POWER GENERATION WITH UCG

Economics of power generation with UCG

A Presentation by NTPC

POWER GENERATION WITH UCG

CONTENTS OF PRESENTATION

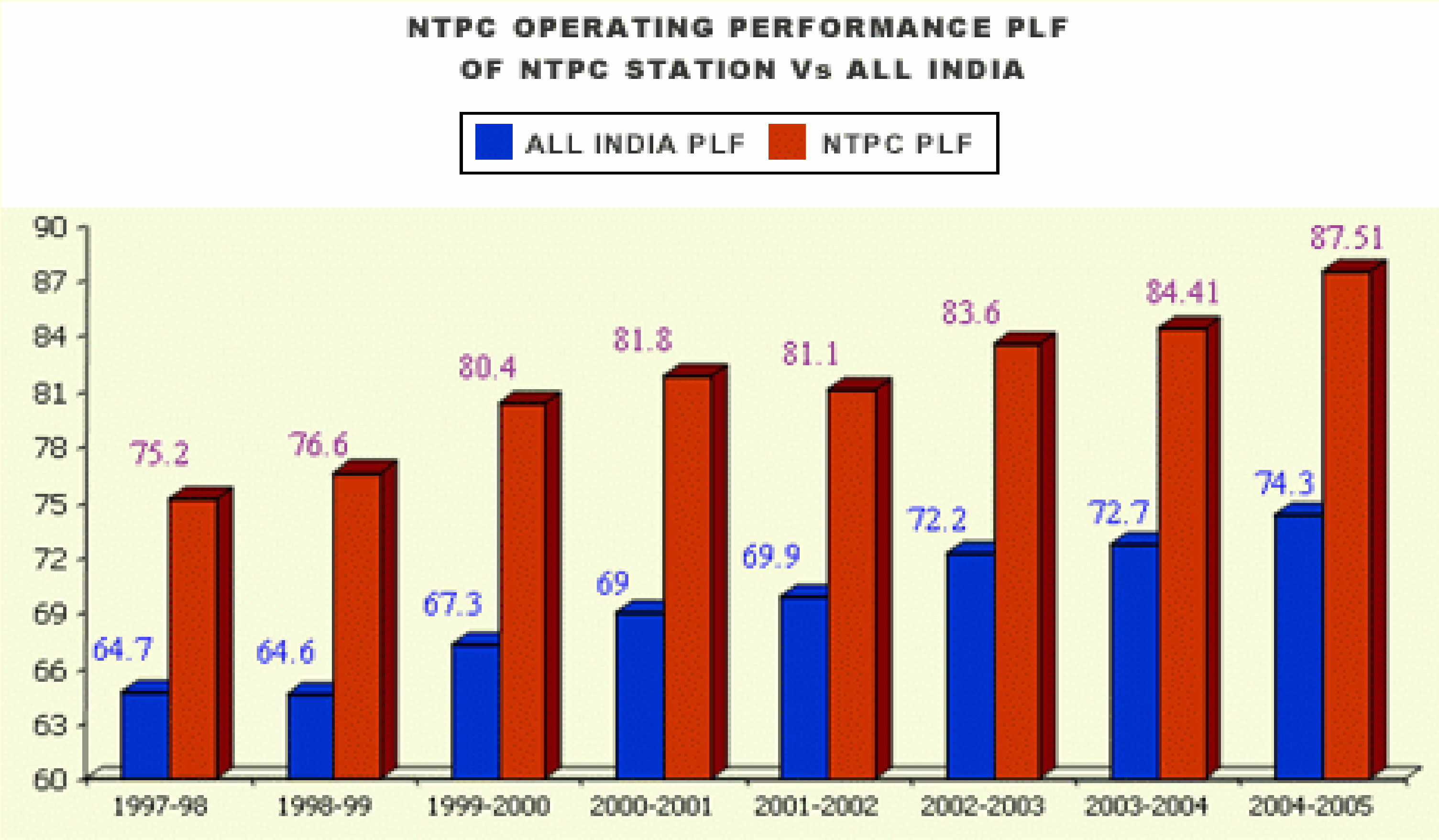
- **NTPC IN POWER GENERATION**
- **GASIFICATION OF COAL**
- **IGCC POWER PLANT**
- **UCG BASED IGCC**
- **ECONOMICS OF POWER GENERATION**
- **ISSUES RELATED WITH UCG FOR POWER GENERATION**

POWER GENERATION WITH UCG

- NTPC's present installed capacity is 26,404 MW.
- Consists of 14 coal based and 7 Gas based and 4 JVs stations.
- Comprising 72 thermal units of 60 / 110 / 200 / 210 / 500 MW rating.
- 22 Gas Turbine units/10 Steam Turbines in combined cycle mode.
- Construction 4000 MW thermal plants and Hydro stations
- Venturing in to Nuclear field/Mining of coal
- Target of 51000 MW installed capacity by 2012

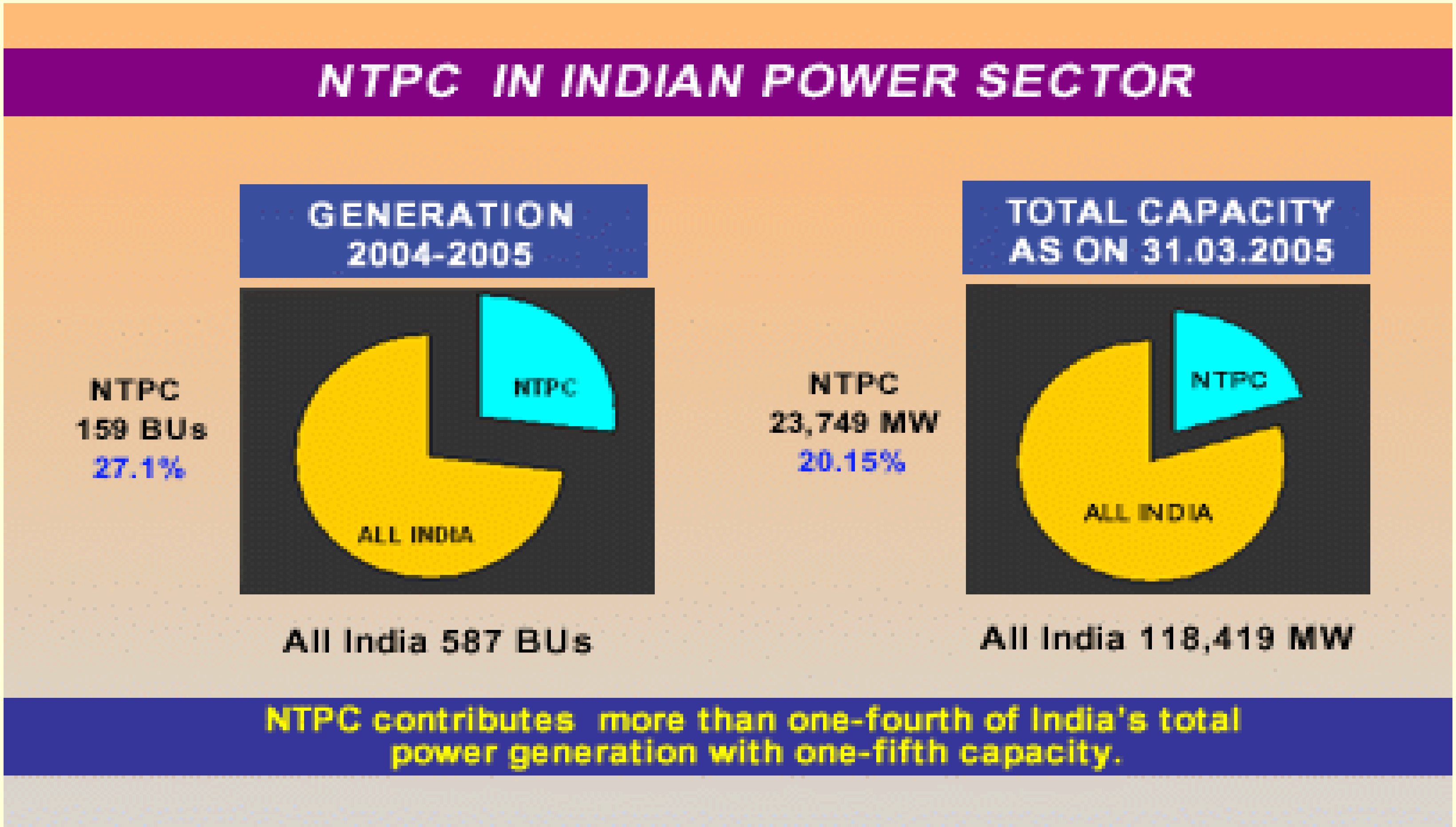
POWER GENERATION WITH UCG

POWER GENERATION WITH UCG

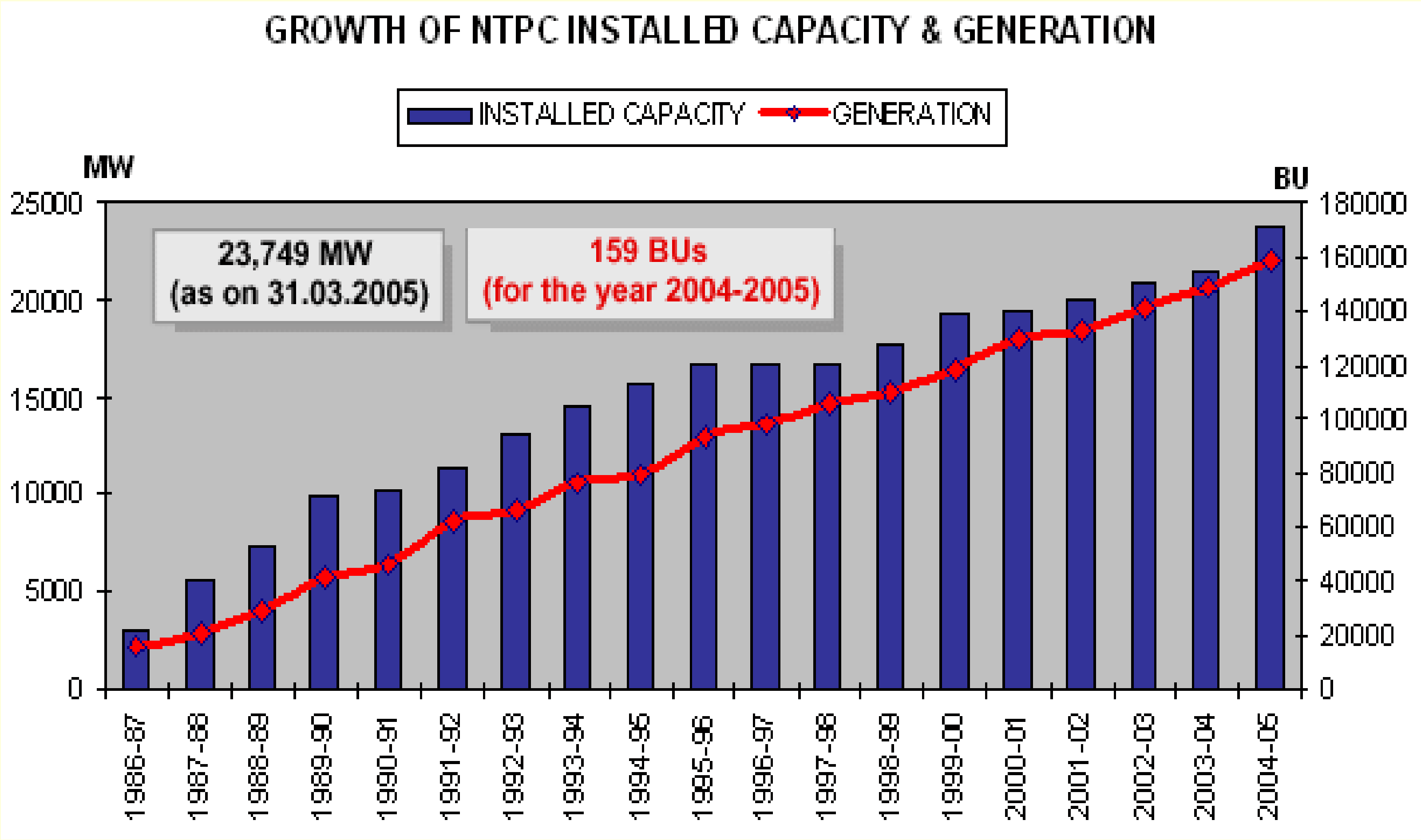


UCG FOR POWER
GENERATION

POWER GENERATION WITH UCG



POWER GENERATION WITH UCG



UCG FOR POWER GENERATION

POWER GENERATION WITH UCG

GASIFICATION OF COAL

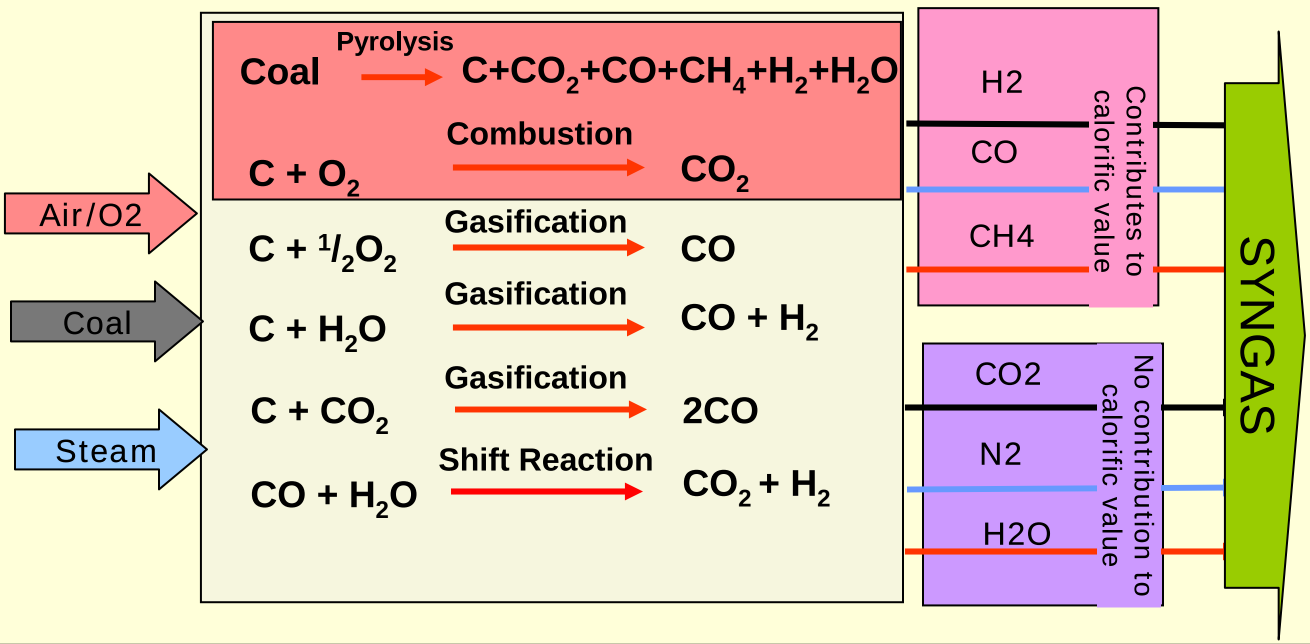
An Indian perspective

What is UCG

- Underground coal gasification (UCG) utilizes coal without mining it.
- UCG can provide energy from coal seams where traditional mining methods are either impossible or uneconomical.
- It can be used to exploit the off-shore coal reserve which is unsuitable for utilization by conventional mining.
- Hence it may be used for coal deep under ground.
- Gas may be used for - industrial heating, power generation, production of hydrogen, synthetic natural gas, liquid fuel or other chemicals.

Gasification

Conversion of Coal to Fuel Gas (Syngas) by Reaction in Oxygen deficit environment and in presence of steam



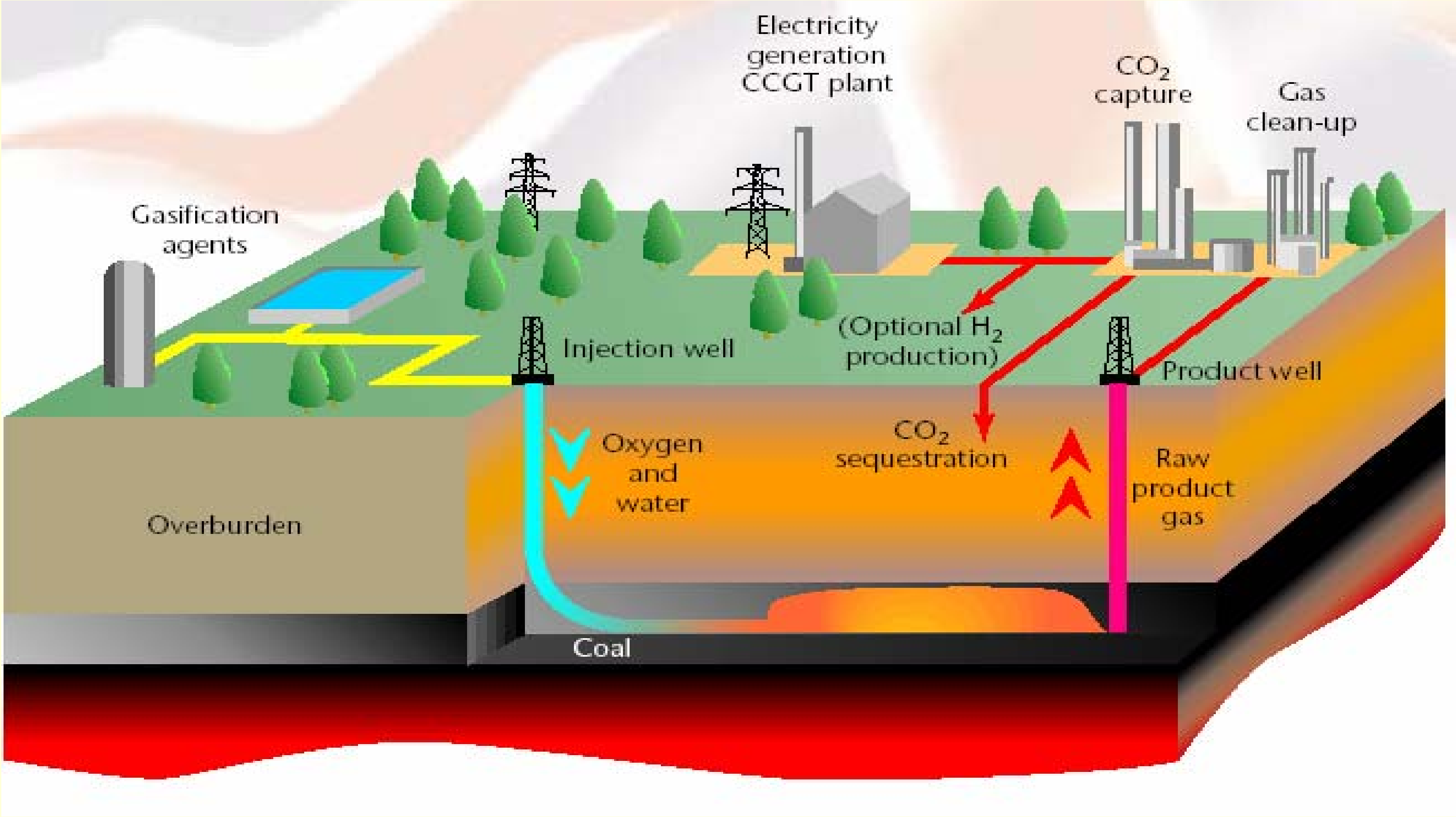
Gasification is slow reaction and require high temperature and more reaction time

Definition and Process

Process for in-situ conversion of coal in the mine to combustible gas

- **Air or oxygen is injected inside the coal mine**
- **Coal is ignited in-situ itself**
- **Fuel gas is produced by providing steam along with oxidizer**
- **Syngas produced contains CO, H_2 , CH_4,CO_2, H_2O, N_2.**

POWER GENERATION WITH UCG



UCG FOR POWER
GENERATION

Advantages of UCG

- Process of Mining is eliminated
- Loss of methane during mining and transportation is avoided
- No ash or coal handling at surface.
- Adjacent strata and cavity are potential Sequestration locations.
- Syngas suitable for high-efficiency power generation.
- High-pressure syngas can be easily treated.
- CO_2 capture and sequestration facilitated.
- Syngas is source of hydrogen, liquid fuel, and chemicals

UCG Global Status

Major International Field Trials & Schemes

Country	Max. Depth	Coal	Oxidant
France	1200 m	Anthracite	Air
Belgium	860 m	Anthracite	Air/ O2/Foamy water
USSR	150 m	Lignite	Air
Australia	100 m	Lignite	Air/ Steam

Russian experience equivalent to about 200 Mwe.

Chinchilla (Australia) was operated at large scale > 200 MWe and a recent pilot project (1999-2003) was successful and commercially available

UGC Technology World Wide

Vertical wells coupled generally with air pressurization to open up an internal pathway

It is suitable for young coal only

Russian

Man-built galleries in the coal seam as the gasification channels and boreholes are constructed to communicate with the surface

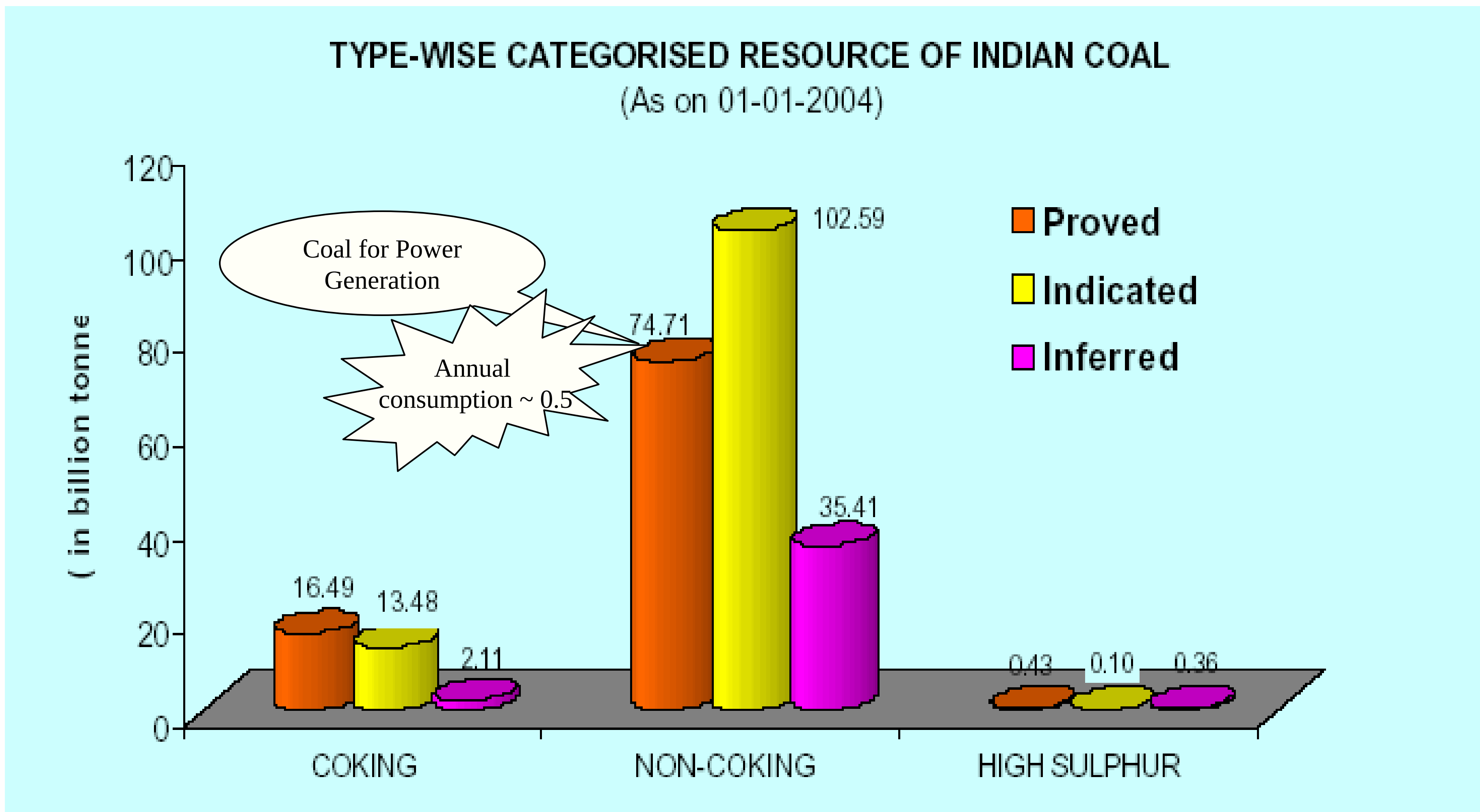
Chinese

Create dedicated inseam boreholes, using drilling and completion technology, adapted from oil and gas Production.

It uses CRIP and O_2

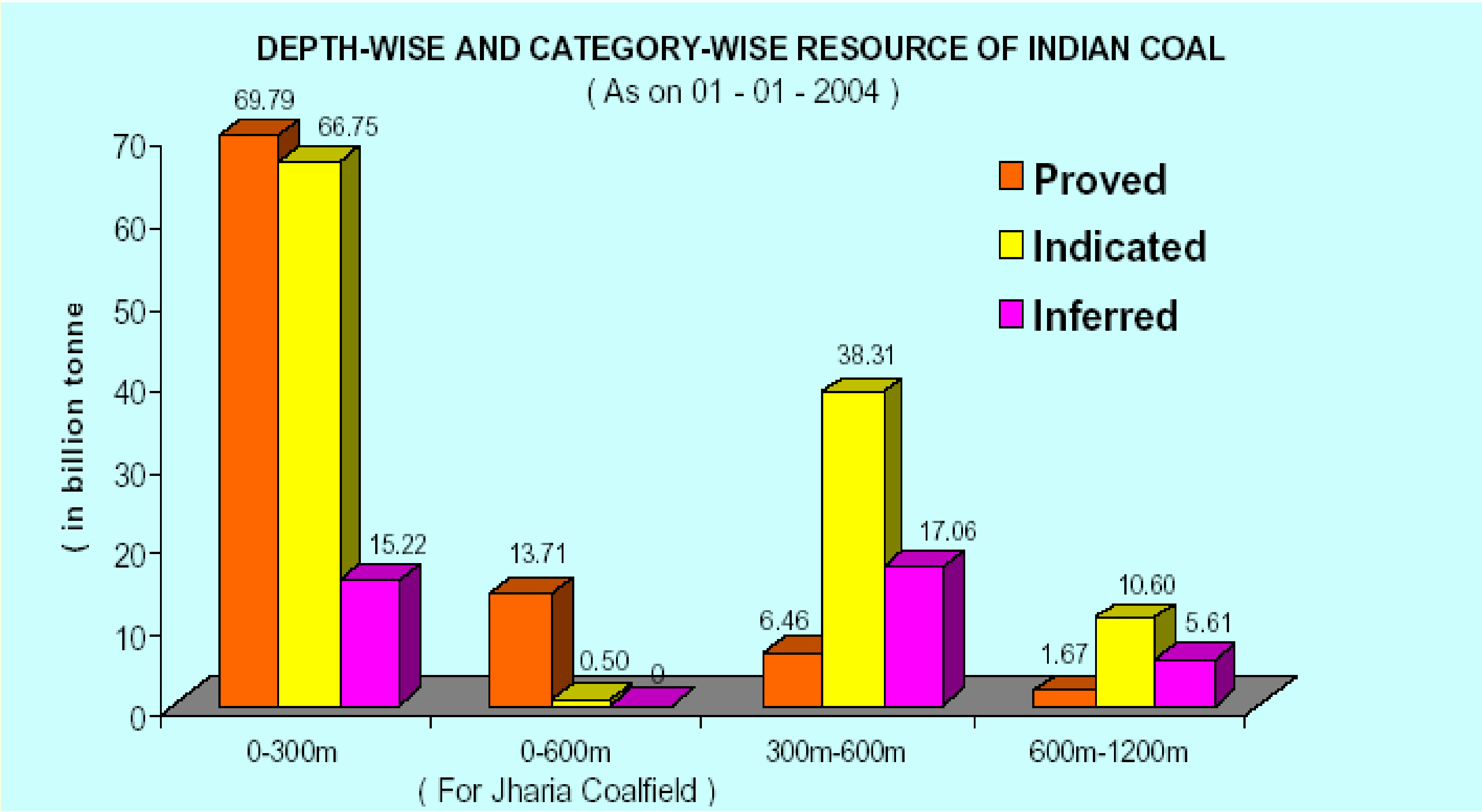
European

Indian Coal Reserves

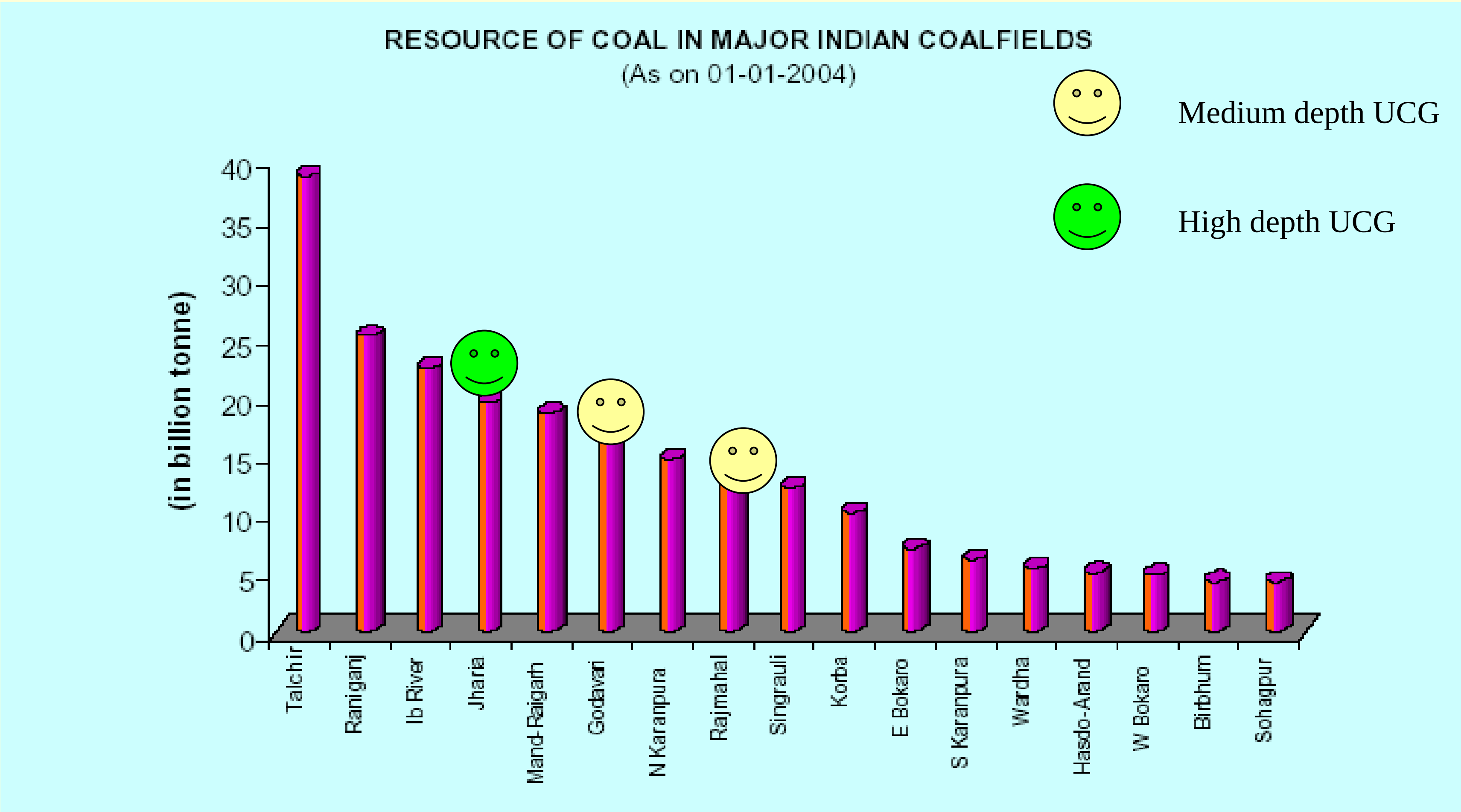


UCG FOR POWER
GENERATION

POWER GENERATION WITH UCG



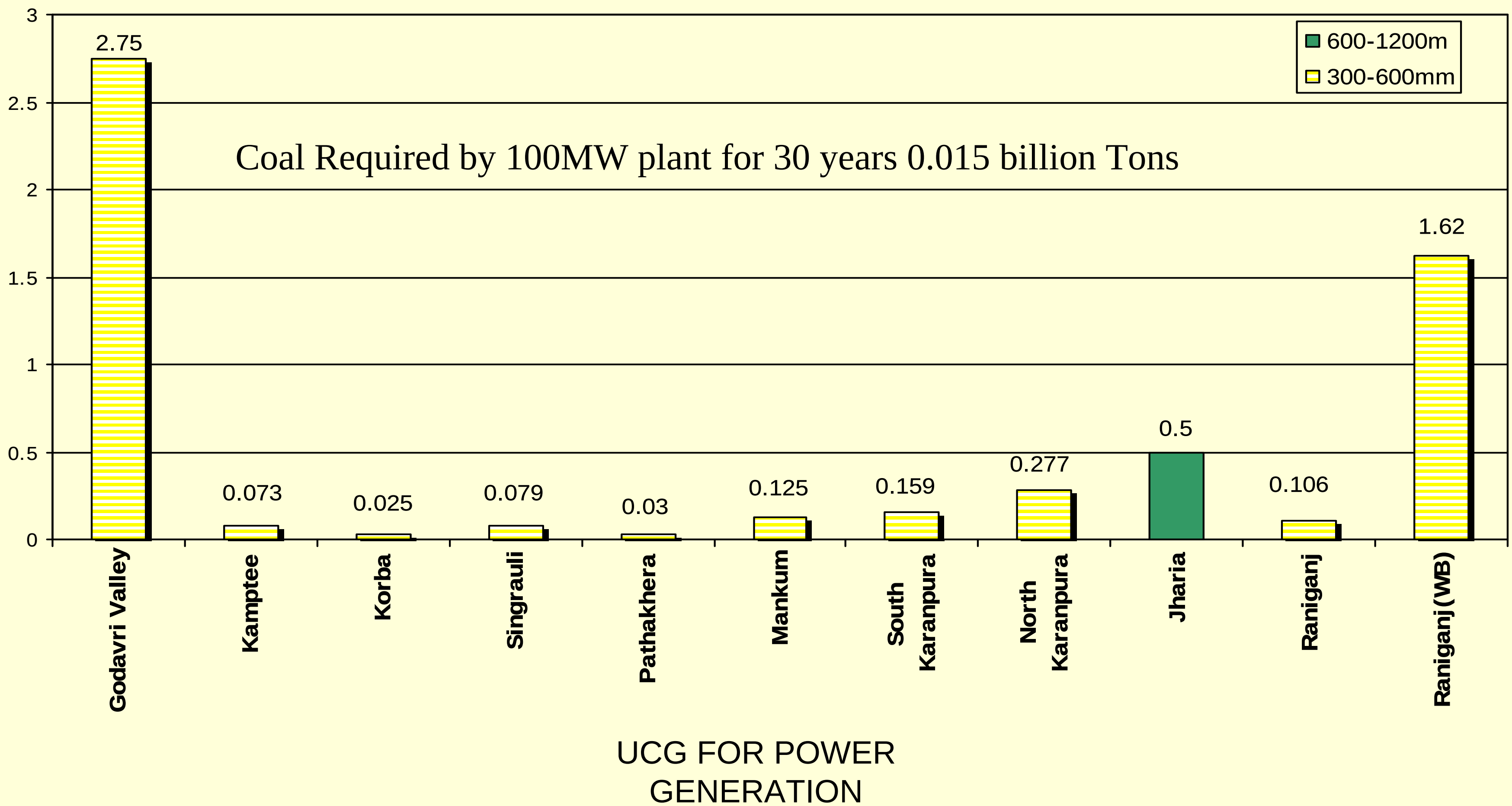
POWER GENERATION WITH UCG



UCG FOR POWER
GENERATION

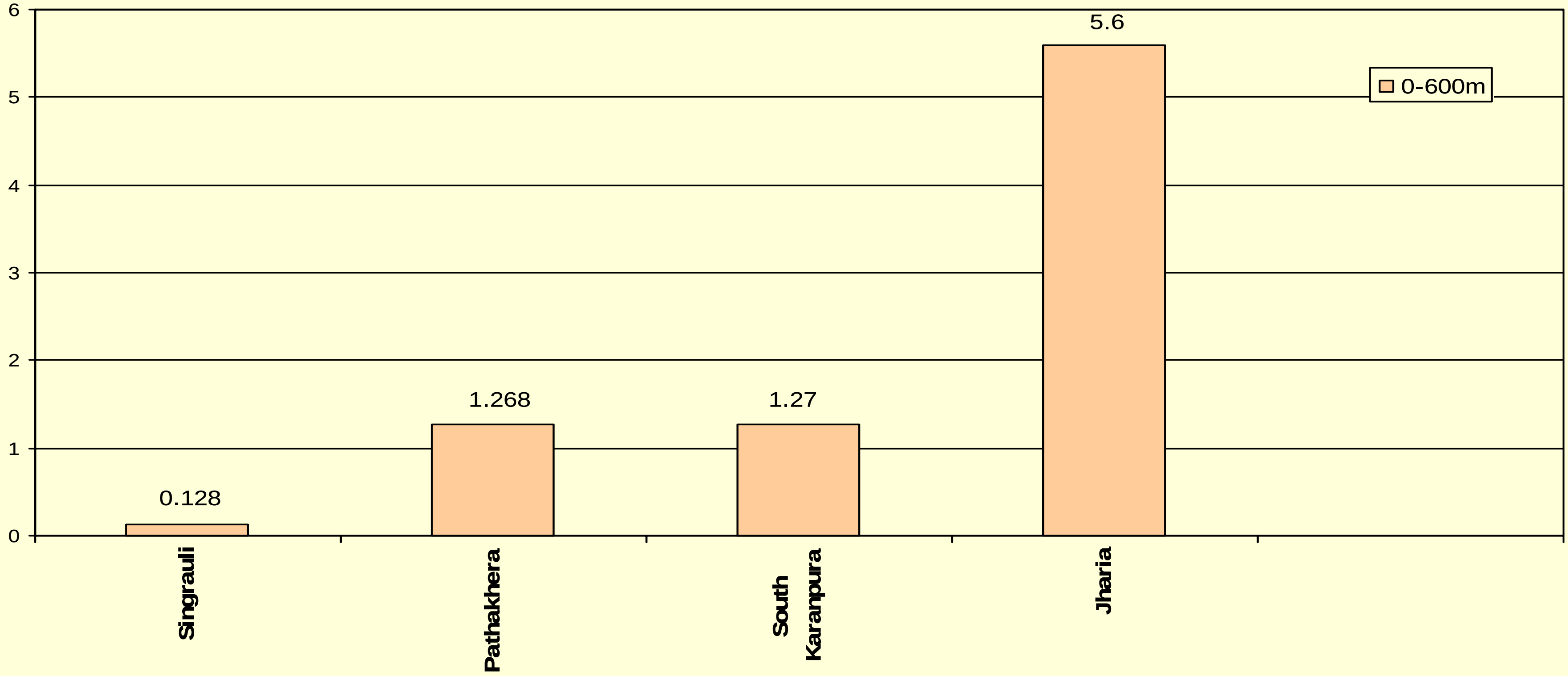
POWER GENERATION WITH UCG

PROVEN NON COKING COAL RESERVE AT 300-1200 m DEPTH(In Billion Tons)



POWER GENERATION WITH UCG

- **Proven Non Coking Coal Reserve at 0-600m depth (In billion Tons)**



UCG Potential in India

Total Coal Resources in India (up to a depth of 1500 m) — **460 billion Ton**

Of which, below more than 300 m depth — **315 billion Ton**

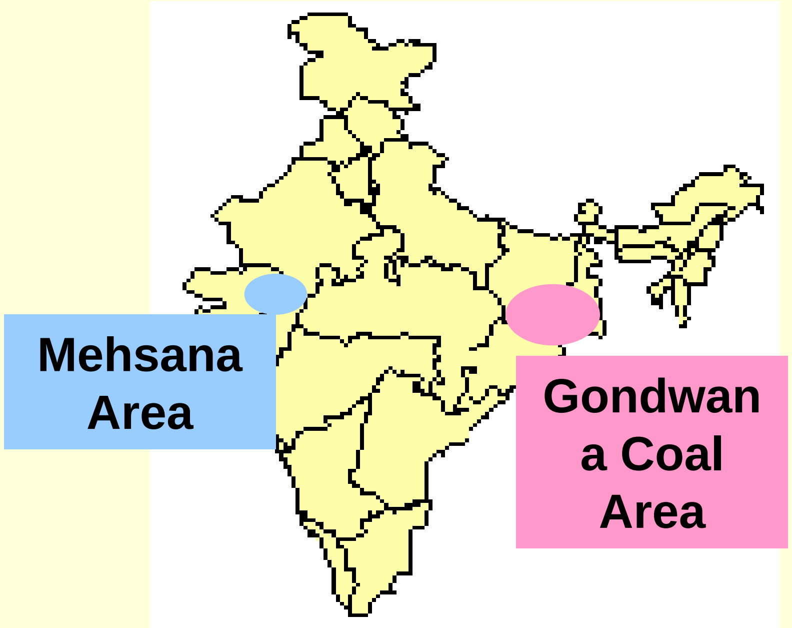
Target coal for underground gasification because of

- ***favorable geographical set up,***
- ***thickness of coal seams,***
- ***optimum rank,***
- ***maturity and***
- ***low sulfur***

UCG Potential in India

Potential Areas in India:

- Mehsana
- Gondwana coal area



About 70 billion ton of coal at Mehsana is available for underground gasification

May result in 15000 billion m^3 equivalent of NG

Present gas production 32 billion m^3

POWER GENERATION WITH UCG

IGCC POWER PLANT

IGCC: Opportunity to utilize coal in high efficiency combined cycle

- *IGCC is gasification of coal and then its use in combined cycle*

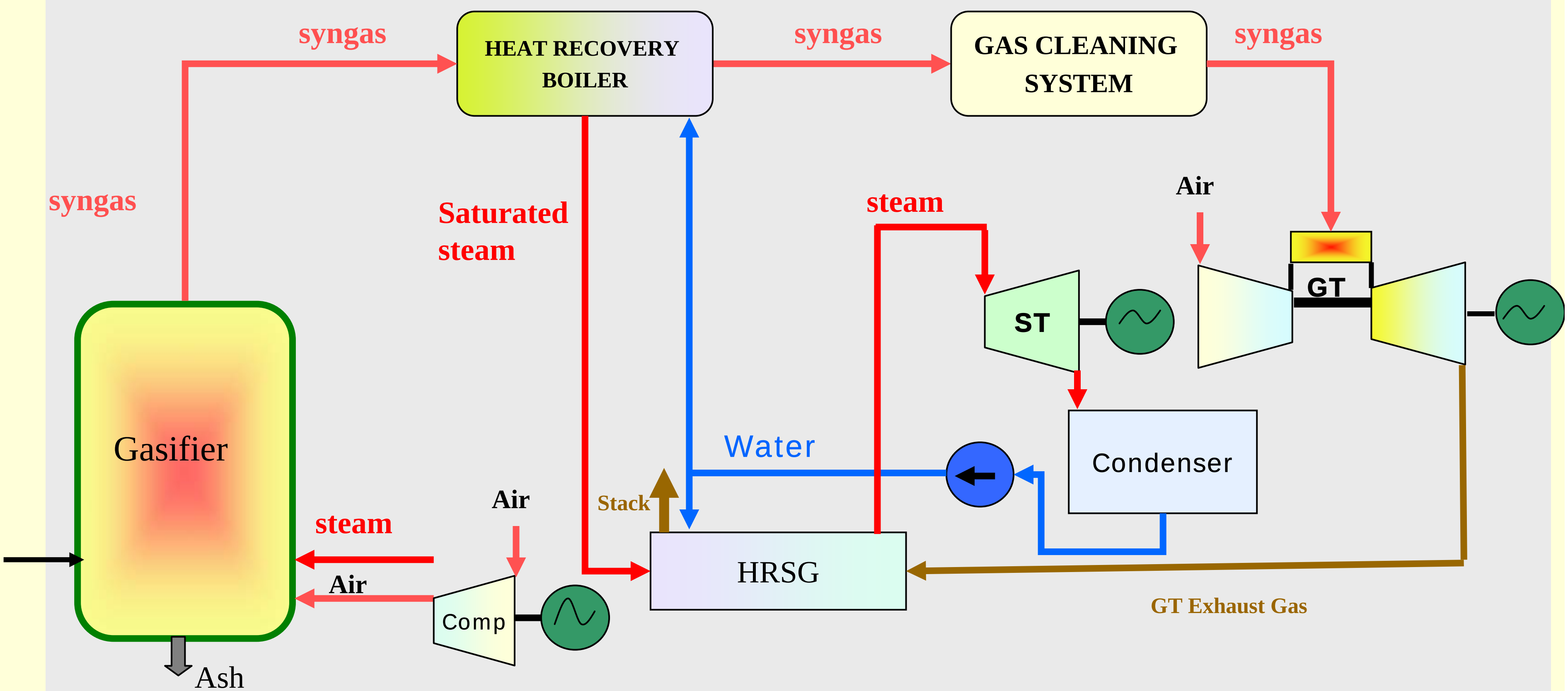
- *Due to higher efficiency, suitability for carbon capture and ease of capturing other pollutant IGCC is promising technology.*

- *With high natural gas prices and pressure for reduction of emission of green house gases, IGCC with carbon capture seems to be a favorable option for fossil fuel based power generation.*

- *UCG is coal gasification without Gasifiers*

- *IGCC considered for Power generation with ICG*

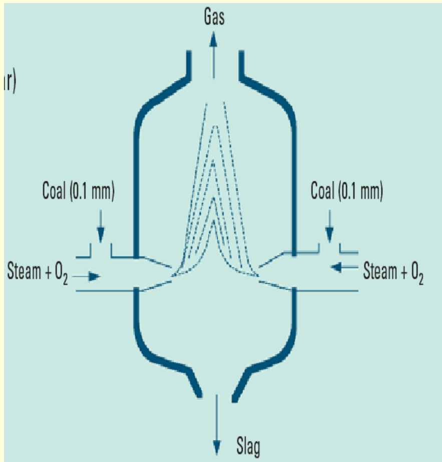
IGCC SCHEMATIC



UCG FOR POWER GENERATION

Types of Gasifier

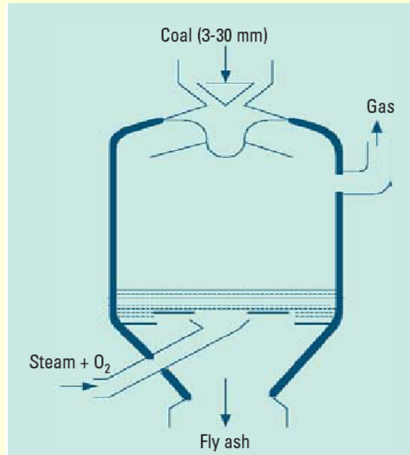
Entrained flow gasifier



Texaco	Commercial
E Gas	Commercial
Shell	Commercial
Noell	Commercial
Prenflo	Commercial
Mitsubishi	Pilot

suitable for Pet Coke and Low Ash Coal

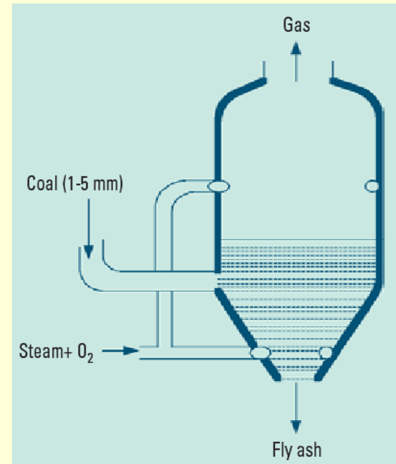
Moving bed gasifier



Lurgi	Commercial
BGL	Demo

Suitable for Reactive Coal, both Low and High Ash Coal

Fluidized bed gasifier

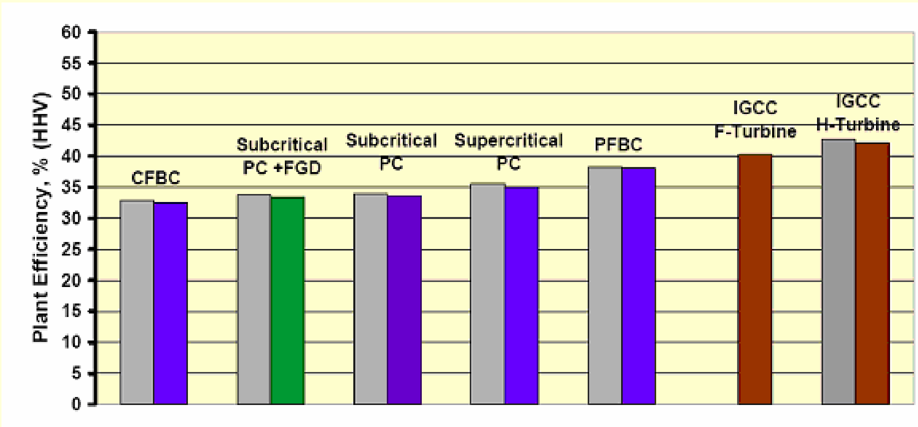


U-Gas	Pilot
KBR	Pilot
KRW	Demo
BHEL	Pilot
HT Winkler	Demo

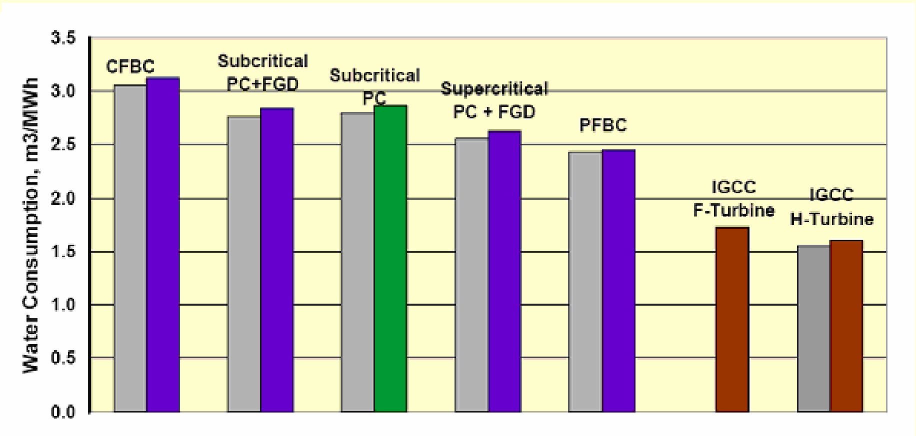
Suitable for Reactive Coal, both Low and High Ash Coal

IGCC is expected to give higher efficiency and lower water consumption than PC pant

Plant Efficiencies for 2x 500MW Plant



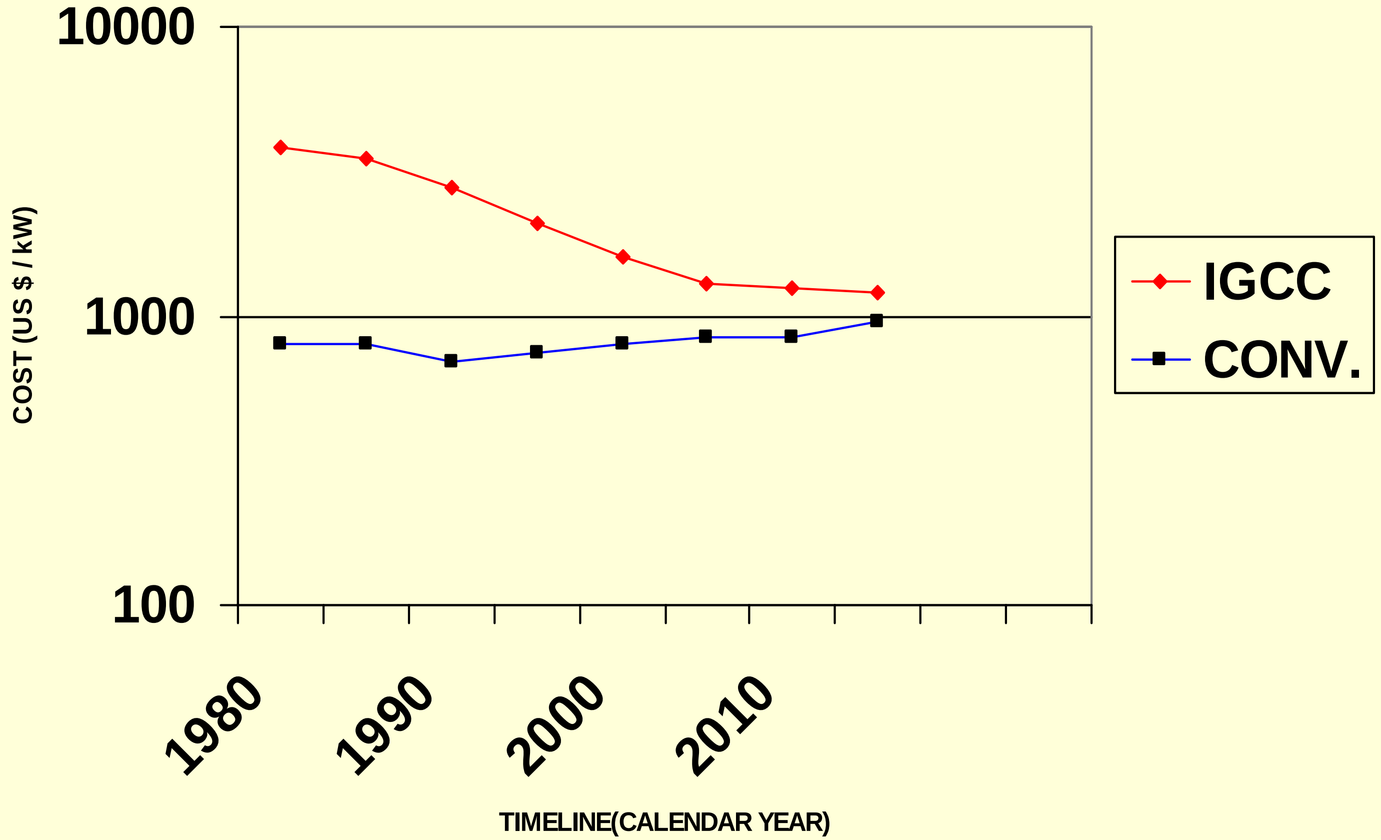
Water Consumption for 2x500MW Plant



Solid bars-Washed coal, coloured bar – ROM coal

IGCC has major advantage in reducing pollutant like SOx and heavy metal
Because of lower volume of syngas carbon capture is economical

EXPECTED TRENDS FOR FUTURE CAPITAL COST



KEY TO COMPETITIVENESS

HIGHER CAPITAL COST MUST BE COMPENSATED BY INCREASED EFFICIENCY TO MAINTAIN SAME COG

IGCC for India needs Indian Coal Specific Development

- **Selection and design of gasifier is coal dependent**
  - **Entrained bed gasifier suitable for low ash coal**
  - **Moving bed gasifier has not been used in IGCC. It is not good at handling fines in coal. Tar and phenol are difficult to handle**
  - **Fluidized bed gasifiers are limited to pilot scale. It is suitable for high ash coal but further development are required.**
- **Penalty for cold gas cleanup is comparatively high for air blown fluidized bed gasifier**
  - **Hot gas particulate cleaning, desulphurization and alkali cleaning is key to utilizing full potential of IGCC**
  - **These technologies are still under development around the world**
- **Gas turbine combustor for low Btu gas from fluidized bed gasifier need to be fully developed/tested**

High temperature Fluidized bed gasifier, Hot gas cleanup and Low BTU Combustor are required for Indian Coal based IGCC

For high ash Indian Coal IGCC Efficiency is comparatively low

Parameter	660 MW Super Critical	500 MW Sub Critical	100 MW IGCC	500 MW IGCC (Expected)
Gross efficiency	38.9	38	37 to 40%	40 to 43%
Auxiliary Power	7-8%	7-8%	13-20%	13-20%
Net efficiency	35.9	35	30 to 33 %	36 to 37 %
Capital Cost (Crores Per MW)	4.5	4.5	8 - 9	7 - 8

Capital Cost High due to cost of development, additional systems etc.

IGCC Scenario for India

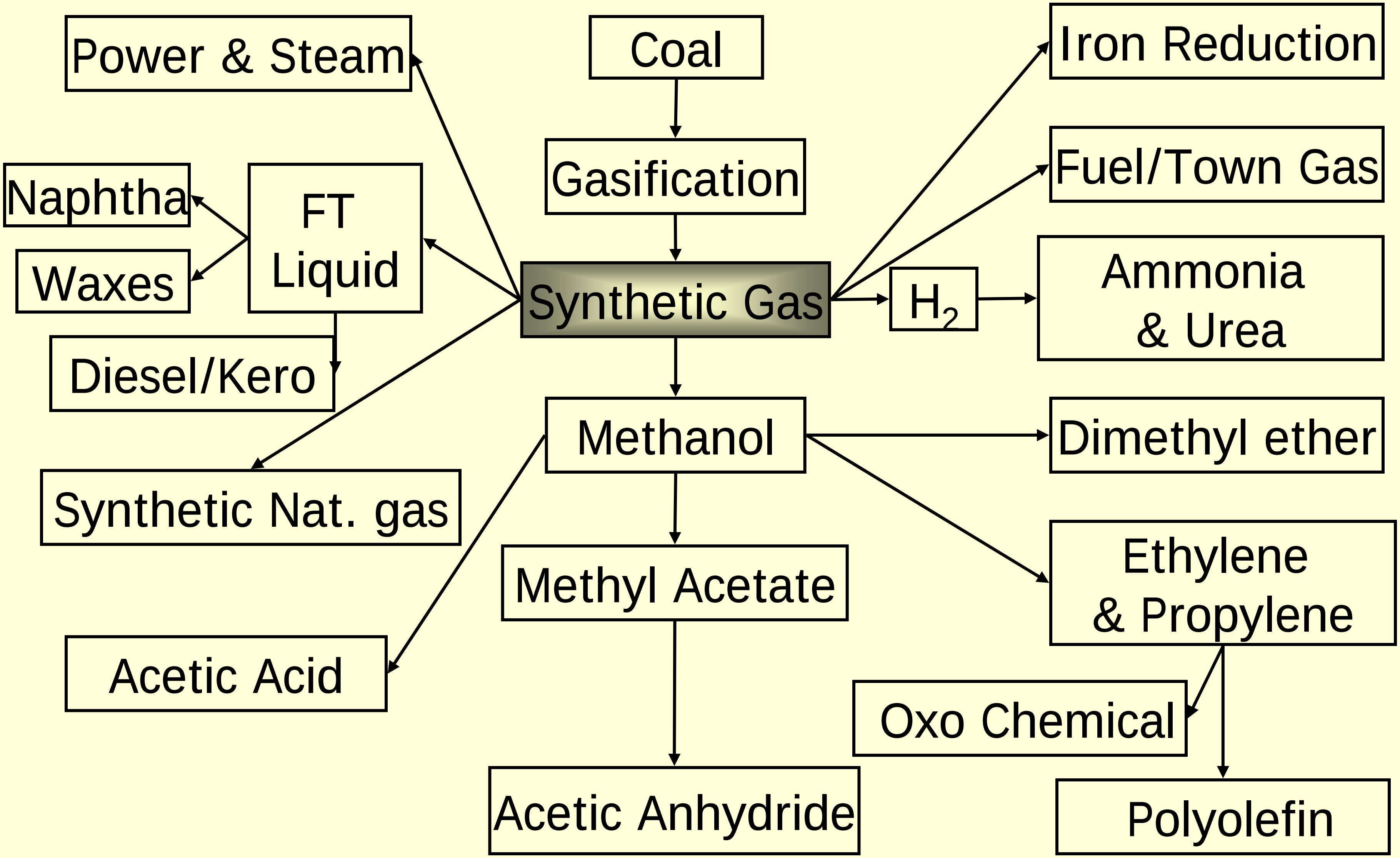
- ***Environmental regulations are going to be stricter in coming years***
- ***Deregulation of power market will require induction of Advanced Technologies at competitive price in future projects***
- ***Super critical/ Ultra-supercritical PC fired plants at present appear to be the most commercially used and viable option for power generation using coal***
- ***With development of higher size CFBC boilers, this technology is expected to be more popular in future .***
- ***IGCC will become cost effective with development of high capacity plants, for more stringent environmental norms, carbon sequestration and also when water consumption becomes a major issue***
- ***Development of IGCC should be perused toward improving efficiency and reliability.***

Coal will Remain Main Stay for Indian Power Generation in future

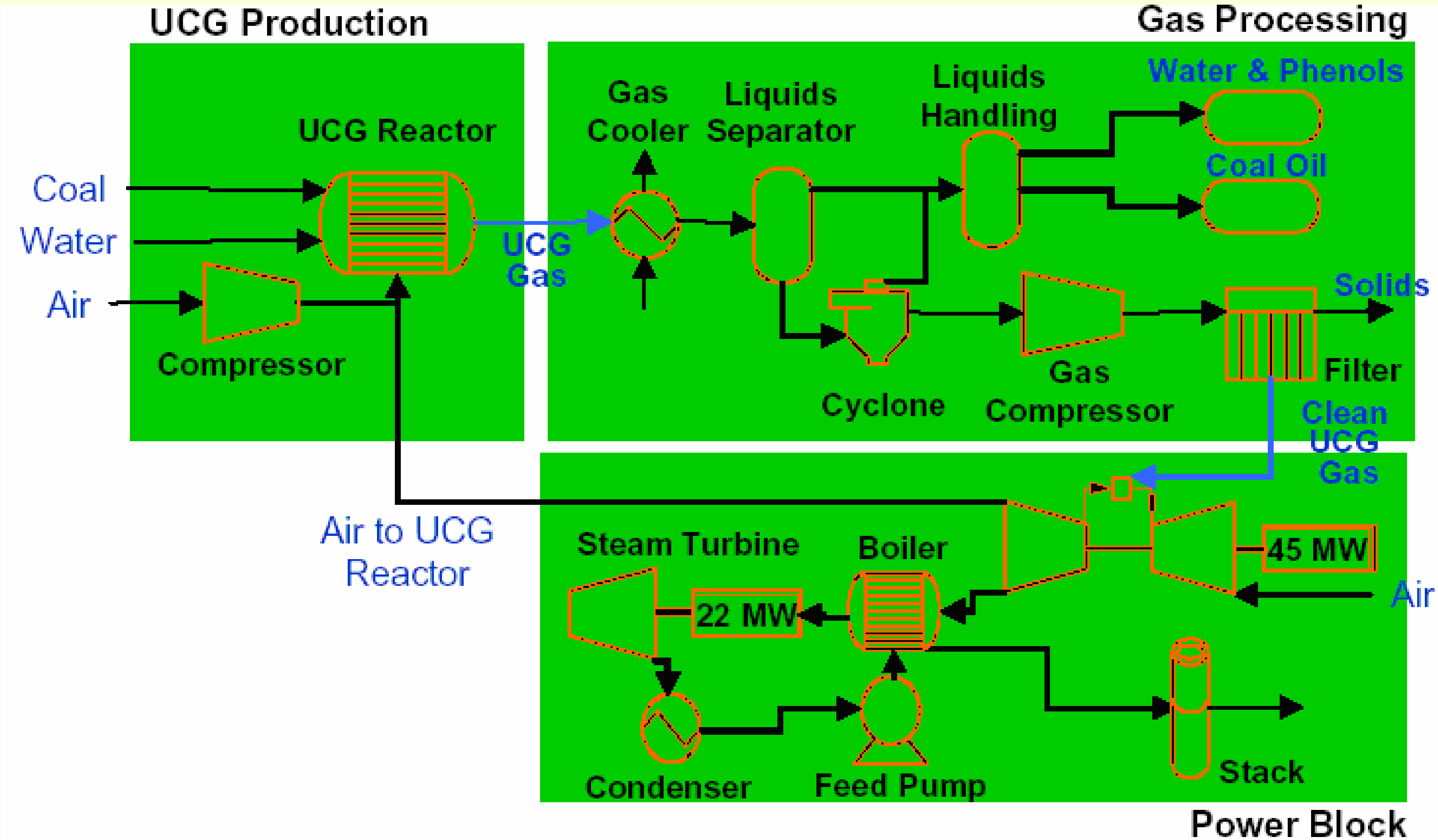
POWER GENERATION WITH UCG

UCG Based IGCC

UCG Product


Power & Steam
Coal
Iron Reduction
Naphtha
FT Liquid
Gasification
Fuel/Town Gas
Waxes
Synthetic Gas
H_2
Ammonia & Urea
Diesel/Kero
Methanol
Dimethyl ether
Synthetic Nat. gas
Methyl Acetate
Ethylene & Propylene
Acetic Acid
Oxo Chemical
Acetic Anhydride
Polyolefin

POWER GENERATION WITH UCG

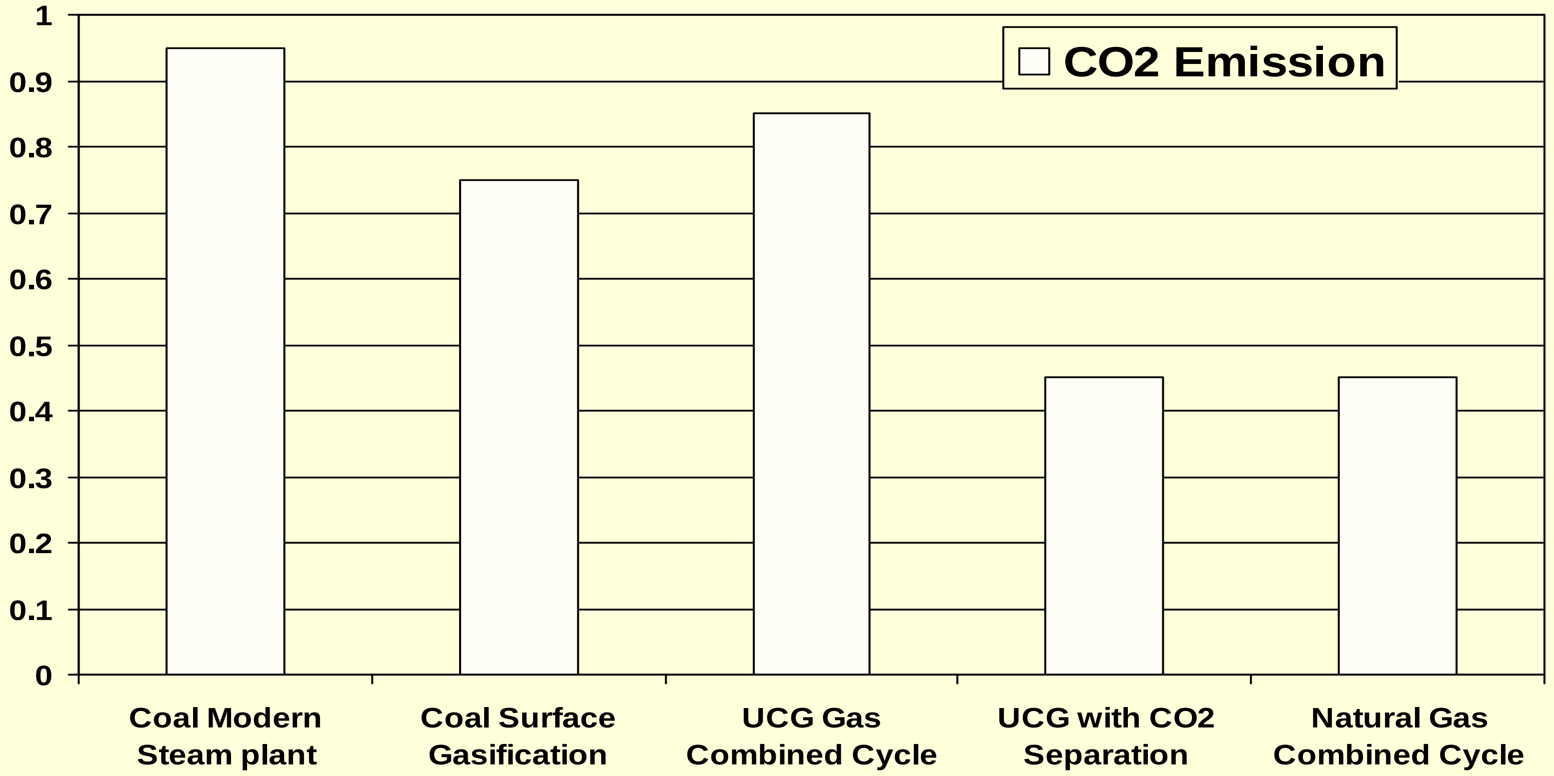


UCG FOR POWER
GENERATION

Environmental concerns of UCG

- There is possibility of leaching of organic substance, which is very likely to be extracted and transferred into the underground water. Phenol is the most obvious organic pollutant due to its relatively high water solubility.
- The concentration of inorganic salt near the gasification zone is likely to increase due to water vaporization in high temperature zone or solubility improvement in existence of CO_2.
- Dissolving of gas such as H_2, CH_4, CO_2, H_2S, and NH_3 in underground water.
- Leaching of heavy metals (Hg, As, Pb, Cr, Cd) may influence the quality of underground water.

CO2 emission in T/MWhr



Indian Effort

- GAIL is prospecting coal and lignite deposits for underground coal gasification (UCG) projects in India along with Ergo Exergy. The design of pilot and commercial UCG plants, their construction, commissioning, operation and maintenance will also be carried out jointly. The companies will cooperate for methods of gas clean-up, safety and environmental engineering of these plants. GAIL plans to set-up 70-80 mw power plants at the pitheads
- ONGC is perusing UCG in collaboration with CIL. ONGC have identified NMRC-Skochinsky Institute of Mining, Russia, as a consultant for the UCG application. ONGC plans to drill 100 wells and use enriched air to generate 1.5 mmscmd of gas. The ultimate aim is to set up a 200-mw power unit.

Pakri Barwadih Mine Survey

- Mine is spread over an area of 40 sq. km
- mine survey report has been prepared by CMPDI
- Mine survey has been done up to the depth of 300m
- Estimate reserve of coal is 1400 million Tons
- 400 million Tons is recoverable
- Water bearing horizons observed between the coal seams also.
- Coal seams separated by shale and sand stone
- MECON is currently preparing the mine planning and Feasibility report for this mine
- More detailed mine survey up to greater depth (say 600 m) is required for UCG

Seams Suitable for Open Cast Mining

Seam	Thickness (m)	Grade	M%	Ash %	VM%	GCV (k.Cal/kg.)
V Top	1.5	D-G	3.5-6.8	22.4-52.2	17.8-22.3	3040-5466
V Bott.	1	B-G	3.9-7.3	15.7-48.7	20.1-21.9	3409-6321
V. Comb.	1.5	C	3.7-7.0	17.9-51.8	18.5-19.7	3136-5858
IV A	1.25	D-G	3.4-5.2	25.2-49.9	18.5-19.6	3329-5475
IV Top	1.25	E-G	3.1-5.8	31.3-43.6	20.4-23.7	3788-4999
IV Bott	2.5	C-G	3.7-5.3	21.6-50.2	18.2-23.8	3438-6070
IV Comb	8	E-G	3.1-5.0	32.2-48.2	17.9-22.7	3000-4832
III Top	1.5	C-E	2.6-5.5	17.2-51.2	18.7-24.0	3200-6136
III Bott	1.25	B-G	2.8-5.7	16.6-50.0	22.7-27.1	3447-6160
III Comb	1.5	D-F	3.4-5.8	25.9-37.9	-	4037-5529
II Top	8	C-G	2.8-5.3	23.3-52.7	18.0-25.3	3130-5724
II Middle	8	C-F	2.0-5.5	23.1-43.2	20.7-25.4	4520-5789
II TM	12	D-E	2.6-5.3	27.2-45.9	21.9-25.5	3854-5550
II Bott.	7	C-G	1.6-4.7	26.9-47.2	21.2-24.7	3736-5578
II MB	16	D-E	2.3-4.0	29.7-35.3	23.3-24.0	4820-5214
II Combo		D-F	3.8-4.6	28.9-36.6	22.9-23.0	4620-5292

Seams not Suitable for Open Cast mining

I Top	2.5	B-G	1.5-4.0	21.2-51.1	20.8-27.8	3525-6280
I Middle	2.5	C-G	1.8-3.9	25.6-50.8	18.0-22.5	3400-5459
I TM		D-G	2.9-4.3	27.2-46.0	20.5	3903-5363
I Bott	2	C	1.5-4.1	20.1-53.9	20.7	2491-6071
I MB		E-F	2.8-3.3	35.6-43.8	-	4016-4716
I Comb.		E-G	2.9-3.6	30.9-49.4	20.1	3484-5114
Local	1.5	B-G	2.3-5.5	15.7-52.8	17.6-21.8	2867-6286
K5		A-G	2.5-5.8	10.9-49.9	-	3502-6753
K4		A-G	2.8-6.0	8.1-45.9	-	3761-6963
K3		A-G	2.6-5.1	7.1-48.7	15.1-23.5	3400-7145
K2		A-G	2.6-5.0	8.2-47.4	22.4	3712-7056
K1		A-G	1.6-3.5	9.6-49.8	19.3-24.1	3603-7213

Suitability of Pakri Barwardi for UCG

- Coal Available up to the depth 600m.
- Present Open Cast mining Limit 200m
- Proposed Open Cast mining Limit 320m
- Grade of Coal E and F Grade hence not economical for Underground Mining
- Water Table depth 60 to 70 m
- So Coal available below 400 m may be available for UCG
- At this depth Rock is generally hard and not permeable.
- Chances of pollution aquifers is little at this depth

Suitability of Pakri Barwadih

- Top four seam of Barakar formation are economically recoverable by open cast mining
- Bottom seam of Barakar formation and all the seams of Karharbari formation may be available for UCG
- European technique involving in seam drilling appears to be more suitable technique
- Many of the seams have depth of less than 1.5 m. These seams may not be viable.
- Seams separated by shale and sand stone are not suitable for UCG.

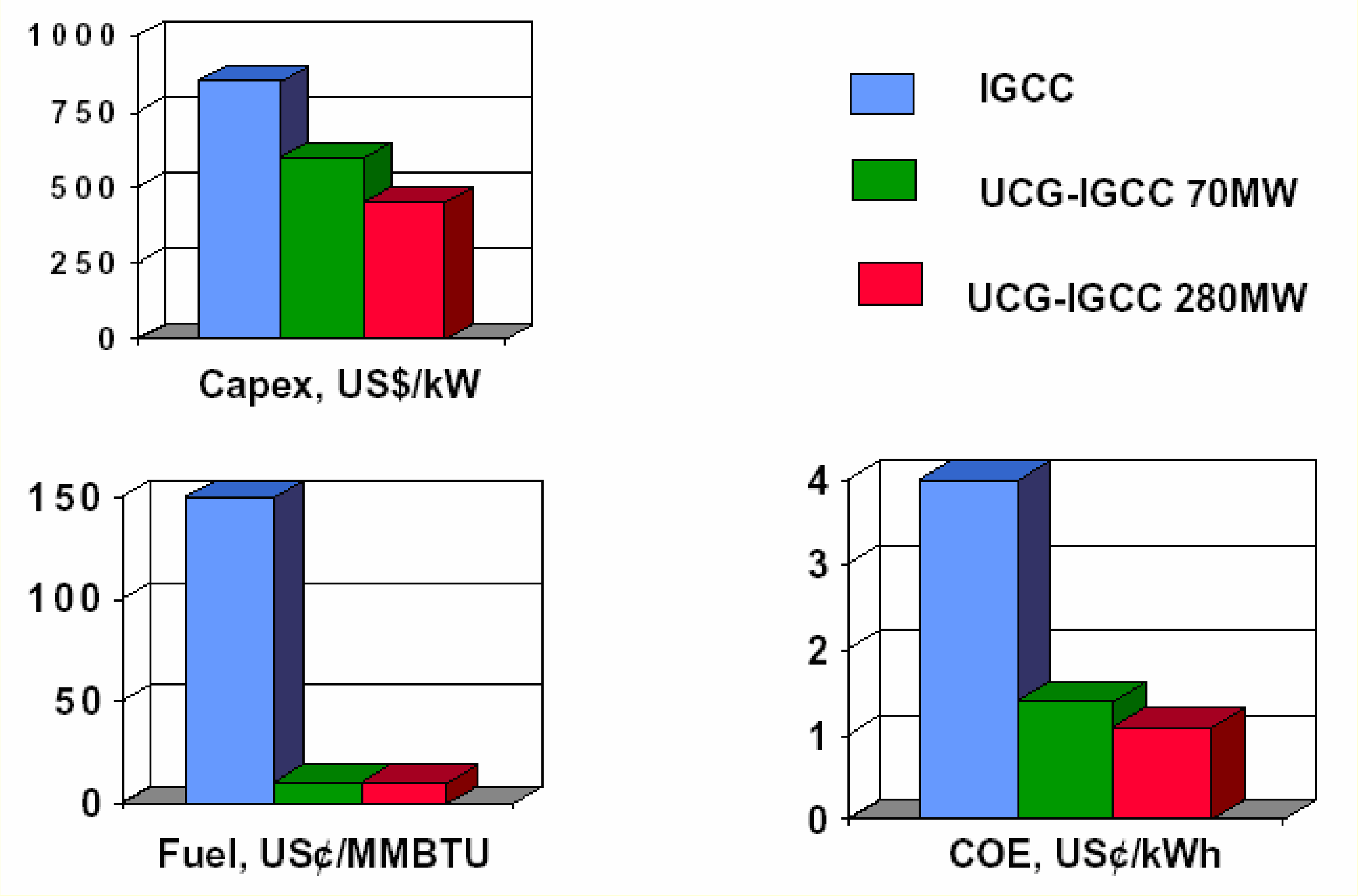
Expertise Requirement for UCG – A Review

Combined Cycle	Available within NTPC
Geology & hydrogeology	Not available within NTPC
Mining	Not available within NTPC (Coal Industry)
Drilling and exploration	Not available within NTPC (Oil and Gas Industry)
The chemistry and thermodynamics of the gasification	Some Knowledge base generated during IGCC study

Economics of UCG Power Generation

Estimate of UCG Power Cost

(Data available –Is it applicable to Indian Mines/Coal/Conditions ?)



Estimate of UCG Cost

- Large-scale UCG with power generation (300MWe) undertaken remote from the gasification site has a generation cost comparable to, and possibly less than, Integrated Gasification Combined Cycle (IGCC) technologies. However, small scale developments (~50MWe) are not likely to be economically viable as standalone project
- UCG with CCS has a power generation and capture cost which lies between the two estimates for IGCC with CCS and is comparable with gas turbine combined cycle (GTCC) with CCS. This assessment assumes post-gasification capture.

Source: dti(UK) internet site

Cost Estimate for 100 MW UCG IGCC
(Indian conditions)

- **Total field cost for UCG IGCC power plant is CC plus additional cost for underground gasifier and piping network for supply of gas**
- **Cost of fuel depend on UCG cost**
- **Cost saving due to elimination of gasifier**
- **Additional cost for underground gasifier and piping network for supply of gas**
- **There is saving due to elimination of mining and coal transportation.**

UCG – Gas Quality for power generation

- Calorific value of gas form UCG with oxygen as oxidant is in the range of 700 to 850 kcal/NM^3 which may not be suitable for firing in gas turbine as calorific value in the range of 1000 Kcal/Nm^3 is considered as minimum requirement for gas turbine and it would be safer to keep design value of syngas CV in the range of 1300 KCal Nm^3

- Calorific value of about 1500 Kcal/Nm^3 has been obtained in UCG with oxidant having 65% O_2 . So UCG with suitably enriched oxidant may provide the gas with desired CV

- Syngas from UCG enriched with oxidant is technically viable for power generation.

Economics of UCG for Power Generation

- **Assumptions made in Techno economics study:**

- **100 MW pit head power station with base load operation**
- **15 years plant life & plant cost estimated based on data**
- **Coal with GCV of 3300 Kcal/Kg with 2m seam depth**
- **Efficiencies of technology based on data available**
- **Fuel cost escalation of 3% for UCG against 7% for others**
- **Aux.power 15% for UCG & 7.5% for PC Boilers**
- **Plant Load Factor of 80% & Financial parameters as per data**

Cost of 100 MW IGCC Plant (Rs Crores)

Description	IGCC	UCG
Power Block (Combined Cycle) cost	365	365
Gasifier and particulate cleaning	100	0
Coal & Ash Handling Plants	35	0
Acid Gas removal and sulfur recovery	50	50
BOP Mech/Elect/Civil	100	75
Land/ Site development/Erection & Commissioning/Taxes/Duties	200	150
Total	**850**	**640**

Cost of Generation from UCG

- Cost of drilling and boring for 500m x 500m panel is about £9.6 million (Rs.76.8 Crores for Rs.80 per £). Other costs associated with underground coal gasification has not been accounted in this analysis.

- For seam thickness of 2m, a 500m x 500m panel will contain about 0.5 million Ton of coal. It translates into drilling cost of Rs. 1920 per Ton of coal. Including royalty of Rs. 65 per Ton, cost of coal extraction by UCG will be Rs.1985 per Ton against pit head coal price of about Rs.550.

- Based on above cost and 12% auxiliary power consumption in gasification process, cost of syngas from works out to about $8.5/MBtu at the pit head.

- Un accounted cost of piping network and cost other than that of drilling will further add to the above costs.

- Gasification efficiency in UCG is about 50%, hence overall efficiency of UCG assuming 50% combined cycle efficiency and 15% auxiliary power consumption works out as 21.5%

- Based on cost of Rs.1985/Ton of coal , net efficiency of 21.5% and capital cost of cost 6.4 Cr. Per MW, cost of generation from UCG comes about Rs 4.10 assuming 15 years plant life, PLF of 80% and 2.5% O&M cost (Possible only when technology becomes mature).

Thicker coal seams with lower ash, reduction in drilling cost and higher gasification efficiency will improve the economics of UCG

COG for UCG vs. other Technology

- **Conventional PC fired plan cost about Rs. 4.5 Crores per MW, has net efficiency of about 35% with pithead coal cost of about Rs. 550/T which gives cost of generation of Rs2.00/KWhr assuming PLF of 80% and 25 years plant life.**

- **Assuming 15 years plant life, PLF of 80% and 2.5% O&M cost , cost of generation from IGCC is expected to be around Rs 3.00/KWhr**

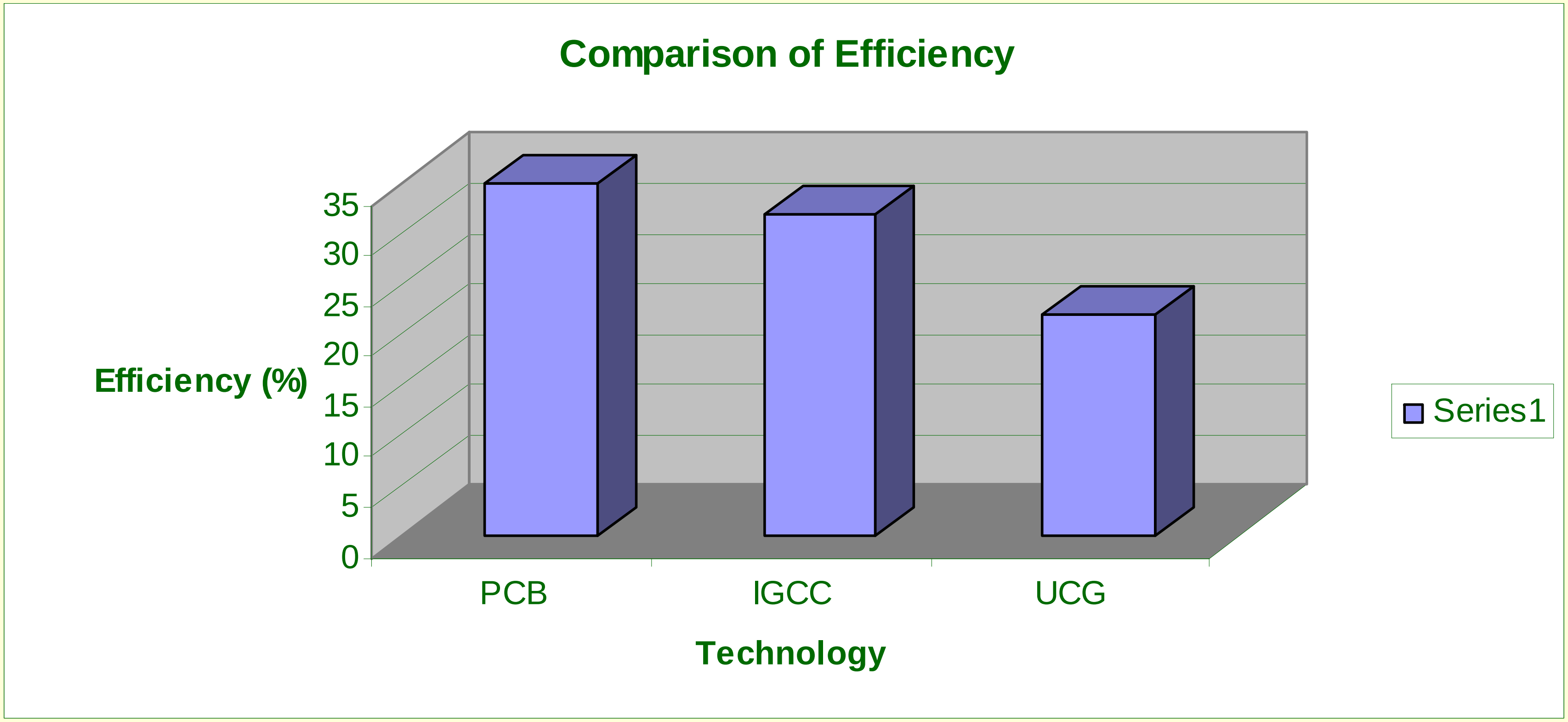
- **Based on coal cost of Rs.1985/T, net efficiency of 21.5% and capital cost of cost 6.4 Cr. Per MW, cost of generation from UCG comes about Rs 4.10 assuming 15 years plant life, PLF of 80% and 2.5% O&M cost (Possible only when technology becomes mature).**

- **Thus Conventional PC plant has significant cost advantage over other two technology**

- **IGCC has significant cost advantage over UCG if seam available for UCG is of about 2 m thick and CV of inseam coal is about 3300 kCal/kg. UCG cost will become comparable to IGCC if Seam thickness is more and CV of coal is higher**

100 MW CAPACITY POWER PLANT

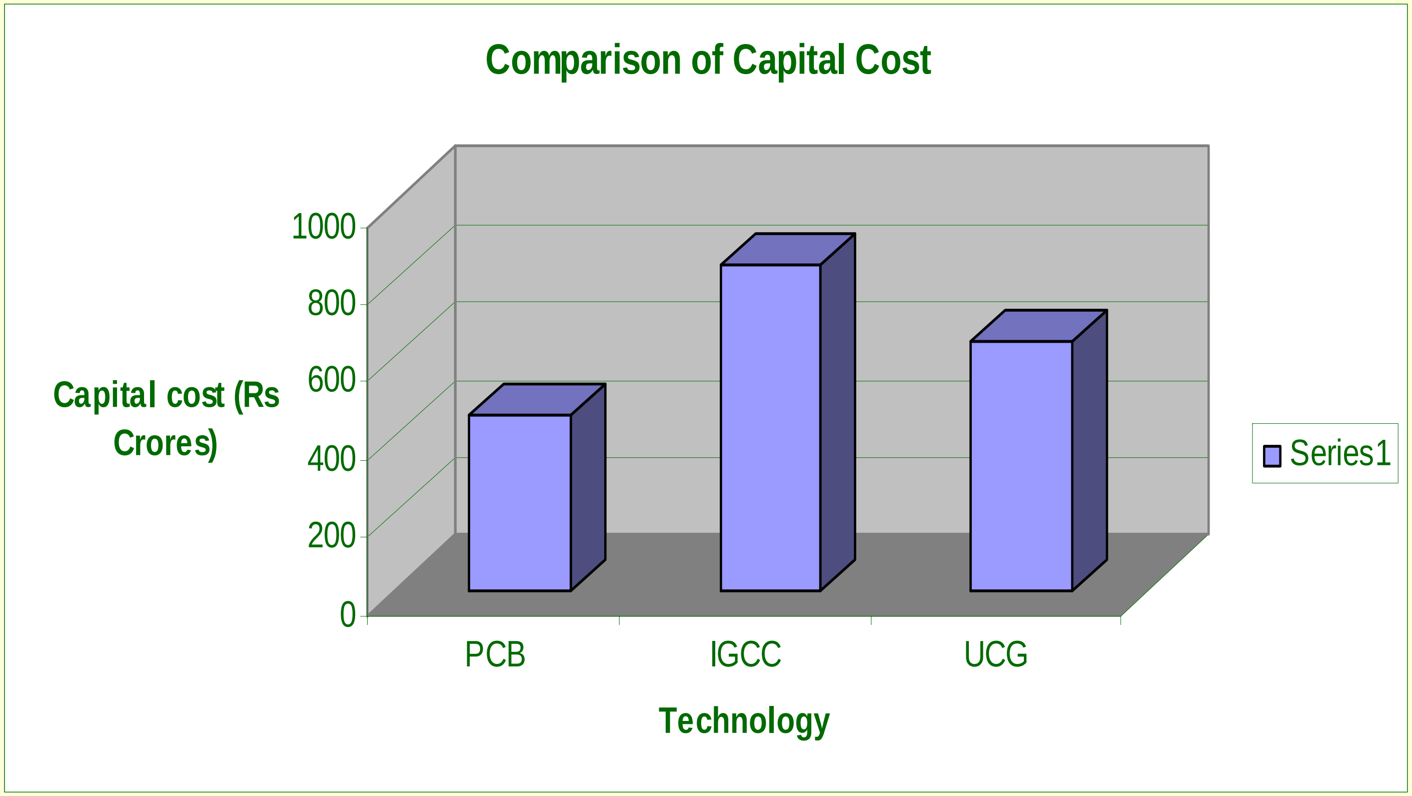
A TECHNOLOGY COMPARISON



UCG FOR POWER GENERATION

100 MW CAPACITY POWER PLANT

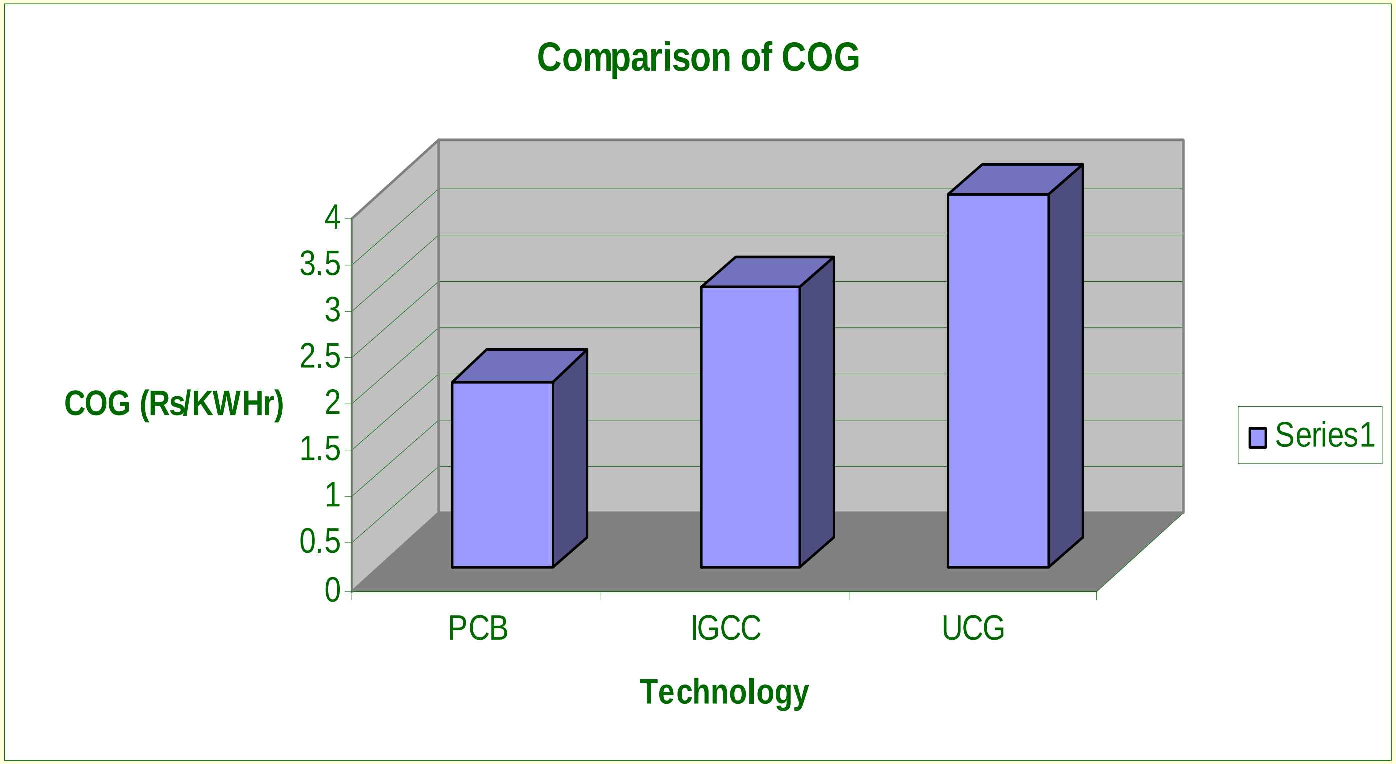
A TECHNOLOGY COMPARISON



UCG FOR POWER GENERATION

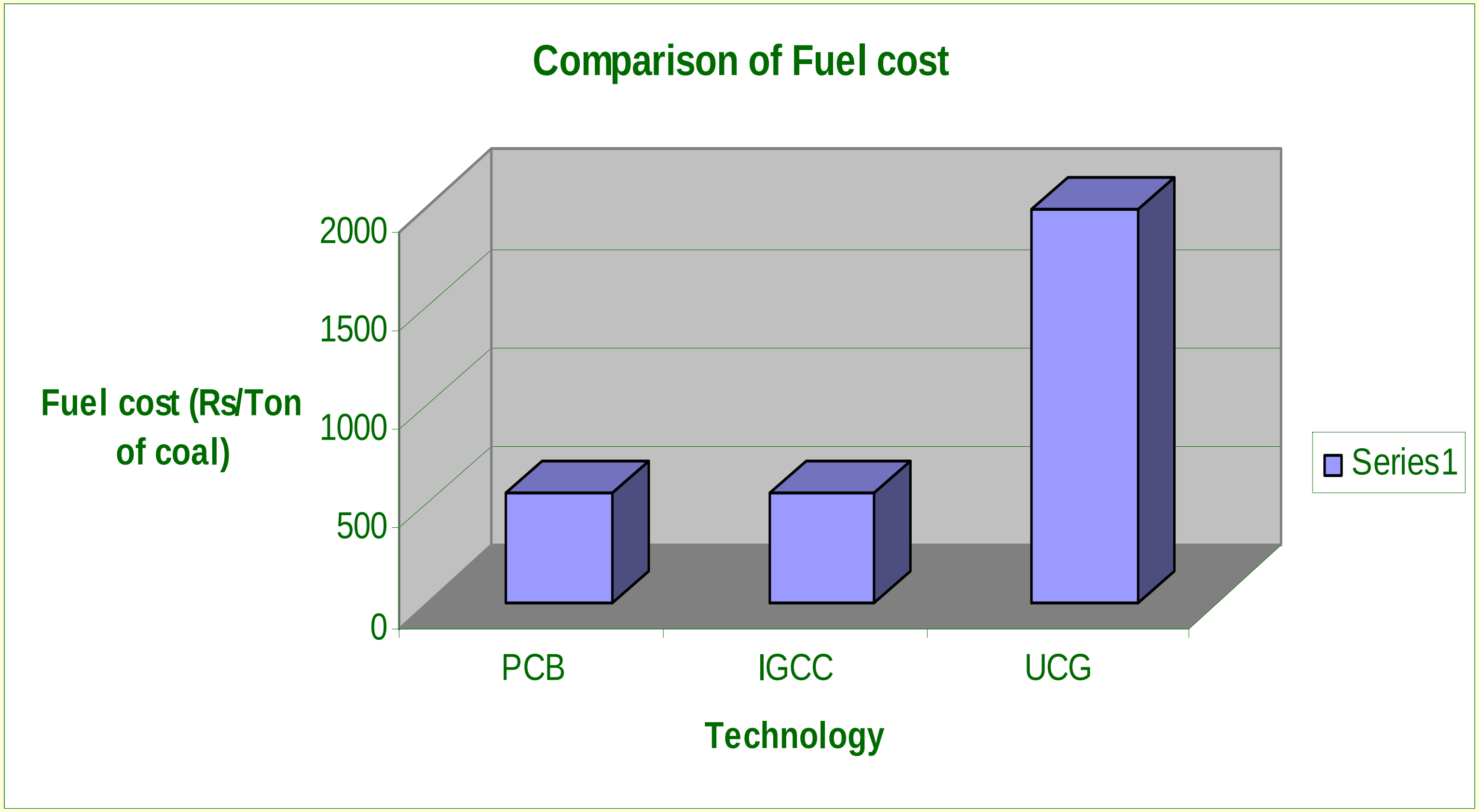
100 MW CAPACITY POWER PLANT

A TECHNOLOGY COMPARISON

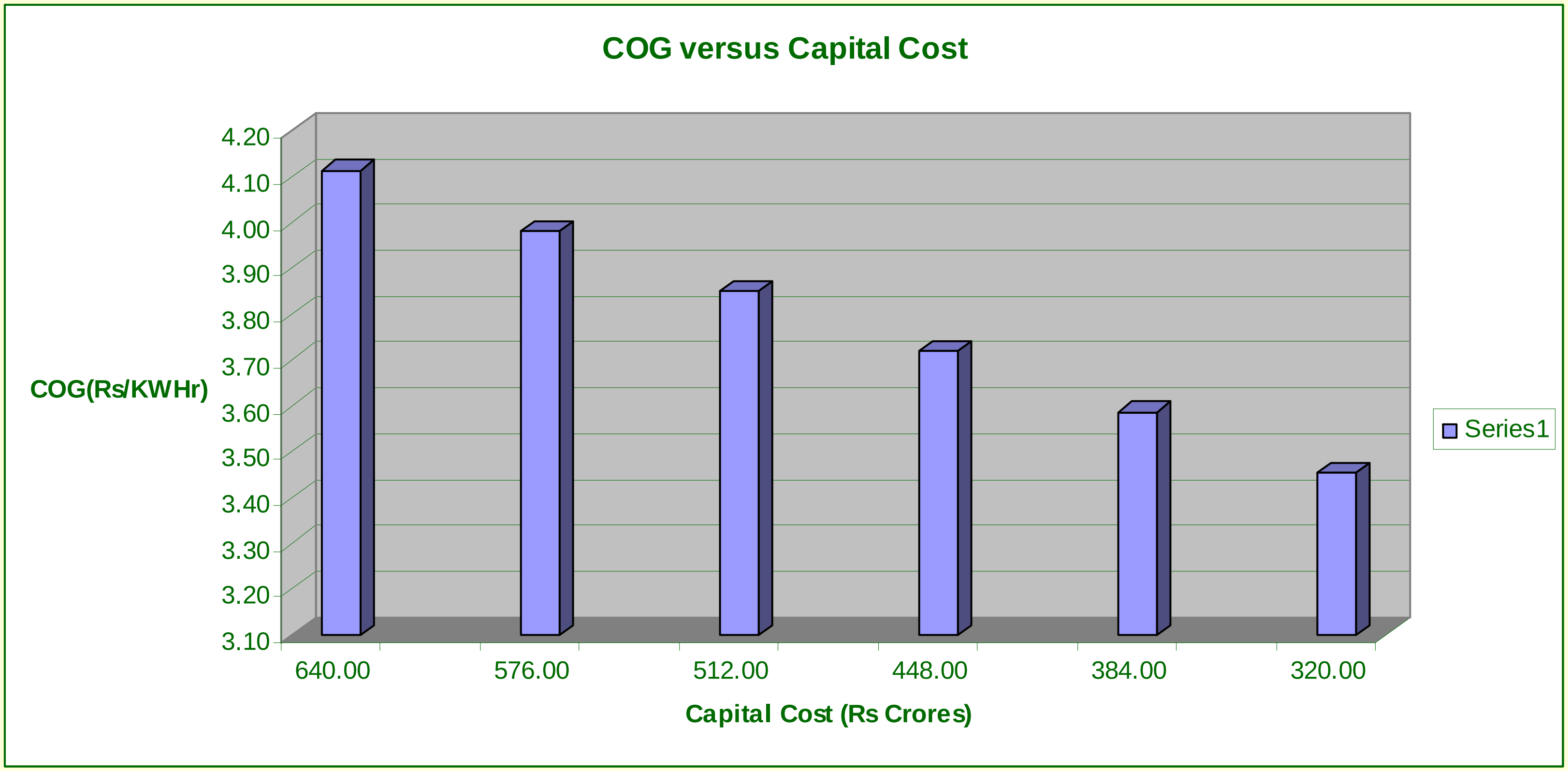


100 MW CAPACITY POWER PLANT

A TECHNOLOGY COMPARISON



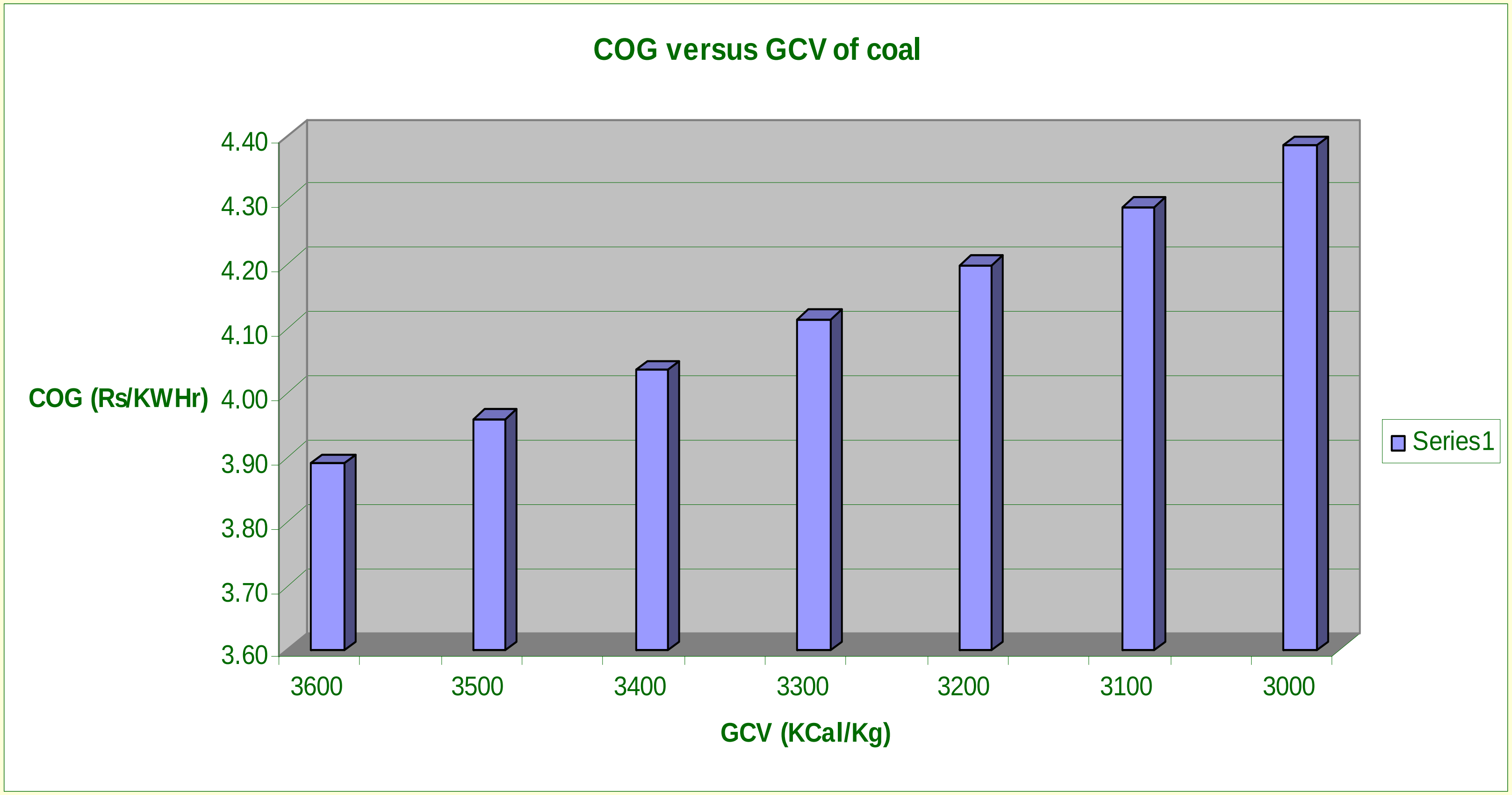
Economics of UCG for Power Generation
UCG Feasibility



UCG FOR POWER GENERATION

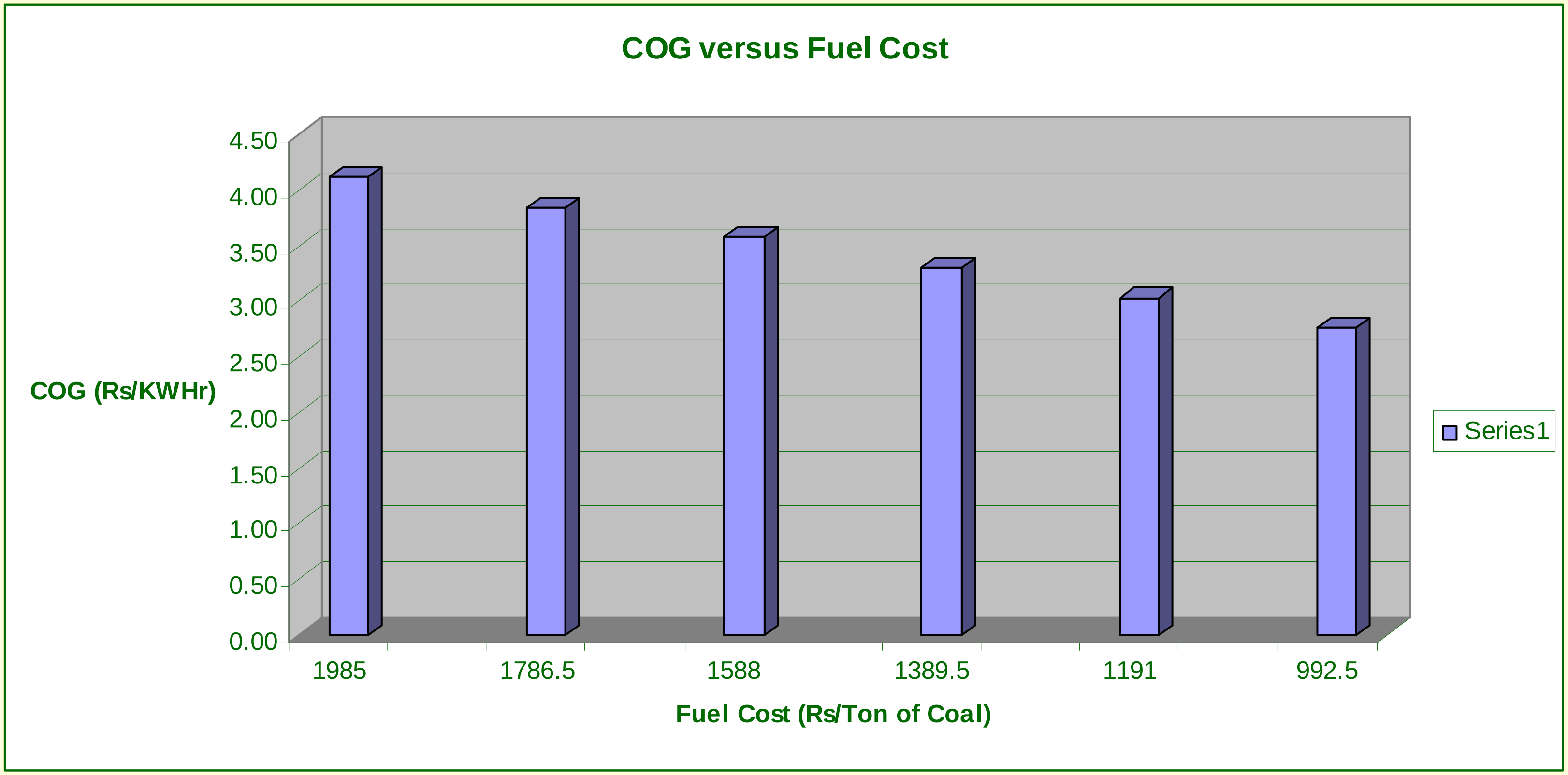
Economics of UCG for Power Generation

UCG Feasibility



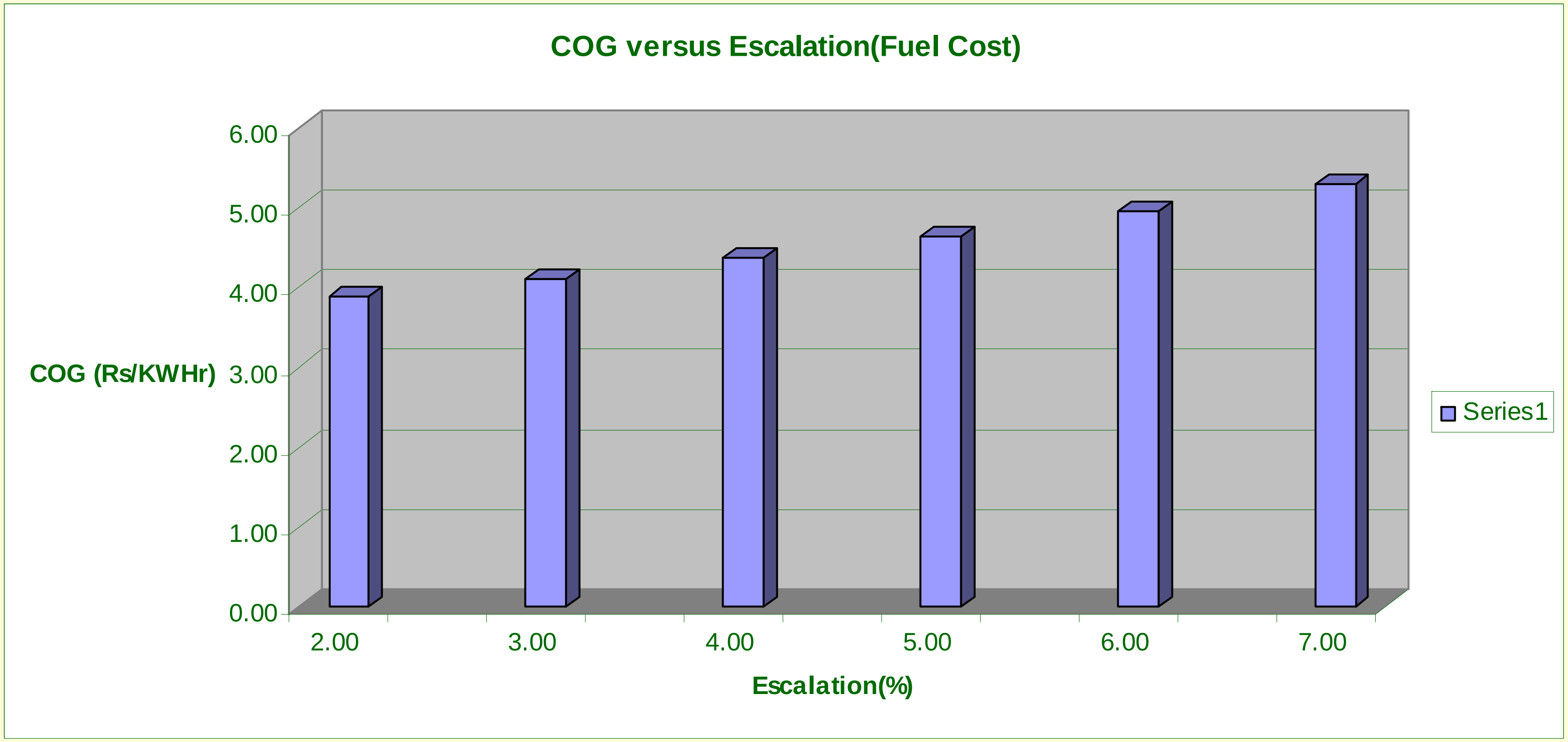
Economics of UCG for Power Generation

UCG Feasibility

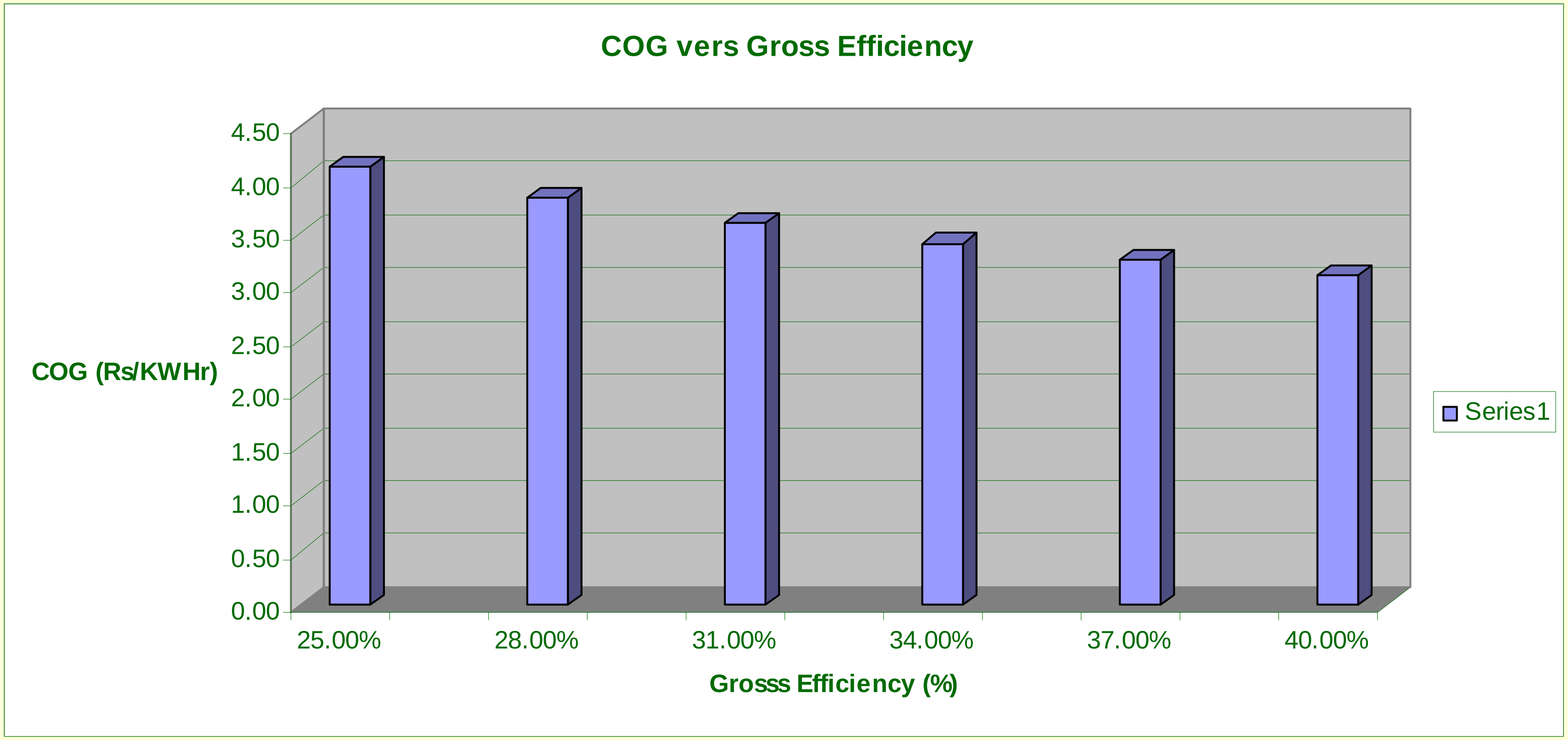


Economics of UCG for Power Generation

UCG Feasibility



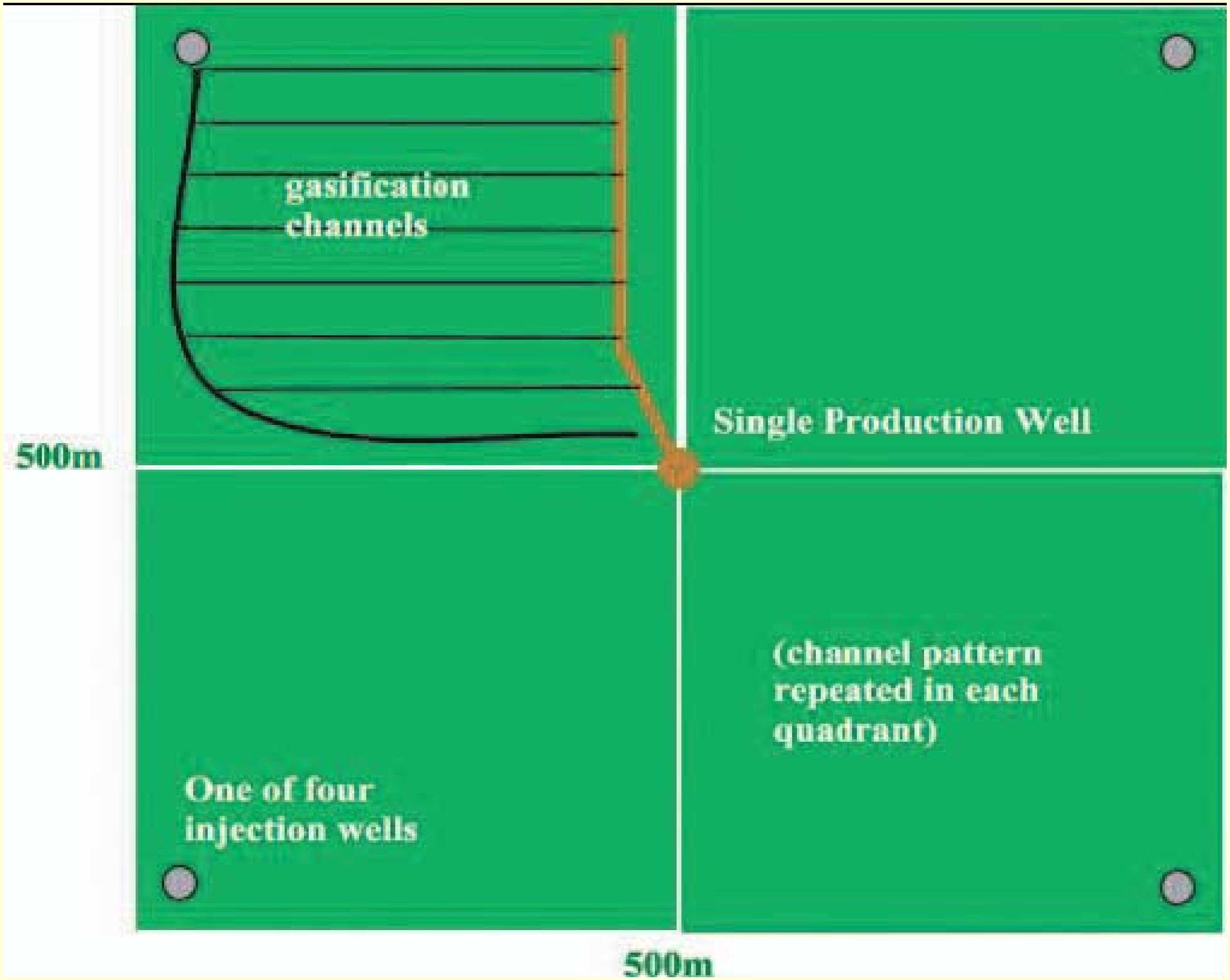
Economics of UCG for Power Generation
UCG Feasibility



Drilling and Boring cost for 500 m x 500 m panel

Plant Item	Cost (£M)
Exploration cost and monitoring cost (seismic, borehole and monitoring well)	0.3
Vertical production well to seam (1 per panel)	0.6
Vertical Injection wells (4 per panel)	2.4
Well site preparation (5x£50,000)	0.3
Inseam production wells (4x250m @£200/m)	0.2
Inseam injection wells (32x250m@£200/m	1.6
Precise steering intersects (32 per panel @ £50,000 each)	1.6
Well completions (28@£50,000 each)	1.4
Drainage well	0.6
Monitoring well (1 per panel)	0.6
TOTAL development cost per panel	9.6

One Panel of UCG



POWER GENERATION WITH UCG

Issues related with UCG Power Generation

Issues related to UCG for Power

- **Uninterrupted supply of syngas from UCG for IGCC**
- **Maintaining the syngas quality on continuous basis**
- **Removal of impurities from syngas**
- **Environmental impact of UCG**
- **Development of efficient GT for low HV syngas burning**
- **Overall design/development of UCG + Power Block**

Road Map

- Framing of regulations pertaining to UCG.
- Estimate coal reserves for UCG
- Selection of mine based on existing geological survey.
- Mapping and assessment of the mine suitability for UCG.
- Establish cost parameters for the process to be competitive.
- Comparison of UCG with other Technologies
- Identification of Competing UCG Technology
  - ➢ Syngas quality and availability on continuous basis
  - ➢ Addressing of Environmental concerns
  - ➢ Identification of economic power plant capacity
  - ➢ Removal of impurities from syngas
- UCG Technology Selection
- Examine the implications of burning UCG gas in gas turbines
- Identify a semi-commercial site.
- Development of a pilot UCG for firsthand experience with the technology and realistic cost assessment.

POWER GENERATION WITH UCG

Thank You

Prepared by : Project Engineering Group/NTPC