Fracking & Coalbed Methane

Unconventional gas in the UK

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When gas fracking and other "unconventional" energy resources[1] are discussed in the media the focus is usually on the technology used to produced the energy, or the impact this might have[2] on the environment. In fact, the significant feature of the exploitation of unconventional energy resources is that our present energy situation is so precarious that companies and governments consider these valid energy sources; public interest demands that this aspect of the problem be examined[3]. Unconventional energy resources are being developed to supplement existing fossil fuel resources, but arguably, due to their lower energy return and high ecological impacts, they exacerbate the energy crisis by giving a false sense of energy security.

Depending upon who you listen to, unconventional gas resources such as shale gas/gas fracking and coalbed methane are either an economic boom for Britain[4] or another step on the road to ecological Armageddon[5]. As conventional gas production in Europe declines, the energy industry is pushing large sums of money into promoting[6] everything from trans-European pipelines and electricity grids to unconventional gas resources in order to maintain and expand Europe's energy consumption. Both sides in this argument focus on the minutiae of the technologies involved, and their ecological impacts. Instead, we should look at the energy system as a whole, and how these resources work within the structure of our energy systems.

Also, with the popularity of documentaries such as *Gasland*[7], or The Ecologist's recent short documentary[8] on hydraulic fracturing, much of the information that is "out there" looks at the experience in the USA. In this sheet we look at the potential of shale gas, coalbed methane and underground coal gasification in the UK. These three technologies represent the last technological wave in fossil fuel extraction, and all have problematic economic and ecological impacts.

Shale gas geology

To understand the difficulties of producing gas (and oil) from shale we must first look at how we produce the bulk of the oil and gas we produce today – via "conventional" drilling and production.

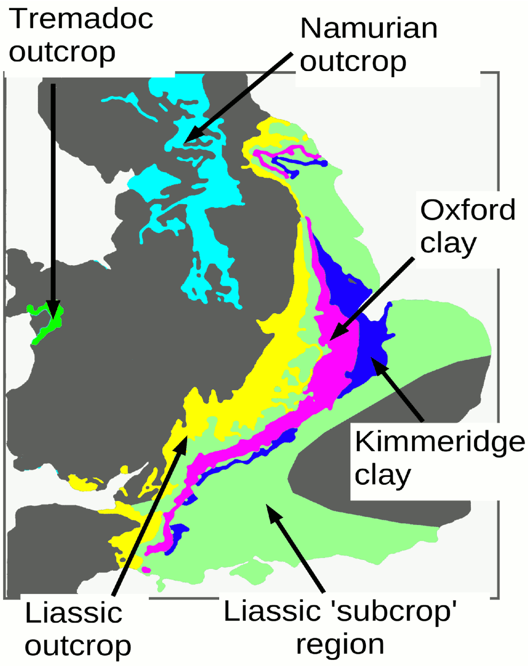
Hydrocarbons – *oil and gas* – are produced from the geological "cooking" of organic matter. When organic matter in river sediments is buried and heated by the geothermal heat from the Earth's core, the plant material breaks down to produce tar and oil compounds. Heat those materials to even higher temperatures and the hydrocarbons break down further to produce gas. What happens to the oil or gas produced by this process is dependent upon what the source rock[9] is composed of and how the rocks in the region are folded and fractured. Whilst the formation of oil and gas might be a common geological process, the conditions that allow it to be easily tapped and produced are not.

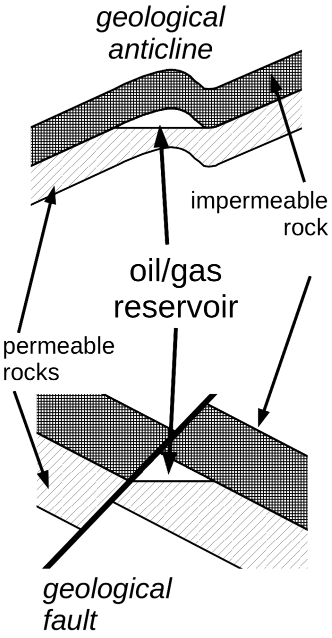
Shale gas resources in the UK

What determines the suitability of rocks to produce gas is the materials that they contain, and the age and geological history of the rocks. Like conventional oil and gas production, the rocks must have been buried to a sufficient depth, and held there for enough time, to allow geothermal heat to cook the organic matter contained in the rocks to produce oil and gas.

The map below shows the distribution of rock strata in England and Wales that have the potential to produce shale gas (Scotland only has a small area of Namurian rocks between Edinburgh and Glasgow). These are mostly hard shale and impermeable clay which require methods such as hydraulic fracturing to extract the gas they contain. There are many non-geological restrictions on the ability to produce gas too – from land values to the designations of national parks – and the locations where gas plants might be developed is dependent upon these local factors.

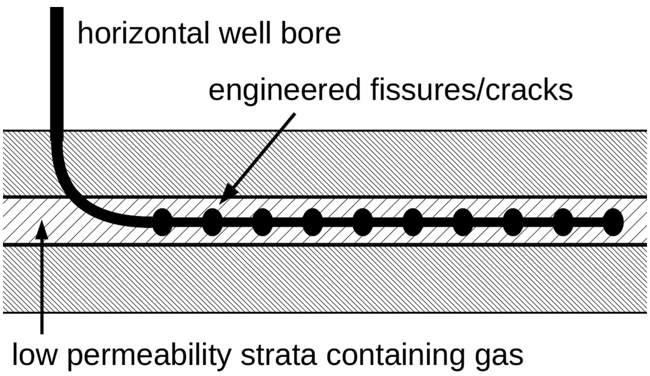
The next round of onshore oil and gas licensing (see map on page 5) is concentrating on these areas – in the hope that they might offset the decline in conventional gas production from the North Sea.





In “conventional” oil and gas production, the hydrocarbons created by geological processes must migrate through the rock strata to a point where they become trapped within special rock structures[10]. These occur when rock strata are fold or fractured to produce a dome-like structure[11], with an impermeable layer of rock above to trap the fluids/gases migrating through the more porous rocks below. Oil and gas are lighter than water, and so they float to the top of permeable rock structures to create oil and gas reservoirs. Drilling into the reservoir releases the oil/gas it contains.

“Non-conventional” oil and gas[1] is created in the same way – organic-rich sediments are buried and heated – but as the material produced is contained in very low permeability clay and shale it can't migrate to a reservoir structure where it can be easily tapped. For this material to be produced the rock strata have to be fractured and the hydrocarbons flushed from the rock using chemicals. In the tar sand[12] production areas of Canada this is done by physically digging-up the rock and then separating the oil in large processing plants. In hydraulic fracturing[13] – or *fracking* – this is done by drilling horizontally along the rock strata which contains the gas or oil, using high fluid pressure and small explosive charges to shatter and force the rock apart, and then filling the resultant cracks with sand to allow the fluid/gases to escape and be flushed out in the production water.



The source of the gas for fracking is usually shale[14] or clay[15] strata. Unlike the sandstone and limestone from which conventional oil and gas are produced, where gas and fluids can easily pass between the grains in the rock, the much smaller particles in shale and clay obstruct the movement of fluids and gases. In Britain the rocks get younger as you move from the north-west to the south-east[16]. In Scotland the rocks are too old to contain useful hydrocarbons. In the south-east, they are too young to have been buried and cooked to form gas or oil. As shown in the map on the previous page, what lies in between can, if it has been subjected to the right geological processes, be capable of producing gas.

What's important is that the shale or clay contains a large quantity of organic carbon, and that it has been buried to the right depth, for long enough to “cook” that material into gas. The best shale and clay for gas production are very dark- or black-coloured – indicating they contain a high concentration of organic matter. Across much of the north of England, the Namurian[17] or Millstone Grit Series[18] of rocks contains many organic-rich shales and mudstones. This was lain down during the Carboniferous era[19] about 320 million years ago, when Britain was a shallow ocean depositing sand and limestone, and swamp areas which created the coal mined across much of the region. For example, Cuadrilla Resources near Blackpool taps the Bowland Shale[20], a strata of organic rich shale and mudstone[21] that forms the base layer of the Millstone Grit Series. The Namurian shales are also the target of Coastal Oil and Gas UK in their exploratory drilling in South Wales[22], as well as by the Australian-owned UK Methane in the Mendips[23].

Across the middle of England stretch the Liassic rocks[24]. These were laid down on the boundary between the Triassic and the Jurassic eras, around 180 to 200 million years ago. Britain was a shallow inland sea, with large amounts of clay and silt rich in organic matter being washed into it. At the base of the Lias is the Rhaetic or Penarth formation[25] – a series of shales and mudstones. Above this are the Lias clays, laid down at the beginning of the Jurassic era, which contain layers of organic-rich shale and mudstone. Later organic-rich clay strata – the Oxford[26] and Kimmeridge[27] clays – were deposited on top of the Lias. For much of the south and middle of England, the Lias forms the base of the hydrocarbon producing source rocks – and are the source for the oil and gas now being extracted around Dorset, Hampshire and Sussex, and the proposed areas for future exploration in the English Channel[28]. For much of the southern extent of the Lias, the landscape is protected by areas of outstanding natural beauty[29] (ANOBs). At the very northern extent it's covered by the North Yorkshire Moors National Park. This means that the most likely locations for the exploitation of the Liassic strata are going to be south of a line from north Oxfordshire and Northamptonshire through to Lincolnshire. It is possible that exploration might take place further south from this line, but the greater depth, and higher population density, makes working the strata more difficult.

Finally, there are small deposits of older sediments – the Tremadoc shale. The outcrop of Tremadoc shale is small, and the fact that both outcrops occur in national parks makes their exploitation less likely. However, at depth this strata underlies much of England and Wales. E.g., Coastal Oil and Gas UK highlighted these older strata as “additional gas targets” in the South Wales area[30].

The mechanics of fracking

There are two problems with flushing the gas from the low permeability rock strata that it is held within. Firstly, the nature of the rock means that flowing liquids don't easily penetrate the rock and open up the cracks. For that reason the fluid used has to contain a range of chemicals to dissolve and open-up small cracks in order to increase the amount of rock in contact with the fracking fluid. Secondly the flushing process produces sludge which can clog the cracks – especially from the other minerals flushed out from the rock. To control this, as well as injecting sand in the cracks to keep them open and allow the fluid to permeate, more chemicals are used to prevent fouling of the channels. The difficulty is that a large proportion of the hundreds of chemicals[31] that may be used to manage/facilitate the well construction and production process are not recovered – *they're lost to the surrounding environment*.

The impact of the fracking chemicals used to create and operate the wells is largely dependent upon the geology of the area in which the operation takes place. The pressures used to create fractures in the source rock are very high – up to 1,000bar or 15,000psi. If the casing of the well below the drilling platform isn't properly sealed fluid can leak back up the well bore into the near-surface strata – most commonly used to supply drinking water, and which act as the reservoir for local natural springs. Even at depth the release of fracking fluids can still give rise to longer-term contamination hazards. Where the chemicals are lighter/more buoyant than water they can rise to the surface. If there are nearby geological faults these can become conduits to bring the pollutants to the surface, or to connect the deep strata to shallower strata used to supply drinking water[32].

Whilst it is possible to engineer any well to meet certain standards, it is never possible to eliminate all risks[33] from the operations involved. That's partly due to the economic pressures of drilling and maintaining adequate inspection of the hundreds of wells required to keep gas production flowing. However, the greater problem is the unknown nature of sub-surface geology. All hydrogeological surveys[34] are largely an inference from a very few data points, and so there exists the likelihood that the characterisation of the local geology could be in error. Unknown faults or sub-surface structures might create migration pathways that could bring pollutants back towards the surface. Gas can travel more easily underground then heavier pollutants. This means that any location where methane gas has been forced into groundwater by gas fracking – which is a phenomena now demonstrated in peer-reviewed scientific papers[35] – could see other pollutants used in or mobilised by the fracking operations travelling to the surface by the same route – *although it might take years to do so*.

Although the media coverage of fracking has most commonly focussed on the contamination of groundwater, the effects of operations at the surface can be equally profound for nearby residents/land users:

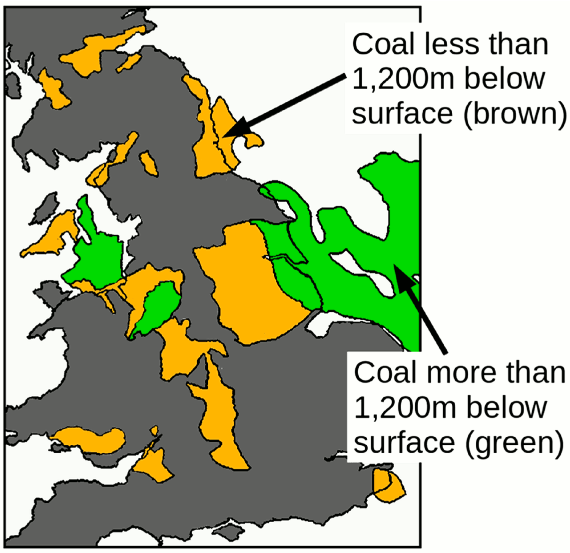
- Drilling and production require different mechanical equipment, specialist supplies and chemi-

Coalbed methane (CBM)

Methane gas has been a hazard for coal mining throughout its history. More recently, as drilling technology has developed, it's now become possible to tap the gas from deep or unused coal strata using techniques similar to gas fracking. Wells are sunk down to and along the coal seams, and then gas is extracted by de-watering and shattering the coal.

Coal, because it contains such a high level of carbon, is naturally more methane rich. However, the history of its production also has an influence on the amounts of gas. Where the coal has been subjected to far higher temperatures and pressures during its formation – such as in the South Wales coalfield – it contains a higher level of methane. Some existing coalfields in the UK[36] extract methane gas from coal workings[37] – extracting the gas as it naturally permeates through the worked areas. Using fracking techniques the gas from unworked areas, or areas considered too deep/difficult to work by conventional methods, can be extracted[38].

Coal mining in Britain isn't a recent activity. It was carried out by the Romans where coal seams outcropped at the surface[39]. From the Medieval times "sea coal"[40] was collected from coastal outcrops dislodged by natural erosion, or from shallow inland workings with access to sea ports, and transported to London. However, the total mass of coal production in Britain peaked in the mid-1920s[41], and has been in decline ever since. There is still unworked coal beneath Britain, but it's very deep. Most early mines were shallow – less then 20 metres deep. More recent mines descend a few hundred metres. Much of Britain's unworked coal lies between 500 and 600 metres to more than a kilometre deep – which is less economically viable to work.



Whilst deep coal is difficult to work with conventional techniques, it's a simple process to tap the methane gas it contains – a process called coalbed methane[42] (CBM) or coal seam gas. As with gas fracking, this is a process that been developed in the USA[43] and Australia[44] for a long time. In the UK[92], it's mostly former mining areas that are likely to see this technology used. Not just areas with a recent mining activity, but also historic areas such as Bristol and the Mendips, Kent or North Wales/Cheshire.

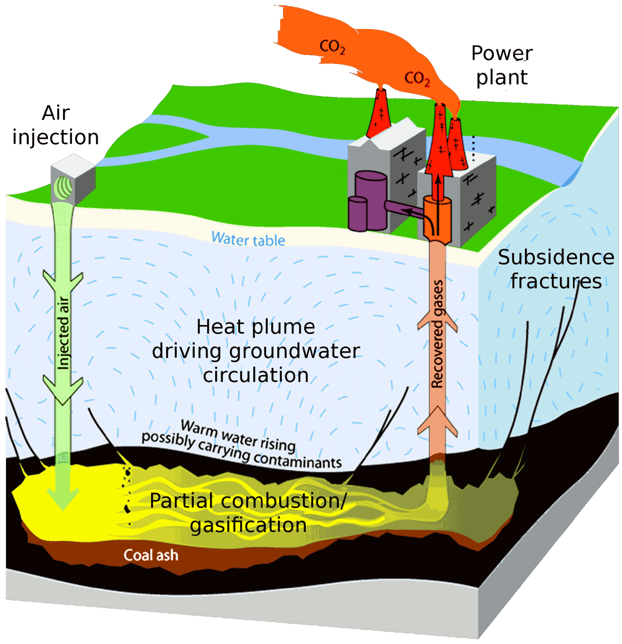
cals, large quantities of water if it can't be sourced locally, and of course staff – and all these demands create traffic/transport impacts.

- Drilling wells produce a large quantity of slurry (or 'drill mud'[45]), which can be contaminated with everything from heavy metals to the oils and chemical compounds used as lubricants for the drill. The slurry is usually allowed to settle in lagoons on-site, and may need de-watering and processing to be sent to local landfill sites if the contamination from drilling operations exceeds certain levels. Slurry lagoons require careful construction[46], and create various risks, from impacts on wildlife to groundwater and air pollution – for example, if they dry out the fine dust they contain can become airborne and affect local air quality and amenity.
- Gas production produces air pollution from the vents and safety valves of the well-head gas processing equipment[47], as well as pollutants which may evaporate from the slurry lagoons, and this can exacerbate local air pollution – especially summertime photochemical smog[48] produced from the volatile organic compounds[49] (VOCs) released from the process.
- Drilling operations and gas production and processing also cause light and noise pollution – usually 24-hours a day. During periods of well drilling and fracturing, there can also be considerable ground vibration that can (depending upon local geology) travel a great distance.
- Process water must be treated to remove contaminants, but the discharge to local watercourses may still contain a range of pollutants that are harmful to the aquatic environment. In the event of heavy rain, storm-water run-off, slurry lagoon overflows and treatment plant overflows may send untreated contaminants into local watercourses.
- As many hundreds of wells may have to be drilled to extract shale gas, and those wells will need to be regularly re-bored every few years to keep gas flowing, the exploitation of shale gas represents an ongoing and incessant level of disruption across the areas actively mined for gas. Whilst individually the effects of a single gas well may not be great compared to other industrial processes, the cumulative impact[50] of unconventional gas operations, as a source of diffuse pollution[51] of the land, water and air, may be more significant in the long-term.

Of course, all such polluting emissions are "controlled" by law, but at the moment those laws are being radically revised by the Con-Dem government. E.g., the bodies who regulate[52] the standards and controls over pollution and health, the responsibilities on local authorities on policing pollution[53], and the pollution laws[54] themselves are all being reviewed by the government to reduce "red tape" and facilitate economic growth. Therefore we have no certainty what the controls over shale gas and coal bed methane might be over the next few years.

Underground coal gasification (UCG)

Compared to fracking, underground coal gasification[55] (UCG) is definitely the "nuclear option" of unconventional gas. In effect, you set fire to the coal in-situ in order to create hydrogen and carbon monoxide-rich flammable gases (or syngas[56]) that can be burnt in a power station at the surface.



Underground gasification was proposed by Carl Wilhelm Siemens in 1868, but wasn't developed experimentally until the first half of the Twentieth Century in Soviet Russia. Today there are experimental facilities in Uzbekistan, South Africa and Australia. Underground gasification was trialled in the UK during the 1950s at near Bayton, near Cleobury Mortimer in Worcestershire, but was later abandoned – and at the time questions were raised in Parliament[57] about the impacts on communities up to 10 miles away.

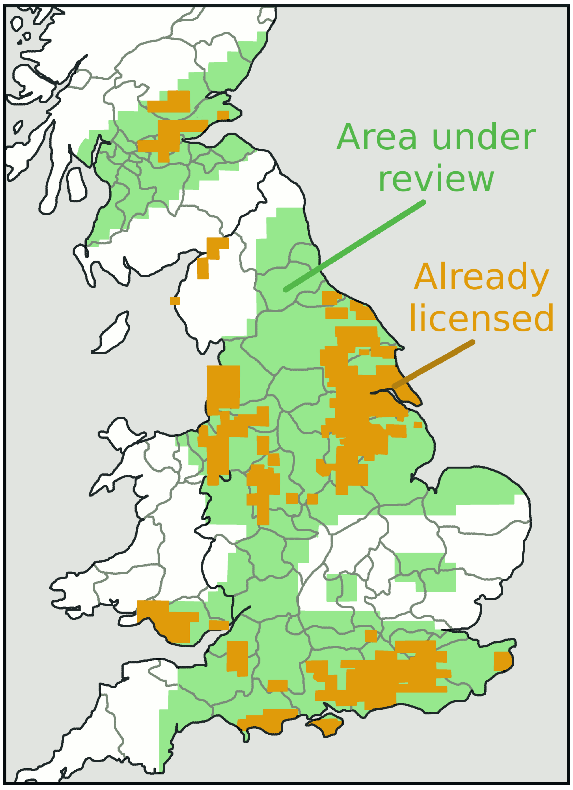
UCG works by gasifying the coal[58] – turning the carbon (and due to the high temperature, the hydrogen in the groundwater) into flammable gases. This process was widely carried out around the world from the early Nineteenth Century in town gas-works[59]. They used mined coal, heating in sealed containers, to produce coke, gas, oils and other chemical compounds (such as the phenolic wood preservative, *creosote*). In the UK, most town gas plants closed between the late 1960s to the early 1980s as the country converted to natural gas. However, due to the wide range of pollutants formed as part of the gasification process, the legacy of land contamination[60] from town gas remains.

There has been a growing industry lobby for UCG[61] in the UK for the last 3 to 4 years. The difficulty with underground gasification is that unlike traditional gasworks, UCG takes place in the "open" environment – just because it is deep underground doesn't isolate the process from the biosphere. The process creates a number of long-lived harmful pollutants. For example, Cougar energy's[62] Kingaroy UCG pilot plant in Australia was closed recently by the state government[63] because of the pollution of groundwater with benzene and other compounds.

Of the aspects of unconventional gas production usually ignored in the media debate, the most significant issue is the energy return[64] of the process. As we move to a situation where energy and material production are constrained by ecological limits, the overall efficiency and net return[65] of the economic process becomes an intrinsic part of its operation[66]. Creating high fluid pressures and pumping large volumes of liquid requires a lot of energy. What gas fracking involves, certainly in the USA, is taking energy from a cheaper/low-value source of energy – *electricity generated from coal and diesel fuel* – and creating a higher value energy source – *natural gas*. Whilst the economics of this process might appear to make sense, in terms of the energy balance it does nothing to improve the efficiency and sustainability of our energy systems; and arguably worsens the situation as other energy sources deplete[67]. The level of energy return on energy invested from gas fracking[68] certainly falls below the "sustainable" figure calculated by ecological economists[69] – *and there is no effective technofix for this problem*.

Unconventional gas in Britain

At present the Government is consulting statutory bodies and other interested parties on the *14th Onshore Oil and Gas Licensing Round*[70], and will announce the licences awarded in 2012. European Law requires that the Government carry out a strategic environmental appraisal[71] (SEA) of the policy – and as part of this the areas which are being considered for oil and gas prospecting in the next round had to be disclosed[72]:



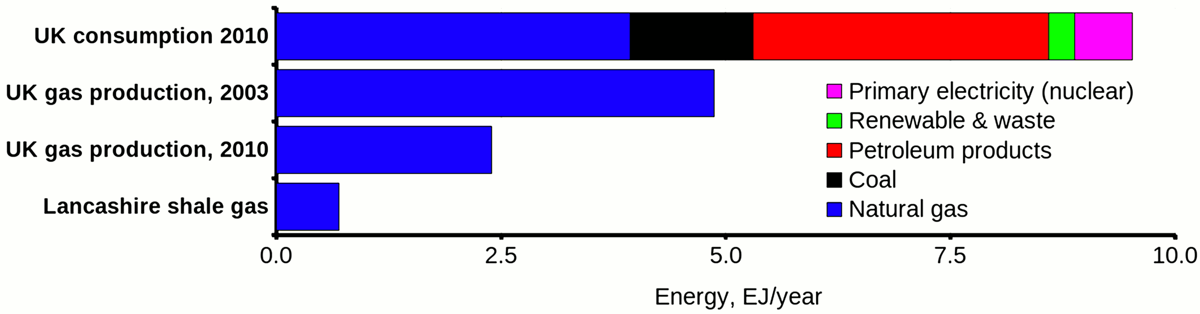
In the map above the brown areas are those already licensed under previous rounds. For example, the areas across southern England have recently been developed to produce conventional oil and gas from reservoir rocks under the Weald anticline. Likewise, the area in South Wales and the Mendips are currently the subject of planning applications for unconventional gas fracking or coalbed methane operations. The green areas are being investigated for the current licensing round.

The Government awards *Petroleum Exploration and Development Licences* (PEDLs) for 10 kilometre square blocks, based on the national grid system[73] – which is why the map looks a little 'chunky'. Under the 13th Licensing Round in 2007, just over 100 wells were planned to be developed – twice the total number projected for the 10th, 11th and 12th Rounds between 2001 and 2007. The nature of the applications has changed too. 20 applications for the 13th Round were specifically for coalbed methane. Under the 14th Round the strategic environmental appraisal assumes[74] that between 6 and 28 conventional oil/gas wells, and between 2 and 50 coalbed methane wells will be developed – and between 60 and 1,080 square kilometres of new seismic surveys will be carried out. However, that's arguably a *very low figure* given the size of the areas that could potentially be developed, and the size of the resource identified in other Government reports[75].

For the last year or so the Government has been promoting the development of "unconventional" energy resources such as shale gas – and the stated purpose of this process is to maximise, not restrict, the scale of investment in oil and gas production from the UK continental shelf[76]. It's actively encouraging the energy industry to develop unconventional gas facilities in the UK, and recent disclosures indicate that – as in the USA – this development will be carried out with little external regulation[77], and a large amount of self-certification of safety and environmental compliance. Both shale gas and coalbed methane fields in other states sink more than a hundred production wells just to develop one installation. For example, a representative of the company that reported a shale gas find near Blackpool recently stated that[78], "About 400 wells could be expected as a conservative estimate... with up to 800 in the licence area between Blackpool and Southport over the next 15 years."Either the Government's projection of the scale of future development assumes that very little unconventional gas will be produced, or they are deliberately under-estimating the number of wells in order to massage the overall level impacts for the strategic environmental appraisal process.

Shale gas and energy demand

Although Britain might be short of gas as North Sea production declines, and therefore political pressure rises to approve more extreme forms of gas production[79], fracking will not solve the problem. Fracking doesn't produce that much gas. Whilst the media recently trumpeted a "huge" shale gas discovery[78] in Lancashire, in fact it's only equivalent to a few years worth of UK annual consumption. And as production will be spread out over a long period of time, in a single year it doesn't represent a large quantity of gas. It has been noted that the company was deliberately "talking-up" the discovery because of the financial difficulties of the project's backers[80].



UK energy consumption, natural gas production and annualised Lancashire shale gas production

Also, fracking doesn't help energy prices. Fracking is an expensive way to produce gas – it requires high energy prices to make it viable. Therefore expanding the use of fracking will not cause prices to fall significantly. Fracking also exacerbates the climate problem[81] – not just because of the fossil carbon released, but also due to the inherent inefficiencies/ lower energy return of the process.

The graph above shows the scale of UK primary energy consumption, natural gas production, and the scale of annual production that might be achieved from Cuadrilla Resources reported shale gas discovery in Lancashire. In 2010, Britain's economy was supplied[82] with 9.5 exa-Joules (EJ) of primary energy[83] – consisting of 3% renewable energy and waste incineration, 7% nuclear, 14% coal, 35% petroleum products and 41% natural gas. As a result of the economic downturn and rising energy prices, energy consumption in Britain fell about 12.5% between 2005 and 2009, but in the year from 2009 to 2010 it increased once more by 3.5%.

In 2003, the year that British North Sea gas production peaked[67], Britain produced over 20% more natural gas than we consumed in 2010 – at the time we exported gas to Europe. In the seven years from 2003 to 2010 North Sea gas production halved, and production continues to decrease significantly year-on-year[79]. If we look at the reported 5.6 trillion cubic metres of gas discovered by Cuadrilla Resources, that might seem a lot but, assuming a 10% recovery rate, it's only about five years of current consumption; and spread over a 30 year production period that's around 0.67EJ/year – or less than a fifth of present annual natural gas consumption.

However, note again the decline in natural gas production from the North Sea. To make up for the loss of North Sea production between 2003 and 2010 *we need to find another four Lancashire-sized shale gas fields*. Then, to make up for the loss of North Sea production in coming years, we'll need to find another three fields over the next two decades. Taking the statements from Cuadrilla Resources in the press, together those eight fields would require up to 6,400 wells to be drilled – *far in excess of the couple of hundred analysed by DECC in their strategic environmental appraisal of the 14th Licensing Round.*

The fact, the greatest energy problem in Britain is that we consume too much... *full stop!* Developing shale gas will not allow us to escape the technical and economic problems created by the depletion of our indigenous energy resources. For example, the largest sector in the UK economy is transport, and nearly all the energy used in that sector is petroleum. Shale gas does nothing to address the global plateau in global oil production[84], and the high prices this creates. If we shifted from oil to compressed natural gas[85] in the transport sector, we simply add even more to UK natural gas demand. And of course, opting for shale gas will cause carbon emissions to rise. There is already a debate over new gas-fired power stations[86], and the need to curb development[87] in order to develop carbon capture systems[88] first (assuming, which is not proven, that is technically and economically feasible). At present the lobby in favour of shale gas has been alleged to have used 'biased' data[89] in its assessment of climate impacts.

Recent research suggests that energy production from shale gas creates more greenhouse gas emissions[90] than stated by the supporters of shale gas. Methane emissions are at least 30% more, and perhaps more than twice as great as, those from conventional gas[91]. These emissions occur when wells are hydraulically fractured, as methane escapes from fracking fluids. Thus the greenhouse gas footprint for shale gas is greater than that for conventional gas or oil when viewed on any time horizon, but particularly so over 20 years. Compared to coal, the footprint of shale gas is at least 20% greater, and perhaps more than twice as great, on the 20-year horizon and is comparable when compared over 100 years.

To sum up, shale gas is not a “solution” to our energy problems. It's a means for the oil and gas industry to generate new income streams as hydrocarbon depletion cuts into their conventional business activities. It's not a sustainable energy solution: At best it's a stop-gap measure, for two or three decades, before global energy shortages precipitate a far greater crisis; at worst, it will not address the problems of energy supply and prices in the UK, but it will contaminate land, generate toxic waste streams and exacerbate air pollution.