

# WHAT ABOUT COAL BED METHANE?

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- The firm was founded in 2010 and has since achieved a number of key milestones
- Experienced and well regarded team from some of the world’s leading buy and sell side institutions
- An investment team with a proven track record across various markets such as the UK, India, MENA and Africa

## TA Typical Investment Criteria

- Sectors: Energy & Natural Resources
- Geographies: Select Asia, LATAM, Europe, select Africa
- Mid-market
- Asset/project size: US\$ 20-100m
- Direct holding – non-operator
- Minority/significant minority
- Governance
- Target IRR: > 20%

Knowledge

Wealth

Ethics

*“Tridevi” is derived from the mythological trinity and symbolises our core values of **knowledge enhancement, wealth creation** and a **strong ethical approach to business***



**CBM – “the evil twin of shale gas in the family of extreme energy methods” – Frack Off**

## SEAMS COME AND GO...

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# COAL FRACTURES – FACE CLEATS & BUTT CLEATS



Storage capacity + permeability  
Dual porosity – matrix + fracture  
Adsorbed methane  
 $GIIP = NRV \times GC \times \text{coal density}$   
GC – gas content cc/g or m<sup>3</sup>/ton  
Coal density g/cc

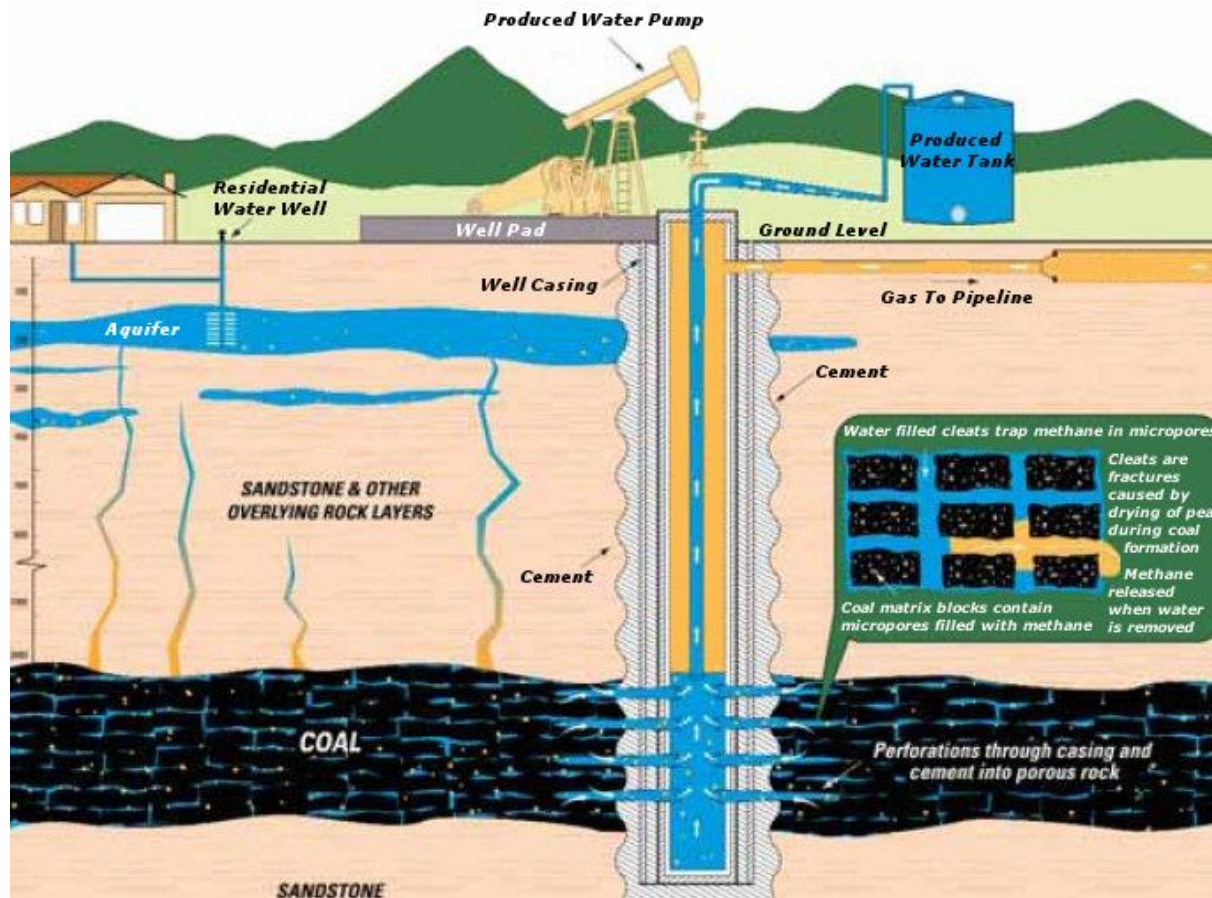
- Cleats: orthogonal fractures, perpendicular to dip
- Shorter butt cleats terminate into longer face cleats

## Composition / type; purity or grade

- Predominant organic constituents or macerals
- VITRINITE – woody, cellulosic plant parts – bright bands
- LIPTINITE or EXINITE – spores, algae, resins – waxy
- INERTINITE – oxidised organic matter – dull black
- GRADE – weight % of organic material determined by chemical analysis

## Maturity or rank

- Measured by maximum vitrinite reflectance, % volatile matter & % carbon
- High volatile 'C' (Ro .47-.57), VM (42-47%), C (66-76%)
- High volatile 'B' (Ro .57-.71), VM (39-42%), C (76-81%)
- High volatile 'A' (Ro .71-1.1), VM (31-39%), C (81-86%)
- Medium & Low volatile
- Sub-Anthracite
- Anthracite
- **High to Low volatile, bituminous coals are CBM candidates**



Dewatering reduces pressure & releases gas

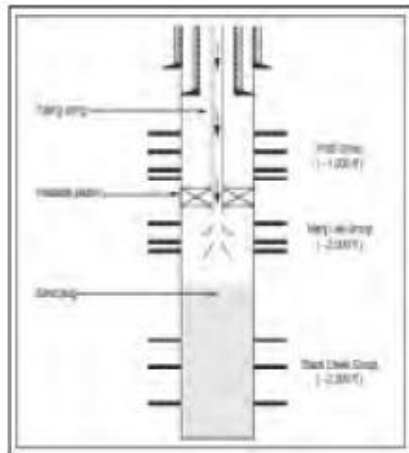
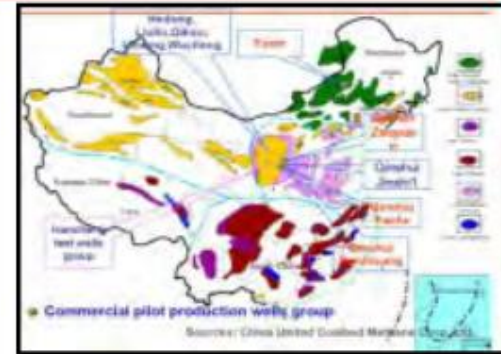
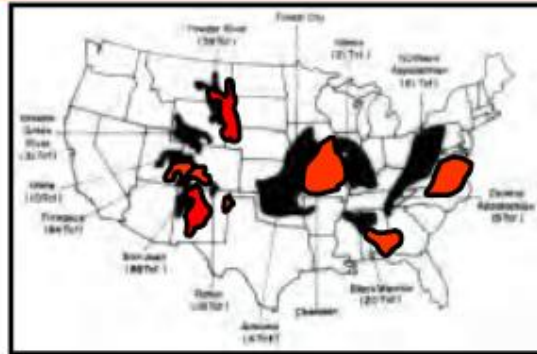
Gas desorbs from the matrix/cleat interface

Dual porosity system: micro. & fracture

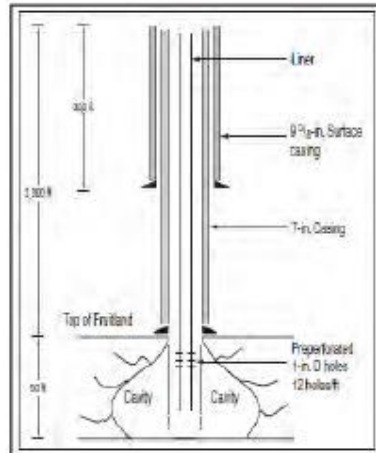


# WELL COMPLETIONS ARE SITE-SPECIFIC

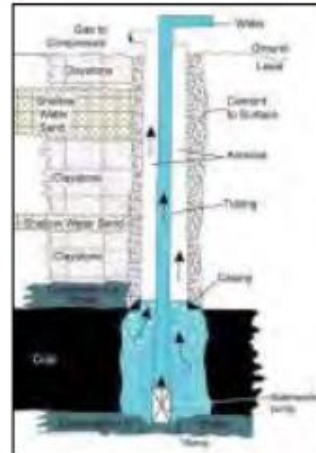
## Successful Well Completion Types



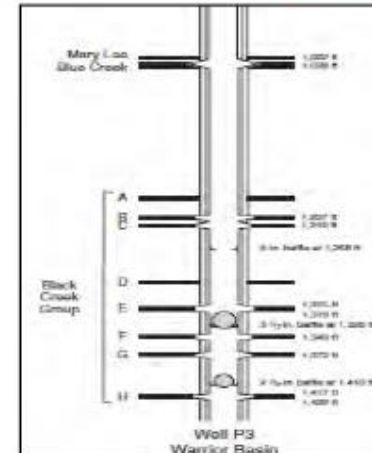
**Open-hole (Barefoot)**  
e.g. Powder River (USA)



**Cavitation**  
e.g. San Juan (USA)



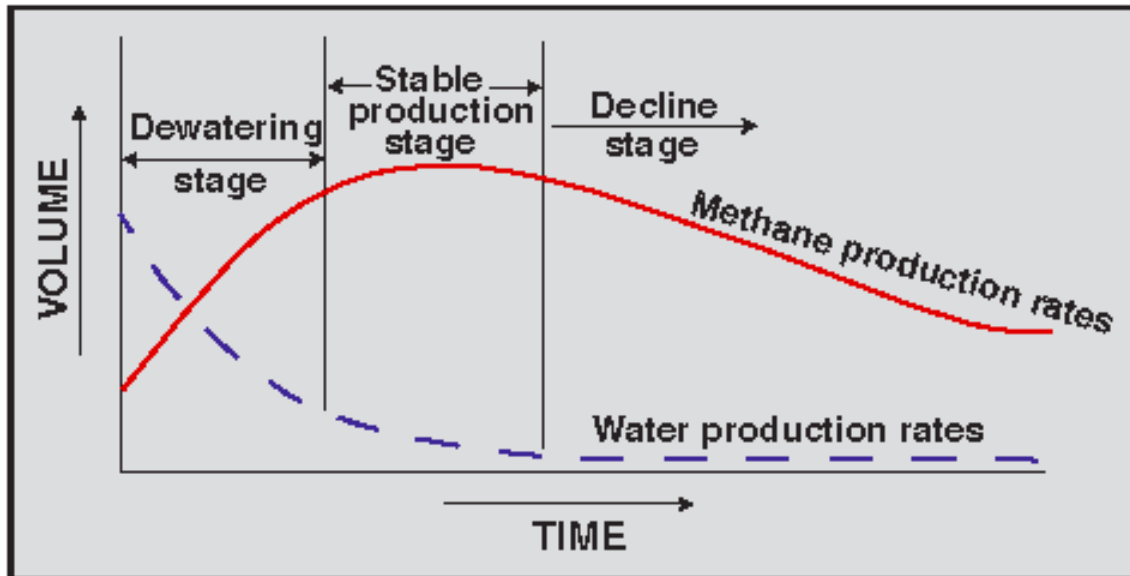
**Under-reamed**  
e.g. Powder River (USA)  
Surat Basin (Australia)



**Fracture Stimulation**  
e.g. San Juan, Powder River  
Quinshui Basin (China)

Source: Essar Energy website

# TYPICAL CBM DEWATERING & GAS PRODUCTION PROFILE



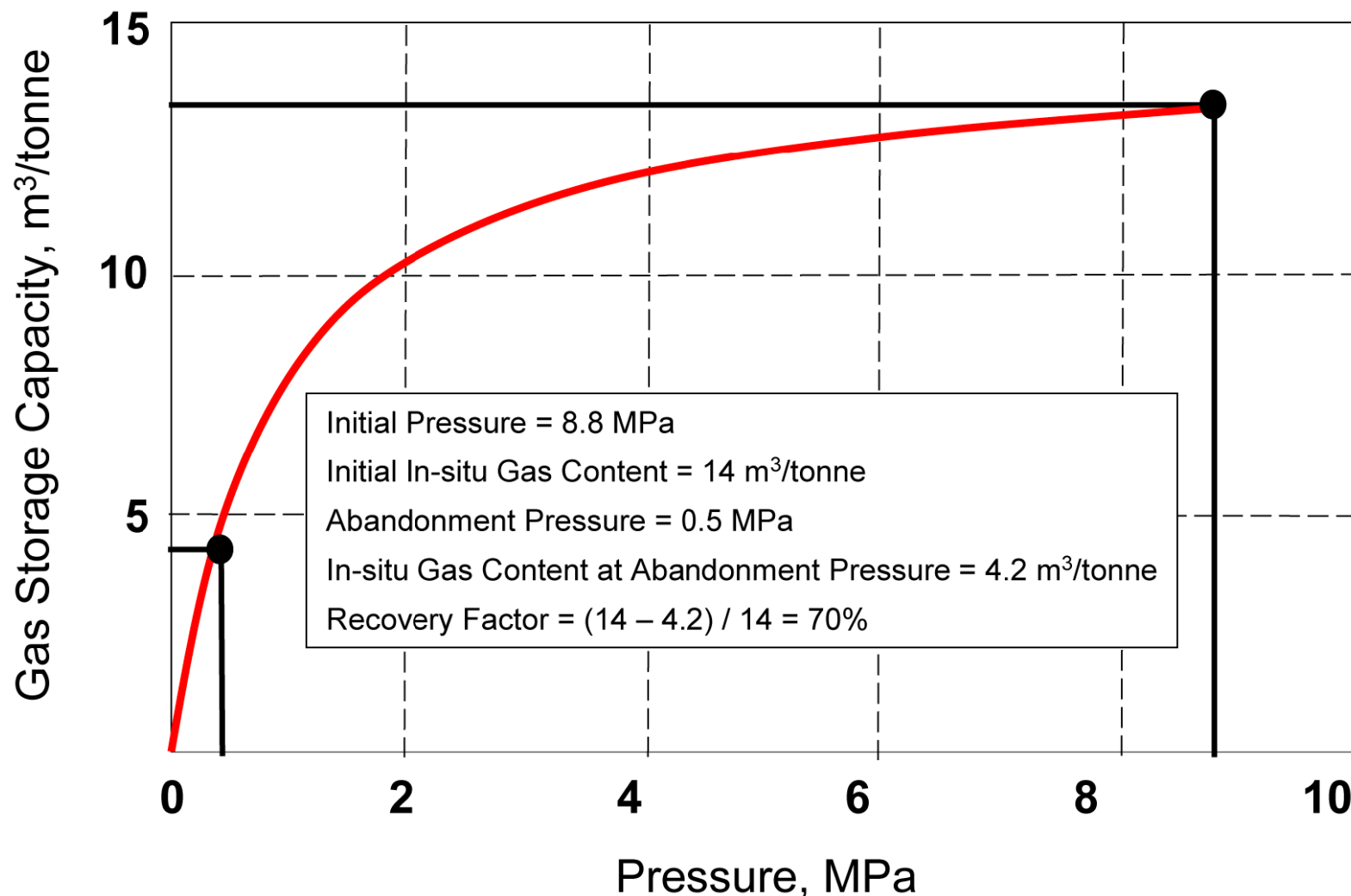
**Figure 2.** Typical production curves for a coal-bed methane well showing relative volumes of methane and water through time. Modified from Kuuskraa and Brandenberg (1989).

Fluid movement in a coal is controlled by:

- Diffusion in the matrix
- D'Arcy flow in the fracture system - cleats

Capacity of coal matrix to store gas as a function of pressure is described by the Langmuir Sorption Isotherm

# A sorption isotherm curve showing how a recovery factor is calculated



## Ernst & Young's Key Investment Considerations

- ✓ Reserve quality – 6m thick seams, rank 77-87% C, sub-bituminous, pressure & depth range – ‘Goldilocks’ conditions
  - ✓ Coal presence & mapping confirmed by drilling
  - ✓ Gas saturation, ash content etc.
  - ✓ Coal quality confirmed by coring & lab analysis
  - ✓ Gas production rates confirmed by testing and/or reliable analog data
- ✓ Land acquisition – considerations on relocation & resettlement requirements
  - ✓ Land acquisition for drill sites, access & export routes
- ✓ Permeability – drilling, completion, perforation, stimulation optimisation
  - ✓ Reliable drilling, gas gathering and processing capital costs
- ✓ Environmental impact – water treatment & disposal, possible subsidence
- ✓ Marketing plan!

## Coal & Coal Bed Methane In-Place in Selected Countries

Country	Coal (Bn tonnes)	CBM (TCF)
Russia	6,500	600-4,000 (1,730)
China	4,000	1,060-2,800 (1,307)
USA	3,970	275-650 (1,748)
Canada	7,000	300-4,260 (699)
Australia	1,700	300-500 (1,037)
Germany	320	100 (N/A)
UK	190	60 (102)
Kazakhstan	170	40 (23)
Poland	160	100 (N/A)
India	160	30 (71)

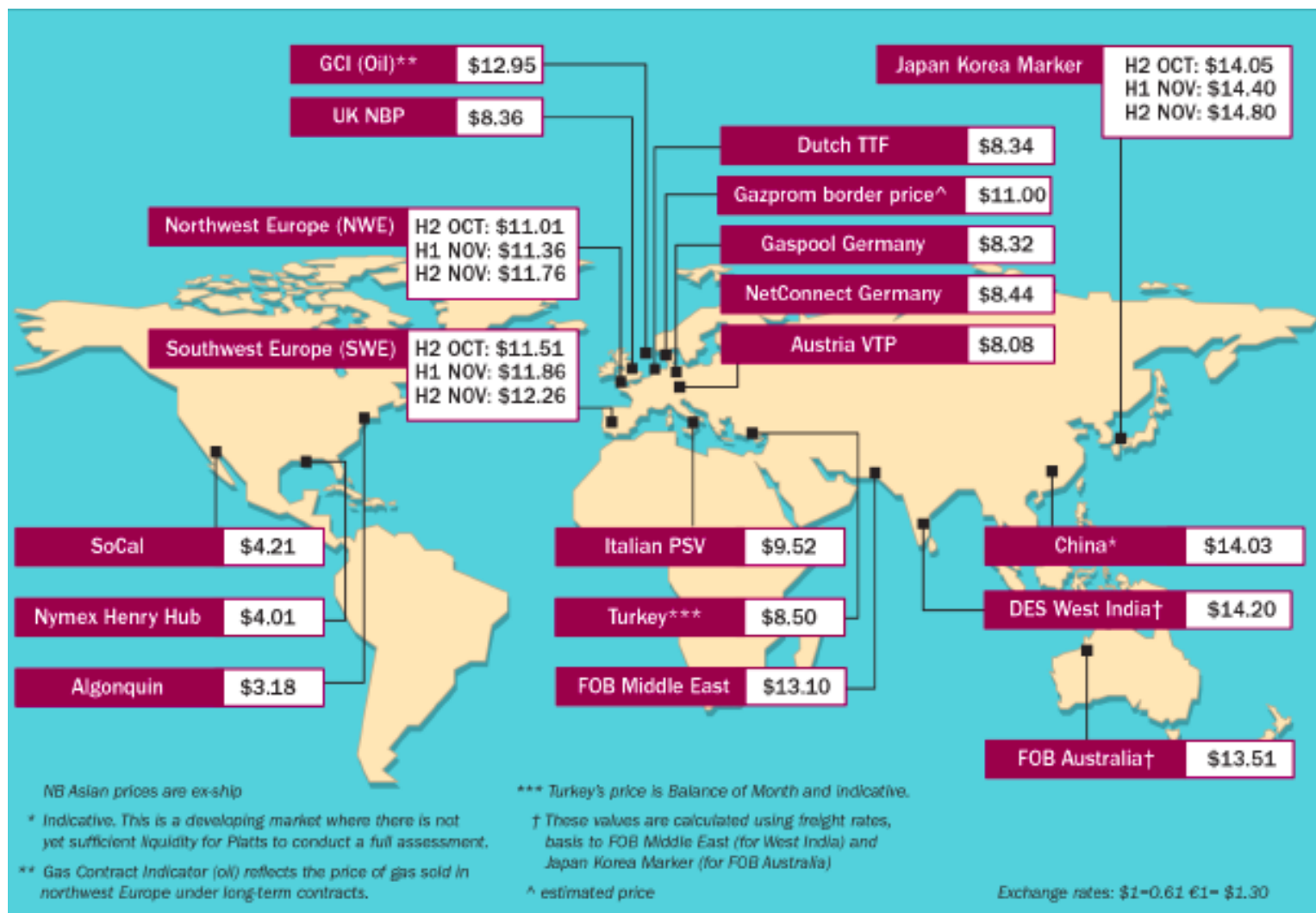
After Kuuskraa et. al. 1992

BP Statistical Review 2008



# Gas Markets & Pricing (17<sup>th</sup> September, 2014)

## US\$/MM Btu Source: Platts

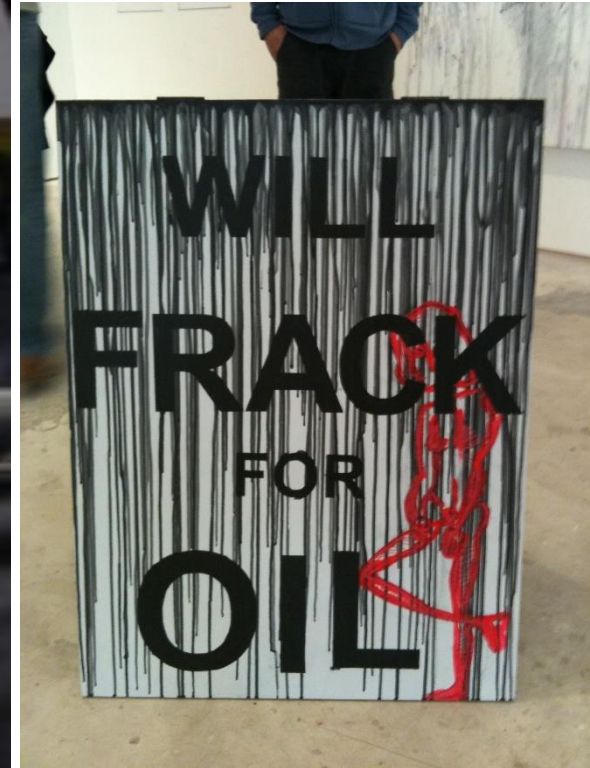


## BILLION M<sup>3</sup>/year in 2015

- |                  |     |
|------------------|-----|
| ◆ UK             | 68  |
| ◆ France         | 39  |
| ◆ European Union | 402 |
| ◆ USA            | 778 |
- 
- ◆ IFP has certified Lorraine Basin CBM resources as equivalent to 5 years of gas consumption in France or ~ 200 Bm<sup>3</sup> or 7 Tcf!

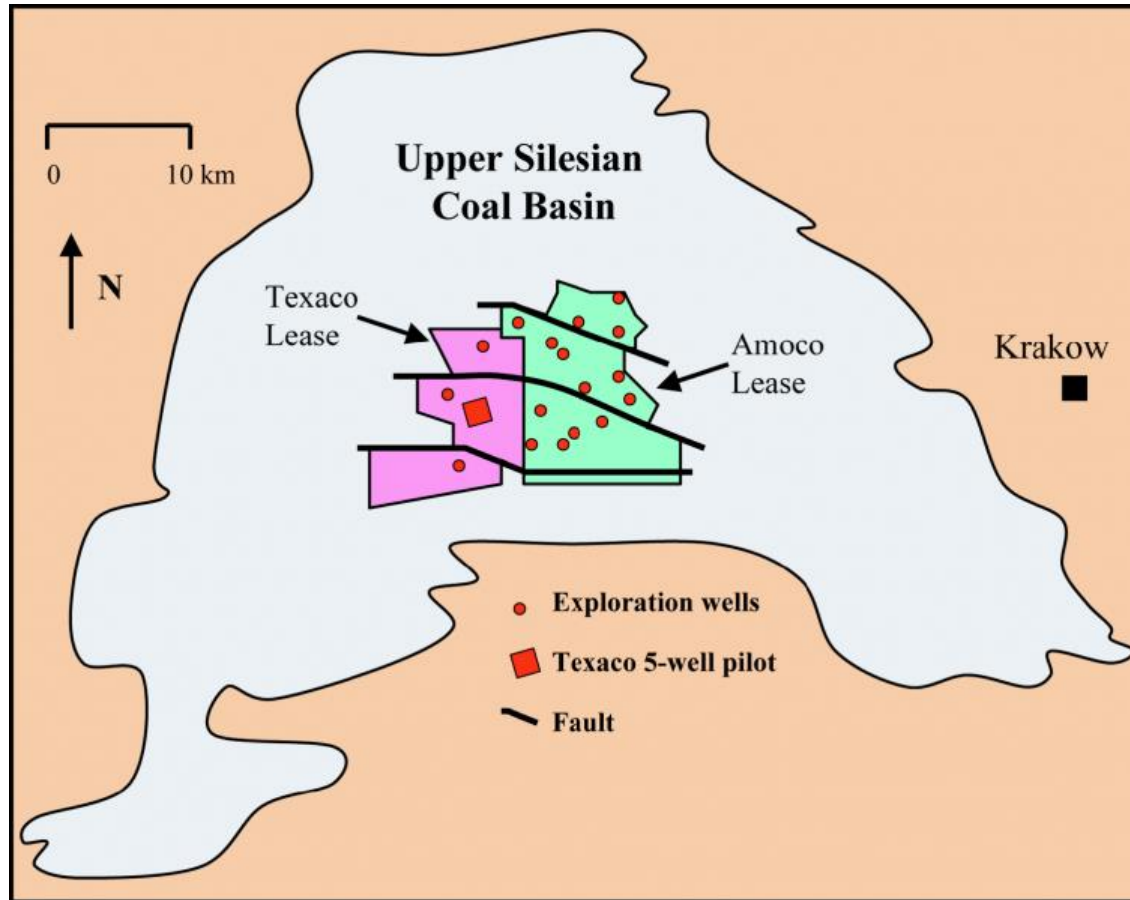
- ◆ 22<sup>nd</sup> September 2006
  - ◆ “Huge CBM gas find for European Gas Ltd (75%) and Heritage Petroleum plc (25%) in Folschviller St I well, located in Alsace Lorraine...strong gas readings over 106 m interval (776-882 m); coring & lab tests to come”
  - ◆ GIIP estimate ~ 990 Bcf
  - ◆ What happened...nowt!
- ◆ 6<sup>th</sup> February 2017
  - ◆ La Francaise de l'Energie (LFDE) announces “CBR-I well located at Lachambre reached a TD of 1080 m & encountered an 11 m coal seam where core analysis indicates excellent gas content of 10m<sup>3</sup> per ton. Cores show an excellent natural fracture network and another seam of 6m thickness at 978 m.”
  - ◆ LFDE's website lists its priorities as:
    - ◆ Environment
    - ◆ Security
    - ◆ The local anchorage
  - ◆ LFDE plan to start “operations” this year and have obtained 8 drilling permits in the last 2 years; hold 2 exploration licenses with 2 applications under review

## THOSE PLOSIVE CONSONANTS



Frack Off claims planning permission for 60 CBM wells in the UK cf ~ 12 shale wells

# POLAND – GAS RESOURCE ESTIMATES 7-46 TCF



## Amoco experience

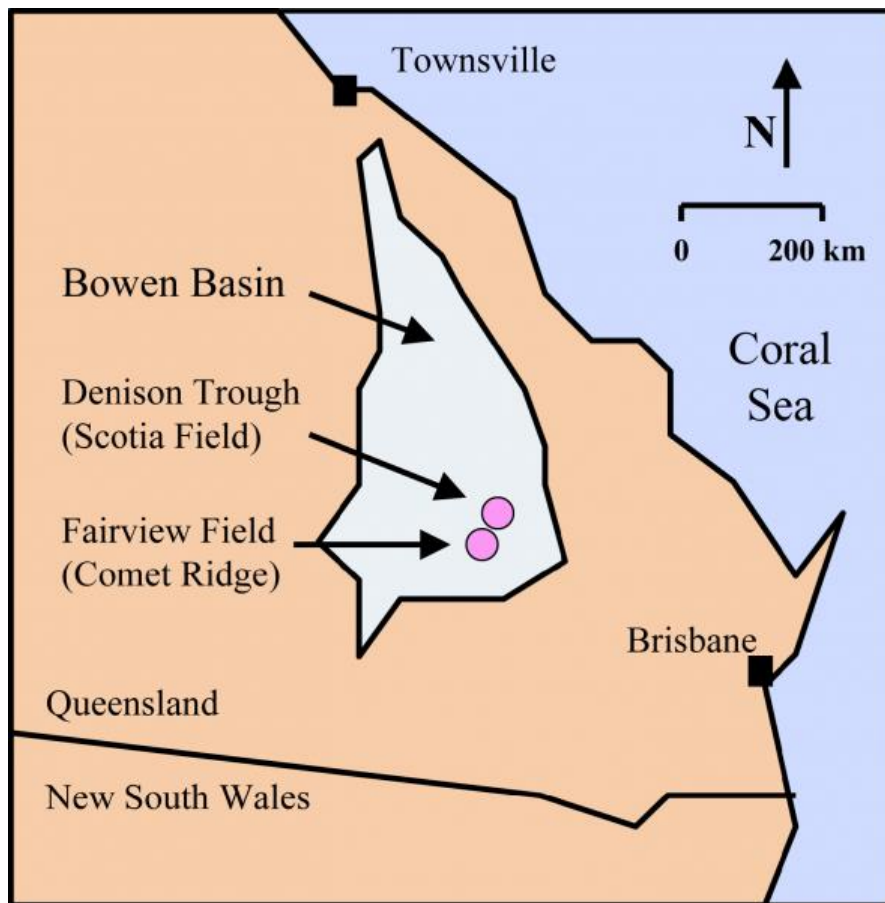
- 1<sup>st</sup> licence 1993 – drill 15 wells, production test 8
- Highly variable gas saturations & permeability

## Texaco experience

- 1997 licence – drill 8 wells
  - 3 exploration, 5 pilot holes
- Well performance & simulation not encouraging, relinquished licence 1998

Complex succession of burial, uplift, degassing, reburial & re-saturation





## Bowen Basin CBM GIIP > 178 TCF

- Permian coals – high volatile bituminous, low ash content, gas-saturated, average 13m<sup>3</sup>/ton gas content
- **Exploration history from '76**
- 1987 – 8 well pilot at Broadmeadow gas field; best rates 98 scfd - uncommercial
- 120 production & test wells over next 10 years (experience)
- Comet Ridge field – 1<sup>st</sup> commercial production in 1998
- Scotia Ridge field – gas sales in 2002

N.B. Queensland Curtis LNG Project (A\$20 B) – from Surat Basin CBM

## CBM India

- 3rd largest proven coal reserves and 4th largest coal producer in the world
- CBM E&P policy formulated by the Indian Government in 1997 to carry out CBM exploration activity
- 33 CBM blocks awarded so far, 2 are in production phase, 6 in development phase and 4 are under exploration phase

## CBM Resource & production in India

- The MoPNG has identified 26,000 sq.km of area for CBM operation
- Total estimated CBM resources in this identified area is c. 91.8 TCF
- Total CBM production FY2015-16 was 392.865 MMSCM (1.0734 MMSCMD)

## CBM Government Policies | Salient Terms

- 10% royalty
- Ad-valorem biddable Production Level Payment payable to the government
- Freedom to market gas in domestic market at market determined prices
- Corporate income tax payable as per the Income Tax Act, 1961

## CBM Utilisation in India

- Power generation
- Auto fuel in the form of CNG
- Feed stock for fertilisers
- Fuel for industrial use (steel plants, cement plants, refractories, rolling mills etc.)

\* Ministry of Petroleum & Natural Gas – Production of CBM 14th Report – August 2016

## 18.9 BCM natural gas production deficit in India (BP 2015 statistical review)



Key energy-drivers: Fast-growing economy, urbanisation, demographics, environmental concerns

Key gas-consuming sectors: Power, fertilizer, CGD, refineries and petrochemicals

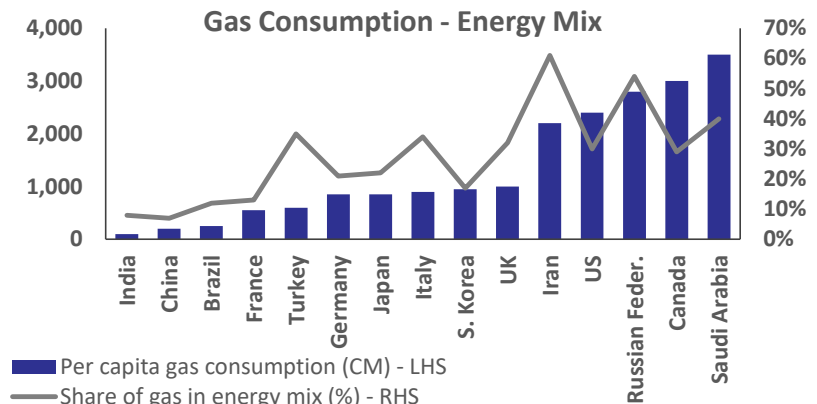
### Indian Gas - Facts & Figures

- Increasingly import dependent – From est. 0.7 TCF (2013) forecast to reach 2.0 TCF by 2023
- Gas-fired plants running at less than quarter capacity due to fuel shortages<sup>1</sup>
- Gov't push to increase natural gas in energy consumption mix (from 7% to 15% - still below world avg. of 24% (See chart))

### Reasons for Supply Gap

- Lack of FDI & private investment into domestic resources due to:
  - Lack of free market pricing
  - Restrictions imposed by previous Gov't policies
- Limited import infrastructure
- High cost of importing LNG - Inability to absorb imports in power & fertilizer sectors

<sup>1</sup> India Energy Outlook, 2015, IEA



Source: EY Analysis, BP Statistical Review of World Energy 2015, World Bank

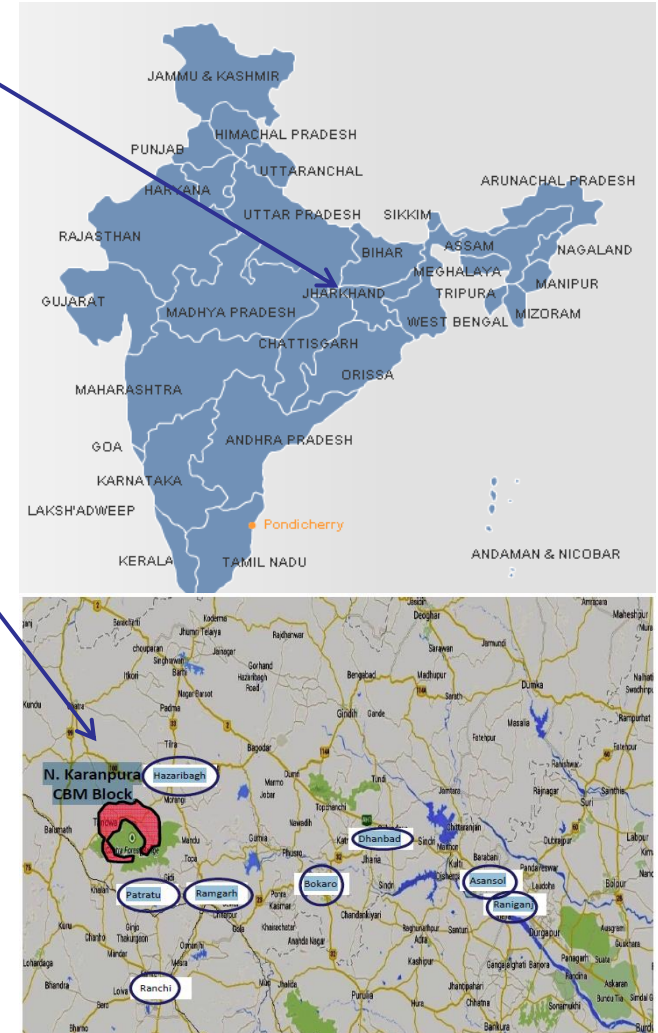
# PROJECT PARAMOUNT | INDIA'S CBM BELT

## Snapshot

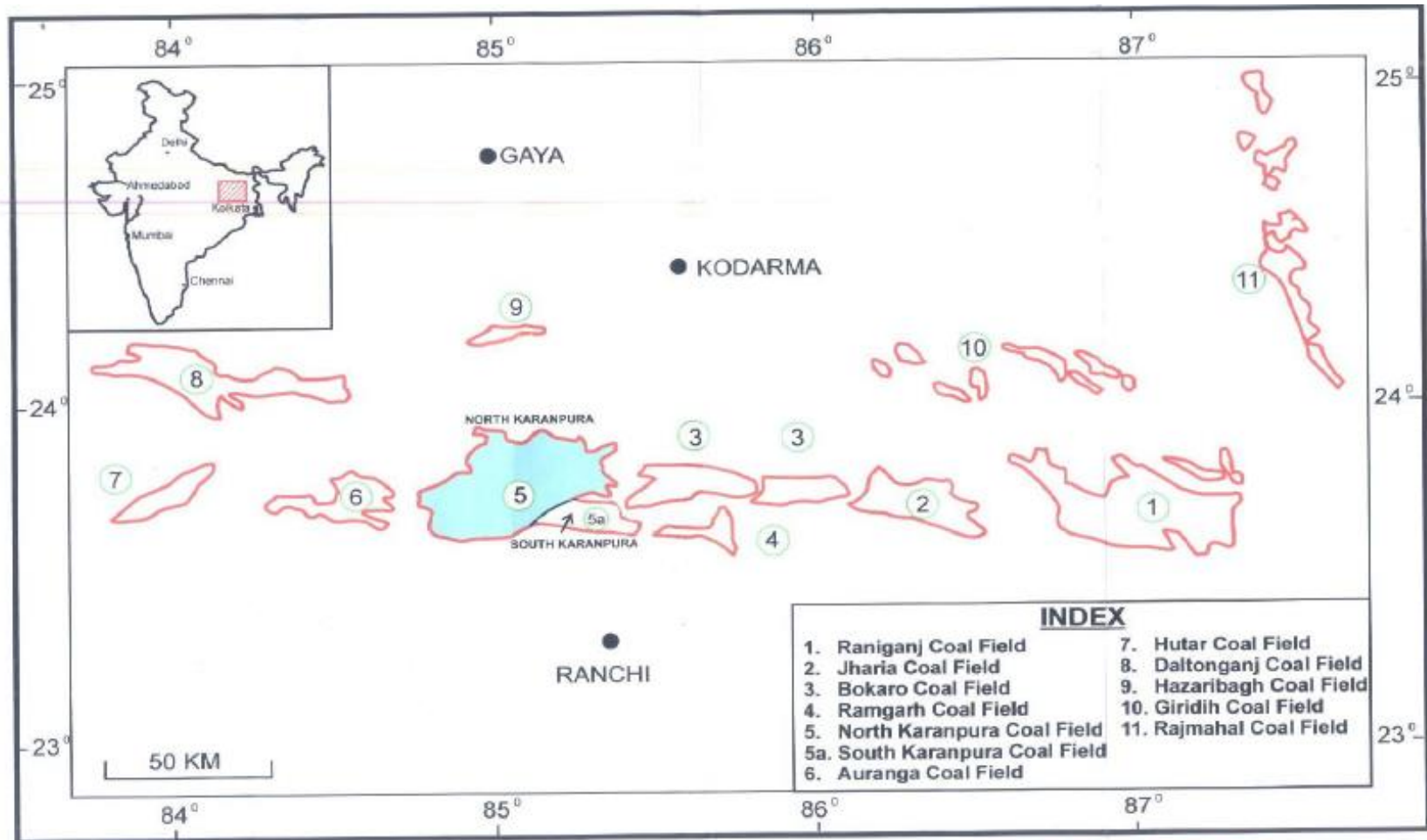
- Favorable pricing market - realised gas prices in the region US\$10-11 per mmbtu: GEEC (West Bengal)
- Demand
  - In 2015, GAIL estimated demand could reach c. 8.8 MMSCMD (3 billion SCM annualized)
  - Potential market incl. small and large towns, industries, transport and commercial segments
  - Fertilizer plants: Matix, Sindri
- Production (MOPNG)
  - In 2015, Jharkhand and Madhya Pradesh: 209 MMSCM or 0.6 MMSCMD
    - c.146MMSCM/year from only 1 producer
  - Jharkhand just 2 MMSCM in production for the whole year
- Severe natural gas shortage in area

Jharkhand State

NKCBM Block



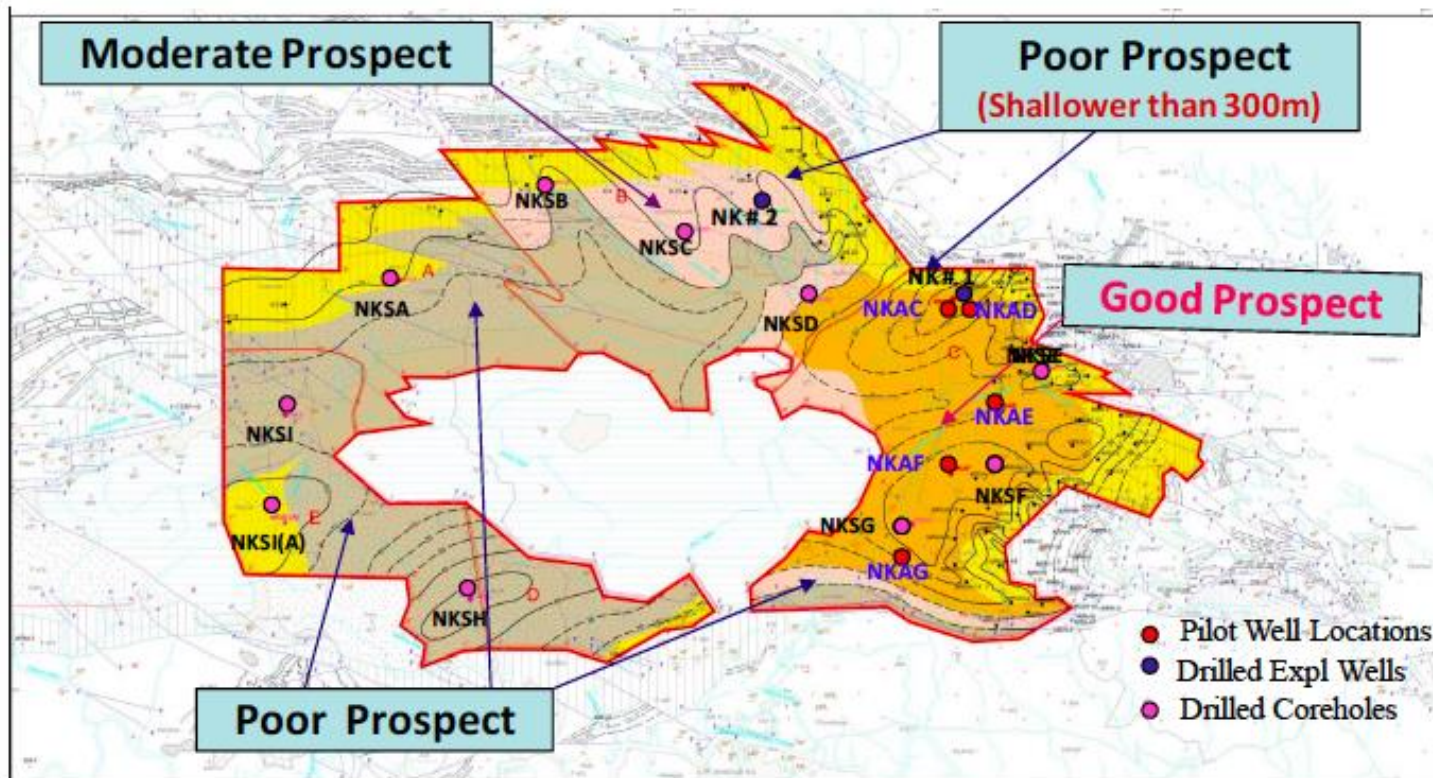
# NORTH KARANPURA COALFIELD



Location Map of Damodar Valley Coal Field



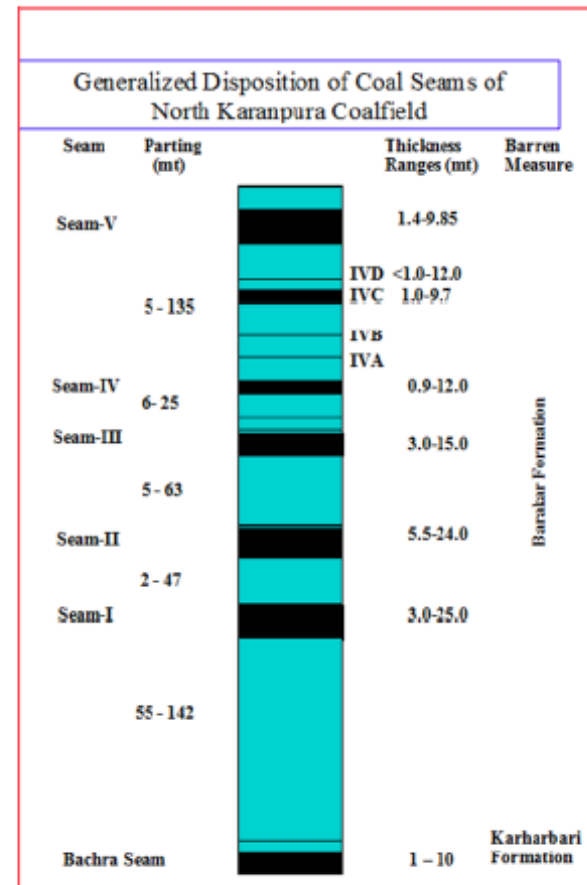
## Approved Field Development Plan : ONGC Perceptions Prospect Map of North Karanpura Block



## Highlights of CBM Exploration in North Karanpura CBM Block

### Coal seams disposition

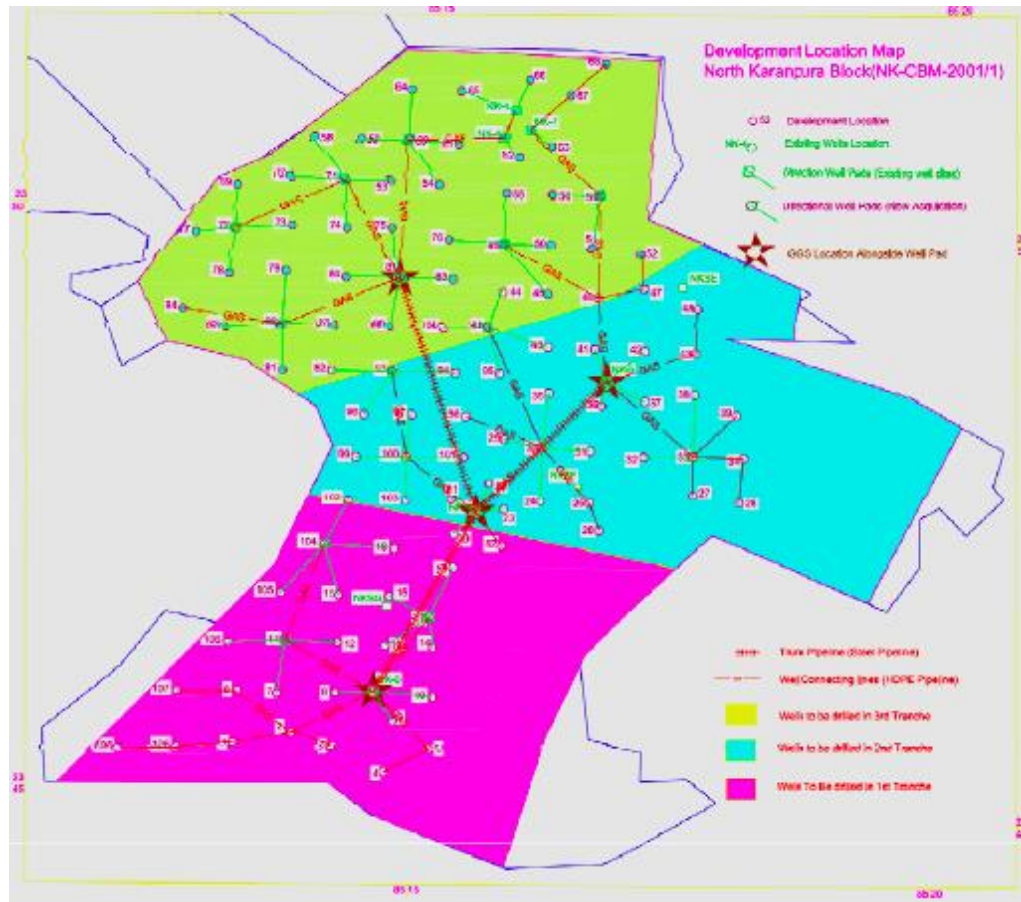
- The Barakar Formation contains five regionally persistent coal seams showing wide variation in thickness, quality and rank across the basin.
- Coal seams are named as Seam-I to Seam-V from bottom to top.
- Cumulative thickness of these coal seams (Seam-I to -V) is in the range of 30-80m.
- Maximum thickness of coal seams is developed in the block area.
- Two impersistent coal seams are also developed in the Karharbari Formation.
- The lower most seam - I (3-25m thick) and the succeeding seam-II (3-24.5m thick) are considered to be the main targets for CBM



# CBM SEAM CHARACTERISTICS

Seam	Seam-I	Seam-II	Seam-III	Seam-IV	Seam-V	Description
VL (cc/g)	13.5	13.8	17.5	14	14.5	Langmuir Volume
PL (psi)	300	310	380	350	300	Langmuir Pressure
Depth (m)	681.9	646.8	585.4	534.5	483.5	Seam depth
Pr (psi)	961.7	912.2	826.3	773.5	688.2	Reservoir Pressure
Gc (cc/g)	8.01	7.85	4.1	8.5	7.9	Gas Content
A (km <sup>2</sup> )						Drainage area
h (m)	8.95	11.17	6.95	8.39	3.51	Net coal thickness
Roh	1.25	1.25	1.25	1.25	1.25	Coal density
Por	0.7 %	0.7 %	0.7 %	0.7 %	0.7 %	Coal porosity
Ash	12.7-51	12.9-44	16.4-41	13.6-41	20.8-46	Ash content
Moisture	0.8-2.4	0.8-2.2	0.7-2.8	1.0-3.3	1.00-4.6	moisture

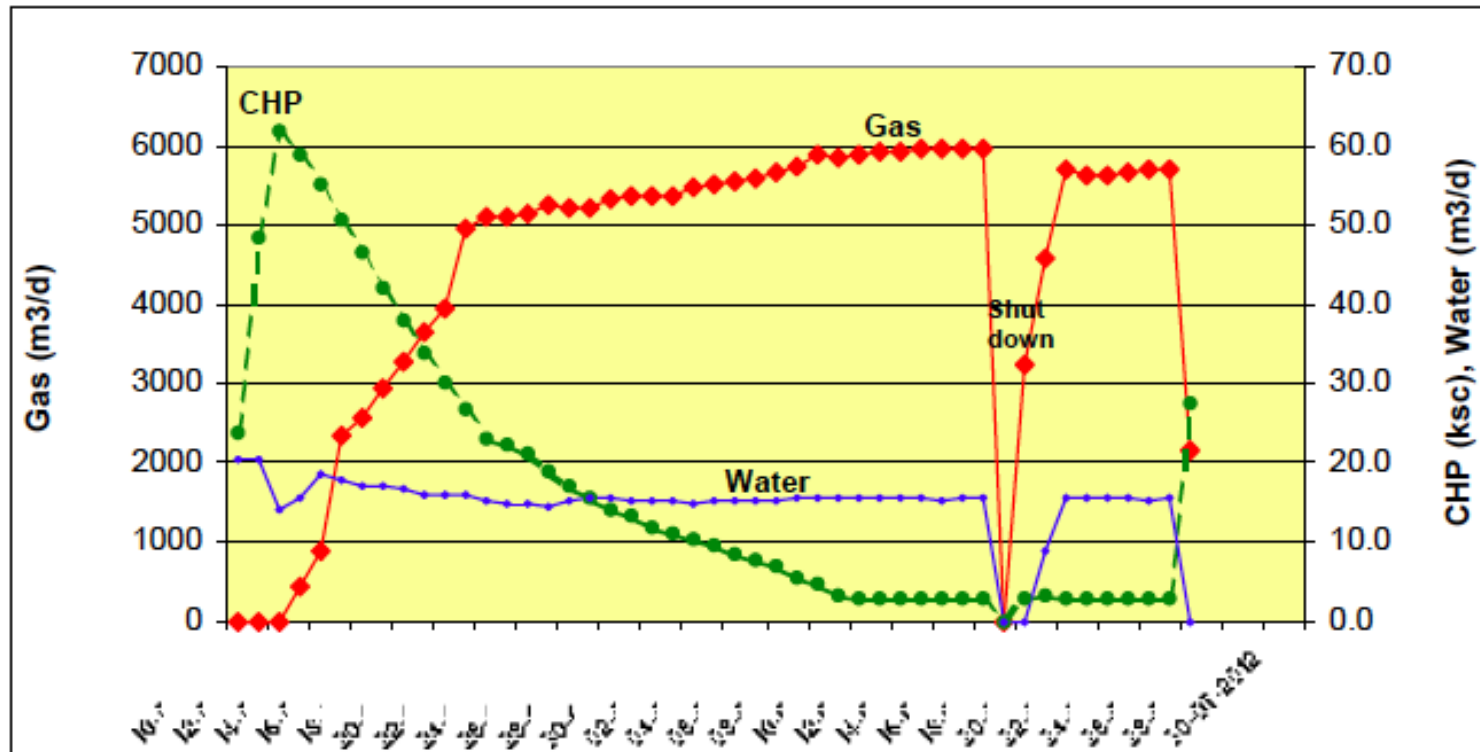
## SECTOR C DEVELOPMENT AREA 74 KM<sup>2</sup>



# WELL COMPLETED IN LOWER 2 SEAMS

## CHP – CASING HANGER PRESSURE

**Performance Curve of Pilot Well NKAG (NK#6)**



~ 70 day test period

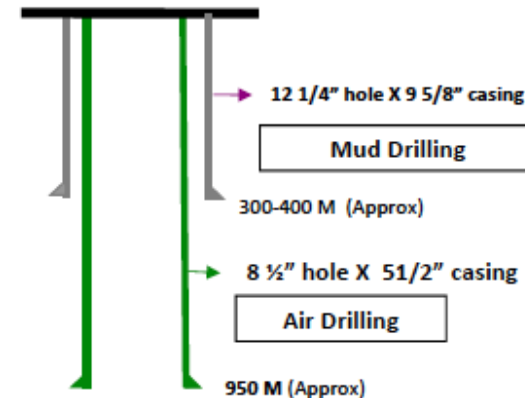


## Drilling & Completion



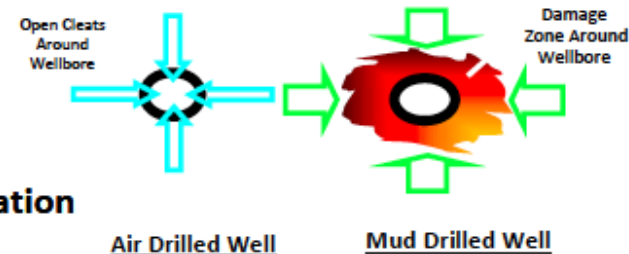
Water Well  
Drilling Rig

- Drilling large number of wells at low cost is a big challenge in CBM.
  - Drilling up to surface casing using water well rigs
  - Coal section to the target depth drilled using Air Drilling rigs
  - This innovative combination drilling results in cost reduction up to 30% per well basis.



Air Drilling Rig

- Air as drilling yielded benefits in terms of :
  - Minimum formation damage
  - Faster penetration rates, Longer bit life and fewer trips



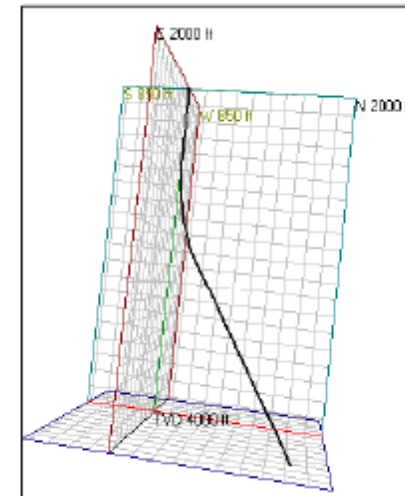
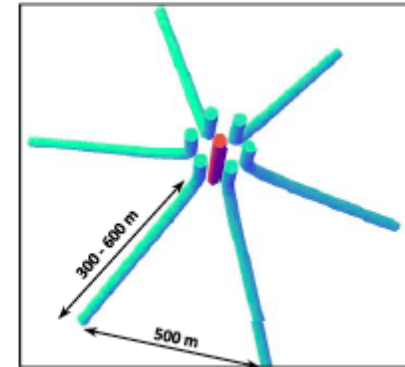
**Air Drilling and Water Well Rig combination reduces drilling Costs**



## LAQ, Site & Access Road Preparation and Maintenance

### Directional Wells from a Pad : An alternative, if required

- One vertical well and six directional wells at 60 Deg phasing.
- Horizontal reach is between 300 m to 600 m (40 – 80 acres spacing).
- Drilling costs increase marginally but provide many benefits
  - Land Requirement reduction up to 70%
  - Land cost savings and Civil work savings
  - Savings on ILMs of drilling rigs, logging trucks, cementing units, HF Units
  - Savings on pipelines, instrumentation and surface facilities
  - Security
  - Logistics
- PEPL to take a call on vertical versus directional wells based on depth of the reservoir and degree of difficulty in Land Acquisition

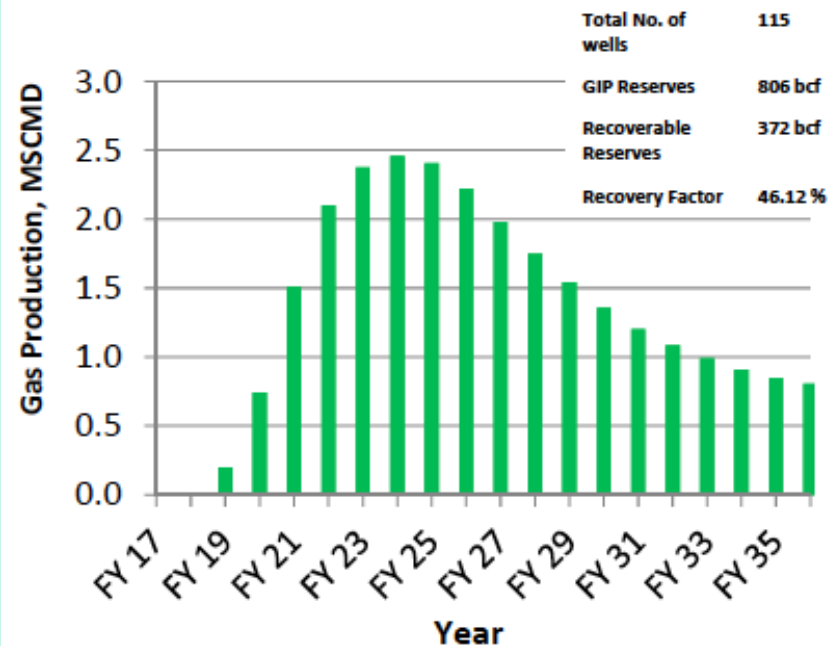


## Highlights of CBM Exploration in North Karanpura CBM Block Reservoir Simulation Studies for Production Forecasting

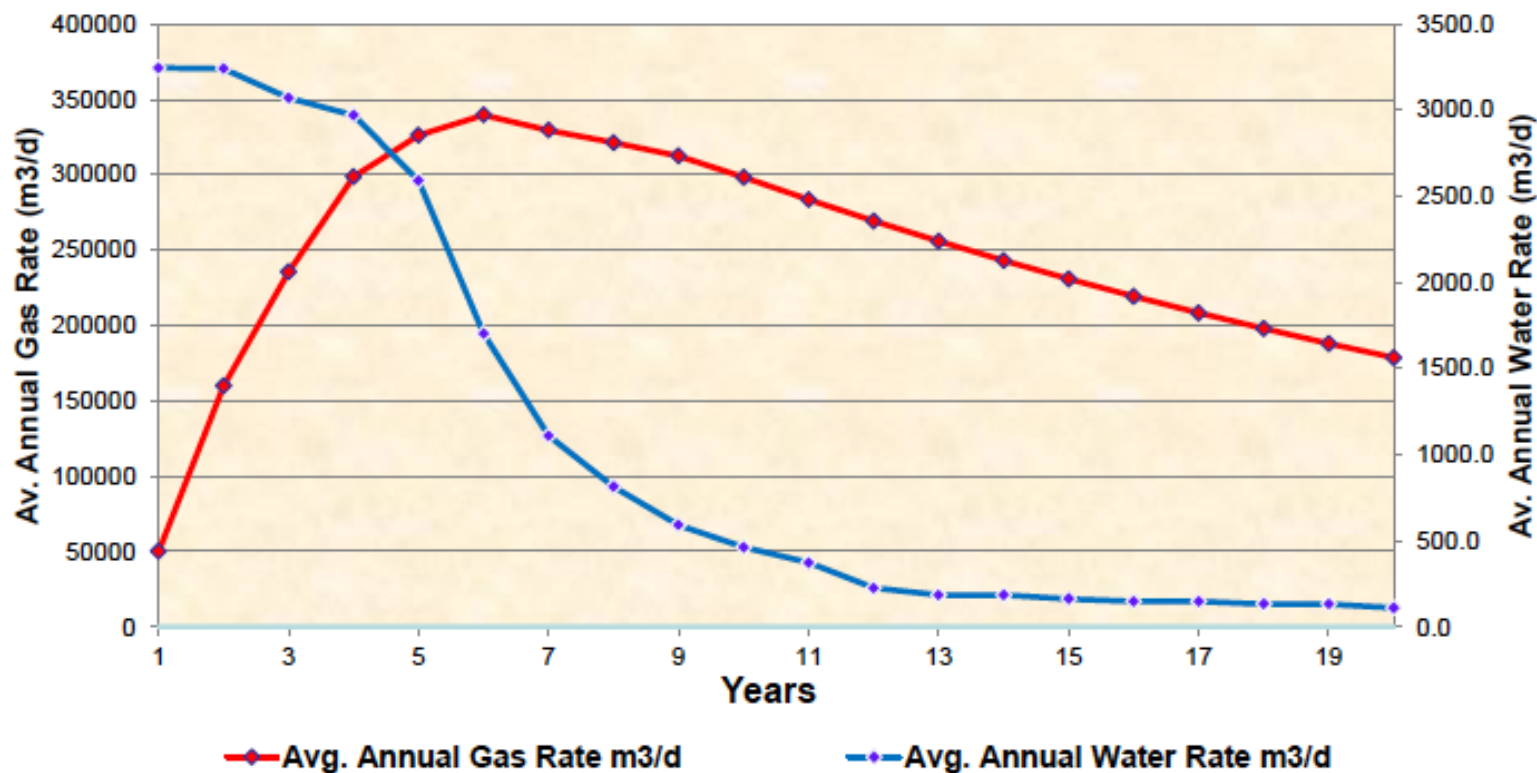
Reservoir simulation studies to forecast gas and water production carried out using industry standard CBM simulator, Comet-3 of Advanced Resources International, USA.

Reservoir Parameters	Sector C	Source
Area (km <sup>2</sup> )	74	
Coal Depth (m)	900	Well Logs
Coal Thickness (m)	35	Well Logs
Langmuir Volume (cc/g)	10.11	Adsorption Isotherm
Gas Content (cc/g)	5.5	Desorption studies
Langmuir Pressure (psi)	455	Adsorption Isotherm
Permeability (md)	7.5	Post Frac Pressure transient tests
Well Spacing (Acres)	160	
Cleat Porosity (%)	2.5	Core studies
Sorption time (days)	8	Desorption study
Reservoir Temp (F)	115	Temperature logs
Pore Volume Compressibility	4*10 <sup>-6</sup>	Core studies
Matrix Shrinkage	1*10 <sup>-7</sup>	Core studies

### Field Gas Production Estimate by PEPL

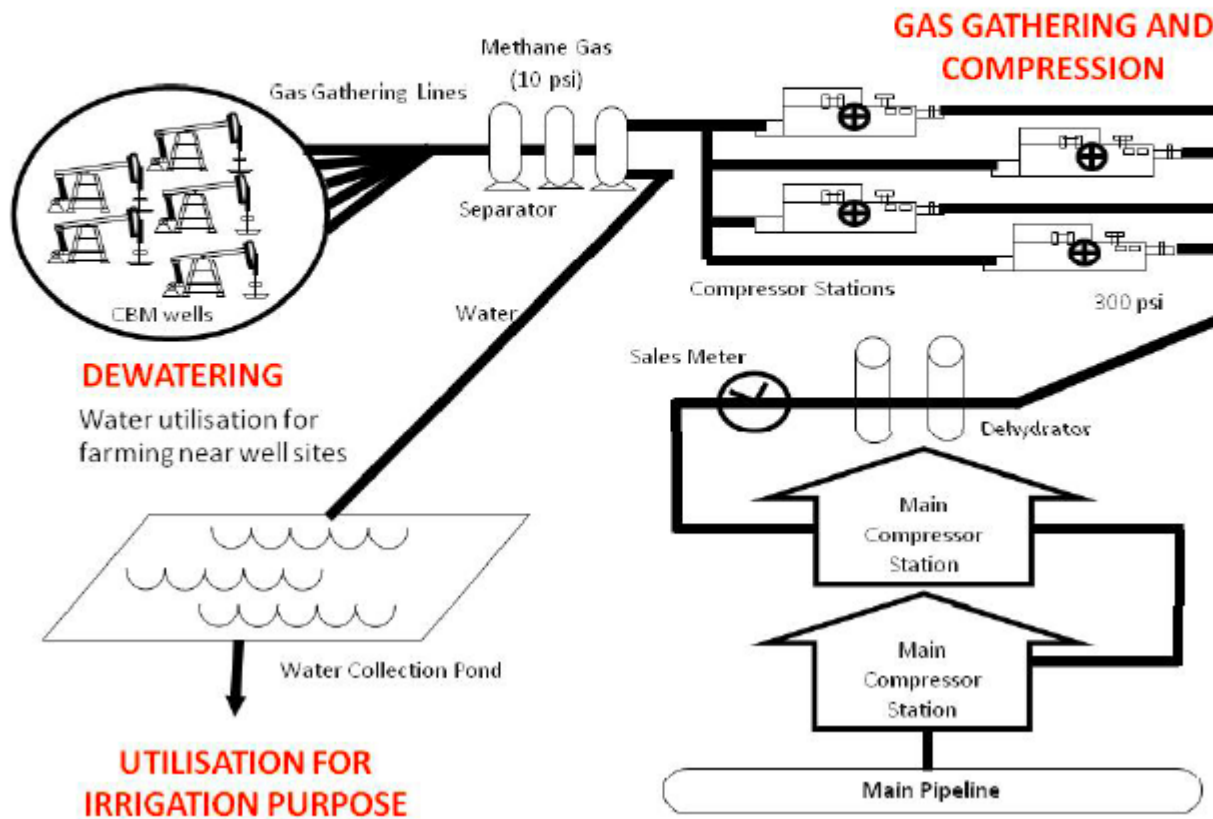


**Fig. 23 : Gas & Water Production Profile of Sector-C**



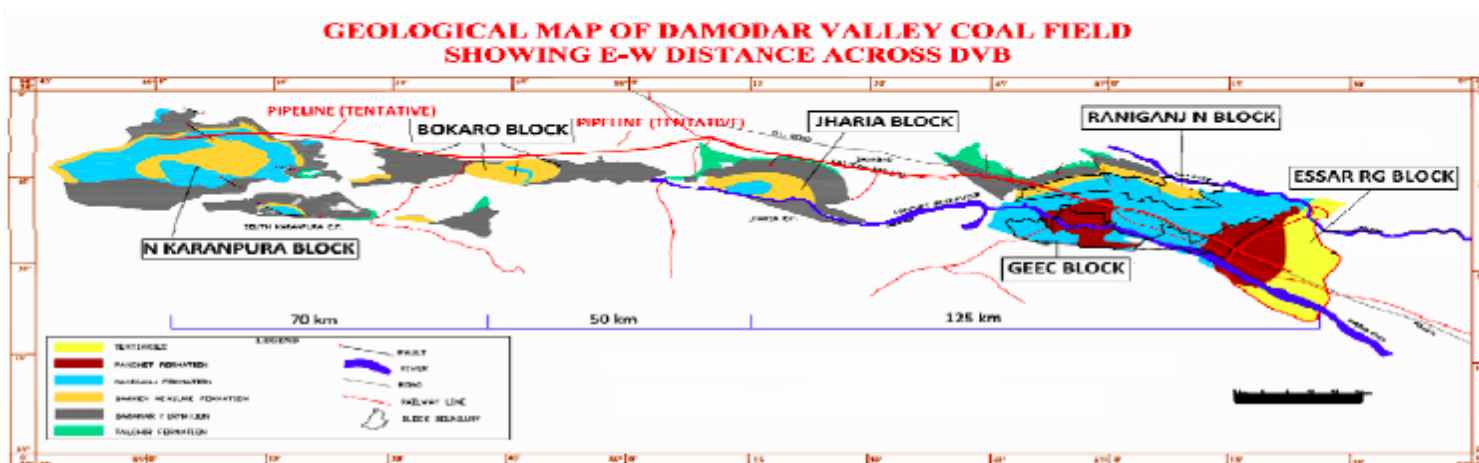
## Well O&M and Gathering, Processing, Compression & Water Management

SCHEMATIC OF A TYPICAL COAL BED METHANE PRODUCTION FACILITY

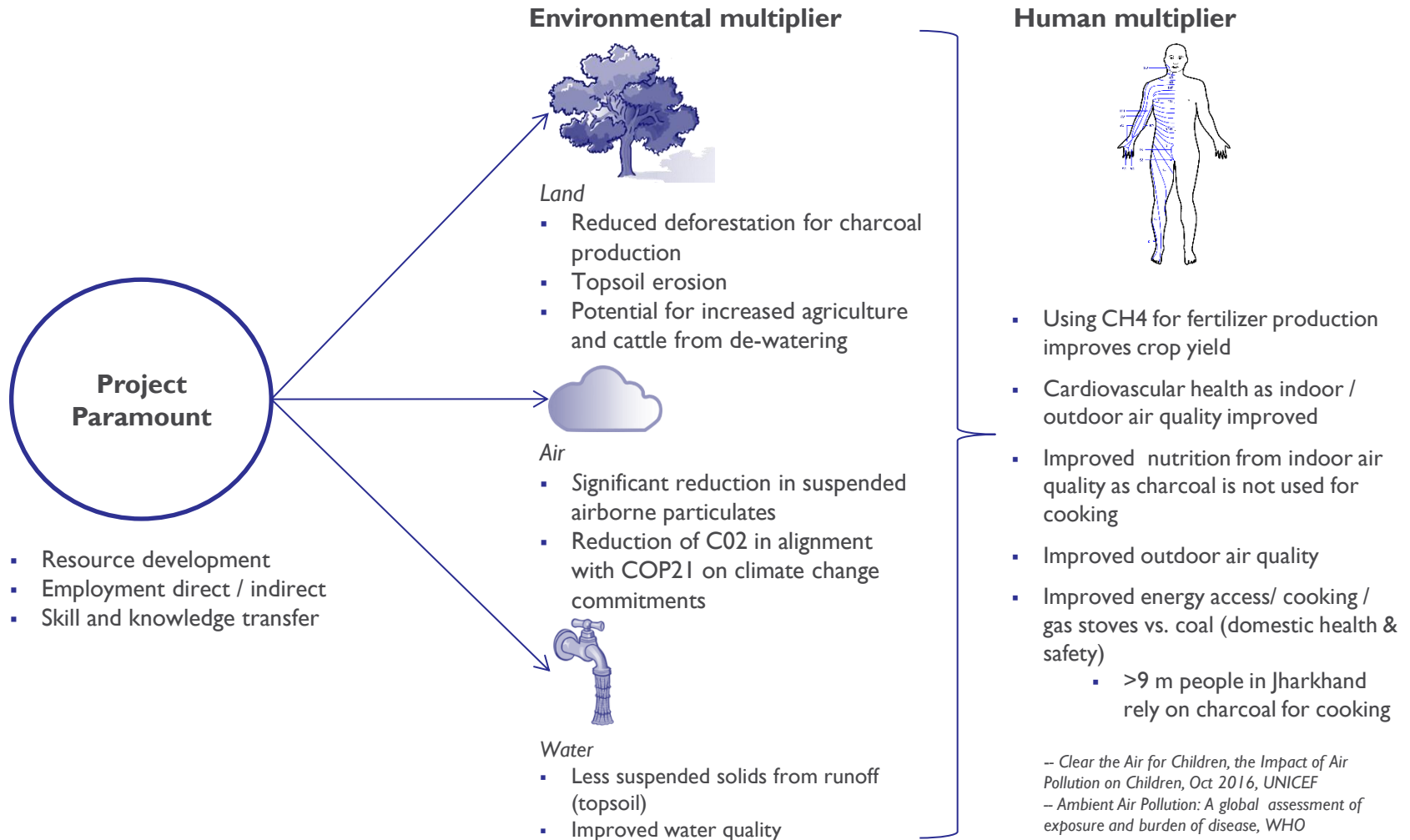


# INITIAL GAS PRODUCTION COMPRESSED & SOLD LOCALLY VIA TRUCK-MOUNTED CASCADES

## North Karanpura CBM Marketing Strategy CBM Gas Evacuation Options–North Karanpura CBM Blocks



- 6 CBM Blocks of ESSAR, GEECL & ONGC/PEPL located on the same axis and within a distance of about 250 kms. The combined production potential is about 7.5 million cubic meters per day.
- A large fertilizer plant is being commissioned in Durgapur area which is about 250 km from the block.
- GAIL, the national gas carrier company has been booking the gas requirements from users in the Eastern CBM block corridor and has firm plans to connect the CBM blocks through a common pipeline.
- CBM gas beyond 0.5 million cubic meters per day will be transported through a common pipeline running from North Karanpura CBM block to Essar Raniganj CBM block meeting major consumption needs of fertilizer, cement, steel, power and other industrial plants in the area.





**Investment**  
US\$ 20m

**Investee**  
Prabha Energy

**Geology**  
GIIP: 806 BCF  
Recovery: 46%

**Consortium Partners**  
ONGC, IOC

**Free Gas Market Pricing**

## Transaction Summary

- Investment of up to US\$ 20m for CBM development & production - Transaction pending fulfilment of customary conditions precedent
- Prabha Energy Private Ltd (PEPL) is holder of 25% farm-in stake and lead technical operator in NKCBM gas field in Jharkhand, Eastern India
- PEPL's consortium partners ONGC and IOC are globally renowned Indian Oil & Gas majors
- Strong stable local gas prices - Realised gas prices in the area of US\$ 8-10 / MMBTU
- Conservative production profile and models demonstrate commercial production for over 20 years
- Significant regional shortfall in gas supply vs consumer demand for bottled gas

## Technical Highlights

### First gas production expected within 12-18 months

- In years 1 to 6 of the FDP, production will ramp up to 2.1 mm m3gd (ca. 76 mm scfgd) coincident with maximum dewatering of the coal seams
- In years 6-10 gas production peaks at over 2.4 mm m3gd (ca. 76 - 87 mm scfgd)

### Operating team in place - Project ready for mobilisation

- Land acquisition and civil works including access roads and well-site preparation underway (years 1-2)
- Surface, water-based drilling and production air-drilling followed by perforation and hydro-fracturing via coiled tubing units, thereafter lowering dewatering pumps (years 2-4)

### Conservative production profile with strong upside potential

- GIIP: 806 BCF – Recoverable: 370 BCF