Shale Gas and Oil: Reality, Hope or Hype?

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CONTEXT
The Energy Mantra

- Affordable
- Secure
- Sustainable
Affordability: Prices Increasing

10% Europeans are in “Fuel Poverty”
Security: 75% EU Energy is Fossil Fuel
EU Net Energy Imports > 50%

Source: Eurostat, energy. Calculations of the European Commission
Sustainability

- EU: 40% CO$_2$ reduction 2030; 80% 2050

- China: Air Pollution; Peak CO$_2$ Emissions 2030
Breakdown of UK Energy Consumption: 1970-2013 with Projections to 2030

Source: DECC
UK Gas Supply Gap: 2004 Prediction……

- 35% UK Energy from Gas
- 80% UK Homes heated by Gas

....and 12 days storage

Source: Modified from WoodMackenzie 2004, ‘From surplus to shortage’
......Correct!

Source: Data from BP 2014a
“North Sea oil revenues fall by 75% in the first three months of 2015” BBC August 2015

“UK North Sea oil drilling work lowest in 15 years” Reuters January 2015

“All but one nuclear power stations to close by 2025

“Energy company SSE confirms Ferrybridge power station closure” BBC May 2015
We're all doomed! DOOMED!
SHALE OIL/GAS
What is an Oil/Gas Shale?

- Petroleum source rock
- Rich (> 10 vol %) in organic matter
- Buried over geological time to > 150°C (5 km)
- Uplifted to e.g. 1-3 km
- Non-expelled petroleum
Shale Oil and Gas: “Unconventional Hydrocarbons”

- **Conventional resources** – Oil and gas that migrated from the shale source rock to more permeable sandstone and limestone formations
- **Unconventional shale resources** – Oil and gas that remains trapped in the petroleum source rock (shale)
Production Requires ‘Fracking’

Hydraulic fracturing common since 1940
Applied with horizontal wells from mainly 2000
Fracking Operation

Water → Proppant

Hydration Unit

Liquid Frac Conc. (Polymer) → Chem. Adds.

Blender → HP Pumps

Monitoring Van
Multilateral and Multistage Fracs

Source: Chesapeake
US Oil Upturn Driven by Bakken and Eagle Ford
Nighttime Satellite Image, SW Texas

10000 wells since 2008
4000 more wells approved
US Now Net Exporter of Petroleum Products

Annual U.S. net exports of total petroleum products, 1949-2011

million barrels per day


exports

net exports

imports
HOW BIG IS THE RESOURCE AND RESERVE?
Resource and Reserve

Play maturation, spatial planning, legislation

Shale gas development plans

Exploration drilling

Geological analysis

Expected Ultimate Recovery (EUR, Reserves)

Economically recoverable (ERR)

Technically recoverable (TRR)

Total Gas Volume (GIP)
Technically Recoverable Gas Shale Resource

Total Gas Shale Recoverable Resource = 190 tcm (source: EIA)
Total Conventional = 190 tcm (source: BP)
We Don’t Know How Much is There: UK Bowland Shale RESOURCE (NOT RESERVE)

260 Tcf = 80 years UK consumption

- Volume Gas Mature Shale
- Porosity
- Gas-filled Porosity
- Organic Matter Content
- Amount Adsorbed Gas
- Pressure

160 Tcf
450 Tcf
Gas Production Data: Well Decline Curves Are Remarkably Similar

Individual Wells

> 8000 Barnett Wells
Patzek et al. (2013)
US Production Forecasts

Inman (2014) Nature
Most Likely Production Rates, US Shale Gas Wells (EIA)

- 2016: 12 tcf/y production from 75,000 wells (US)
- UK consumption = 3tcf/y = 18,000 wells

Graph showing peak production in 2016 and projected recovery by 2040 to 291.7 Tcf.
The European Challenge

- Security: 60% gas, 80% oil imported
- Sustainability: 40% CO$_2$ reduction 2030; 80% 2050
- More complex geology
- High population density
- Low, unchanging level of societal acceptance
Weald Shale Oil: Is It Worth It?

- 124BBO P50 (Nutech 21 Oct 2015)
- 42BBO total produced oil N Sea
Weald Oil: Is It Worth It?

<table>
<thead>
<tr>
<th>CHRONOSTRATIGRAPHY</th>
<th>LITHOSTRATIGRAPHY</th>
<th>SOURCE ROCK UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRETAUCEOUS</td>
<td></td>
<td>(Some immature shales)</td>
</tr>
<tr>
<td>VALANGINIAN</td>
<td>WEALDEN GROUP</td>
<td></td>
</tr>
<tr>
<td>RYAZANIAN</td>
<td>PURBECK GROUP</td>
<td>Purbeck Anhydrite</td>
</tr>
<tr>
<td>PORTLANDIAN</td>
<td>PORTLAND GROUP</td>
<td>Portland Limestone, Portland Sandstone</td>
</tr>
<tr>
<td>KIMMERIDGIAN</td>
<td></td>
<td>Kimmeridge Clay Formation</td>
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</tbody>
</table>

15% of section = tight carbonates: 19 BBO

5% recovery = 0.9 BBO = 2 years UK consumption = 6000 wells

2% recovery = 0.4 BBO = 1 year UK consumption
Bowland Shale Gas Example

- Up to 20,000 wells or 2000 pads to recover 40 tcf in northern England
- 13y UK consumption so NOT a game changer
- UK drilled 20 onshore wells per year 1902-2013
- Population of 8 million
Figure 4.4.1
Annual supply pattern in Gone Green

National Grid’s Future Energy Scenarios: Gone Green = No Shale
National Grid’s Future Energy Scenarios: Consumer Power = Max Shale

Figure 4.4.4
Annual supply pattern in Consumer Power

32bcm/y = 1.1 tcf/y = 40% UK gas in 2031, production starting 2021
Would need ca. 1000 wells per year
Modelled Shale Gas Production over 10 Years

- 3000 wells = 300 wells per year
- Average Barnett Production per well
- 10% UK gas consumption after 10 years

Rogers (2013)
GEOLOGICAL AND ENVIRONMENTAL CONCERNS
Important Issues

• Transport Disruption
• Water Use and Disposal
• Aquifer Contamination
• Induced Seismicity
• Leakage through Boreholes
• Climate Change
### Water Use: Substantial but Incremental

<table>
<thead>
<tr>
<th>Shale Play</th>
<th>Public Supply</th>
<th>Industrial and Mining</th>
<th>Power Generation</th>
<th>Irrigation</th>
<th>Livestock</th>
<th>Shale Gas</th>
<th>Total Water Use (Bbbl/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barnett</td>
<td>82.70%</td>
<td>4.50%</td>
<td>3.70%</td>
<td>6.30%</td>
<td>2.30%</td>
<td>0.40%</td>
<td>11.15</td>
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<tr>
<td>Fayetteville</td>
<td>2.30%</td>
<td>1.10%</td>
<td>33.30%</td>
<td>62.90%</td>
<td>0.30%</td>
<td>0.10%</td>
<td>31.9</td>
</tr>
<tr>
<td>Haynesville</td>
<td>45.90%</td>
<td>27.20%</td>
<td>13.50%</td>
<td>8.50%</td>
<td>4.00%</td>
<td>0.80%</td>
<td>2.15</td>
</tr>
<tr>
<td>Marcellus</td>
<td>11.97%</td>
<td>16.13%</td>
<td>71.70%</td>
<td>0.12%</td>
<td>0.01%</td>
<td>0.06%</td>
<td>85</td>
</tr>
</tbody>
</table>

But flowback water is often saline and must be disposed of according to strict Environment Agency rules (already in place)

ALL Consulting (2009)
UK Earthquakes $> M_L 1.5$

Wilson et al. (2015)
Seismicity Since 1990, Netherlands
Subsurface Water Disposal Does Induce Seismicity

Davies et al. (2013)
US Data: Fractures Very Unlikely to Intersect Aquifers
New and Old Wells Can Leak

- During Production: strict UK rules about double/triple casings through drinking/saline aquifers

- Pennsylvania and Alberta data suggest 5% wells have leaked – rate is key here
CH$_4$ Flux from Decommissioned UK Wells

- 30% of well sites had CH$_4$ at the soil surface that was significantly larger than their respective control
- 39% of well sites significantly lower

“Flux low relative to the activity commonly used on decommissioned well sites (e.g. sheep grazing)”

(Boothroyd et al., 2015)
Fugitive Emissions: Drilling, Production, Transportation
Doing it Better: Haynesville Production

- <1-6 bcf/well EUR
- 30% wells and fracks fail: $100 billion annual waste in US
Concluding Comments

• Globally large volumes of shale oil/gas – and tight gas
• Shale not a game changer in the UK
• US shale success will be harder elsewhere
• Transparent, strong and effective regulation and monitoring
• Social licence to operate: public engagement essential but may be insufficient
• Doing it better: water management, geology and engineering