Enabling a Gasification and Carbon Capture Economy in India : An Integrated Techno-Economic Analysis

IEA 9th International Conference on Clean Coal Technologies

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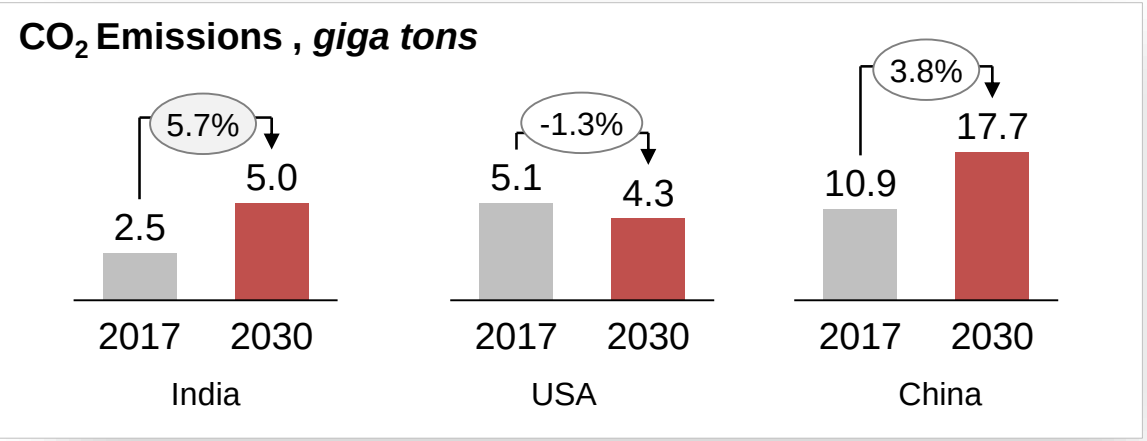
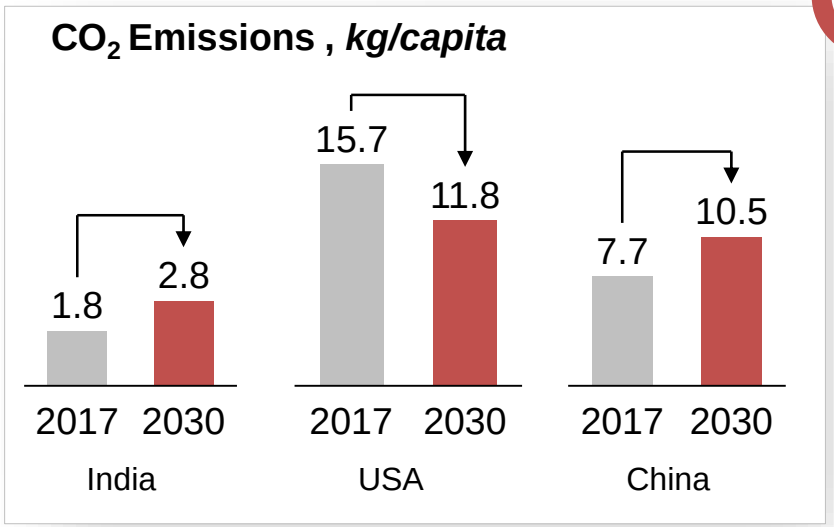
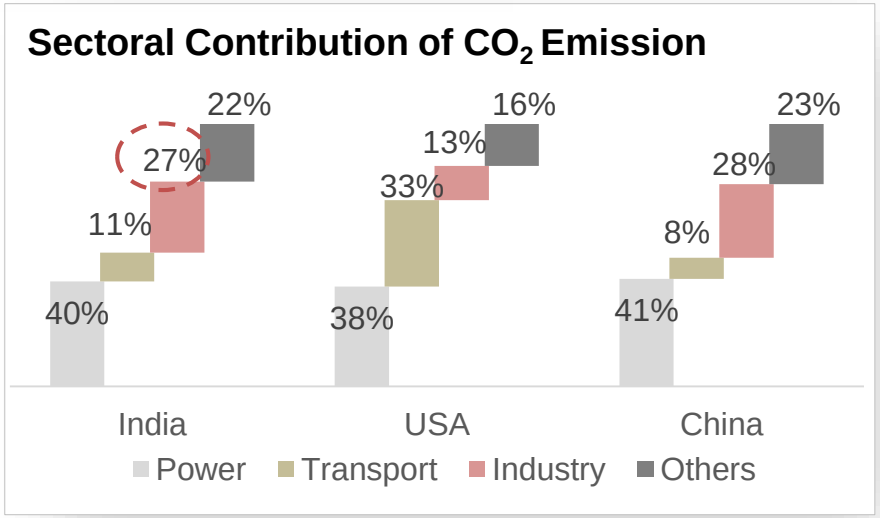
DASTUR

The GHG emissions in India is on a rising trajectory







Source: IEA, PBL Netherlands Environmental Assessment Agency, World bank, Dastur Research

Goals of Clean Coal Based Industrial Economy

1. Seed a clean coal based economy by exploiting Indian **coal** endowments through **gasification**, and **carbon capture**

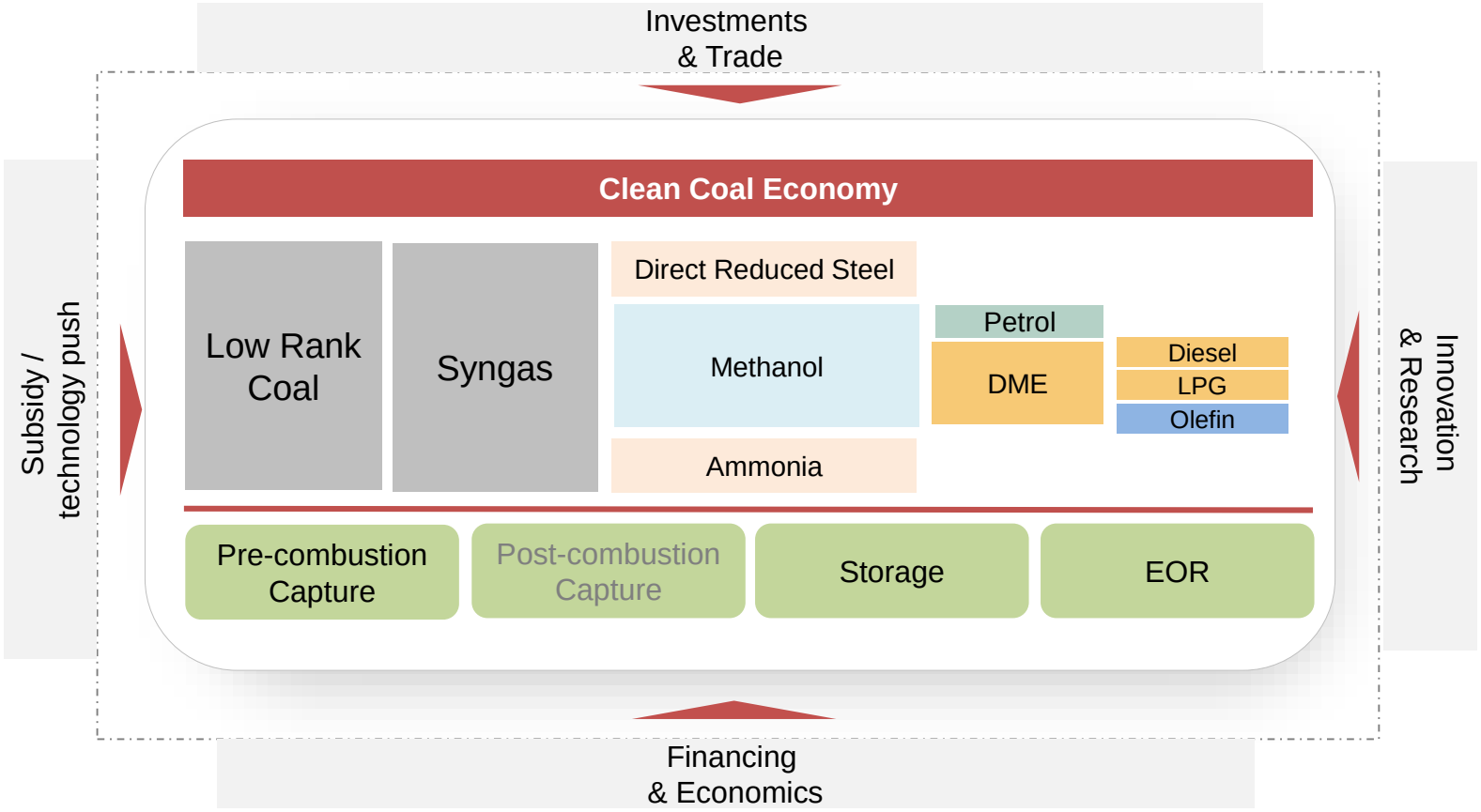
2. Build a competitive and sustainable **methanol, steel and ammonia based** gasification value chain

3. Develop the most efficient and viable **carbon capture and storage** infrastructure for a sustainable coal gasification economy

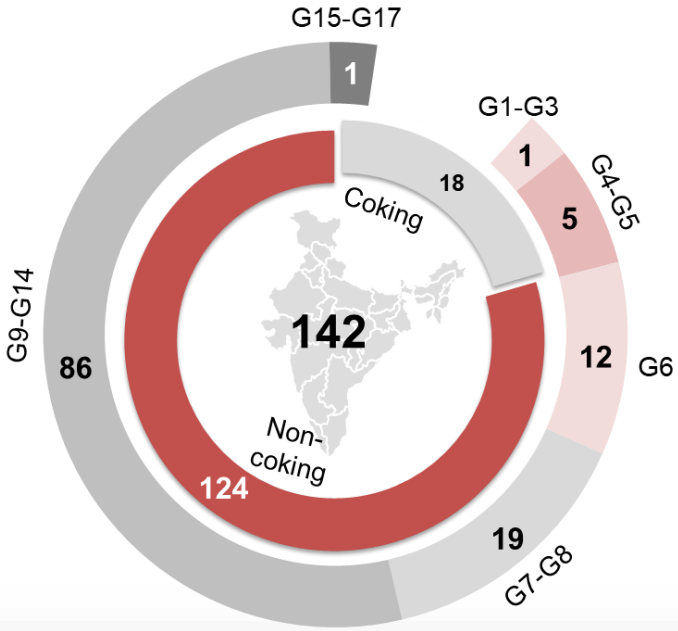
4. Reduce CO_2 emissions by 100 mtpa over an equivalent legacy industrial infrastructure while reducing SOx, NOx emissions

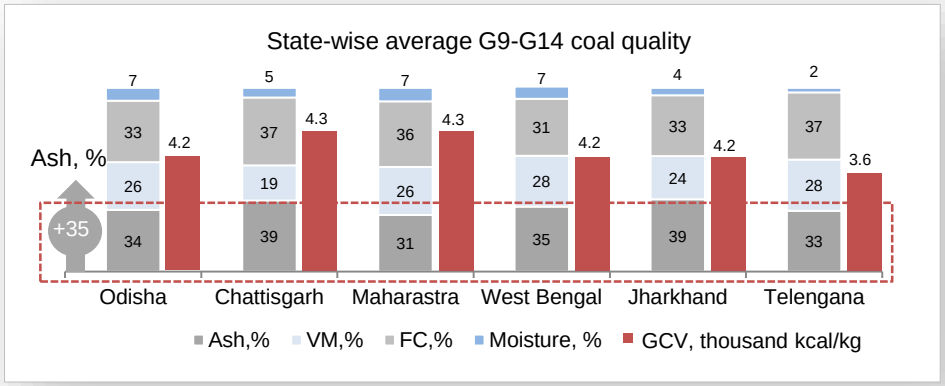
5. Be an efficient, globally competitive and sustainable producer of **clean coal based industrial products and power**

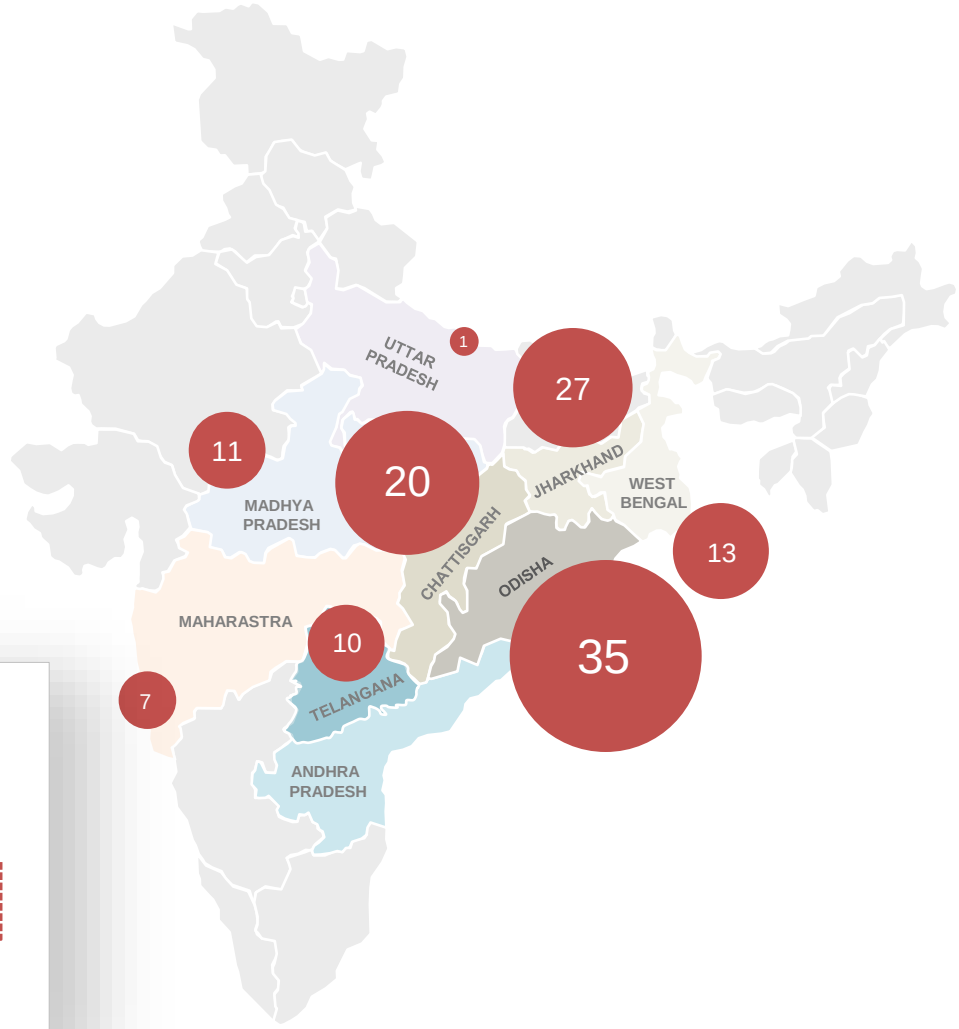
Structure of a policy enabled clean coal economy



India has ~150 billion tons of proven high-ash low rank coal resources







Bubble Size: Coal reserve size
All figures in billion tonnes
Resource = Measured only

Source: GSI , Dastur Research

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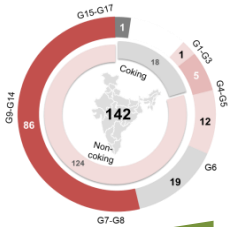
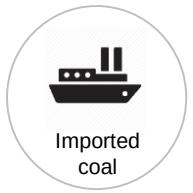
A gasification & carbon capture based industrial economic framework for India

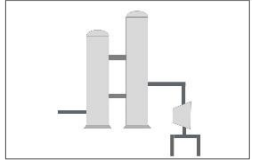


265 mt → 360 mt



40 mt → 0 mt

Carbon Capture	~ 85 mtpa
	1.4 BB$

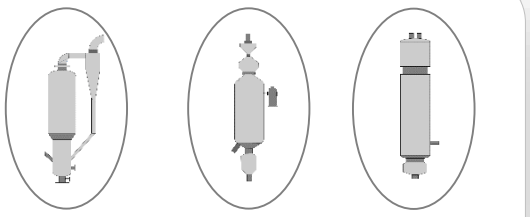


Utilization & Storage

EOR	Storage
17 mtpa	68 mtpa
0.7 → 4.5	2.5 BB$

70%

Pre-combustion capture

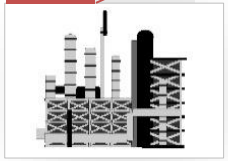


50⁺ BB$

* Capacity

Capex → Rev/yr. in BB$, 2030

Methanol	40 mtpa
	20 → 17



Gasoline (M 15)

Diesel & LPG (DME 20)

MTO

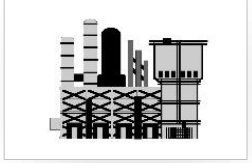
Steel	50 mtpa
	30 → 28

Rebars, Wire rods, SBQ

AHSS, IF

HRC, CRC

Ammonia /Urea	16 mtpa
	16 → 5



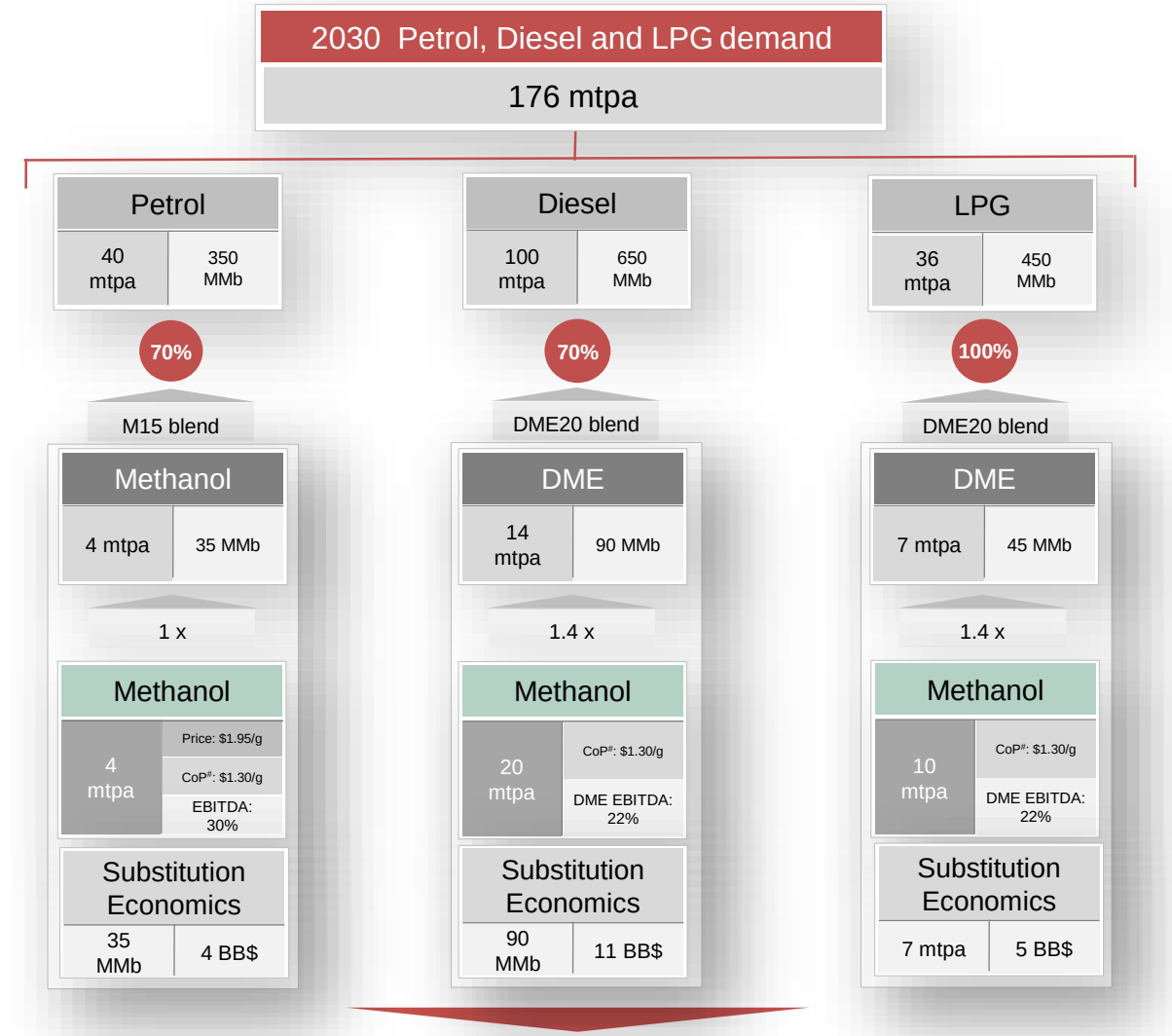
Urea

Source: NETL, IPCC, USDOE, Global CCS Institute, Dastur Research, Dastur Computable General Equilibrium model

Methanol based substitution through gasification creates large demand

Source: DASTUR Research

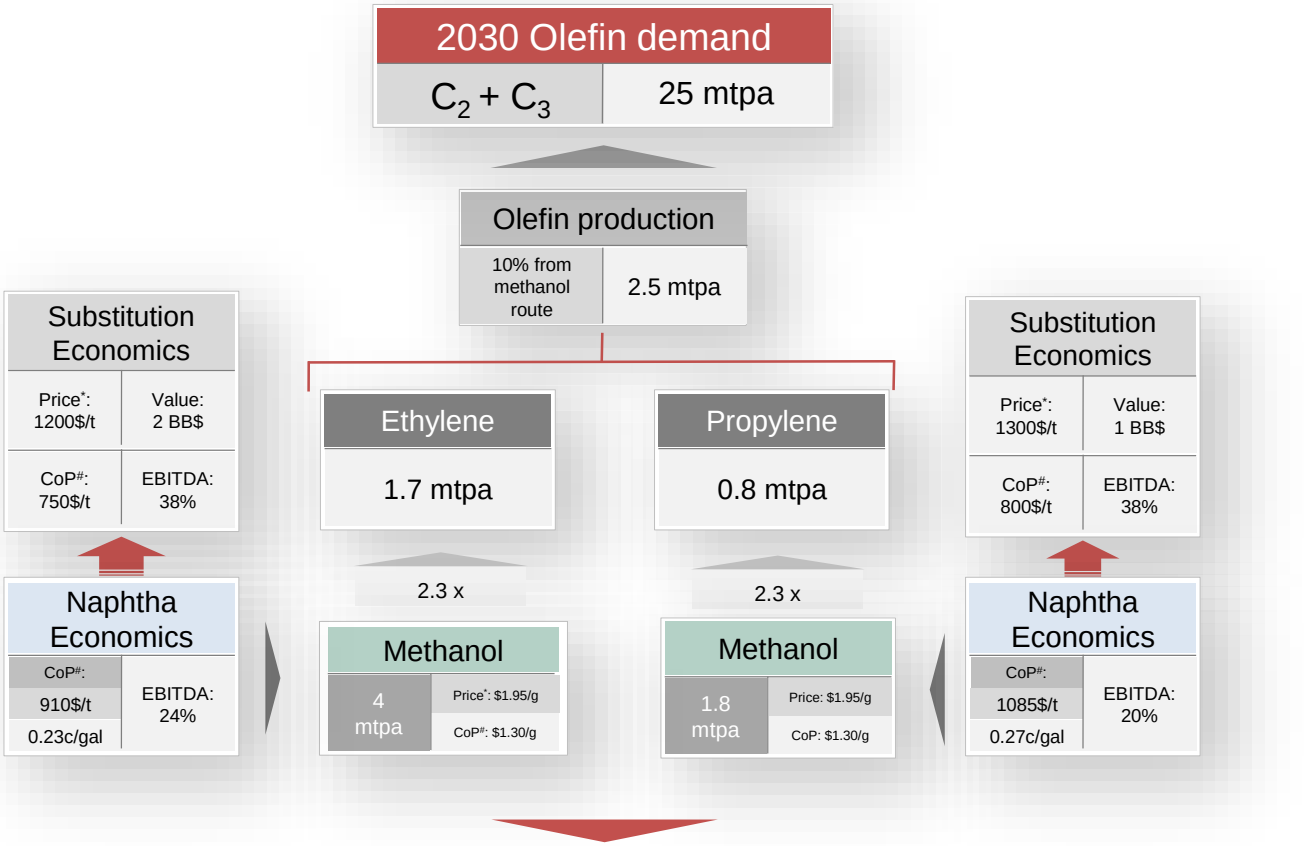
Methanol has significant substitution effect on oil through blending



› Fuel substitution of 20 BB $
› DME blending economics is viable only through an integrated plant

#Cost of Production
g:gallons

Methanol can substitute imported naphtha to produce olefins at lower cost

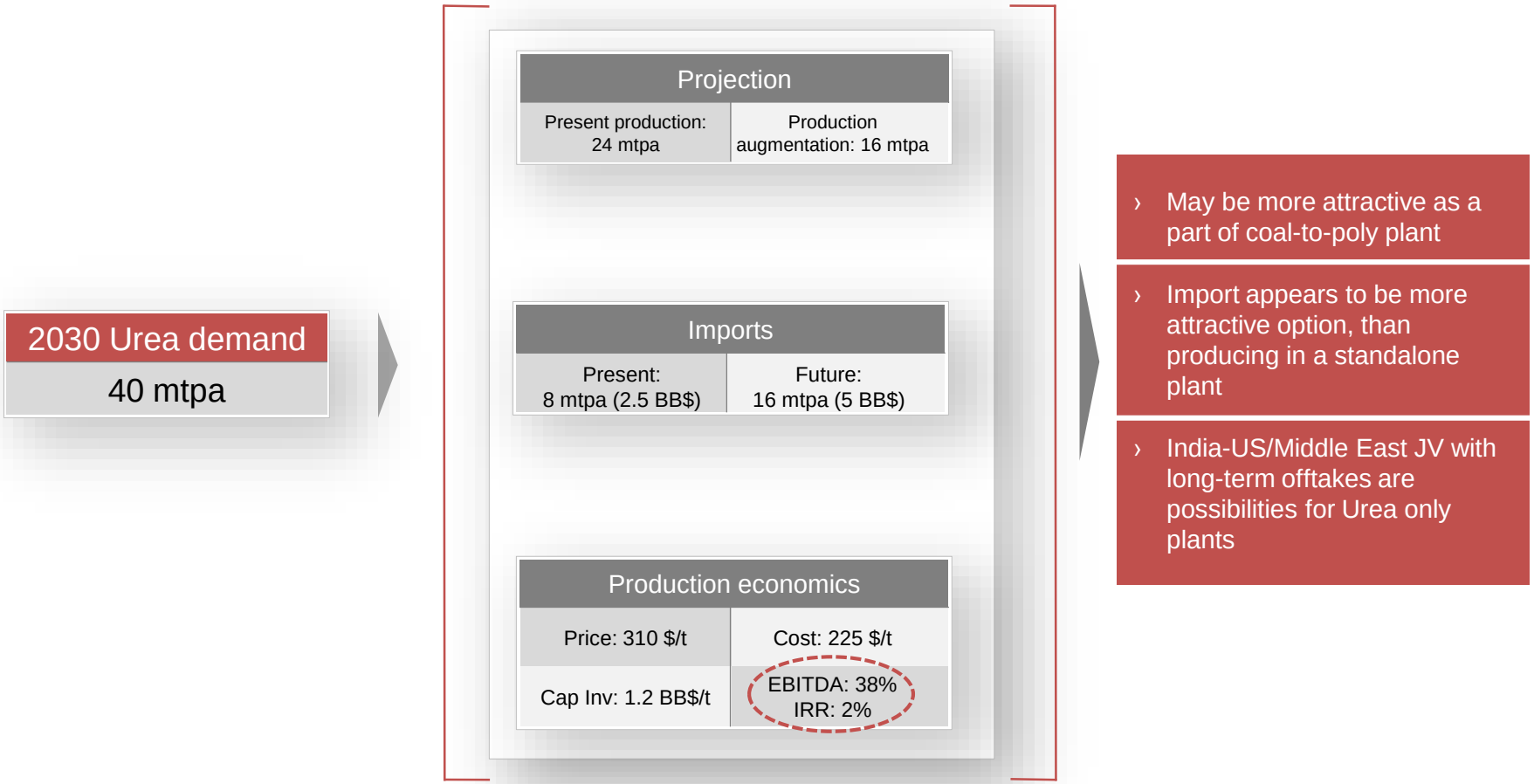


5 mtpa Naphtha substitution amounting to 3 BB$

Olefin production through Methanol route is economically viable only in an integrated plant

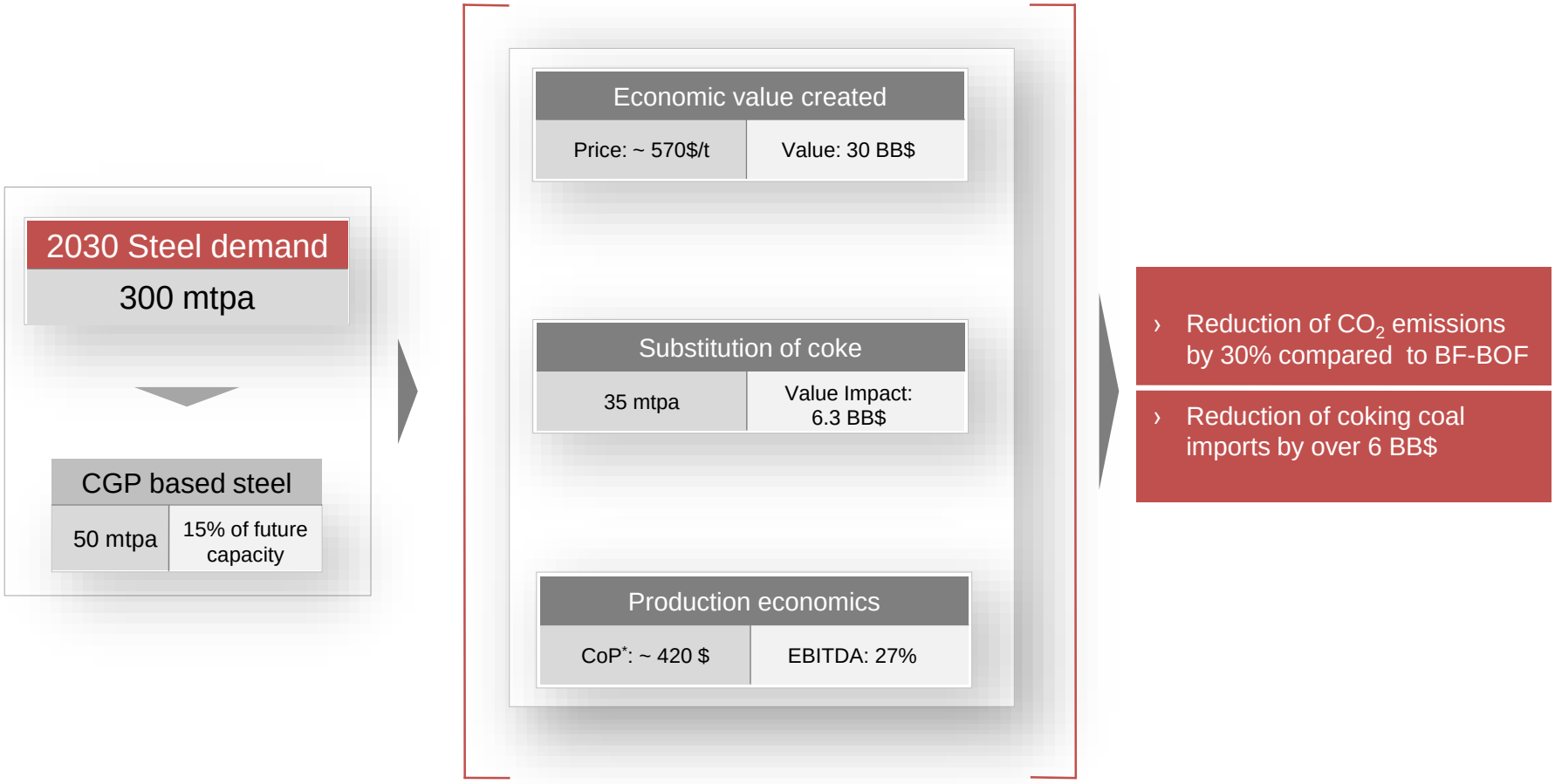
#Cost of Production
g: gallons

While gasification can produce ammonia-urea , it is not as capital efficient



Source: DASTUR Research

Coal gasification based steel creates highest value while reducing carbon and substituting coking coal



#Cost of Production

Techno-economics favor Fluidized Bed gasification for Indian coal

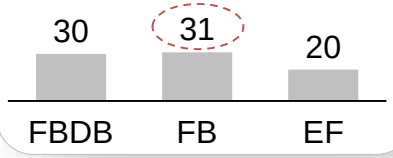
Gasifier	Fixed Bed Dry Bottom (FBDB)	Fluidized Bed (FB)	Entrained Flow (EF)
Types	Dry bottom (Lurgi, Sedin)	Dry ash (Winkler, HTW, KBR) Agglomerating (U-GAS, SES)	Slagging (KT, Shell, GE-Texaco)
FEED CHARACTERISTICS			
Preferred feedstock	Lignite, reactive bituminous coal	Lignite, bituminous coal, biomass	Lignite, reactive bituminous coal, pet coke
Acceptability of ash content	< 35%	< 40%	< 20%
OPERATING CONDITIONS			
Operating temperature	Low (500-650°C)	Moderate (900-1050 °C)	High (1250-1600 °C)
Oxygen demand	Low	Moderate	High
Steam demand	High	Moderate	High
H_2/CO in raw gas	1.5-1.7	0.9-1.0	0.5-0.6
CH_4 reforming	More	Less	Not required
Water gas shift for methanol	Not required	Low	High
Ash/Slag	Consistent ash quality	Consistent ash quality	High flux requirement
Cold gas efficiency	72%	72%	81%
By-product recovery	Yes	No by-product	No by-product
Fines utilization	Limited to 5%	No limitation	No limitation
Carbon conversion	Moderate	Moderate	High
EXPENDITURE			
CAPEX	High	Low	Medium
OPEX	Low	Low	High

FB and FBDB gasifiers are preferred choice for low rank high ash Indian coal

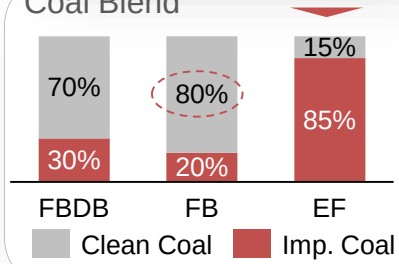
Tentative techno-economics of gasification based on Indian coals

Operating Parameters*

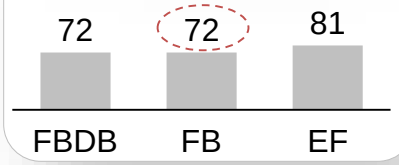
Ash in Coal Blend, %



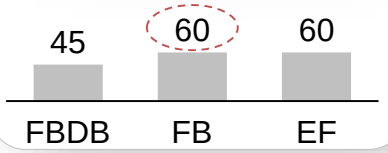
Coal Blend



Cold Gas Efficiency, %

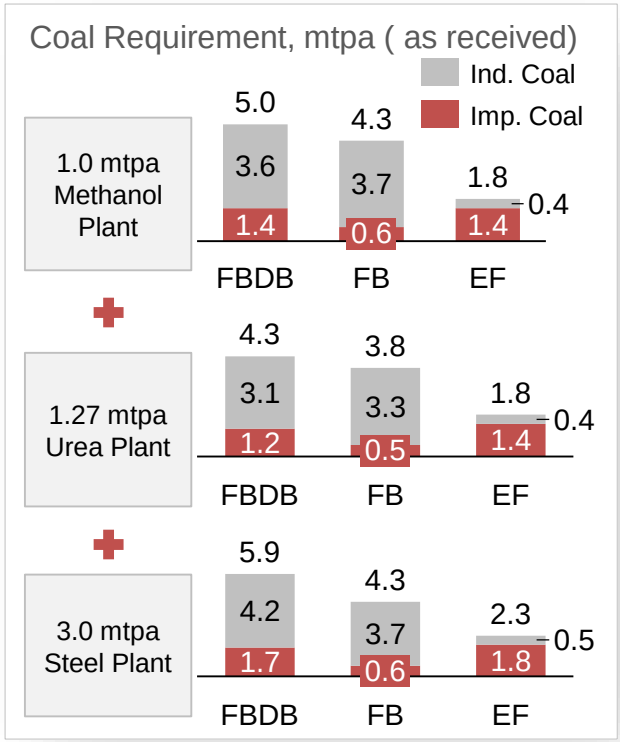


Ind. Coal Washery Yield, %



Coal Consumption Volumes*

Coal Requirement, mtpa (as received)



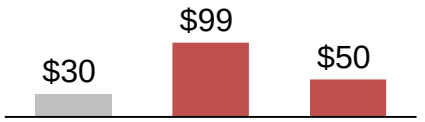
40 mtpa Methanol
16 mtpa Urea
50 mtpa Steel

265 mtpa Indian Coal

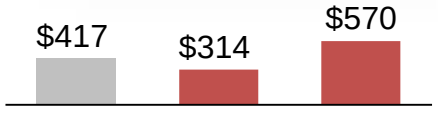
40 mtpa Imported Coal

Cost & Financial Parameters*

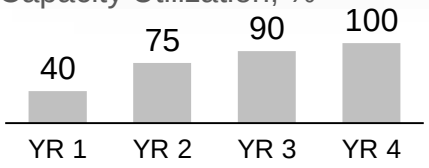
Input Cost, USD/T



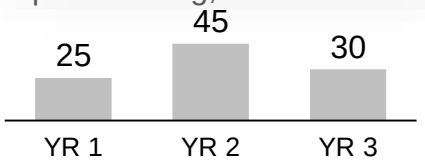
Sales Realization, US$/T



Capacity Utilization, %



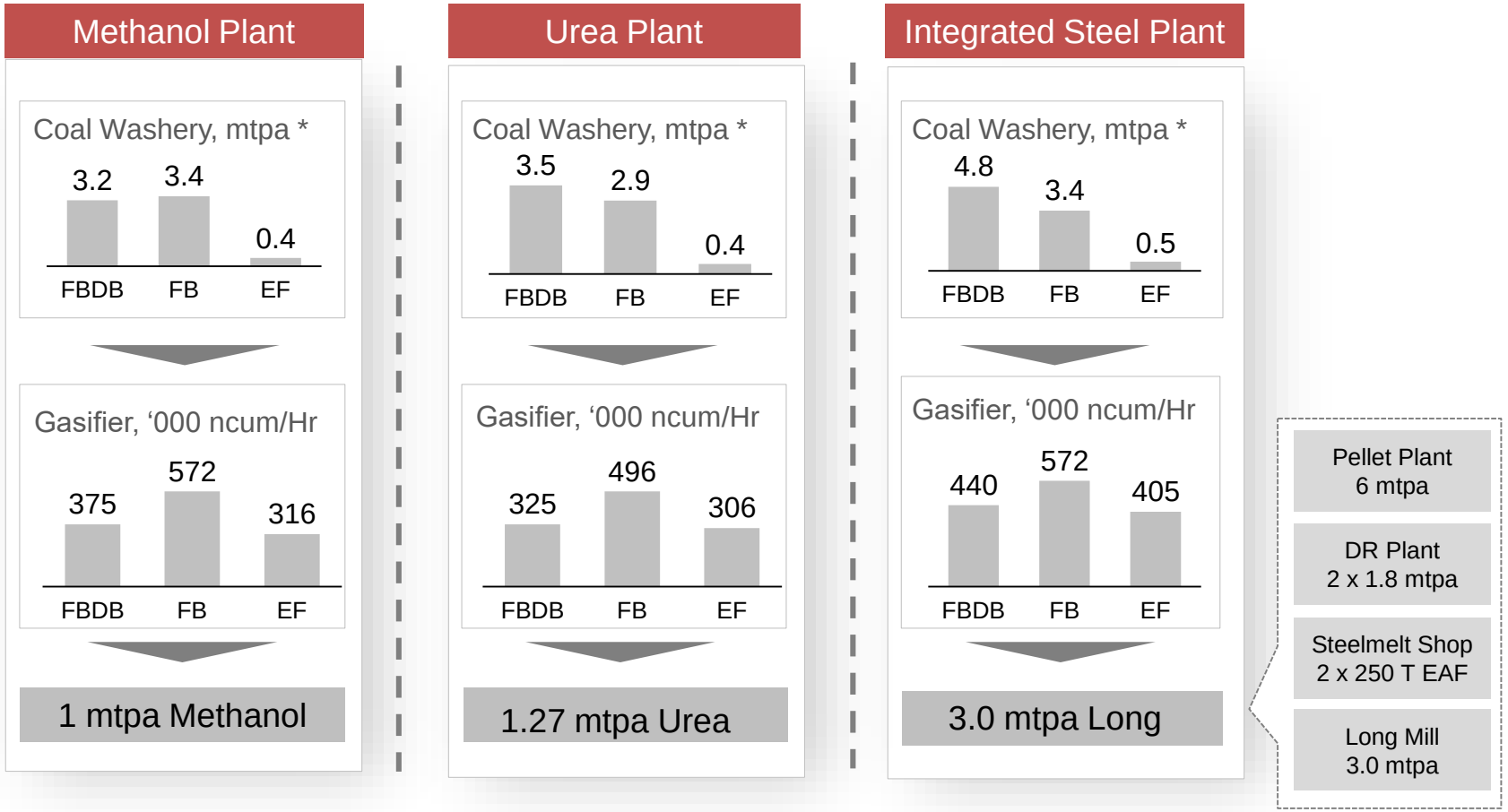
Capex Phasing, %



* Dastur Research - Database & Econometric Models

Matching capacity of ASP, Power Plant considered

Representative configurations methanol, steel and urea plant based on gasification of high ash Indian coals

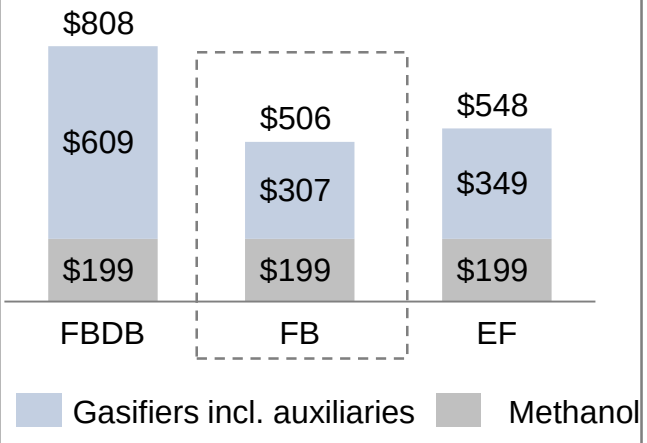


* Net & Dry Basis

Economics of 1.0 mtpa Methanol plant units

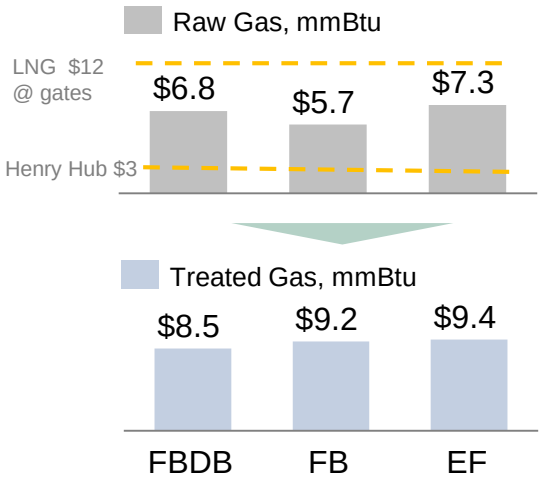
Investment

In MM$

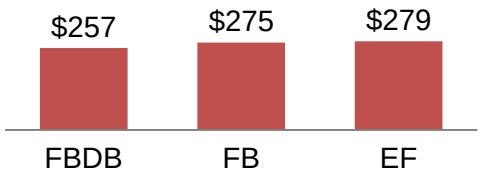


Profitability

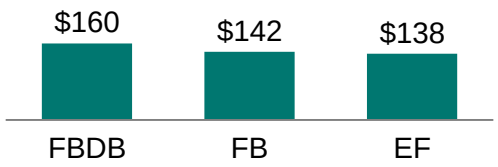
Cost of Production, US$ per Unit



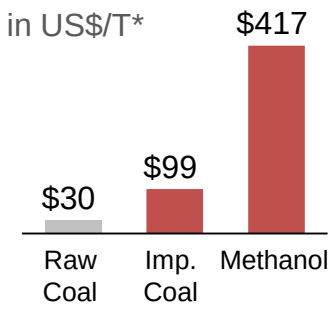
Annual manufacturing Cost, MM$



EBITDA, MM$

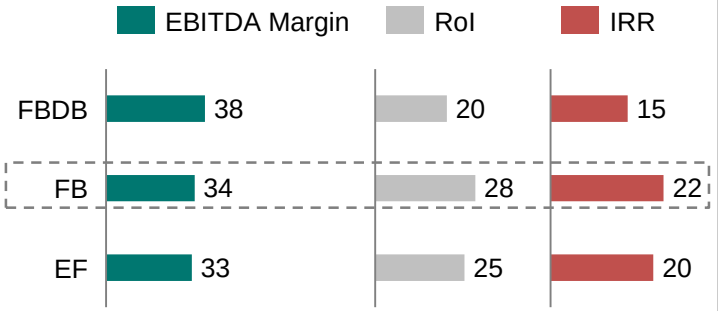


Cost & Price



* Dastur Econometric Models

Financial Return, %

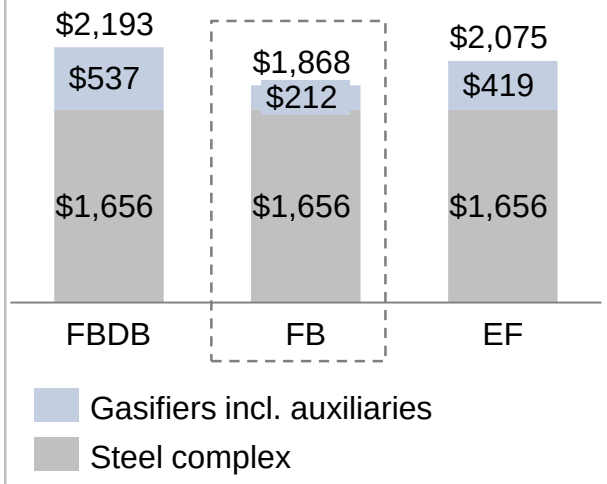


Fluidized Bed Gasifier appears to be an optimal techno-economical solution for methanol production -

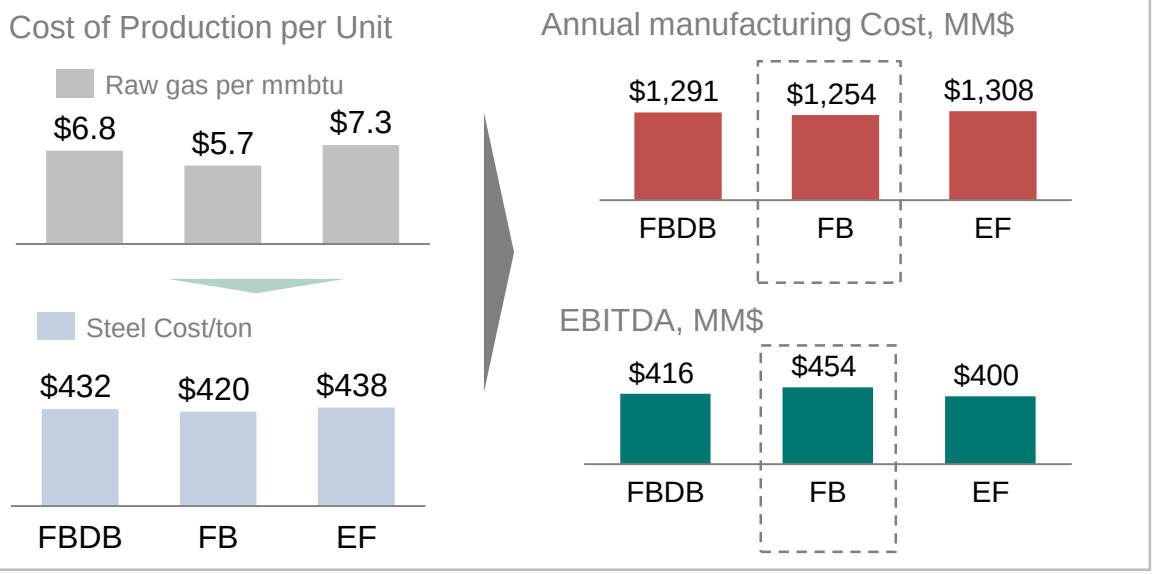
- Abundant coal at reasonable cost
- High ash acceptability
- Acceptability of fines
- Lower Capex

Economics of 3.0 mtpa Direct Reduced steel plant units

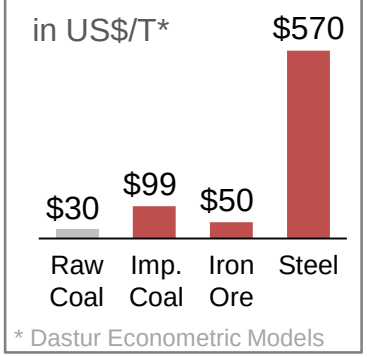
Investment



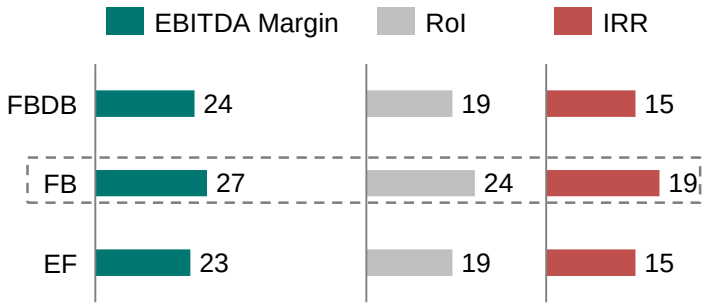
Profitability



Cost & Price



Financial Return, %

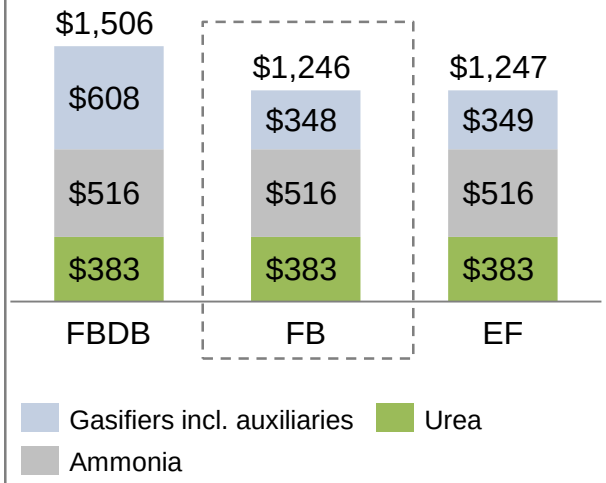


Can compete with BF-BOF route with following benefits

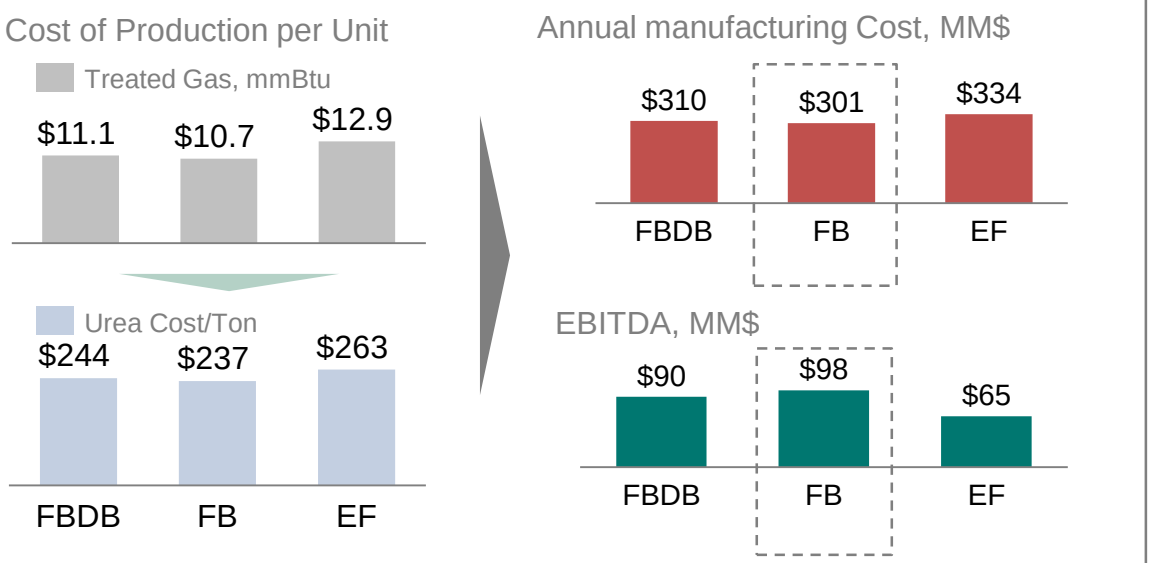
- Zero dependency on coking coal
- Usage on high ash Indian coal
- Lesser carbon emission after capture

Economics of 1.27 mtpa Ammonia - Urea plant units

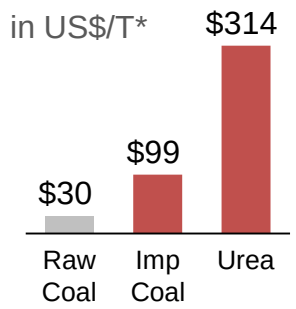
Investment



Profitability

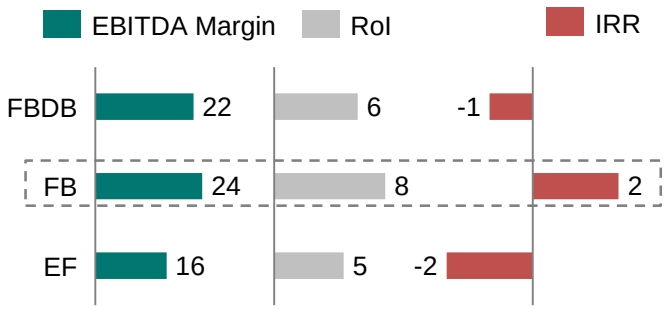


Cost & Price



* Dastur Econometric Models

Financial Return, %

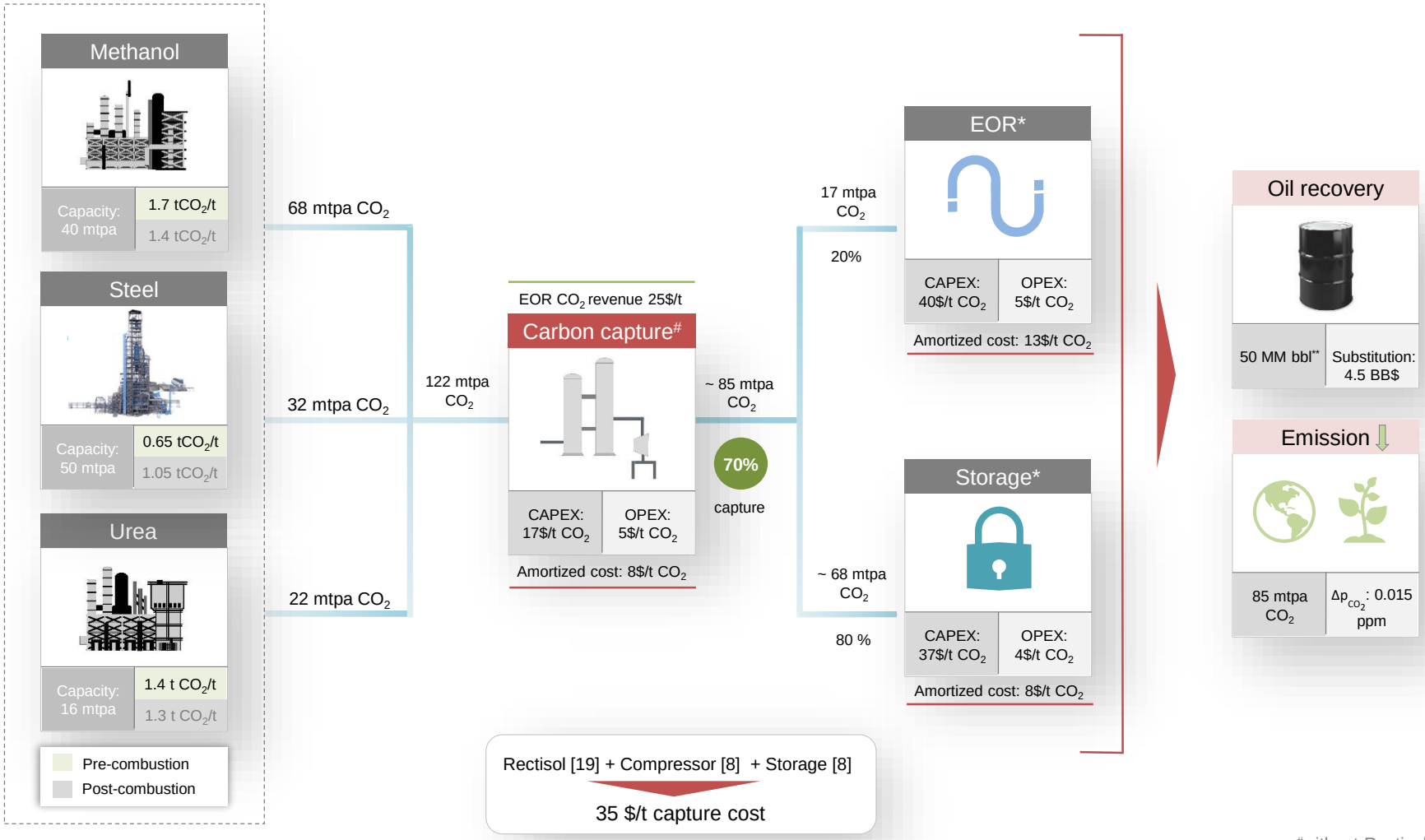


Ammonia/Urea may be more attractive as a part of coal-to-poly plant

Other alternatives are :

- Opt I: Import Urea on long term contract
- Opt II: 51% JV with partners to put Urea plant in USA/Middle East

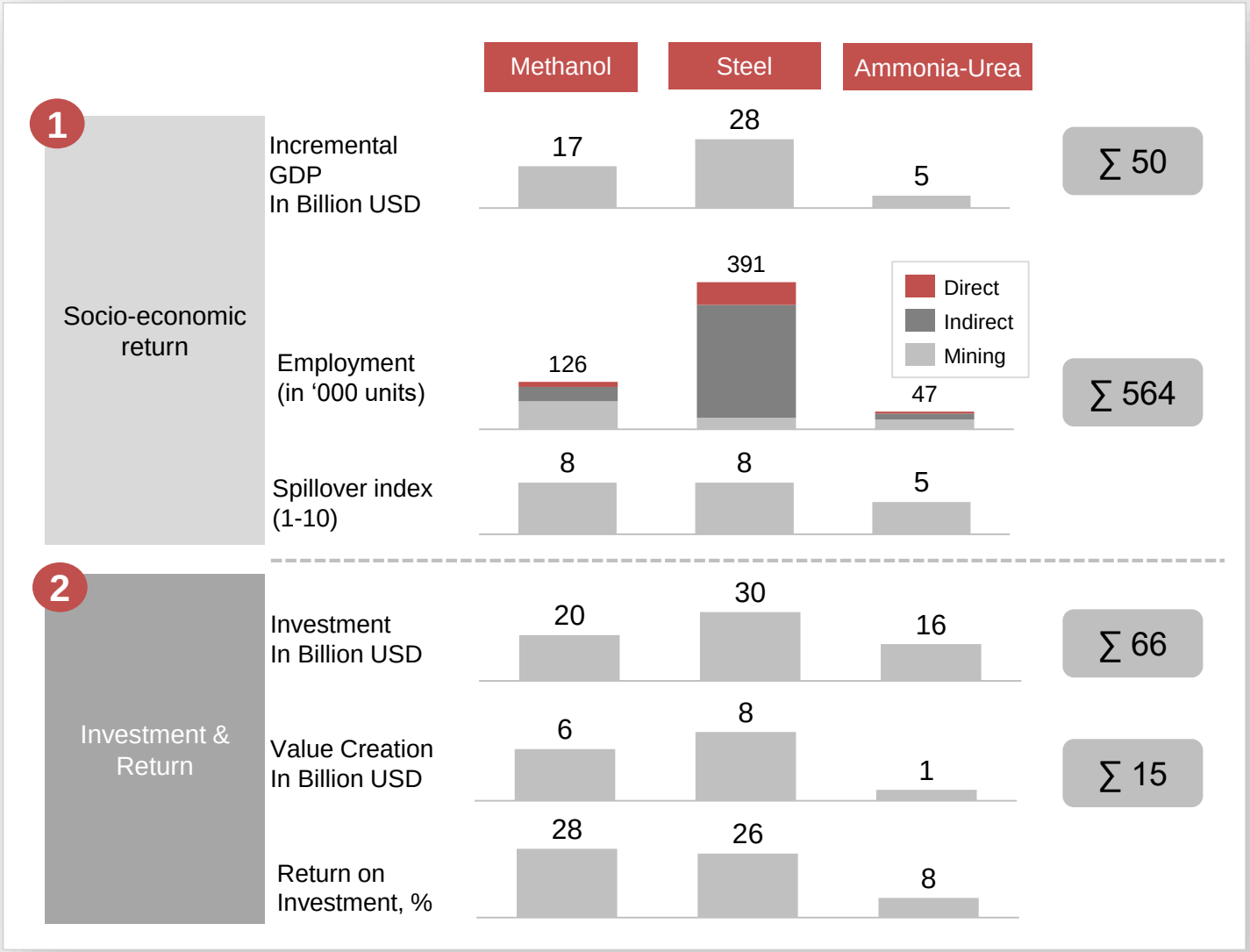
Pre-combustion carbon capture with EOR and storage can capture over 85 mtpa of CO_2 generated in the clean coal economy



#without Rectisol
**1 t CO_2 ~ 3.5 bbl
*per 250 km; transport CAPEX: 30$/t CO_2 & transport OPEX: 2$/t CO_2

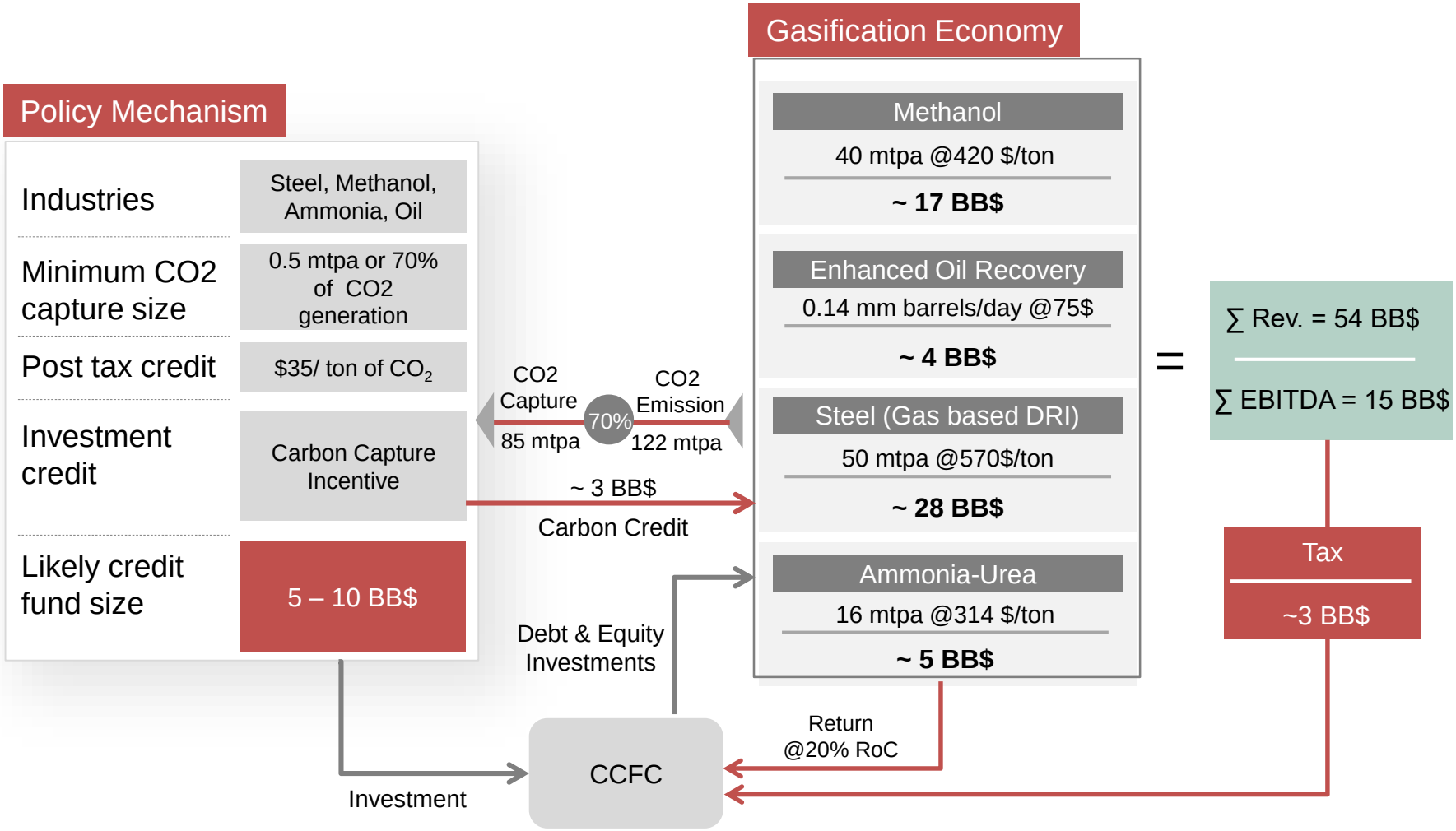
Source: NETL, IPCC, USDOE, Global CCS Institute, Dastur Research

The socio-economic multipliers for India's gasification economy

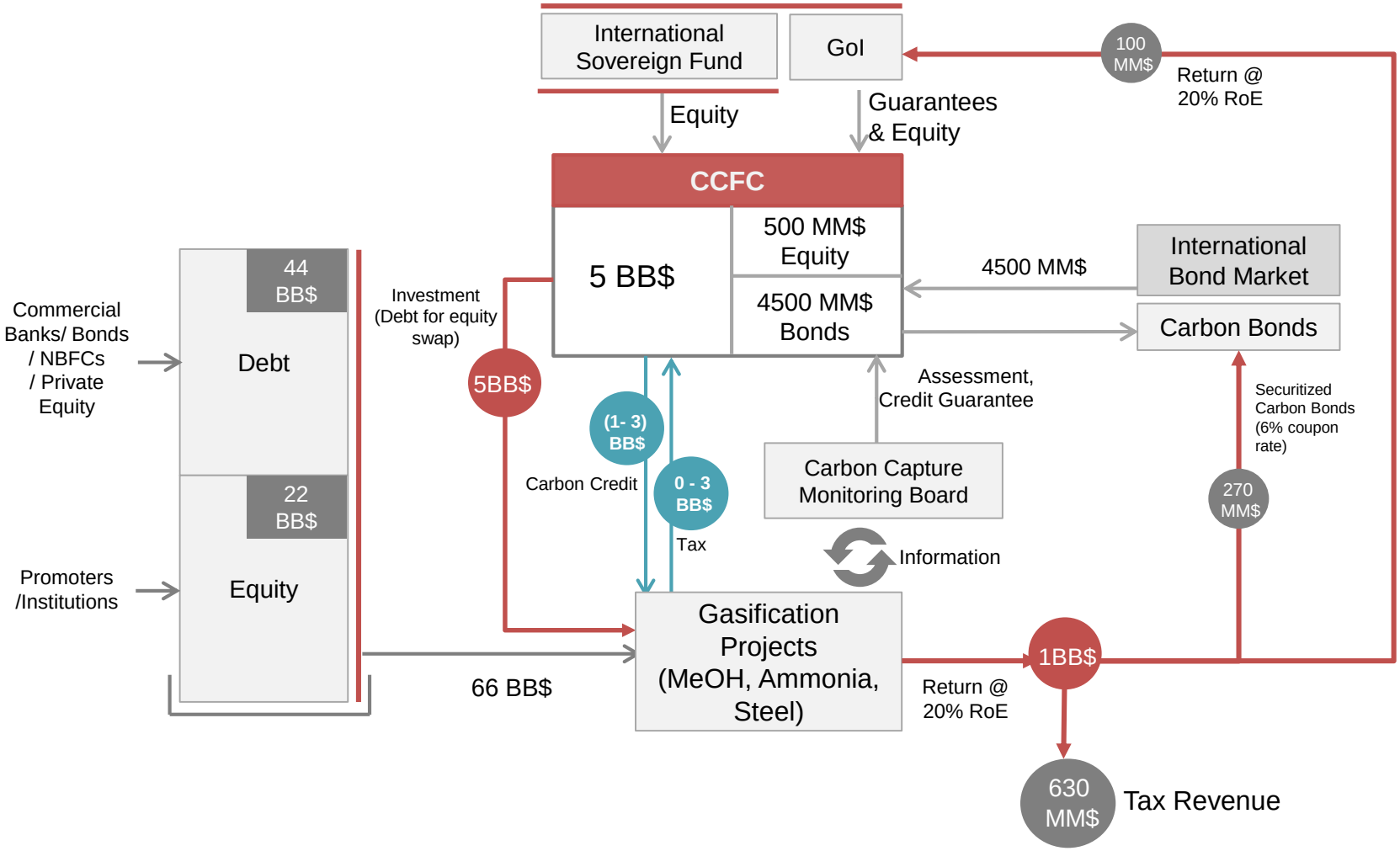


Source: DASTUR Research

Policy mechanism is essential for enabling carbon neutral gasification

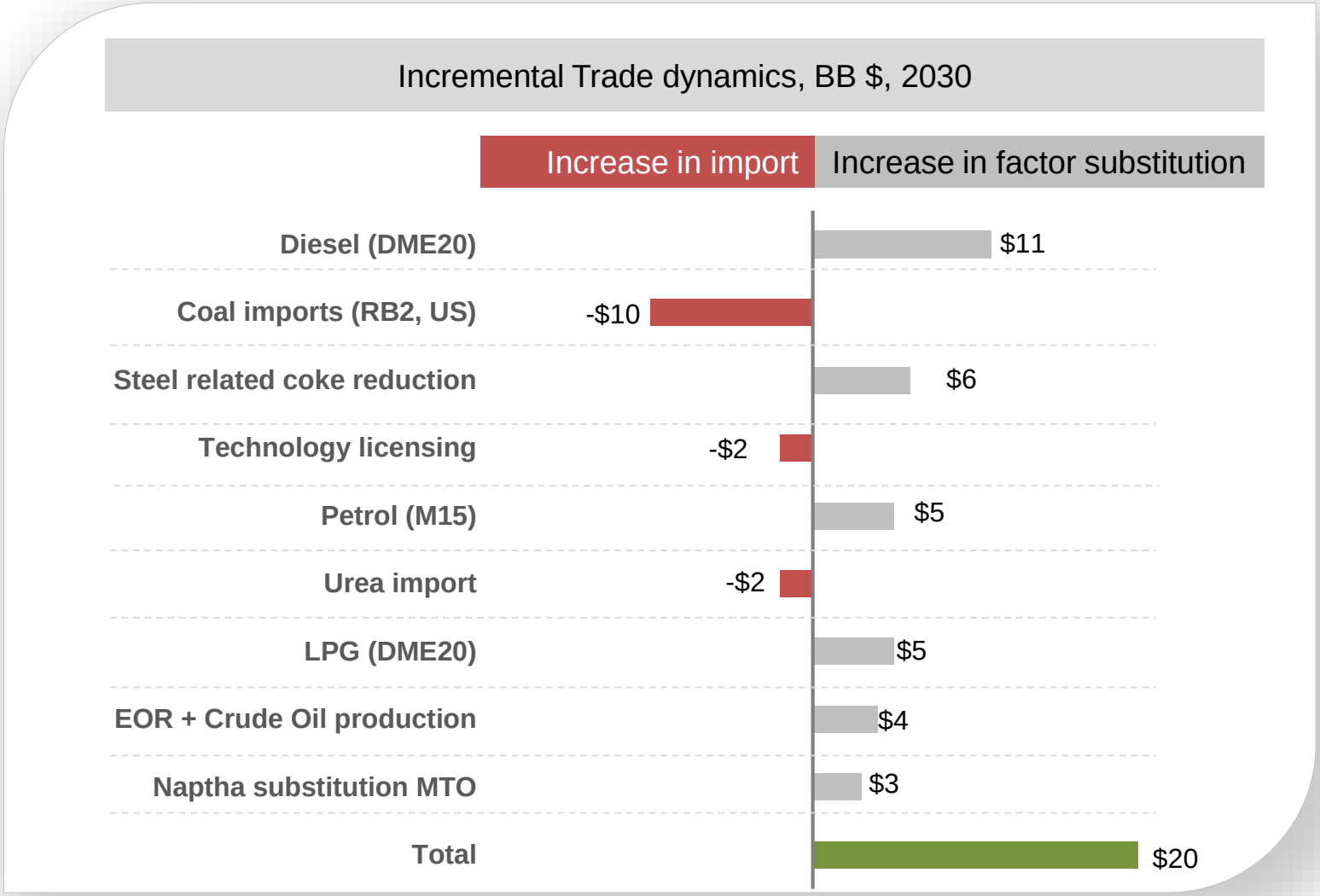


A Carbon Credit Finance Corporation (CCFC) is a deficit neutral way of financing capture



* Source : Dastur Finance Models

Eventually, the gasification economy will change the trade dynamics



Trade and substitution effect through a 'coal gasification + CO_2 EOR' framework creates a diversified, secure and win-win energy potfolio

Conclusions

- A coal gasification based Indian economy with pre-combustion CCUS can enable a viable industrial ecosystem of methanol, steel and ammonia :
  - Direct contribution of 50+ BB$ to the economy
  - Extended macro-economic multiplier impacts on the GDP
  - Abatement of CO_2 emissions by close to 100 mtpa

- Prerequisites for a techno-economically viable gasification economy:
  - Bring “technology to coal NOT coal to technology” : FB & FBDB yield positive techno-economic outcomes, with the FB gasifiers yielding the best outcomes on Indian coals with the right blend
  - Adoption of technology push policy instruments for viability of CCUS
  - Introduction of innovative carbon capture credit mechanism & carbon credit financing model to support policy options

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Gasification: High ash-coal can be gasified at a competitive production cost of $6/mmbtu