Unconventional Gas E&P : Essar Approach

26 -27th November, 2015

Essar Exploration & Production
Peninsula Techno-park, Tower II, LBS Marg, Mumbai 400070, India.

www.essar.com
About Essar

Essar is a multinational corporation with annual revenues of US Dollar 35 billion, investments in Steel, Energy, Infrastructure and Services, presence in more than 29 countries and more than 60,000 people.

1.36 bn boe reserve and resources
World energy consumption will remain heavily reliant on hydrocarbon sources

- **Oil & Gas (conventional and unconventional) would continue to have more than 50% of world energy mix**
- **The conventional resources are decreasing fast and discoveries are far and few, so the trend for unconventional hydrocarbons is going strong globally.**
CBM – End use options

COMMERCIAL
Hotels, Hospitals, Restaurants

DOMESTIC
Households

FEED to INDUSTRIES
Fertilizer, Carbon Black

FUEL to INDUSTRIES
Steel, Power Others

CNG
Automobiles

Specific carbon dioxide emissions of various fuels
Total Petroleum System

- **Entrapment**
- **Migration**
- **Generation**

- **Gas Cap**
- **Oil**
- **Water**
- **Seal Rock**
- **Reservoir Rock**
- **Source Rock**

Temperature: 120°F, 350°F

Armentrout, 2001
Hydrocarbon Plays

- Conventional non-associated gas
- Coalbed methane
- Conventional associated gas
- Sandstone
- Seal
- Tight sand gas
- Gas-rich shale
- Oil

Production vs. Time graphs for Methane and Water.
Global CBM footprints

69 Coal Bearing Basin : activity in 35 countries

Global CBM Resource : 270 TCM (9500 TCF)

Source: Oilfield Review
India CBM Progress

- **Gas production from Raniganj, Bokaro, Jharia & Sohagpur**
- **No conventional O&G in the eastern part of India which has the best Gondwana coals in the country.**

<table>
<thead>
<tr>
<th>State</th>
<th>No. of Blocks</th>
<th>Area (Sq.Km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Bengal</td>
<td>4</td>
<td>1308</td>
</tr>
<tr>
<td>Jharkhand</td>
<td>7</td>
<td>2454</td>
</tr>
<tr>
<td>Madhya Pradesh</td>
<td>7</td>
<td>3701</td>
</tr>
<tr>
<td>Rajasthan</td>
<td>4</td>
<td>3972</td>
</tr>
<tr>
<td>Chattisgarh</td>
<td>3</td>
<td>1917</td>
</tr>
<tr>
<td>Andhra Pradesh</td>
<td>2</td>
<td>1136</td>
</tr>
<tr>
<td>Maharashtra</td>
<td>1</td>
<td>503</td>
</tr>
<tr>
<td>Gujarat</td>
<td>1</td>
<td>790</td>
</tr>
<tr>
<td>Orissa</td>
<td>2</td>
<td>766</td>
</tr>
<tr>
<td>Tamil Nadu</td>
<td>1</td>
<td>766</td>
</tr>
<tr>
<td>Assam</td>
<td>1</td>
<td>113</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>33</strong></td>
<td><strong>17,246</strong></td>
</tr>
</tbody>
</table>

- **33 Blocks CBM Resource potential 62 TCF ; 9.9 TCF established**
- **Main operators are Essar, GEECL, RIL & ONGC, GEECL**
Essar – CBM Portfolio

- Pioneer in Indian CBM E&P
- Presence in key CBM Basins
- Largest CBM acreage and Resources
- Raniganj Block in Developmental stage while others are in exploration stage
- Technology Leader in India

ESSAR CBM blocks in Gondwana basin
Raniganj Coalfield-Storehouse of Unconventional

Degree III Mines

ONGC Shale R&D

Generalized Stratigraphy
Development Phase Block: RG(E)-CBM-2001/I

- EOL 100% PI
- Area: 500 sq.km
- Exploration Phase I (2009) successfully completed and identified CBM fairway.
- Pilot Assessment Phase II (2012) completed successfully and incidental CBM gas flow established.
- Currently in Development Phase (Phase III)
- Largest number of development wells (~275) in the country
- Third party reserves certification carried out in 2009 & 2011 (0.85 Tcf Recoverable). Next phase of certification in progress.
- Highest CBM producer (c. 24 mmscfd) in the country today. Sizeable is under sale to local industries.
- GGS and Pipeline infrastructure operational.
Key Strategy for field development

- Systematic Reservoir Acquisition
- Fairway Identification
- Pad Drilling – minimum surface footprint
- Cased hole multi seam completion
- Massive Frac Job
- Production Enhancement
  - Well Spacing - 40 & 60 Acres
  - Production Performance monitoring
- Development Plan – 500 Wells
- Prioritization based on Production Data

- Cleats are the pathways for gas migration
- Raniganj Coal Seams have well developed cleat system
Key Reservoir properties

- Suitable Density cut-off thickness of coal - Log based
- Gas content (Desorption) and Gas saturation (Adsorption)
- Coal Permeability by in-situ coal Injection Fall-off (IFOT) tests

**Geophysical Log - Extract**

**Interpreted coal**

**Composite**

**Single**

**Adsorption Curve**

**IFOT field curve**
Pad Drilling

- Pad drilling for reducing the surface foot print.
- Time reduction to drill a well by deploying single schramm Rig
- Around 30% reduction in drilling cost
Well Completion

- Casing and Cementing
- Perforation
- Hydraulic Fracturing
- Work-over Operations
- Completion
No threat to Ground water

Withdrawn water has no interference with ground water due to Iron casing.
Hydro-Fracturing

• Per Job cost saving is ~11%
  ✓ Pumped more number of HF jobs per month - saved pumping charges
  ✓ Optimised fluid design – 25# guar loading instead of 30# (upto 6 ppa sand)
  ✓ Improvised job designs – use of water in flush stage & acid displacement
  ✓ Reduced use of Acid – saving by eliminating Acetic acid consumption
Main Fracture Job Plot

MainFrac EDP-122 Job#2(RN-3)
Surface Facility at Site
Pipeline Network & Water Handling

Water Tank & Interim RO

MATIX

RO Facility

Produced Water Pit
CBM ....Well head to Market

- Drilling Rig For CBM
- PC Pumps running at Well site
- Separators installed at Well site
- Pipe line Construction
- Gas Gathering Station
- RO Plant
- First Gas
- Produced Water
- Plantation at Well site
Resource Migration

[Diagram showing different categories of resources such as production, reserves, contingent resources, prospective resources, and their respective uncertainties and chances of commerciality.]
Exploration Blocks
### Status: 4 Exploration Blocks

<table>
<thead>
<tr>
<th>BLOCK NAME</th>
<th>SP(NE)-CBM-2008/IV</th>
<th>RM(E)-CBM-2008/IV</th>
<th>TL-CBM-2008/IV</th>
<th>IB-CBM-2008/IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>STATE</td>
<td>M .P</td>
<td>Chhattisgarh</td>
<td>Jharkhand</td>
<td>Odisha</td>
</tr>
<tr>
<td>AREA (sq km)</td>
<td>339</td>
<td>1128</td>
<td>557</td>
<td>209</td>
</tr>
<tr>
<td>DISTRICTS (sq km)</td>
<td>Shahdol-231 Koriya-108</td>
<td>Pakur -1117 Sahibganj- 09 Dumka -02</td>
<td>Sambalpur-342 Angul-185 Deograh-30</td>
<td>Sundargarh-202 Jharsuguda-07</td>
</tr>
<tr>
<td>Resources (TCF)</td>
<td>0.6 (DGH); Recoverable: 0.37</td>
<td>3.2 (DGH); 4.7 (ARI); Recoverable: 1.2</td>
<td>2.6 (DGH); Recoverable: 0.49</td>
<td>1.2 (DGH); Recoverable: 0.4</td>
</tr>
<tr>
<td>Minimum Work Programme (as per bid)</td>
<td>Phase I-02 Yrs</td>
<td>25 Coreholes &amp; 03 test wells</td>
<td>30 Coreholes &amp; 03 test wells</td>
<td>30 Coreholes &amp; 03 test wells</td>
</tr>
<tr>
<td>Phase II-3 Yrs</td>
<td>25 pilot wells</td>
<td>20 pilot wells</td>
<td>25 Pilot wells</td>
<td>20 Pilot wells</td>
</tr>
</tbody>
</table>
World-wide
- Sub-Saharan Africa
- China
- Turkey
- USA
- UK
- Indonesia
- Poland
- Australia

SAARC
- Being part of the master Indian sub-continent regional geology and coal occurrences are very similar across all these SAARC countries.
- Essar internal Unconventional Hydrocarbon Team is already having a good understanding of regional SAARC country geology and keen to work there.
- Ideally positioned to venture into fellow SAARC countries for suitable business ventures under suitable terms.
EOL-CBM Raniganj-ToR
Essar – Other Clean Coal Technology ventures

**Underground Coal Gasification (UCG)**

- Strong understanding of Technology and Alliances with few global expert agencies like Clean Global Energy (CGE), Australia.
- Essar had actively bid/participated in various tender/offers for UCG development so far in India like - Singareni Collieries Company Limited (SCCL) Coal India Limited (CIL) and Rajasthan State Petroleum Limited (RSPCI).
- A Draft Policy Note for UCG/Production of syngas obtained through gasification has been notified by the Govt. of India but yet to be formally announced.

**Coal Mine Methane (CMM)/Abandoned Mine Methane (AMM)**

- Huge CBM ressource locked in Indian coal mining leasehold areas (possibly in excess of 200 TCF).
- The Team has a good understanding of the process and already worked on CMM/AMM projects in UK and its scope in Raniganj/Jharia Coalfields.
- CIL had in 2011 offered blocks for CMM development in its leaseholds which was bid and qualified by Essar. Final Award on announcement of Development Policy by GoI.
- The Govt. of India is expected is shortly expected to announce the policy for CMM development in CIL and/or private mining leaseholds. Essar with its CBM expertise, experience and service contracts is keen to work with these coal mining companies.
Map of 106 basins in 46 countries
Global Shale Gas – 35,782 tcf, Shale Oil – 6753 bboe
The Trend

Estimated U.S. shale gas production was 41.4 Bcf/d in May 2015 about 55% of total U.S. dry production (74.6 Bcf/d)

Sources: EIA Natural Gas Monthly data through December, STEO through April 2015 and Drilling Info.
Shale Gas – Indian scenario

The major Gondwana basin CBM plays are strategically central part of the Shale Gas map

- 6 prospective basins identified by DGH for shale gas exploration
- Final version of Shale Gas Policy 2012 yet to come in force
- 584 TCF of shale gas resource and 87 billion Barrels of shale oil resource in 4 basins: Cambay Onland, Damodar, Krishna Godavari Onland & Cauvery onland (EIA 2013)
- ONGC pioneered drilling of Shale wells in Damodar Valley and successfully tested in Raniganj(N) block, close to Essar’s Raniganj(E) block.
- Presently ONGC is drilling R&D wells in Gujrat.

Source: DGH & EIA
Shale Gas Feasibility

- Essar Shale gas Feasibility study for its CBM blocks and Mehsana O&G block with support from USTDA

- Objective was to a) establish the potential, prospect and risk with Shale Gas development & b) Design an execution from pilot to field Development

- Combined in place resources of Mehsana & RG (E) is of the order of 10 TCF.

- Shale Gas can be developed in synergy with current CBM development in RG (E ) with common infrastructure
Essar – Expertise

• Multiple geographic and geological province working experience
• Established leadership position in Unconventional CBM gas in India
• A highly enriched technical team consisting of Geoscientists, Engineers, and other technical staff along with a highly motivated management team, consisting of specialists in finance, business development, logistics, human resources, project consultancy and advisors.
• Use of industry benchmark hardware (high-end workstations) and softwares (Prizm-Geographix, Petrel, Eclipse, Comet, Kingdom suites, Frac-Pro, etc.) at offices.
Unconventional – SAARC co-operations

- Significant geographical and geological similarities in the region.
- All these countries have heavy import burden in terms of primary energy resource.
- Coal resources are known and huge Shale Gas/Oil resources has been reported by expert.
- Energy transfer through Cross-country pipelines appear imminent.
- There is a strong need for mutual co-operation in sharing of technology & expertise among SAARC nations for Energy Security.
- Efforts required to unlock ~1000 TCF in-place locked up in SAARC countries in CBM & Shale Gas.