“ENVIRONMENTAL CONSEQUENCES of FRACKING for OIL and GAS”
1. WHAT IS SHALE GAS, TECHNOLOGY of PRODUCTION and IMPACTS on ENERGY MATRIX

2. ENVIRONMENTAL ISSUES and FUTURE TRENDS
1. WHAT IS SHALE GAS, TECHNOLOGY of PRODUCTION and IMPACTS on ENERGY MATRIX
• The Revolution of the SHALE GAS

• The Conceptual Innovation for Shale Production

• US Learning Curve
  – Footprint Concerns
  – Induced Seismicity

• Knowledge of Rocks and Evaluation of the Potential

• Can the US Shale Model be exported?
What is the SHALE GAS?

A world class source rock and a potential shale gas reservoir – the Devonian-Mississippian Woodford Shale
Unconventional Gas Definitions

• Tight Gas
  – siltstones, carbonates and very fine sandstones with low permeability
  – Slightly better flow rates than shales however higher risk of low charge

• CBM
  – Coal bed methane is usually trapped in coal deposits that have been buried to the kitchen window.
  – Gas is adsorbed to mineral surfaces.

• Gas Hydrates
  – Requires very cold conditions to maintain a solid state. Usually found in hard-to-reach places e.g. Siberia, Alaska or some locations in deep water offshore.

• Shale Gas
  – Shales are usually marine, deltaic or lacustrine deposits, often laterally extensive
  – Wide range of properties with permeability usually on the nanodarcy scale
  – Gas in natural fractures, pores, adsorbed to mineral or organic matter
EXPLORATION AND PRODUCTION OF SHALE GAS

- Expensive and requires specific technologies
- In USA costs reduced by:
  - Limited/focused exploration phase
  - Production focused and pragmatism: - Drill, frac and see if it can be produced
    - Drill, as much as you can
- Gas transport to production wells requires conductive network of open fractures:
PRODUCTION SOLUTION: HYDRAULIC FRACTURING

- Fracture Technology is responsible for USA success in gas shales
  - Use large amount of water in a short period of time to develop a gas well
  - Addition of sand or other material (proppants) to the fluid to keep induced fractures open
  - Most wells are horizontal with one or more horizontal legs extending to the target sections
  - The legs may extend more than 2 Km from the surface location of the well
SHALE GAS: Rocks and Production Operations

Source: Shale Gas World – Europe 2011
New Abundance

U.S. natural gas proved reserves, in trillion cubic feet

Shale gas’s rapidly growing share of total reserves

Source: Energy Information Administration

The Wall Street Journal
Top Natural Gas Producing Countries in 2012

<table>
<thead>
<tr>
<th>Country</th>
<th>Billion Cubic Metres</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S.</td>
<td>681.4</td>
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<tr>
<td>Russian Federation</td>
<td>592.3</td>
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<tr>
<td>Canada</td>
<td>156.5</td>
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<tr>
<td>Iran</td>
<td>160.5</td>
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<td>Algeria</td>
<td>81.5</td>
</tr>
<tr>
<td>Indonesia</td>
<td>71.1</td>
</tr>
</tbody>
</table>

Source: BP Statistical Review of World Energy June 2013
U.S. Production, Consumption, and Net Imports of Natural Gas
1980-2040

Trillion Cubic Feet

Year

Source: Energy Information Administration
WORLD TOTAL GAS RESERVES

Source: The Economist, 6th August 2011
APPLICATIONS

- Gas is most versatile of fossil fuels
- Used both in power generation and transportation
- GTL may be competitive solution for transport in Medium Term

DECARBONIZATION OF ECONOMY

- Gas is the least poluent of fossil fuels
- May play key role in transition of energy paradigm

EFFECTS OF JAPAN NUCLEAR CRISIS

- Decision of some countries to slowdown nuclear power (Germany, Italy, Japan)
- Opens a more decisive role for Gas
SUCCESS FACTORS of US SHALE GAS MODEL.
Can it be exported?

Private Ownership of the Land
- Fosters dynamism and individual initiative
- Avoids bureaucracy and complication

DYNAMICS of US ENERGY MARKETS
- Role of small/medium size Independent Companies

US ENERGY LAW
- Promotes Entrepreneurship
- Design mechanisms
- Incentives

ENVIRONMENTAL REGULATIONS
- Identity environmental impacts
- Act through regulation not through prohibition

GEOLOGY
- Huge basins with vast resources
- Ability to design incentives to tap resources

CREATIVITY/INNOVATION
- Ability to challenge existing paradigms
- Invent new concepts

SERVICE COMPANIES
- Drilling/Fracturing
- Logging/Operations
- Very active
- Easy access

INFRASTRUCTURE
- Availability of pipelines and transmission/distribution system
- Easy access
- Use based on a “pay tariff”
- No Monopolies

PRODUCTION SYSTEM
- Active and mature industry
- Production close to pipelines and consumers
- Water needs

ACCESS to FINANCING
- Easy
- Simplified
- Supportive

PRIVATE OWNERSHIP OF THE LAND

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THE FUTURE OF NATURAL GAS

Gas should make the world a cleaner, safer place

Source: The Economist, 6th August 2011
The growing role of international trade

Inter-regional flows = 605 Bm³ (75% for Europe) by 2020

[Map showing global trade flows with numbers indicating volumes in Bm³.]
WORLD ENERGY MATRIX

UNCONVENTIONAL GAS RESERVES
- “The unconventional revolution”
- Shale Gas huge reserves
- 60% to 250% of conventional
- Developments in US world’s big producer
- Implications for Middle East/Europe
- Feasible solution for Middle East domestic gas needs

GAS PRODUCTION
- Rapidly increasing
- 7.3% growth in 2010

GAS CONSUMPTION
- Rapidly increasing
- 7.4% growth in 2010
- The most rapid increase since 1989

LNG
- Exponential growth in trade (+22%) and consumption
- Major role in Japan crisis due to its flexibility

GAS INFRASTRUCTURE AND STORAGE
- Underinvestment
- Constraints may arise from current level of developments

MARKETS AND PRICES
- Desindexation of gas from oil prices (Atlantic basin)
- Is this a permanent trend?
- Role of spot markets more significant
- Atlantic basin before Japan crisis split 50-50 (oil and non-oil indexed prices)

GAS TRADE
- 10.1% growth in 2010
- Driven by strong growth in LNG (22.6%)
- LNG accounts for 30.5% of global gas trade
- Pipeline shipments grew 5.4% led by Russia
- Europe and Eurasia account for 2/3 of pipeline gas trade

GAS TRANSPORTATION ROUTES
- Changes in structural patterns
- LNG flexibility and versatility
- Overcome difficulties with “Stranded Gas”
- Main threat from further congestion in key routes

GAS IN THE INDUSTRY

15 May 2014
US OIL SHALE: TEXAS HEARTLAND HEADS THE US OIL REVIVAL

Re-energising America

Key oil and gas shale regions in the US

- Bakken/Three Forks
- Permain Basin
- Eagle Ford

Top countries with shale oil resources

- Russia: 75
- US: 58
- China: 32
- Argentina: 26
- Libya: 26

Companies leading exploration in Bakken and Eagle Ford

- Bakken/Three Forks
  - Continental Resources
  - Whiting Petroleum
  - Hess Corporation
  - Statoil
  - EOG Resources

- Eagle Ford
  - EOG Resources
  - ConocoPhillips
  - Chesapeake Energy
  - GeoSouthern Energy
  - Anadarko
  - Plains Exploration & Production

Top 10 Permian Basin operators, 2012

- Occidental Permian
- Pioneer Natural Resources USA
- Apache Corporation
- Kinder Morgan Production Co
- XTO Energy
- ConocoPhillips
- Chesapeake Energy
- Pioneer Natural Resources
- EOG Resources
- Apache Corporation

US oil production forecasts

Source: FT, 8th July 2013

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Rising Supply
The U.S. is the world's fastest growing oil producer

Source: BP
2. ENVIRONMENTAL ISSUES and FUTURE TRENDS
ENVIRONMENT ISSUES

Source: Shale World Gas, Europe 2011
FOOTPRINT CONCERNS

**AIR:**
- Emissions (CO2 & others...)
- Noise and dust (trucks, operations...)

**LAND:**
- Disposals (solid waste...)
- Wildlife/Habitat disruption
- Surface Footprint
- Roads & Traffic
- Induced Seismicity
- Pipelines
- Soil erosion

**WATER:**
- Aquifers quality / contamination
- Availability / supply
- Sustainable management (flow back...)

Transparency in Operations
Regulatory Response
ENVIRONMENT SOUND WAY?

Source: Shale World Gas, Europe 2011

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Frac Spread Surface Footprint
Stage 1: 12,385 bbl (incl. mini-frac) + 101.1 metric tons of propanent
Stage 2: 14,710 bbl (incl. mini-frac) + 116.6 metric tons of propanent

2,3 magnitude 10 hours after pumping

Operations stopped and additional monitoring stations installed
Stage 3: 5,031 bbl (incl. mini-frac) + 52.2 metric tons of propanent
Stage 4: 10,590 bbl (incl. mini-frac) + 82.2 metric tons of propanent
Stage 5: 9,870 bbl (incl. mini-frac) + 110.7 metric tons of propanent

1,5 magnitude 10 hours after stage 4 pumping

Stage 6: Voluntarily stopped operations
Geomechanical study of Blackpool Seismicity on-going

INDUCED SEISMICITY

www.cuadrillaresources.com

Seismicity Magnitude vs Injected and Volume Flowback Volume

Source: Shale World Gas, Europe 2011

Preese Hall-1, PEDL 165, Elswick, UK
North America Competition

Bakken formation

Minneapolis-St Paul

Chicago

Eagle Ford

Photo: Nasa
Environment Concerns

Shale Hydrofrac Concerns Addressed”  AAPG Dec 2010

- 1903 proven process, used commercially since 1948
- Shale reservoirs normally have ‘000’s ft separation from underground sources of drinking water
- At shallow depths overburden often the minimum principal stress, so fractures propagate horizontally not vertically
- Little risk of surface spills, but if it did occur it would be rapidly cleaned-up before causing damage
- Passive microseismic enables fracture hazard avoidance
- Fracture water reuse as great as possible
- ‘Green chemistry’ employed to ensure safe additives
- ‘Slickwater’ fracture fluid simply water + friction reducer

Source: AAIG, 2010
WORLD GAS MARKET

- Going for a global Convergence?
- Or Multi-Regionalization?

GAS VERSATILITY
- Most versatile of fossil fuels
- Used in power generation and transportation

GAS GOLDEN AGE
- Gas may displace oil as dominant fuel
- Increasing share of world energy matrix

UNCONVENTIONAL GAS
- Rapid booming of gas demand will require more unconventional
  - Huge reserves
  - Competition with LNG may be “smoother” than anticipated

TECHNOLOGY
- Floating LNG may change production pattern offshore projects
- GTL may open gas share in transportation system
- Increasing use of renewables may liberate part of gas for exports.

GAS SUPPLY
- Structural shifts in gas supply availability
- Expansion in Qatar and West Africa
- Growth of unconventional gas
- Success of major projects critical for the supply of Atlantic/Pacific basins

ENvironmental Concerns
- Differentials with coal will not lead to coal dominance
- Costs of non-decarbonizing the economy
- Increasing role of gas in a transition to a more “clean” paradigm

LNG
- Totally globalized by 2022/2025
  - Finish the syndrome of the “Stranded Gas”
  - Flexibility in transport responds quickly to shifts in Demand

Pipeline Transportation
- It will play a major role on interregional flows
CITIES are BEST INVENTION of MAN
- Mark death of distance
- Rotating platform for markets and cultures
- Connect human capital
- Cities are main drivers of innovation

THE NEED of a PARADIGM SHIFT for WORLD CITIES
- Cities occupy 2% of planet surface
- 50% of world population
- Consume 75% of energy produced
- Responsible for 80% of CO2 emissions

CHALLENGES for FUTURE CITIES
- More sustainable models
- Address energy security
- Smart grids
- New model for mobility
- There is no sustainability for future without a new vision for the development of more intelligent cities
- Sustainability is a multidimensional concept and needs to question the excess of the constant growth logic and fight the waste of resources

NEW MODEL for CITIES
- Water management
- Energy management
- Residuals treatment
- New role of transport system based on public transport + electric cars + evaporation of traffic jams
- New modes of access and distribution of resources

CITIES with CURRENT LANDSCAPE IMPLY HUGE RISKS
- Frenetic urban growth
- Difficulties in resources management
- Drivers of atmospheric pollution
- "Heat-Islands"
- Negative impact on earth climatic system
- Key issue: transport system

15 May 2014
THANK YOU