# *Indian Perspective on Carbon Sequestration*

**Technical Committee Meeting CSLF**

**Oveido, Spain**

**29th April'2K5**

***National Thermal Power Corporation Ltd***
***India***

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***P.hD, FNAE***

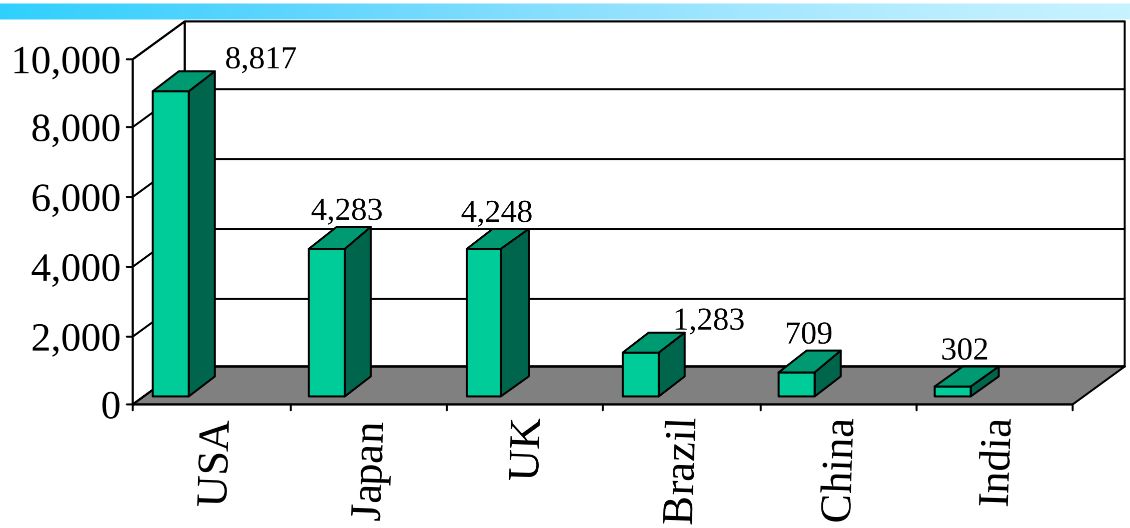
***ED (Energy Technologies)/ NTPC***

# Part- A

# Indian Energy Scenario- oil deficient

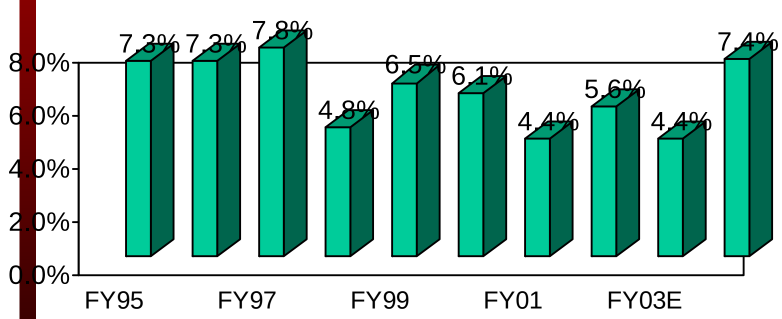
**need for Electricity Interface**

## India has a very low energy consumption intensity …

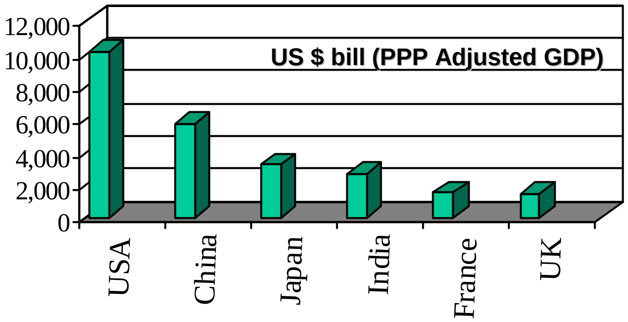



## But the economic development trends indicate multifold rise …

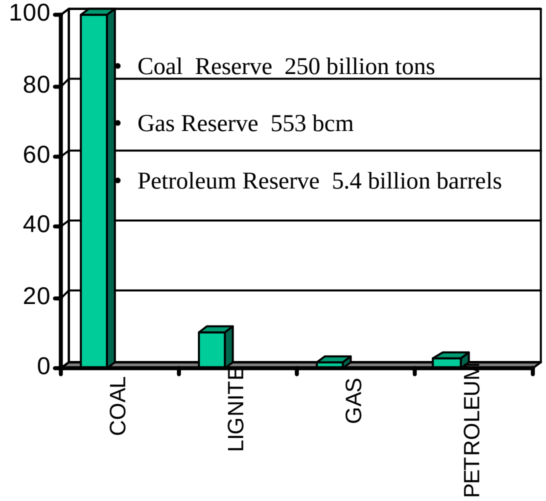
### consistent GDP growth…




### made us fourth largest economy

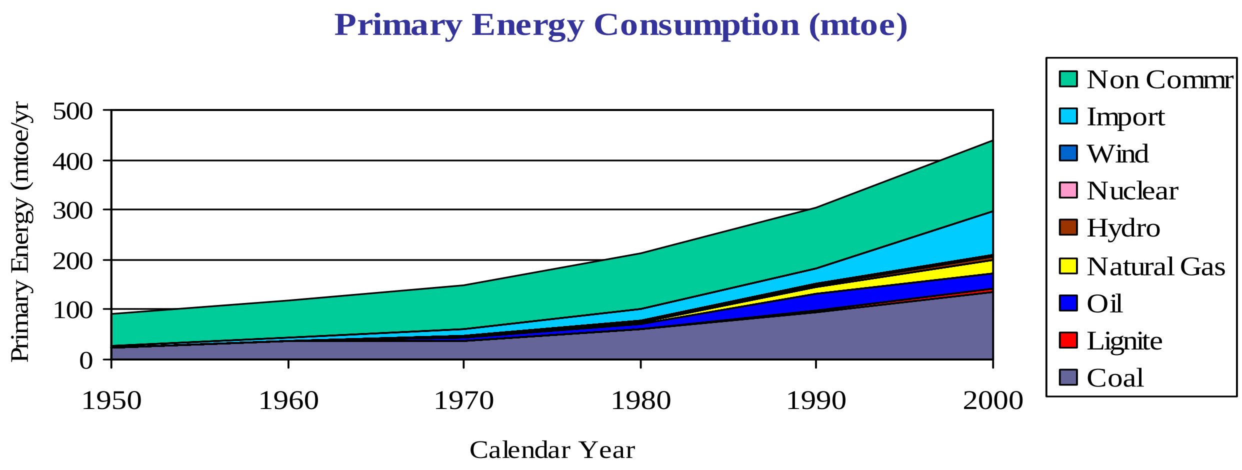


**The country has plentiful energy sources marked coal superabundance and weak hydrocarbons…**



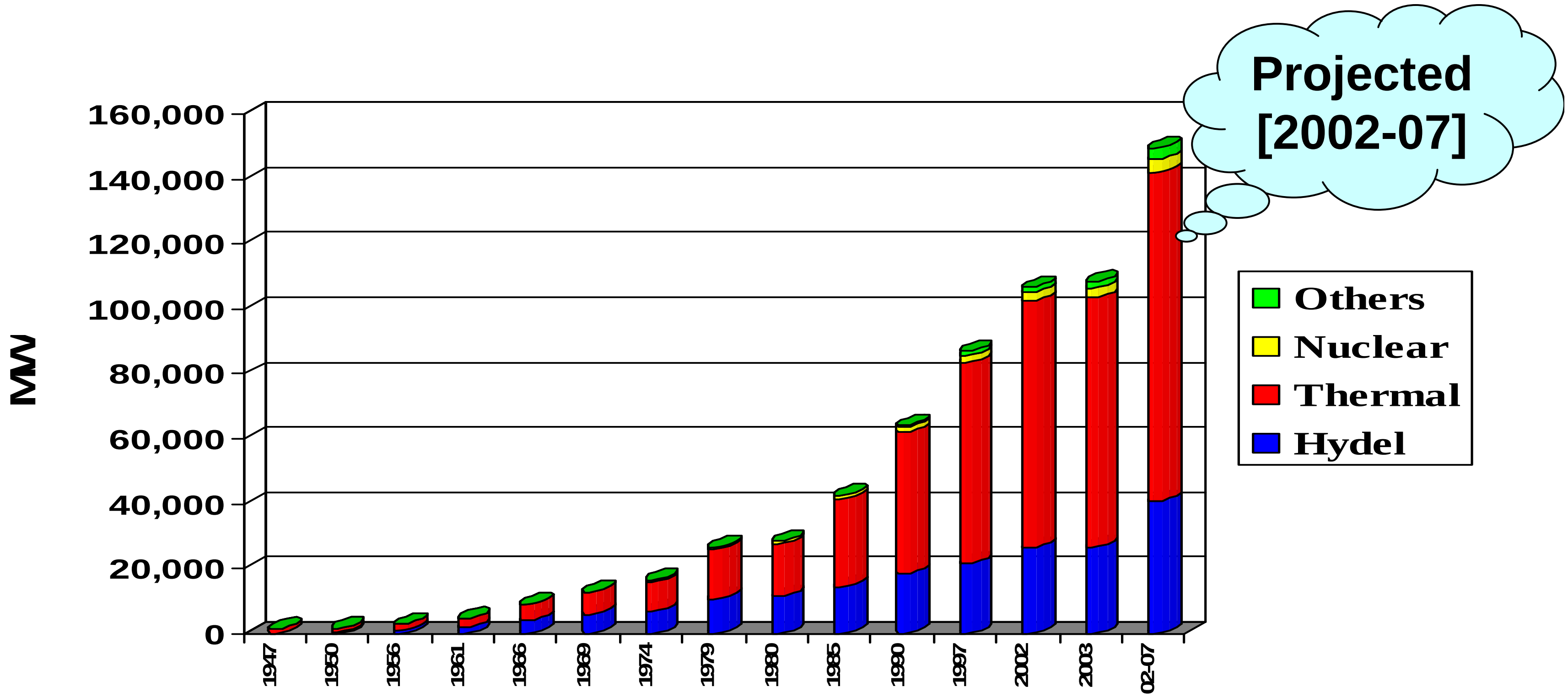

Balance Energy Basket
- Solar
- Wind
- Biomass
- Fuel wood
- Hydro
- Geothermal

**The energy consumption pattern is marked by high use of non commercial energy and oil imports…**



# Indian Power Scenario

- Phenomenal growth: From 1362 MW after independence in Dec'47 to 1,04.917 MW in March'02
- 6th Rank in total consumption of commercial energy
- Future Growth: 1,49,525 MW by Year 2007




- However, Per capita energy <300 kgoe (World avg~1500 kgoe)
- Energy shortage of 11.5% and peak demand shortfall of 18%.

# Indian Power Scenario

- **Power Mix: 71% comes from thermal and 25% from Hydro.**
- **In the domain of Thermal, it is 59% from Coal & 10% from Gas.**

## *The Fuel*

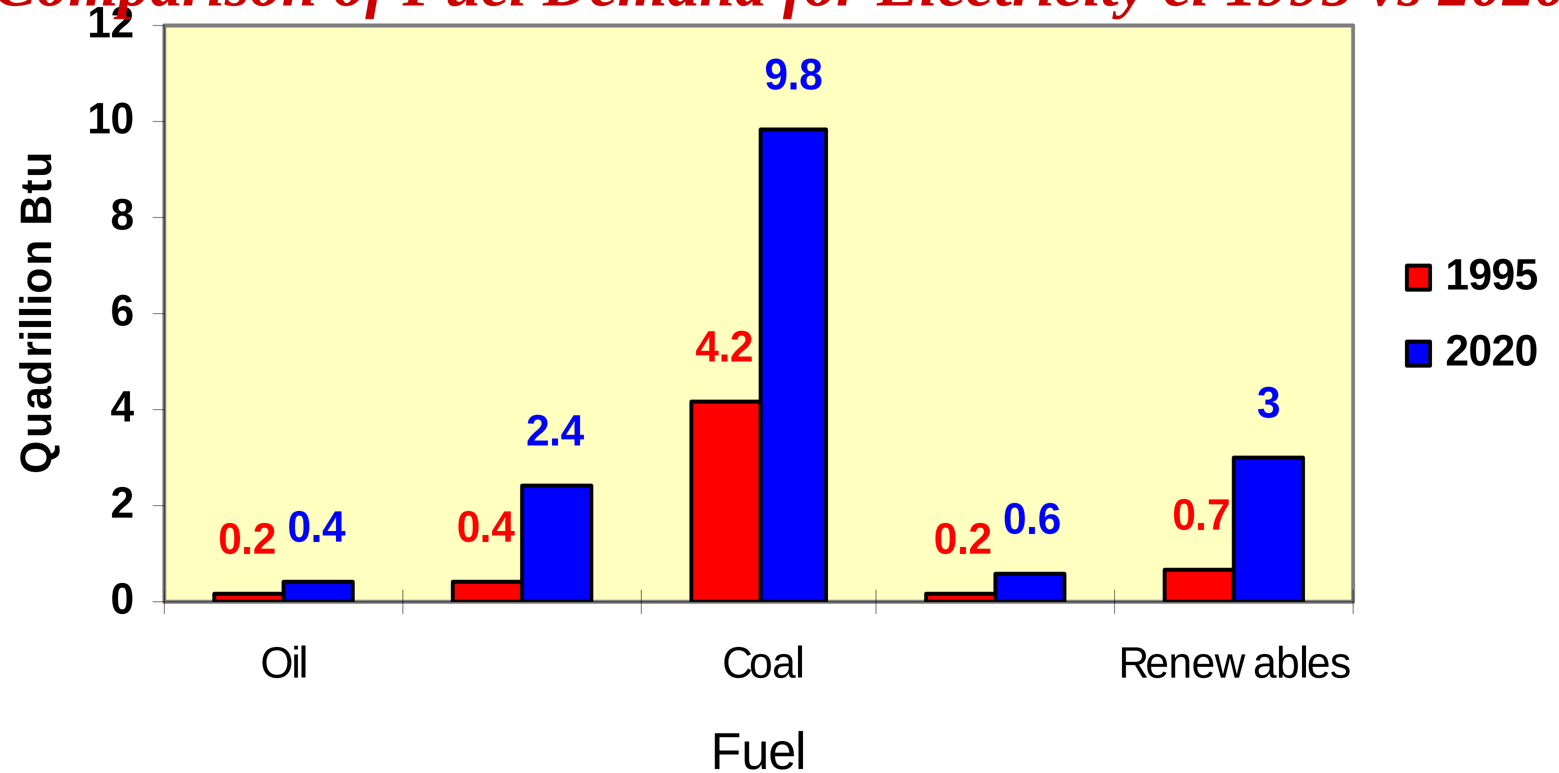
- **Coal remains the most important fuel for power industry.**
- **New Gas wells are being found, but it is unlikely to substitute coal by any significant number.**

## *Indian Coal - Some Highlights*

- Total Reserves - 211 Billion T
- Proven Reserves - 82 Billion T
- Current production - 300 million p.a
- Coking Coals - 15% (Rest – Non-coking)
- Major Coal Mining States - Bihar, Jharkhand, Chatisgarh , Orissa, MP, W. Bengal

# Indian Power Scenario

## Comparison of Fuel Demand for Electricity el 1995 vs 2020




## *Indian Coal: The Issues*

- Very High Ash Content: 40% - 50%
- Low Heating Value: 2500 – 4000 Kcal/Kg
- High Alfa Quartz Content
- High Abrasive Index
- Very Low Sulfur Content

# Energy Carbon Conflict

## *India' strategy for managing Energy-Carbon Conflict*

- **Efficiency enhancement technologies (EIDM, Waste Heat, MALAE cycle etc.)**
- **IGCC big development**
- **Carbon capture technologies**
- **Carbon storage technologies**

*The bottom line is that cost impact on power production must be minimised. This calls for huge investment in R&D and international support*

# Carbon capture, transport & fixing (CTF)

1. Carbon capture technologies contribute about 67% of the total cost. Balance being shared by transport and fixing technologies. The cost impact must be less than 10%.

2. Carbon capture technologies are highly IPR driven and mechanism for international collaboration needs thorough policy framework.

3. Developing nations like India with good intellectual Prowess, needs funding support for R&D

# *Carbon Emission Reduction Technologies*

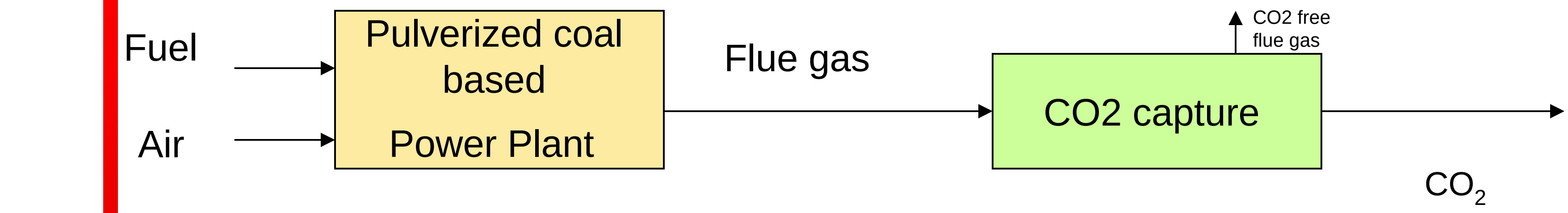
## Efficiency Enhancement

- Combustion efficiency improvement in conventional power plant
- Low grade heat utilization
- IGCC
- Super critical & Ultra super critical technology
- Advanced class gas turbine
- Hydrogen technology & Fuel Cell

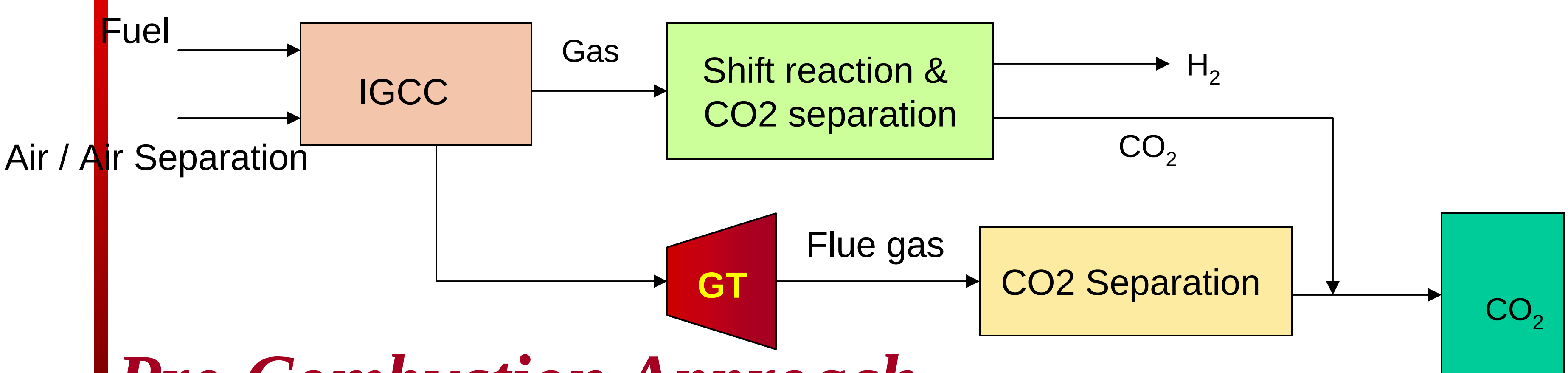
## $CO_2$ Capture

- Pre-Combustion
- During Combustion
- Post Combustion

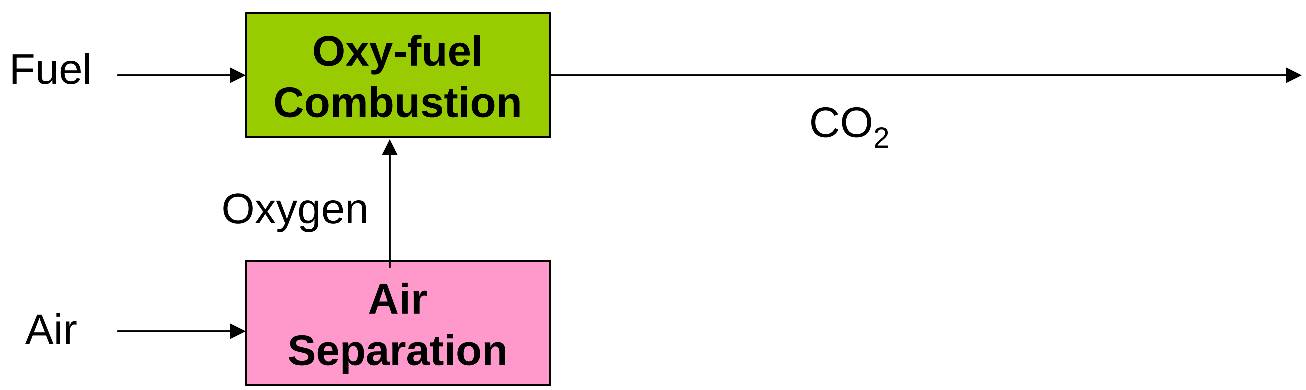
# Carbon capture : pre & post




## *Post Combustion approach*




## *Pre-Combustion Approach*



# *IGCC Technology*

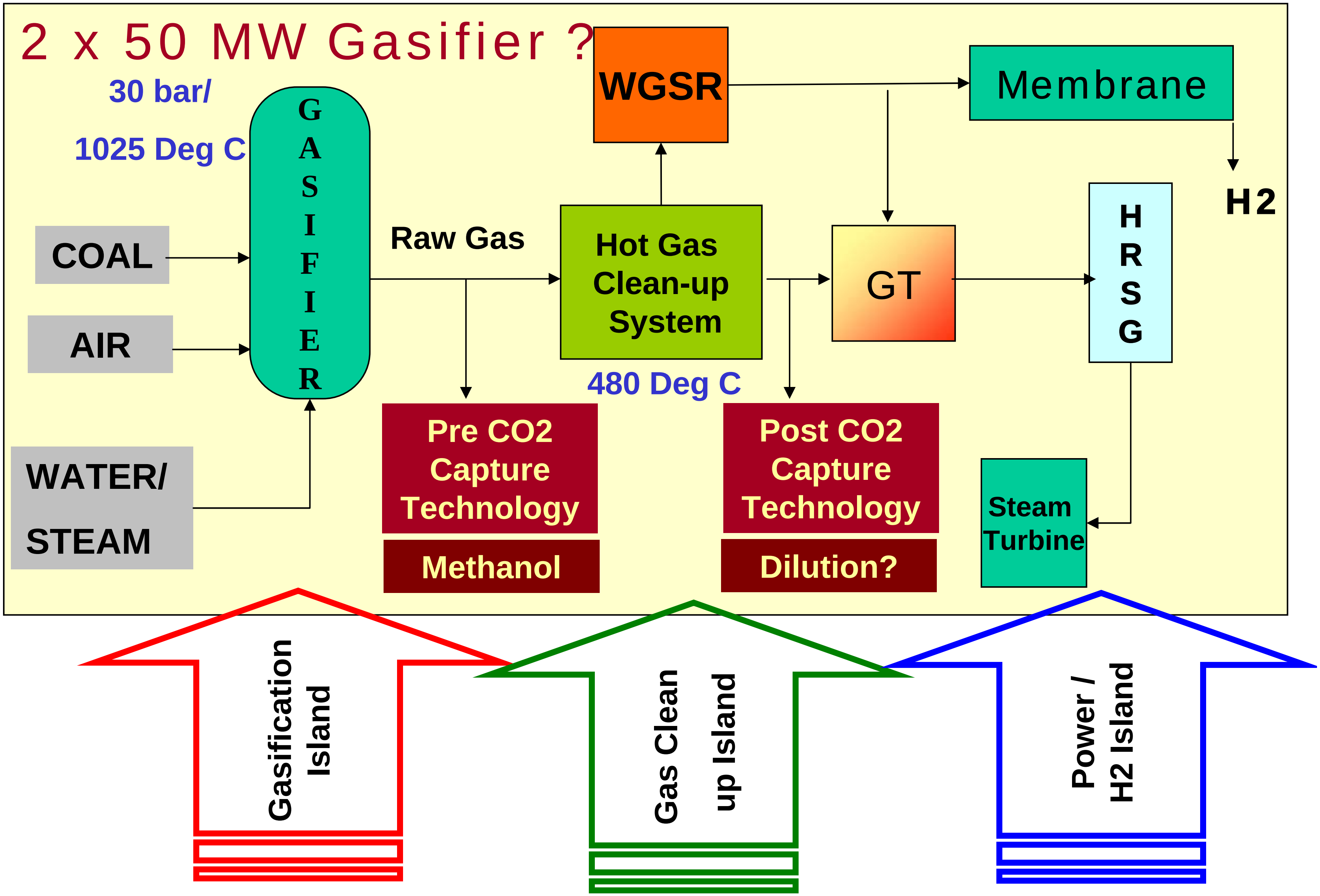
## *IGCC: Elegant in CO2 capture*

**Tough challenge given India's poor quality coal & poor coal gasification kinetics**

## *Challenges:*

- **Gasifier design**
- **Hot gas clean up**
- **Air blown gasifier needs to be changed over to oxygen blown – Need for development of efficient air separation membranes**

# *IGCC – Block diagram*



# Carbon Sequestration: Post Capture Technologies

## *Capture technologies:*

- **Amine Process – Whether a Global Solution?**

  **Removal of SOX and ash becomes a mandatory requirement even if not required otherwise.**

- **NOx, Oxygen and High temperature remains as other concern.**
- **Other technologies need to be explored**

## *Other processes worth consideration (Huge R&D efforts called for)*

- **Adsorption**
- **Membrane contactor and ionic liquids**
- **Bio chemical process development**

# *Adsorbents for $CO_2$ recovery from flue gas*

## *Low temperature*

- Zeolites Molecular Sieves
- Activated Carbon
- Carbon Molecular Sieves
- Modified Silica
- Ion Exchange Resins
- $\pi$-Complexation
- Activated alumina

## *High Temperature*

- CaO, $Ca(OH)_2$
- Hydrotalcite
- Lithium Zirconate

# *Adsorbents for CO2*

## $CO_2$ adsorption capacity for various zeolite determined from single bed adsorption breakthrough

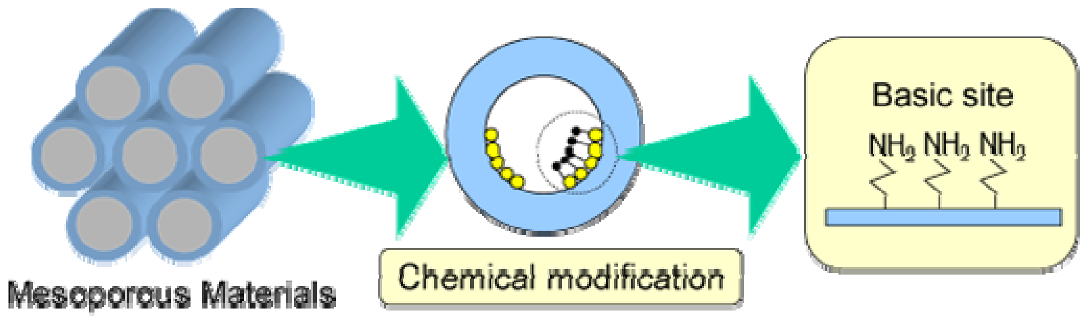
| Adsorbent | $SiO_2/Al_2O_3$ | Adsorption capacity, $ml_N$ /g $CO_2$ | $N_2$ | $CO_2$ Selectivity |
|---|---|---|---|---|
| NaX | 2.5 | 14.88 | 2.68 | 122 |
| CaX | 2.5 | 11.87 | 1.66 | 151 |
| LiX | 2.8 | 11.77 | 2.27 | 108 |
| BaX | 2.5 | 7.81 | 1.63 | 100 |
| KA | 2.0 | 1.96 | 1 | - |
| CaA | 2.0 | 11.1 | 3 | 78 |
| NaA | 2.0 | 5.02 | 0.22 | 440 |

10g adsorbent in SS column with 10,, id and 250mm height; CO2=5% and N2=95% a t 298K and 1.0 dm3 min-1. Desorption by vacuum

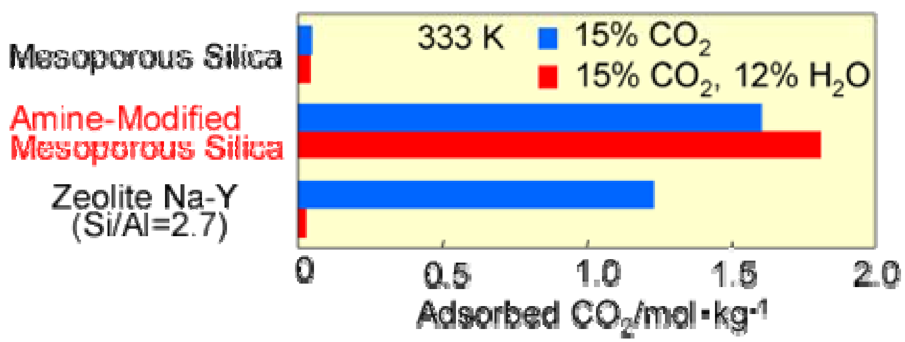
Y.Takamura et al., Sep. Purification Technol., 24, 519, 2001

# CO2 Capture Technologies

## Surface-fictionalized Mesoporous Silica as CO2 adsorbents




**Novel adsorbent for $CO_2$ separation**




**Adsorption capacity of amine-modified mesoporous silica**

In conventional $CO_2$-PSA using zeolite, a dehumidification process, which consumes about 30% of total energy, is necessary, because water vapor is adsorbed more strongly than $CO_2$ on zeolite surface. Amine modified mesoporous silica show selective adsorption for $CO_2$ in the presence of water vapor

# 2. Membrane Process

- Modular in nature: Thus easy scale up, process optimization & applicable at remote areas.
- No regeneration required
- Low maintenance
- Selectivity of $CO_2$ / $N_2$ = 20 - 40 (PEI, PSF, CA)
- Membrane Plasticization: Lowering of selectivity
  - High pressure $CO_2$
  - Heavy hydrocarbons and wax : protection required
- Significant methane quantities are lost in permeate
- $CO_2$ Recovery: Two stage system: cost intensive

# *3. Hybrid Process: Membrane Contractors*

- Combines advantages of Membrane + Absorption
- Diffusion occurs through gas / liquid interface
- SLM demonstrated with base solutions, several amines & other $CO_2$ sorbing liquids
- High gas / liquid contact area
- (HF packing density = 500-1500 $m^2/m^3$) => less voluminous
- Not disturbed by flow rates
- Gas / liquid flow rate can be independently tuned
- Foaming eliminated

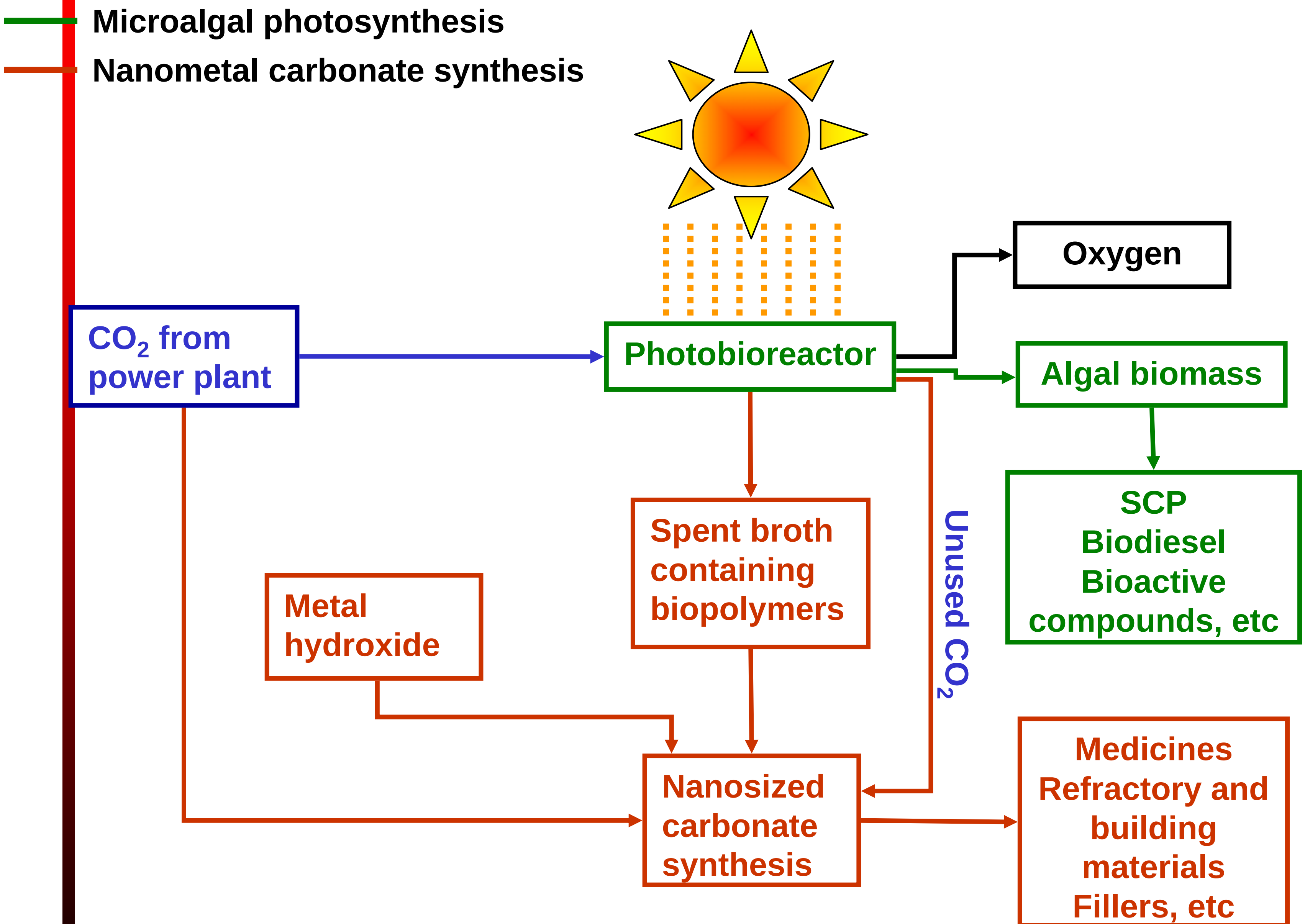
*Why Ionic liquids?*

- Avoid instability of SLM caused by loss of carrier solution
- Evaporation at high temperature and trans membrane pressure
- Selectivity of $CO_2$ / $N_2$ as high as 400 can be obtained

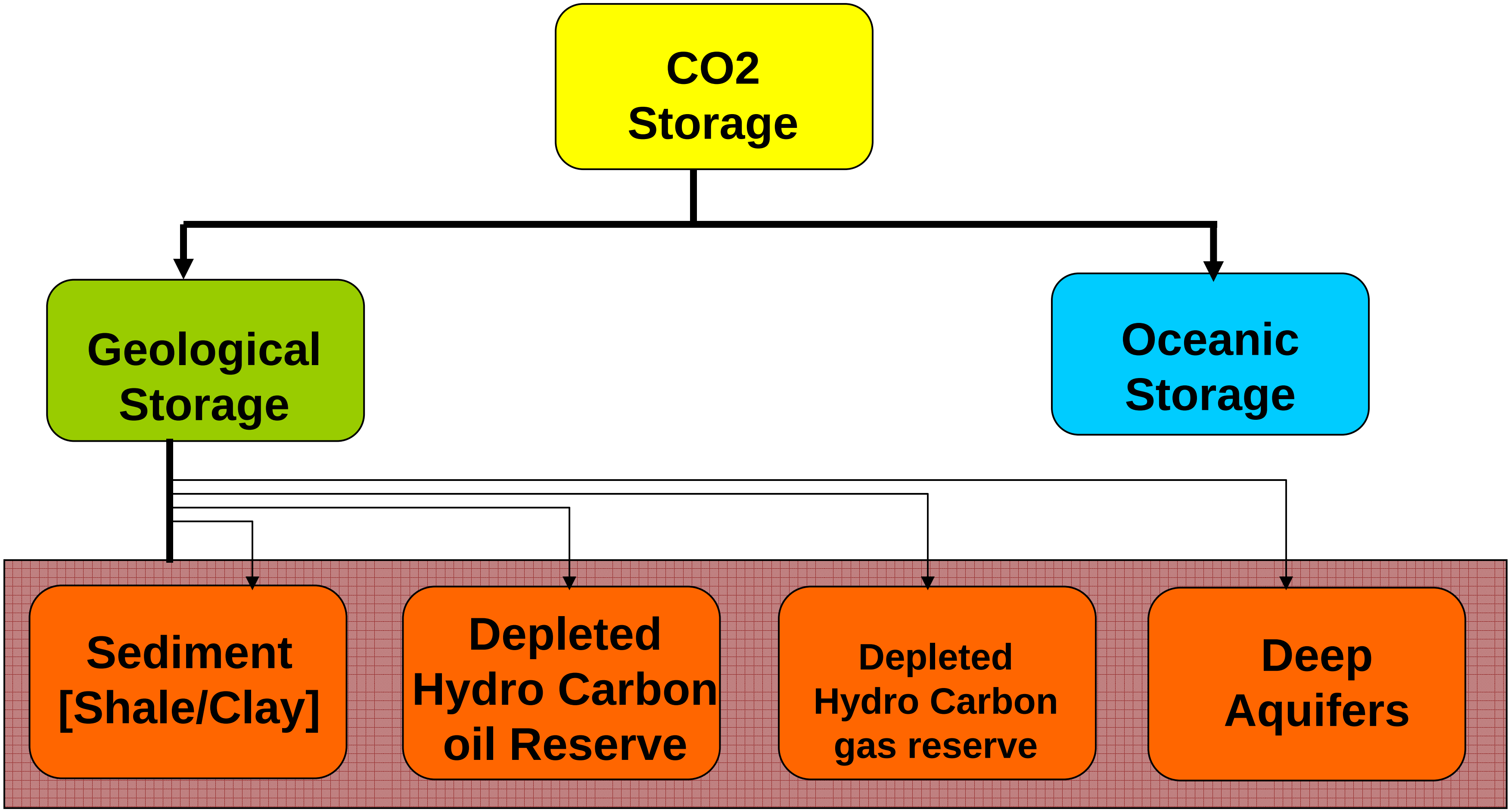
# Ionic liquids: General properties

- Organic salts composed of cations and anions
  -Cations: Based on Imidazolium, pyridinium (org. compounds)
  -Anions: $BF_4^-$ , $CF_3COO^-$ ,$PF_6^-$ ,$NO_3^-$ ,$EtSO_4^-$
- Physical State: liquids at ambient
  - Disruption of crystal packing overrides Vander Waals interactions
  - Increasing chain length in cation decreases melting point
- Density: 1.1 - 1.6 gm/cm$^3$ at ambient
- Viscosity: several tens to 100 times higher than of water at RT
  -Longer alkyl chain in cation increases viscosity
  -Affected by structure and basicity of anion
- Non volatile / Negligible vapor pressure
- Good thermal stability
- Green solvents : Good solubility

# 4. INTEGRATED BIO CHEMICAL PROCESS



# CO2 Storage Technologies




*Issues:*

- **Fault in Sediment Layer**
- **Mapping for the Geological Reserve.**

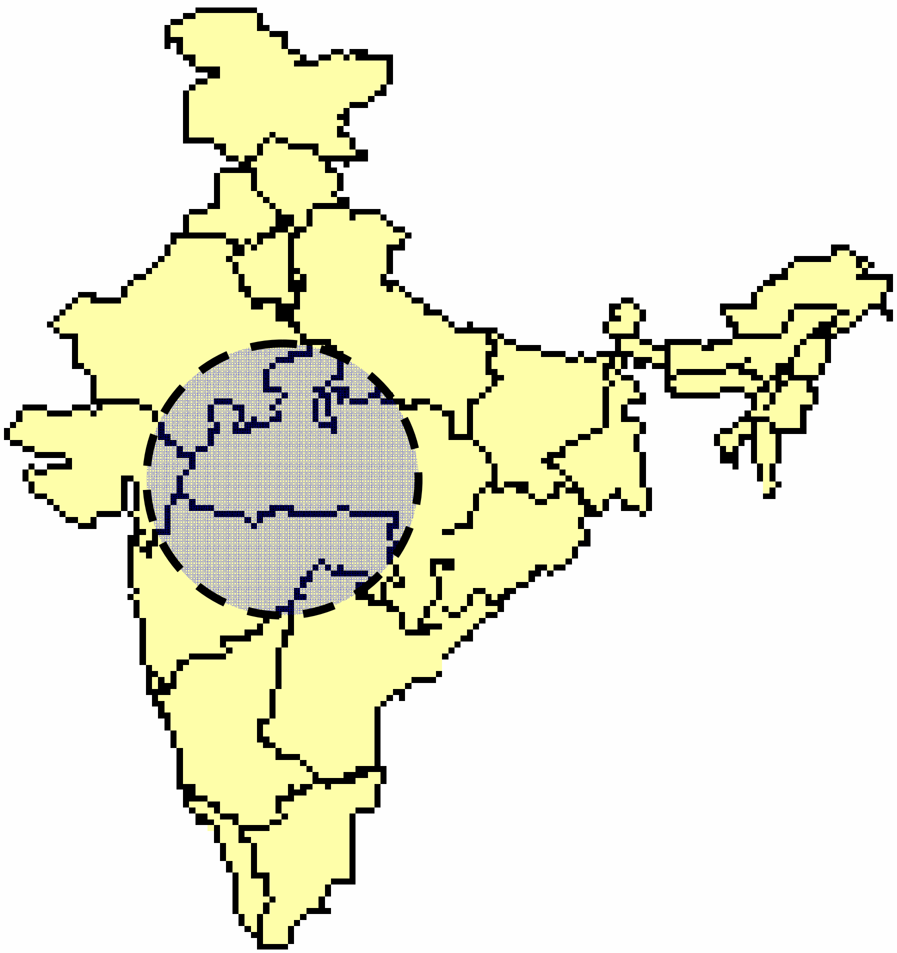
# CSLF Projects (new proposals from India)

## *CSLF project listing from India*

- **Demonstration of capture, injection and geological sequestration of CO2 in sediments in Basalt formations of India**
- **Development of high temperature sorbents for in-situ capture of CO2**
- **Bio chemical process**

# CSLF Projects

***Project-1:*** ***Process Demonstration of capture, injection &Geological sequestration of CO2 in sediment in Basalt formations of India***



- India has a sub-trapean sedimentary basinal area of 400,000 sq.km giving a potential for sequestration of about 100 Giga Tons of $CO_2$.
- In the project, the experiment shall comprise of selecting a basalt area in western India with a trap thickness of 600 meters and injecting $CO_2$ of 150 Tons/Day for 10 days through a 6” bore hole.

# CSLF Projects

**Project-2:** ***Development of high temperature sorbents for in-situ capture of CO2***

- Short listing of Meso porous Sodium / Potassium Bi-Carbonate for high temperatureCO2 caapture.
- Design and development of Reactor.

# CSLF Projects

## *Project-3:* *Bio Chemical Process*

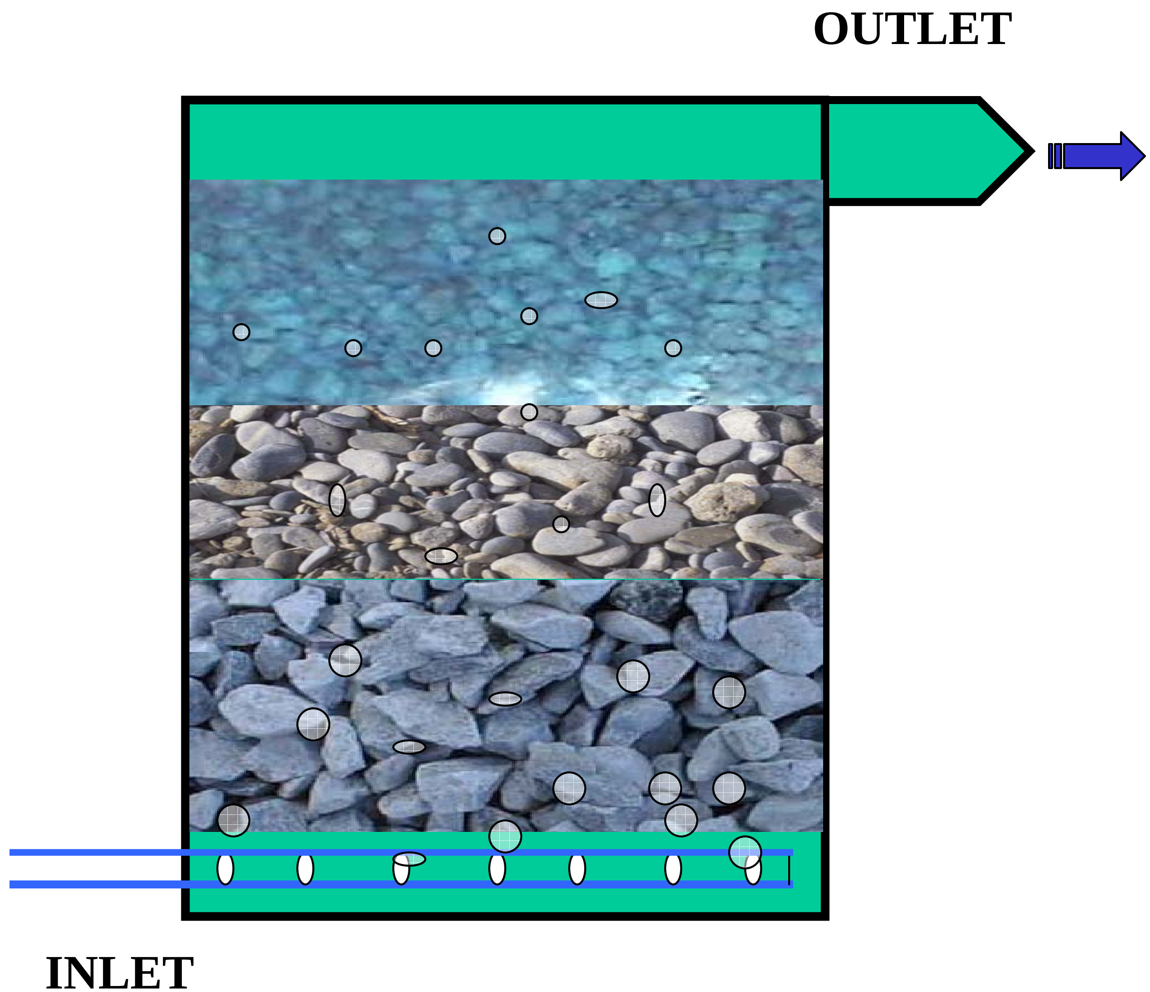
- Extraction of Carbonic Anhydrous enzyme and transportation of CO2 enzymitic.
- Design & Development of Photo Bio-Reactor for CO2 conversion into Bio-mass.
- Design & Development of Anoxic Reactor for conversion to Methane.

## Design of near natural microcosm for evaluating effects of $CO_2$, $H_2$, Zn and/or biotin on microbial community structure in biofilms

1. $CO_2$
2. $CO_2$ + $Zn^{2+}$
3. $CO_2$ + biotin
4. $CO_2$ + $Zn^{2+}$ + biotin

**BIOFILMS**

$CO_2$/ Zn/ biotin



# CONLUSIONS

1. Capture technologies which are amine centric must also focus on non amine processes

2. CSLF may consider a combined Bio chemical process. India can take a lead position.

3. India would like to register three projects for CSLF recognition

***"When you really want something to happen, the whole universse conspires to help you to achieve your dreams"***

…….. The Alchemist

*by Paulo Coelho*

# Thank

# *You*

# *Presentation Synopsis*

**A. NTPC**
**A Fact File**

**B. Energy-Carbon Conflict**
**The Need for Carbon Sequestration**

**C. ‘Challenges in Carbon Capture’**
**Indian Conditions in Variance with the World**

**D. Existing Process technologies**
**Economically Unviable for Power Plant Applications**

**E. New Technologies**
**Identifying technologies**

**F. Networking for Success**
**partners in virtual research**

# Part-A

# NTPC

## A Fact File

# *Genesis & Vision of NTPC*

***NTPC was set up in 1975 in the central sector to bridge the widening gap of demand and supply of power in India.***

## NTPC Vision

**"To be one of the world's largest and best power utilities, powering India's growth"**

# NTPC-The Premier Power Company

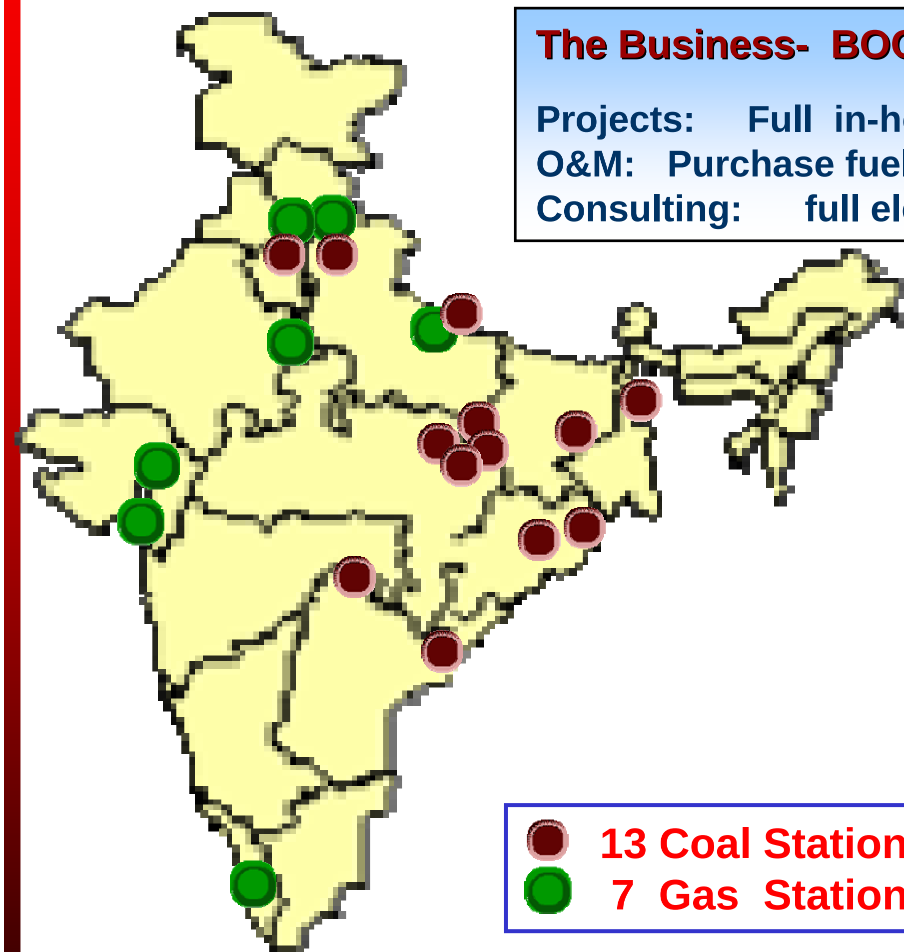
## Present Generation Capacity is 22,249 MW

| | (Nos.) | CAPACITY (MW) |
|---|---|---|
| **NTPC OWNED** | | |
| COAL | 13 | 17,980 |
| GAS / LIQ. FUEL | 7 | 3,955 |
| TOTAL | 20 | 21,935 |
| **OWNED BY JVCs** | | |
| COAL | 3 | 314 |
| GRAND TOTAL | 23 | 22,249 |

In addition, NTPC also manages Badarpur Thermal Power Station (705 MW ) of GOI in Delhi.

# NTPC Today- Lighting 1/4th of India

**One of the largest thermal generator in the World- Data Monitor UK**



**The Business- BOO thermal plants**

**Projects:** Full in-house implementation
**O&M:** Purchase fuel to bulk power sale
**Consulting:** full electricity value chain

13 Coal Stations
7 Gas Stations

| NTPC- CAPACITY PROFILE (MW) | | |
|---|---|---|
| Capacity | Present | 22,249 |
| | Constrctn | 5,000 + |
| | Active | 9,000 + |
| Fuel Mix | Coal | 17,000 + |
| | Gas | 4000 + |
| Technology | Conv- Sub | 500/200 |
| | CCPP-GT | 80-150 |

**NTPC is surging ahead to add another 20,000 MW and become 40,000 MW company by 2012**

# New Capacity Addition- Rendezvous 2012

*(All Figures in MW)*

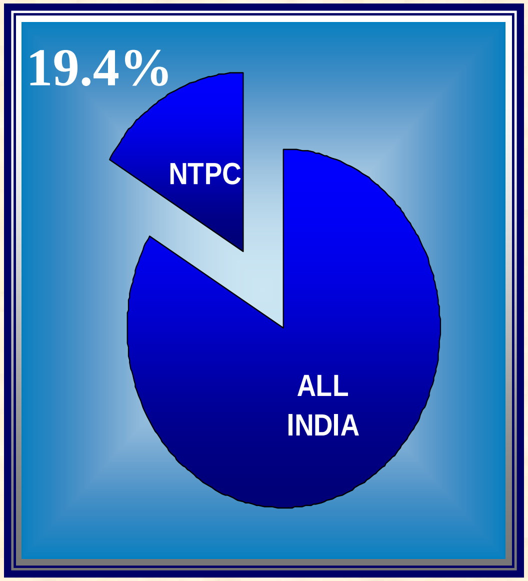
| Projects | Target | Commissioned |
|---|---|---|
| **X Plan**<br>Awarded/On-going<br>Joint Venture Projects<br><br>**Total** | <br>8370<br>1000<br><br>**9370** | <br>2000<br>-<br><br>**2000** |
| **XI Plan** | **11558*** | **-** |
| **TOTAL(X & XI PLAN)** | **20928*** | **2000** |

* Further around 5000 MW of hydro projects have been identified for capacity addition during XI/XII Plan periods.

# *NTPC- A Major Player in Indian Power Sector*

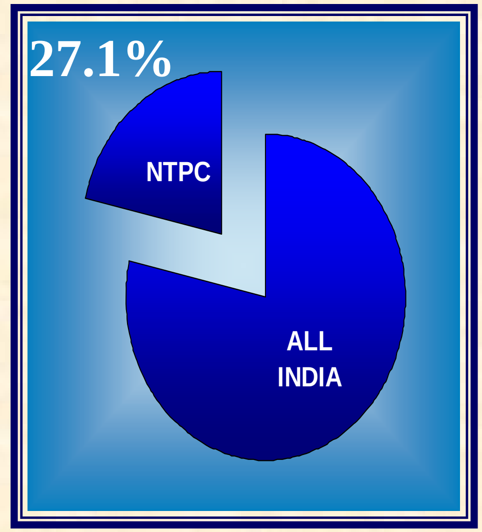
**TOTAL CAPACITY AS ON 31.03.2004**

NTPC
21,749
MW.
19.4
%
of
All
India
112,058
MW




**GENERATION 2003-2004**

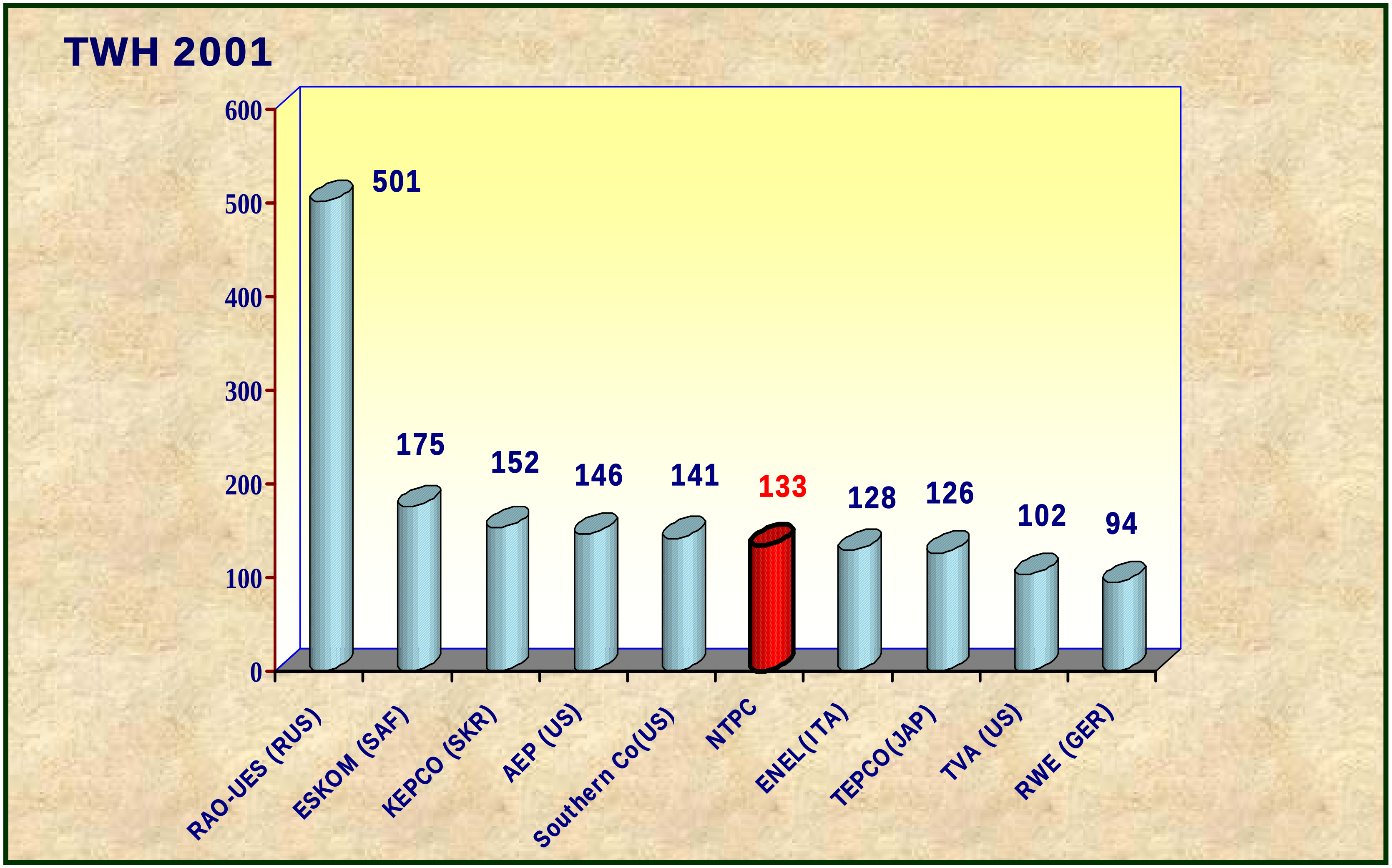
NTPC
149
BUs.
27.1%
of
All
India
558
BUs




***NTPC contributes more than one-fourth of India's total power generation with less than one-fifth capacity.***

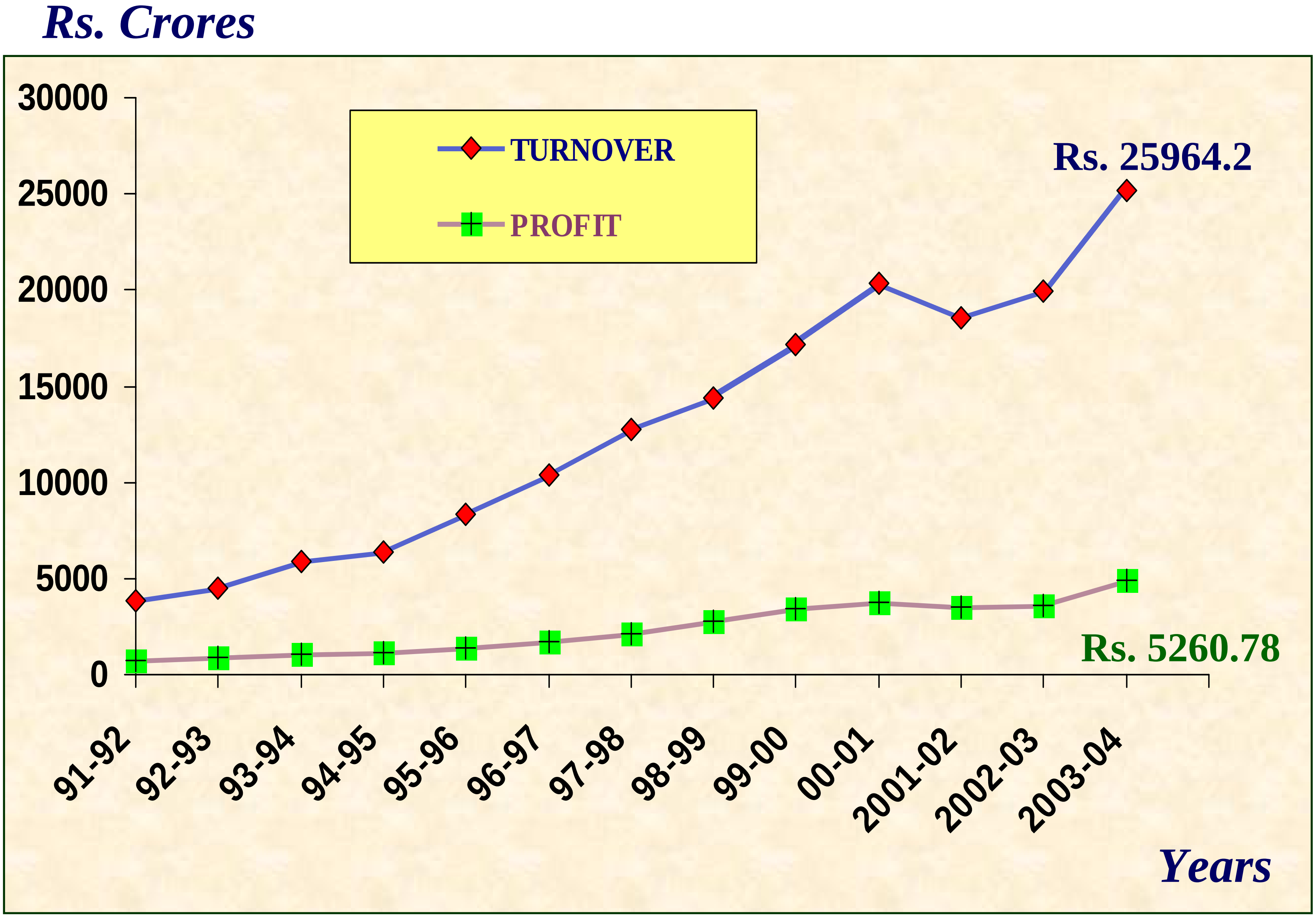
# Global Stature

## Sixth Among the Top Ten Global Thermal Generators




*Source: A.T. Kearney*

# Financial Performance



# NTPC - 2017

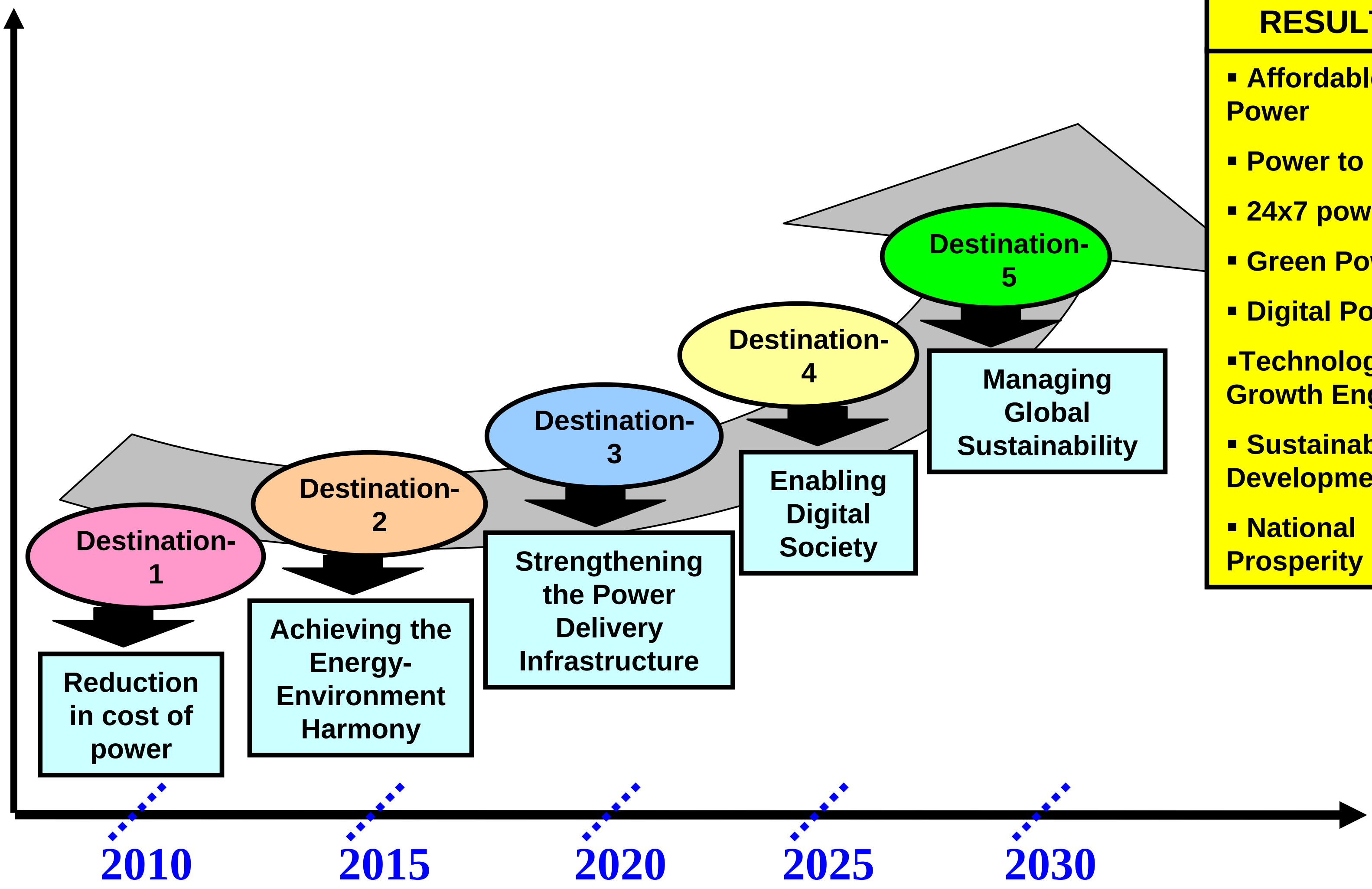
***In summary, NTPC would be a leading power utility in the world by 2017, in line with its current vision***

## NTPC in 2017…

**Fortune 500 company**

- **An Indian MNC with presence in many countries**
- **Diversified utility with multiple businesses**
- **Amongst top five market capitalisation in the Indian market**
- **Group turnover[1] of over Rs. 1,400 Bn with 30000+ employees**
- **Setting benchmarks in project construction and availability and efficiency**
- **Have a strong research and technology base**
- **Loyal customer base in both bulk and retail supply**
- **Preferred employer**
- **A leading corporate citizen with a keen focus on executing its social responsibility**

# The Destinations




**KEY RESULTS**

- Affordable Power
- Power to all
- 24x7 power
- Green Power
- Digital Power
- Technological Growth Engines
- Sustainable Development
- National Prosperity

# Part- B

# Energy-Carbon Conflict

## The Need for Carbon Sequestration

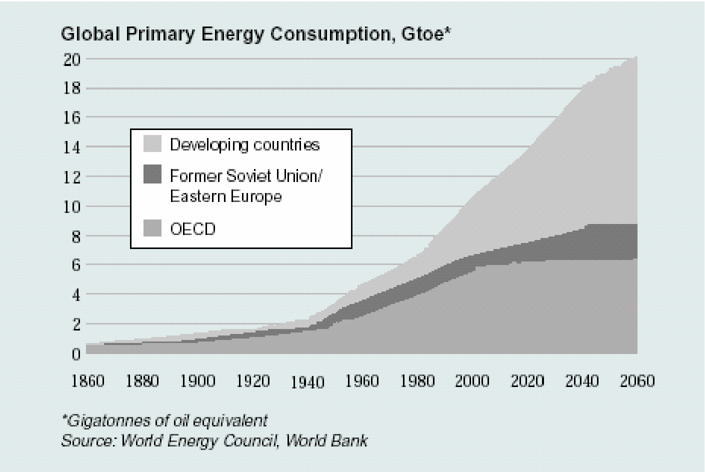
# Global Development :Shape of the Things to Come

## Global Scenario - 2050

| World Benchmarks- Global Energy System | 2000 | 2020 | 2050 |
|---|---|---|---|
| Population (billion) | 6.2 | 8 | 10 |
| Primary Energy, Gtoe/yr | 10 | 13 | 17 |
| Electricity Fraction of primary energy (%) | 0.38 | 0.5 | 0.7 |
| Electricity Consumption (trillion kWh/yr) | 13 | 28 | 60 |
| Electricity Generating Capacity (thousands of GW) | 3 | 5 | 10 |
| Maximum Carbon Emissions (GT per year) | 7 | 8 | 10 |

## India - 2050

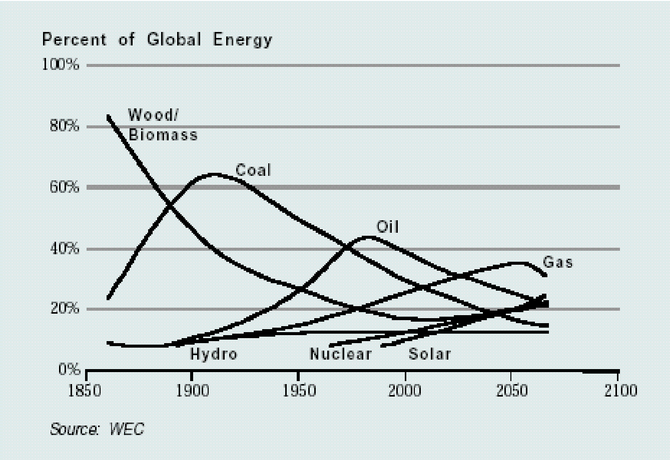
- Population: 1.5 billion
- Per Capita GDP: US$ 17,000/-
- Electricity Requirement: 5400 BUs
- Required Capacity: 10 Lac MW




**The world is predicted to become more and more dependent on electricity**

# The Energy-Carbon Conflict

- World-wide, including India, fossil fuels- coal, oil & gas- are main source of primary energy
- Though, alternate sources shall be developed- their deployment shall take a while
- Coal is expected to be main source of energy in foreseeable future

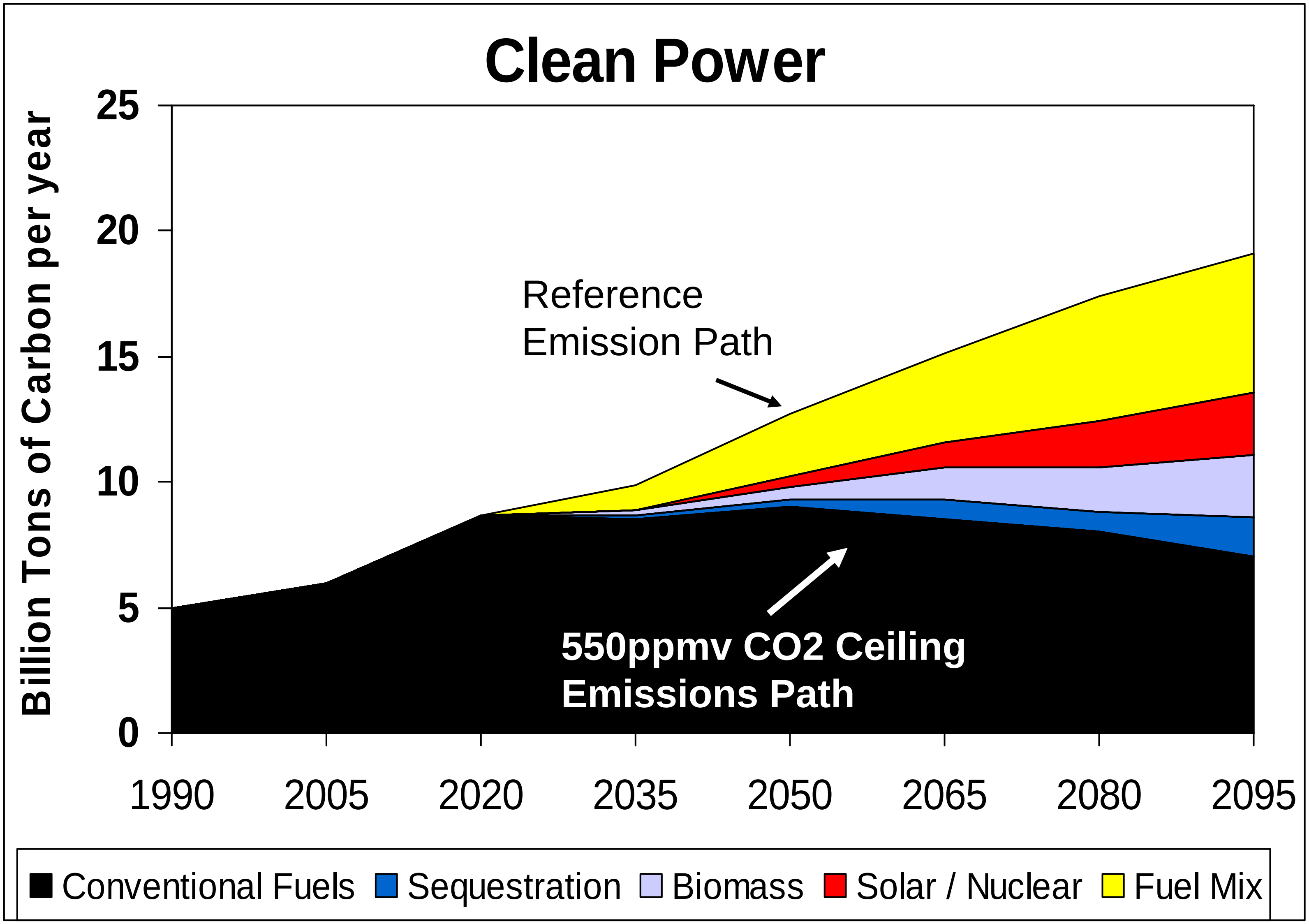



- **Combustion of Fossil fuels result in emissions of $CO_2$, a green house gas**
- **$CO_2$ concentration has increased from 280 ppmv to 368 ppmv in the last century.**
- **'Global Warming' is one important environmental issue today**

- *With status-quo, the $CO_2$ concentration shall increase to 1020ppmv by 2100*
- *The Average Global Temperature shall increase by 1.5-5 Deg C*

**Global warming turnaround is necessary**

**The turnaround is to be driven by new Technological innovations**


Clean Power
Billion Tons of Carbon per year
25
20
15
10
5
0
1990
2005
2020
2035
2050
2065
2080
2095
Reference
Emission Path
550ppmv CO2 Ceiling
Emissions Path
Conventional Fuels
Sequestration
Biomass
Solar / Nuclear
Fuel Mix

# Climate Change : Technologies that fill the gaps

**New Technologies**

**-IGCC, PFBC & other end –use efficiency**

**-Plant improvement**

**-Bio mass,Nuclear & Renewables**

Technologies for carbon- constrained world

-Capture , Transport & fixation

- Tree plantation & soil carbon enhancement

Technological break throughs

-ZEPP

-LT water splitting

-CO2 capture under ambient conditions

# The Energy-Carbon Conflict

- There are three option to control the $CO_2$ emission without severely or negatively changing the standards of living:
  - Increase in energy efficiency
  - Switching over to less carbon intensive source of energy
  - Carbon sequestration

**Major steps for carbon sequestration:**

- **C**apture -$CO_2$ separation from flue gases
- **T**ransport -Probably in liquid form at high pressure
- **F**ix -Back to mother Earth- storage in geological formation

**The Separated gas may also be used for:**

- Use for enhanced coal bed methane [ECBM] recovery
- Use for enhanced oil recovery [EOR]
- Making value added products

# Part- C

# Challenges in Carbon Capture

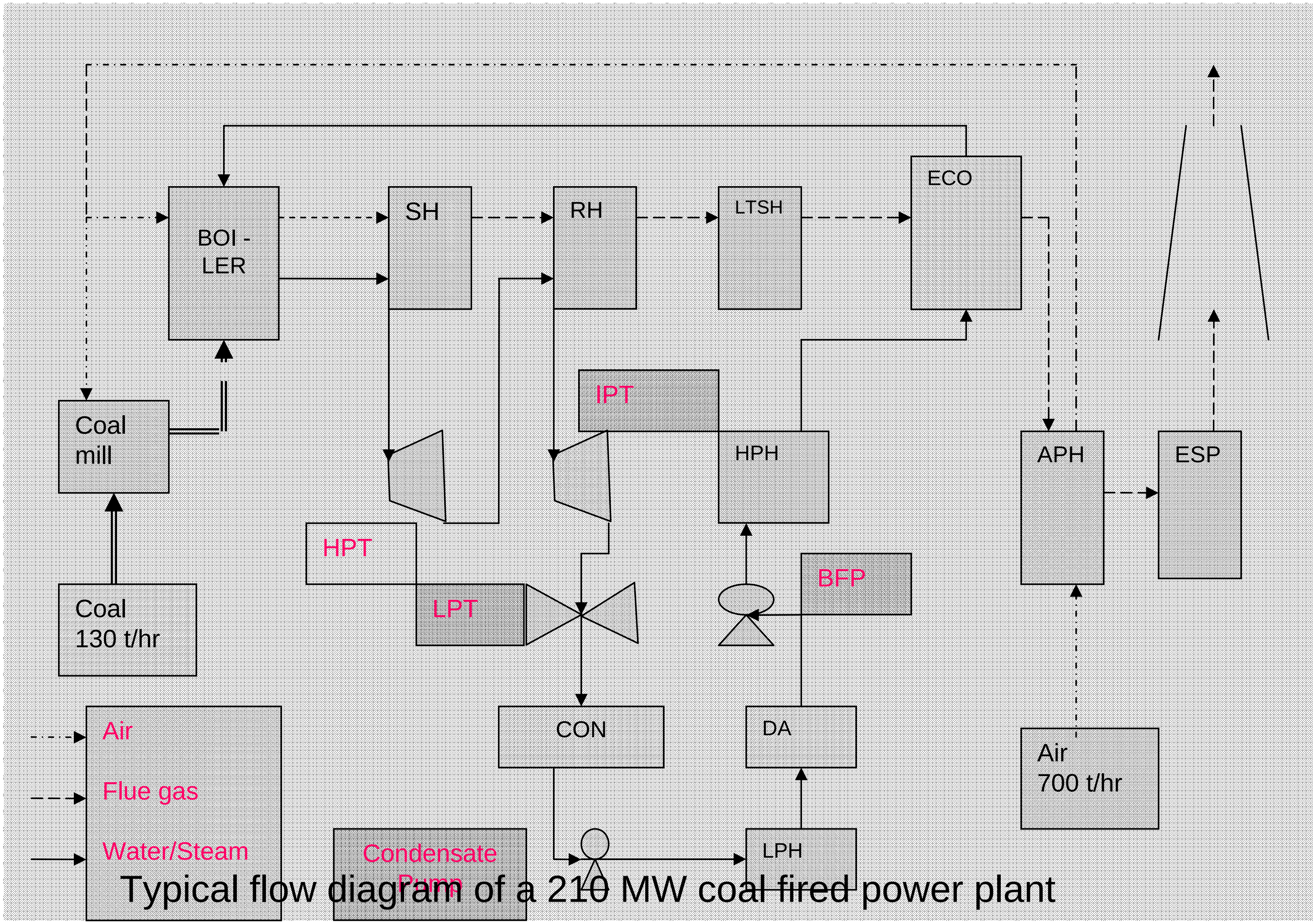
## Indian Conditions in Variance with the World

# *Challenges in Carbon Capture*

## Typical parameters for a 210 MW  Indian Coal Unit

| | |
|---|---|
| Coal | : 130 ton / hr |
| Air | : 700 ton / hr |
| Volume of flue gas | : 800 ton/ hr or 410-430 m3/sec |
| Temperature | : 140-170 °C |
| Pressure | : 350-500 mmwc |
| Excess oxygen | : 3-4% |
| $CO_2$ | : 13 - 15 % |
| Moisture | : 4-5% |
| $SO_x$ | : 700-1200 mg/Nm3 |
| $NO_x$ | : 300-500 mg/Nm3 |
| Fly ash | : 65000 mg/Nm3 (before ESP) |
| | About 120 mg/ Nm3 (after ESP) |

***Huge Quantities of Flue Gases in a Typical Power Plant***




Typical flow diagram of a 210 MW coal fired power plant

# Challenges in Carbon Capture

## *1. Low partial pressure of $CO_2$*

### *Facts*

- Combustion in boiler at Atmospheric pressure
- Low Discharge pressure of Flue Gas: 350-500 mmwc
- Low $CO_2$ concentration in Flue Gas: Coal fired boiler: 13-15%
- Low $CO_2$ concentration in Flue Gas: GT / Gas fired boiler is 4-5%

### *Issues*

Bulky equipment - Higher capital costs

High Energy for pressurization

*Low partial pressure of $CO_2$*

High partial pressure based $CO_2$ separation process like Benefild or Catacrab cannot be used

# Challenges in Carbon Capture

## 2. High temperature of flue gases

### Facts

- Flue gas temperature is generally 140-160 °C
- Present solvent based process operates at 40-50 °C
- $CO_2$ laden solvent is regenerated at 120 °C - 130 °C

### Issues

- Cooling is required for $CO_2$ separation
- Flue gas cooling below 50°C is required for membrane or PSA process

### Concerns

- Cooling is very energy intensive process
- Lower temperatures also pose risk of acid corrosion

# Challenges in Carbon Capture

## 3. SOx Removal

### Concerns:

- Cost of FGD (not mandatory otherwise), results in higher cost of $CO_2$ capture

### Issues:

- The acceptable limits of $SO_2$ for solvent process is 10 ppmv
- A lime stone or wet FGD system followed by caustic soda or soda ash based scrubber is must for $SO_2$ removal

### Facts:

- Flue gases from coal fired units contains 700-1200 mg/Nm3 of SOx
- In amine process, $SO_2$ reacts with amines to form thermally stable corrosive salt.
- $SO_3$ forms sulfuric acid mist in cooler causing corrosion
- SOx may adversely reacts with membrane materials or solid adsorbent or may get adsorbed on adsorbent

# Challenges in Carbon Capture

**4. NOx Removal**

## Facts

- Level in flue gas 500-800 mg/Nm3
- In amine process, solvent degradation due to formation of thermally stable salts
- Corrosion due to nitric acid formation
- Adverse reaction or adsorbed in solid absorbents
- NOx may degrade membrane materials

## Issues

- NOX is removed by SCR process at 250-300 °C
- Plugging of catalyst by fly ash is a problem
- Flue gas heating to reaction temperature not possible when SCR is after Economizer.
- SNCR at high temperature is an option

## Concern

- **Cost of NOx removal results in higher cost of CO2 capture**
- **Development of Nox / corrosion resistant process will be better option**

# Challenges in Carbon Capture

## Facts:

- Corrosion in solvent based process, particularly at high temperature

## Issues:

- Corrosion in solvent based process, particularly at high temperature
- Solvent degradation
- Degradation of membrane due to oxidation
- Oxygen may get adsorbed on solid absorbent thus reducing its adsorption capacity
- In solvent based process, corrosion inhibitor or oxygen scavenger is used

## Concerns:

- Screening of Oxygen may be a very cost intensive process

**5. Oxygen in Flue Gases**

## 6. Fly Ash in Flue Gas

### Facts:

About 100 -150 mg/Nm3 of fly ash present in flue gases

### Issues:

This causes plugging, erosion, solvent degradation etc. in solvent based process

Fly ash may also plug membranes and solid adsorbents

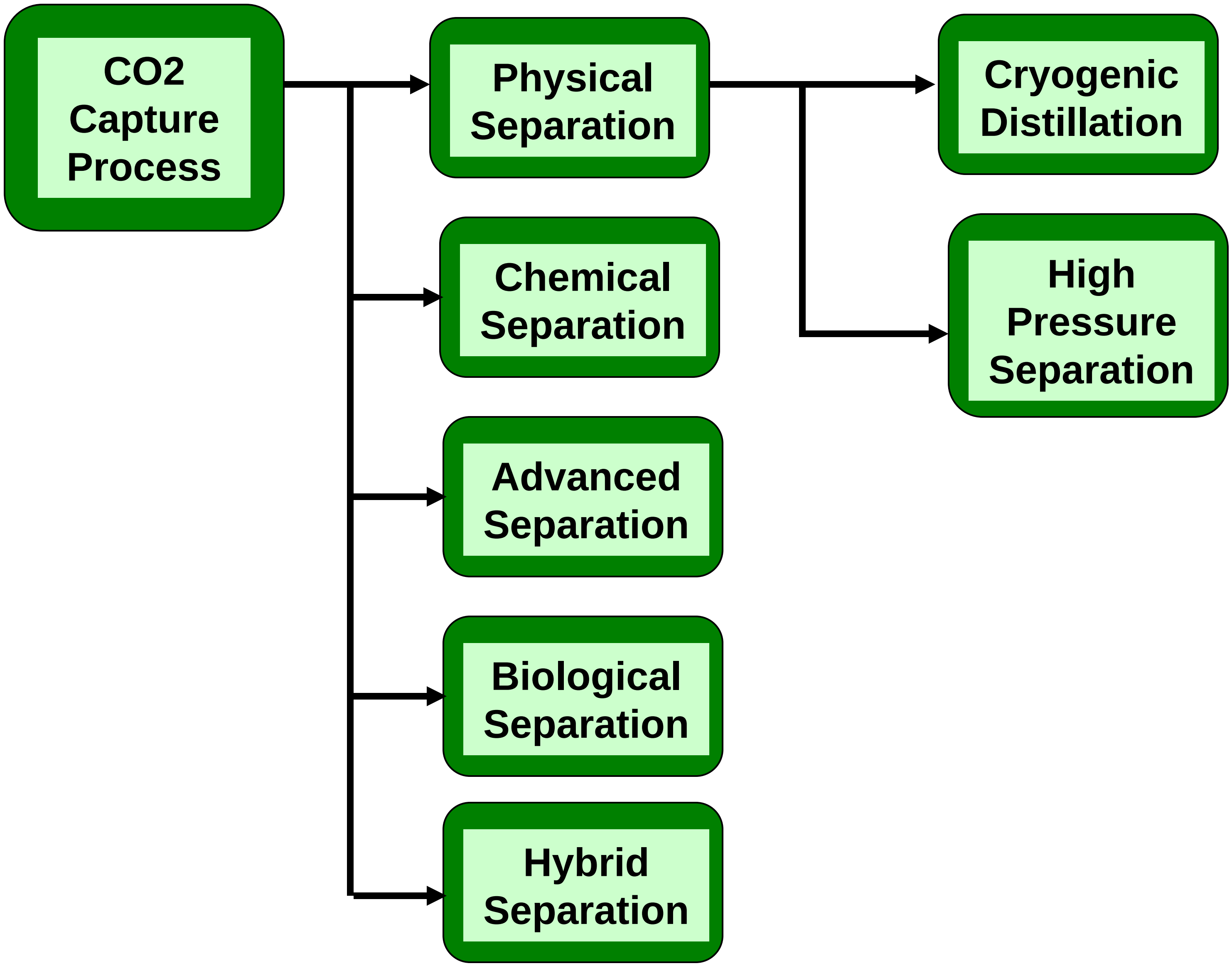
Generally Direct Contact Cooler or FGD removes most of the fly ash

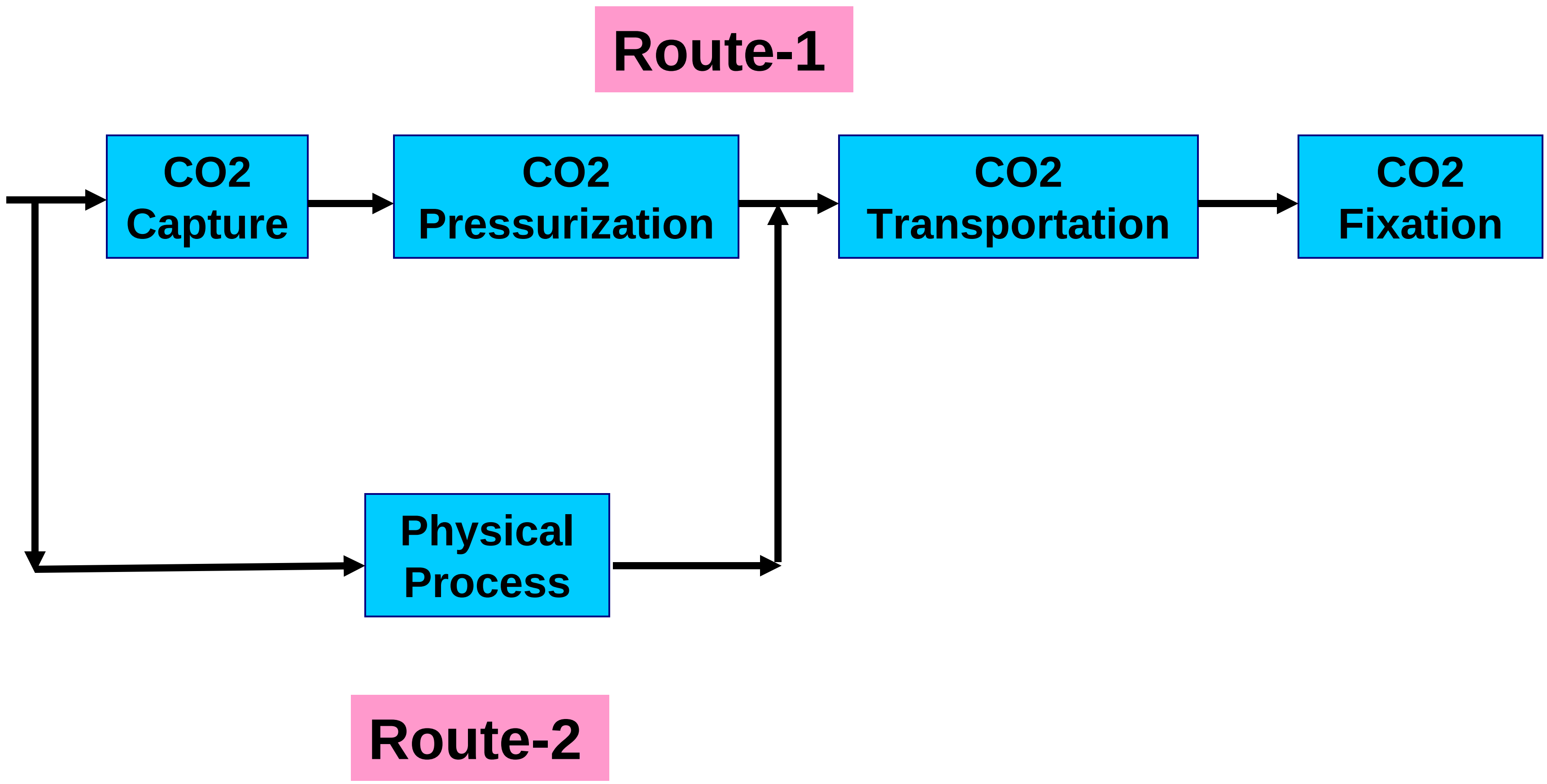
# Part- D

# Existing Process Technologies

**Unviable for TPS applications**

# Technologies for CO2 Separation



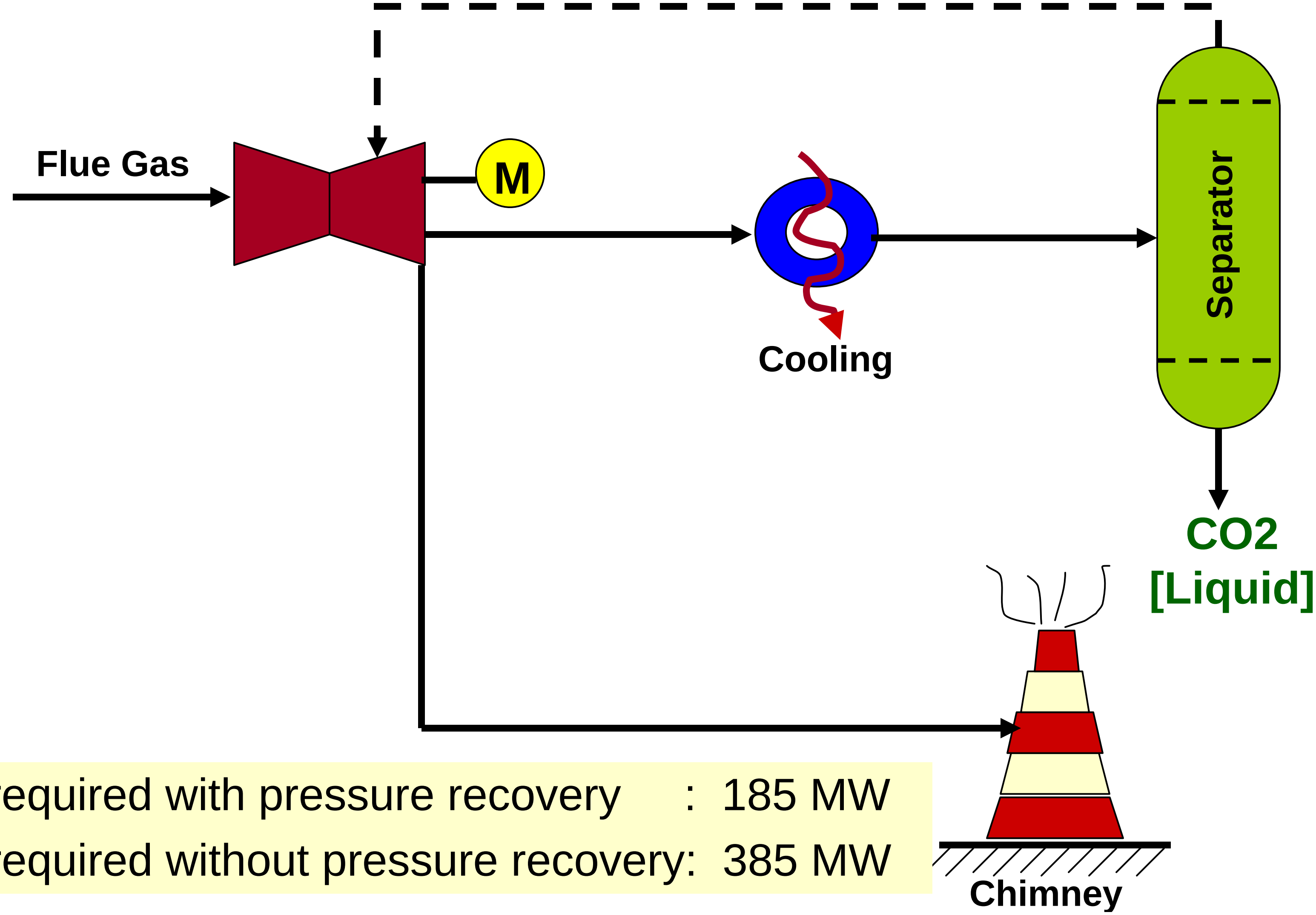



**Overall CPTF Flow Sheet**

एनटीपीसी
NTPC

# Physical Process

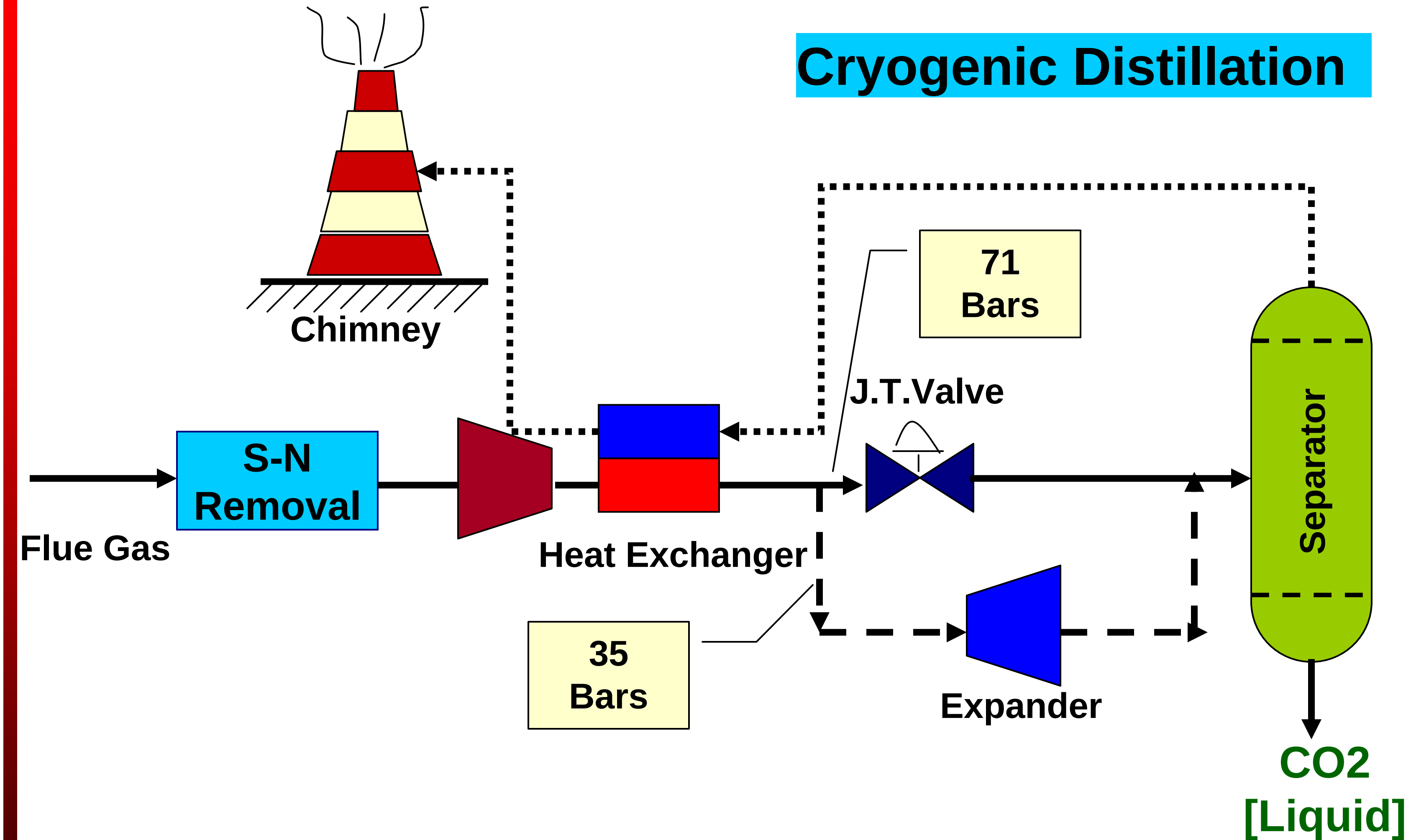
## High Pressure Liquefaction




Power required with pressure recovery : 185 MW

Power required without pressure recovery: 385 MW

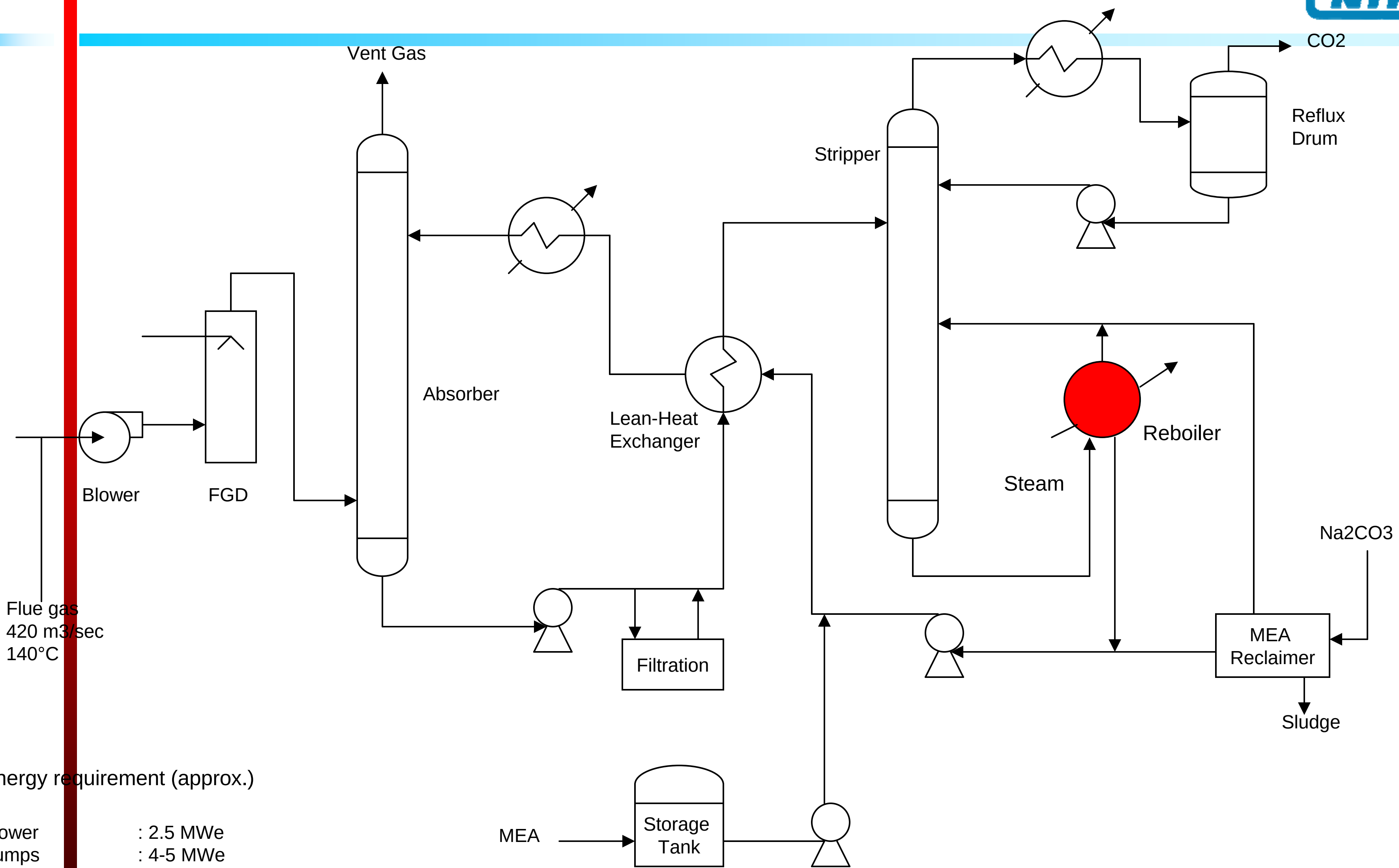
# Cryogenic Distillation




Power required with J-T Valve: 160 MW

Power required with Expander : 120 MW

# MEA PROCESS TECHNOLOGY




Energy requirement (approx.)

| | |
|---|---|
| Blower | : 2.5 MWe |
| Pumps | : 4-5 MWe |
| CO2 regeneration | : 55-58 Mme |
| Total | : 65 MWe |

Process flow diagram for an MEA process for CO2 capture from flue gas

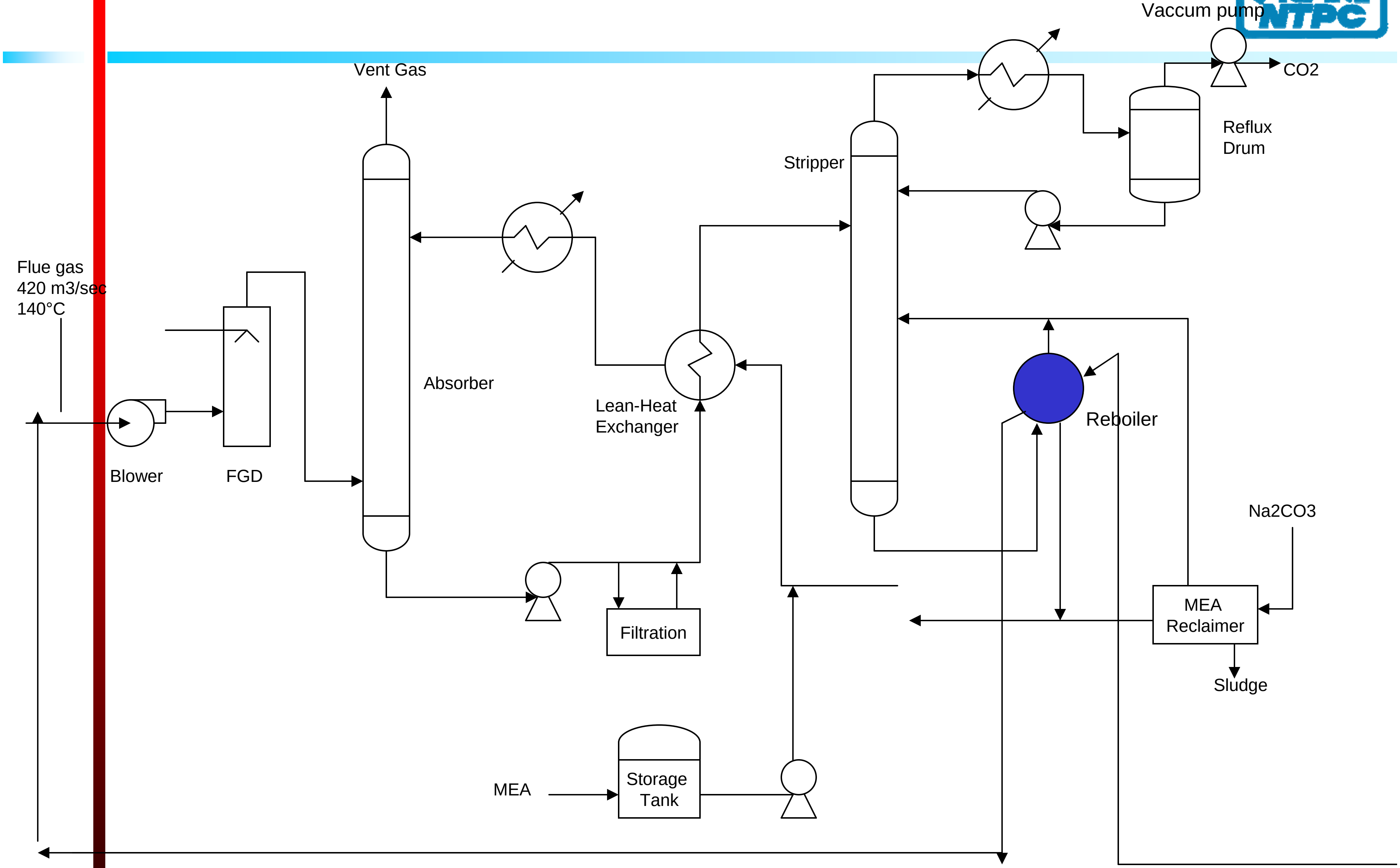
## *Alternative Technologies for $CO_2$ Separation*

- **Steam = 2t/ t of $CO_2$**
- **Total steam = 320 t (210 Mwe)**
- **Power requirement = 7 MW**
- **Total Energy = 65 MWe**

# Chemical Process for CO2 Separation

**Major Concerns:**

- **In amine process, 80-90%of total energy required, is consumed in solvent regeneration**
- **For a 210 MW coal fired boiler the total energy requirement is about 65 MWe of power.**
- **This will bring down total efficiency by at least 30%.**
- **This will increase total operating cost by Rs. 1500-1700/ ton of CO2 captured**
- **This will approximately double the power generation cost**




Process flow diagram for an MEA process for CO2 capture from flue gas with waste heat recovery system

# *Alternative Technologies for $CO_2$ Separation*

Energy requirements with waste heat recovery system

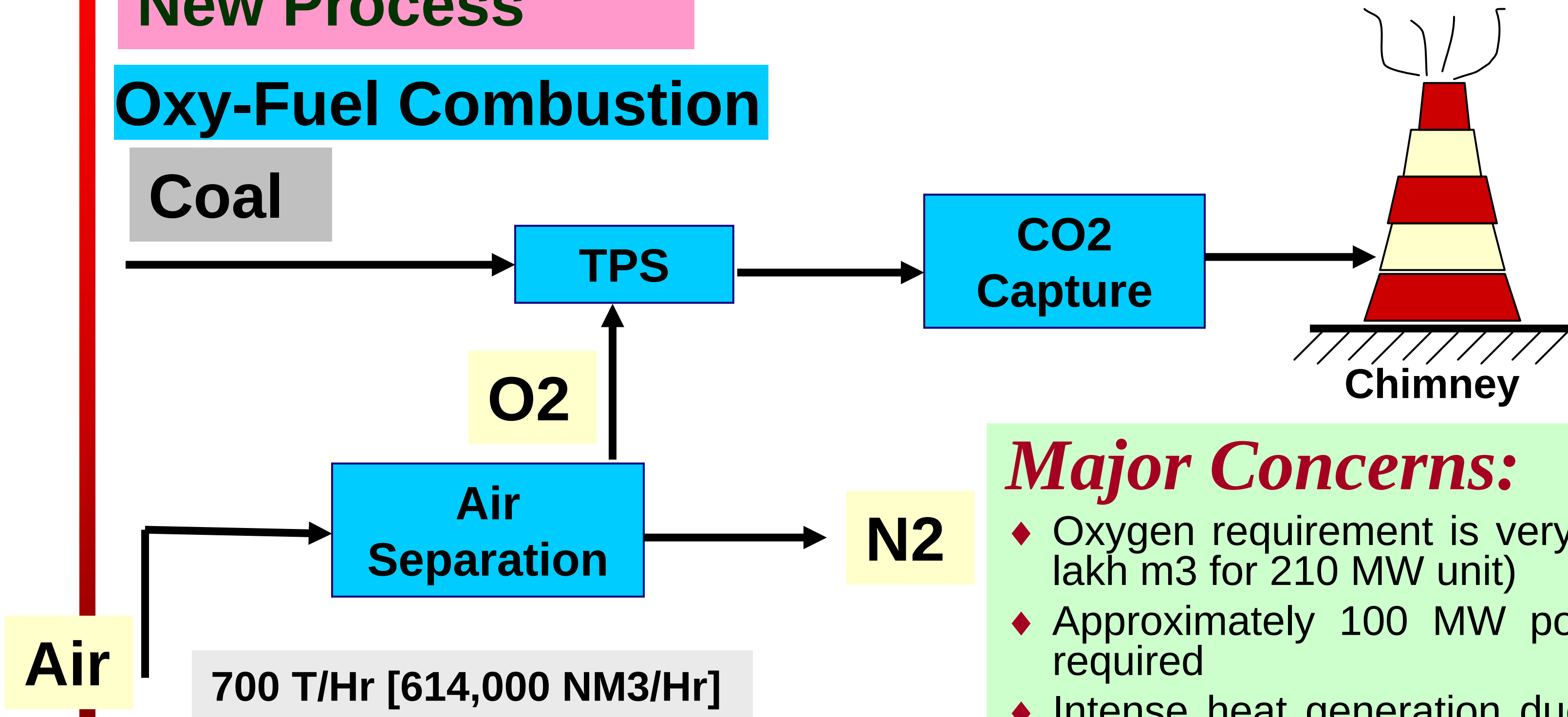
- **Steam = Nil**
- **Power requirement = 9 MW**
- **Total Energy = 9 MWe**

# Major areas of research in solvent process

- Development of hindered amines or formulated amines for increase in $CO_2$ absorption capacity
- Development of low temperature regeneration solvent to reduce the regeneration energy
- Development and/or formulation of solvent(s) or combination of them to increase its concentration in aqueous medium to reduce regeneration energy
- Development of less corrosive solvent
- Design of absorber and stripper column to increase efficiency of $CO_2$ absorption and separation, etc.

# New Process

## Oxy-Fuel Combustion




### *Research Areas:*

- Cheaper source of oxygen like membrane separation
- Burner design for high temperature oxygen combustion
- Metallurgy of boiler water-wall tube
- Recirculation of flue gas to minimise NOx formation

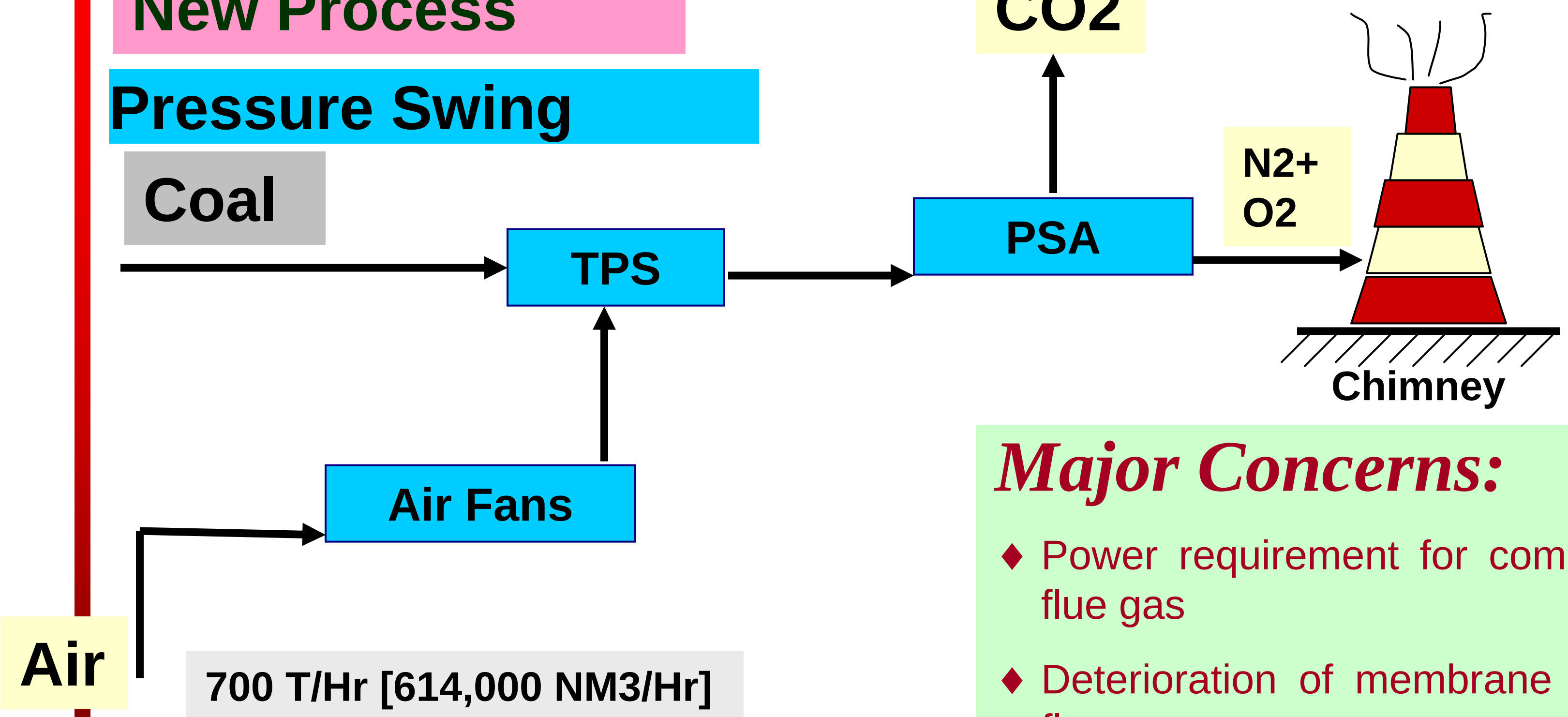
### *Major Concerns:*

- Oxygen requirement is very large (1.25 lakh m3 for 210 MW unit)
- Approximately 100 MW power will be required
- Intense heat generation due to oxygen combustion
- High temperature in boiler and NOx formation
- Metal degradation due to high temperature

Power required : 122 MW

# New Process

## Pressure Swing




### *Research Areas:*

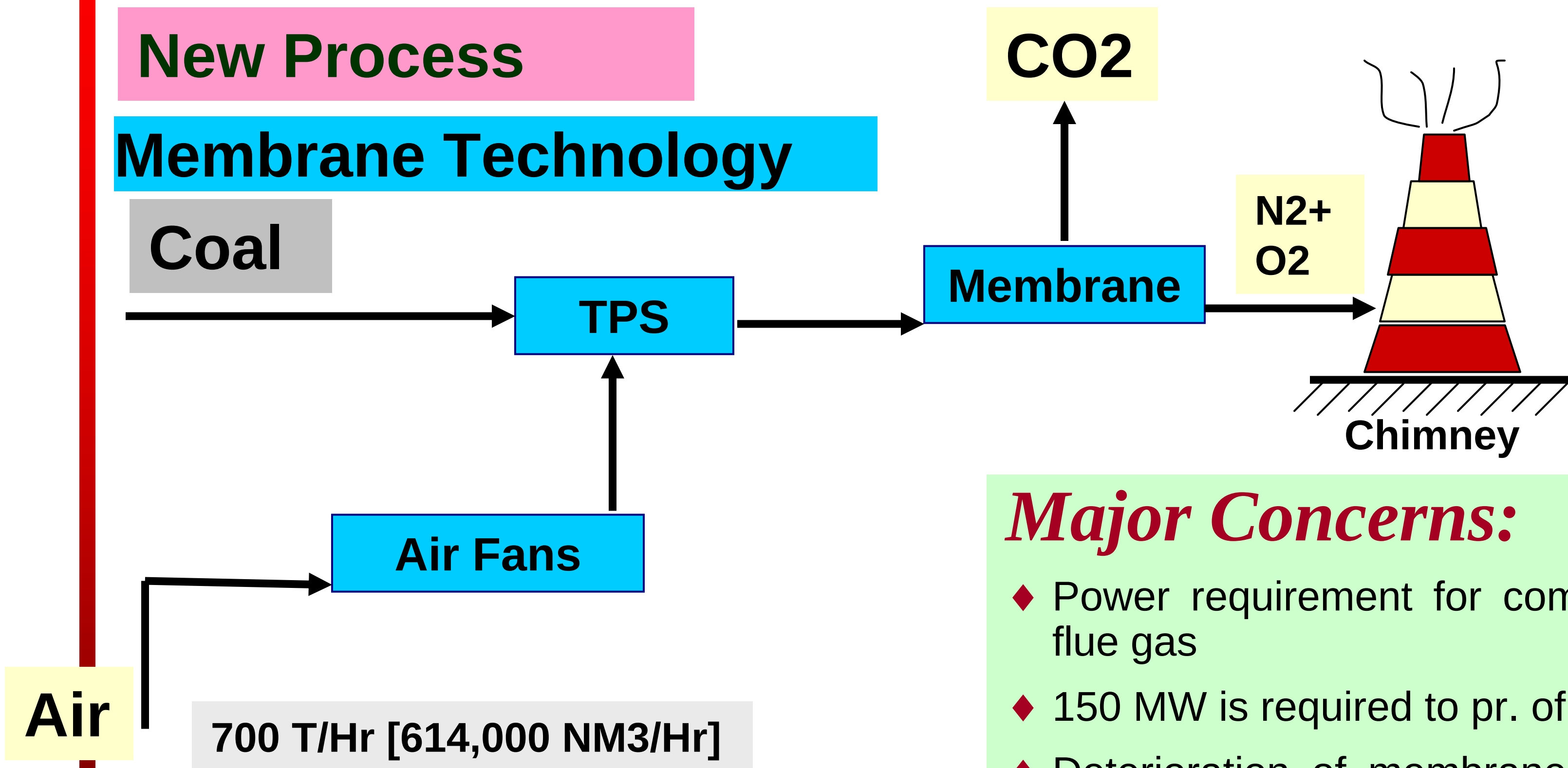
- Development of more $CO_2$ selective membrane materials
- Development of high temperature membrane
- Design and fabrication of membrane stack, etc.

### *Major Concerns:*

- Power requirement for compression of flue gas
- Deterioration of membrane due to hot flue gas
- Lack of established membrane technology

## New Process

## Membrane Technology




### *Research Areas:*

- Development of more $CO_2$ selective membrane materials
- Development of high temperature membrane
- Design and fabrication of membrane stack, etc.

### *Major Concerns:*

- Power requirement for compression of flue gas
- 150 MW is required to pr. of 40 bar
- Deterioration of membrane due to hot flue gas
- Lack of established membrane technology

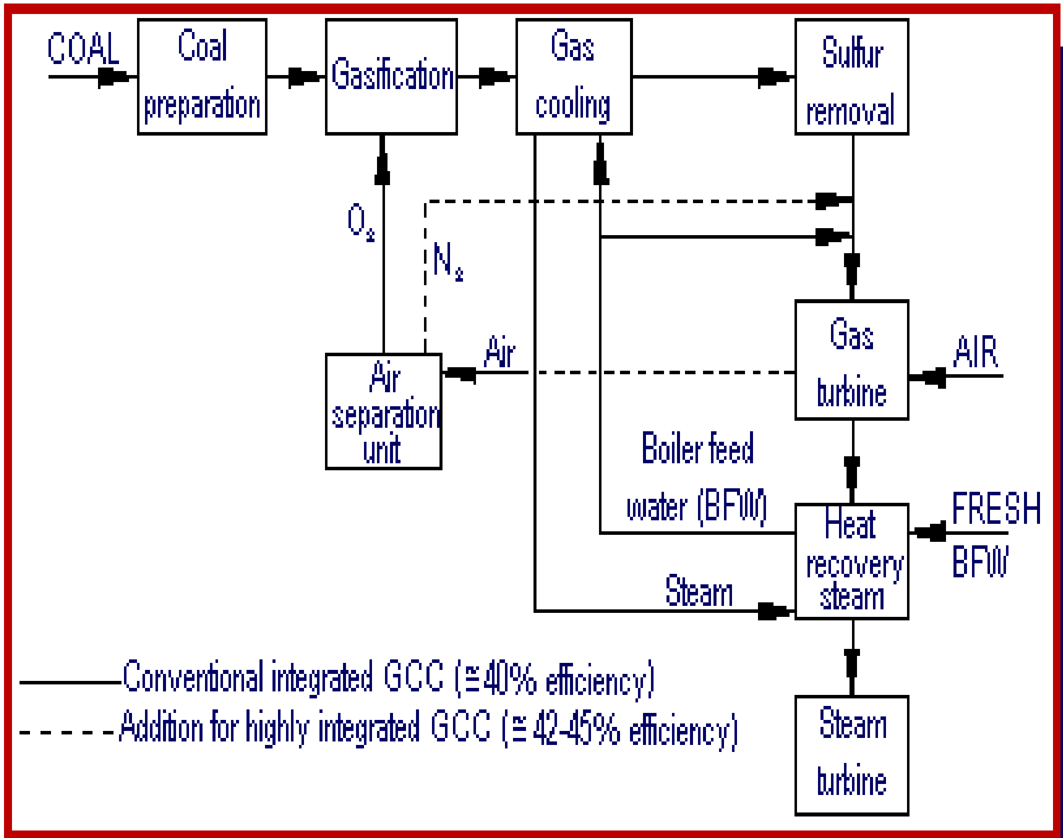
## *IGCC process*

- Unlike pulverized coal fired power plant, the pressure of flue gas from IGCC based power plant is around 30 bar. The flue gas contains 22-25% of CO2. The higher partial pressure of CO2 in flue gas from IGCC makes it more suitable for high pressure based CO2 separation process like PSA, membrane or Benfield/Catacrab process.

# IGCC

## TM- 2.1: IGCC Technologies

- IGCC Technologies
  - Fludised Bed Gasifier Design & Development (high pressure 100 mm gasifier)
  - Gas Clean-up (pilot scale set up)
  - IGCC System Integration
  - Advanced Gasifier Cycles




- IG-FB: Design/ Scale-up/ Optimization of Gasifier
- IG-GC: Design & Development of Gas Clean up system
- IG-SI: System integration for a base cycle

- IG-AC: Advanced cycle consisting of
  - -O2 Transport membrane
  - - CO2/ H2 Separation
  - - Gasifier/ Combustor design

# CHALLENGES TO SCIENTIFIC COMMUNITY

ANY PROCESS DEVELOPMENT SHALL BE SUCH THAT COST OF POWER WILL NOT BE INCREASED BY MORE THAN 5-8%

# Ideal CSTF Process

Flue Gas

Preferential Capture of CO2

CO2 Pressurization /Transportation

15 MW

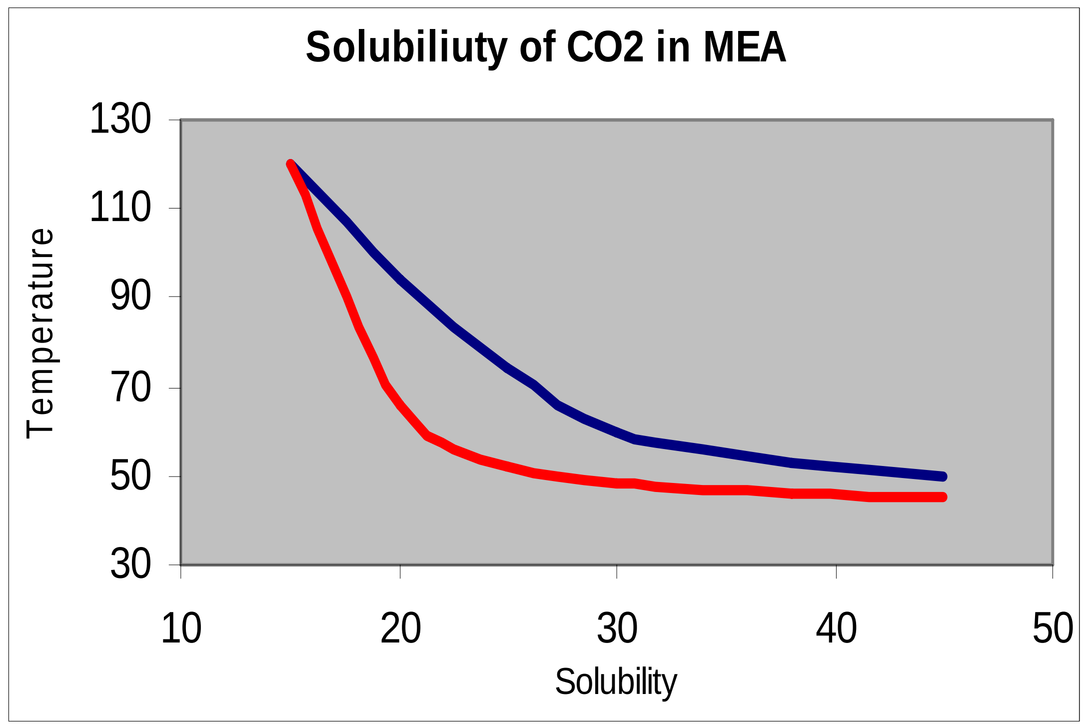
CO2 Fixation

CO2 Seperation

5 MW

Ideal Characteristic

?



# New Directions

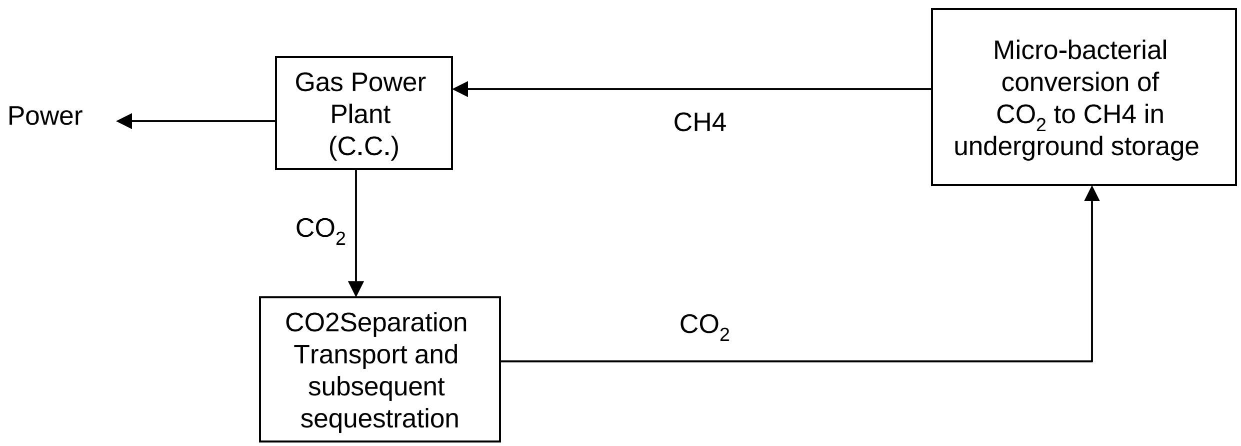
## 1. Nano- materials

- Due to high surface area absorption capacity of nano-materials is high.
- Different nanoporous materials based on carbon, ceramic materials, zeolite, lithium zirconate are being developed to increase $CO_2$ separation efficiency.

## 2 Bio-technology

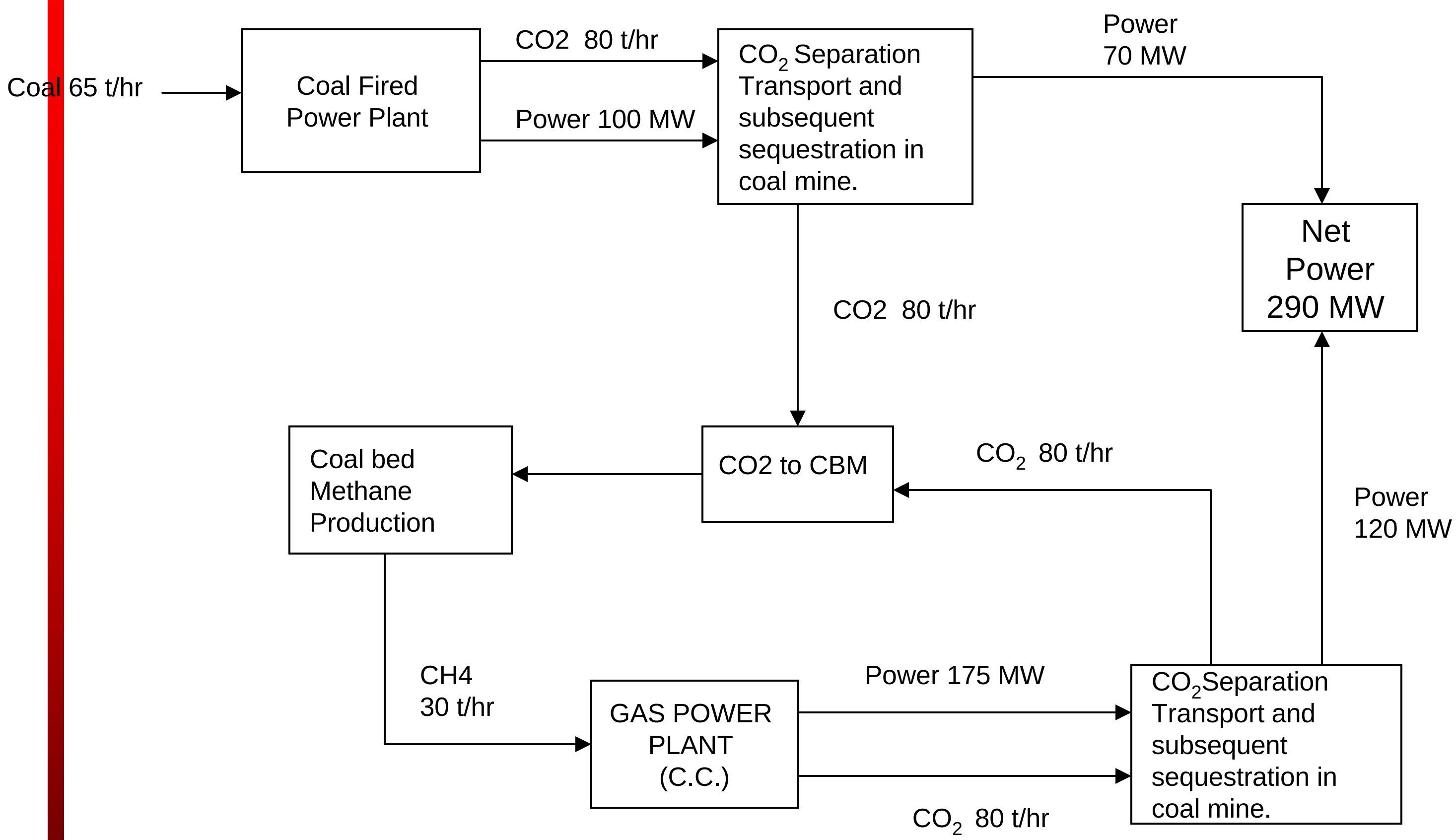
- Intervention of bio-technology in carbon sequestration could be technological break through for the green house gas emission control
- Enzymes like carbonic anhydrase may be used to enhance photosynthesis. One of the option of carbon sequestration is to store $CO_2$ in geological formations at elevated pressure and temperature
- The break through concept will be to convert $CO_2$ anaerobically to methane using some micro-organism. Then the methane can again be used for power production.

## Conceptual flow diagram for micro-biological Methane-$CO_2$ cycle




Power

# Power generation through Coal Bed Methane



3. Electron beam technology

- The basic concept is to pass a beam electron though flue gas to energize $CO_2$ and spray ammonia into it
- This will give ammonium carbonate or ammonium bicarbonate as a product
- Further ammonium bicarbonate may be converted to urea

4. Artificial Photosynthesis Technology

- In artificial photosynthesis, natural photosynthesis process is mimicked to covert $CO_2$ into useful products like methanol, formalin etc. This technology is still in its infancy stage. Ru, Mn doped zeolites have tried as a catalyst for the process.

5. Other technologies

- $CO_2$ bubbles through ammonia solution to produce ammonium bicarbonate.
- $CO_2$ loading capacity is 1.20 kg/ kg of $NH_3$ as compared to 0.40 kg per kg of MEA.
- SOx and NOx removal may not be required as ammonium bisulphate and ammonium nitrate will be useful products.

- In presence of moisture solid sodium carbonate reacts with $CO_2$ and converts into bicarbonate
- $CO_2$ may be recovered by decomposing the bicarbonate at elevated temperature
- Carbonate is recycled back for $CO_2$ absorption

- To enhance mass transfer across membrane membrane-liquid contractor are being developed
- PTEF based “gate membrane” with high hydrophobocity and compatible with aqueous amines has been developed for $CO_2$ separation.

***"When you really want something to happen, the whole universe conspires to help you to achieve your dreams"***

…….. The Alchemist

*by Paulo Coelho*

# Thank

# *You*

# *Introduction*

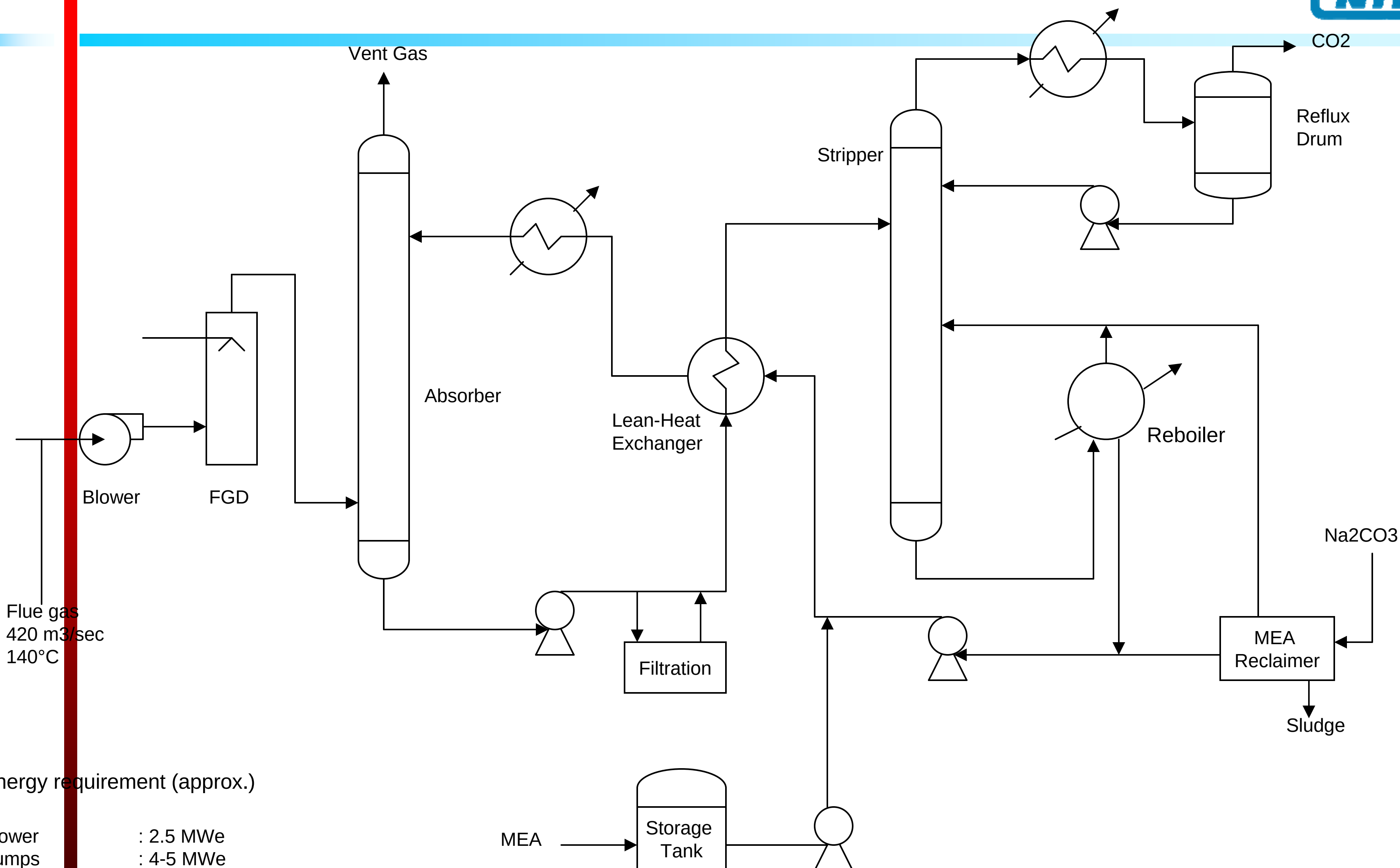
$CO_2$ separation from flue gas cost 70 % of total carbon sequestration cost.

$CO_2$ capture using monoethanol amine [MEA ] is the most commonly used technology

Generally $CO_2$ removal by MEA process doubles the cost of power generation.
Cost of transportation and and storage in geological formations will add up the cost.

Alternative cost effective technology for $CO_2$ removal are to be developed to make the sequestration process to be economically acceptable

EOR and ECBM using $CO_2$ will partially compensate sequestration cost.




Energy requirement (approx.)

Blower : 2.5 MWe
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Total : 65 MWe

Process flow diagram for an MEA process for $CO_2$ capture from flue gas

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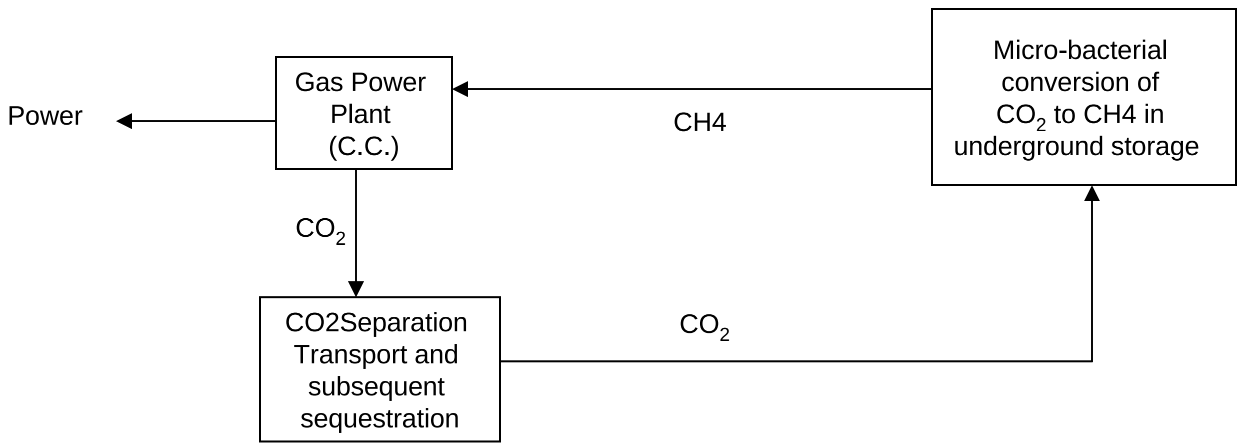



Power

| Green-house gas | Pre-industrial Concentration | Concentration in 1994 | Atmospheric Lifetime | Anthropogenic source | Global-Warming Potential** |
|---|---|---|---|---|---|
| Carbon Dioxide, ($CO_2$) | **(ppmv/v)** | **(ppmv/v)** | **(years)*** | Fossil Fuel combustion | 1 |
| Methane, ($CH_4$) | 278 | 358 | Variable | Land Use conversion | 21*** |
| Nitrous Oxide, ($N_2O$) | 0.7 | 1.721 | 12.2 +/- 3 | Cement production | 310 |
| CFC-12, ($CCl_2F_2$) | 0.275 | 0.311 | 120 | Fossil fuels | 6200 |
| HCFC-22 ($CHClF_2$) | 0 | 0.0005 | 102 | Rice paddies | 7100**** |
| Perflouro-methan ($CF_4$) | 0 | 0.000105 | 12.1 | Waste dumps | 1300-1400 **** |
| Sulfur Hexaflouride ($SF_6$) | 0 | 0.00007 | 50,000 | Livestock | 6500 |

# ISSUES DELIBERATED IN THE TWO DAY TPDM

MAJOR FOCUS WAS ON THREE VITAL FIELDS

-SHORTLISTING OF R&D REQUIRED FOR $CO_2$ CAPTURE

-BIO-CHEMICAL PROCESSES

-$CO_2$ TRANSPORTATION, CBM & OTHER SEQUESTRATION ISSUES

-$CO_2$ UTILISATION AND VALUE ADDITION

# SUMMARY OF TPDM

NUMBER OF PROJECTS REVIEWED :  23

NUMBER OF INSTITUTIONS PARTICIPATED :23

NUMBER OF PARTICPANTS: 35

EXPERTS REVIEWING THE PROJECTS: 5

# CARBON CAPTURE TECHNOLOGIES

-CHEMICAL ABSORPTION

-PHYSICAL ADSORPTION

-CHEMICAL ABSORPTION

-MEMBRANE PROCESSES AND IONIC MEMBRANE CONTACTORS

-BIO-CHEMICAL PROCESSES

# ABSORPTION (CHEMICAL)

ISSUES  DISCUSSED

-IMPROVEMENT IN BASIC MEA PROCESS

-PROCESS ENGINEERING & DEVELOPMENT OF SUPERIOR SOLVENTS

-SOLUTIONS TO OXIDATIVE DEGARDATION

-ADVANCED PROCESS INTEGRATION

-ENHANCEMENT OF PROCESS THROUGH MULTIPHASE SYSTEMS

PARTICIPATING INSTITUTIONS: EIL, UICT, IIP, NCL

# SUMMARY OF DELIBERATIONS

-SELECTION OF THE BEST SOLVENT

-HOW DO WE HANDLE SOx & NOx ISSUES UNDER OUR CONDITIONS

-HEAT INTEAGRATION AND OPERATING STRIPPER UNDER VACUUM

--MODELLING ISSUES WITH SIDE RXNS. FOR SOLVENT'S XOIDATIVE DEGENRATION

--OPTIMISATION OF THE CYCLE

# ACTION PLAN ON ABSORPTION PROCESS

1. CHOICE AND TESTING AND SELECTION OF FEW SOLVENTS OUT OF BASKET OF SOLVENTS (UICT/IIP)
2. PROCESS ENGINEERING AND OPTIMISATION (EIL/NTPC)
3. PILOT SCALE FACILITY (NTPC)

# ADSOPRTION PROCESSES

ISSUES DISCUSSED:

-CONVENTIONAL ZEOLITES AND ACTIVATED CARBON

-FUNCTIONALLY MODIFIED ADSORBENTS

-CMS & ZEOLITES FROM FLY ASH

- NANO MATERIALS (LITHIUM ZIRCONATE)

# ADSORPTION PROCESS

-PSA/ TSA/PTSA/PVSA ???

-CYCLE DESIGN AND INTEGRATION

PARTICIPATING INSTITUTIONS

-NEERI / IIP / CSCMRI

# DELIBERATIONS ON ADSORPTION PROCESSES

ZEOLITIES VS. OTHER ADSORPBENTS

-HUMIDIFICATION ISSUES

-OPTIMISATION OF CYCLE

# ROLES AND RESPONSIBILITIES

WHO WILL DEVLOP MATERILAS AND ADSORBENTS

-WHO WILL DEVELOP THE PROCESS

-ENGINEERING SISUUES

IT WAS FELT THAT THE DEVELOPMENT OF ADSORBENTS (ENTIRE RANGE) MAY BE CARRIOED OUT IN THE LAB. WHILE PROCESS DEVELOPMNET OF THE PSA CYCLE AND TESTING MAY BE DONE BY NTPC AS A JOINT COLLAORATIVE PROJECT

# OTHER INTERESTING ISSUES

IONIC MEMBRANES FOR $CO_2$ CAPTURE

ISSUES:

FEASIBILITY STUDIES & COST FACTOR

# FUTURE ROAD MAP

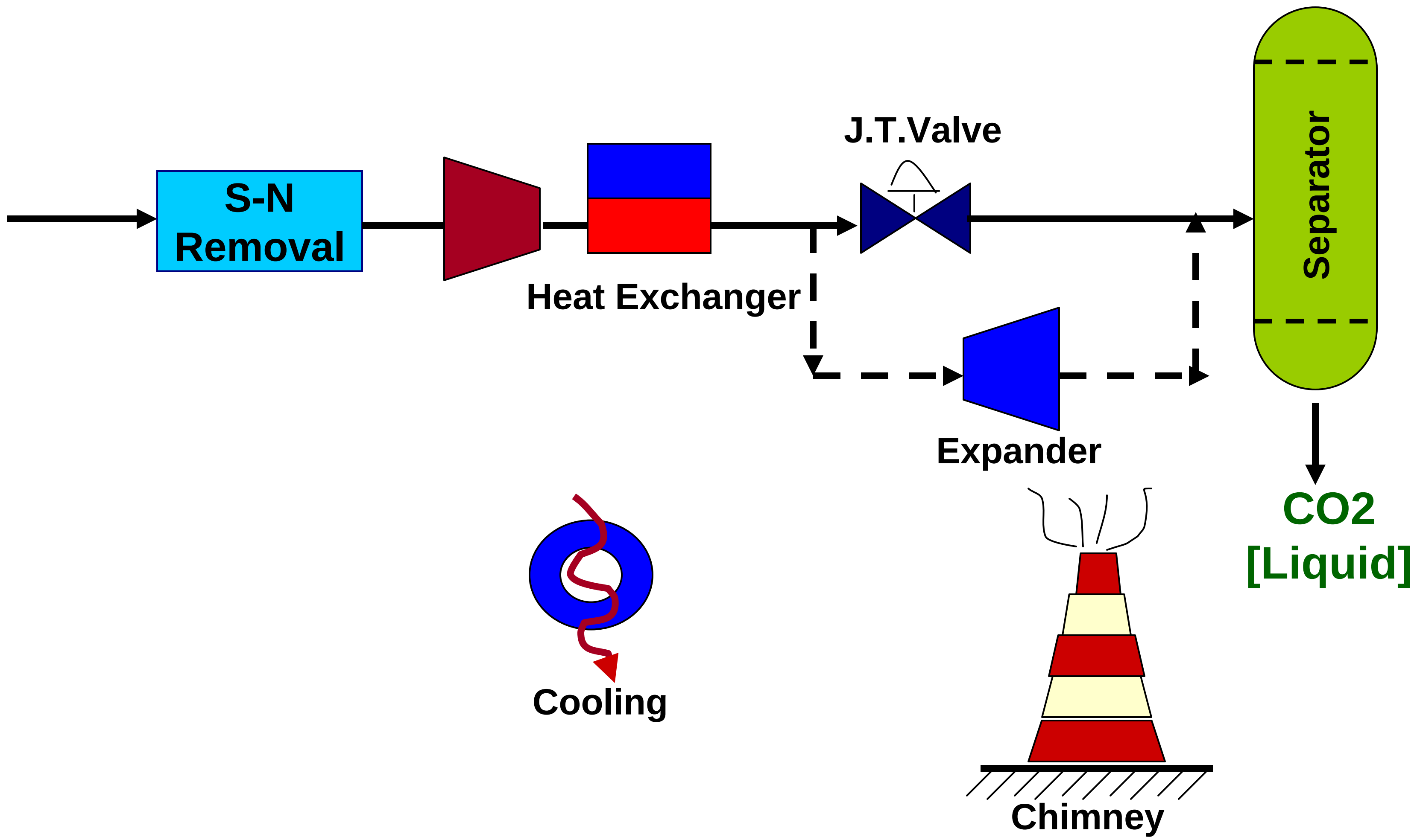
SHORT LISTING OF THE PROPOSALS WILL BE CARRIED OUT BASED ON THE DISCUSSIONS HELD BY THE EXPERT GROUP OF THE TPDM

MEANWHILE, ALL THE PROPOSEES TO MODIFY THEIR PROPOSALS BASED ON THE DISCUSSIONS HELD DURING TPDM AND NTPC CAN FACILITATE FOR MULTI-INSTITUTIONAL COLLABORATION IF FOUND SUITABLE

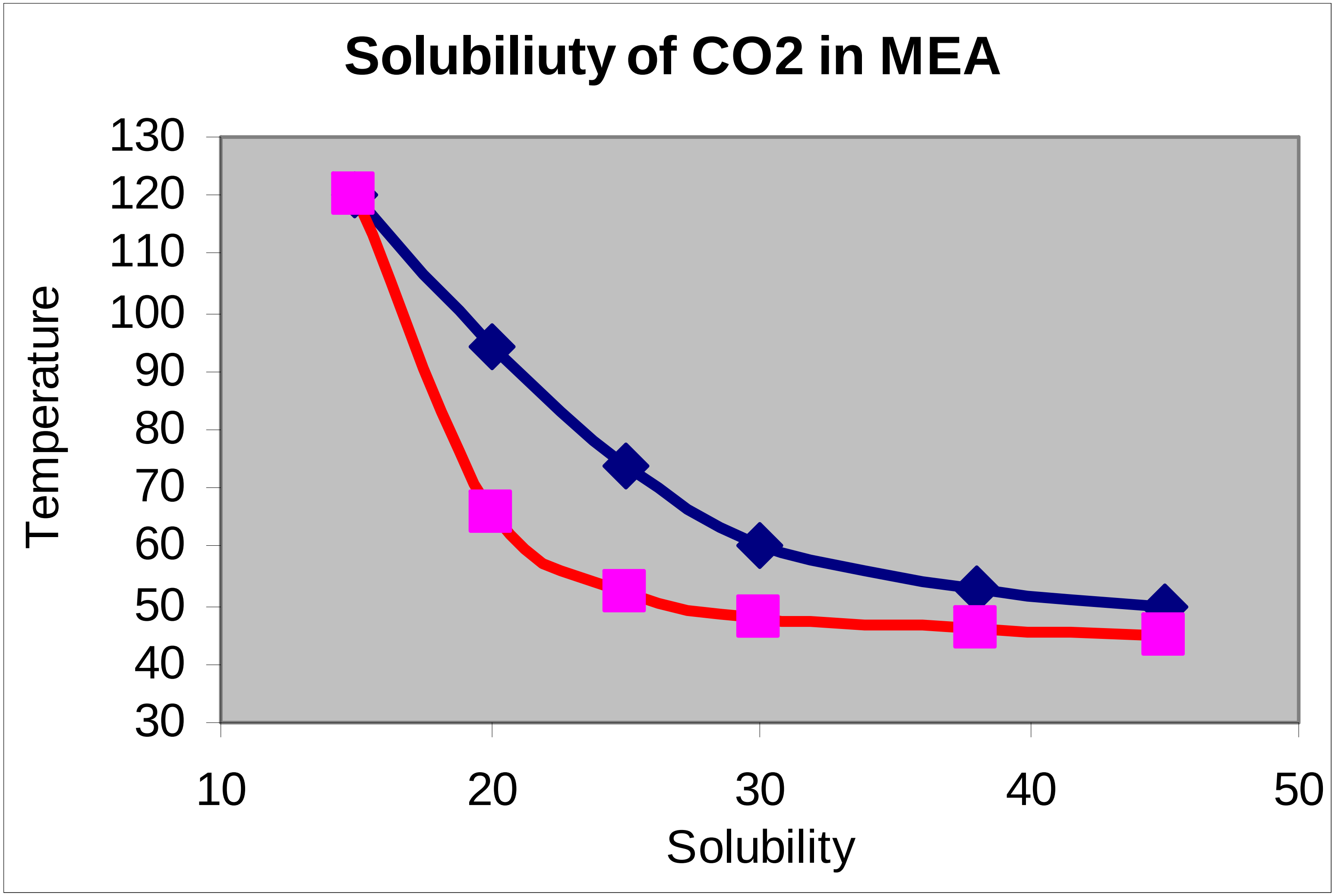
FINAL ROUND OF THE MEETING PROPOSED IN NEXT THREE WEEKS TIME

# BIO CHEMICAL PROCESSES

# TRANSPORTATION AND SEQUESTRATION

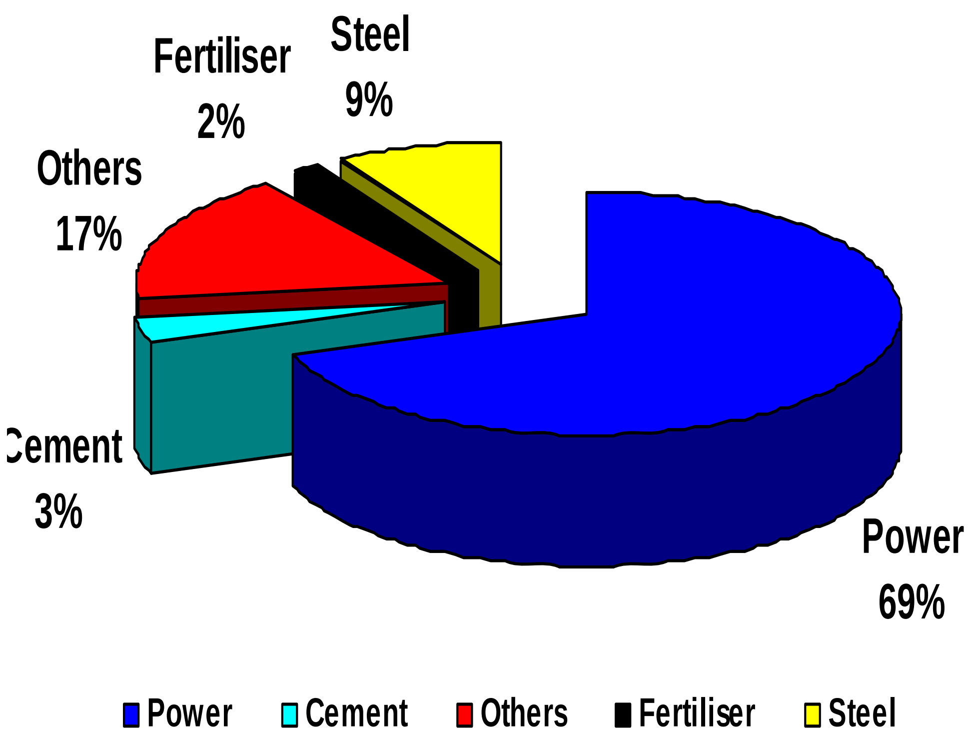

S-N
Removal
Heat Exchanger
J.T.Valve
Separator
Expander
CO2
[Liquid]
Cooling
Chimney

# *Alternative Technologies for CO2 Separation*



# Indian Power Scenario

***Power Sector - The largest consumer of the coal produced***




***Indian Coal: The Issues***

- Very High Ash Content: 40% - 50%
- Low Heating Value: 2500 – 4000 Kcal/Kg
- High Alfa Quartz Content
- High Abrasive Index
- Very Low Sulfur Content

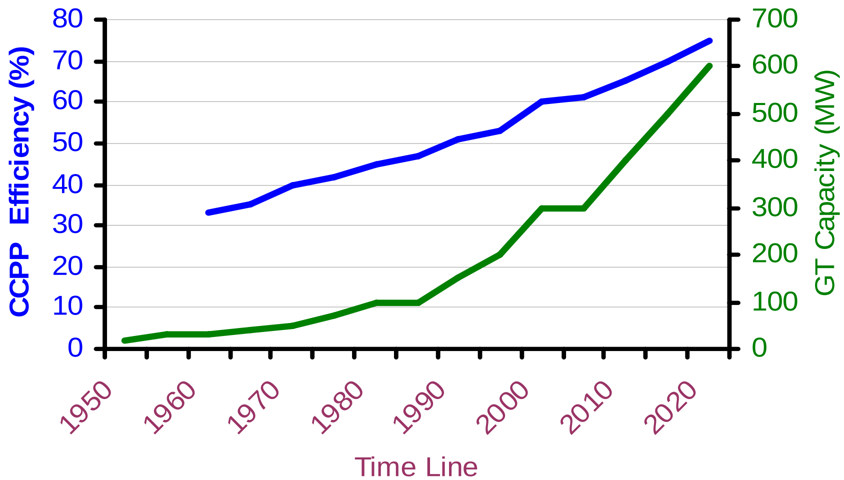
- India’s Power production (Current)
- Fuel Mix
- Future projections (2020-2050)
- India’s position globally
- India’s emerging economy and need for increased power

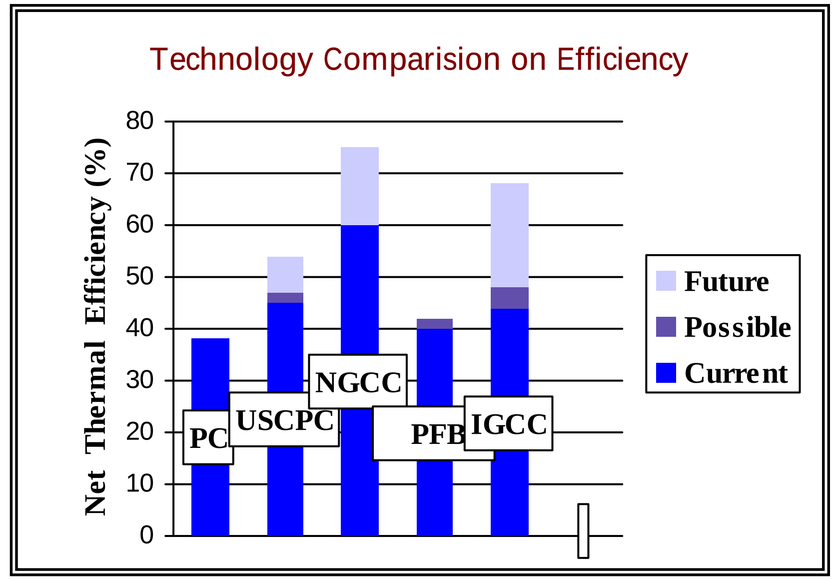
# IGCC- fundamentally better way to use Coal

**Efficient Coal Utilization**

•Higher efficiency
•Elegant environment parameters
•Good source of bulk Hydrogen &liquid fuels
•Carbon sequestration

GT Technology Status



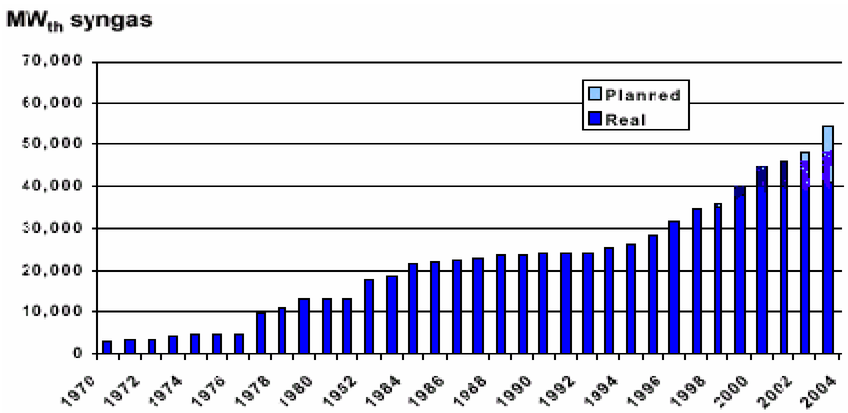



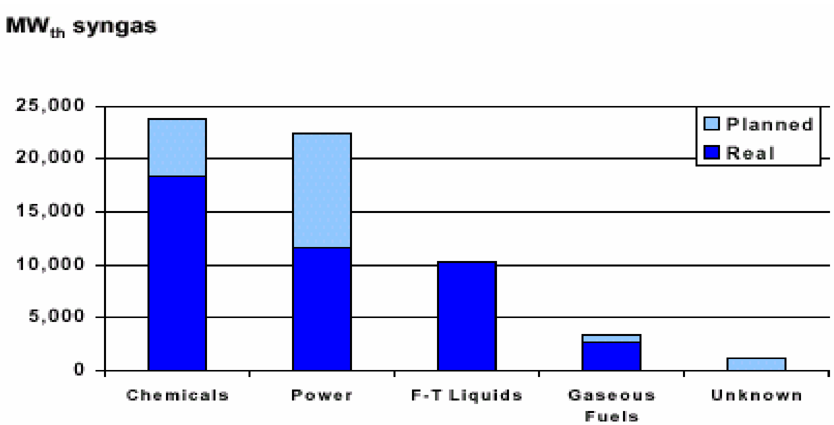

On the Road Map of developed world
Efficiency & capacity will keep rising

IGCC efficiency will see rising trend

# *IGCC Worldwide- no benchmarks available*

IGCC as a technology is established though yet to see full throttle




## IGCC Worldwide- not a guide

Factors are against full throttle IGCC use in developed countries

- Capacity mission already over
- Natural gas in plenty for future
- Too much market focus restricts choices
- Political capping on oil prices

IGCC use will be moderate in these countries in near future.

IGCC utilization levels Worldwide shouldn't be a guide for us