# Shale Gas and Oil;

## A British Perspective on Unconventional Forms of Supply.

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Clean Rivers Trust 2014.

Clean Rivers Trust is a registered charity; number 1037414.

It was initially formed in 1990/91 to clean up the River Trent and see its water quality improve; this the Trust achieved and found it was needed elsewhere to establish cleaner river environments across the UK. Since then it has been instrumental in the research and implementation of many clean-up operations; it has become particularly active in the fields of abandoned minewater pollution and the minerals industry's impacts on the aquatic environment.

Harvey Wood has written two books relating to mining and minewater management;

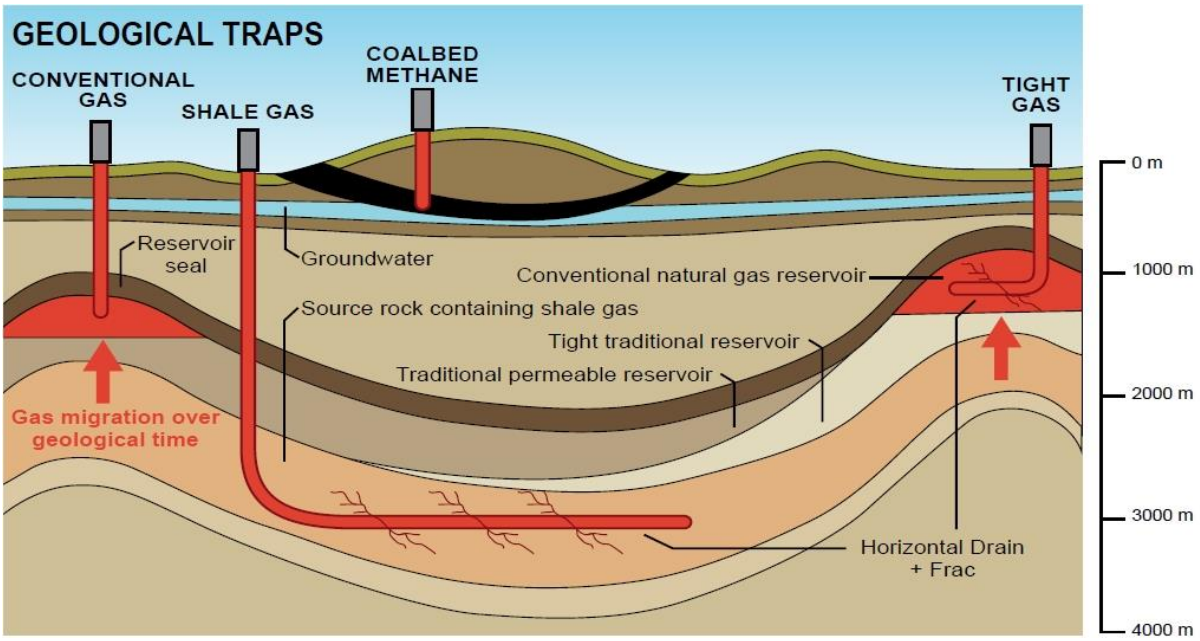
Minewater Treatment; Technology, Application and Policy, 2002 with Melany Brown and Bob Barley and Disasters and Minewater, Good Practice and Prevention. 2012. Both are published by the International Water Association Publishing of London. They are both available in print and as e-books from IWAP.

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# Introduction.

This is not written so as to be the definitive work on shale gas and oil in the United Kingdom. It is designed to be a short guide to the issues surrounding the subject including the history of both the sources of energy and the methodologies that might be employed to win it. It is not taking any stand with regard to being for or against the various issues that surround these likely resources but, hopes to give a fair and unbiased resume of the issues within the perspective of this small island.

Shale gas and oils are terms used for a widely differing group of hydrocarbon resources that are found at different horizons within the geological sequence. Shale gas and oil are known as unconventional in that they are available not just in shale rocks but can be met in sandstones and limestones within the shale sequences, these can be termed tight gas and oil. They are also unconventional fuels in that they have not been taken from rock formations that have been commercially exploited previously. Attention has turned to unconventional fuels in the last ten or so years and then primarily in the United States.

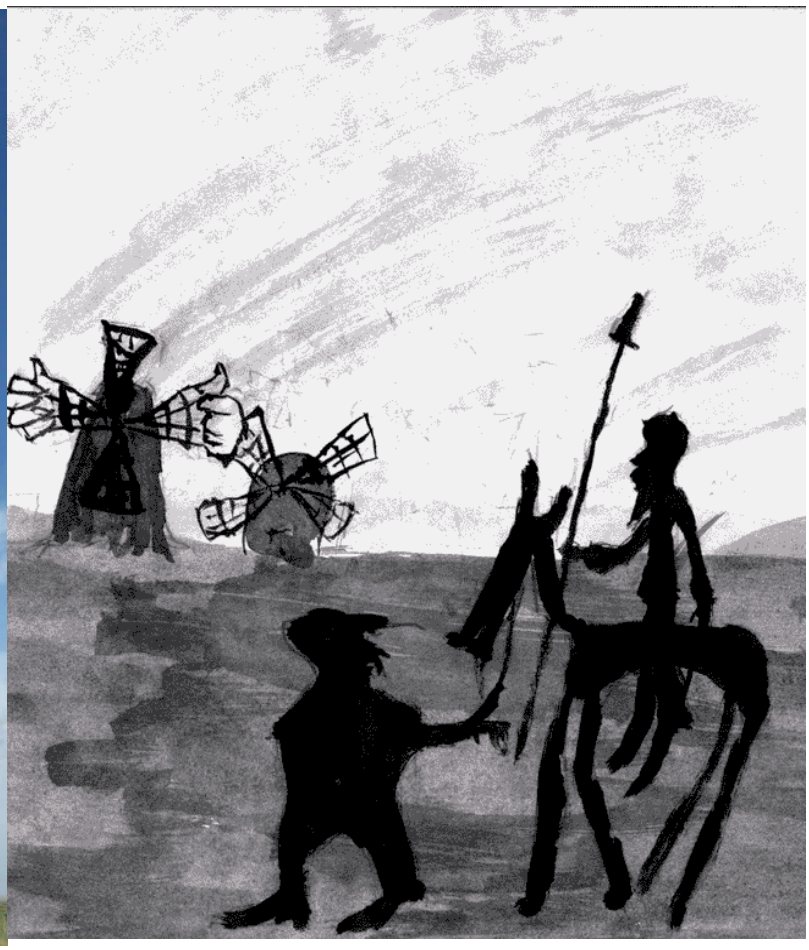



Shale gas and oil have hit the headlines over the last months; against a background of poor public knowledge and understanding of the subject and a popular scepticism of the minerals and energy industry. Publicity was given to an energy company; Cuadrilla, who had sunk one set of wells in Lancashire. At one of these boreholes the company carried out a strata fracture test which immediately was blamed for creating an earthquake.[;] T[t]his fear locally and at Westminster engaged the government which ordered Cuadrilla to stop its fracking trial. Once the company was allowed to resume its activities it ceased operations in the North West of England and moved south to carry out experimental borehole drilling in Sussex. This well publicised action does make many hardened mining engineers shake their heads in disbelief. The change in location for the company's resumption of activity to leafy commuter countryside was always going to bring much unwanted attention to their activities. It is little wonder that Cuadrilla is considered an inept organisation and by several in the media to be a stalking horse for the major mining companies waiting in the wings. This latter matter being underscored by the knowledge that a growing number of other trial drilling operations were being carried out with no publicity or protest elsewhere by other companies.

Britain is a country that has benefited from mineral wealth far greater in relation to its size than would ever have been thought possible even today. The abundance of coal, iron and copper gave the country the wherewithal to lead the way into the industrial age. It also lead the way in polluting its environment and for a century and a half the nation accepted this situation as the consequence of becoming the economic powerhouse that such mineral wealth allowed. Eventually deposits of the home sourced minerals that were needed most were eventually exhausted or production declined in favour of less costly imports from abroad. This is especially true of coal.

Britain and the British have become unused to the need to produce fuel from on top or beneath its own soil. There have been many and still are some large open cast coal operations carried out in the UK. North Sea oil and gas has been a balm to the British people, few though saw the production platforms apart from the rig workers and passing mariners. The coalfields across the land are for the most part closed today, the colliery waste heaps, the desolate areas surrounding the pits are now treed, grassed or built over. Today the energy this country uses is all but invisibly produced with gas, oil, or nuclear generation emanating from concrete boxes that are only a minor blot on the landscape. Now seeing renewable energy generation in the form of windmills brings forward Quixotic tilting at their inefficiency and complaints of detraction from the valued landscape around them. It is hard to judge but such structures may not be permanent and in 20 to 30 years of useful life they may be removed in contrast with the castles and abbeys that dot the nation's landscape, put there to dominate the population and protect the Crown, and which are now protected as heritage structures.





Shale gas or oil is a non-item on the landscape agenda; it can be extracted from sites that are unobtrusive, less than the size of a football pitch, without tall buildings and none that are

permanent. The drill rig will come, but will leave again; a momentary curiosity. The main issue that appears to be the public's concern is earthquakes moving the ground beneath their feet, the meddling with the strata that supports the world in which we daily have to survive.

Across many parts of Britain the earth is in motion. The M6 outside of Stoke on Trent is constantly moving due to coal and fire clay extraction carried out many years ago, only when the mining subsidence eventually ceases will the road and the surrounding area be still. These movements are not noticeable in 'real time' but can be monitored by time lapse cameras set up on road bridges over the carriageway which show[s] that the surface of the carriageway heaves and sways quite alarmingly. The ground also supplies earth movement events at irregular times and while once these were called tremors they are now publicized as quakes; the media being unable to resist the sensational.



Spectacularly, in America, a video has been made and widely distributed via You Tube and other web sites, showing a kitchen water tap pouring flame (such an unsettling image but also a curiosity). The sensation of a flaming forcet is an image much treasured by groups that fear the poor methodology of tapping such resources as shale gas and oil. The kitchen tap is supplied by a private water supply that is in some way linked to a source of gas which most likely emanates from old coal workings beneath the aquifer that are venting coal bed methane that has infiltrated the property's water supply well. If the aquifer itself was contaminated the problem would be widespread rather than apparently a one off. It might be too simplistic to suggest a plumbing error for the phenomenon. The cause is not explained in any of the web versions viewed so far.

The spin off from these aquatic flames is the fear that if gas can enter an aquifer so can chemicals that might be used in solution with the water utilised in fracturing the shale rock. Holding the gas or oil. The solution is used to 'slick' the gas or oil from the strata being fractured and to free up the reserve if it will not give itself up to extraction naturally. Assurances are easy to give that such an event is impossible and the mining industry has done severe damage to aquifers in the UK before. One such event took place in Kent between the 1930s and 1950s when saline water pumped to the surface as part of the dewatering of the coal seams at Tillmanstone and Snowdown Collieries, was allowed to drain away into the groundwater table. The effects of this poor water management [are] still blight the East Kent aquifer today. This consideration may be quite cogent in a country where the need to protect aquifers from pollution is little known. The exploitation of the strata beneath major aquifers has been a technique pioneered in the UK to extract coal, iron, phosphate and conventional oil. Such events as in Kent were brought about by laziness and a total lack of understanding of the surface geology of the area, which with today's knowledge is unlikely to be a factor.

In the United States water with chemical solutions is captured after use in lagoons at the surface alongside the borehole for reuse or for treatment before release into the natural environment. Such

a method of water management would not be satisfactory in the UK where the integrity of the lagoon and the risk of accidental release have been deemed by the Environment Agency in England and Wales and the Scottish Environmental Protection Agency as unacceptable. The water/chemical solution once used has to be transported to specialist storage or treatment facilities off site. All fracture waters have to be in closed storage tanks at the surface whilst awaiting reuse.





The lobbyists opposed to the development of shale gas have used fear or uncertainty within communities close to sites of drilling by stoking concerns that their communities will be blighted. This approach is all pervading especially when the use of a technology or set of technologies is unfamiliar to the public. The practice at present is to screen the sites from full view engendering mistrust whereas if presented openly and attractively there would be less to fear. A perturbed public is a commercially dangerous phenomenon. The company most publicly active in the UK, Cuadrilla, has unlocked this phenomenon well. Fears have given rise to the 'flat earth groups' amongst others who believe that the land will sink below the waves if you drill for gas too deep or set off volcanic eruptions. There are extreme, but true instances, there are 'experts' in these fields talking to the media. They may be misguided, some may be simply unhinged but people will hear them and think that 'there is no smoke without fire'.

The early sections of this short overview deal with past exploration and exploitation of shales; it also looks at early uses of rock fracturing techniques at depth. There is a need to understand the historic position of the resources now being offered up for exploitation; these are being put forward as new resources, though it is rather that the technologies needed to harvest the gas were not previously available. The availability of coal undermined any early inclination to carry forward the technical developments for the exploitation of the shales. Coal in the 1960s onwards was to be replaced by the nation's reliance on nuclear electricity and the abundance of North Sea sourced oil and gas.



# I

# Sources and History.

Mineral.

Shales are found in cross sections of strata around the globe; they are amongst the most common rock formations on earth. They are made up predominantly of mud and silt derived rocks. In Britain many are well known as being of the carboniferous series that also include the productive coal measures of the country (they are though not just from this series and arise in older and younger formations).

Naturally available shale derived oils and gas have been found within strata in the UK and indeed almost anywhere else on earth. They were formed from organic deposits that were laid down over millions of years. Conventional oils and gas deposits are the conversion of forest and dense vegetation growth over vast time scales allowing the hydrocarbons to be concentrated in fields of oil and gas such as those in the Middle East, the North Sea, Texas and the Arctic similar to the manner of the formation of coal fields. Shale gas is of similar nature to traditional gas and oil but the volumes are more widely spread through the long term laying down of organic materials in a less permeable host, including huge growths of alga, that have coalesced within the muds of the primeval oceans and seas many millions of years past. These remains have decomposed to form hydrocarbon, gas and oil, not in pockets or layers, but spread out within the pores of the rock making it part of the composition of the host strata. The nature of its deposition was within the sediments, mudstones, shales and clays that act as traps to the reserves and impede their migration into concentrated bodies.

In Britain these resources have been known of and in places locally exploited for several hundreds of years. Natural oils and gases have been recognised as seeps at outcrops of rocks or from cliff faces, burning beaches, tar springs and pits that have spewed from the earth often in quite unnerving manner, one such was the spectacular conflagration of a cliff to the east of Weymouth in the 1800s which burnt for several years and became known as the Lyme or Dorset Volcano.



Lyme Volcano 1908.

The shale gases and oils that are of interest today are in many instances derived from strata at widely varying horizons and depths, the deeper shale levels being likely to be considered the most productive strata as they are under the greatest atmospheric pressure and their resource held in place by both the depth of strata and atmospheric compression.

The methodologies of hydraulic fracture have been around for a long period of time, it is over fifty years since the technique of hydraulic fracturing was pioneered by Floyd Farris of Standard Oil in the 1940s. Halliburton applied the technology of massive fracture using higher pressures to engage the recovery of larger volumes of oil that were normally attainable by standard suck recovery. Prior to this, trials had been used in Texas and Kansas oil basins to increase flow speed and volume using liquefied nitro-glycerine. The trials were marginal in their success and proved to be more useful in the gas industry and to increase volumetric production of wells where the water bearing rock was slow to deliver supplies at a suitable flow rate.

The Eastman Kodak factory and works at Harrow on the Hill, North London developed their water flow within the Chalk aquifer by fracturing the wells and headings of the strata using TNT explosive charges to aid the liberation of water held within the rock. Similarly in many areas of the country that relied on wells driven into chalk limestone water was slow to flow from the pores of the rock and were fractured in a number of ways (lighting fires underground in the adits being one that, though dangerous to the firemen, was effective, extending headings up to several miles through the rock in search of faults or imperfections that allowed free flow of water into the mine). The use of gunpowder in the 17$^{th}$ Century was common. These adits, tunnels and headings were the equivalent of the present day use of directional drilling.

Fire was the earliest known method of fracturing rock, significant evidence has been found both in Sussex and Norfolk in the flint mines where it was used to apparently aid the extraction of major flints from the tunnel roof and walls. At Grimes Graves, Norfolk, this method has been noted as the cause of at least one fatality where the whole tunnel roof collapsed upon the miner.

Fracturing Rock Today.

Fracking as a method of encouraging conventional oil and gas wells to flow more productively has been a muddled historical method whereby mixes of chemicals, particularly surfactants, have been

placed under pressure to slick the target to flow more freely out of its reservoir. The use of directional drilling was a method which allowed the use of one site to access reservoirs of oil away from the drill site's footprint allowing an economy of not moving the site even short distances. This method was particularly attractive in the off-shore industry where moving to a new vertical drill and production platform was hugely costly.

With the development of shale gas and oil it was used to initially try to find flows of marketable volumes as shale gas which was found to be reluctant to flow economically from vertical boreholes. The rock has compressed the gas into itself. As directional drilling technology developed during the 1990s with horizontal boreholes came of age. The formulae for opening the rock pores also developed; some mixes were expensive and were in time shown to be ineffectual in many strata. The basic mixes of sand and surfactants in a water solution was effective in many instances. The use of anti-bacterial additives was found helpful to lessen the effect of algal or bacterial growth blocking the gas or oil flow paths from the host shale rock. The use of directional and horizontal drilling allowed for a far larger area of ground to be accessed enabling the rich and poorer pockets to be developed simultaneously at comparatively lower overhead cost.

The development of the technology of directional and horizontal drilling has advanced from less than 1 kilometre in the early 2000s to as far as you can reasonably desire taking into consideration strata fluctuation and the want to 'stay in seam' and not wander from the horizon that is being targeted. The techniques have developed as the need had pressed the drillers to experiment and use new assemblages of drive mechanisms. The initial drilling is carried out vertically, thus ensuring the meetings with aquifers and other hazards such as coal seams can be isolated by traditional tubing and encasement. The turning of the borehole direction is only then developed up to 90 degrees once clear of such major hazards.

# II

# Early Exploration and Exploitation.

‘ The shales found at shallow depths in Scotland were considered of economic importance from the 1850s and by comparison to those found in much of England and Wales far superior, the oil and gas content being higher and economically worthwhile.’ (Lignites, Jets, Kimmeridge Oil-Shale, Mineral Oil and Cannel Coals, Natural Gas – Part 1 England and Wales. BGS 1918.)



Five Sisters Bing,

Oil shale waste Bings after oil extraction 80 years ago.

The first use of shale oils was from the beds of the Kimmeridge shales, the outcrops along part of the Dorset Coast leak hydrocarbon residues which can be highly volatile. This phenomenon has been noted over hundreds of years with it being known as Dorset Coal or Black Rock, in some parts of the county it has been mined. The beach deposits at places such as Burning Cliff or Black Head near to Weymouth indicate by their name the occurrence of natural spontaneous combustion of the hydrocarbons present in the shale cliffs. The best view of the succession of the Kimmeridge clays and shales is to be found at Kimmeridge Beach, a popular location for geological expositions of the strata.

In many instances oil and gas from concealed shale was no more than a curiosity when it was first encountered during prospecting which was being undertaken for minerals of greater immediate financial gain, such as coal or metals, gypsum or water. In many instances throughout the 19$^{th}$ Century hydrocarbon rich shales were identified whilst boring operations were being undertaken to define the extent of the coalfields across the country.

Today the UK's geological makeup is generally well known, the major and intermediate faults, directions of throw and thickness of strata are recognised, but the local condition of strata is still at times a surprise with regard to the exact nature of the ground. This has been best recorded by the coal industry when coal seams that should have been present disappeared, often due to wash out, combustion or local faulting. These discoveries over the years, particularly local faulting has seen many coal mines close due to the excessive costs of driving through to the new horizon that could be many metres away either up, down or even just mining through to the seams continuation beyond.

# III

## The Kimmeridge Experience.

The shales and clays that outcrop on the cliffs at Kimmeridge demonstrate over two hundred feet of the formation's 900 to 1000 feet depth of strata at this point. The oil shale are particularly visible as thick black bands of Dorset Coal or Black Stone. There are several levels that have been driven into the face of the cliff which by working the mineral band incline towards the outcrops which in the nineteenth century were marked by abandoned surface workings half a mile inland. There were also shafts sunk to extract the stone by mining in some of the deeper parts of the beds two hundred yards inland from the cliff.



Kimmeridge Cliffs.

The rock was used from pre Roman times; and apparently not just as fuel which has been evidenced at several Iron Age sites of habitation but also for some decorative funerary wares that have been found interred in barrows in the area also similar finds have been made around Weymouth from the Roman period. During the 16th and 17th Centuries alum was produced in the area, as was glass with both using the Black Stone as fuel, similarly salt pans were established using the local fuel.



Kimmeridge Oil Shale Burnt on the Beach.

Today there is a single pumping engine on the top of the cliff at its northern extremity that has been extracting oil from the shales at a depth of 350 metres below the cliff since 1961. The well originally produced 350 barrels of oil per day; today it is still producing 65 barrels a day. The reason for this one oil well's longevity is that the surrounding geology is naturally fractured, thus allowing small oil reserves to migrate slowly but copiously to the base of the pumps borehole. The other boreholes sunk into the oil shales failed to secure any oil flow due in all likelihood to the strata at those points being sound.



Still Producing Oil after 50 Years.

In recent times it has been recorded, most recently by the BBC (2012) that flames have been seen on the beech coming from the rocks after their likely ignition by a lightning storm. It is also a common practice on geological fieldtrips for pieces of shale to be set alight to demonstrate their combustible properties.

# IV

## Sussex the First Time Round.

Balcombe, Sussex in the summer of 2013 became the site of protest camps and anti 'fracking' protest. The 'fear for the planet' was highlighted by large numbers of police protecting a field being used to drill an exploratory borehole surrounded with razor and barbed wire to keep protesters out. The explanation for protest was that shale gas was unnecessary and undesirable as a fossil fuel and that the issues of global warming would be better served by renewables such as tidal and wind generation. The merits of comparison might change when the government puts forward proposals for a Severn Estuary barrage though discussion of this is not within the remit of this paper or in question at the moment.




The Balcombe Protest

There have been many finds of gas and oil during exploration for other minerals and during the constant exploration for coal during the Victorian period. A borehole at Brightling, near Robertsbridge was one such trial where no coal was present but oil, gas and gypsum were found instead (1872). The oil and gas, being of little interest at the time, was not exploited though the gypsum was mined and continues to be a major resource of the area. Unusually for a non-fuel mine the gypsum mines in the area have had to be run under full safety lamp regulations due to the dangers of volatile gaseous hydrocarbon build up underground since the 1960s. It is felt that the atmospheric concerns have been brought about by fractures that have developed during the mining of the gypsum over the years of mineral extraction.

Another borehole put down at Heathfield Railway Station in 1898 to a depth of 312 feet was in search of a water supply for railway use, but instead the bore taped into an accumulation of natural gas. This discovery was utilised to light the station buildings until 1936 when town gas was installed. The bore hole was not capped off until 1963 when the station was closed.

The story of the areas second round of natural gas interest is yet to be written, but as of the present time little information is available.

# V

## The Scottish Experience and Beyond.

Scotland has seen much shale oil extracted at its shallower horizons over one hundred years ending in the middle of the 20th Century. The large hills of red cinder coloured dirt that were visible in the distance seen from the Royal Mile in Edinburgh bore testament to its extraction. Today most of the waste heaps have developed vegetation, much of which is unique to the composition of their makeup; though few people are aware today of their origin.



Waste Heaps; the 'West Lothian Alps'

The under vegetation after nearly 70 years.

The method used to gain the shale oils was by mining it as rock which passed through retorts and chemical processes, heating and distilling to recover the oils and other materials of value. The mining of oil shales was in many instances carried out alongside that of coal. The oil rich shales being often in the same geological series and alongside the economic coal seams.

The Scottish experience of winning oil from these rich strata was that the higher concentrations were gained at greater depth giving rise to the theory that at depth the hydrocarbon content did not have the ability to shed its volatile load to the atmosphere as, similarly, coal calorific values increase with depth away from the outcrops.




Scottish Oil Shale Industry.

The environmental effects of this form of exploitation of the shales was extreme; sulphur escaped to the atmosphere in huge quantities from the processing of materials causing poor air quality, acidification of rain: these impacting on the health of the population of the Scottish Midland Plain which when added to the horrendous air quality brought about by the industrial and domestic burning of coal was responsible for bringing about many acute illnesses and increased mortality in the population.

Today the Estonian people are close to being self-sufficient in gas and oil, their major supply of electricity coming from burning of shales, extracted by vast surface mining operations in the north of the country. The scale of these quarrying/opencast operations is similar to that by which lignite was won in East Germany before perestroika and the reunification of Germany when an open sea of opencast lakes was left before mining became better regulated.



Estonian Oil Shale Production.



German Lignite Production.

The atmospheric pollution both as CO2 and sulphur are both high and the government is working to lessen the county's reliance on shale into the future. The low thermal efficiently of shales makes electrical generation expensive.

# VI

## Kelham Hills and Beyond.

The Kelham Oil Field in Nottinghamshire was one of a number of confined, traditional, oil fields that were strategically important in that oil of all sorts was necessary for the war effort between 1939 and 1945, and was a source of home production which led over time to further exploration in Nottinghamshire, Lincolnshire and Yorkshire with oil being won in many parts. Small oilfields are still producing across the country one such at Wytch Farm in Dorset is locally popular and a source of pride and amusement regarding the fact that it is Europe's largest conventional on shore oil field.

The Kelham Hills Oil Field was identified, before its exploitation as a resource area, by the British Geological Survey during the early years of the 20th Century whilst carrying out their researches into national natural resources. The expertise, as with the North Sea oil developments, fell to Americans who came from the oil fields of Texas and elsewhere to enable the first production wells to be put in place.



Nodding Donkey in its Original Location at the Kelham Hills Museum © Kelham Hills Museum.

The first productive boreholes were sunk in 1939 using an imported mobile drilling rig from the United States that was copied many times over so as to meet the needs of the country at the time.

The oilfield developed during the war and then spread to the oil basin at Eakring a few miles to the north of Kelham Hills; Eakring has now developed into the location of the national centre for teaching oil production technologies. Yorkshire and Lincolnshire, both proved viable reserves of oil that were exploited as each well could be proved. The reserves are still coming online because those sites that were previously worked out traditionally are being revisited to ascertain the possibility of fracturing the strata to allow fresh reserves to be won.

The traditional oil sites are also, naturally, sites worthy of investigation for shale gas extraction. Their past use will ease grants of planning permissions although fracking may be problematic in areas where past traditional oil wells have been used as depositories for toxic liquids disposal. This practise was common in the 1980s particularly in parts of Lincolnshire.

At Kelham Hills today woodland walks lead to the isolated remains of the oilfield which is now being now treated as an historical site and treasured by conservationists of the UK's industrial and wartime past. The diversity of the flora does demonstrate that a leaky and rudimentary oil exploration and production regime has not tainted the area in the long-term.

# VII

## Water Resources and Fracturing Strata.

Fracturing strata to make water flow from its host rock has and still is a common methodology for gaining the maximum volumes of water from wells and boreholes that fail to yield the amounts of water that they are expected to produce. This is particularly true in areas of finely bedded limestone such as the chalk strata around London and elsewhere in the United Kingdom. One notable example was at the Kodak factory at Harrow on the Hill where a series of wells and adits designed to supply the large water needs of the photographic laboratories needed to use high explosive placed into the roof sides and floor of the adits. These were driven at depth from the wells to fracture the surrounding rock and allow the free drainage of water from the chalk aquifer to the wells. The local population were not warned but it was announced afterwards that the earthquake had successfully filled the wells. The explosion had only been a few hundred feet below the streets surrounding the factory and was a notable surprise to the population.

In the chalk of the North Downs of Kent many wells had to have their catchment adits extended over large distances to find fractured strata or develop desirable water volumes by explosive fracturing. The use of these adits in their own right often did not need the use of artificial aids to breaking the rock's hold on the water held within them.

The issues of winning energy and the effects on aquifers is a long and at times troubled one. From Roman times in parts of their empire coal was mined from surface deposits that eventually developed into shallow drift mines. The Forest of Dean in Gloucestershire being a good example where coal at the periphery of the coal field was mined, the overlying sandstones being an aquifer of note as well as the limestones beneath the coal seams which were also mined through to access the important iron deposits that were deposited within the composition of the rocks. The mines originally took water away from the villages' and habitations' wells and water was only available from the water resting in the mine adits; this was the case in certain parts through to the 1940s in villages such as Scowles to the west of the Forest of Dean.

A notable ruination of an aquifer took place outside Alcaniz in Spain in the middle 1990s when a trial to burn coal in situ was carried out. The project was a European Community project part funded by Spain, Belgium and Britain. The coal seam was successfully set alight, but as the coal burnt the void space that was created weakened the strata above it which was a sandstone aquifer, this leaked and then collapsed into the cavity created by the coal. The resultant heat, coal residues and water reacted together creating a high pressure build-up of phenols and steam which rebounded to the surface contaminating the surrounding surface area.

Such events do occur, even with the best made plans, and it is often the case when trying to carry out short term research and not the 'real thing'. Remarkably the project was judged both by the researchers and the independent auditors to have been a total success and the blowback an interesting glitch. The next phase of research into this concept is to take place in the UK once funders are identified. It has been decided that further development of this technology will be carried on off shore to negate pollution concerns.

The concern for aquifer protection is valid; in that poor planning and bad engineering can lead in some cases to irreparable damage to aquifers. The situation that the industry is in today has come about by making mistakes and solving problems that have arisen in the US. Even there the regulation

of oil and gas exploration and production has seen legal tightening of environmental safeguards alongside an increase in awareness in the participants with regard to safeguarding underground environments. One example is the development of specially engineered borehole/well casings that avoid any cross contamination. Such a development is equally advantageous to the drillers who do not wish to have extraneous water entering their production or exploration wells as these would generate false information and likely shorten the life of any borehole in gas production.

The UK driller's ability to satisfy both regulation and the ethical considerations of the regulators, the water companies and other interest groups across the UK are well borne out by the number of trial and conventional hydrocarbon production boreholes already developed across many of the country's major aquifers and particularly the Sherwood sandstones of the Midlands and Yorkshire.

# VIII

# The Focal Strata.

Unlike most shale oils and gas that have been accessed in the UK in the past the strata now in question are often far deeper, the two to three thousand metre levels being the depths most often targeted. In many instances the depth is far greater and certainly can be beyond any traditional gas and oil deposits which are generally to be found as accumulation lakes resting above the upper layers of shale sedimentary strata.

In the UK the British Geological Survey on behalf of Department for Energy and Climate Change (DECC) have carried out an assessment of the shale group known as the Bowland Hodder series of shales in the central northern region of England and north Midlands. These shales are generally found beneath the carboniferous and millstone grit series of rocks. The depths are in the region of four to twelve thousand metres, though in some areas due to the earth's uneven strata coverage, contortions of folding, slippage and other changes have resulted in some of the formations being found to outcrop and in other[s] areas their depths can be below twenty thousand metres ordnance datum.

The technologies of fracturing are relatively new (such work on shale gas only became active in the early years of the 21st Century) with their initial development being in America where they is a rapidly developing science. Over the last decade and a half the depth of shales has been viewed as of critical importance and, dependent on the gas volume, there are apparent thresholds for not going below some depths though these decisions are made on a site by site basis.

As has been said the shales most productive and therefore attractive to exploitation are those at considerable depth. This may not be the case in circumstances where the shales are not outcropping but lifted by faulting and surface layer erosion. In such cases the productive shales can be isolated from atmospheric interference but only with modest overlying strata of minimal depth. Such shale strata has been found to fracture even to surface when pressures have been exerted from within the strata pores over protracted time frames. The length of time being far in excess of those used normally within the shale gas and oil industry and with many times the volumes of water that economic fracking techniques would allow for. Such is nature that it has breaking points that are far more resilient than might often be anticipated.

# IX

# Issues.

**Fracture Liquids.**

**Non Chemical Additives.**

The main additive to the fracture water is sand of varying grain size. Its inclusion is to ensure that during the process of fracturing the pores within the rock that are opened up cannot comfortably close again. Without this fine mineral mix being injected under pressure the fracture would not be held open to allow the slicking chemicals to work.

**Chemical Additives.**

The US Congress reported in 2011 that there were over 600 hydraulic fracturing chemical additives in use in the United States, many of which were recognised as carcinogenic, many were also on the Environment Protection Agency's prescribed list of chemicals that are not to be found in drinking waters. Congress during interrogation of witnesses from within the fracturing and extractive industries found that many such solutions were proprietary brands and were 'trade sensitive' and confidential and only known to the company manufacturing it, thus many companies carrying out fracturing of the strata had little idea of the chemicals involved. Such an admission was considered concerning by the politicians on the committee.

There is an understandable need for chemicals. The use of water alone has been shown by trials in the US to be unsatisfactory in that the borehole and the fractured surfaces become rapidly contaminated with alga or bacteria which have the propensity to armour the strata, slowing down the feed of gas and oil and can lead to the feeds stopping altogether. Such algal or bacterial damage is swift due to the progressively warmer conditions the deeper the strata is from the surface.

The sand used with the hydraulic fluid to maintain the fractures within the rock's open pore structure needs to be kept in suspension and not allowed to coagulate which, in a water only matrix would happen quite rapidly. The resultant muds would not be fine enough to carry out their operational functions.

Certain of the chemicals, particularly surfactants allow for the gas or oil to leave the strata by reducing surface tension of the water/rock interface so allowing the gas and oil to flow more freely. This set of mechanisms allows for a greater percentage of the target to be recovered than otherwise might be achieved, thus increasing the return economically and reducing the environmental impact of each site pro rata.

The Halliburton web site states that they use three particular formulations; Pennsylvania Water Frac, Pennsylvania Hybrid Frac and North-eastern Foam Frac. They state that due to varying geological makeup of individual boreholes the fluids will vary by location. The site states that the formulations vary over time due to the ongoing developments of the technology and it is hoped that more information with regard to fracture fluids composition will be made available in time.

Since 2011 some websites in the US have reported the chemical additions to frac water where they are available, but in others the generic or trade name is all that can be discovered until the

manufacturers feel confident of international regulation for the protection of their product formulae.

The chemicals used are, as already stated, a cocktail that contains many undesirable constituents but it is a fact that the broth is diluted many thousands of times by the water that is the primary fracture medium. This water/chemical mix is likely to be much changed after use when it has been in contact with the subterranean strata; the actual composition of this returning aqueous waste might vary at each well site. Such variation will be brought about by the strata mineralogy which in each case will vary {most noticeably from region to region}.

**Return Water or Waste Water.**

The return or waste water that is brought back to the surface after fracturing has been carried out is potentially a different cocktail to that used as the fracture fluid that went down the borehole initially. Each used water might be if not totally altered have additions to and subtractions from their formulae. The shales accessed in each borehole will have variable constituents of metals particularly; this might be influenced by the makeup of the shales and the strata below and above the target layer. This will be most pronounced in the more metalliferous areas of the country and their constituent mobility.

The fracture water may be found to alter its chemistry by the alternative occurrence of additives adhering to elements within the fractured strata or combining chemically with metals or similar reactions so removing them from solution.

The other issue that has been put forward by those that oppose the practice of fracture technology is the concern that the water will contain levels of natural radiation that are above those normally encountered in the day to day environment and their discharge to water bodies from licensed treatment facilities is at present unregulated. This is not the case in several water treatment facilities that are operating today where low level radiation is monitored from several industries and medical facilities with some consents set with acceptable levels at discharge which are already enforced by the Environment Agency and Scottish Environment Protection Agency.

The concern that elevated radiation levels in water used in shale drilling exploration had entered the Manchester Ship Canal became an issue in late 2013. The Environment Agency placed an embargo on such discharges until further guidance had been developed or received from the government. The discharge was not directly from a drilling site but from a wastewater treatment facility owned and operated by United Utilities. It is uncertain as to the discharge situation across the UK at present but it is likely that other sewage treatment works are being utilised for the disposal of similar waste to different water bodies.

**Water Availability.**

Water is a major resource within the shale gas and oil industry that at this early stage of exploration has not had direct public review. The need for millions of gallons of fracture water per frack without the opportunity to lagoon the return water for a second or third attempt where needed is a problem, in many ways, harder to deal with than negative publicity and earth tremors. The need to access and store in secure holding facilities on sites around the country the various preferred solutions is a major challenge to be tackled.

The need for recycling water for dedicated fracture work would be an ideal world involve a water treatment facility operating in tandem.

The use of recycled water has much to recommend it in this instance, particular attention has to be given to decontamination of the virgin flow back from the initial fracture run as it cannot be reused with unknown contaminants. These contaminants will in all likelihood have present, in the 60% return supply water, petroleum hydrocarbons, oil and grease, diesel related organic compounds, BTEX, polyacrylamides, transition metals such as strontium and barium. The company KTI can treat for reuse 100,000 gallons per day from a mobile unit or 500,000 gallons via a fixed site installation.

It is best to look at some of the detail of the water use by the technology in the major area of shale gas and oil in the United States. The Marcellus Shale Field is the premier gas and oil production area in the US and has been in production since 2000. It covers a large area including lands in New York State, Pennsylvania and West Virginia, at the height of fracing activity which was between 2005 and 2007. When the technology was bedding itself in it was using approximately 5 million US gallons of water per well. This is a large amount of resource per well, and the annual water take was in the region of 650 million gallons of water per annum, representing the development of 130 wells annually. This water volume is remarkable in that it represents less than 1% of water used across the whole area annually.

Since 2010 several of the larger exploration and development companies have taken to recycling the fracture waters rather than taking the various disposal routes for each well; companies such as Denver Energy are taking the model to other fields such as Barnett Shale in Texas.

**Water Treatment.**

The development of fracture fluids to aid hydraulic fracturing of the shale strata to give up its gas and oil gives rise to concerns as to the end of life rout for the millions of gallons of fluids that will in time arrive in the UK waste stream, the initial appraisal of such aqueous waste being that little is of commercial value for recycling as the additions though small may be highly polluting, especially once re-concentrated.

At the well head the storage of waste liquors will not be by using open lagoons due to the possible damage an escape to the natural environment, as well as the possible damage to wildlife that might come into contact with it. The possibility of constructed expanding tanks with integral bunding or rubber pillow type holding facilities can be envisaged that could once emptied be moved from site to site.

Discussions with several of the water utilities have demonstrated that the companies have a horror of receiving unknown chemical cocktails, particularly as they will be heavily diluted on arrival, also it might be difficult to assess individual load [s ] effects on main plant treatment processes that are in place at major water treatment and recycling facilities. Such ‘housekeeping’ arrangements are little discussed at the present time.

Certain operators are offering on site treatments for the waste water including Halliburton have set up ‘CleanWave®’ a method of electronically coagulating the majority of the pollutants and leaving a reusable water supply. The methodology is not dissimilar to treatments for minewater from abandoned mine workings that have been developed over the last 15 years. In the case of minewater the unknown elements of volume and constituent volumes made such operations unsuitable but in a known set of parameters the technology would be adequate for the purpose and satisfactory results should be expected.

Other companies have designed alternative methods;

Ecologix have designed a mobile three trailer treatment scheme using chemical dosing, dissolved air flotation and physical separation of solids. The plant is capable of treating 900 gallons per minute.

Siemens are offering onsite treatment using 'FracTreat' ™ which uses flotation, precipitation and clarification; the plant has a throughput of around 6000 gallons per minute. The same company offers a small continuous treatment and dosing in line addition to a fracture and production well assembly.

All treatment methodologies have come out of research and development carried out in the US, but the technologies are now being put together in the UK for the benefit of the pan-European market which is present in its infancy.

**Earthquakes.**

The issues of seismic activity being triggered by fracturing shales is not considered the norm. In the US where this issue has been studied in detail it is acknowledged that the fracturing event can be seen by seismographs as an earth movement as is the case with many sonic or percussive surveys and prospecting methods. There have been trace or echo earth movements reported along fault lines in some geological formations, but none have been classifiable as earthquakes though they can be justifiably seen as tremors. There is a natural antipathy and fear of earthquakes in the west of the US and exploration in California is limited to areas at a distance from the San Andreas Fault.



The triggering of an earthquake in an area of low seismic activity, as in the UK is considered unlikely by most mining geologists though there are some who have gained notoriety by taking the opposing view. Earth movements are a particular highlight for the media, the most recent occurrence (February 2014) was put forward to being caused by the regional flooding or if not that a secret fracking trial was taking place. One of the red top newspapers asked if Cuadrilla were to blame.

The one fracture trial that was carried out in North West England in 2011 was said to have triggered an earthquake. British Geological Survey gave credence to the belief by saying that the trial may have been the source of the event; this stance has now altered. The seismic event was not a true earthquake and in future trials less fracking fluid should be used. The feeling of the industry is that trials have to be carried out in-situ and that [as] there is no other way of finding the correct volumes needed to activate gas flow from the strata.

The main study on all moderate and large seismic events induced by the prospecting and extraction of hydrocarbons around the world published in 2010 showed 70 events. This was related to all oil and gas fields and does not focus exclusively on shale gas and oil. The paper notes that the term 'induced' is highly subjective; the fact that some of the events are thought to be linked to the processes of inducing flow of hydrocarbons is equally likely to be the result of extraction by conventional wells removing their target. This is a form of subsidence within the strata that is less likely to be brought about in many forms of fracking where the rock pores are held apart by the structure of the sands injected as part of the fluid pressure process.

The paper lists the fields that have demonstrated seismic conductivity with regard to extraction with the majority being from conventional oil and gas fields.

| Hydrocarbon field | Country | Potential cause |
|---|---|---|
| Snipe Lake | Alberta, Canada | |
| Strachan | Alberta, Canada | extraction |
| Gobles | Appalachian, Canada | injection |
| Eagle&Eagle West | British Columbia, Canada | extraction |
| Shengli | Shandong Province, China | injection |
| Dan | North Sea, Denmark | extraction |
| Lacq | Aquitaine, France | extraction |
| Meillon | Aquitaine, France | extraction ? |
| Söhlingen / Rotenburg | Rotliegendes, Germany | |
| Caviaga | Po Valley, Italy | |
| Umm Gudair | Kuwait | burning |
| Burgan | Kuwait | burning |
| Groningen | Rotliegendes, Netherlands | extraction/fault reactivation |
| Roswinkel | Rotliegendes, Netherlands | extraction/fault reactivation |
| Bergermeer | Rotliegendes, Netherlands | extraction/fault reactivation |
| Eleveld | Rotliegendes, Netherlands | extraction/fault reactivation |
| Bergen | Rotliegendes, Netherlands | extraction/fault reactivation |
| Annerveen | Rotliegendes, Netherlands | extraction/fault reactivation |
| Appelscha | Rotliegendes, Netherlands | extraction/fault reactivation |
| Emmen | Rotliegendes, Netherlands | extraction/fault reactivation |
| Dalen | Rotliegendes, Netherlands | extraction/fault reactivation |
| Roden | Rotliegendes, Netherlands | extraction/fault reactivation |
| VriesNoord | Rotliegendes, Netherlands | extraction/fault reactivation |
| Ureterp | Rotliegendes, Netherlands | extraction/fault reactivation |
| Emmen-Nw. A'Dam | Rotliegendes, Netherlands | extraction/fault reactivation |
| Schoonebeek | Rotliegendes, Netherlands | extraction/fault reactivation |
| VriesCentraal | Rotliegendes, Netherlands | extraction/fault reactivation |
| Coevorden | Rotliegendes, Netherlands | extraction/fault reactivation |
| Ekofisk | North Sea, Norway | extraction |
| Valhall | North Sea, Norway | extraction |
| Visund | North Sea, Norway | various |

| Hydrocarbon field | Country | Potential cause |
|---|---|---|
| Shuaiba | Oman | |
| Romashkino | Volga-Ural, Russia | injection |
| Novo-Elkhovskoye | Volga-Ural, Russia | |
| Starogroznenskoye | Russia | |
| Barsa-Gelmes-Vishka | Russia | |
| Gudermes | North Caucasus, Russia | |
| Grozny | Tchetchuy | |
| Big Escambia Creek | Alabama, USA | extraction ? |
| Little Rock | Alabama, USA | extraction ? |
| Sizemore Creek | Alabama, USA | extraction ? |
| Coalinga | California, USA | extraction/fault reactivation/ isostasy |
| Kettleman | California, USA | extraction/fault reactivation/ isostasy |
| Montebello | California, USA | extraction/fault reactivation/ isostasy |
| Orcutt | California, USA | injection |
| Wilmington | California, USA | extraction |
| Rangely | Colorado, USA | injection |
| South Eugene Island | Louisiana, USA | injection |
| Hunt | Mississippi, USA | injection ? |
| Sleepy Hollow | Nebraska, USA | injection ? |
| Catoosa District | Oklahoma, USA | injection ? |
| Love County | Oklahoma, USA | injection ? |
| East Durant | Oklahoma, USA | injection ? |
| Gobles | Ontario, USA | injection |
| Apollo-Hendrick | Texas, USA | injection ? |
| Blue Ridge | Texas, USA | extraction/subsidence |
| Clinton | Texas, USA | extraction/subsidence |
| Cogdell Canyon Reef | Texas, USA | injection ? |
| Fashing | Texas, USA | extraction/fault reactivation |
| Goose Creek | Texas, USA | extraction/subsidence |
| Imogene | Texas, USA | extraction/fault reactivation |
| Kermit | Texas, USA | injection |
| Keystone | Texas, USA | |
| Mykawa | Texas, USA | extraction/subsidence |
| South-Houston | Texas, USA | extraction/subsidence |
| War-Wink | Texas, USA | extraction ? |
| Webster | Texas, USA | extraction/subsidence |
| Dollarhide | Texas/New Mexico, USA | injection ? |
| Gazli | Uzbekistan | erratic production/fault reactivation ? |
| Costa Oriental | Lake Maracaibo, Venezuela | extraction/subsidence |

*Table 1. Compilation of 70 reported cases of induced seismicity in hydrocarbon fields. Please refer to Suckale, 2009, for details and additional references.*

**Ownership of Mineral Rights.**

In the UK the ownership of minerals such as sand gravel, clay and similar materials that can be won via quarrying or open pit access are the property of the holder of the rights to them. This might be the land freeholder or it might be an outsider body; ownership of the right to the minerals can be and often is divorced from the surface ownership. The beliefs that land and mineral ownership are vested in a single body that has rights of ownership to that which lies below; theoretically to the earth's core, as in a vast pie chart are contentious.

The simple fact of ownership of land does not give one rights to untold wealth. This is most noticeable if silver or gold are present (precious metals); if so the monarch is the owner and can either lease rights to those who will extract them or carry out the mining in their own name. In the past this has led to controversy as other metals that the state has needed supply of, such as copper may be found alongside trace precious metals giving the state rights to exhume the metal body to gain the most useful waste for its own use (Elizabeth I possessed gold mines producing copper and tin for the supply of cannon to her navy).

The state has always been involved in non-aggregate mineral extraction either by granting royal licences or general permissions to mine. This being particularly relevant in areas directly under royal stewardship; areas such as the Forest of Dean are divided into gales, areas that can be leased to a Free Miner for the purpose of iron or coal extraction. Similar arrangements are in place for the other Royal Forests including Charnwood, New Forest, Mendip, Dartmoor; the list goes on.

The minerals of energy are under the state's stewardship, the legislation to bring what was originally something of a free for all was firmed up as its prerogative during World War I. This control was developed further during the Second War and was brought wholly under government control by the vesting of the coal industry into nationalisation in 1946.

**Ownership of Rights of Access.**

The issues of access to minerals have been a periodic and at times nasty area, it may be contentious, petty, spiteful or clever. The use of ransom strips has been used by large and small land owners to delay opencast coal projects. The desired route for accessing a prospective mine can and has in the past made fools of the mining companies' directors and made the owners fiscally extremely satisfied.

Several large estates including that of the Cowdrey family in Sussex have stated that they would need compensation for the despoliation of their property if their environment is to be damaged by directional/horizontal drilling taking place beneath their properties. Their requesting compensation has been linked to being against the development of shale gas and oil; they state that there will be no exploration on their lands. At the same time their agents are aware that there are profits beneath the chalks and gaults of their estates.



Shale boreholes are minor rock removals and even with the fracturing of the strata there is little chance of any visual or measurable change on the surface. At the likely depths of operation the borehole will cause not even a millimetre of subsidence and will not affect any known aquifers that the borehole might pass through.

Historically in deep coalmines the removal of coal from seams required the driving of roadways underground to access faces and to draw away cut mineral; the similarity to shale and the access to gas and oil is remarkable and at depths that are below those mined for coal there appears to be little justification of claiming 'trespass'.

The UK Government are even so considering the urgent enactment of an Act of Parliament to allow directional boring and fracture to take place. This piece of legislation will bypass the expensive use of legal opinion and underscore that HMG wish to develop this energy source as swiftly as possible. The alternative is to allow the judicial system to decide the future of the industry; this would inevitably lead to a series of contentious court cases that would develop into individual inquiries as there could be individual and unique issues for each site that might be considered for exploration or development.

The easing of legal tribulations for drilling will assist the exploitation of the resources and the placement of production wells will be expedited though there will inevitably be some residual resentment locally and nationally.

**Trespass.**




© David Sheppard Estate.

In England the term trespass has been put forward as a method of disallowing access to gas at depths of possibly miles below the surface of a property. As already noted above the UK Government is considering legislation to bar such a move on behalf of those who are opposed to the extraction of shale gas and oil; the term in reality is that of 'criminal trespass' for there is no actionable issue as Trespass in English law. Damage needs to be shown to have been done. Subsidence or other permanent damage would need to be proven in a court of law for the act to be shown to have been committed.

In the case of an act of trespass on land owned by an individual or combination such as a company one may only request an individual on private land to leave the property and by the shortest route that will not put them in jeopardy or danger. To bring about a court action there needs to be shown

that the trespass was criminal where some damage or harm that has been brought about to the property. This damage would need to be demonstrable both in fact and by specific action.

Trespass is a law steeped in history and has a notorious past where estate owners through time have behaved callously in protection of their rights to their land, often to the detriment of others freedom and wellbeing. They used mantraps in the 18th and 19th century to catch those entering property and most famously the confrontation at Kinder Scout in Derbyshire in 1932 denied ramblers access to walk across the High Moor of Derbyshire. Interestingly the mass trespass did not see those imprisoned prosecuted under trespass laws but for breaches of the King's peace.

**Stalking Horses.**

BP, Chevron, Halliburton, Royal Dutch Shell, Exon Mobil and the other international oil and gas production companies see the development of British shale gas reserves as a logical progression from their involvements in the shale gas and oil projects in the United States and Canada, and a continuation of involvement in Europe with operations in the North Sea that are winding down, although much more slowly than was originally envisaged.

The industry, the mining colleges, the institutions of state were all aware that shale gas and oil was present throughout the bedrock of much of Great Britain. The billions of tons of coal that have been mined and the research carried out to assess the resource at the height of the coal mining industry: that which would be left unmined, led to an understanding of the likely shale resource and to some great degree the nature of its hydrocarbon content.

The research into strategic reserves of all fuel and minerals in the country which was carried out by the British Geological Survey, on behalf of the government ministries, published between 1902 and 1920 demonstrated that there was a bank of shale supplies at that time but no official could excite themselves over much about the fact because the technologies which were available available were incapable of teasing gas and oil from the strata except for the shallower resources, particularly the oil shales of the Lothian region of Scotland. Politically the knowledge of shale gas that has been published recently (2013) has been engineered so as to assure the media 'play the public' so the mood for home grown less expensive energy ('as long as it is not in my back yard') is strong and with news of impending energy price hikes a ready supply with less distance to travel might encourage the producers to lessen the costs of the power generating and supply companies. It might have been simpler under the old Central Electricity Generating Board who could access their own resources without fuss but those days have passed.

The industry is fully aware of the growing alliance that includes the climate change, anti-capitalist, environmental activist, flat earth and many other groups that would rise up as one and stand full square against the development of shale gas and oil. The industry gave them the verbal tools, frack, contamination, aquifer, all are easy to string together and in the correct hands the anti-lobby can seriously frighten the public at large. We all know that Cuadrilla has a license to trial yet at the same time other exploration companies are using their own permissions to put down boreholes elsewhere without fuss.

As a public relations operation Cuadrilla has done a remarkable job in demonstrating the spirit of a sheep on its way to slaughter. It is uncommunicative with 'no comments' when it can and should be showing some pride in its engineering capability. The company is led by a wealthy and well regarded ex-chairman of a powerful and well run multinational energy company who ably plays his part in what some might call the Great Game.

**Unconventional Gases, an Issue of Clarity.**

There are several unconventionally sourced feeds of natural gas finding their way into the market place emanate from traditional energy zones such as coal-bed methane extracted from old coal workings. One such source of methane is the main income stream for Harworth Colliery in Nottinghamshire, a part of the rump of UK Coal that is at present under care and maintenance but might reopen if the political and economic situation for coal improves.

Cuadrilla has set up a one megawatt power plant in north western England which is the company's sole production and income generating unit. This operation takes coal-bed methane from an abandoned mine and is passed through their onsite generating unit, the power being sold to the national grid.

There are several other coal-bed based energy companies working across the UK; Celtic and Alkane being the most successful to date.

Coal bed methane, methane drainage and other coal seam derived resources are being targeted as part of the same debate as shale gas and oil. The anti-fracture groups are naturally concerned as to the continued role of fossil fuel and especially coal derived energy sources. The presence of methane from abandoned mines is releasing a resource which is also a pollutant that is adept at causing unwanted appearances by naturally seeping away from abandoned deep workings. Notably it was necessary to relocate of the village of Arkwright in the 1990s. The management and use of such gases for the generation of electricity or as an addition to the gas grid supply is preferable to the unexpected appearance of methane in situations that might be a hazard to life.

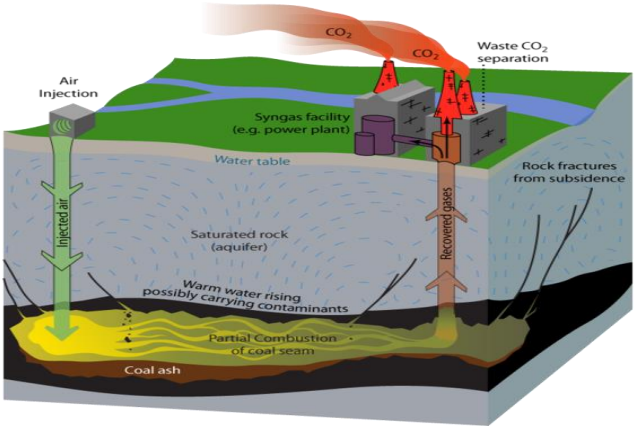
As with shale and tight gas installations coal-bed methane exploration and production units have small footprints, their outputs are also generally small but when put in a collective aggregated form become more substantial. Their function also has some positive impact on the monitoring of the water environment within the abandoned mine workings which allows for the preparation for possible pollution control. Measures can to be planned and placed to protect threatened major aquifers and surface waters in the UK.

The use of coal seam derived gas drainage is not a recent activity and is well illustrated by the utilisation of methane drained in advance of coal cutting at Silverdale Mine in Staffordshire which closed in 1999. Prior to cessation of coal production Johnson's tile works fired their kilns using the gas for many years. When the mine closed the loss of this source of energy was a financial blow for the company and was instrumental in its future problems.

**In-Seam Gasification.**

One use of coal that has been put alongside shale gas exploitation is the burning of coal within seam. Although this is a quite different and more 'industrial' process, it does require similar directional/horizontal borehole technology to shale gas extraction. The process has been carried out in Russia particularly, and has generated a large amount of power since the 1940s. There are reservations as to its operational credibility in Europe.

The basic methodology of winning power by this method is to sink a borehole down to the target coal seam and once reached change to horizontal boring for a distance to reach another vertical borehole. At one end of the borehole is placed a generator unit and at the other an ignition and air supply injection system to encourage combustion.




The coal is set alight and fanned to develop an even combustion across the coal face which can then be developed or retarded to ensure the correct burn within the coal seam. The gas (methane) and hot air travel along the borehole to discharge through the generation unit that is able to develop energy from the heat as well as the gas being driven off from the burning coalface.

The trialling of this technology in Western Europe has had a long and chequered past, from the 1940s in Derbyshire to 1990s in Spain; none of the schemes went according to plan. The 1940s experiment was carried out by the then newly created National Coal Board. Initially the concern was for the setting alight of the coal face, though this proved to be much easier to achieve than the extinguishing of the fire. To achieve this the ground above the burning Strata had to be removed and the burning coalface removed manually. In Alcaniz, Spain the target coal seam was situated directly below an aquifer so as the coal burned and the aquifer strata collapsed into the resultant void causing the water to wash out the fire but at the same time sending a volume of phenolic liquor under pressure to the generator unit bursting out into the wider environment and creating a pollution event.

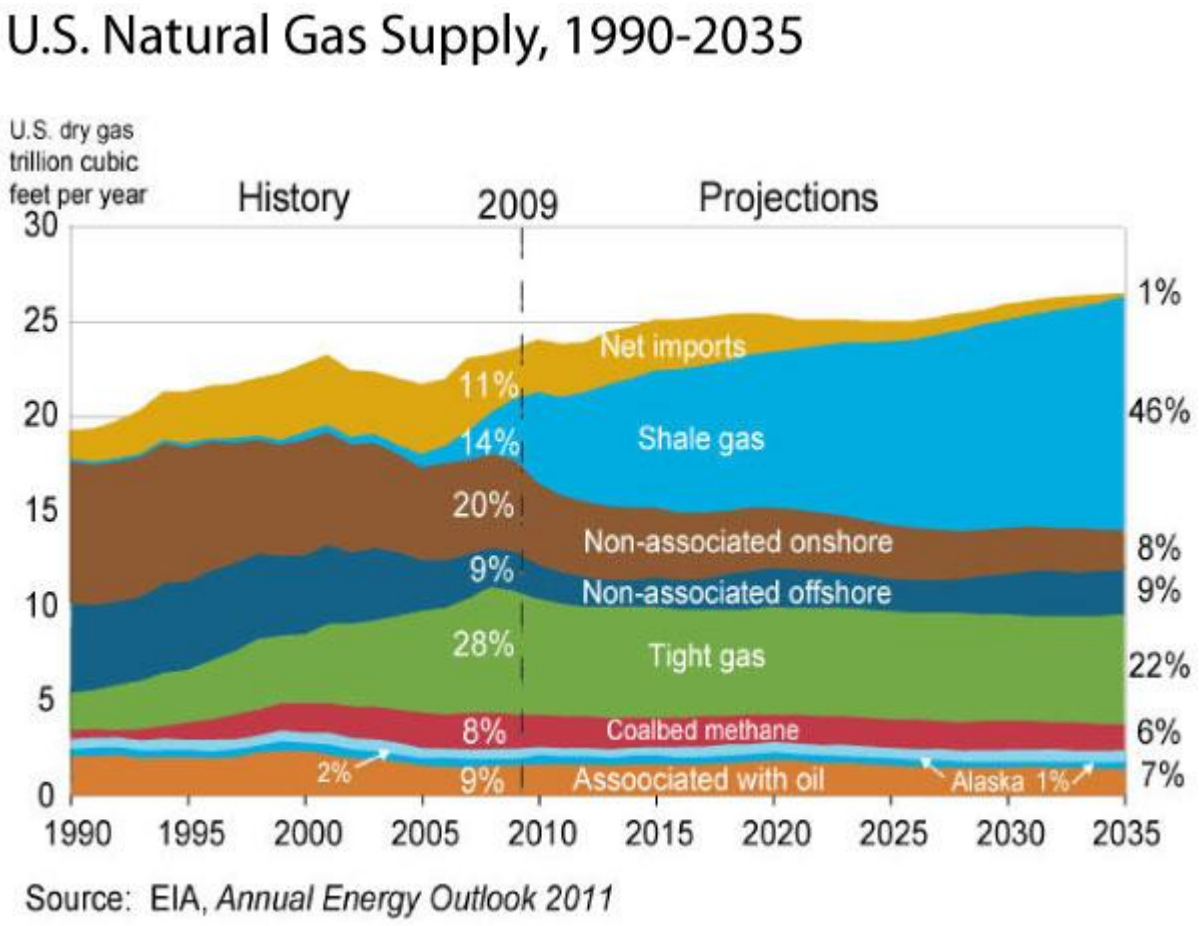
The next stage of the planned development of this technology is earmarked to be carried out either in the Firth of Forth or off the coast of Northumberland. It is not a surprise that the private investment has yet to be committed.

X

# US Energy Perspective.

The United States of America are reliant on natural gas as their crossover fuel. In the late 1980s oil production onshore declined to the point that North America, particularly the US, were beginning to import large volumes of their supplies. At that time it was the increasing importation of Saudi Arabian oil that concerned successive governments, the fear that that resource could decline before other resources were secure, alongside the machinations of the OPEC nations and their continuing pricing strategies. By the early 2000s the US was wanting to rid the nation of coal fired power generation due to the national desire to come in line with international climate change protocols. This required that natural gas could plug the gap in power generation between coal and the coming online of sufficient renewable. The lack of home produced natural gas was a concern that led to proposals to start importing the resource from Qatar and even Russia as the importation of Mexican and Canadian gas was slowing down.

There had been twenty years of small scale activity in the US looking for economic oil and gas resources from other geological formations than those that had been traditionally tapped. There had been many areas particularly shales that had been noted during exploration for traditional resources as having the apparent petrochemical assay but from which it was impossible to extract.



The blind faith in these rocks being worth exploring took years of trials both in drilling and in learning that some rocks did not shed their gas to vertical boreholes but when the rock was entered at an angle or horizontally the flow was spectacular. Some rocks still needed to be encouraged to bleed, so fracturing was developed, different techniques had to be developed, sand, water, polymers and chemicals. Such activities were not cheap with several companies falling by the wayside due to lack of funds. Borehole prices were between $3 million to $10 million from set up to production if the well was not dry.

The EIA chart of US natural gas supply above, demonstrates their thinking of 2011 had been considered by energy analysts as an optimistic projection, this has now been overtaken by events and the country is now self-sufficient in gas and is exporting some of its excess as LNG allowing a stability of prices to the home market.

The scale of North American shale gas and oil exploration is massive and is carried out across both semi urban and wilderness areas of the continent. The issues arising are [both] magnified by the scale of the deposits and diminished by the populations' acceptance of need for fuel at acceptable prices. The US population particularly became aware of rapid rises in natural gas prices in the late 1990s which fuelled the economic imperative to secure long-term energy security to the nation. Across the states power-outs had been a developing issue which only received international attention when they occurred in major cities and conurbations. Alongside the boom in technological developments in directional drilling and gas slicking there were plans being put in place to import natural gas from the Middle East that led to huge terminal facilities being built for the purpose of importation. These terminal developments have proved unnecessary and are in the process of having their process plants reversed so that natural gas can be liquefied and exported.

# XI

# The UK Position Today.

The UK is in the vanguard of European shale gas exploration; protest and government policy development. The companies that are present include several multinational as well as smaller operators.




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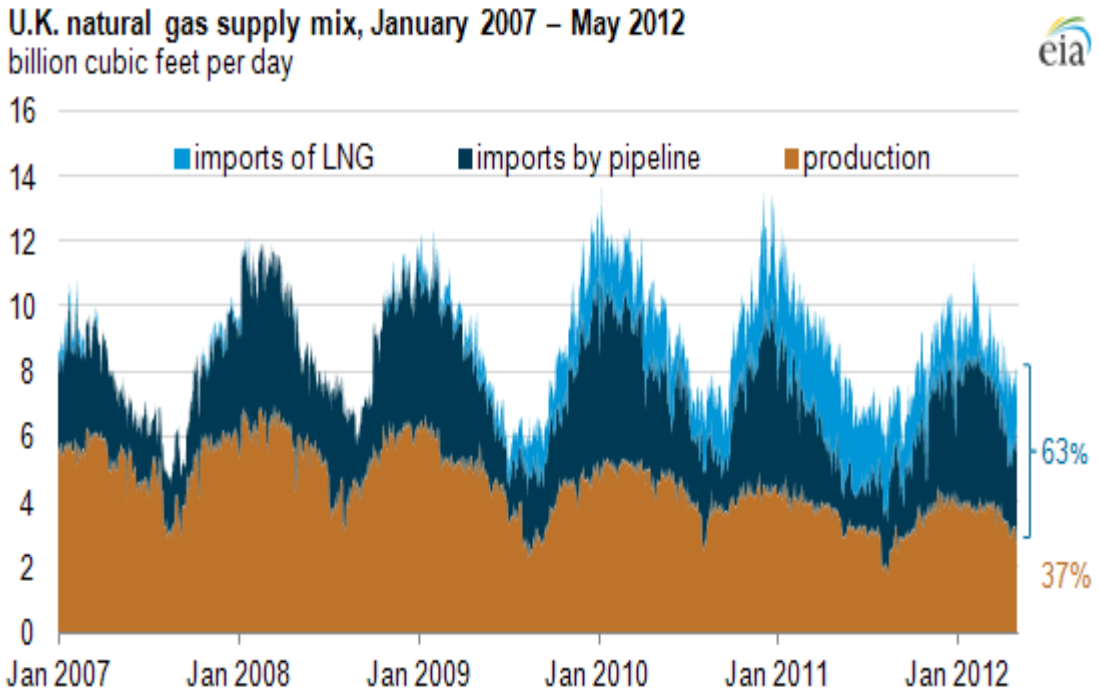
Many of the exploration companies are the companies that were set up to exploit the gas that became available with the wholesale closure of the coal industry and the methane that would then be more easily exploited. The first time that on-shore gas licenses were offered for tender in the late 1990s many of the coalfield areas were licensed to companies who had little ability or intension to exploit their areas when granted. They were rather holding the tranches of land in the anticipation

that their asset might become attractive to the mainstream gas companies who would buy the licenses from them at inflated prices. This situation failed to materialise and by 2002 many gas licenses were either relinquished or removed from their holders due to inactivity.

The license once granted has to be acted on; potential access points located, borehole development, not just a cosmetic set of low cost activities but demonstrable investment in the initial license area. Once such research has been undertaken the licensed areas were to be refined to areas considered most likely to deliver the needs of the operator with the remaining fractions of the area being returned to the state for possible re-allocation.

The map above shows the UK PEDL licence areas with the red areas being those licenced over the last few years, the orange being areas up for applications and the green those at this point are considered either non-viable or are reserved for a future round of applications. The map shows areas that are unlikely to ever be considered viable such as central London due to engineering difficulties such as drilling locations and planning antipathy.

The chart below demonstrates the UK's position with regard to natural gas, its reliance on imports that substantially augment the dwindling home produced (mainly North Sea) supply.



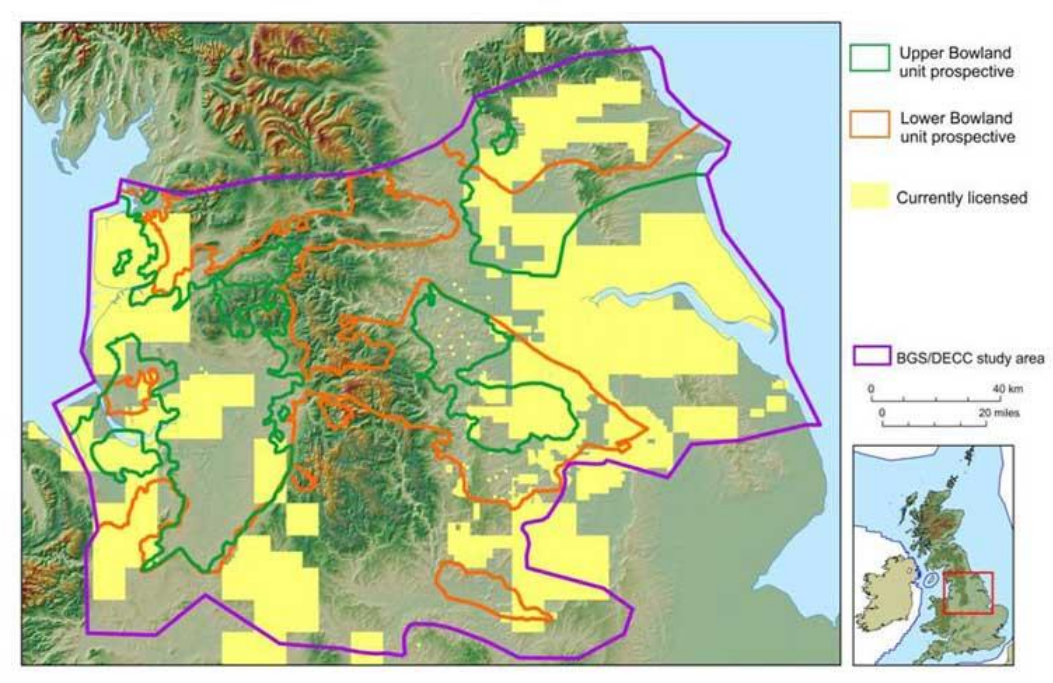

The desire of government to see less dependence on imported natural gas is understandable in that the major sources of the fuel, apart from Norway, are Russia and Algeria. The British Government has just prior to the announcement of the possible development into shale gas agreed terms for UK plc to buy volumes of LNG from Qatar; this was stated to be the long-term solution to many of Britain's energy supply concerns until shale gas could possibly come on line in fifteen to twenty years time.

Government ministers never considered, as Americans did, that shale gas could cushion sooner the nation's need for fuel until a full palate of renewable energy sources could be sustainably developed.

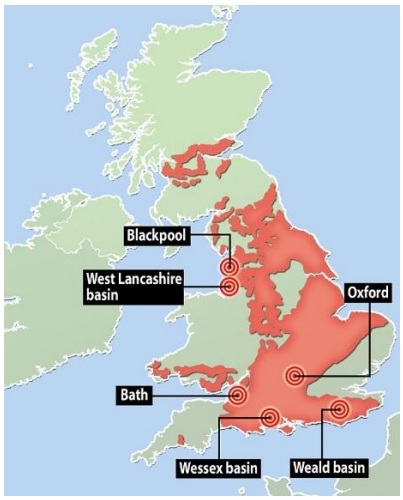
The negativity of HMG encompassed the whole issue of shale gas and its presence worried both the mining engineers and puzzled the anti-fracking lobby; the former as they could not understand the official blindness of the ministries and the latter for the same reason had to look forward to preparing for campaigns they knew were bound to happen.

Today the British government see that the development of shale formations is a likely vote winner, especially if the fracking can be carried out away from the Tory heartlands of the South of England. Nationally the price of gas has increased by leaps and bounds over the last ten years, many consumers are turning to extra clothes rather than their central heating to stay warm; particularly the elder generations, for whom central heating has always been a novel luxury. Shale gas could lead the way to, if not reduced gas billing, the cost levelling out for a period.

The knowledge and desire to use natural gas; amongst the least polluting of the hydrocarbon basket of fuels, is still as strong as during the dash for gas power generation of the early 1990s. The only other new contributor to the English energy pallet of known technologies being a new nuclear power station to be constructed at Hinckley Point, Somerset. The broad array of sustainable renewable options are slowly gaining a small hold on the Energy ladder in England and Wales. [though]



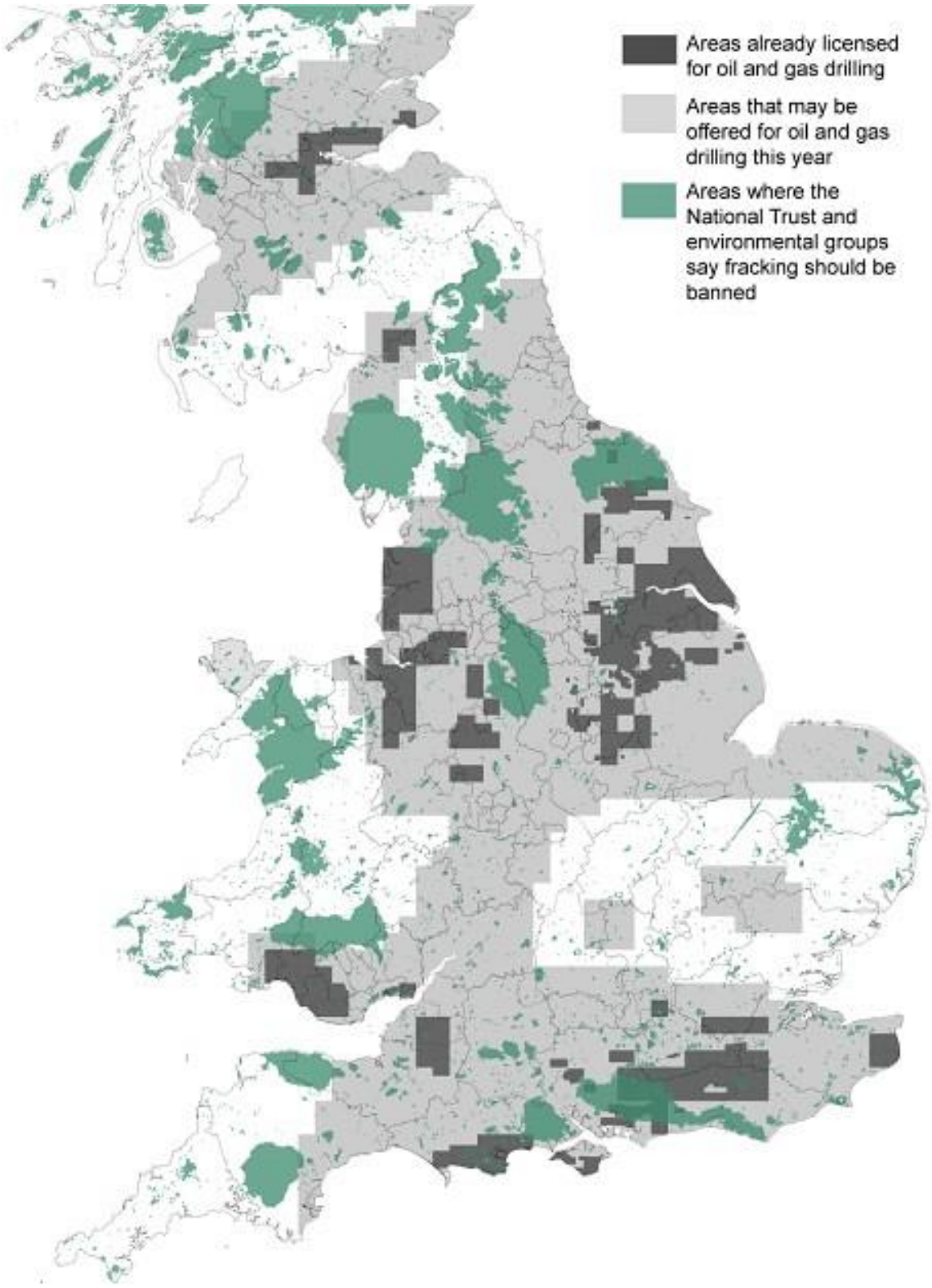

The above map outlines the most recent published area of study carried out by the British Geological Survey (2013) for the Department of Energy and Climate Change which outlines the Bowland shale strata alongside the licenced areas, the other areas beyond the Bowland are also likely to be rich in both oil and gas due to the developing methodologies in [in] production drilling.




The map demonstrates the large shale areas of the UK showing the locations of particular interest that have received some publicity. The areas highlighted are almost more important in that they give more substance to the vacant areas which are being explored with ever greater intensity.

The British Geological Survey in May 2014 have now confirmed the facts regarding the southern areas of the country as possessing large hydrocarbon reserves; both of oil and gas locked into the shales. The UK Government have announced that those that do not with for fracking beneath their property will not be accorded the law in their eyes.

A bonanza is waiting in the wings.


Areas already licensed for oil and gas drilling
Areas that may be offered for oil and gas drilling this year
Areas where the National Trust and environmental groups say fracking should be banned

# XII

# In Conclusion.

The development of what appears to be large volume reserves of exploitable natural gas beneath many areas of the UK is a political as well as economic crutch for the country. The North Sea oil and gas industry is in its depression curve of production and with ever increasing volatility in international oil and gas prices and supply security and exists alongside the slow deployment of alternative energy sources and the ever decreasing coal fraction of power generation. The trumpeted salvation of new green power from a new generation of nuclear power stations is going to ensure that the costs of electricity will rise steadily as they gradually come online, at the same time the decommissioning of older ones are raising concerns regarding time scales and long term waste storage facilities or the lack of them.

This all sounds depressing; the future is uncertain and the generators dangle the visions of shortage at the same time as putting prices up, so what you receive is mentally skewed to have an almost rarity or scarcity value. Not one of us can do without the power from our plug sockets if we are not to lose touch with news, friends, family or just chill out. TV, DVD CD, Blue Ray, maths homework of to get the dole, society and each individual requires it. Even anti fracking campaigners need it to find out the next location for ante Cuadrilla activity!

All developed countries are in agreement that low carbon is the right star to steer our national economies by, but the public also do not like wind, hydro, tidal barriers or solar arrays, which are considered unsightly, damaging to river fauna, altering eco-systems and wasting agricultural land respectively.

In the UK the prospecting and evaluation of many shale gas deposits is known to be active, but to find out who and where such activities are taking place appears shrouded in secrecy due to the underlying concerns of both the companies involved and in several instances the communities in which the exploration is taking place. This is not so much that these residents are in favour per say of the development of gas and oil resources locally but more that they wish to avoid the area being inundated by protesters and their attendant media circus which can bring normal life and activity to a standstill.

To reiterate the statement at the beginning of this short outline of issues, facts and history the public deserves energy that it needs, at prices that it can afford, which is reliable and is not handed out in an alarmist fashion. The prospect of reliance on nuclear generation or imported fossil fuel makes a nonsense of environmental and sustainable supply. We are confronted with potentially serious implications over a long-term analysis. The credibility of government is at risk if it does not take a lead in the governance of the state. There is cause for concern when the populace sees it shilly-shallying on the periphery and with only 1 year to a General Election.

If shale reserves are to be used let the whole thing be set in motion with regulation and the public aware of the alternatives and at the same time renewing the development of energy from renewable sources and not just carrying through those schemes that allow compliance and remove risk of fiscal penalties from Europe and admonition from the rest of the world.

There are justifiable fears of a future ruled by sun, wind and tide, but this is a true brave new world: or is it?

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