UK Unconventionals have become a topic of much debate over the last year, but what are unconventionals, what is fracking, and what does it mean for the UK?

This edition of Drill Bits is an introduction to the world of unconventional oil and gas and it begins where it all began, in North America, where the industry started and in a very short space of time has had a huge impact, not only in North America itself, but also across the globe.

The US unconventional story is a relatively recent one and continues to develop rapidly, with the Canadian industry also picking up strongly in recent years.

Abundant success finding and producing gas has depressed US prices in recent years and a switch in focus to shale oil is the latest big thing. Capital expenditure on North American shale oil is strong with US majors such as Exxon, Chevron, Conoco, Marathon, Apache and many other active operators ramping spending up this year, being attracted to the strong returns, despite the correspondingly high capital demands.

Cheap and plentiful energy supplies are having a remarkable effect on the US economy:

- Cleaner emissions as coal is diverted to Europe for power
- Re-invigorated industrial competitiveness and rapid economic recovery which is driving up living standards
UK Unconventionals - Will it happen here?

- Global unconventional story still in its infancy, estimates of future potential still largely a rough estimate
- Experience in North America: once a sweet spot is identified in a play, things move fast and reserves adds are big
- Recent events in UK are encouraging
  - Positive drilling results
  - Government support
- Should significant economic reserves be found, there is a compelling case to develop them; the need for cheap safe supplies of gas is high, and will continue to grow

UK Gas & Oil Import Requirement Grows Rapidly Without Shale

- Oil Export / Import
- Gas Export / Import

Current Unconventional Reserves by Country (billion boe)

- Gas
- Oil

Source: EIA

Industry Skepticism Remains Strong

Most Popular Response Marked

- US Tuscal. Marine Shale
- US Brown Dense
- UK Shale Gas
- China Sichuan Shale
- Ukraine Shale Gas
- Bazhenov Tight Oil
- Algeria Shale Gas

Decreasing Industry Understanding

- 1bcfe/d by 2020
- after 2020
- Never commercial

Source: Wood Mackenzie 2013 Client Survey

UK shale extraction may be more expensive than US, but gas prices are better

US Henry Hub Spot $4.6
UK Spot $8.4
Gas price ($/million btu)

Source: DECC

Source: UK Government

Source: Wood Mackenzie
‘Unconventional’ developments require the use of hydraulic stimulation (fracking) to produce economic reserves

Possible scenarios:
- Shale: source rock with very low porosity and permeability, which has hydrocarbons from organic origin held locally within the matrix
- Tight: low porosity and permeability sand or siltstone into which hydrocarbons have migrated from a source rock and which requires fracking to make a well economic

Advanced wells: Low permeability rock means hydrocarbons drained around an individual well are often limited in extent, therefore requiring higher well-bore coverage than conventional developments to optimise economic recovery. This is why horizontal wells are often favoured

Fracking involves pumping most often water-based fluid into reservoir at high pressure to cause a fracture to grow in the rock at a targeted point. ‘Proppant’ is then pumped down as a slurry mix into a growing fracture to prevent it closing once the pumps are stopped. Proppant beads are usually a few millimetres in diameter and are often made of high strength sand or ceramic material to prevent it being crushed by very high rock closure forces which are exerted when the pressure is reduced and the well is flowed

Frack fluids have been developed with sophisticated rheology to maximise effectiveness of the frack. Organic and low toxicity chemicals are required as most flows back to surface when well is ‘cleaned-up’ (initially started)

Recent technological advances have revolutionised unconventionalns:
- Long ‘steered’ horizontal wells provide greater formation exposure
- Well completion technology allows many fracks to be placed along the lateral length of a horizontal well, one immediately after another, with much reduced cost, however this requires large amounts of fluid to be readily available. Construction of large ponds and flow-back pits near well site significantly increases footprint and can be unsightly. Preference recently is to group wells together on a single “pad” and to pipe water in, minimising storage requirements and disruption to an area being developed
- Spacing of laterals and frack size/density is particular to the play and local rock properties, which can vary both from play to play and within a particular play. Optimal well and frack design is often a complex cost-benefit challenge which balances cost; lateral length, frack number and size against well production profile and economic reserves
Unconventional developments are usually laterally very extensive and require many more wells to develop a play compared to conventional oil and gas reservoirs.

Drilling a well and fracking it requires large amounts of consumables.

Many of the concerns raised about the safety of fracking are unfounded. Key risks, as with any process, can be safely managed and controlled by regulations and well-understood engineering design and operational procedures to protect people and the environment.

The biggest challenge in the UK, which has largely not been discussed in detail to date, is minimising any disruption to the local area during the operational phase, namely:
- Footprint for operations
- Trucks and rig site traffic
- Visual impact
- Noise and lighting

Very large logistics operations are required during the drilling and fracking phase of development. Deliverables to a well site include:
- Tubulars (drill pipe, casing, tubing, frac strings)
- Consumables (fuel, proppant, guar, cement, etc.)
- Water
- Rigs, cranes, coiled tubing, well testing, pumping, plant, wireline

Rigs and well operations run 24-7
- Can be noisy (squeaky brakes, gensets, plant)
- Lighting towers
- Noisy well operations (e.g. jarring)
- Night traffic for short notice deliveries
- Tannoys, shift change traffic, etc.
- Well testing (flame luminescence and noise)

Post rig and frack operations, the well site will be largely clear of equipment and unobtrusive. The key is to minimise disruption during initial drilling and fracking operations on the well pad.

Some plays characterised by large areas of open space, commonly on low-value land, however some areas have similar issues with local populations, Pennsylvania (Marcellus), Ohio (Utica) and Texas (Barnett), which have, or are, being addressed with results which are continually improving.

Mineral rights of landowners provide major incentive to provide access.

Long developed onshore energy industry, large rig count and extensive infrastructure.

Widely dispersed population outside cities often with limited local infrastructure.

State owns all mineral rights. Economic benefits to country and local area less obvious, particularly in early stages.

Existing onshore UK oil and gas developments localised in nature, very few people currently employed locally in oil and gas industry where shale gas will be developed.

Majority of land either high-value agricultural, protected or valued by local population as outdoor space.
UK Unconventionals - Concentrate activity on a super pad

- A single lateral in the Bowland shale could typically be:
  - Landed at 2,500 m depth
  - Have a step-out of 1,750 m
  - Have 20 fracks placed along its length

Bowland is unusually thick, so for this example, assume three wells are required vertically through the shale to optimally drain the reservoir vertically.

**Example: Small Shale Development**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of wells per pad</td>
<td>30</td>
</tr>
<tr>
<td>Subsurface length (km)</td>
<td>3.5</td>
</tr>
<tr>
<td>Subsurface width (km)</td>
<td>1.0</td>
</tr>
<tr>
<td>Areal size in reservoir (km²)</td>
<td>3.5</td>
</tr>
<tr>
<td>Size of play (km²)</td>
<td>400</td>
</tr>
<tr>
<td>Number of pads required</td>
<td>114</td>
</tr>
<tr>
<td>Number of wells required</td>
<td>3,420</td>
</tr>
</tbody>
</table>

**Rig on Pad With Pond For Fracking Behind**

**Universal Pressure Pumping Frack Spread on Pad**
UK Unconventionals - Example well design

Stages are fracked in sequence by series of ever increasing diameter balls which are dropped down well and simultaneously isolate well lower down and open new frack port using sliding sleeves.

Balls can flow back to surface when well is flowed, or they can be designed to dissolve after a suitable time delay.

This image represents a single stage in a frac string which may comprise 20-40 stages over a mile long.

Too Many Truck Movements: Requires Alternative

<table>
<thead>
<tr>
<th>Hole Section</th>
<th>Depth (ft)</th>
<th>Vol., bbl</th>
<th>Wt. (T)</th>
<th>Tons (cum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductor hole section 32&quot;</td>
<td>150</td>
<td>224</td>
<td>103</td>
<td>103</td>
</tr>
<tr>
<td>Surface casing section 24&quot;</td>
<td>1,050</td>
<td>1,175</td>
<td>542</td>
<td>645</td>
</tr>
<tr>
<td>Common 6&quot; section</td>
<td>4,000</td>
<td>1,119</td>
<td>516</td>
<td>1,161</td>
</tr>
<tr>
<td>12-1/2&quot; Well-2 (middle target)</td>
<td>8,300</td>
<td>4,837</td>
<td>2,230</td>
<td>3,391</td>
</tr>
</tbody>
</table>

Pipe L (ft) lb/ft Wt. (T)

<table>
<thead>
<tr>
<th>Pipe L (ft)</th>
<th>lb/ft</th>
<th>Wt. (T)</th>
</tr>
</thead>
<tbody>
<tr>
<td>26&quot; conductor</td>
<td>150</td>
<td>10</td>
</tr>
<tr>
<td>18-3/8 surface casing</td>
<td>1,050</td>
<td>87.5</td>
</tr>
<tr>
<td>9-5/8&quot; Lateral 1</td>
<td>8,500</td>
<td>50.0</td>
</tr>
<tr>
<td>9-5/8&quot; Lateral 2</td>
<td>9,500</td>
<td>50.0</td>
</tr>
<tr>
<td>9-5/8&quot; Lateral 3</td>
<td>10,500</td>
<td>50.0</td>
</tr>
<tr>
<td>Frac string</td>
<td>4,050</td>
<td>12.0</td>
</tr>
</tbody>
</table>

Cementing & Mud Sacks Additives (T)

<table>
<thead>
<tr>
<th>Cementing &amp; Mud Sacks Additives (T)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mud additives (total)</td>
<td>4,000</td>
</tr>
<tr>
<td>Frac string</td>
<td>4,050</td>
</tr>
</tbody>
</table>

Frack Dry Goods T/stage Stages Total

<table>
<thead>
<tr>
<th>Frack Dry Goods T/stage Stages Total</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proppant</td>
<td>30</td>
</tr>
<tr>
<td>Additives</td>
<td>4</td>
</tr>
</tbody>
</table>

Water bbl Tons

<table>
<thead>
<tr>
<th>Water bbl Tons</th>
<th>Total Per Well</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drift water</td>
<td>150,000</td>
</tr>
<tr>
<td>Frack water</td>
<td>80,000</td>
</tr>
</tbody>
</table>

Total Per Super Pad: 30 wells 3,602,942

Total Per Play: 50 Pads 180,147,124

357 Truck movements Required 5,147,061
UK Unconventionals - Using a CPF to minimise disruption

CENTRAL PROCESSING FACILITY (CPF)

- Unconventional developments are capital intensive so drilling and fracking operations must be both efficient and unobtrusive. By ensuring the impact a development has on a local area is well below that considered unduly disruptive, and that there are no incidents which adversely impact the environment, the benefits of shale development will soon become readily apparent.

- The apparent tension between the need to control costs and the necessity to ensure the license to operate is protected is illusory, as the two are actually complimentary: robust and efficient processes go together with efficiency. The Central Processing Facility (CPF) is a possible key to delivering this objective.

- Construct a Central Processing Facility (CPF) to centralise the maximum amount of activity in one location. CPF for an unconventional project will have much more capability than is usual in a conventional onshore gas development due to the need to minimise the impact drilling and fracking has at the pad locations pre-production.

- Ideal location is an existing brownfield site already zoned for light/medium industrial use which is near rail lines with new siding constructed for bulk transport to area.

- Core tasks
  - Central termination area for buried pipelines to and from pads
  - Water treatment and management, drill cuttings treatment and management
  - Gas conditioning and export
  - Other capabilities
    - Warehouse, workshops and laboratory
    - Training school and central stores
    - Vehicle base, rail car marshalling yard and central storage
    - Servicing sheds and storage areas
    - Accommodation and back-office support
    - Catering (which can also support pads)

- Benefits
  - All bulk logistics to and from pads for water and consumables, drill cuttings, etc. can be distributed to pads via buried lines, eliminating the need for majority of truck movements locally.
  - By-products can be piped back to CPF where state-of-the-art processing can be installed to maximise recycling and ensure high quality hazardous waste processing (i.e. oil-based drilling mud, water clean-up and reuse, etc.).

- Restoration
  - After main operations cease, pads to be fully cleared of non-essential equipment and landscaped to minimise visual impact. All sites restored to original condition promptly after operations cease, and overall environment impact to be positive (i.e. additional conservation work done to offset and surpass impact of operations).
UK Unconventionals - Pad operations

OPERATIONS SEQUENCE
- Construct access road, well pad and lay flow lines from CPF
- Conductor rig moves to location to install conductors and fabricate cellars for each well
- Short-string rig arrives and drills top-hole section, installs wellhead and suspends well ready for big rig
- Long-string rig arrives and drills lateral sections and installs frac string
- Frac spread arrives and fracks wells
- Completions installed and wells brought on-line for commercial gas
- Equipment demobilized and pad cleared of all non-essential equipment

Timing of various operations and overall number of rigs to be extensively optimised

IMPORTANT CONSIDERATIONS IN UK
- Locate pad in secluded and screened area where possible
- Plant trees around perimeter to reduce noise and visual impact
- Fairly compensate those affected by operations, maintain good relations with local community
- Use specially modified rigs and plant which are quiet
- Ensure access roads are upgraded where required and logistics operation is carefully managed
Unconventional developments are capital intensive industrial processes which, like any industry, need to be properly managed to ensure people and the environment are protected. Drilling and fracking have been routinely conducted by the oil and gas industry for many years. These processes are well understood and have been routinely conducted safely in the UK for many decades without incident.

Greatest challenge is not safe operations but minimising disruption to the local area. The UK is densely populated across many locations of potential interest, so innovative solutions need to be found to ensure unconventions are developed in a manner that reduces impact on the area to acceptable levels. One strategy which could achieve this is through the use of super pads and a Central Processing Facility (CPF).

Some of those objecting to fracking are fundamentally opposed to the use of fossil fuels. This relatively small group is distinct from the majority of the population who are not opposed to hydrocarbon development, but need and deserve assurance that activities are safe and not overly disruptive.

Benefits are less obvious to general public at this early stage. Industry needs to recognise that it will take time for this to become more readily apparent, but the requirement to secure low-cost energy means a way must be found to make this work.

Today, many who have settled in rural locations have made a conscious life choice to do so. Often their needs and requirements will have less in common with those supportive of unconventional developments. Their concerns need to be carefully managed during early phases of exploration, appraisal and development.

The industry will grow over a number of generations. Increasing proportions of those employed on rigs and in supporting the industry will settle locally over time. As they raise families and local services grow to support them and the industry, support will grow for this activity across the UK.

As in the offshore oil and gas industry, the UK has an opportunity to take the lead on this in Europe and become a leader in unconventional developments in populated areas across Europe and beyond.

HM Treasury are encouraged to share more of the tax-take with local area. Benefits should be more directly applied to local population in a tangible manner rather than using public trusts, as is currently proposed. One suggestion would be to use it to offset council tax, with additional rebates to residents in close proximity to operations.

Preese Hall-1 well - first fracked UK shale well

Source: Cuadrilla Resources

Estimated Annual Effect of Domestic Hydrocarbon Resource Availability on Consumer Spending in the United States ($billion)

Source: EIA
Look Ahead

- A number of companies are actively exploring unconventional plays in the UK at the moment and are quite advanced in some areas. Key indicators of commerciality will relate to:
  - **Well logs.** Usually ‘quick-look’ interpretation is available within days, which will be updated and calibrated to core data later. What does the petrophysical interpretation say about the presence of hydrocarbons and type, matrix properties, mineralogy, natural fractures and in-situ stress regime? Is the resource tight rock, shale or a mixture of both? How many potential pay zones are there, what pressures and depths?
  - **Core.** Used to calibrate the logs, estimate play potential and design frack program; can take laboratory months to analyse. What hydrocarbons are present and type, organic content and maturity? What are the mechanical properties of the rock, will it frack effectively or is it too soft? Matrix porosity and permeability, mineralogy, can the core be typed to another existing shale play? Is the rock naturally fractured?

- If above is encouraging, can begin **planning for fracking**
  - Use core and log data to design frack program, establish required pumping horsepower, frack fluid design and proppant size
  - Once design is finalised, can begin frack permitting and planning processes. **This is very complex in the UK and takes approximately a year**

- **Frack well.** Mobilise equipment to site and complete frack job. Then flow the well, clean it up and test, assess results. This can take about 6 months

- Once results are available, will have much better knowledge of play potential and can begin **optimising well design and multi-stage frack programs.** Expect the appraisal stage to take some years as well and frack designs are optimised and the sweet-spots in the play are sought

- **Process is lengthy,** partly due to the technical complexity of unconventional reservoirs and partly due to the regulatory environment in the UK which is currently very onerous and involves multiple government agencies (note that UK Oil & Gas offshore operations are much more streamlined when compared to onshore)

- If significant commerciality is confirmed expect game-changing results for the industry and the UK economy
ABOUT BMO CAPITAL MARKETS

BMO Capital Markets is a leading, full-service North American financial services provider offering equity and debt underwriting, corporate lending and project financing, merger and acquisitions advisory services, securitization, treasury management, market risk management, debt and equity research and institutional sales and trading. BMO Capital Markets has more than 2,300 employees operating in 29 locations around the world, including 16 in North America.

BMO Capital Markets is a member of BMO Financial Group (NYSE; TSX: BMO), one of the largest diversified financial services providers in North America with US$332 billion total assets and more than 48,500 employees as at January 31, 2014.

BMO Capital Markets is a trade name used by BMO Financial Group for the wholesale banking businesses of Bank of Montreal, BMO Harris Bank N.A. (member FDIC), Bank of Montreal Ireland p.l.c., and Bank of Montreal (China) Co. Ltd and the institutional broker dealer businesses of BMO Capital Markets Corp. (Member SIPC) and BMO Capital Markets GKTST Inc. (Member SIPC) in the U.S., BMO Nesbitt Burns Inc. (Member Canadian Investor Protection Fund) in Canada and Asia, BMO Capital Markets Limited (authorised and regulated by the Financial Conduct Authority) in Europe and Australia and BMO Advisors Private Limited in India. “Nesbitt Burns” is a registered trademark of BMO Nesbitt Burns Corporation Limited, used under license, “BMO Capital Markets” is a trademark of Bank of Montreal, used under license, “BMO (M-Bar roundel symbol)” is a registered trademark of Bank of Montreal, used under license.

BMO Capital Markets
95 Queen Victoria Street
London, EC4V 4HG
United Kingdom

BMO Nesbitt Burns Inc. makes no representation or warranty, express or implied in respect thereof, takes no responsibility for any errors and omissions which may be contained herein, and accepts no liability whatsoever for any loss (whether direct or consequential) arising from any use of or reliance on this Announcement or its contents. Information may be available to Nesbitt Burns Inc. which is not reflected herein. This document is not to be construed as an offer or solicitation to buy or sell any security.

The contents hereof are intended solely for the use of, and may only be issued or passed on to, (i) persons who have professional experience in matters relating to investments falling within Article 19(5) of the Financial Services and Markets Act 2000 (Financial Promotion) Order 2005 (the “Order”) or (ii) high net worth entities falling within Article 49(2)(a) to (d) of the Order (all such persons together referred to as “relevant persons”). The contents hereof are not intended for the use of and may not be issued or passed on to, retail clients.

Unauthorized reproduction, distribution, transmission or publication without the prior written consent of BMO Capital Markets is strictly prohibited.

© Registered trademark of Bank of Montreal in the United States, Canada and elsewhere.

TM Trademark Bank of Montreal

BMO CAPITAL MARKETS ENERGY ADVISORY, EMEA

Rupert Newall,
Managing Director, Head of Energy, EMEA
+44 207 664 8180
rupert.newall@bmo.com

Vicary Gibbs,
Director, Energy, EMEA
+44 207 664 8122
vicary.gibbs@bmo.com

Michael A. Rosen, M.Sc.,
Managing Director, Head of Energy A&D Advisory, EMEA
+44 207 664 8082
michael.a.rosen@bmo.com

Simon Compton, M.Sc.,
Director, Energy A&D Advisory, EMEA
+44 207 664 8173
simon.compton@bmo.com

Oberon Houston, B.Eng., M.Eng,
Director, Energy A&D Advisory, EMEA
+44 207 664 8175
oberon.houston@bmo.com