cyclone designs.
- The key advantage is that it offers a higher recirculation of the hot fly ash which to improving the carbon conversion efficiency.
- It also minimizes the dust loading on hot gas candle filtration system

Impact of Ash Recycle



Fly ash recycle with non mechanical valves (loop seals) to improve carbon conversion – similar to CFB boilers

Fluidization experience of BHEL with various non-coal feedstock



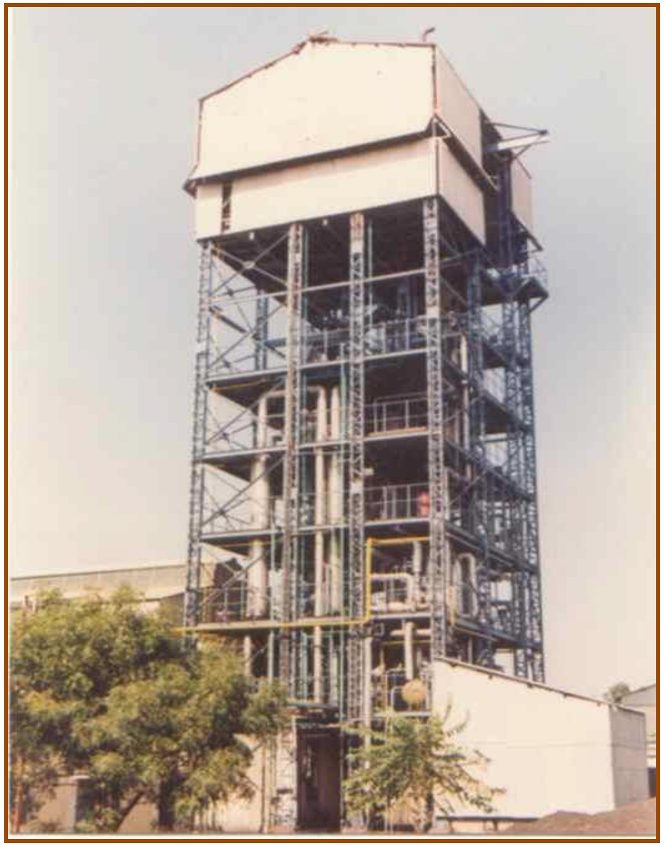
NON COAL FUELS TESTED AT FACILITIES

BHEL's Extensive Research

BHEL Coal Research Centre and advanced facilities to characterize coals for their combustion and gasification behavior

The analysis from these techniques used in modeling procedures to provide a better prediction of coal conversion behavior

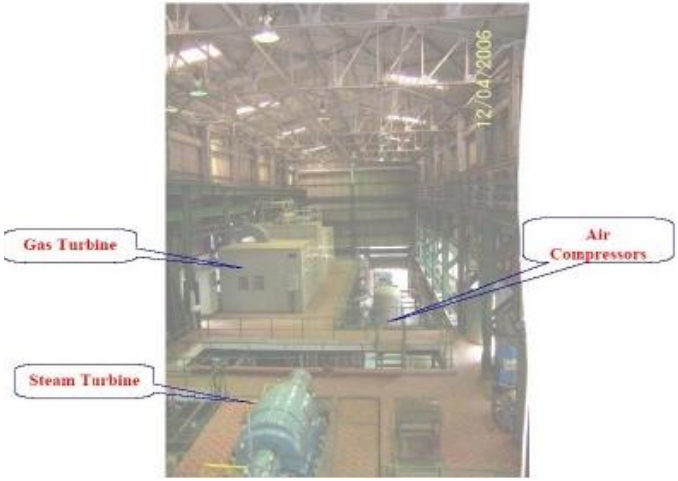
Process Evaluation & Demonstration Unit (18 TPD) at Corp R&D



Coal throughput	18 T / DAY
Gasifier diameter	450 mm
Gasification media	Air / Steam mix
Gasification pr.	11 kg / cm^2

Glimpse of the 6.2 MW PFBG based IGCC Demo Plant at Trichy

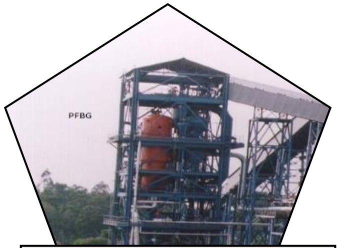
Coal throughput	168 T / DAY
Power Output	6.2 MW
Gasification media	Air / Steam mix
Gasification pr.	13.0 Kg/cm^2



BHEL's Gasification Journey- A timeline

MBG
Trichy

PEDU
Hyderabad



CCDP
Trichy

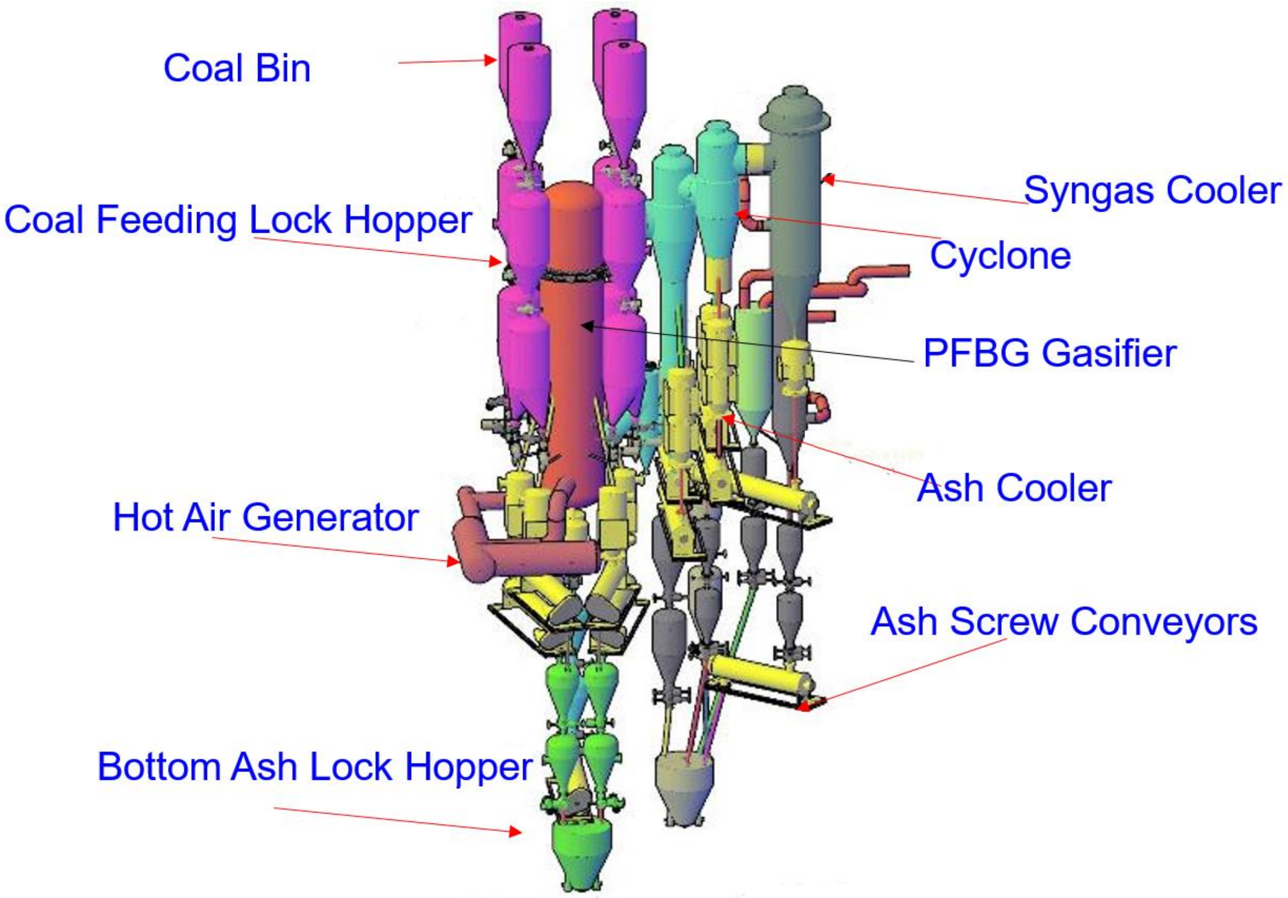
APFBG
Hyderabad

Coal to Methanol Plant
Hyderabad

1988-92	1992-96	1997	2000	2021
Moving Bed Gasifier (MBG)	Process Equipment Development Unit (PEDU)	Combined Cycle Demo Plant (CCDP)	Advanced Pressurised Fluidised Bed Gasifier (APFBG)	Coal to Methanol Plant
150 TPD	18 TPD	168 TPD	1.2 TPD	0.25 TPD
First Experience	Process development (Fluidized Bed)	Upscaling	Flexible Test Rig Multiple fuel firing	First Indigenous Methanol Plant

Demonstration of Coal to Methanol (0.25 TPD)

BHEL's Pressurized Fluidized Bed Gasifier (PFBG)



MoU with CIL & NLCIL for Coal Gasification business

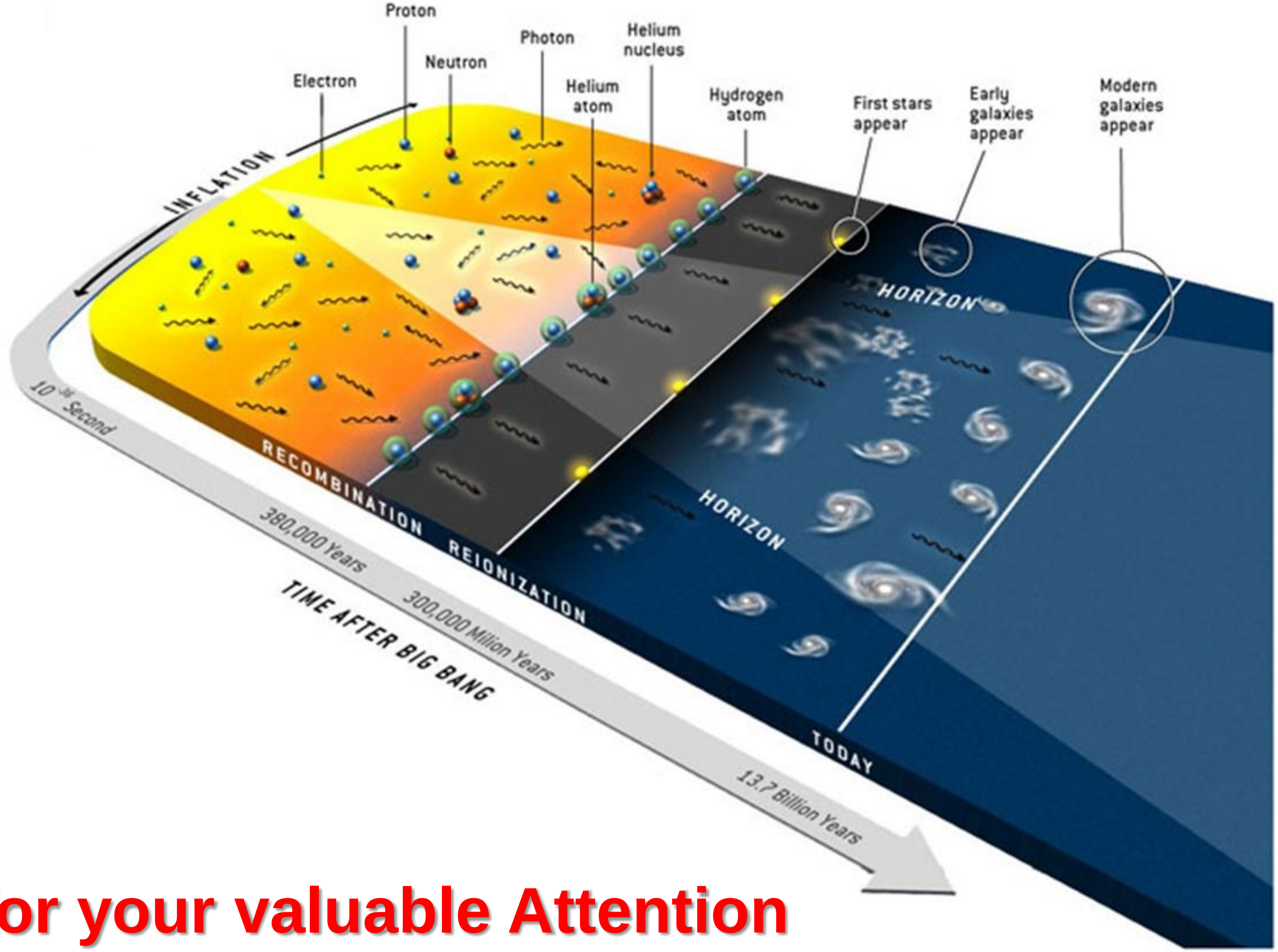
MOU SIGNED ON 12TH OCT 2022

Conclusions

- ❖ Understanding of "Coal"
- ❖ Development of Appropriate Technology
- ❖ Demonstration & Validation
- ❖ Capability to Provide Solutions

- ❖ 34 IPRs in gasification area and 16 IPRs in Methanol Synthesis
- ❖ Advanced Process simulation tools for designing Syngas to chemicals
- ❖ Techno economic Models to improve over all Coal to Chemical Processes
- ❖ 18 manufacturing facility across India & two engineering centres, R&D units
- ❖ Erection & commissioning centres in four regions of country for EPC activities
- ❖ End-to-end Gasification Island – gasifier, coal and ash handling, syngas cooler, Auxiliary Boiler
- ❖ In-house Manufacturing of Critical equipment – gasifier, syngas cooler, reactors, absorption and distillation columns, compressors, pumps etc
- ❖ Reference plants/equipment in refineries, fertilizer plants and other process industries.
- ❖ **BHEL is ready with modular gasifier concepts for 500 TPD, 750 TPD & 2000 TPD Methanol synthesis and 1000 TPD Ammonia.**

ALL major components of Coal to Chemical plants can be manufactured by BHEL



Thanks for your valuable Attention