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NETRA

Bioenergy with carbon capture, utilization, and storage (BECCUS): Induction to Hybrid Model (BECCUS) for sustainable Power generation from Coal.

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Outline of the presentation

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- Literature Research & Available know-how
- Low Carbon Transition – Indian & NTPC Perspective
- NTPC Initiatives – CCUS & Biomass Cofiring
- BECCUS as Hybrid Model
- Roadmap-BECCUS as Hybrid Model
- CO2 Utilization - Potential Avenues
- Recommendations & Way forward

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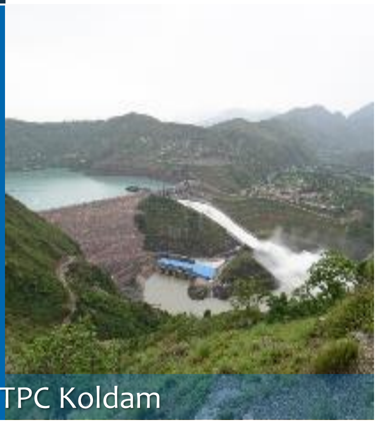
Literature Research

&

Available know-how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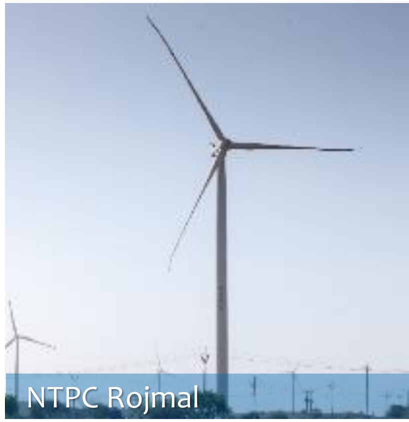
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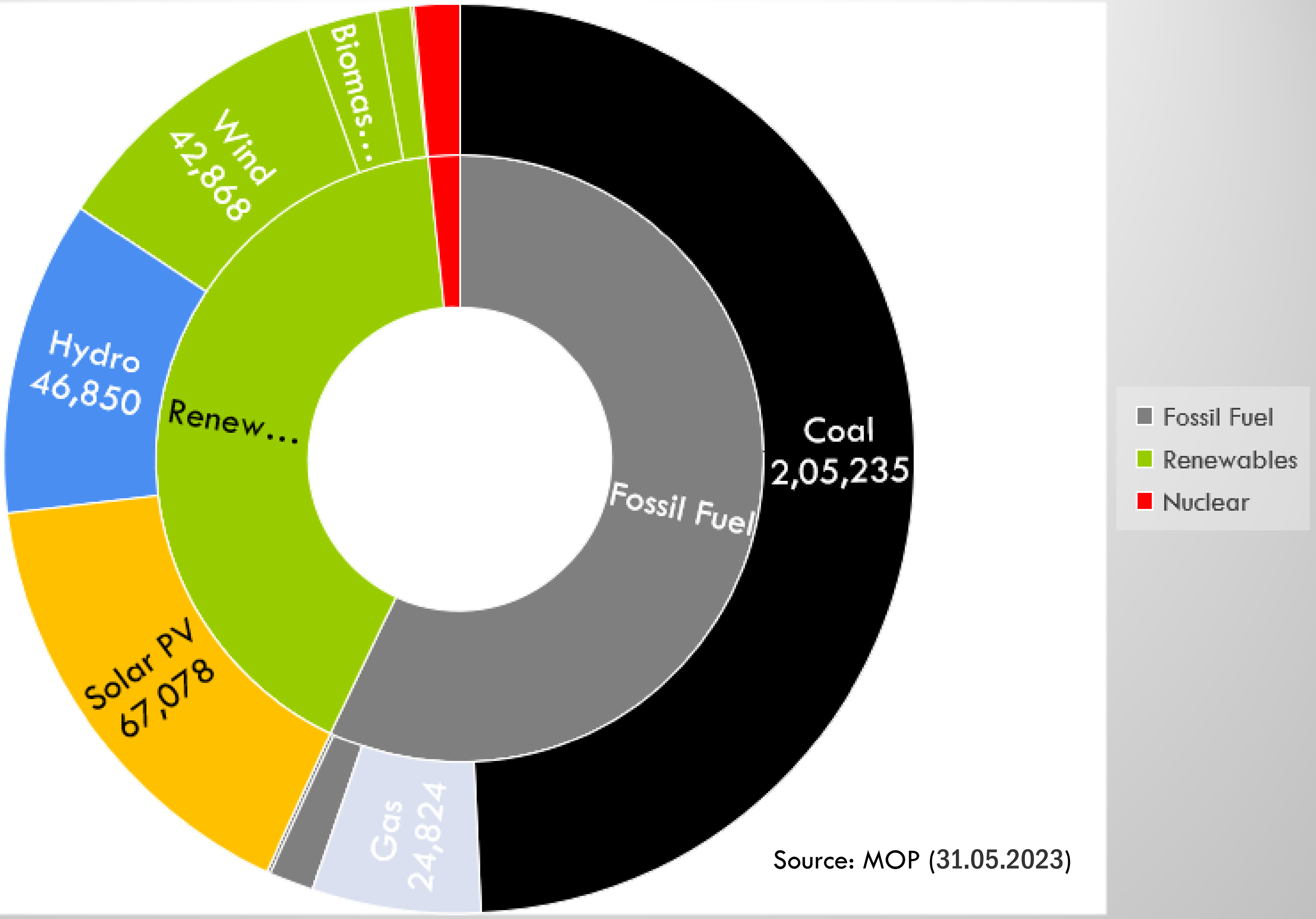
Low Carbon Transition - Indian Perspective

OVERVIEW OF POWER SECTOR

- Total installed power generation capacity in India is ~**417** GW (till 31.05.2023)
- Installed capacity of Coal Power Plant is ~205 GW (~49.1% of total installed capacity (till 31.05.2023)
- In Energy Terms, In FY 2022-23, ~1624 BU electricity was generated – Coal based (73%) Renewables (11.85%)excl. hydro (Source: CEA Report)
- Total investment made in coal power plants are in excess of 10 Trillion INR – this is a significant investment which needs to be handled carefully

INSTALLED POWER GENERATION CAPACITY OF INDIA (MW)



Source: MOP (31.05.2023)

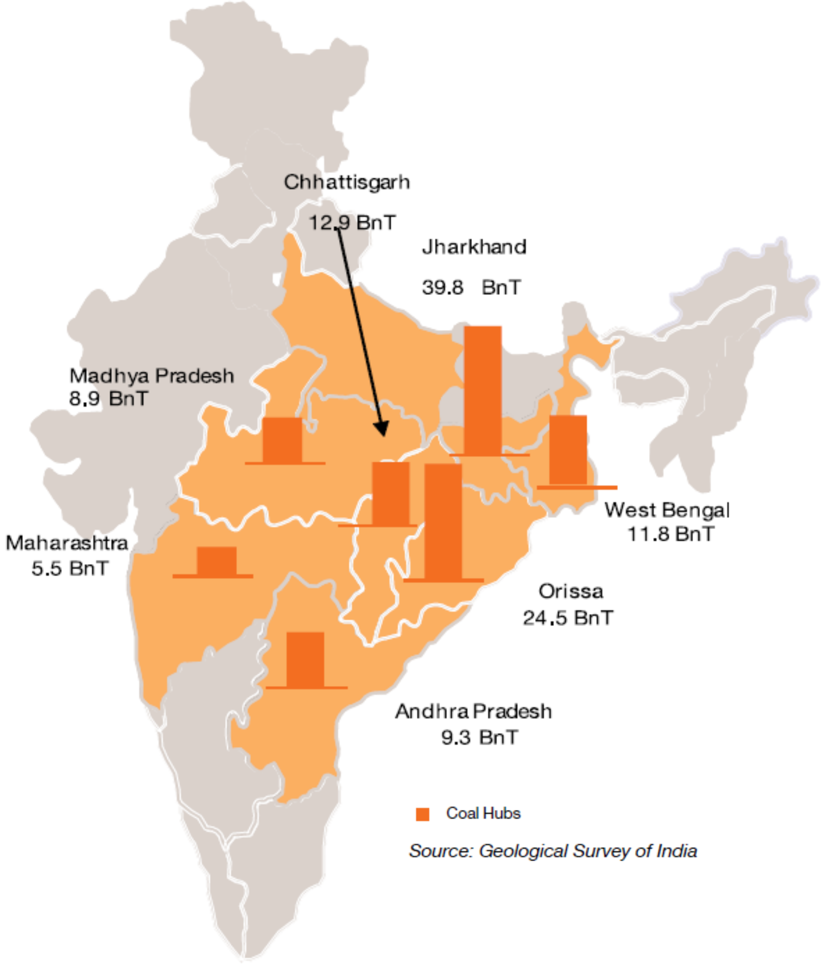
Low Carbon Transition - Indian Perspective

COAL RESERVE

- India has 149 Billion Tons of 'Proven Coal Reserve' & 319 Billion Tons of 'Total Coal Reserve' (GOI-Ministry of Coal)
- Bulk of Indian coal is of 'Non-coking' variant - which can only be used in Power Plant Installed capacity of Coal Power Plant (129 out of 149 Billion Tons i.e ~87% & 283 out of 319 Billion Tons i.e ~89%) (GOI-Ministry of Coal)

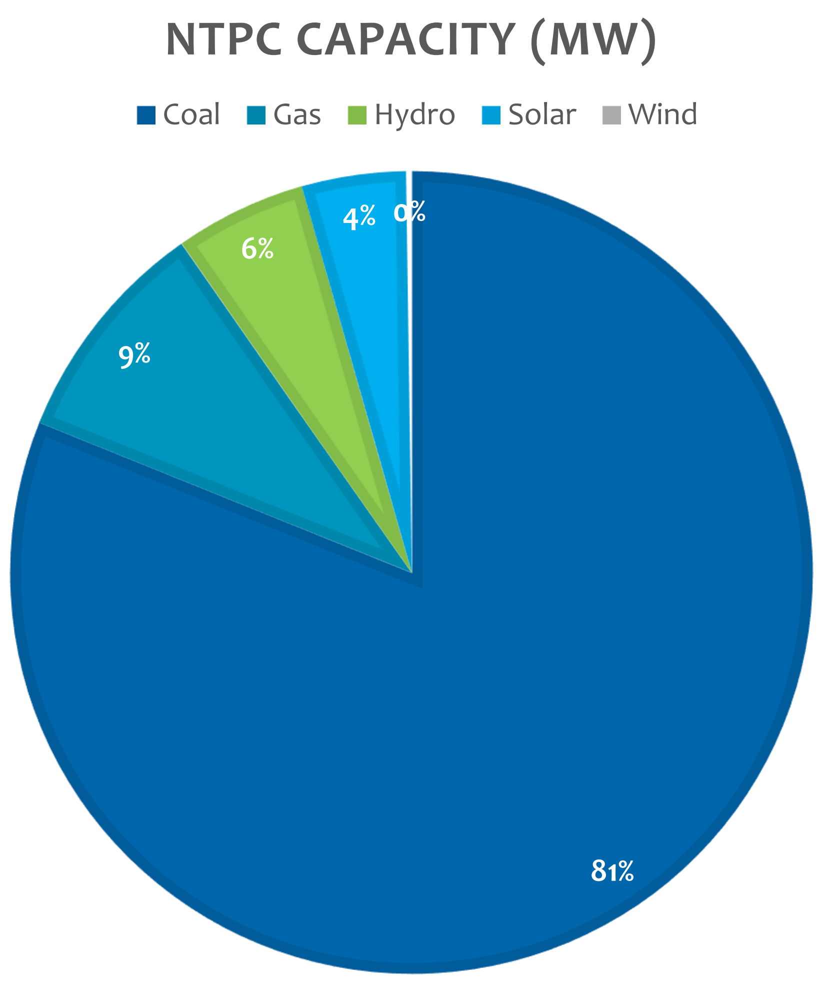
ECONOMY & EMPLOYMENT CONNECT

- Economy of few Indian States are critically dependent on coal mining. State-wise, share of coal in mining sector are: (i) Jharkhand: 91%, (ii) MP: 73%, (iii) Chhattisgarh: 66%, (iv) Odisha: 38% (TERI: Coal Transition in India)
- It generates large quantum of employment – estimated 355,000 to 500,000 Nos – across various skillset (TERI: Coal Transition in India)

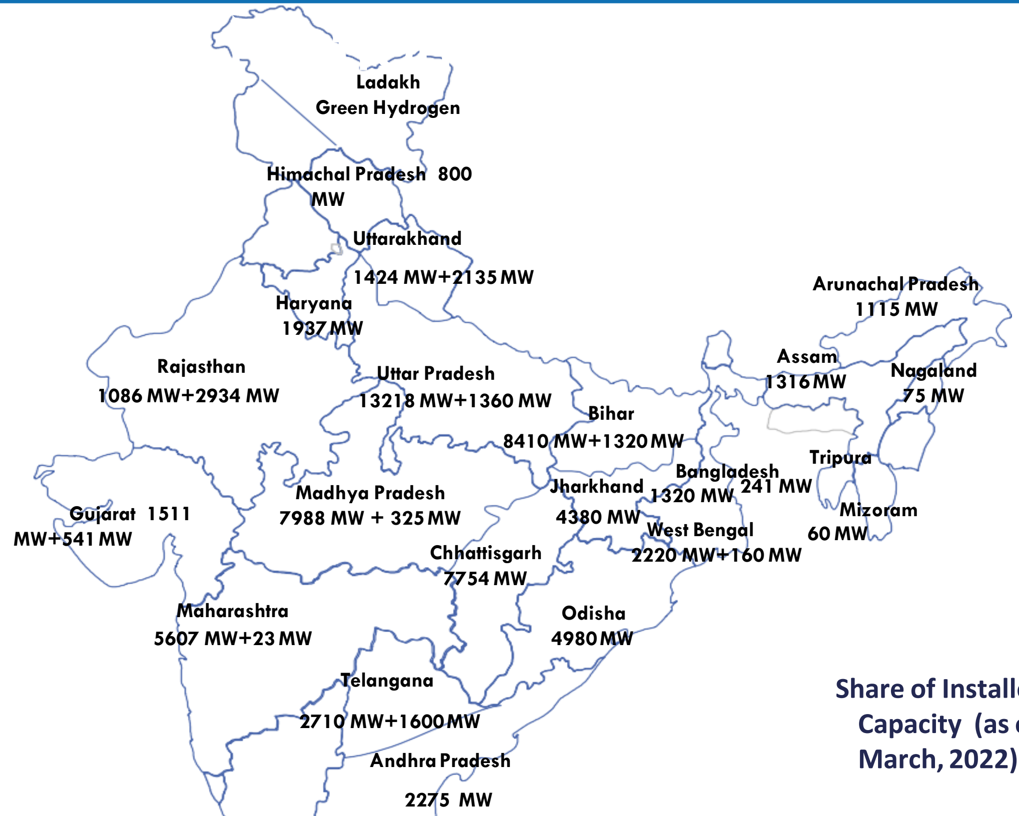


NTPC CO_2 Emission

- Total Installed Coal Fired Power Station 57494 MW around 81% of Total Business Portfolio in Power Generation.
- Total CO2 emission with 100% PLF is around 637493 TPD considering 11% CO2 in Flue gas.
- Per Year Total CO2 Emission from said capacity is around 0.23 Gigaton
- For next 50 years Total CO2 Emission with said same Capacity shall be around 11.6 Giga Ton
- The Emission shall increase with growing energy demand if more Coal fired plants installed.
- Energy Security with Grid Stability will be key factor in continuous running of coal fired station inn coming Future or during transition period



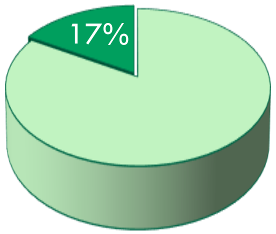
NTPC's Unparalleled Presence across the



LEGEND:
MW: MEGAWATT, GW: GIGAWATT, BU: BILLION UNITS

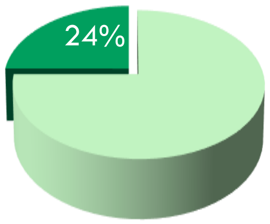
Installed Capacity as on 5th Sep 2022 : 70,064 MW			
NTPC Owned	Stations	in MW	Mix %
Coal	24	48,720	69.53%
Gas/Liquid Fuel	7	4,017	5.73%
Hydro	1	800	1.14%
Renewables	23	2162	3.08%
Sub-total	**52**	**55,699**	**79.50%**
Owned by JVs and Subs			
Coal	9	8,754	12.49%
Gas/Liquid Fuel	4	2,494	3.56%
Hydro	8	2,925	4.17%
Renewables	5	192	0.27%
Sub-total	**26**	**14,365**	**20.50%**
Total	**78**	**70,064**	**100.00%**

Share of Installed Capacity (as on 31 March, 2022)



Rest of India : 3,30,535 MW
NTPC (Group) : 68,962 MW

Share of Electricity Generated (during FY22)



Rest of India : 1132 BUs
NTPC (Group) : 360 BUs

NTPC RE @ PRESENT	GW
Installed	2.02
Under Construction	4.09
Near Construction (Bids won)	2.21
Under tendering (Others)	3.22
Total	**11.54**

60 GW+ Renewable capacity by 2032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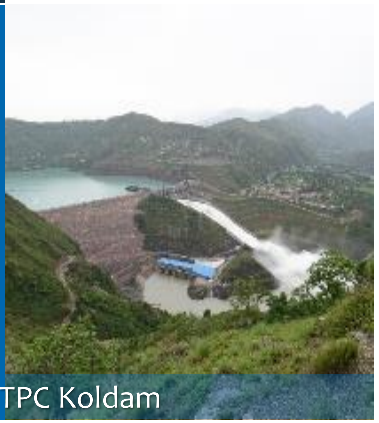
NTPC Initiatives

CCUS & Biomass-Cofiring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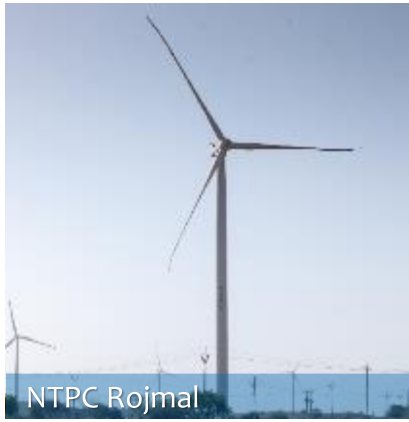
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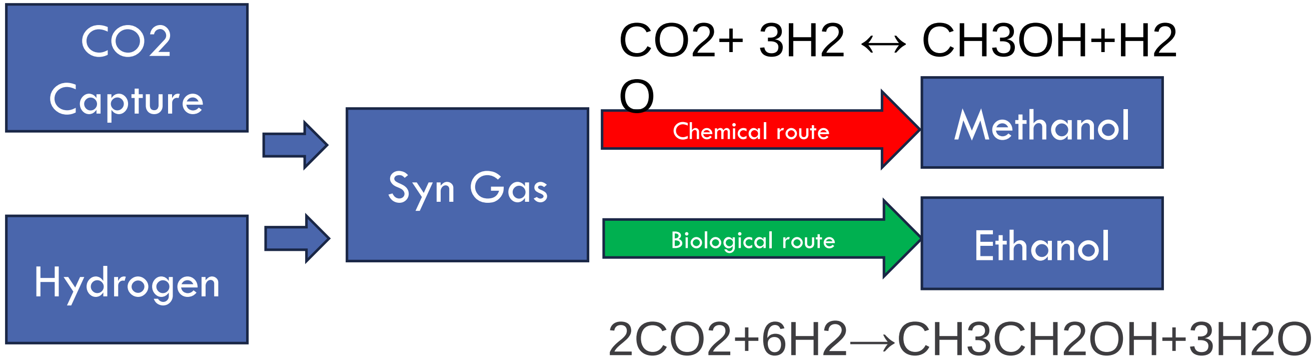
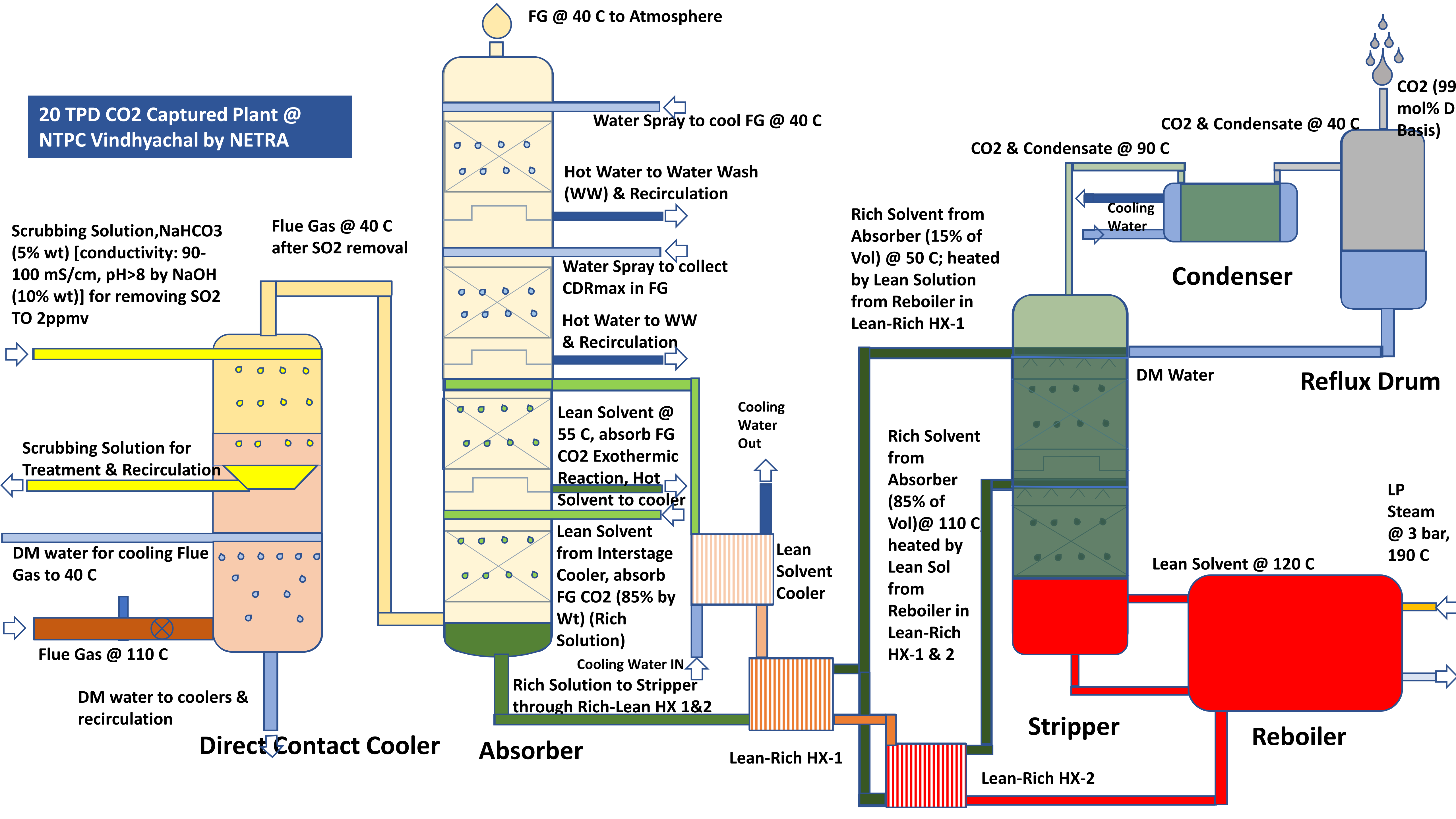
NTPC's Initiative-CCU

Design, Engineering & Development of 10TPD CO_2 to Methanol Plant

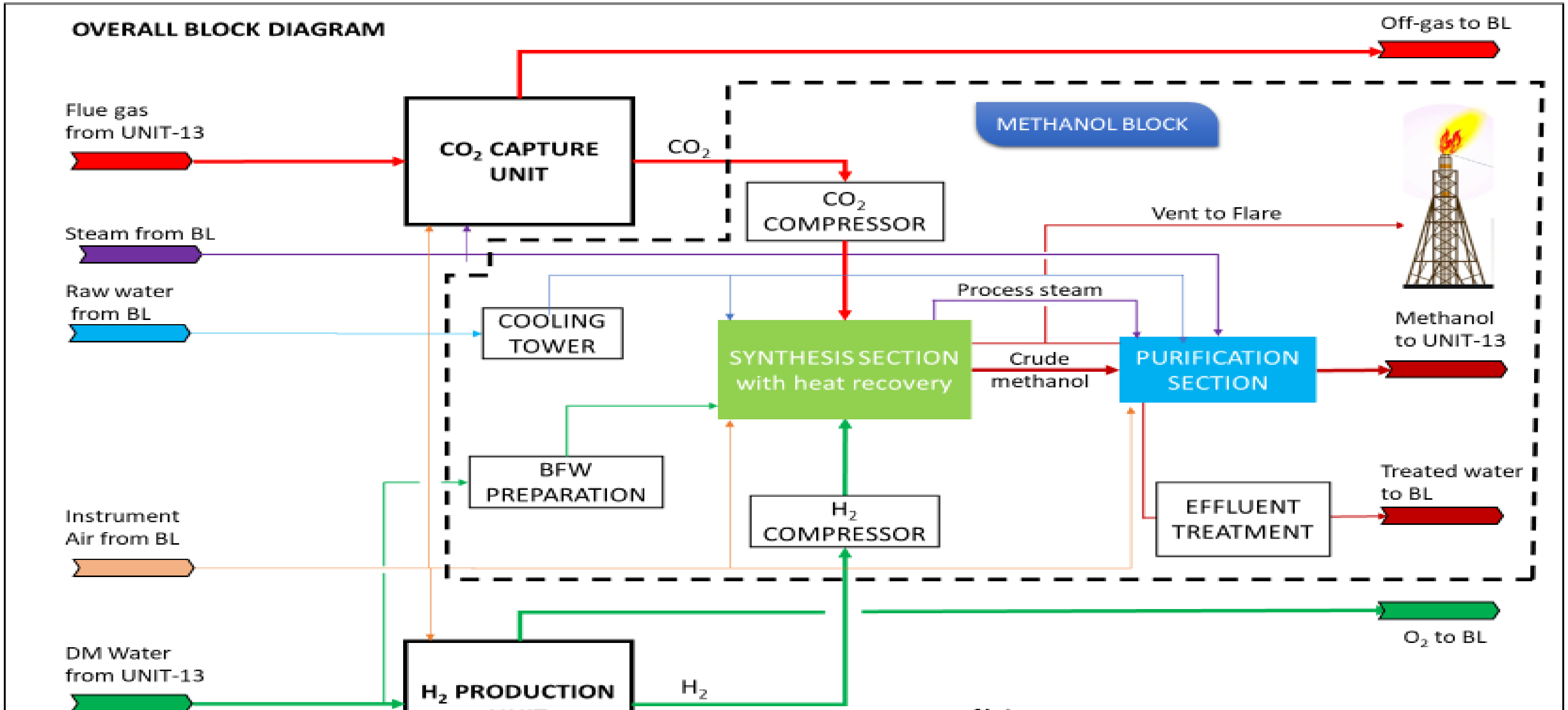
- Upon setup, this shall be the **first plant, globally**, where CO_2 is stripped from waste thermal power plant flue gas and then converted to Methanol

Conceptualization of CO2 to Ethanol: 10 TPD Ethanol generation through Bio-Catalyst based reactor under award Stage.




20 TPD CO2 Captured Plant @ NTPC Vindhyachal by NETRA
FG @ 40 C to Atmosphere
Water Spray to cool FG @ 40 C
Hot Water to Water Wash (WW) & Recirculation
Water Spray to collect CDRmax in FG
Hot Water to WW & Recirculation
Lean Solvent @ 55 C, absorb FG CO2 Exothermic Reaction, Hot Solvent to cooler
Lean Solvent from Interstage Cooler, absorb FG CO2 (85% by Wt) (Rich Solution)
Cooling Water Out
Lean Solvent Cooler
Cooling Water IN
Rich Solution to Stripper through Rich-Lean HX 1&2
Lean-Rich HX-1
Lean-Rich HX-2
Scrubbing Solution,NaHCO3 (5% wt) [conductivity: 90-100 mS/cm, pH>8 by NaOH (10% wt)] for removing SO2 TO 2ppmv
Flue Gas @ 40 C after SO2 removal
Scrubbing Solution for Treatment & Recirculation
DM water for cooling Flue Gas to 40 C
Flue Gas @ 110 C
DM water to coolers & recirculation
Direct Contact Cooler
Absorber
Rich Solvent from Absorber (15% of Vol) @ 50 C; heated by Lean Solution from Reboiler in Lean-Rich HX-1
Rich Solvent from Absorber (85% of Vol)@ 110 C heated by Lean Sol from Reboiler in Lean-Rich HX-1 & 2
CO2 & Condensate @ 90 C
CO2 & Condensate @ 40 C
Cooling Water
Condenser
CO2 (99 mol% D Basis)
DM Water
Reflux Drum
Lean Solvent @ 120 C
LP Steam @ 3 bar, 190 C
Stripper
Reboiler

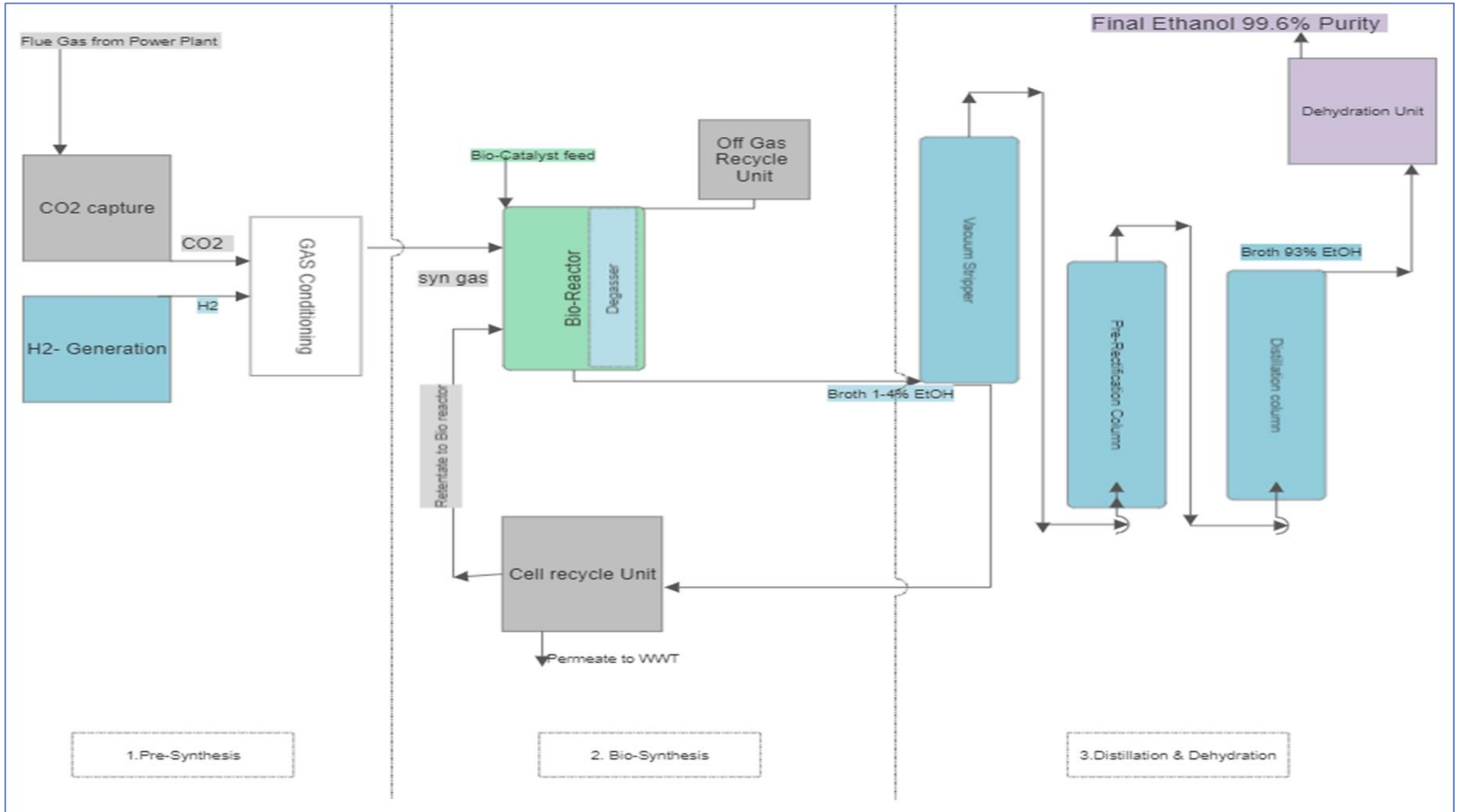
10 TPD CO2 to Methanol (CTM) Plant at NTPC Vindhyachal



Note:

1. Utilities shown in block diagram are tentative, shall be confirmed based on Licensor's requirement
2. Common utilities like potable water, condensates, fire water and power are not shown in the block diagram

Projected CO_2 to Ethanol Block



"10 TPD Ethanol Synthesis" Plant From Flue Gas Scheme

Niti Aayog report recommendations for CCUS

Comparison of Carbon Credits/Incentives & Carbon Tax Based Policy

Policy type	Carbon credits based policy	Carbon tax based policy
Key aspects of the Policy	- Incentivizes CCUS adoption & drives down the cost of capture - Establishes markets for carbon-based products - Offsets carbon capture costs through financial instruments and future taxes & growth - Most suitable for decarbonization of existing industrial asset base	- May not directly incentivize CCUS - CCUS not established in India - acceptability and affordability of carbon tax is uncertain - Eventually required in the long term - Potential near term problems: • May lead to industrial migration and loss of competitiveness • Effectiveness questionable in the near term
Trading scheme	Tax credit equity trading	Carbon emissions trading
Application examples	- US 45Q tax credits - Netherlands' SDE++ scheme - UK power sector Contracts-for-Difference (CfD) - UK CCUS Infrastructure fund - EU Innovation fund	- EU ETS - China ETS - Norway CO_2 tax - Canada Output-Based Pricing System (OBPS) - California cap-and-trade
CCUS project examples	- Petra Nova CCUS (USA) - Gorgon LNG (Australia)	- Sleipner (Norway) - Snøhvit (Norway)
Carbon subsidy/tax examples	- US 45Q tax credit: • up to 60 USD/t CO_2 for EOR & conv. • up to 85 USD/t CO_2 for storage • up to 180 USD/t CO_2 for DAC - Australia: AUD 60 MM$ for Gorgon LNG project - Canada: CAD 865 MM$ for Quest	- EU ETS: 34 Eur/t CO_2 - Canada ETS: • 2021: 30 USD/t CO_2 • 2030: 170 USD/t CO_2 - Norway: • 2021: 590 NOK (~70 USD) /t CO_2 • 2030: 2000 NOK (~237 USD)/t CO_2
Suitability	Developing economy like India	Developed economies like EU

Key Elements of a CCUS Policy Framework for India

Element	Details
Policy path	- In the near term, CCUS policy should be carbon credits or incentives based, to seed and promote the CCUS sector in India through tax and cash credits - Over time (probably beyond 2050), the policy should transition to carbon taxes, so as to enable reaching India's net zero goals by 2070 - The policy should establish early stage financing and funding mechanisms for CCUS projects
Hub & cluster business model	- Regional hub & cluster models need to be established to drive economies of scale - The role of emitters, aggregators, hub operator, disposers and conversion agents needs to be defined
Low carbon products	- Preferential procurement in Government tenders for low carbon or carbon abated products - Incentives to foster innovation for low carbon products through schemes like PLI
Environmental and social justice	- Distribution of benefits of economic value added created to communities most affected by environmental and climate change - Protection of communities and jobs, especially in sectors affected by clean energy regulations
Accounting and regulatory framework	- Regulated emission levels and allowances for different sector - Adoption of Life Cycle Analysis (LCA) framework to take into account Scope 2 and Scope 3 emissions and drive effective carbon abatement
Risk mitigation	- Limiting the CO_2 liability and ownership of participants across the CCUS value chain - Monitoring, Verification and Accounting (MVA) framework and monitoring for risk management

Worldwide CCUS Projects

Country	Project	Start Y ear	CO_2 source	CO_2 capture capacity (mtpa)	CO_2 disposition
USA/Canada	Great Plains Synfuels (Weyburn/Midale)	2000	Synthetic natural gas	3.0	EOR
USA	Core Energy CO_2-EOR	2003	Natural gas processing	0.35	EOR
Norway	Snohvit CO_2 storage project	2008	Natural gas processing	0.7	Storage
USA	Arkalan CO_2 Compression Facility	2009	Ethanol production	0.29	EOR
USA	Century plant	2010	Natural gas processing	8.4	EOR
Brazil	Petrobras Santos Basin pre-salt oilfield CCS	2011	Natural gas processing	7.0	EOR
USA	Bonanza Bioenergy CCUS EOR	2012	Ethanol Production	0.1	EOR
USA	Air Products steam methane reformer	2013	Hydrogen production	1.0	EOR
USA	Lost Cabin Gas Plant	2013	Natural gas processing	0.9	EOR
USA	Coffeyville Gasification	2013	Fertilizer production	1.0	EOR
USA	PCS Nitrogen	2013	Fertilizer production	0.3	EOR
Canada	Boundary Dam CCS	2014	Power generation (coal)	1.0	Various
China	Karamay Dunhua Oil Technology CCUS EOR	2015	Methanol production	0.1	EOR
Saudi Arabia	Uthmaniyah CO_2-EOR demonstration	2015	Natural gas processing	0.8	EOR
Canada	Quest	2015	Hydrogen production	1.3	Storage
UAE	Abu Dhabi CCS	2016	Iron and steel prod.	0.8	EOR
USA	Petra Nova*	2017	Power generation (coal)	1.4	EOR
USA	Illinois Industrial	2017	Ethanol production	1.0	Storage
China	Jilin oilfield $_{CO2-}$EOR	2018	Natural gas processing	0.6	EOR
Australia	Gorgon Carbon Dioxide Injection	2019	Natural gas processing	3.4 - 4.0	Storage
Canada	Alberta Carbon Trunk Line (ACTL) with Agrium CO_2 stream	2020	Fertilizer production	0.3 - 0.6	EOR
Canada	ACTL with North West Sturgeon Refinery CO_2 stream	2020	Hydrogen production	1.2 - 1.4	EOR
Iceland	ORCA	2021	Direct Air Capture	0.004	Storage
Canada	Glacier Gas Plant MCCS	2022	Natural gas processing	0.2	Storage
China	SINOPEC Qilu-Shengli CCUS	2022	Chemical production	1	EOR
USA	Red Trail Energy CCS	2022	Ethanol production	0.18	Storage

Biomass Cofiring

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Stubble Burning in open fields

Blending of Biomass with Coal

Devolatilization & combustion Characterization

Implementation in NTPC

Parameter	Coal	Paddy straw
Carbon content	34-35%	14.31%
Volatile content	20-21%	63.50%
Ash content	38%	13.3%
Moisture	6%	8.8%
GCV	3500 Kcal/Kg	3650 Kcal/kg
Alkali content (K, Na)	-	6-8%
Chlorine content	0.05-0.08%	0.8-1.5%
Density	833 kg/m3	700 Kg/m^3
Ignition temperature	454 C	240 C
Grind ability index	70-80	Fibrous
Particle type	Brittle	
Ash Fusion Temp.	1150 C	850-900 C
Ash resistivity	moderate	High

Characterization of Raw Biomass for 10% Firing (2017)

- VM evolution at 190-200°C- Limiting mill operation
- Softness and hygroscopic nature- Limiting mill grinding capability
- Alkali and Chlorine content: Slagging/Clinkering
- In view of above trial carried out with 10% co-firing with modified handling and mill operating procedure

Characterization of torrefied biomass (Mar-July 2021)

- Hydrophobic- Handling/Conveying capability similar to coal
- Enhanced mill Grindability- Increased % of co-firing
- Increased VM release temperature- Improved Mill Temperature
- Indices predicts minimum slagging till 20-25% co-firing
- For presently fired sample of Biomass (April 2021) similar assessment as above
- Further samples are being characterized for consistency of results

Effect of co-firing on CO2, SOx, NOx and Particulate emission

CO_2

Proximate analysis of Rice straw briquettes suggests that it has calorific value very near to that of bituminous coal. So, its 10% co-firing would cut down CO_2 emission by approx. 10%.

SOx

Coal blend principally affecting SO_2 emissions are:

- The total sulphur content (represents maximum amount of sulphur oxides that could be formed)
- The ash composition (since typically 5-10% of the SO_2 is generally captured by alkalis in the coal ash)

Biomass generally has much lower contents of sulphur, together with higher concentrations of alkalis in its ash, so SO_2 emissions are generally considerably reduced when cofiring.

NOX

- Can reduce NOx through lower N content (depends on biomass) and higher volatiles release in the fuel rich zone of the flame.
- Also gives lower flame temperature, reducing thermal Nox.
- But may affect the SCR – larger quantities of alkalis such as K, Na, Ca and phosphorus may blind or poison the catalyst, leading to higher NOx emissions and potentially high ammonia slip
- Can need earlier catalyst change

Particulate

- Chemical and physical properties of fly ash particulates from biomass combustion are different from those of coal
- Can give higher release of trace metals
- Reduces fly ash loading
- Can increase overall collection efficiency of ESPs due to larger particulates and ease of agglomeration
- But on higher co-firing ratio it may instead reduce collection efficiency, due to high resistivity of fly ash, and increase PM2.5 emissions

Strategic advantages of Biomass co-firing

- Biomass co-firing has been recognised by UNFCCC as a technology to mitigate GHG emissions.
- India has large coal-based capacity which can be utilized to generate renewable energy.
- RE generation through co-firing does not require compensatory cycling of thermal plants, thus increases their life and incurs no cycling cost as well as no indirect cost of integration.
- Cost competitive with solar and wind if indirect cost of integration is also taken into account
- Having a world's largest area under cultivation, India has vast unutilized biomass resource.
- Unlike solar and wind, it may meet peak demand
- 30000 MW potential of biomass power = 125000 MW Solar capacity (CUF-15-20 %)
- Thus, to meet NDC target of India aimed at reducing carbon footprint (of GDP of 2005 level) by 35%, biomass co-firing may prove strategic alternative to reduce carbon footprint without need of compensatory cycling of coal based plants.
- Older plants providing cheaper power to consumer may not be required to be phased out by reducing its carbon foot through biomass co-firing and with appropriate tariff policy for same, creating a win-win situation for all.

Biomass pellets : A carbon neutral fuel

Carbon neutral cycle

Activity	Fuel consumption	CO_2 emission per unit	Total CO_2 emission (kg)
Diesel consumption in collection and storage	3 liter/ton	2.86 kg/liter	8
Electricity consumption for pelletization	25-40 unit/ton	1.68 kg/unit	42-67.5
Diesel Consumption in transport of pellets up to 150-300 KM	5-10 liter/ ton	2.86 kg/liter	13.4-26.8
Total			**63-102**
Co2 emission reduction from per ton of Biomass Co-firing	**1 ton of pellet**	**1283 kg/ton**	**1283**
Net CO_2 emission reduction per ton			**1181**

SWOT Analysis

1. Decades of expertise
2. Plant production systems & procedures
3. Workplace culture and personnel practice.
4. New Initiatives Acceptance
5. Project Management
6. Dedicated R&D

1. Thermal obsolete, coal shortage, Ash disposal problem, water shortage (ZLD)
2. Regulated business
3. Environment norms, NZE(net zero emission), carbon footprint.
4. Weak Biomass supply chain, CCUS technology

1. Huge chemical market opportunities in Green Chemicals (Methanol , Ethanol , Urea etc.)
2. Huge futuristic potential of Green H2 - supportive compound in CCUS
3. Longer Period Run of Installed Plants in sustainable manner by meeting emission norms.

1. Handling public money- Vendors- equal opportunities, L1 model follow tendering
2. Unit economics of CCU based product market.
3. Additional financial burden through BECCUS

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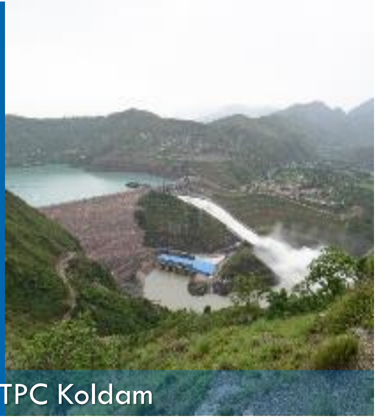
Proposed Solution

BECCUS as Hybrid Model



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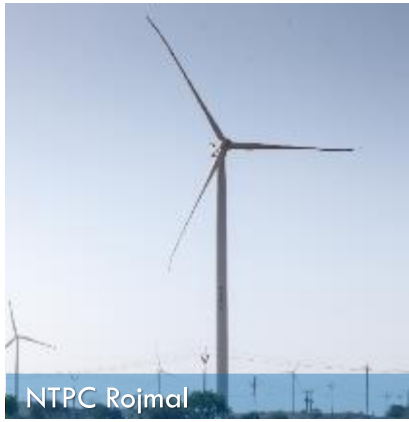

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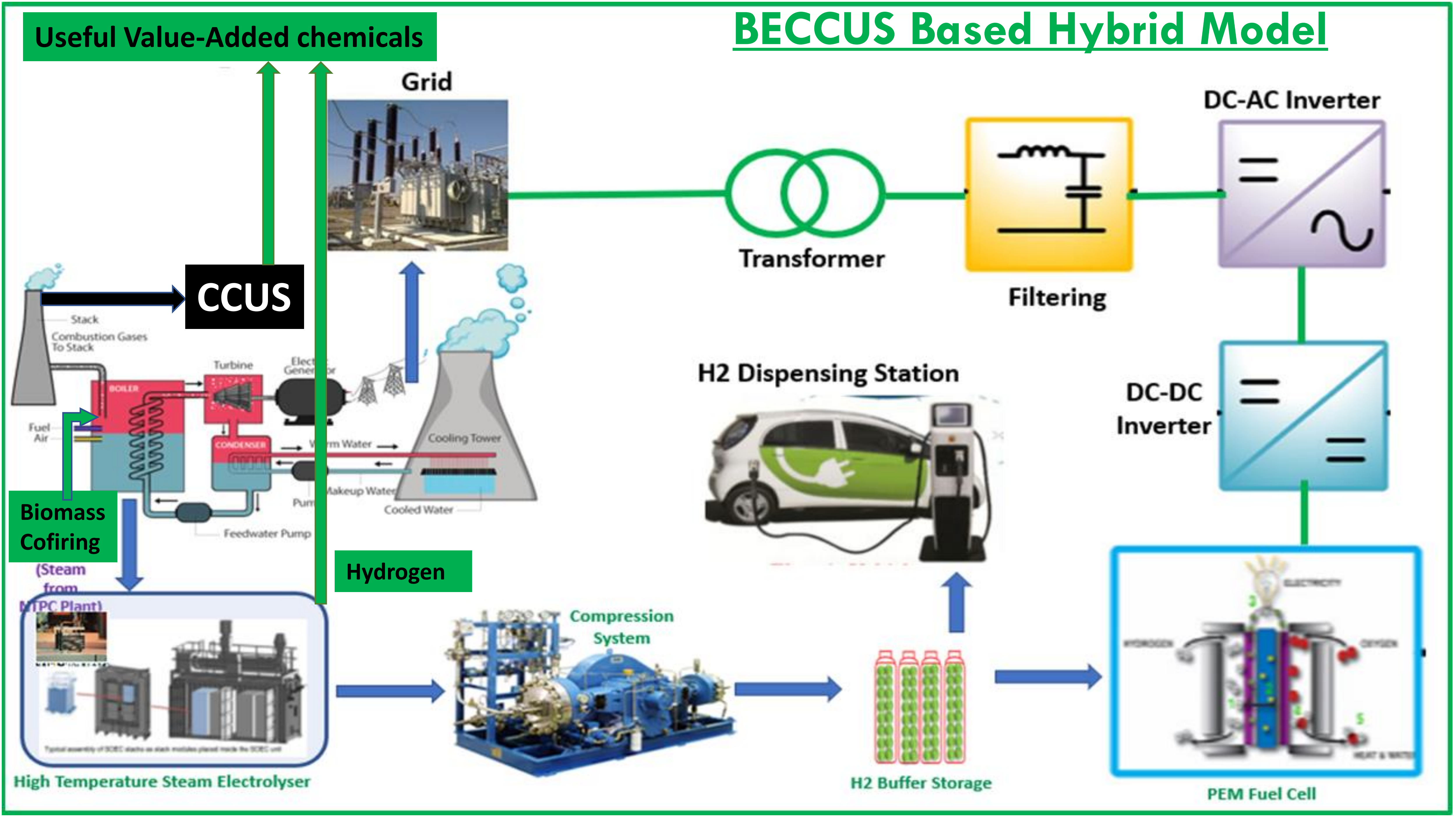
BECCUS Based Hybrid Model
Useful Value-Added chemicals
Grid
CCUS
Stack
Combustion Gases To Stack
Turbine
BOILER
CONDENSER
Fuel
Air
Cooling Tower
Cooled Water
Feedwater Pump
Biomass Cofiring
(Steam from NTPC Plant)
Hydrogen
Transformer
Filtering
DC-AC Inverter
DC-DC Inverter
H2 Dispensing Station
Compression System
High Temperature Steam Electrolyser
H2 Buffer Storage
PEM Fuel Cell

Case study on Analysis of Hybrid Model:

Refer below table as input data to CCU shall be used from Power plant.

Description	Unit	Input Data
Plant Capacity	MW	500
No. of Unit	No.	2
Coal Consumption for 500 MW	TPH	360
Coal Consumption for Two Unit	TPD	17280
20% Pellet Biomass Blend	TPD	3456
flue gas from single Unit	TPH	2100
Total flue gas	TPH	4200
Total Flue gas	TPD	100800
CO_2 % in Flue gas	%	12
Total CO_2 In Flue Gas	TPD	12096
CCU Plant Efficiency	%	85
Capturable CO_2	TPD	10282

With reference to above input which shall be used in hybrid model for reducing footprints refer below table thru BECCUS

Hybrid Model

Supporting Technology/Process in Reducing CO2 footprints	% Contribution in reducing GHG Emission (CO2)	CO2 (TPD) Reduced from Emission	Out Put Products (in TPD) from CCU
Methanol	10	1028	734
Ethanol	10	1028	514
Total CCU Compounds	**20**	**2056**	
CO2 Storage	5	514	
Total CO2 captured in CCUS	**25**	**2570**	
Agri, Biomass Pellet Co-firing	20	2419	20% of pellet shall be blend with Coal which accounts reduction in emissions 20% against Coal
Total		**4990**	

Analysis of BECCUS Based Hybrid Plant

- With 45% of Hybrid Power Plant Total CO_2 Emission reduced to 41%.The difference is due to efficiency of CO_2 capture Plant.

- 1248 TPD (734 Methanol+514 Ethanol) as CCU Low carbon products and diversifying business portfolio thru meeting the futuristic chemical demand

- Roadmap towards Net Zero Emission with coal fired plants in operation.

- Meeting the energy security , employment and economy of states and country based on Coal.
- Circular Economy and Usage of wastage in from of pellets.

- Maintaining the Grid Stability and it helps in providing uninterrupted power supply irrespective of natural variables (like in renewables)


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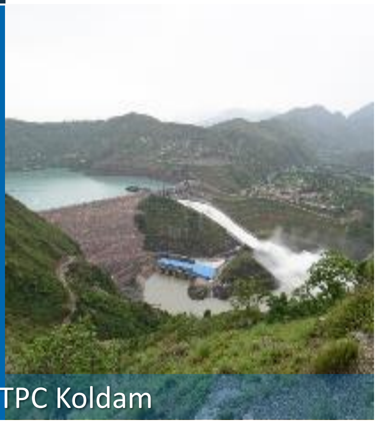
Roadmap-BECCUS as Hybrid Model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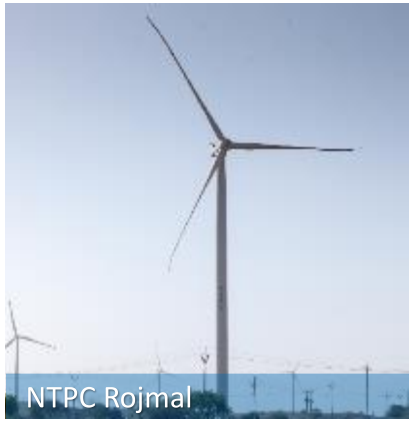
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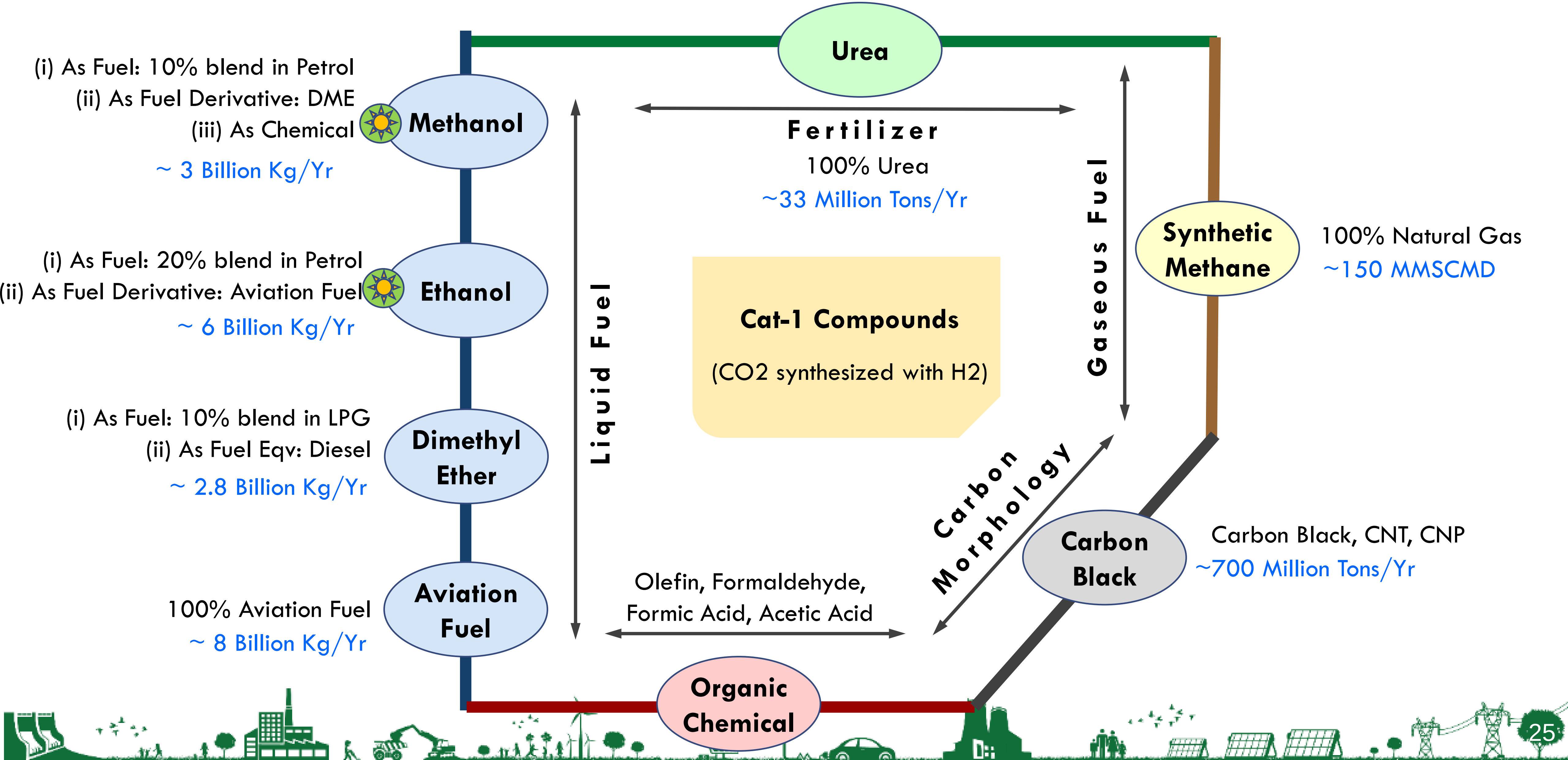
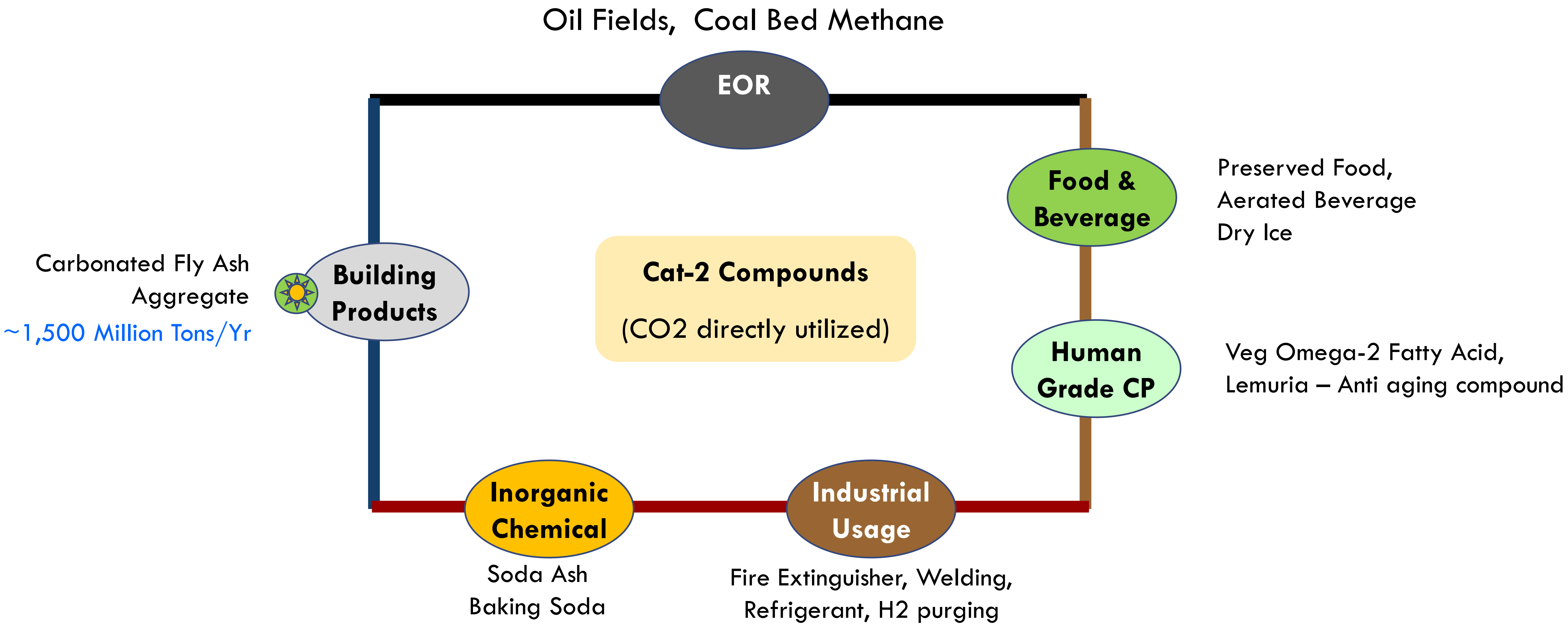
BECCUS: Potential Avenues



BECCUS: Potential Avenues



Roadmap - BECCUS as Hybrid Model

- With above methods used in hybrid Model shows that the Co-firing of Pellet, Agri and biomass has led to reduce the GHG emission when blended with coal. The rest of coal which are responsible for emission partially CO_2 from flue gas when captured can be utilized to produce hydrocarbons to meet the market demands.
- The challenges in this Models are like collection of Agri ,biomass at large scale in order to meet the 20% blending with coal. In CCU the competitive pricing of products from CO_2 utilization is one of the major factor due to nascent stage technologies and cheap conventional available process.
- The government shall require to frame policy for consumption of these compounds before it reaches to a competitive level.
- This model helps us to utilize our natural reserve to some extent ensuring our energy security, grid stability and uninterrupted power supply along with narrowing down the gap in meeting Net Zero compliances.

Roadmap - BECCUS as Hybrid Model

BECCUS Model: Low carbon transition with sustainable Power

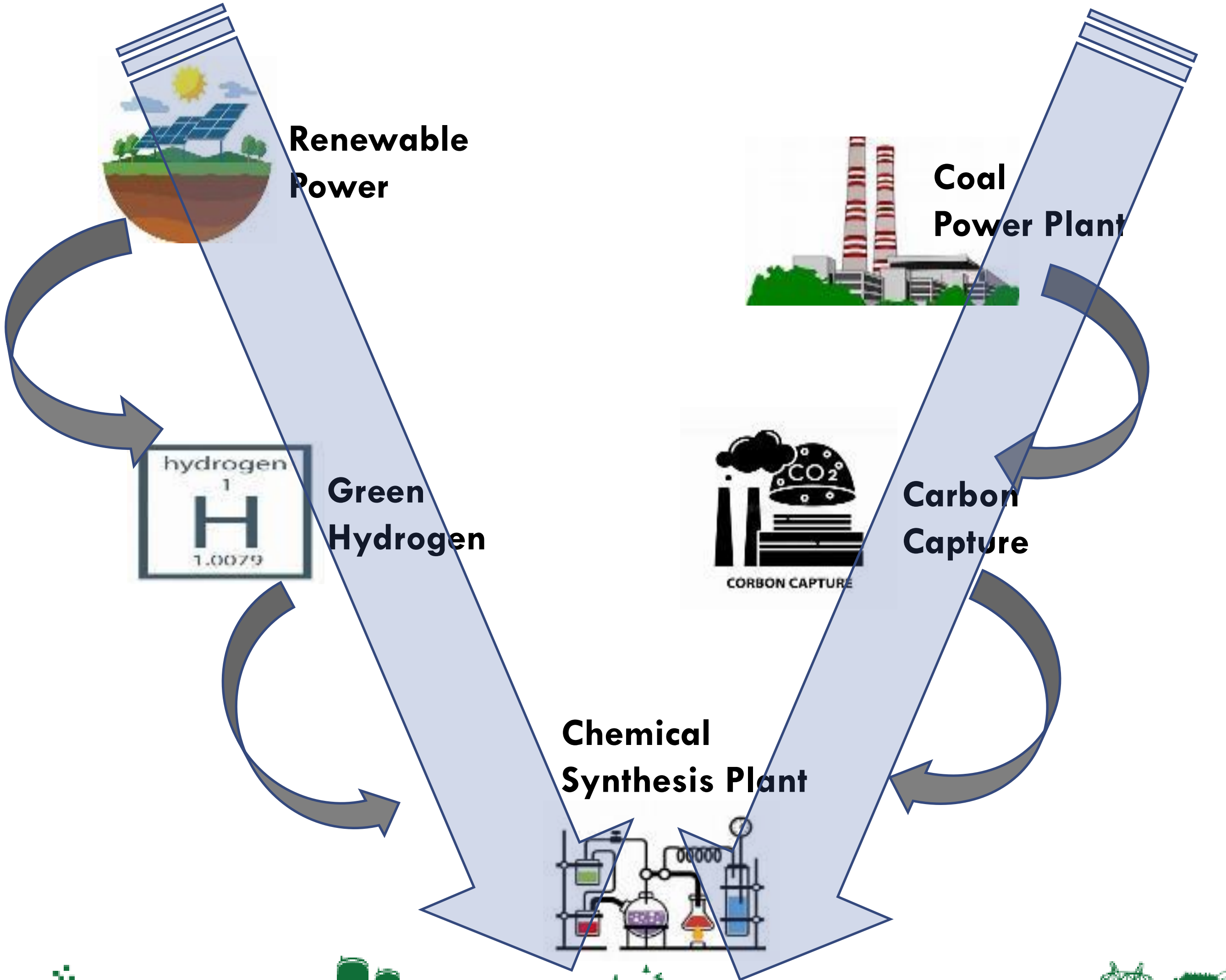
Hybrid BECCUS Model in based on **inter-linking** (i) Renewables, (ii) Green Hydrogen & (iii) Carbon Capture and Utilization iv) Biomass

KEY BENEFITS:

- 'Low Carbon Intensity' Coal Power Plants- A step towards Net Zero CO2 Emissions
- Maintain the (i) Employment in Coal Sector, (ii) Economy of coal rich states, (iii) Investment in Coal Power Plants,
- CCU based compound Industries

CONTRIBUTE TOWARDS COP-26 COMMITMENTS:

(i) 500 GW Non-fossil capacity; (ii) 50% energy from RE; (iii) Carbon intensity < 45%; (iv) 1 billion tons emissions reduction; (v) Net-zero emissions by 2070.



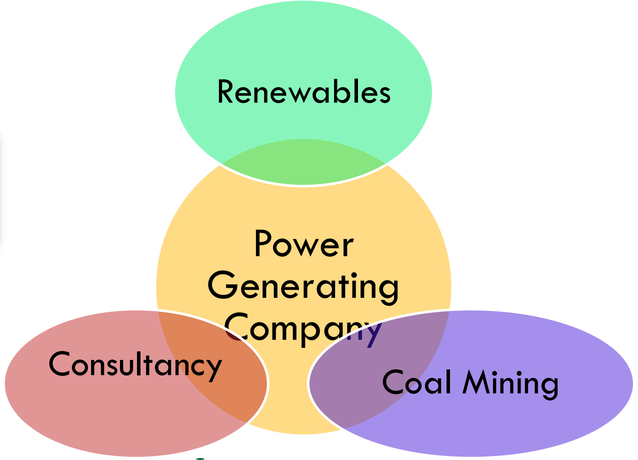
Leading Indian Energy Company - Spearheading Energy Transition in Future

Key Growth Pointers

1. Planned Capacity Addition
2. Leading Green Energy Push
3. Captive Coal Production
4. Acquisitions & Diversification

- Firm Action Plan to comply with New Environment Norms.
- Blue Sky Initiatives of NTPC
- Green hydrogen initiatives.
- CCUS plants in India

2024



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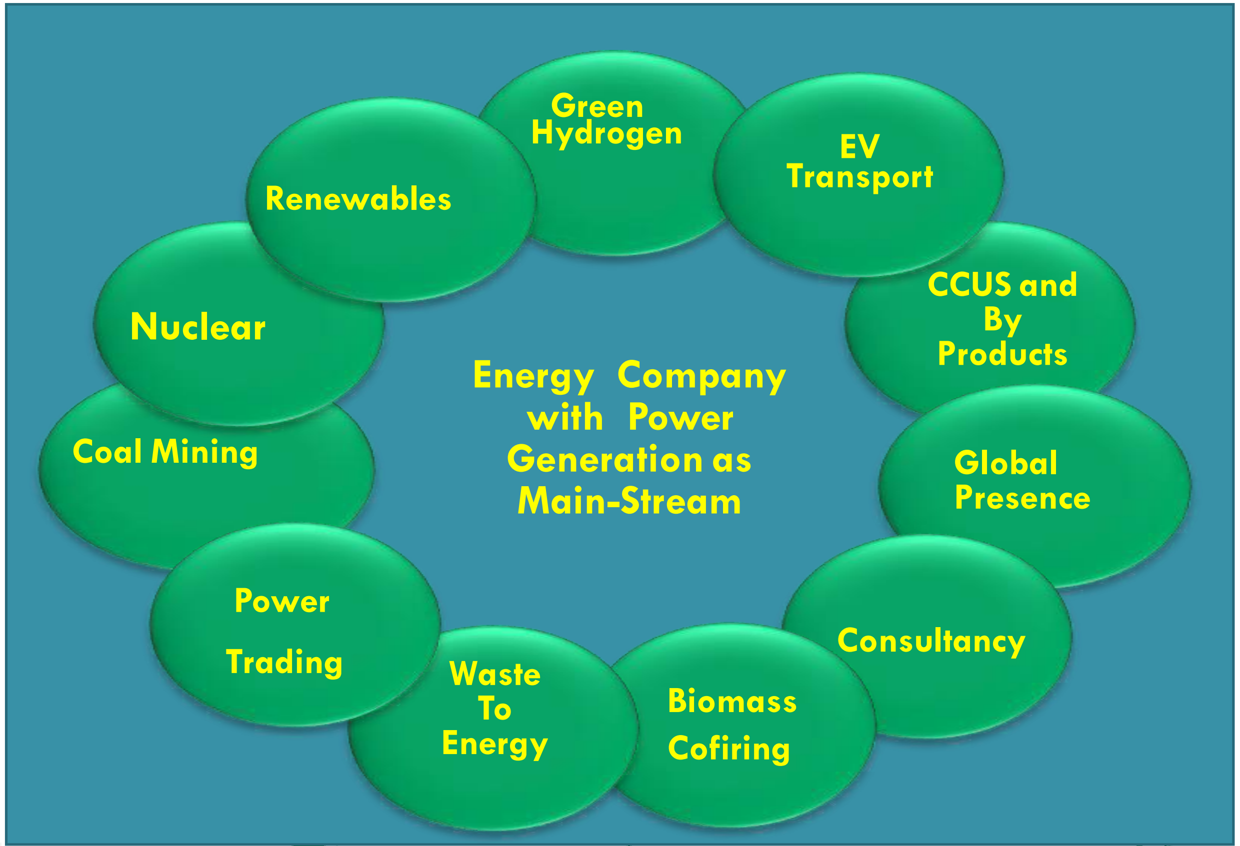

THANK YOU

NETRA Solar PV

NETRA Solar Thermal

Carbon Capture plant, Vindhyachal

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