CO_2 Capture & Sequestration Project

An Impact Project of DST at RGPV Bhopal

MODELING & SIMULATION OF CARBON RECYCLING TECHNOLOGY THROUGH CONVERSION OF CO_2 INTO USEFUL MULTIPURPOSE PRODUCTS: CO,H2, & METHANOL

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The Four Dimensions of Low Carbon Technologies

- 1: ***Low Carbon Technologies (LCT)***

  Renewable Energy Technologies- Planning for Energy security and Environmental Sustainability

- 2: ***Clean Development Mechanisms (CDM)***

  Barriers, Policy & Action Plan and Roles of Market Players- Impact of Low-Carbon Life Style on Climate Change

- 3: ***Clean Coal Technology (CCT)***

  Mega Power Projects based on Supercritical & IGCC Technologies – Plans in Power Sector.

- 4: ***Carbon Capture& Sequestration (CCS)***

  Impact R & D Projects & Technology Issues – Technology Transfer Strategies.

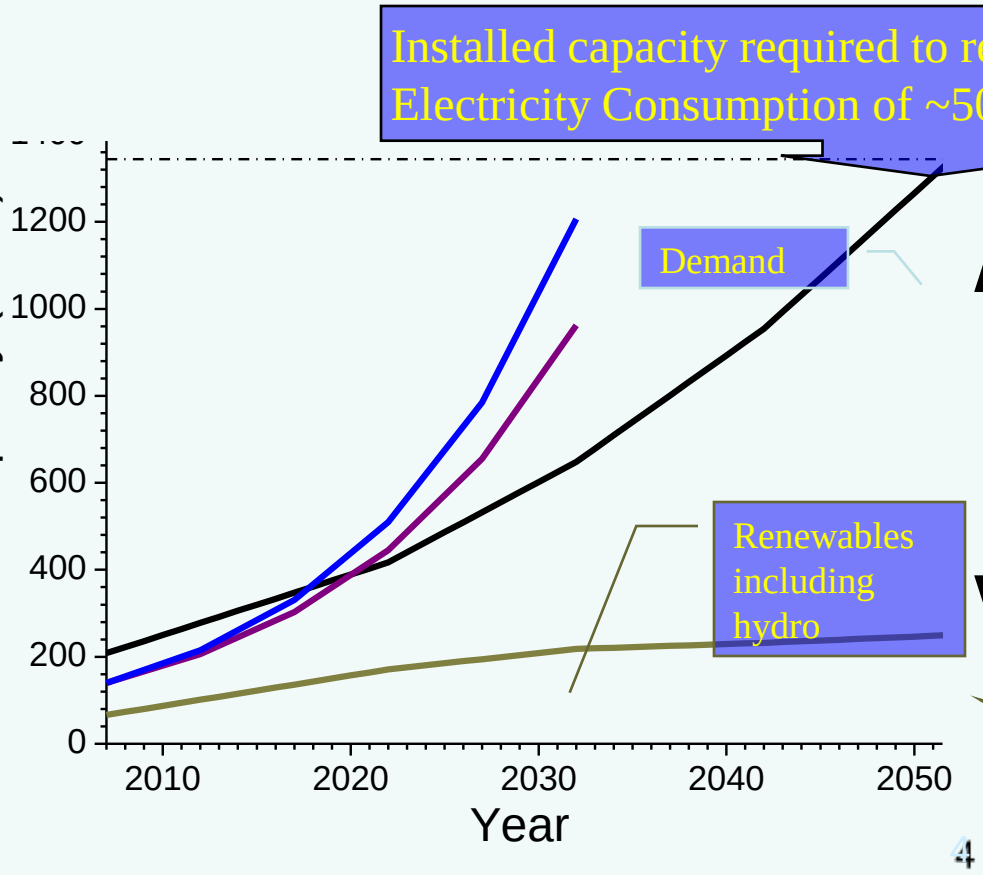
Issues in LCT & CCS

- Promotion of Clean Coal Technologies
- Technology break thoughts in the areas like CO_2 capture & Sequestration and Clean Coal Technologies
- Development of low cost solar photo voltaic cells
- Bringing Energy Efficiency & Energy Conservation on the top of the National Agenda
- Promotion of Carbon Trading on the strength of Energy Efficiency and Green Environment initiatives.
- Base line methodologies for variety of Clean and Green Technologies need to be redefined.

India's long-term Energy Security can me met primarily from Coal & Nuclear

India Fifth Largest Producer (1,82,700 MW)

Low Per Capita Consumption (704 U)



Deficit: ~1094 GWe to be met with
- Nuclear
- Coal

Coal

- ~4.7 billion tonne /year [>4 times current US coal consumption for electricity generation]
- ~7.7 Gte of CO_2 emissions

Per Capita Electricity Consumption: 593 kWh/year

Comparison of CO_2 capture & Sequestration Technologies with other leading mid-to long-term option

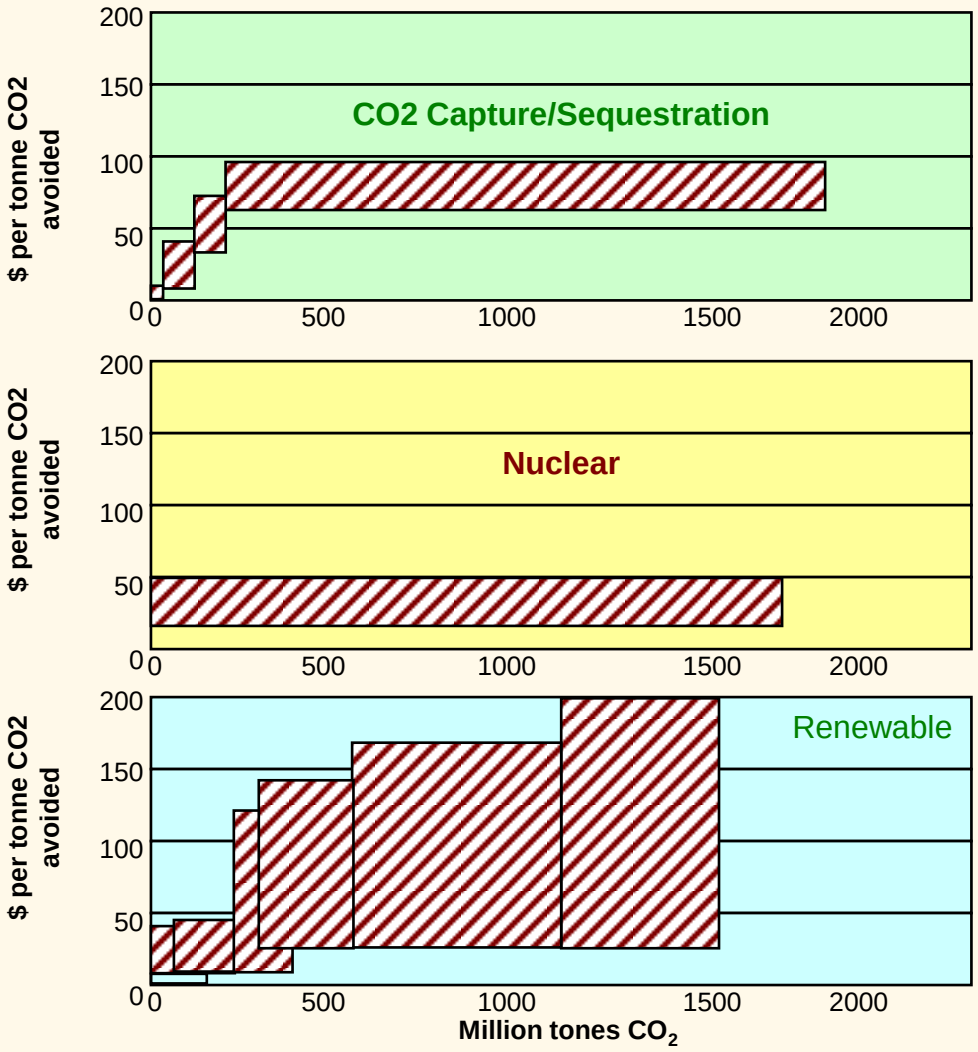


Figure: Comparison of CO_2 capture & Sequestration Technologies with other leading mid-to long-term option

1. Project Details:

a. ***Title of the project:***

"MODELING & SIMULATION OF CARBON RECYCLING TECHNOLOGY THROUGH CONVERSION OF CO2 INTO USEFUL MULTIPURPOSE FUEL"

b. ***DST File No.:*** ***DST /IS-STAC / CO2-SR-31 /07 Dt. 11-01-2008***

c. ***PI details*** Principal Investigator's): **Prof. P.B. Sharma, V.C., DTU, Delhi, Dr. V. K. Sethi, Director- UIT-RGPV, Bhopal, Dr. Mukesh Pandey, Dean, RGPV, Bhopal, Dr. J.P. Kesari, Prof. Mech., DTU**

Patron: Prof. Piyush Trivedi, Vice Chancellor, RGPV, Bhopal, M.P.

d. ***Date of start :*** ***1st April 2008***

e. ***Date of completion:*** ***30th June 2010*** **(II stage in progress)**

f. ***Total cost of project:*** **25.324 Lakhs**

Broad area of Research:

CO_2 SEQUESTRATION (Under the National Program on Carbon Sequestration – NPCS of DST)

Sub Area – Project Title: Modeling & Simulation of Carbon Recycling Technology Through Conversion of CO_2 Into Multipurpose Fuels.

g. Approved Objectives of the Proposal:

1. **To establish a pilot plant for CO2 sequestration and conversion in to multipurpose fuel.**
2. **To develop Zero Emission Technology Projects and recycle Carbon-di-oxide to add value to clean energy projects by adopting two pathways:**

- Sequester CO_2 and convert the same into fuel molecules.
- Use CO_2 to grow micro algae to produce Bio-diesel and Methane Gas.

3. **To develop mathematical & chemical models for CO_2 sequestration, Hydro Gasifier, Catalytic conversion & Algae pond systems.**

Methodology

Description of the Pilot Plant:-

Rated Capacity of the Capture of CO_2 : 500 kg/ day

Source of CO_2: Boiler of capacity 100kg/hr. steam & Biomass Gasifier of 10kWe

Solvent used for capture of CO_2 : Mono Ethanol Amine (MEA)

SOx & NOx Removal: Na H CO_3, NaOH & Lime.

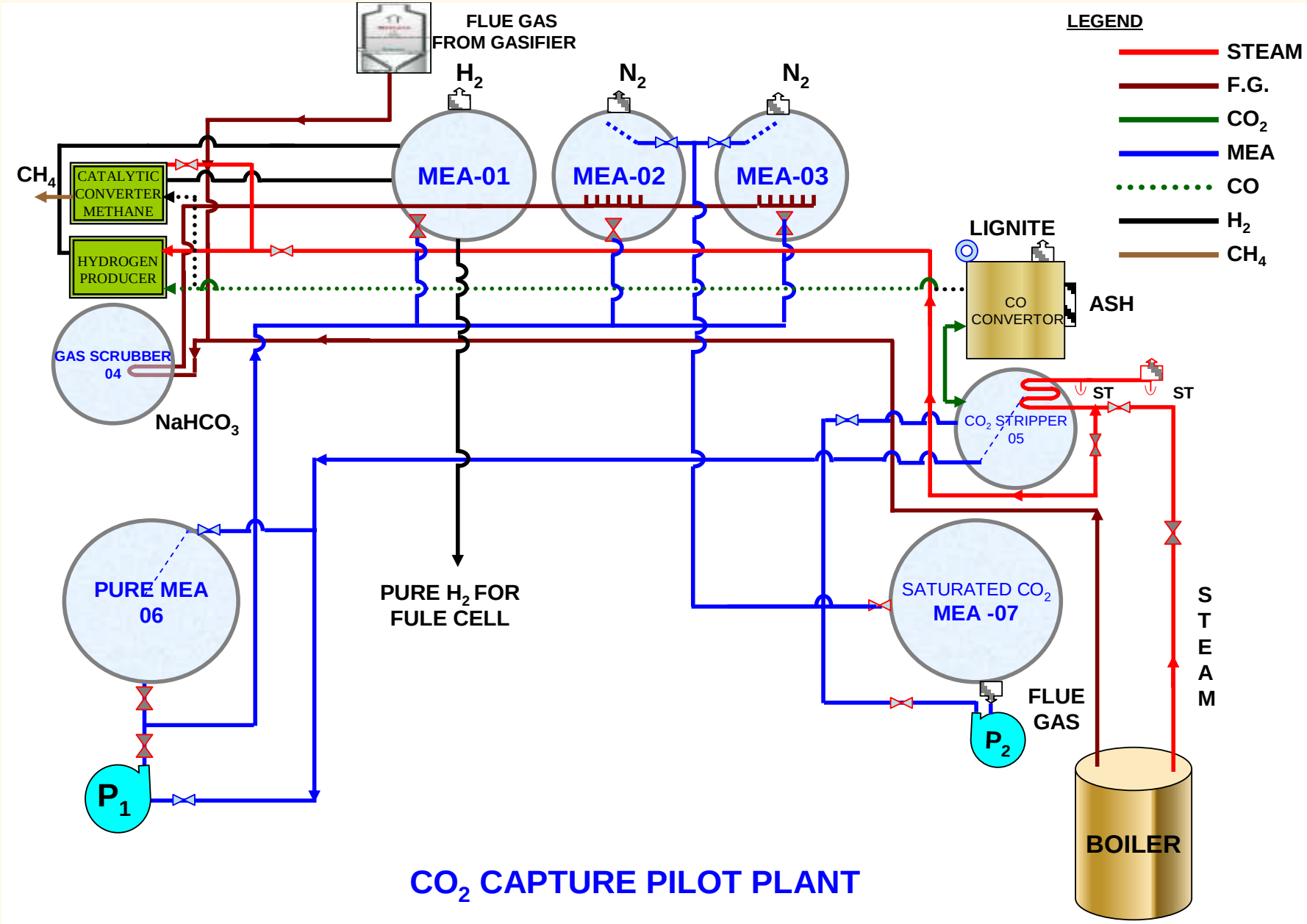
Catalytic Converters / Reduction Unit

- For Methane.... Input CO and H_2, Catalyst “R - 01 *

- For Hydrogen.... Input CO and Steam, Catalyst “R - 02 *

- For CO ... Input CO_2 and Lignite /charcoals

CO_2 Sequestration Pilot Plant installed under the DST Project



CO_2 CAPTURE PILOT PLANT

Scheme Diagram of CO_2 Capture Pilot Plant

2.Salient Research Achievements

The following four systems have been incorporated in the Pilot Plant:

1. **CO_2 Capture & sequestration system – Indigenous Development**
2. **Catalytic Flash Reduction of CO_2 using charcoal from gasifier/lignite. Production of Hydrogen from CO**
3. **Production of Methane using Catalytic Conversion process**
4. **Production of Algae from CO_2 Sequestration with Solar flux.**

- **This project revalidated the useful application of the Amine absorption system to strip the CO_2 from the flue gasses but also validated the data on its efficiency for a Power Plant.**

- **The simulation study further revealed that in a Thermal Power Plant, if a slip stream of the Flue gasses is recycled then a 30% reduction of CO_2 would be achieved by direct abatement and recycle would result in a decline of fuel consumption by at least 7% and thereby reducing the CO_2 emissions by about 36% in the most cost effective manner.**

Innovations:

- **Capture of CO_2 from Biomass and a Boiler on Pilot Scale and achieving capture efficiency of the order of 78%**
- **Production of CO in stable form and Water Gas shift reaction to produce fuel molecules like H_2**
- **Catalyst development to produce Methane from the captured CO_2**
- **Enhancing productivity of selected Micro-Algae for production of Bio- diesel**
- **Plant Cost optimization through in-house designing and erection work**

Long Term Application:

Deployment of the Technology to Actual Power Plants

Immediate Application

Green Energy Technology Centre (GETC) has been set-up for R&D and purpose

The pilot plant installed at RGPV can be utilized variety of application such as:-

- Study of CO_2 capture in Mono – Ethanol Amine (MEA) ranging from 1 molar to 3 molar solutions.
- Sequestration of CO_2 released from the stripper unit to variety of Algae and Development of lipid content for Bio-diesel production.
- The pilot plant can be used for recycling of CO in stable form to the boiler for reduction in Green Home Gas Emission.
- The pilot plant as well as table top plant shall be used for development of low cost catalysts for production of fuel elements like H_2, CH_4 etc.
- The plant is being used for academic purpose like M.Tech. Projects/ practical and dissertations for Ph.D.

THE ROAD MAP AHEAD

- Government of India has declared its policy on CO_2 abatement by the announcement and adoption of the 'National Action Plan on Climate Change'.

- It has also made voluntary commitment at the Copenhagen Summit that the Country shall decrease its Carbon Intensity by 20% by 2020 and 50% by 2050.

- The bulk of CO_2 is emitted by the Thermal Plants in the Power Sector. For EPA regulations to be implemented there have to be a road map as to how this can be done without major impact on the cost or efficiency of the Thermal Plants

Solution lies in…

- **The thermal plants in India have a thermal efficiency of 35% and an emission ratio of 0.90Kg/kWh of CO_2 emissions as published by CEA. The reduction of 30% intensity would translate to a decrease of 0.27Kg/kWh of CO_2 emissions i.e. below 0.63Kg/kWh CO_2 emissions by 2020.**

- **This decrease is possible by a combination of abatement and recycling measures. The CO_2 reduction by an Amine system of 30% CO_2 capture would mean a decrease of Thermal Efficiency by a minimum of 2%.**
- **Energy penalty because of CCS is a major issue**

Recycling of CO_2

- The CO_2 so captured needs to be either compressed to be used in Enhanced Oil Recovery or recycled. The better option would be that the same be recycled.

- The system additions to the existing thermal plants would be a two stage gasifier to use up this CO_2. This would help recycle the Carbon of the CO_2 and the treated/ converted CO would be re-fed into the Boiler by means of a Gas Burner.

The Chemistry of Recycling

Energy in various molecules:

- Carbon Dioxide production is exothermic reaction having energy (-) 393.5 kJ/mol there is no energy in this molecule after its formation and the value of the exhaust CO_2 is in fact zero. The CO_2 here in heat balance is seen as a waste, which it is.
- Hydrogen has a heat value of 141.8 MJ/Kg or the heat value would be 33875 kcal/Kg or in terms of power 1 kWh = 860 kCal would be 39.40 kWh/Kg.
- Like wise the Methanol has 22.7 MJ/Kg. this would mean a heat value of 5423 kcal/Kg or in terms of power would be equivalent to 6.30 kWh/Kg.
- Carbon monoxide has a heat value of 10.112 MJ/Kg, this would mean a heat value of 2416 kcal/Kg or in terms of Power would be equivalent to 2.8 kWh/Kg.

The Chemistry of Recycling

- The coal based power plant data for existing power plants to be retrofitted with CO_2 capture was studied; there are a number of projects using Amine Based System.
- For every 44 kg of CO_2 captured the CO produced would be 56kg with 12 kg of Carbon which has a heat value of 7840 kcal/kg or a total of heat of value of 94080 kcal.
- This would result in a total production of 56kg of CO which has a heat value of 2414 kcal and the total heat value of 1,35,184 kcal.
- In percentage terms it is 43.80% increase, but heat input to this endothermic reaction should be accounted for.
- The heat input (endothermic as %age of input heat value) of 21.92% should be accounted for i. e. 43.80 – 21.92 = 21.88%

THUS THE HEAT GAIN IS 21.88% IF WE PRODUCE CO FROM CO_2

Thus in nutshell

(A) PRODUCING CO FROM CO2 :-

- **21.88 % is the heat gain if we produce only CO from CO_2.**

(B) PRODUCING HYDROGEN FROM RECYCLED CO_2 :-

$$CO + H_2O = CO_2 + H_2$$

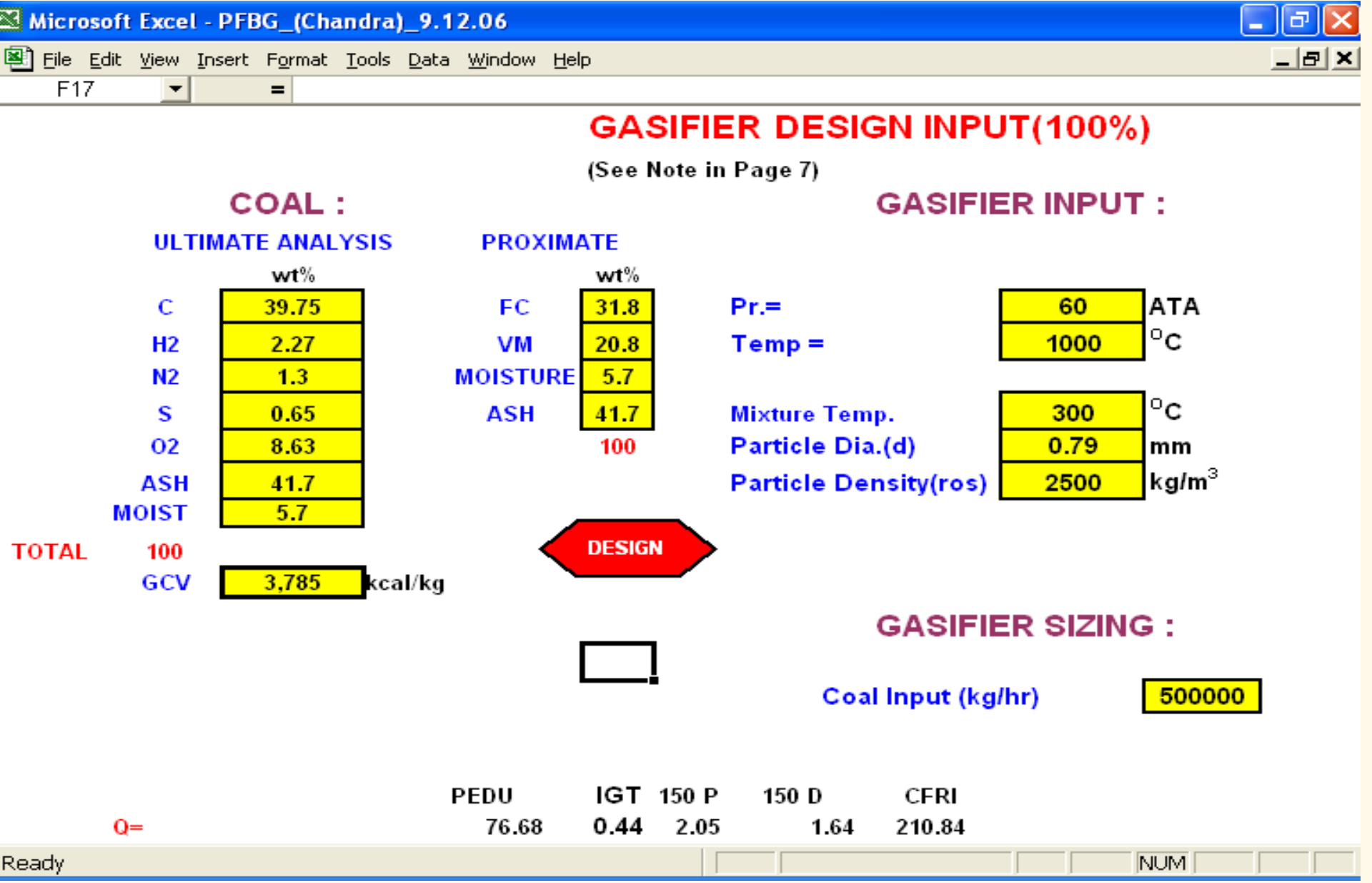
- **Net heat energy gain of 18.72%**

(C) METHANOLE PRODUCTION FROM RECYCLED CO2 :-

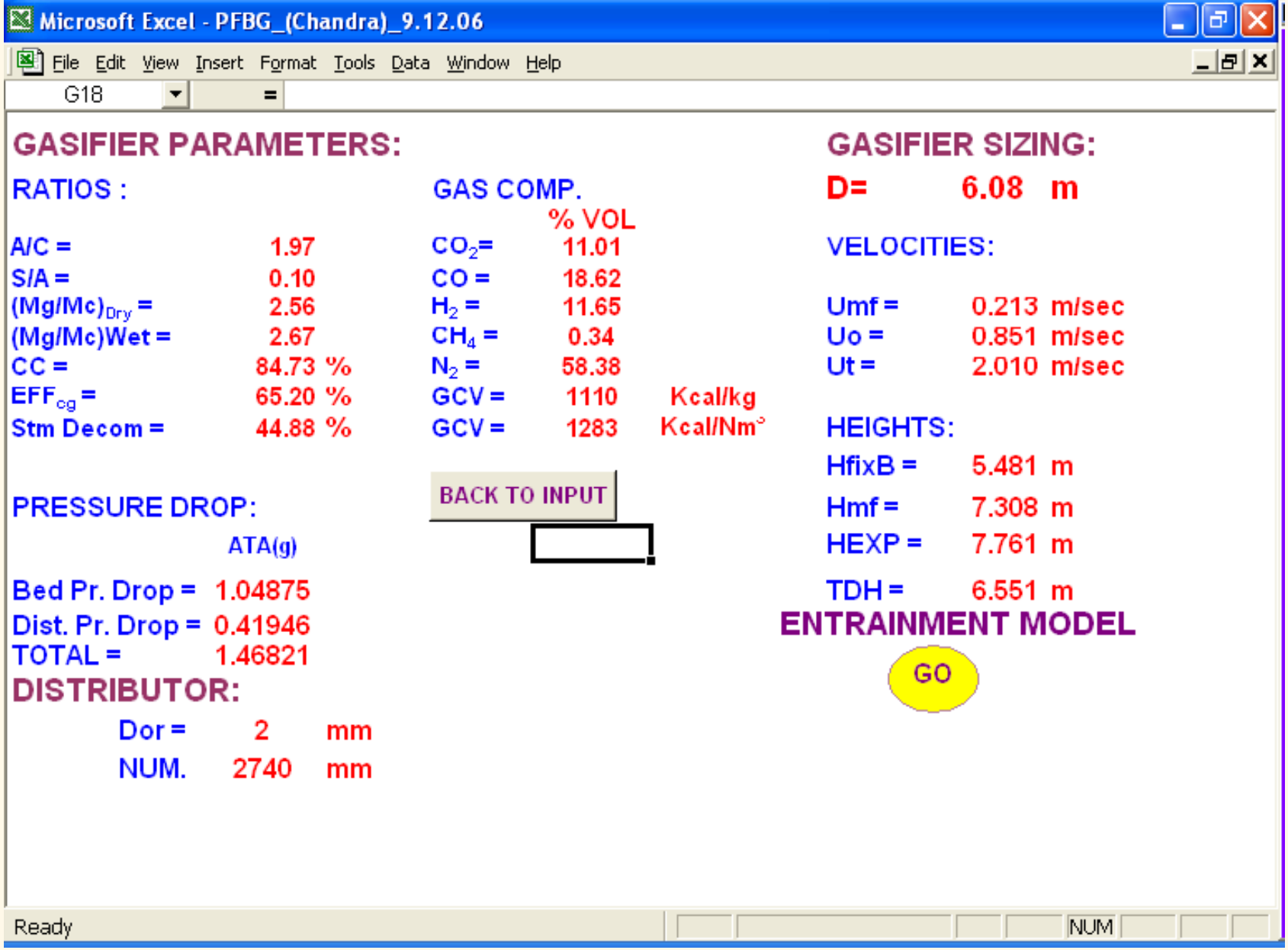
$$2H_2 + CO = CH_3OH$$

- **When using recycled inputs there is a net gain in Heat value terms of 14.58%**

(D) 30% CO_2 Capture & Recycling reduces 7.79% Coal



Gasifier Design - Input



Gasifier Design - output

Application Potential:

Long Term

- **Deployment of the Technology to Actual Power Plants of NTPC through BHEL / TOSHIBA or any other major player**

Immediate

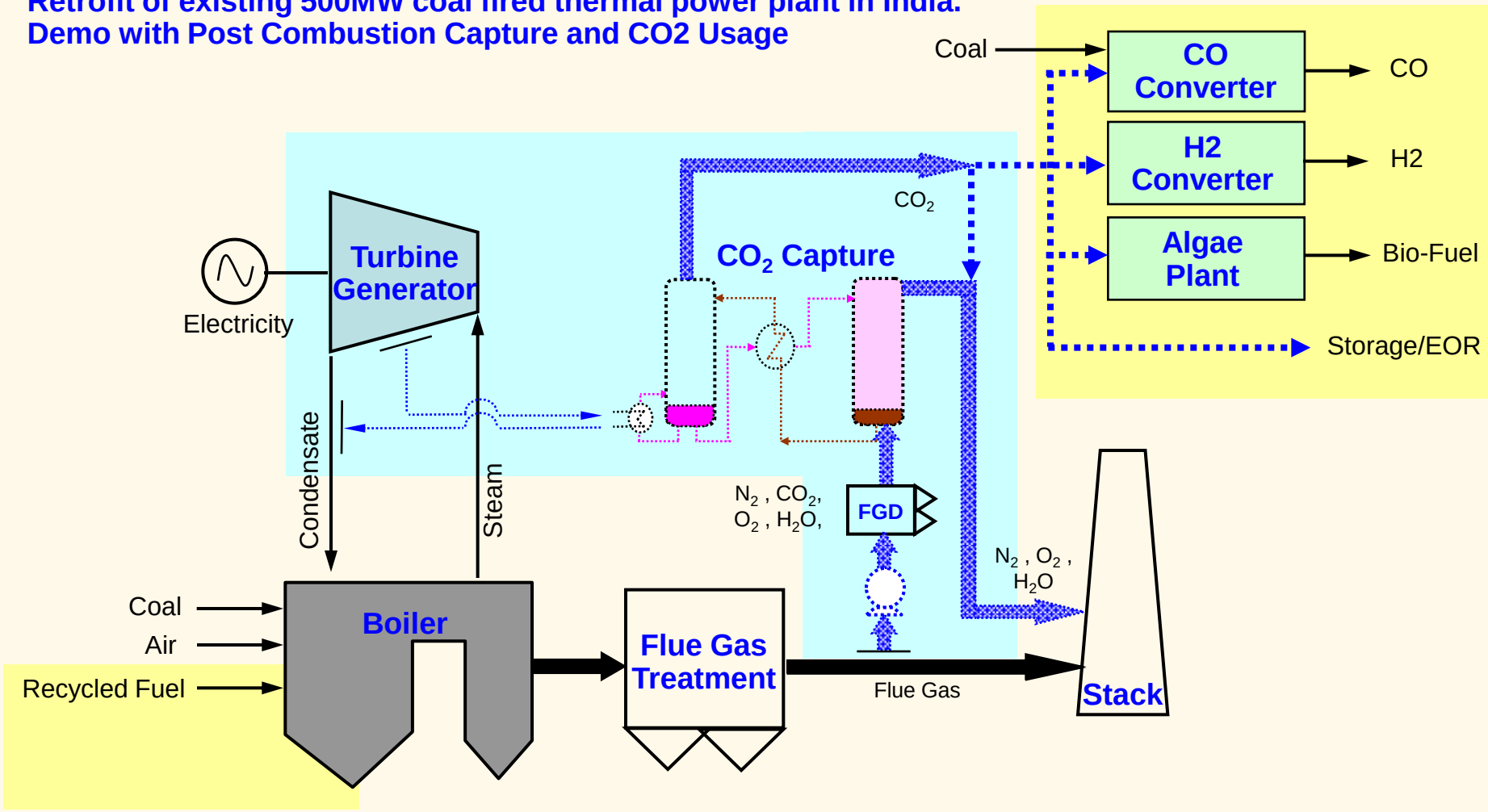
- **Green Energy Technology Centre (GETC) being set-up for Teaching & Research (M. Tech & PhD)**

Future action plan:

- **Efforts are underway to extend the scope of the process by incorporation a Coal gasifier and recycling of carbon through collaborative research and Distributive Research Initiatives (DRI) with Research Organizations and Power Industries.**

Schematic of Demo Project (Idea)

Retrofit of existing 500MW coal fired thermal power plant in India.
Demo with Post Combustion Capture and CO2 Usage

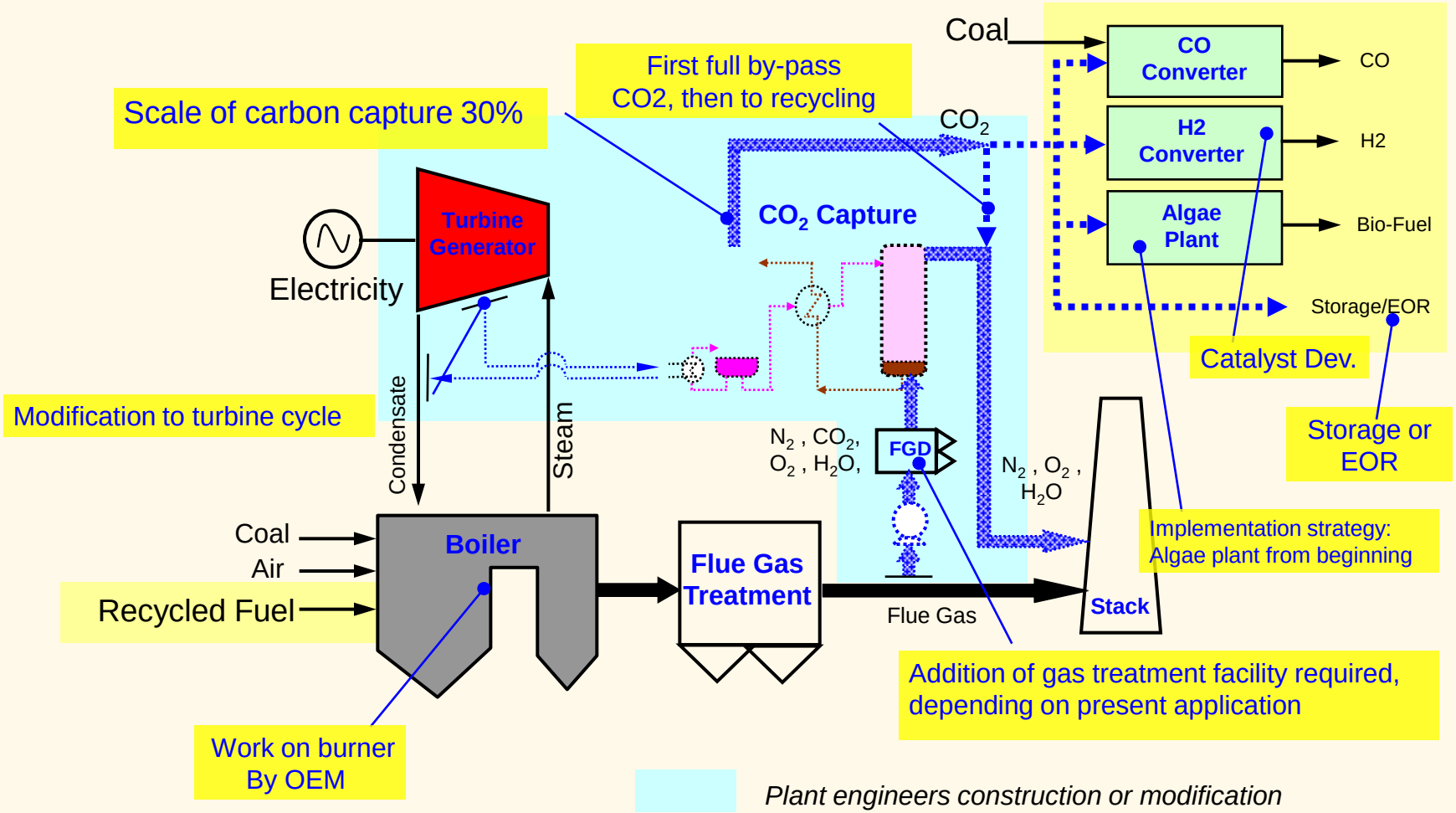


Plant engineers construction or modification

RGTU specifies requirements – Industry partner engineers construction or modification

Demo Project –Strategy Plan

- **Retrofit of existing 500MW coal fired thermal power plant in India.**
- **Demo with Post Combustion Capture and CO2 Usage**



If the technology of CO_2 Capture Recycling & Sequestration is applied on a 500 MW Coal based Thermal Power Plant with 30% capture we will get benefits like:-

- **Levelised Cost of Electricity or LCOE on a long term basis calculated for retrofitting would be Re. 1.05 per kWh. The energy penalty for 30% abatement would be 3% and the Loss in generation due to use of steam in MEA process would be 15000 kWh/hr for 30% CO2 reduction. The Capital cost would be Rs. 1.50 Crs. per MW.**

- **The Net emission reduction when the Recycling of CO2 is used in tandem with abatement would be down from 0.9kgmCO2/kWh to 0.63kgmCO2/kWh.**

Thanks