HOW TO MONETIZE INDIAN COAL IN A CLEANER WAY?

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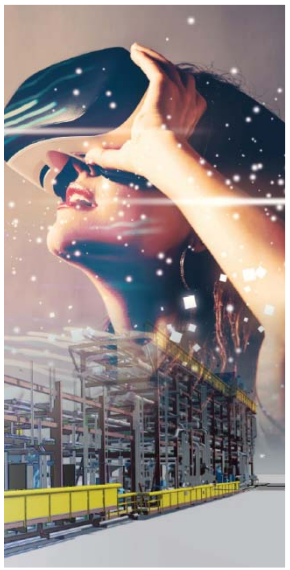

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AGENDA

- Coal Scenario in India
- Gasification
- Gasification Technology Options
- Gasification Product Options
- Relative Value Addition for Various Gasification Products
- Gasification Drivers in India
- Conclusions
- Select Fluor Gasification Experience

COAL SCENARIO IN INDIA

- Estimated coal reserves in India as on April 1, 2019:

Coal Type	Measured/Proved	Indicated	Inferred	Total
Prime Coking	4.67	0.66	0.00	5.32
Medium Coking	14.88	11.25	1.86	27.98
Semi Coking	0.52	0.99	0.19	1.71
Sub-Total of Coking	**20.06**	**12.90**	**2.06**	**35.00**
Non-Coking	134.96	127.49	27.42	289.87
Tertiary Coal	0.59	0.12	0.9	1.62
Grand Total	**155.61**	**140.51**	**30.38**	**326.50**

- India had second-largest production of coal with record production of 729 million tonnes in 2018-19
- Coal production trend in India is 4.64 CAGR

COAL SCENARIO IN INDIA
Contd…

- Majority of Indian Coal is low grade with:
  - High ash content, up to 60 wt%
  - Presence of chlorides and fluorides
  - High ash fusion temperature
- Most of the non-coking coal is used for power generation in direct fired boilers resulting in high CO_2 and other emissions
- Price of domestic coal is determined by the level of supply and demand and does not show direct relation with crude oil price trend/outlook

GASIFICATION

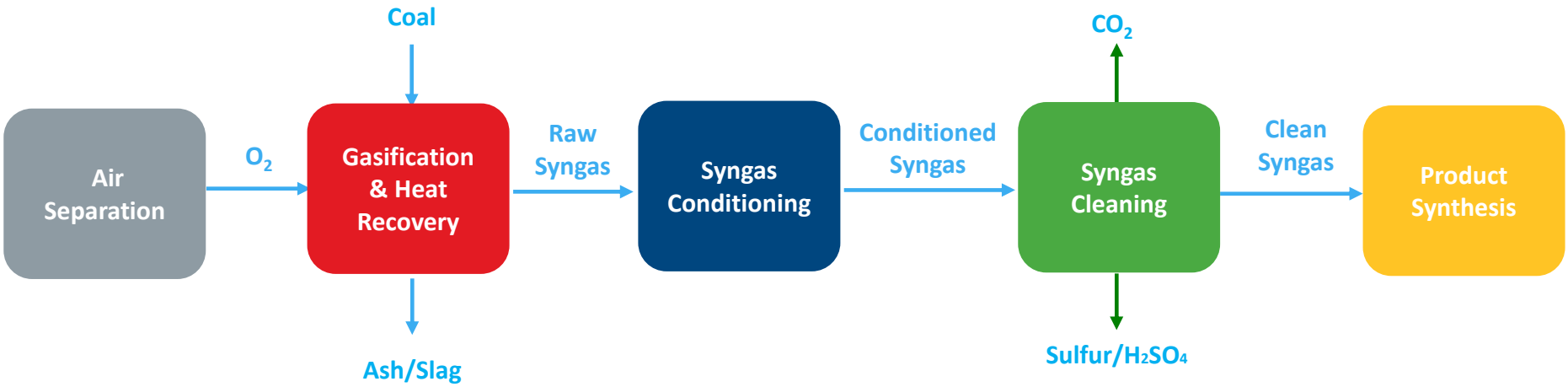
- Reaction of low value fuels such as coal, petroleum residues, biomass, industrial wastes, MSW, etc. with oxygen and steam at high temperature to produce H_2 + CO synthesis gas
- Primary Gasification Reactions:
  - Partial Oxidation $2\ C + O_2 \rightarrow 2\ CO$
  - Steam Gasification (Reforming) $C + H_2O \rightarrow CO + H_2$
  - Water Gas Shift $CO + H_2O \rightarrow CO_2 + H_2$
  - Methanation $3\ H_2 + CO \rightarrow CH_4 + H_2O$
- Operating Conditions: 900 – 2000°C/0.3 – 85 barg
- Heteroatoms:
  - N converted primarily to N_2, NH_3, HCN
  - S converted primarily to H_2S, COS, CS_2
  - Many trace components (e.g. formic acid, chlorides, sulphur & nitrogen compounds, cyanides, soot, metal carbonyls and others)

GASIFICATION
Contd…

- Water gas shift to adjust H_2/CO ratio as required for end product
  - $CO + H_2O \rightarrow H_2 + CO_2$
- Syngas clean up and acid gas removal to condition gas for downstream catalysts and to meet environmental regulations
- Sulphur recovery as elemental sulphur or sulphuric acid
- CO_2 is capture ready and can be used for Coal Bed Methane/Enhanced Oil Recovery or Sequestration
- Gasification is a complex and challenging process
  - Project execution requires integration of technologies from several parties
  - Attention to trace components, corrosion, catalyst life and process control
  - Special attention to CAPEX and OPEX from the early stages of project development
  - Requires a highly qualified team with gasification experience
  - Frequent routine maintenance and replacement of specific component which result in downtime
  - Handling of solids

GASIFICATION
Contd…

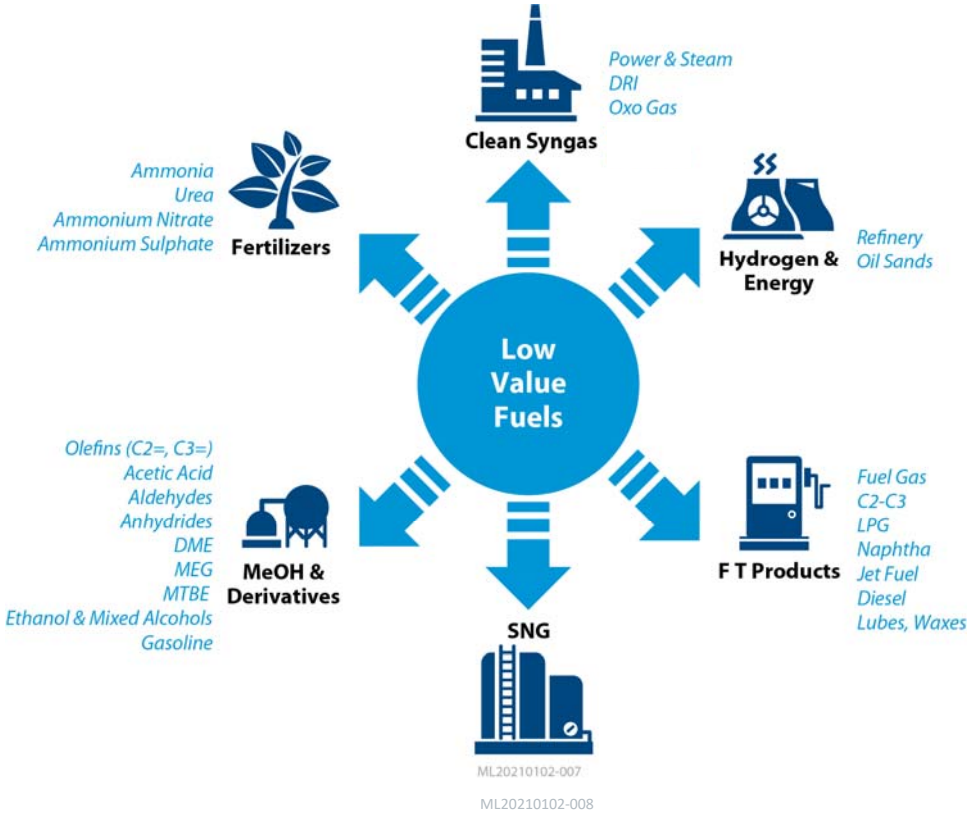
- Simplified Block Flow Diagram



GASIFICATION TECHNOLOGY OPTIONS

Flow Regime	Fixed or Moving Bed	Fluidized Bed	Entrained Flow
Feedstock Type	solids only	solids only	solids or liquids
Feedstock Size	5 – 50 mm	0.5 – 5 mm	< 500 microns
Residence Time	15 – 60 minutes	5 – 50 seconds	1 – 10 seconds
Oxidant	air or oxygen	air or oxygen	almost always oxygen
Gas Outlet Temperature	400 – 500 °C	700 – 1000 °C	1000 – 1500 °C
Ash Handling	slagging and non-slagging	non-slagging	always slagging
Commercial Technologies	Lurgi, Zemag, Sedin	SES, Uhde HTW, KBR-TRIG	Shell (AP), MHI, Uhde Prenflo, Siemens, R-Gas (GTI), HT-L (CECO), Choren, HCERI, GE (AP), MCSG, Tsinghua, ECUST, E-Gas (TCG)

GASIFICATION PRODUCT OPTIONS



RELATIVE VALUE ADDITION FOR VARIOUS GASIFICATION PRODUCTS

Product/Commodity	Price, $/MMBtu	Market Price[1]
High Ash Indian Coal	1.3 – 1.7	$ 18 - 25/MT
Methanol	21 - 22	$ 400 - 420/MT
Ethanol	31.4	$ 797/MT
Propanol	42.6	$ 1240/MT
Ethylene	29	$ 1320/MT
Propylene	26	$ 1125/MT
Acetic Acid	42	$ 515/MT
MTBE	25	$ 825/MT
Ammonia	23 - 25	$ 400 - 440/MT
Urea	35 - 38	$ 300 - 330/MT
Naphtha	12	$ 530/MT
Petrol (Gasoline)	13.8	INR 31.8/Ltr[2]
Diesel	14.3	INR 31.9/Ltr[2]
SNG	8 / 12	LNG Landed/Gate Price
Hydrogen	16	Based on $8 natural gas price

1. Indicative market prices in India
2. Refinery gate price

GASIFICATION DRIVERS IN INDIA

- Growing national and global energy demands
- Heavy dependence on petroleum and natural gas import
- Use of domestic resources will provide immunity to price fluctuations due to volatile prices and geopolitical instability in global energy market
- Abundant coal reserves in India
- Low feedstock cost → high value added products → mitigates higher CAPEX
- Higher value added → improved margin certainty

GASIFICATION DRIVERS IN INDIA Contd…

- Byproduct ‘S’ or H_2SO_4, CO_2, Slag, N_2, Ar can fetch additional revenue
- Ammonia recovery from sour/acid gases as ammonium phosphate, anhydrous ammonia or ammonium sulphate
- Syngas cost of production more economical than imported LNG
- Clean fuels/products from gasification offer reduced air emissions
- Low carbon emissions compared to direct fired boilers for power generation
- Feed to end product overall carbon conversion efficiency ~ 30–50% when converted to carbon containing chemicals/fertilizers
- Growing demand for chemicals/fertilizers in India

CONCLUSIONS

- Gasification is a complex and challenging process but –
  - Cost effective option to convert low grade coal into high value added products
  - Gasification offers alternate to use domestically available vast coal reserves to make value added products in an environment friendly manner
  - Syngas cost of production is more economical than imported LNG in India.
  - Byproducts 'S' or H_2SO_4, CO_2, Ash/Slag, N_2, Ar can fetch additional revenue
  - Gasification can play a vital role in India's long term demand growth for chemicals/petrochemicals/fertilizers eyeing self-reliance (Atmanirbhar Bharat) and maximum utilization of available resources in the country
  - Coal to chemicals/fertilizers can address growing concerns over CO_2 emissions to a large extent compared to coal uses in direct fired boilers for power generation
  - While challenging, several gasification projects have been successful. Must employ best technologies and employ gasification experienced design engineers

SELECT FLUOR GASIFICATION EXPERIENCE

Client	Location	Scope	Feed	Products	Technology	Completed
PTBA	Indonesia	Pre-FEED	Coal	Polypropylene, DME, Urea	Confidential	2019
GTI, USA	China	PDP	Coal	Ammonia	GTI R-Gas	2018
Lake Charles Methanol	Louisiana	FEED, EPFC	Petcoke	Methanol	GE	Ongoing
Reliance Industries	India	E, P and PM Support	Petcoke, Coal	Hydrogen, SNG, Power	CB&I E-Gas	2017
Celanese/IOCL	India	Pre-FEED	Petcoke, Coal	Ethanol, Power	Confidential	2015
Pertamina	Indonesia	Pre-FEED	MSW	Power	Solena	2014
Confidential	Indonesia	Pre-FEED	High Moisture Indonesian Coal	SNG, Urea, CO_2	Confidential	2012
Jindal SynFuels	India	Pre-FEED	High Ash Indian Coal	FT Liquids, Ammonia	Confidential	2012
Reliance ADAG	India	Pre-FEED	High Moisture Indonesian Coal	SNG, Power	Confidential	2012
MAK	Mongolia	Pre-FEED	High Moisture Brown Coal	MTG, Power	Confidential	2012
Fulcrum Sierra BioFuels	Nevada	FEED Refresh, EPC	MSW	Ethanol, Power	InEnTech (IET)	2012
OPTI Canada Phase II	Alberta	FEED	Residue	Hydrogen, Power, CO_2	Shell	2012
Rentech	California	FEED	Woody Waste	FT Liquids, Power	Rentech SilvaGas	2011

SELECT FLUOR GASIFICATION EXPERIENCE contd…

Client	Location	Scope	Feed	Products	Technology	Completed
Summit	Texas	FEED	Coal	Urea, Power, CO_2	Siemens	2011
Swan Hills	Alberta	Pre-FEED, FEED	Deep Unmineable Coal	Power, CO_2	Swan Hills In-situ Coal Gasification	2011
MSEZL	India	Pre-FEED	Petcoke	Acetic Acid, Hydrogen, Power	Confidential	2010
Eastman	Texas	FEED	Petcoke	Hydrogen, Methanol, Ammonia, CO_2	GE	2009
Confidential	Montana	Pre-FEED	Coal	Urea, Power, CO_2	Siemens	2009
Valero	Texas	Pre-FEED	Petcoke	Hydrogen, Power, CO_2	ECUST	2009
OPTI Canada	Alberta	FEED, EP	Residue	Hydrogen, Power	Shell	2008
Valero	Delaware	EP	Petcoke	Power, Steam	GE	2008
Steelhead	Illinois	FEED	Coal	SNG	CB&I E-Gas	2006
Total	France	FEED	Residue	Hydrogen, Power	GE	2004
ISAB	Italy	Owner's Eng.	Residue	Hydrogen, Power	GE	1999
Great Plains	North Dakota	Owner's Eng.	Coal	SNG	Lurgi	1988
Shell	Netherlands	FEED, EPCM	Residue	Hydrogen, Power	Shell	1997
Texaco	Kansas	EPCM	Petcoke	Power, Steam	GE	1996
Motiva	Louisiana	EP	Residue	Hydrogen	GE	1985
Eastman	Tennessee	C	Coal	Chemicals	GE	1986
Sasol	South Africa	EPCM	Coal	FT Liquids, Chemicals	Lurgi	1980

Note: Constructed plants in red

STAY CONNECTED..

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