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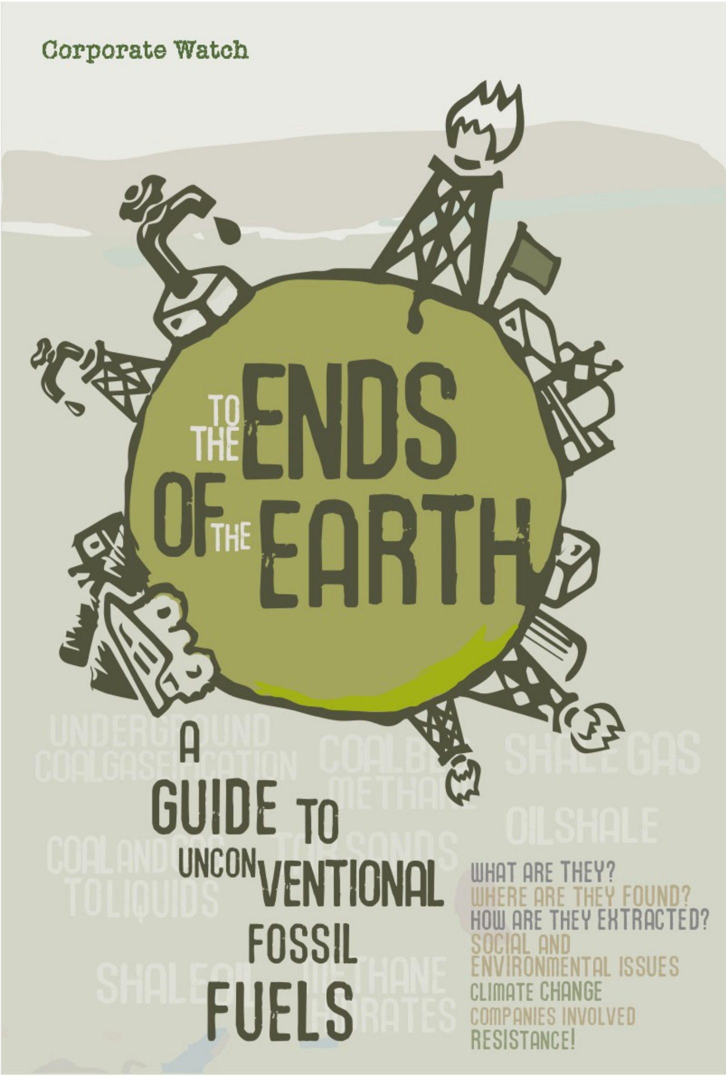
TO THE ENDS OF THE EARTH

A GUIDE TO UNCONVENTIONAL FOSSIL FUELS

UNDERGROUND COALGASIFICATION
COALBED METHANE
SHALE GAS
OILSHALE
COALANDGAS TOLIQUIDS
TAR SANDS
SHALE OIL
METHANE HYDRATES

WHAT ARE THEY?
WHERE ARE THEY FOUND?
HOW ARE THEY EXTRACTED?
SOCIAL AND ENVIRONMENTAL ISSUES
CLIMATE CHANGE
COMPANIES INVOLVED
RESISTANCE!



Unconventional Fossil Fuels in Liverpool and the UK

This briefing summaries the information on unconventional fossil fuels in Liverpool and the UK, based on our recent report (available here:http://www.corporatewatch.org/publications/2014/ends-earth-guide-unconventional-fossil-fuels).

What are unconventional fossil fuels?

The term is generally used to describe fuels that cannot be extracted using conventional drilling or mining. They often involve new technologies such as directional drilling and hydraulic fracturing (fracking)

What is happening in the UK?

There are four types of unconventional fossil fuel that are currently being developed in the UK:

- **Shale Gas**
- **Shale Oil (tight oil)**
- **Coal Bed Methane**
- **Underground Coal Gasification**

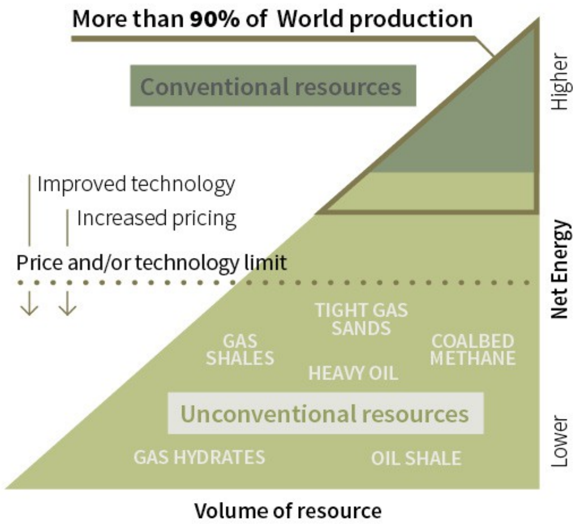
Factsheets on each of these fuels are included in this briefing.

As of August 2014, over half of the UK is now open to fracking for shale gas and shale oil extraction. In addition 24 licences for Underground Coal Gasification have been awarded and a host of Coal Bed Methane sites have already been drilled in Scotland, Wales and England.

What is behind the development of unconventional fossil fuels?

As global energy consumption continues to rise, primarily driven by growth based economic systems, more easily accessible energy sources (such as convention oil and gas) are starting to run low.

This pushes up energy prices making previously uneconomical energy sources viable. Along with the development of new technologies, this is resulting in ever more extreme forms of energy extraction, including the development of harder to access fossil fuels.



Resource triangle
At the top are conventional resources, in small volumes that are easy to extract. At the bottom are unconventional resources, in large volumes that are difficult to extract. Increasing price and improved technology allow resources further down the triangle to be extracted.

What are the implications?

Unconventional fossil fuels are generally spread out over wider areas, require more energy to extract and have much greater impacts on water resources and the global climate.

Climate change

In order to avoid the most serious impacts and the risk of irreversible and uncontrollable changes to the climate, a total limit of 500 billion tonnes (Gigatonnes or Gt) of carbon emitted to the atmosphere is required. Since the start of the industrial revolution we have already emitted 370Gt leaving a limit of 130Gt that could be further added. In order to stay within this limit we would have to leave the vast majority of the remaining conventional oil, coal and gas in the ground. Estimates vary significantly, but remaining conventional coal reserves alone are well over 500Gt of carbon.

Developing unconventional fossil fuels, and releasing the enormous amounts of carbon they contain, is thus absolutely incompatible with staying below this limit or maintaining anything like a reasonably habitable climate. We need to move away from all forms of fossil fuel, conventional and unconventional, as fast as possible. See the carbon budget info-graphic below for more information.

Environmental impacts

Harder to access resources not only require more energy to extract, they also require more water and land and produce more waste. For example in Alberta, Canada, where the tar sands are being extracted, the area of land required per barrel of oil produced increased by a factor of 12 between 1955 and 2006. If the expansion of unconventional fossil fuels continues, this trend will be replicated around the world, since unconventional fossil fuel resources are spread over much greater areas. This means a much greater impact on wildlife and far more local communities being exposed to the impacts of extraction, such as water and air pollution. These impacts will be even more pronounced in the UK due to the high population density.

Water

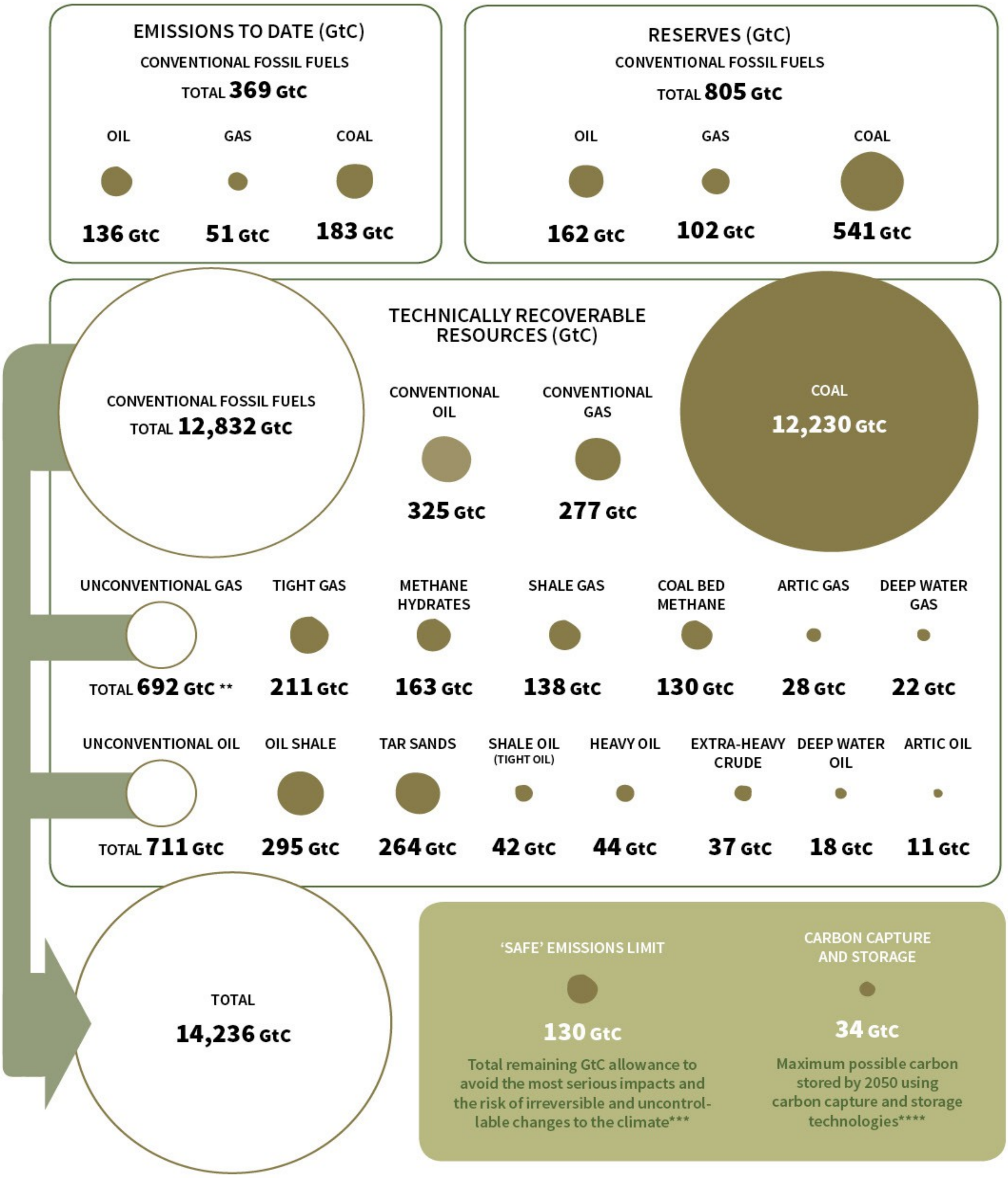
The effects on water resources are particularly profound. Globally, freshwater is becoming more and more scarce. The UN predicts that by 2025 two thirds of the world's population could be living under water-stressed conditions. The UK is no exception, water shortages are common and are set to become more severe and more frequent in the future. The development of unconventional fossil fuels will dramatically increase water consumption and leave enormous volumes of contaminated water. For example the U.S. Environmental Protection Agency estimates that fracking in the US uses 70 to 140 billion gallons (265 - 531 billion litres) of water per year, equivalent to the total amount of water used each year in a city of 2.5 - 5 million people. The huge poisonous lakes created by the tar sands industry now cover an area of 176km^2. In 2002, the oil shale-fired power industry used a staggering 91% of all the water consumed in Estonia.

What is the alternative?

Energy efficiency measures can go some way to reducing consumption, and renewable energies have enormous potential, especially in the UK where we have bountiful wind resources. However, we need to understand the wider social, political and ecological contexts of energy production and consumption rather than approaching them as isolated issues. Ultimately if we are to address our energy problems we have to radically change our whole attitude to energy and move away from the growth based economic systems that are behind our ever increasing energy consumption.

Our carbon budget

The graphic shows estimates for the global carbon content in each of the types of conventional and unconventional fossil fuel*, along with the limit that we can still add to the atmosphere while avoid the most serious impacts and the risk of irreversible and uncontrollable changes to the climate. It also shows the maximum amount that could be stored by 2050 using Carbon Capture Storage technologies.



* Carbon content estimates were calculated by taking averages from a variety sources and using conversion factors where appropriate (for example from a resource's volume in barrels to the weight in carbon). As there is significant disagreement over the various resource estimates, some judgement had to be used in which figures to include in the calculations. For details of how the estimates were made go to <http://www.corporatewatch.org/uff/carbonbudget>.

** This is a minimum estimate. Other sources estimate that the technically recoverable resource for unconventional gas could be greater than 2,000 GtC.

*** Limit taken from: 'Assessing "Dangerous Climate Change": Required Reduction of Carbon Emissions to Protect Young People, Future Generations and Nature'. Hansen et al (2013). <http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0081648>

**** Figure from: 'Unburnable Carbon 2013: Wasted capital and stranded assets'. Carbon Tracker & The Grantham Research Institute, LSE (2013). <http://www.carbontracker.org>.

Unconventional fossil fuels in Liverpool and the surrounding area

The North West of England is the area of the UK of most interest to fracking companies due to the significant shale gas and oil resources in the 'Bowland Shale', a geological formation covering most of 'central' England. While the sites with the greatest potential resources are found in the North of Lancashire, particularly the Fylde Peninsular and Ribble Estuary, the Bowland also extends into Liverpool, Merseyside and into Cheshire. Extensive areas of this region have been awarded exploration licences.

The coal seams under Liverpool also mean the area is being targeted for two other forms of unconventional fossil fuel extraction: Coal Bed Methane and Underground Coal Gasification (see factsheets for more information on these technologies).

Companies involved

There are five main 'fracking' companies operating in the area:

Cuadrilla Resources

The UK's highest profile fracking company and the only company to have carried out high volume hydraulic fracturing in the UK, at its site in Weeton, Lancashire (which resulted in a small earthquake and a UK moratorium on fracking operations which has since been lifted). Cuadrilla have the largest licensing block in the country, covering about 460 square miles of Lancashire. They were also the company testing for shale oil (see Shale Oil factsheet) in Balcombe, the site of major protests against the industry. Investors in Cuadrilla include Australian company AJ Lucas and US based Riverstone LLC. Its chairman is Lord Browne, former chief of BP.

- Address: Cuadrilla House, Stowe Street, Lichfield, Staffordshire, WS13 6AQ
- Website: www.cuadrillaresources.com

IGas Energy

IGas has a number of licence blocks stretching from Salford to the Dee estuary. They are involved in Coal Bed Methane (CBM) and shale gas extraction and are already producing small amounts of CBM gas from some sites. As well as licence areas in the North West, they also have permission to explore for oil and gas in the East Midlands, the Weald Basin in southern England and the northern coastal area of the Inner Moray Firth in Scotland.

IGas was the company involved in test drilling of the Barton Moss site in Salford, which was met with strong opposition from the local community (see below). In May 2014 IGas acquired Dart Energy (see below) in a deal worth nearly £120m.

- Address: 7 Down Street, London W1J 7AJ, UK
- Website: www.igasplc.com/

Dart Energy

Dart Energy, an Australian fracking company, have licenses across the UK (including the North West). So far they have been focused on CBM and shale gas in Cheshire, East Midlands and Scotland.

- Address: 2 Polmaise Road, Stirling, Stirling FK7 9JJ, UK
- Website: www.dartgas.com/page/Europe/United_Kingdom/

Aurora Energy Resources

Aurora Energy Resources Limited are a UK company based in Aberdeen. They are currently mainly focused on small scale conventional oil extraction from the Formby Oilfield, but the deeper Bowland Shale is likely to contain shale oil in this area (see Shale Oil factsheet for more information).

- Address: Westfield Estate Milltimber Aberdeen AB13 0EX United Kingdom
- Website: www.aurora-energy-resources.com

Alkane Energy

Alkane Energy is currently mainly focused on Coal Mine Methane operations (CMM - see Coal Bed Methane factsheet for more information).

- Address: Edwinstowe House, Edwinstowe, Notts, NG21 9PR
- Website: www.alkane.co.uk/

In addition to licences for shale and CBM exploration, the Coal Authority has also given away two Underground Coal Gasification (UCG) licences in the North West: one for the Liverpool Bay area to Australian company Riverside Energy and one in the Dee Estuary to Cluff Natural Resources.

Cluff Natural Resources

Founded by multi-millionaire Algy Cluff, Cluff Natural Resources also have a licence to carry out UCG operations under the Firth of Fourth in Scotland, which, if plans go ahead, would be the first site in the UK to carry out UCG operations

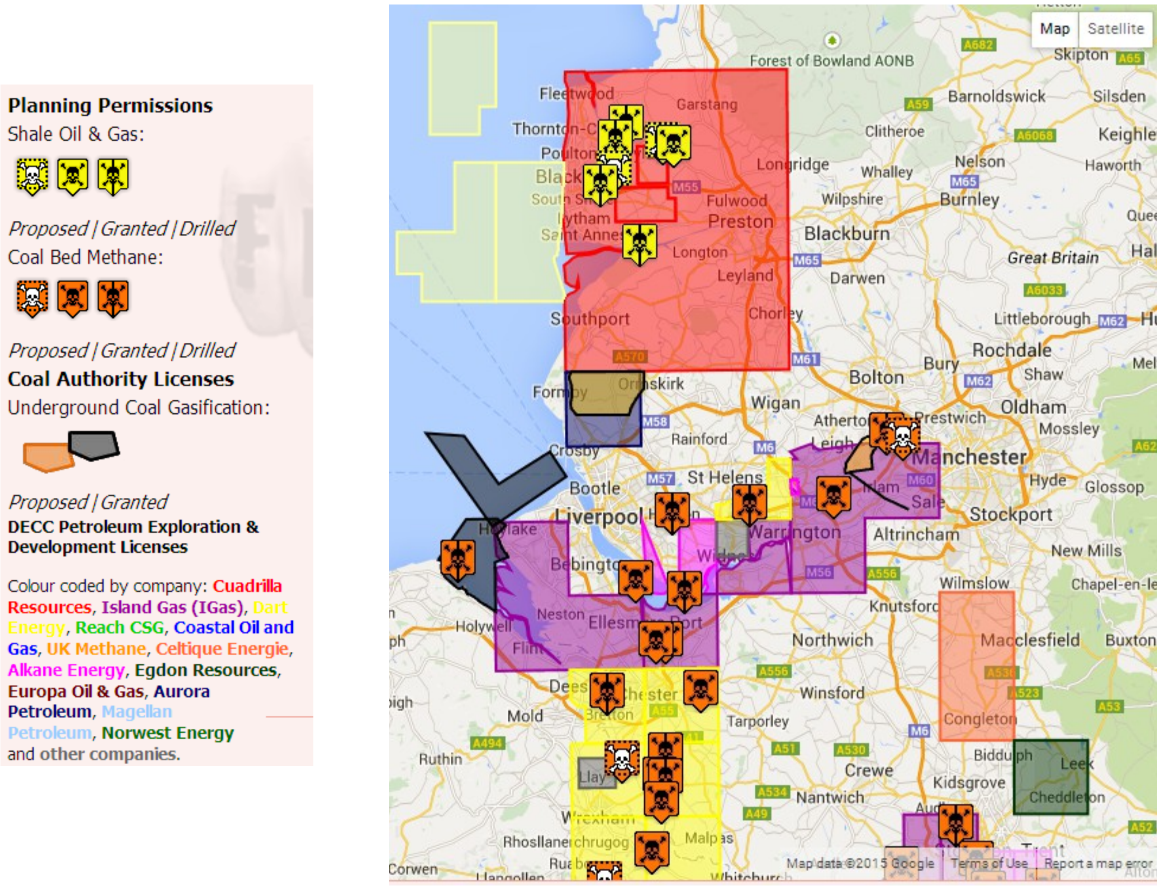
- Address: Third Floor, 5-8 The Sanctuary, London, SW1P 3JS
- Website: www.cluffnaturalresources.com

Riverside Energy

An Australian UCG company. Also has licences for UCG operations in the Thames Estuary.

- Address: Belgrave House 39 -43 Monument Hill, Weybridge, Surrey, United Kingdom, KT13 8RN

The image below, taken from the website of extreme energy campaigners, Frack Off (http://frack-off.org.uk/), shows the various planning permissions awarded according to the type of technology and company awarded.

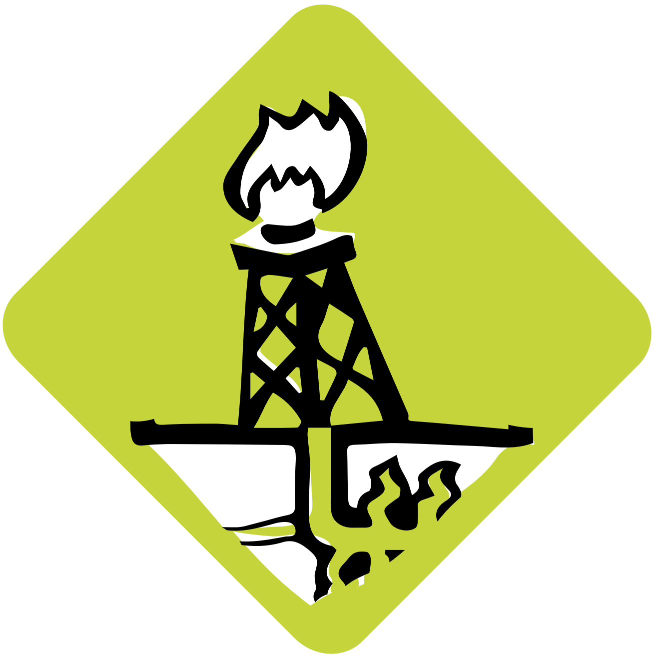


Community resistance: Barton Moss campaign

In November 2013 anti-fracking campaigners set up a protest camp in Salford to oppose test drilling being carried out by energy firm, IGas. The company was carrying out tests to see if there was potential for commercial extraction of shale gas or coal bed methane in the area, which would include the use of the controversial 'hydraulic fracturing' technique, otherwise known as fracking.

Over a period of several months, IGas drilled 6,000ft beneath the site in Eccles, Salford, to collect samples to test for levels of gas in the coal bed and shale rock formations. A protest camp was set up in nearby Barton Moss Road, and was made up of a mix of local campaigners and environmentalists. The camp was successful in attracting a lot of attention to the issue and gained significant local and national media coverage. It was also successful in causing serious disruption to IGas operations, with the use of community blockades and protesters locking themselves to gates to prevent lorries from accessing the site.

The policing of the event came under extensive criticism, with many accusing the police of heavy handed tactics. An investigation by a supposedly 'independent' panel set up to look into the policing of the event, was reported to have “cleared officers of brutality”. However, the investigation was criticised by police watchdog Netpol, who said it did not match with testimony they had gathered. The policing operation cost £1.7 million, which the Home Office refused to pay.



SHALE GAS (TIGHT GAS)

SHALE GAS IS NATURAL GAS THAT IS TRAPPED UNDERGROUND IN SHALE ROCK WHICH MUST BE FRACTURED TO EXTRACT THE GAS.

EXTRACTION CAUSES WATER POLLUTION AND METHANE LEAKAGE WITH SERIOUS CONSEQUENCES FOR CLIMATE CHANGE.

WHAT IS IT?

Natural gas is mainly methane and is usually extracted from oil or gas fields and coal beds (see coal bed methane), but it can also be found in shale formations.

Shale is a form of sedimentary rock formed from deposits of mud, silt and clay. Normally natural gas is extracted from sandstone or carbonate reserves, where the gas flows fairly easily once the rock is drilled into. However shale is relatively impermeable, meaning that it is harder for the gas to escape. It is only with the development of horizontal drilling and advanced hydraulic fracturing (see below) that shale gas extraction has become possible.

TIGHT GAS

Tight gas refers to natural gas reservoirs trapped in highly impermeable rock, usually non- porous sandstone and sometimes limestone. It is found in different geological formations from shale gas (although according to some definitions shale gas is a form of tight gas). Over time, rocks are compacted and undergo cementation and recrystallisation, reducing the permeability of the rock. As with shale gas, directional drilling is used and fracking is necessary to break up the rock and allow the gas to flow. In addition to fracking, acidisation is also sometimes used. This is where the well is pumped with acid to dissolve the rock that is obstructing the flow of gas.

While many of the problems posed by tight gas, such as water pollution and contributing to climate change, are similar to those of shale gas, there are some differences. For example the differing natural carbon content in tight gas means that it stores different kinds of contaminants and therefore produces different pollutants. Shale gas is also generally harder to extract, being even less permeable and requiring more fracking.

HOW IS IT EXTRACTED?

Shale gas has been known about for a long time. The first commercial gas well in the USA, drilled in New York State in 1821, was in fact a shale gas well. However, it is only since around 2005 that it has been exploited on a large-scale. This has been driven by the huge rise in energy prices resulting from declining fossil fuel reserves and the development of two new technologies, horizontal drilling and advanced hydraulic fracturing, which have opened up reserves previously inaccessible by conventional drilling.

Hydraulic fracturing, often just referred to as fracking, is used to free gas trapped in rock by drilling into it and injecting pressurised fluid which creates cracks which release the gas. The fracking fluid consists of water, sand and a variety of chemicals which are added to aid the extraction process such as by dissolving minerals, killing bacteria that might plug up the well, or reducing friction.

Production from shale gas wells declines very quickly and so new wells must be drilled constantly. This process of continual drilling and fracking means that huge areas of land are covered with well pads where thousands of wells are drilled, with each well requiring millions of litres of water.

The fracking process also produces a large volume of waste water, containing a variety of contaminants both from the fracking fluid, and toxic/radioactive substances which are leached out of the rocks (see below).

CLIMATE CHANGE

Natural gas, whether it comes from shale or conventional sources, is a fossil fuel and when it is burned it releases significant greenhouse gas emissions (GHG).

It is sometimes argued that as burning natural gas produces less GHG emissions than coal it can be used as a 'bridging' or 'transition' fuel, replacing coal while renewable energy technologies are developed and implemented. This argument is widely used by governments and industry to promote gas as a low carbon energy option. However as long as energy demand increases, additional sources of fossil fuels such as shale gas are likely to supplement rather than replace other existing ones such as coal.

This has happened in the US where the shale gas boom, instead of reducing coal extraction, has simply resulted in more of it being exported and used elsewhere.[1]

When comparing fuel types it is important to look at 'lifecycle' GHG emissions, the total emissions generated by developing and using the fuel. In the case of shale gas these include direct emissions from end-use consumption (e.g. from burning gas in power plants), indirect emissions from fossil fuels used to extract, develop and transport the gas, and methane from 'fugitive' emissions (leaks) and venting during well development and production.

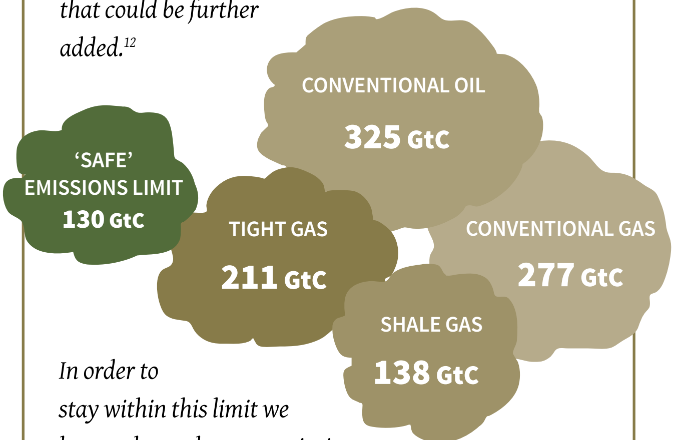
There is a lot of debate about how much gas escapes as fugitive methane emissions in the process of extracting and transporting natural gas. The gas industry is particularly reluctant to investigate this, which is partly why it is hard to find reliable figures. However various studies have found significant leakage, and since methane is a more potent GHG that CO_2, even if just a small percentage of the gas extracted escapes to the atmosphere it can have a serious impact on the climate.

Some studies have concluded that fugitive emissions from shale gas could be between 3.6% and 7.9% particularly when the gas vented during flow-back is included.[2] [3] [4]. This would make the GHG contribution from shale gas similar to or even worse than coal in terms of contributing to climate change.

The shale gas industry attacked the findings and although there is ongoing dispute over the figures,[5] [6] recent hard data estimated methane leakage rates in some areas to be 6 to 12%, [7] up to 9%,[8] or even as high as 17%.[9]

Methane is a powerful greenhouse gas, particularly in terms of its short term influence on the atmosphere. If more than 3.2% of methane is lost to the atmosphere then switching from coal to gas will result in no immediate benefits in terms of contribution to climate change.[10]

If we are to reduce carbon emissions to anything like the levels required to maintain a reasonably habitable planet we must move away from all forms of fossil fuel as fast as possible. Measuring from the start of the industrial revolution (around 1750), a maximum of 500 Gigatonnes of carbon (GtC) can be emitted to the atmosphere while still avoiding most serious impacts and the risk of irreversible and uncontrollable changes to the climate.[11] Between 1750 and now (2014), we have already emitted about 370 GtC leaving a limit of 130 GtC that could be further added.[12]



In order to stay within this limit we have to leave the vast majority of the remaining conventional oil, coal and gas in the ground. Estimates vary significantly, but remaining conventional coal reserves alone are well over 500GtC.[13]

Exploiting the world's shale gas resources would add around 138 GtC to the atmosphere (with tight gas adding a further 211GtC).[14] This is a huge amount and is clearly incompatible with staying within the limit outlined above. All of this means that, far from making things better, the development of shale and tight gas is dramatically worsening the problem of climate change.

Shale gas and Carbon Capture and Storage (CCS)

There has been some discussion about the possibility of using exhausted shale gas formations as a storage location for CO_2. Injecting CO_2 into fracked shale deposits is also being considered as a way of both storing CO_2 and extracting more gas at the same time (so called Enhanced Gas Recovery -see 'Other Unconventional Fossil fuels' factsheet). However, their viability as CO_2 storage sites is questionable, and there are currently no shale gas sites being used to store CO_2. In addition there are concerns that fracking may be compromising other potential CO_2 storage sites, as the fracked shale formations are no longer impermeable and would therefore not keep CO_2 trapped in the deep saline aquifers below them.[15]

In addition fracking, the underground injection of fracking waste water (see below), and even the injection of CO_2 itself have been shown to cause earthquakes, which reveal a major flaw in CCS technology.[16 17]

Proponents of unconventional fossil fuels often argue that with CCS technologies, these new energy sources could be exploited at the same time as reducing GHG emissions. However, even if the huge problems with CCS technology are overcome (and this currently looking extremely unlikely), it would not change the fact that we need to move away from all forms of fossil fuel, conventional and unconventional, as soon as possible.

In the most optimistic (and highly implausible) scenario, CCS could be used to reduce a small proportion of emissions from fossil fuels. In reality, the promise of CCS being implemented in the future is being used to allow the continued expansion of fossil fuel production, to prevent alternatives from being developed, and to deflect attention away from approaches which tackle the underlying systemic causes of climate change and other ecological crises. Ultimately CCS is a smokescreen, allowing the fossil fuel industry to continue profiting from the destruction of the environment. (see 'Carbon Capture Storage' factsheet for more information).

OTHER SOCIAL AND ENVIRONMENTAL ISSUES

Water use

Fracking requires huge volumes of water, which once used is contaminated and cannot be returned to the water table. The amount of water needed varies from well to well, but will be somewhere between about 3 million and 40 million litres. [18]

In 2011, the U.S. Environmental Protection Agency estimated that 70 to 140 billion gallons (265 – 531 billion litres) of water was being used to fracture 35,000 wells in the United States each year.[19] Sourcing water for fracking is a major problem. Because of the transportation costs of bringing water from great distances, drillers in the US usually extract on-site water from nearby streams or underground water supplies. This puts pressure on local water resources which can lead to the worsening of droughts and competition with farmers for irrigation water.[20]

Water and air pollution

There has been a great deal of controversy over the chemicals contained in fracking fluids. In the US many companies have resisted revealing the recipes for their fracking mixes, claiming commercial confidentiality, or have adopted voluntary reporting measures in order to avoid stricter mandatory reporting requirements. Although the specific mix of chemicals used varies significantly, a US House of Representatives Committee on Energy and Commerce report found 750 different chemicals had been used in fracking fluids, including many known human carcinogens and other toxic compounds such as benzene and lead.[21] Chemicals found to be most commonly used in fracking fluids such as methanol and isopropyl alcohol are also known air pollutants.

A variety of chemicals are also added to the 'muds' used to drill well boreholes in order to reduce friction and increase the density of the fluid. Analysis of drilling mud has also found that they contain a number of toxic chemicals. [22 23]

Increasing numbers of studies analysing water quality in drinking wells near natural gas extraction sites have also found increased levels of contamination, [24 25 26]and several studies have suggested possible pathways through which contaminants could reach drinking water aquifers from fractured shale. [27]

Another area of controversy is that of methane pollution of local water supplies. Footage of people living close to fracking sites setting light to the water coming out of their tap has rapidly spread across the internet.

The industry was quick to respond, saying that these were just cases of supplies that were already prone to natural gas contamination. However, a leaked 2012 US Environmental Protection Agency presentation suggests that methane could be migrating more widely to water supplies as a result of fracking, a conclusion that was censored by the Obama administration.[28] Other research has also found evidence of methane and other contamination of water supplies due to fracking,[29] including a 2011 peer-reviewed study which found "systematic evidence for methane contamination" of drinking water associated with shale gas extraction.[30] There is, however, currently a lack of research on the health impacts of long-term exposure to methane in drinking water.[31]

Leakage of both methane and other chemicals involved in fracking is a huge problem. Despite industry claims that leakage is due to bad well design, research has shown that some leakage is an inevitability and that fracking only exacerbates the problem.[32] Wells routinely lose their structural integrity and leak methane and other contaminants outside their casings and into the atmosphere and water wells. Even research by oil services company Schlumberger suggests that half of all gas wells will be leaking within 15 years (see climate change section for more on leakage of methane to the atmosphere).[33]

Local air pollution at shale gas sites is also a serious concern. This includes emissions from vehicle traffic, flaring and venting during drilling and completion, on-site machinery such as compressors, and processing and distribution, where gas can leak from pipes and at compressor stations. Local air pollution from these sources includes BTEX (benzene, toluene, ethylene and xylene), NOx (mono oxides of nitrogen), VOCs (volatile organic compounds), methane, ethane, sulphur dioxide, ozone and particulate matter.[34]

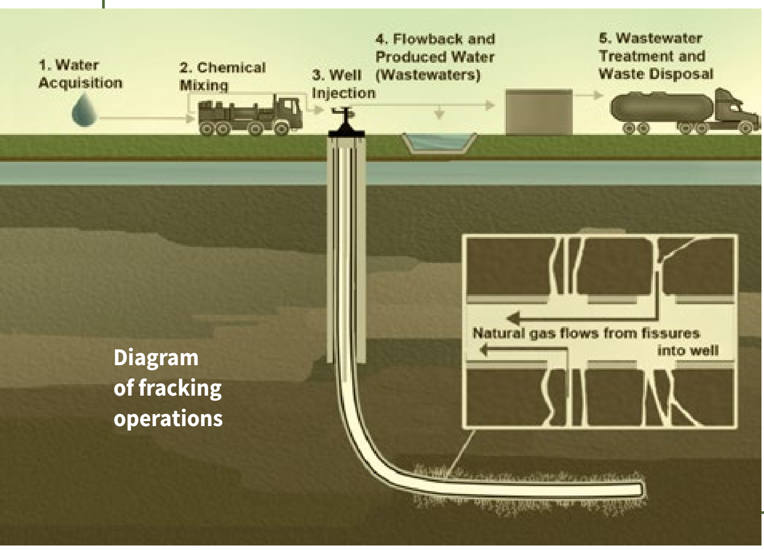


Diagram of fracking operations

Research has shown that air pollution caused by extraction may contribute to acute and chronic health problems for those living near natural gas drilling sites,[35] and there is a growing body of research identifying the health impacts of fracking and unconventional gas extraction.[36 37 38]

Waste water

The fracking process produces large volumes of waste water, contaminated by fracking fluids, and naturally occurring chemicals leached out of the rock. These can include dissolved solids (e.g., salts, barium, strontium), organic pollutants (e.g., benzene, toluene) and normally occurring radioactive material (NORM) such as the highly toxic Radium 226.[39]

This leaves the problem of how to dispose of this waste water. In many cases, the waste water is re-injected back into the well, a process that has been shown to trigger earthquakes (see earthquake section). In the US, there have been numerous cases in which drilling cuttings have been dumped and waste water stored in open evaporation pits. In some cases waste water has even been disposed of by spreading it on roads under the guise of dust control or de-icing. Treatment of fracking waste water is expensive and energy intensive, and still leaves substantial amounts of residual waste that then also has to be disposed of. In addition, the waste water from most sites would have to transported large distances to specialised treatment plants. The sheer volumes of waste water generated and the kinds of contaminants it contains makes treating and disposing of it safely extremely challenging. All stages of the waste water disposal process are of course prone to accidents, which could have serious environmental and human health consequences.

Human and animal health

It is difficult to assess the health effects of fracking sites, as many impacts will take time to become apparent and there is a lack of background data and official studies. Despite this there is mounting evidence linking fracking activities to local health impacts on humans and animals.[40 41 42]

Industrialisation of countryside

Unlike conventional gas, exploiting shale gas requires large numbers of wells to be drilled. As shale is impermeable the gas cannot easily flow through it and wells are needed wherever there is gas. In some cases up to sixteen wells per square mile have been drilled.[43]

In addition to the wells, extensive pipeline networks and compressor stations are required. In the US tens of thousands of shale wells have been drilled leading to widespread industrialisation of the landscape in some states. Similarly, to replace the UK's current gas imports with local shale gas would require up to 20,000 wells to be drilled in the next 15 years.[44]

Apart from the noise, light pollution and direct impact on local wildlife and ecosystems due to the well pads, shale gas extraction also results in large increases in traffic for transportation of equipment, waste water and other materials. It has been estimated that fracking requires 3,950 truck trips per well during early development of the well field.[45] A single well pad could generate tens of thousands of truck journeys over its lifetime. [46]

Earthquakes

Underground fluid injection has been proven to cause earthquakes, and there are instances in the UK where fracking has been directly linked to small earthquakes.[47] The injection of waste water from fracking back in to wells has also been shown to cause earthquakes.[48] Although these earthquakes are usually relatively small, they can still cause minor structural damage and of particular concern is the possibility of damaging the well casings thus risking leakage. This did in fact happen after the earthquake at Cuadrilla's site in Lancashire, UK. The company failed to report the damage and were later rebuked by the then UK energy minister, Charles Hendry, for not doing so.

Occasionally larger earthquakes are triggered. A 2013 study in prestigious journal Science linked a dramatic increase in seismic activity in the midwestern United States to the injection of waste water. It also catalogues the largest quake associated with waste water injection, which occurred in Prague on November 6, 2011. This measured 5.7 on the Richter scale, and destroyed fourteen homes, buckled a highway and injured two people.[49] It should be noted that mining and conventional gas and oil extraction can also cause earthquakes.

Jobs

Those trying to promote shale gas often cite the employment that it will generate as an argument in its favour. In practice much of the employment related to fracking will come from outside the area where the gas is extracted, and any boost to the local economy is relatively short-lived as the industry moves on once wells are depleted. Industry backed studies have been found to routinely exaggerate estimates of the number of jobs fracking will create. [50]

Economic issues

The rate at which a resource can be extracted strongly influences its value as a fuel source. Estimates of reserves containing 'so many years worth' of a country's gas supply ignore the fact that it will take many years and thousands of wells drilled before production rates rise sufficiently to provide significant amounts of fuel. This counteracts the argument that shale gas can be used as a 'bridging fuel' in the short term while renewables are developed. [51]

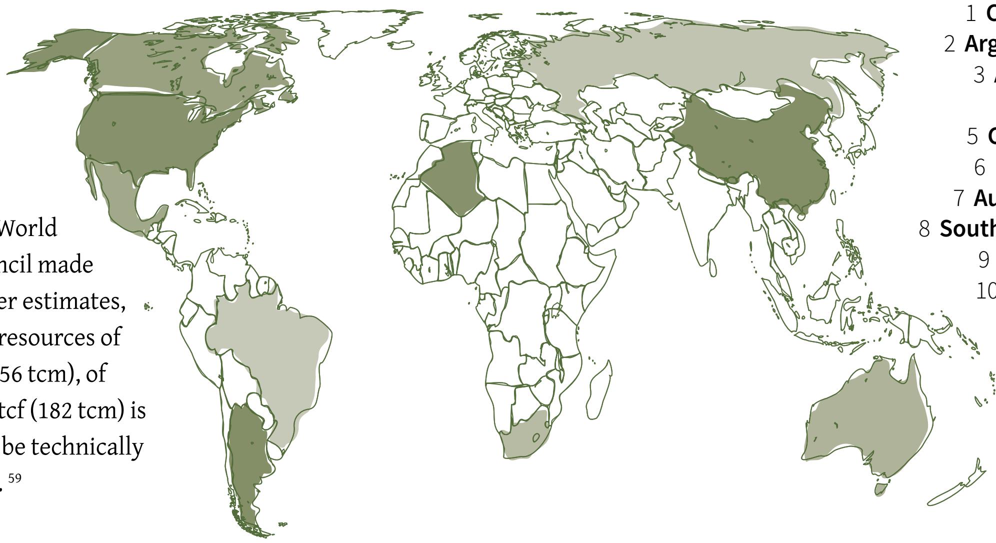
In the US, which is largely isolated from the world gas market due to transport issues, the shale gas boom has coincided with a recession, which has led to a reduction in energy demand and gas prices. This has actually made it uneconomical to produce shale gas, and has stalled drilling. Well production rates have also declined faster than expected, and spending on new sites has reduced as shale gas assets have lost value.[52] For these and other reasons to do with more integrated gas markets, shale gas is unlikely to make a significant impact on the price of gas in Europe and Asia, and promises of cheaper fuel prices for consumers are unlikely to be realised.

Natural gas can be converted to Liquefied Natural Gas (LNG), which can then be transported in specialised ships rather than pipelines. This is one way for the US to export shale gas to other markets. However, the processes of liquification, tanker transportation and gassification mean that using LNG requires significantly more energy and results in greater GHG emissions.[53]

As the most productive shale plays and their 'sweet spots' are exploited first, it becomes increasingly more expensive, both in terms of money and energy, to maintain production levels.[54] There are predictions that the shale gas boom in the US may have already peaked.[55] There have also been suggestions that much of the investment into shale gas in the US was based on over estimation of reserve sizes and underestimation of the costs involved.[56] Concerns that the same kind of financial practices that led to the US housing bubble were used to provide investment (with the prospect of profitable merger and acquisition deals attracting the financial sector) have led some to predict that the financial bubble behind the US shale boom will burst, possibly instigating another global economic crisis.[57]

WHERE AND HOW MUCH?

Shale gas deposits occur across the globe, but there are significant variations in the estimates of how much shale gas exists and how much of it can be extracted, partly due to the variations in geology from region to region. In 2013 the US Energy Information Administration put the global amount of technically recoverable shale gas as 7299 trillion cubic feet (tcf),[58] or 207 trillion cubic metres (tcm), with the top 10 countries in terms of resources (in tcf) as:



1 China **1,115**
2 Argentina **802**
3 Algeria **707**
4 US **665**
5 Canada **573**
6 Mexico **545**
7 Australia **437**
8 South Africa **390**
9 Russia **285**
10 Brazil **245**

In 2013 the World Energy Council made slightly lower estimates, with global resources of 16,110 tcf (456 tcm), of which 6444 tcf (182 tcm) is expected to be technically recoverable. [59]

The industry is by far most advanced in the US, where there has been a boom in shale gas with tens of thousands of wells drilled. Other countries with large reserves are at various stages of exploration and production. China has the largest shale gas resources in the world, but the geology of its shale formations, particularly their depth, may make extraction much more difficult than in the US. Activity in China is mainly at the exploration and test well stage, but production capacity is rapidly increasing.[60] In Argentina, which has the second largest resources, several contracts have been awarded and exploration and test wells have been drilled by a number of companies. A host of other countries are exploring shale gas production including, Australia, Austria, Canada, Germany, Hungary, India, New Zealand, Poland, South Africa, Sweden and the UK.

COMPANIES INVOLVED

In the US, the shale gas industry is not dominated by the multinational super-majors such as Exxon, Shell and Total. Instead variously sized American companies operate, anywhere from tiny start-ups to mid sized companies worth tens of billions. Notable US shale companies include Chesapeake Energy, Continental Resources, Marathon Oil, Occidental Petroleum, Pioneer Natural Resources, Apache, Whiting Petroleum, Hess, EOG Resources, ConocoPhillips. That said, some large multinational oil companies have now also acquired significant stakes in North American shale gas including Exxon, Total, Shell, CNP and Reliance Industries.

In places where the shale gas industry is yet to gain a foothold, sometimes small exploratory companies carry out the initial drilling and testing. These are then acquired by larger gas companies if economically recoverable deposits are found. This serves to protect the risk to bigger companies if testing is unsuccessful. However large oil multinationals are also involved in exploratory drilling in a number of regions, including China, Europe and South America.

ⓒ Adrian Kinloch

ⓒ Adam Welz for CREDO Action

RESISTANCE

Shale gas extraction, and particularly fracking, has met wide-spread resistance around the world. In the US, spurred on by the 2010 documentary film Gasland, a national anti-fracking movement is now active across the country. Following protests, various countries and regions have introduces moratoriums or outright bans on fracking. These include France, Bulgaria, Romania and the Czech Republic (see <http://keeptapwatersafe.org/global-bans-on-fracking/> for an updated list of countries and regions).

A number of countries have seen protesters using direct action and civil disobedience to oppose fracking. Australia's 'Lock the Gate' movement has involved environmental activists joining forces with local communities to prevent exploration, with widespread use of blockades.
Despite violent repression from the police, the villagers of Pungesti, Romania have put up strong resistance to Chevron's plans to frack the area, removing and sabotaging their testing equipment. The indigenous Elsipogtog First Nation along with other local residents blockaded a road near Rexton, New Brunswick, Canada, preventing South Western Energy from carrying out tests at a potential shale gas site. In the UK dozens have been arrested in community blockades of exploration sites , such as in Balcombe and Barton Moss.

For more information on resistance see the Corporate Watch website (corporatewatch.org/uff/resistance)

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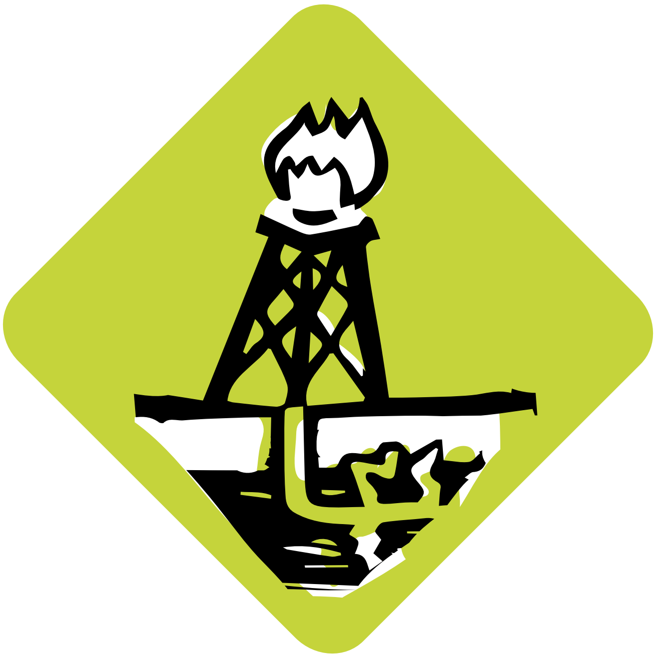


COALBED METHANE

EXTRACTING **METHANE** FROM **COAL SEAMS** BY DRILLING LARGE NUMBERS OF WELLS. USUALLY INVOLVES PUMPING OUT VERY LARGE VOLUMES OF GROUNDWATER TO GET THE GAS TO FLOW AND OFTEN INVOLVES HYDRAULIC FRACTURING (FRACKING).

POSES A SERIOUS RISK OF GROUNDWATER POLLUTION, AND CAUSES SIGNIFICANT GREENHOUSE GAS EMISSIONS, PRIMARILY THROUGH METHANE LEAKAGE.

WHAT IS IT?

Coalbed methane (CBM), also known as coal-seam gas (CSG) in Australia, refers to methane found in coal seams (underground layers of coal, also called 'coal beds'). It occurs when methane is absorbed into coal and is trapped there by the pressure from the weight of the rocks that overlie the coal-seams. CBM is formed and trapped during the geological process that forms coal (coalification). It is commonly found during conventional coal mining where it presents a serious hazard (see 'Coal Mine Methane' below). As well as methane, CBM is typically made up of a few percent carbon dioxide (CO_2), carbon monoxide (CO) and nitrogen (N_2) and traces of other hydrocarbons such as propane, butane and ethane.

The amount of methane in a coal seam varies according to the geological conditions, particularly the type of coal and depth of the seam, with higher quality and deeper coal containing more methane.[1] CBM is usually found at depths of 300-2000 metres below ground.[2] At shallower depths (less than about 300 metres) the CBM concentration tends to be very low as the pressure is not high enough to hold the gas in place. At greater depths, while the gas concentrations are generally higher, the high pressures and the lower permeability of higher quality coals (e.g. bituminous coals and anthracite) make extraction less efficient. Studies of the major coal-bearing basins of the world suggest that more than 50% of the estimated CBM is found in coals at depths below 1500 metres.[3]

Methane has been removed from coal mines for a long time, but it was not until the 1980s following a tax break in the US, that commercial production of CBM began.[4] The industry continued to expand almost exclusively in the US and by 2000 Australia was the only other country to have commercial production, although on a very small scale. There is now widespread CBM extraction, both from coal mines (see Coal Mine Methane below) and from 'stand-alone' CBM operations, in the US, Canada, Australia and China, and a handful of production wells in the UK.

COAL MINE METHANE

CBM often accumulates in the working areas of underground coal mines. In this context, CBM is commonly referred to as coal-mine methane (CMM) and presents a serious explosive and suffocation hazard. Miners used canaries (and later Davy's lamps) to warn them of the presence of methane and other dangerous gases. CMM is commonly vented into the atmosphere or flared (controlled combustion) and both of these processes release significant amounts of greenhouse gasses (GHGs) into the atmosphere.

Increasingly CMM is being used as an energy source and is extracted in manner very similar to CBM (see below). While the CBM industry is keen to promote this as a way of reducing GHG emissions from venting or flaring, exploiting CMM results in the same environmental problems associated with CBM.

"COUNTRIES THAT HAVE CARRIED OUT CBM ACTIVITIES HAVE EXPERIENCED NUMEROUS BLOW-OUTS, SPILLAGES AND OTHER ACCIDENTS"

HOW IS IT EXTRACTED?

To extract CBM, wells are drilled into the coal seam and groundwater is pumped out (known as de-watering). This reduces the water pressure within the bed, releasing the methane trapped in the coal. The gas then migrates along fractures in the coal and is pumped out of the well. The process involves removing large amounts of groundwater from the coal bed, especially in the initial phases where mainly water is produced and only small amounts of gas. About 7,200 to 28,800 gallons (27,255 to 109,020 litres) per day are initially pumped from a coal bed methane well to release the methane.[5] As production continues, the amount of water extracted reduces, and the amount of gas extracted increases until it peaks and declines. Typically a well peaks in production after one or two years. In order to maintain production rates from a seam more and more wells are needed to keep the gas flowing.

There are a variety of methods used to extract the methane, depending on the characteristics of the coal seam being exploited. In the most permeable seams, found at shallower depths, water is pumped out and the gas simply flows after it. Most seams are less permeable, and fracking or cavitation is sometimes used to break up the coal and allow the gas to flow more readily (see 'Fracking' and 'Cavitation' sections below). Other technologies such as multilateral wells (where one well exploits a number of seams) and horizontal drilling are also utilised.

Coal bed methane equipment

Occasionally de-watering is not required and wells produce gas immediately. This can be as a result of previous production or for wells completed in coal seams where water has been removed during mining operations.

Although producing Coal Mine Methane (CMM) can involve simply extracting the gas that has accumulated in old coal mines (in which case a CBM-air mixture is recovered, from which the methane can be separated), in practice, many of the same drilling extraction techniques used in CBM extraction, such as fracking, are also used.

CLIMATE CHANGE

It is sometimes argued that since burning natural gas produces less greenhouse gas (GHG) emissions than coal it can be used as a 'bridging' or 'transition' fuel, replacing coal while renewable energy technologies are developed and implemented. This argument is used by governments and industry to promote gas as a low carbon energy option. However, natural gas, whether it comes from shale or conventional sources, is a fossil fuel and when it is burned it releases significant GHG emissions. Further, as long as energy demand increases additional sources of fossil fuels such as coal bed methane are likely to supplement rather than replace existing ones such as coal.

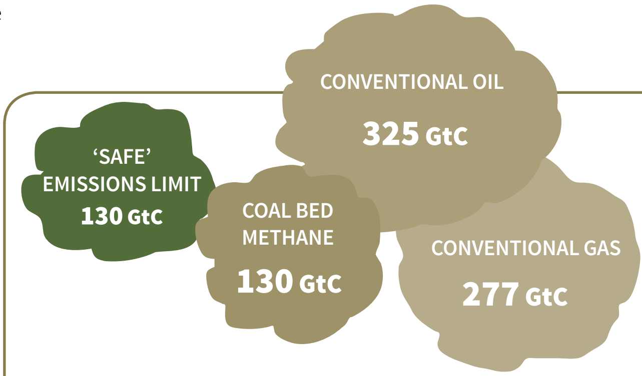
When comparing fuel types it is important to use lifecycle GHG emissions, the total GHG emissions generated by developing and using the fuel. In the case of CBM these include direct CO_2 emissions from end-use consumption (e.g. from burning gas in power plants), indirect CO_2 emissions from fossil fuel derived energy used to extract, refine and transport the gas, and methane from 'fugitive' emissions (leaks) and venting during well development and production.

The gas industry is particularly reluctant to investigate how much gas escapes as fugitive methane emissions in the process of extracting and transporting natural gas. However various studies have found significant leakage, and as methane is such a powerful GHG, even a small percentage of the gas extracted escaping to the atmosphere can have a serious impact on the climate.

Lifecycle emissions from CBM are similar to those of shale gas, but there are a number of factors that could mean either slightly greater or lower emissions. For example CBM requires lots of wells to be drilled into the seam to keep the gas flowing, all of which need to be connected to a central processor. This means additional sources of fugitive emissions from the wells and connecting pipes. During the initial phases when water is pumped from the coal seam, any gas that comes out with it is either flared (where gas is burned off) or vented directly to the atmosphere, but there is generally less gas flared or vented during these initial phases than with shale gas. Fracking is also normally used less with CBM than shale gas, which could mean lower fugitive emissions.

An investigation by Southern Cross University into atmospheric methane at a CBM field in Australia, found methane levels to reach 6.9 parts per million (ppm), compared to background levels of lower than 2 ppm outside the gas fields, suggesting significant leakage.[6] It has been estimated that leakage rates may be as high as 4.4%.[7]

Methane is a powerful greenhouse gas, particularly its short term influence on the atmosphere. This means that if more than 3.2% of extracted methane is lost to the atmosphere then switching from coal to gas will result in no immediate benefits in terms of contribution to climate change.[8]



If we are to reduce carbon emissions to anything like the levels required to maintain a reasonably habitable planet we must move away from all forms of fossil fuel as fast as possible. Measuring from the start of the industrial revolution (around 1750), a maximum of 500 Gigatonnes of carbon (GtC) can be emitted to the atmosphere while still avoiding most serious impacts and the risk of irreversible and uncontrollable changes to the climate.[9] *Between 1750 and now (2014), we have already emitted about 370 Gt leaving a limit of 130Gt that could be further added.*[10]

In order to stay within this limit we have to leave the vast majority of the remaining conventional oil, coal and gas in the ground. Estimates vary significantly, but remaining conventional coal reserves alone are well over 500GtC.[11]

Exploiting the world's CBM would add around 130 GtC to the atmosphere.[12] This is a huge amount and is clearly incompatible with staying within the limit outlined above. This means that rather than being part of the solution, the development of CBM is dramatically worsening the problem of climate change.

CBM and Carbon Capture and Storage (CCS)

Those involved in the CBM industry say it is ideally suited for CCS, as the coal seams that hold the methane will also readily take up CO_2. However in practice technical and economic problems have prevented the use of CCS at CBM sites. Only certain highly permeable coal seams would be appropriate for injecting CO_2, and not all CBM sites fit this criterion. Another problem with CCS in coal seams is the fact that the coal expands and reduces in permeability as it absorbs CO_2, meaning that injection becomes more and more difficult. CBM is also trapped in the coal and held in place by water pressure rather than by a layer of impermeable 'cap rock' above the seam (as is the case with conventional gas). As CO_2 dissolves in water much more readily than methane it is less likely to be held in place by water pressure. Injecting CO_2 into the coal seam is also used as a way to eke-out the remaining gas (see ECBM below).

Proponents of unconventional fossil fuels often argue that with CCS technologies, these new energy sources could be exploited at the same time as reducing GHG emissions. However, even if the huge problems with CCS technology are overcome (and this currently looking extremely unlikely), it would not change the fact that we need to move away from all forms of fossil fuel, conventional and unconventional, as soon as possible.

In the most optimistic (and highly implausible) scenario, CCS could be used to reduce a small proportion of emissions from fossil fuels. In reality, the promise of CCS being implemented in the future is being used to allow the continued expansion of fossil fuel production, to prevent alternatives from being developed, and to deflect attention away from approaches which tackle the underlying systemic causes of climate change and other ecological crises. Ultimately CCS is a smokescreen, allowing the fossil fuel industry to continue profiting from the destruction of the environment. (see 'Carbon Capture Storage' factsheet for more information).

Enhanced Coal Bed Methane (ECBM)

ECBM is the process of injecting CO_2 into a coal seam containing CBM in order to extract more gas. The CO_2 pushes out the remaining methane, and is intended to stay trapped in the coal. While the industry argues that this is a way of making CCS economical, in reality it is just a way to extract more methane [See enhanced recovery section Other Unconventional Fossil Fuels factsheet].

OTHER SOCIAL AND ENVIRONMENTAL ISSUES

Fracking

Fracking, or hydraulic fracturing, is used to free gas trapped in rock by drilling into it and injecting pressurised fluid, creating cracks and releasing the gas. The fracking fluid consists of water, sand and a variety of chemicals which are added to aid the extraction process e.g. by dissolving minerals, killing bacteria that might plug up the well, or reducing friction.

Fracking is sometimes used in CBM extraction and often takes place before water is pumped out from the coal bed. This means that most of the fracking fluid will be extracted along with the groundwater, adding further contaminants to the waste water. In Australia about a tenth of CBM sites have been hydraulically fractured to date, but this expected to grow to 40% or more, since there is a tendency to target the seams that are easiest to exploit first. A much higher proportion of CBM wells in the US are fracked.

As the coal seams are generally shallower and closer to aquifers CBM fracking poses a greater risk of contamination than when it is used to extract shale or tight gas and oil. Fracking can both create connections to aquifers and lead to cross-contamination between aquifers.

There has been a great deal of controversy over the chemicals contained in fracking fluids. In the US many companies have resisted revealing the recipes for their fracking mixes, claiming commercial confidentiality, or have adopted voluntary reporting measures in order to avoid stricter mandatory reporting requirements. Although the specific mix of chemicals used varies significantly, a US House of Representatives Committee on Energy and Commerce report found 750 different chemicals had been used in fracking fluids, including many known human carcinogens and other toxic compounds such as benzene and lead.[13] *Chemicals found to* *be most commonly used in fracking fluids such as methanol and isopropyl alcohol are also known air pollutants.*

A variety of chemicals are also added to the 'muds' used to drill well boreholes in order to reduce friction and increase the density of the fluid. Analysis of drilling mud has also found that they contain a number of toxic chemicals.[14 15]

Water use and waste water

Aside from climate change, the main environmental issues with CBM concern its impact on water resources. Extracting CBM involves removing large volumes of groundwater, and also results in large volumes of contaminated waste water. The contaminants in the waste water arise both from fracking chemicals, if they have been used, and from higher concentrations of harmful substances naturally present in coal-seams and coal-seam waters.

Waste water from CBM varies greatly depending on the geology of the coal seam, with deeper seams usually containing saltier water. It can be saline (with high concentrations of dissolved salt), or sodic (with high concentrations of sodium) or both. Highly saline or sodic waters damage soils and affect plant growth.[16]

As the water is pumped out it brings along the naturally occuring contaminants stored in the coal seam. These can typically include heavy metals,[17] radioactive material,[18] and hydrocarbons,[19] including carcinogenic organic compounds.

Waste water is dealt with in a variety of ways, either directly disposing of it into streams and rivers, discharging onto land or roads, storing in surface 'impoundments' and sending it to be processed, or re-injecting it into the coal seam or the rock below. All of these disposal methods have associated problems.

Surface impoundments are often unlined, meaning that subsurface water can be contaminated and accidents can lead to surface water contamination. Evaporation from impoundments can also further concentrate pollutants in CBM waste water.[20] Disposal on land or into streams and rivers pollutes the local environment,[21] and re-injection can lead to pollution of aquifers. Re-injection is also only possible in certain high-porosity formations located below saline aquifers, and risks contaminating ground water. Treatment of the contaminated water is extremely difficult due to the volumes involved, the salinity of the water, and the variety of containments present, particularly radioactive material.[22]

Effects on groundwater and aquifers

In some places coal seams are adjacent to or are themselves important aquifers, and both pumping out water for CBM extraction and re-injecting waste water can seriously affect local drinking water sources.

Extracting water for CBM production also affects pressures and flows of surrounding groundwater and can result in lowered water levels in aquifers, making water more difficult or impossible to access from wells and springs.[23] Water levels several miles away from the CBM site can be reduced by tens of feet and levels can take years or even decades to recover.[24]

The changes in water pressure can also mobilise naturally occurring pollutants, and enable any remaining fracking fluids to flow in to surrounding groundwater. Methane released in the process can also contaminate groundwater. Research on the health impacts on those living near CBM sites is now starting to emerge.[25 26]

Well failure and methane leakage

Methane can naturally leak from coal seams into surrounding aquifers. However, de-watering the coal seam for CBM extraction releases the methane and significantly increases the risk of seepage to aquifers, water wells and surface soil.[27] Methane pollutes drinking water and if it reaches soil it displaces oxygen, killing vegetation.

Failure of CBM well casings also increases the risk of leakage and contamination. Despite industry claims that leakage of methane and fracking chemicals is due to bad well design, research has shown that some leakage is inevitable and that fracking only exacerbates the problem.[28] Wells routinely lose their structural integrity and leak methane and other contaminants outside their casings and into the atmosphere and water wells. Even research by oil services company Schlumberger suggests half of conventional gas wells will be leaking within 15 years.[29] Failure rates for some CBM wells could be even higher due to fracking activities. Well failure is a problem as it contributes to both groundwater pollution and greenhouse gas emissions (see climate change section for more on methane leakage rates).

Cavitation

Cavitation or Open-Hole Cavity Completion involves injecting a very high pressure foamy mixture of air and water into the coal seam, then suddenly releasing the pressure, causing an explosive release of coal, water and rock from the well, a bit like shaking up a bottle of fizzy drink and taking the lid off. The violent process of liquid, foam and fragments of rock flowing out the well, sometimes know as 'surging' can last up to fifteen minutes and is extremely noisy. The cavitation process is repeated dozens of times over about a two week period,[30] expanding the diametre of the initial bore hole. It also connects the natural fractures in the coal, creating channels for gas to flow.

Gas produced by the process is vented or flared off, creating huge flames. Cavitation also produces significant quantities of coal and other solid waste which is burned or stored on-site. Caviataion is used as an alternative to fracking to increase permeability of coal seams, but is very unclear how frequently it is used, in what situations and how its use is evolving with time.

Industrialisation of countryside

In order to be economically viable CBM requires an ever expanding networking of wells, pipelines, compressor stations and roads to be built, leading to widespread industrialisation of the countryside. Equipment also needs to be monitored in future, meaning that the impact will last long after the wells have stopped producing gas. The various stages of CBM extraction also generate significant noise, through heavy traffic, drilling, gas compressors and other industrial equipment, flaring and explosions.

CBM operations have a very high density of wells (boreholes), typically varying between 1 to 3 wells per square kilometre.[31]

Underground fire risk

The process of removing water from the coal-seams during CBM extraction from old or operating mines increases the risk of underground fires, as oxygen from shafts and tunnels can replace the water and come into contact with the coal, resulting in spontaneous coal combustion. The lowering of the water table can also increase the fire risk to nearby seams. Underground coal fires pose a serious risk of groundwater contamination and are also a source of significant CO_2 emissions.

Air pollution

As well as GHG emissions, CBM extraction produces various sources of local air pollution, including increased vehicle traffic, venting and flaring, and pollutants from compressor stations. Air pollutants from CBM operations are likely to be similar to those of shale gas extraction including BTEX (benzene, toluene, ethylene and xylene), NOx (mono oxides of nitrogen), VOCs (volatile organic compounds), methane, ethane, sulphur dioxide, ozone and particulate matter.[32]

Subsidence

Removing large volumes of groundwater, particularly from shallow aquifers, can result in significant subsidence at the surface. This can damage infrastructure and put ground and surface water resources at risk. Depending on the site, removing water for CBM extraction can cause subsidence.[33] Many CBM sites are in former coalfield areas, where de-watering will have significant impacts on surface stability; reactivating old subsidence faults, as well as creating new ones. Subsidence also increases the risk of fugitive emissions, creating new pathways for gasses to escape to the atmosphere.

Accidents

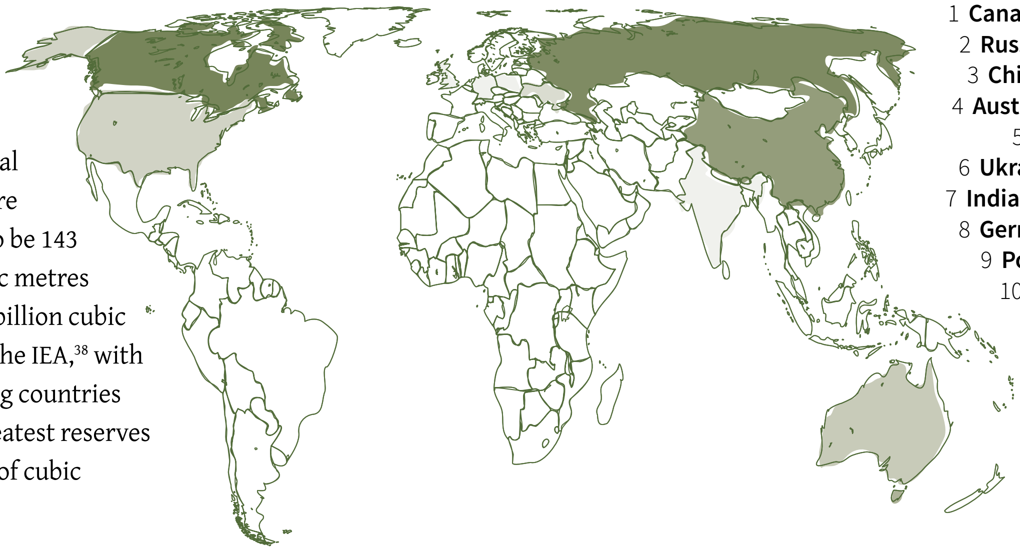
Despite industry claims of it being a safe, controlled process, countries that have carried out CBM activities have experienced numerous blow-outs, spillages and other accidents.[34] [35]These have resulted in serious ground and surface water contamination.

WHERE AND HOW MUCH?

Coal bed methane occurs around the world alongside coal resources, and although it is only currently extracted on a large scale in a few countries, it is being rapidly adopted in other places. Extraction is widespread in the US (over 55,000 wells), Canada (over 17,000 wells), Australia (over 5,000 wells) and China (thousands of wells). India also began commercial production in 2007 and now has hundreds of wells, and there are a handful of wells in the UK. Around forty other countries are looking into exploiting their CBM resources.[36]

The global market for coal bed methane was estimated to be 2,932 billion cubic feet (bcf) or 894 billion cubic metres (bcm) in 2010 and is predicted to reach market volumes of 4,074 bcf (1,242 bcm) by 2018.[37]

In 2006 global reserves were estimated to be 143 trillion cubic metres (or 143,000 billion cubic metres) by the IEA,[38] with the following countries have the greatest reserves (in trillions of cubic metres):



1 Canada **17-92**
2 Russia **17-80**
3 China **30-35**
4 Australia **8-14**
5 US **4-11**
6 Ukraine **2-12**
7 India **0.85-4.0**
8 Germany **3.0**
9 Poland **3.0**
10 UK **2.45**

COMPANIES INVOLVED

Current major players in the industry include:

Australia: QGC (BG Group), Santos, Origin

Canada: Apache, Encana, MGV

US: Pioneer, CONSOL, Williams

UK: Dart, IGas (though they are tiny compared to companies in other countries)

Other companies involved include Arrow Energy, Baker Hughes, Far East Energy Corp, Queensland Gas, Sydney Gas, Sinopec and PetroChina.

Many of the well known 'super majors' such as Royal Dutch Shell, ConocoPhillips, BP and ExxonMobil are also involved in CBM production.

RESISTANCE

Coal Bed Methane operations have been met with sustained resistance in the US and even more so in Australia, where the Lock the Gate movement has seen land owners, community groups and environmentalists join forces to prevent exploration and production of CBM (known as Coal Seam Gas in Australia).

For more information on resistance see the Corporate Watch website (corporatewatch.org/uff/resistance)

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UNDERGROUND COAL GASIFICATION

BURNING **COAL SEAMS** UNDERGROUND AND EXTRACTING THE RESULTING GAS TO USE AS FUEL.

VERY HIGH **WATER CONSUMPTION**, CATASTROPHIC GROUNDWATER CONTAMINATION, AND DRAMATICALLY INCREASES ACCESSIBLE COAL RESOURCES WITH SEVERE IMPLICATIONS FOR CLIMATE CHANGE.

WHAT IS IT?

Underground Coal Gasification (UCG) is a way of producing fuel from coal seams, generally those that are uneconomical to extract using conventional mining methods because they are too thin, too deep or too low-quality. Pairs of wells are drilled into the coal seam. One well is used to ignite the seam and control the flow of air, oxygen or steam, allowing the coal to be partially burned. The other well is used to extract the resulting gases which can then be separated at the surface into carbon dioxide, water, and syngas (see below). Prior to ignition, hydraulic fracturing (fracking), directional drilling, or various other techniques are used to connect the wells together and allow the gas to flow.

The syngas (an abbreviation of synthesis gas) is made up of hydrogen, methane, carbon monoxide, and can be directly burned to generate electricity, or used to make other fuels and chemicals such as hydrogen, ammonia and methanol. The process is chemically similar to how town gas (also known as coal gas) used to be made from coal before the adoption of natural gas in the mid 20th century.

Experiences with town gas should as serve as a warning. The industry left a legacy of highly contaminated industrial sites around the world. The UCG process results in similar pollutants, the main difference being that UCG takes place in the open environment instead of a sealed metal chamber, increasing the risk of contamination.

The idea of UCG has been around for a long time, and experiments have been carried out since the 1912 in the UK,[1] with further experiments in the 1930s. The use of the technology peaked in the 1960s in the Soviet Union, with up to 14 industrial-scale UCG fired power plants operating at different times between the 1950s and 1960s. Except for the Angren plant still operating in Uzbekistan, all the USSR's plants were closed down by the end of the 1960s, following significant natural gas discoveries. Initially projects exploited shallow, easily accessible coal seams, but recent technology such as directional drilling, means that deeper and harder to reach seams can now also be accessed.

Recent pilot projects have been carried out in Australia, China, New Zealand, South Africa, New Zealand, Canada and the US, and one commercial plant has been operating in Uzbekistan (Angren) for over 40 years.[2] A host of other countries are developing projects including the UK, Hungary, Pakistan, Poland, Bulgaria, Chile, China, Indonesia, India, and Botswana. Most UCG projects aim to produce electricity at the same site where extraction and gasification takes place. There are also plans to create liquid fuels from syngas using the Fischer-Tropsch process (so-called ‘coal to liquid’ technology – see separate factsheet).

Test projects have been plagued by accidents, and have resulted in massive long term groundwater pollution. The implications for climate change are disastrous, as the technology produces large greenhouse gas emissions and would give access to vast previously inaccessible coal resources.

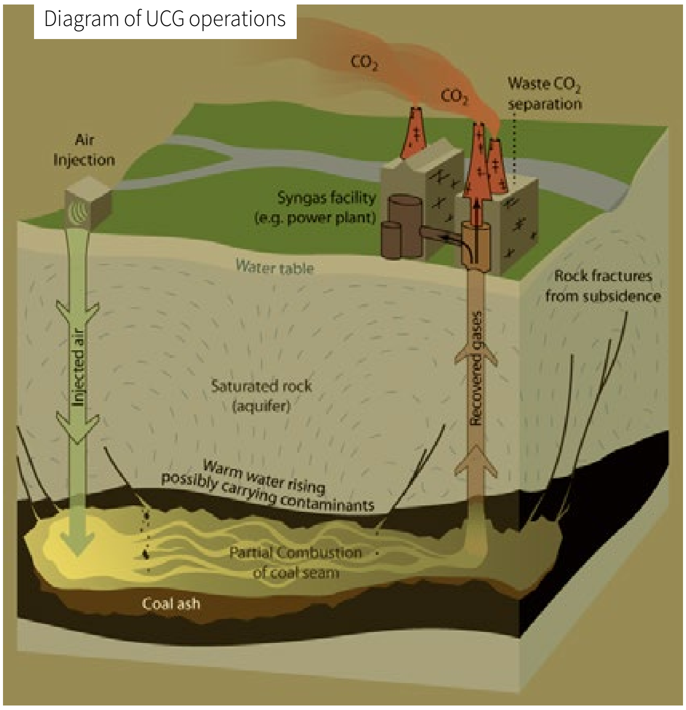

Diagram of UCG operations

CLIMATE CHANGE

Whether in coal power stations or using UCG, burning coal produces more greenhouse gas emissions (GHG) than almost any other fossil fuel. UCG is particularly inefficient as energy is wasted heating the rock surrounding the chamber where the gasification takes place (known as the gasifier or combustion chamber). Other processes, such as removing hydrogen sulphide from exhaust gasses also require large amounts of energy. Altogether around 40% of the energy from burning the coal is lost in the process.[3]

This wasted energy, combined with the high CO_2 content and relatively low energy content of the syngas, mean that UCG produces large greenhouse gas emissions. Reliable figures are difficult to find, but it has been estimated that UCG would have CO_2 emissions comparable with that from a conventional coal power station.[4]


Damage from coal seam fire in Glenwood springs, U.S.

"UCG PROJECTS AROUND THE WORLD HAVE BEEN PLAGUED WITH ACCIDENTS, INCLUDING EXAMPLES OF CATASTROPHIC GROUNDWATER CONTAMINATION"

Another issue is the amount of coal that UCG would allow to be accessed. Global coal resource figures vary significantly, but it has been estimated that there are still around 860 billion tonnes of coal remaining that can be accessed with conventional mining techniques,[5] possibly enough to last over a hundred years. However, using UCG technologies, coal seams that are uneconomical to mine can be exploited, giving access to even more coal, conservatively estimated as an extra 600 billion tonnes.[6] The real figure could be much higher, as the total global coal resources (which includes coal that cannot be accessed with current technology) have been estimated to be in the trillions of tonnes.[7]

If we are to reduce carbon emissions to anything like the levels required to maintain a reasonably habitable planet we must move away from all forms of fossil fuel as fast as possible. Measuring from the start of the industrial revolution (around 1750), a maximum of 500 Gigatonnes of carbon (GtC) can be emitted to the atmosphere while still avoiding most serious impacts and the risk of irreversible and uncontrollable changes to the climate.[8] *Between 1750 and now (2014), we have already emitted about 370 GtC leaving a limit of 130 GtC that could be further added.*[9]

In order to stay within this limit we have to leave the vast majority of the remaining conventional oil, coal and gas in the ground. Estimates vary significantly, but remaining conventional coal reserves alone are well over 500 GtC.[10]

Clearly developing UCG and giving access to enormous further coal resources, is absolutely incompatible with staying below this limit.

Carbon Capture and Storage (CCS)

Proponents of UCG say that the technology is ideally suited for combination with CCS as it is relatively easy to remove the concentrated CO_2 and inject it back into the exhausted coal seam. The argument then goes that CO_2 could be removed directly from the UCG gas, or from the flue gas after combustion. However, there are significant concerns over the viability of CCS and UCG technologies, and there are no demonstrated projects where they work in combination.

Despite industry claims that exhausted gasifiers would be ideal storage sites for CO_2 produced during the process, there are in fact a number of serious problems that make them unsuitable. The expected collapse of the rock layer above gasifier means that the integrity of any potential 'cap rock' is likely to have been compromised, allowing CO_2 to escape. High pressures and temperatures during and after gasification may also cause fracturing and changes in the permeability of the rock surrounding the gasifier, creating pathways through which CO_2 could escape.[11] There is also no guarantee that there is any 'cap rock' present above the coal-seam since, unlike oil and gas, coal seams don't need impermeable rock above them to hold the coal in place.

Due to high underground pressures, UCG carried out on deep coal seams would mean that the CO_2 would have to be stored in a 'supercritical' fluid state (a state in which the CO_2 has the density of a liquid but flows like a gas). If this supercritical fluid escapes to shallower depths where pressures are lower, the CO_2 would turn into gas, leading it to rapidly expand and become much more mobile. This could result in a sudden release of CO_2 gas to aquifers or even to the surface. CO_2 stored in the seam is also likely to react with pollutants and make them more mobile. It can also react with water and ash to make carbonic and sulphuric acid which can leach further contaminants from the rock, and reduce the sites' ability to store CO_2.[12] Due to these and other factors, investigations into UCG have concluded that "it is considered unlikely therefore, that sequestration in an exhausted gasifier could provide a secure long term repository of CO_2"[13] and that there "remains substantial scientific uncertainty in the environmental risks and fate of CO_2 stored this way".[14] CO_2 storage in adjacent coal seams is also being considered, however this would only be possible in the highest permeability seams.

There are also numerous critical problems with CCS itself, which remains a largely unproven technology, especially at the enormous scale that would be required (see CCS factsheet).

Proponents of unconventional fossil fuels often argue that with CCS technologies, these new energy sources could be exploited at the same time as reducing GHG emissions. However, even if the huge problems with CCS technology are overcome (and this currently looking extremely unlikely), it would not change the fact that we need to move away from all forms of fossil fuel, conventional and unconventional, as soon as possible.

In the most optimistic (and highly implausible) scenario, CCS could be used to reduce a small proportion of emissions from fossil fuels. In reality, the promise of CCS being implemented in the future is being used to allow the continued expansion of fossil fuel production, to prevent alternatives from being developed, and to deflect attention away from approaches which tackle the underlying systemic causes of climate change and other ecological crises. Ultimately CCS is a smokescreen, allowing the fossil fuel industry to continue profiting from the destruction of the environment. (see 'Carbon Capture Storage' factsheet for more information).

OTHER SOCIAL AND ENVIRONMENTAL ISSUES

Groundwater pollution

The various UCG projects that have been carried out around the world have been plagued with accidents, including examples of catastrophic groundwater contamination.[15] Studies in the Soviet Union in the 1960s revealed that UCG could result in widespread groundwater contamination.[16]

In the 1970s a project at Hoe Creek, Wyoming, USA resulted in massive groundwater contamination.[17] Potable groundwater was polluted with benzene, requiring an expensive long-term clean up operation.[18] In 2011, Brisbane based company Cougar Energy was ordered to shut down its trial underground coal gasification project at Kingaroy due to environmental concerns over benzene contamination.[19]

The gasification cavity is a source of both gas and liquid pollutants that risk contaminating nearby groundwater. These include mercury, arsenic and selenium,[20] coal tars containing phenols, BTEX (benzene, toluene, ethyl benzene, xylene) and other volatile organic compounds, and polycyclic aromatic hydrocarbons (PAHs).[21] [22] Of particular concern are benzene and phenols, as they are water soluble, can be transported by other chemicals, and are more likely to float upwards due to their low molecular weight. Altogether, one hundred and thirty-five compounds that might pollute the local groundwater sources near UCG sites have been identified.[23]

There have been instances of contaminants being forced out into groundwater due to high pressures in the gasifier. The industry claims that by maintaining pressures lower than those in the surrounding grounwater they can eliminate the risk of contamination, as water will flow towards the gasifier rather than away from it. However, in practice controlling the pressures has proven difficult, and operating at lower pressures can result in less efficiency and more contamination.[24] The Chinchilla test site in Australia claimed to have prevented contamination by controlling pressures, however others described it as

Damage from an underground coal fire in Centralia, U.S.

"rather unsuccessful".[25] In addition, during previous test projects gasses escaped from the gasifier, finding the paths of least resistance, and carrying liquid pollutants along with them against the direction of groundwater flow.[26] Any large open fissures or faults, the presence of which could be impossible to predict, would create emission pathways that could not be controlled by changing the pressures. Coal seams typically contain many natural fractures.

In many demonstration projects in shallow seams the area above the combustion chamber collapsed, and it is assumed at deeper sites that this will always happen. This can cause surface subsidence (see below), but also creates fractured pathways around the collapsed chamber for contaminants to leak into the groundwater. There is also the possibility of so called 'cross contamination' where already poor quality groundwater around the coal seam can flow to good quality ground water areas due to the changes in rock structures and water pressures caused by the UCG process. Another issue is the fact that the heat generated by gasification causes groundwater above the gasifier to rise, carrying contaminants with it.

The contaminated ash left in the exhausted coal seam will remain there more or less indefinitely, meaning that it is a potential source of groundwater contamination decades or even centuries after gasification. Due to the depth of the coal seams where most UCG would be likely to take place it would also be extremely difficult to deal with any water contamination problems.

Water consumption, waste and surface water

Several aspects of the UCG process (such as initial mining, operation, then flushing and venting once gasification has finished) require injecting and extracting water from the gasifier. This means that the process consumes large volumes of water and produces large volumes of contaminated water. Waste water will vary significantly in terms of the contaminants present, as different coal seams and different stages of the process will generate different pollutants. This makes treating the waste water particularly difficult.

There is also the risk of surface spillage from waste water storage facilities and transportation, and pollutants being released to the environment due to accidents at the site. In Australia, Carbon Energy was charged in 2011 with not reporting a series of "very serious" incidents involving spills and disposal of waste water.[27]

Syngas and air pollution

The burning of UCG syngas at the surface to produce electricity is known to generate air pollution, including oxides of sulphur and nitrogen, hydrogen sulphide, particulates and heavy metals such as mercury and arsenic.[28] The syngas also contains contaminants which create problems for processing and transportation. These contaminants include dust, soot and tars which can clog up pipes and equipment; oxygen, from air or poor combustion control, which can potentially result in explosive mixtures; chlorine and chlorine compounds which can corrode equipment.[29]

Subsidence

As the reaction burns through the coal seam in the gasification chamber, it leaves a hole behind it filled with ash. The roof area directly above this hole usually collapses, which can result in subsidence at the surface, potentially damaging roads and buildings. The risk and extent of surface subsidence is greater the shallower the exploited coal-seam is, the larger the dimensions of the combustion chamber are and the weaker the rock is above the coal-seam. Underground and resulting surface subsidence can also affect the drainage patterns of surface water, the movement of ground water, with the potential to increase contamination, and can damage UCG injection and production wells.

A burning coal seam

Explosions and accidents

The high temperature and pressure flammable gases created by UCG, along with the blockages which can result from tar and soot contaminants mean there is the potential for explosions. This happened at the European UCG trial in Thulin, Belgium (1979-87), intended to test the feasibility of UCG on deeper coal seams. The trial had to be halted after one of the supply tubes to the burner became blocked leading to an underground explosion which damaged the injection well.[30] In 1984, another test project in France was stopped due to tar and particles blocking the production well.[31]

During tests in the 1990s in Spain, an attempt to restart a UCG operation caused the accumulation of methane underground resulting in an explosion which damaged the production well.[32] The injection and production wells are also prone to being damaged, as the gasification process results in extreme temperatures and pressures, and creates (as discussed above) cavities that are likely to collapse and compromise the integrity of the wells.

Scale

UCG plants produce a relatively small amount of power. The European trial in Tremedal, Spain in the 1990s only sustained gasification for a few days at a time, and briefly peaked to produce gas with the equivalent of 8 Mega Watts (MW)of power.[33] Eskom's trial project in South Africa has a similar output of about 9 MW.[34] A small coal fired power station produces well over a hundred times this much power and gets through as much coal in a day as many of the test projects burned in a year. Taking into account the energy lost from producing and burning the syngas, this means hundreds, possible even thousands of UCG plants could be required in order to replace just one coal power station. Considering the greenhouse gas emissions and the impact on groundwater resources experienced in test projects, scaling up UCG technology to provide a significant proportion of our energy would have a devastating impact on local environments and the global climate.

Industrialisation of countryside

UCG sites also require industrial equipment at the surface including drilling rigs, wellheads, connecting pipework, and plants for handling and processing the injection and production gases. As operations continue, additional wells and pipelines will be required, progressing further away from surface plants to access new coal supplies. There will also be a substantial increase in traffic volumes, in order to transport equipment and waste.

Damage from an underground coal fire in Centralia, U.S.

Uncontrolled burns

Coal seams sometimes start burning naturally as a result of lightning, forest fires or spontaneous combustion following exposure to oxygen in air. These fires can continue to burn for decades or even centuries. When close to the surface, oxygen from the atmosphere fuels the fire, with subsidence from the burning seam often providing more air as the burn continues. In uncontrolled burns at greater depths, such as old deep coal mines, the oxygen usually comes from ventilation shafts. Coal seam fires can have serious consequences. For example, in Centralia, Pennsylvania, US an uncontrolled mine fire beneath the borough that has been burning since 1962 has resulted in the population dwindling from over 1,000 residents in 1981 to 10 in 2010.[35]

Even with UCG of deeper coal seams there is a risk of uncontrolled burns as forgotten mine shafts, boreholes, damaged wells or geological faults could provide a source of air

WHERE, HOW MUCH AND WHO?

In recent years there has been renewed interest in UCG. There are about 30 projects using underground coal gasification in various phases of preparation in China and the Indian government has plans to use UCG to access the country's huge remaining coal reserves.[36]

South African companies Sasol and Eskom both have UCG pilot facilities that have been operating for some time. In Australia, Linc Energy has the Chinchilla site, which first started operating in 2000. Demonstration projects and studies are also currently under way in the USA, Western and Eastern Europe, Japan, Indonesia, Vietnam, India, Australia and China.[37] The Chukotka autonomous district in Russia's Far East looks set to be the first place in the country to implement the technology,[38] and Eon has signed a memorandum of understanding with the Hungarian government to develop UCG projects.

In the UK Cluff Natural Resources have plans to implement the first UK UCG site in Warwickshire. Another UK company, Clean Coal Ltd, had planned to carry out the first UK test project under Swansea Bay in Wales.

Other notable companies around the world involved in the development of UCG include: Swan Hills Synfuels in Alberta, Virginia, USA, Santos in New South Wales, Australian and Carbon Energy and Portman Energy which have developed UCG techniques.

In addition, the Underground Coal Gasification Association,[39] an industry membership organisation, has been playing a key role in promoting the technology.

For more information on resistance see the Corporate Watch website (corporatewatch.org/uff/resistance)

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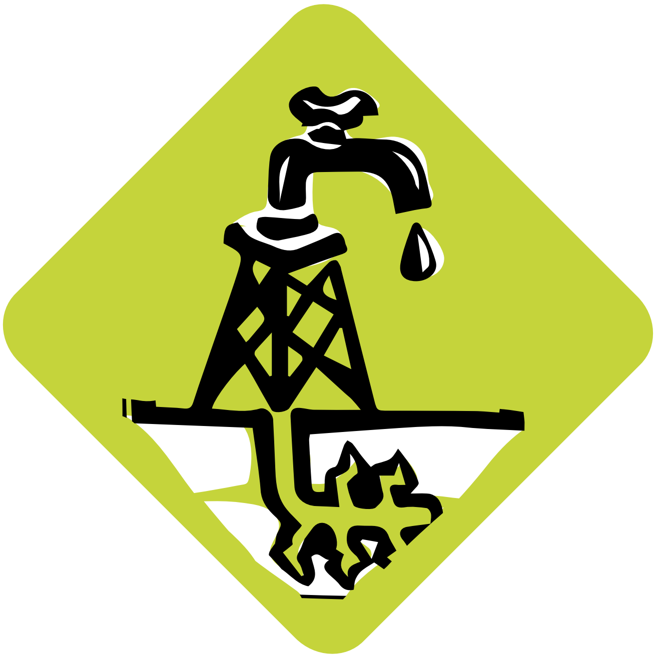


SHALE OIL
(TIGHT OIL)

CRUDE OIL FOUND IN **SHALE** OR OTHER ROCK WHERE IT IS TIGHTLY HELD IN PLACE AND DOES NOT FLOW EASILY.

REQUIRES USE OF **FRACKING** WITH RISK OF **WATER POLLUTION** AND WORSENS CLIMATE CHANGE.

WHAT IS IT?

Shale oil, or tight oil, is a type of crude oil that is found in low permeability rock formations such as shale or tight sandstone. The 'tight' refers to the fact that the oil is tightly trapped in the rock, unlike conventional oil formations where the oil flows relatively easily. Recent technologies used for shale gas extraction, such as fracking and horizontal drilling, have made it economical to extract shale and tight oil.

HOW IS IT EXTRACTED?

Shale oil has been known about for a long time, but has only been exploited on a large-scale in the last ten years or so. This has partly been driven by the development of two technologies: horizontal drilling, which opens up deposits inaccessible by conventional vertical drilling, and advanced hydraulic fracturing, or fracking.

Fracking is used to free oil or gas trapped in rock by drilling into it and injecting pressurised fluid, creating cracks and releasing the oil or gas. The fracking fluid consists of water, sand and a variety of chemicals which are added to aid the extraction process e.g. by dissolving minerals, killing bacteria that might plug up the well, or reducing friction. The fracking process produces a large volume of waste water, containing a variety of contaminants both from the fracking fluid, and toxic and radioactive materials which are leached out of the rocks. In addition to fracking, acidisation is also sometimes used. This is where the well is pumped with acid to dissolve the rock that is obstructing the flow of oil.

Production from shale oil wells declines very quickly and so new wells must be drilled constantly. This process of continual drilling and fracking means that huge areas of land are covered with well pads where thousands of wells are drilled, with each well requiring millions of litres of water.

Shale and tight oil deposits are also highly heterogenous, meaning there is substantial variation within the formation in the qualities of the rock and the oil it contains. Even adjacent wells can have very different production rates. The oil that is extracted from shale is very similar to crude oil from conventional sources and does not require further processing before it can be refined.

Oil shale or shale oil?

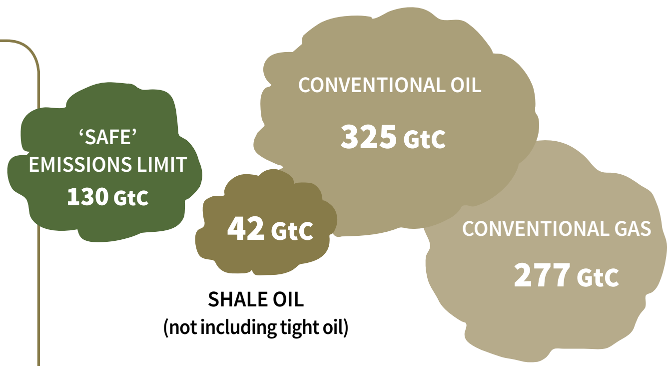
Confusingly, 'shale oil' can refer oil extracted from shale rock using techniques such as fracking, or to the liquid fuel extracted from 'oil shale' by heating it (see separate Oil Shale factsheet). The first definition began being used when the US boom in shale gas resulted in shale formations also being exploited for oil. A great deal of confusion and disagreement persists, but many have started to use the term 'tight oil' to refer to oil extracted from shale formations using horizontal drilling and fracking. Even more confusingly, the term 'oil shale', which usually means the oily rock rich in kerogen (discussed in a separate factsheet), is also sometimes used to refer to shale formations which contain oil. Baffled? Well, you're not alone!

CLIMATE CHANGE

Oil, whether from shale or conventional sources, is a fossil fuel and releases significant greenhouse gas emissions when burned. As long as energy demand increases additional sources of fossil fuels such as shale oil are likely to supplement rather than replace other existing ones such as coal.

If we are to reduce carbon emissions to anything like the levels required to maintain a reasonably habitable planet we must move away from all forms of fossil fuel as fast as possible. Measuring from the start of the industrial revolution (around 1750), a maximum of 500 Gigatonnes of carbon (GtC) can be emitted to the atmosphere while still avoiding most serious impacts and the risk of irreversible and uncontrollable changes to the climate.[1] Between 1750 and now (2014), we have already emitted about 370 GtC leaving a limit of 130 GtC that could be further added.[2]

In order to stay within this limit we have to leave the vast majority of the remaining conventional oil, coal and gas in the ground. Estimates vary significantly, but remaining conventional coal reserves alone are well over 500GtC.[3]



Exploiting the world's shale oil resources would add around 42 GtC to the atmosphere.[4] This is certainly an underestimate as it excludes Russia, which is estimated to have the largest shale oil reserves, much of the Middle East, and tight oil formations other than shale. The carbon locked up in shale and tight oil represents a huge source of emissions which, given the limits outlined above, we clearly cannot afford to add to the atmosphere.

Carbon Capture and Storage (CCS)

Proponents of unconventional fossil fuels often argue that with CCS technologies, these new energy sources could be exploited at the same time as reducing GHG emissions. However, even if the huge problems with CCS technology are overcome (and this currently looking extremely unlikely), it would not change the fact that we need to move away from all forms of fossil fuel, conventional and unconventional, as soon as possible.

In the most optimistic (and highly implausible) scenario, CCS could be used to reduce a small proportion of emissions from fossil fuels. In reality, the promise of CCS being implemented in the future is being used to allow the continued expansion of fossil fuel production, to prevent alternatives from being developed, and to deflect attention away from approaches which tackle the underlying systemic causes of climate change and other ecological crises. Ultimately CCS is a smokescreen, allowing the fossil fuel industry to continue profiting from the destruction of the environment. (see 'Carbon Capture Storage' factsheet for more information).

There has been some discussion about the possibility of using exhausted shale oil formations as a place for storing carbon dioxide. Injecting CO_2 into fracked shale formations is also being considered as a way of both storing carbon and extracting more oil at the same time (so called Enhanced Oil Recovery – see 'Other Unconventional Fossil Fuels' factsheet). However, their viability as CO_2 storage sites is questionable, and there are currently no shale oil sites being used to store CO_2. In addition there are concerns that fracking may be compromising other potential CO_2 storage sites, as the fracked shale formations are no longer impermeable and would therefore not keep CO_2 trapped in the deep saline aquifers below them.[5]

In addition fracking, the underground injection of fracking waste water (see below), and even the injection of CO_2 itself have been shown to cause earthquakes, which reveal a major flaw in CCS technology.[6] [7]

Fracking equipment

Other social and environmental issues

Water use

The fracking process uses huge volumes of water, which becomes contaminated and cannot be returned to the water table. Depending on the characteristics of the well, the amount of water needed will be somewhere between about 3 million and 40 million litres.[8]

Sourcing water for fracking is a major problem. Because of transportation costs of bringing water from great distances, drillers in the US usually extract on-site water from nearby streams or underground water supplies. This puts pressure on local water resources which can lead to the worsening of droughts.[9] In 2011, the U.S. Environmental Protection Agency estimated that 70 to 140 billion gallons (265 – 531 billion litres) of water are used to fracture 35,000 wells in the United States each year.[10]

Water pollution

There has been a great deal of controversy over the chemicals contained in fracking fluids. In the US many companies have resisted revealing the recipes for their fracking mixes, claiming commercial confidentiality, or have adopted voluntary reporting measures in order to avoid stricter mandatory reporting requirements. Although the specific mix of chemicals used varies significantly, a US House of Representatives Committee on Energy and Commerce report found 750 different chemicals had been used in fracking fluids, including many known human carcinogens and other toxic compounds such as benzene and lead.[11] Chemicals found to be most commonly used in fracking fluids such as methanol and isopropyl alcohol are also known air pollutants.

A variety of chemicals are also added to the 'muds' used to drill well boreholes in order to reduce friction and increase the density of the fluid. Analysis of drilling mud has also found that they contain a number of toxic chemicals.[12 13]

Waste water

Shale oil extraction results in large volumes of waste water contaminated by fracking fluids and naturally occurring chemicals leached out of the rock. These can include dissolved solids (e.g., salts, barium, strontium), organic pollutants (e.g., benzene, toluene) and normally occurring radioactive material (NORM) such as the highly toxic Radium 226.[14]

The volumes of waster water generated and the kinds of contaminants it contains makes treating and disposing of it safely extremely challenging. Treatment of waste water is expensive and energy intensive, and still leaves substantial amounts of residual waste that then has to be disposed of. In addition the waste water from most sites would have to transported large distances to specialised treatment plants.

In many cases, the waste water is re-injected back into the well, a process that has been shown to trigger earthquakes (see earthquake section below). In the US, there have been numerous cases of dumping of drilling cuttings and storage of waste water in open evaporation pits. In some cases waste water has even been disposed of by spreading it on roads under the guise of dust control or de-icing.

Any accidental spillages could have serious environmental and human health consequences.

Human and animal health

It is difficult to assess the health effects of fracking sites, as many impacts will take time to become apparent and there is a lack of background data and official studies. Despite this there is mounting evidence linking fracking activities to local health impacts on humans and animals.[15 16 17]

Air Pollution

Air pollution at shale oil sites includes emissions from vehicle traffic, flaring and venting during drilling and completion (where gas is burned off or released to the atmosphere) and on-site machinery. Local air pollution from these sources is likely to be similar to that of shale gas extraction, including BTEX (benzene, toluene, ethylene and xylene), NOx (mono oxides of nitrogen), VOCs (volatile organic compounds), methane, ethane, sulphur dioxide, ozone and particulate matter.[18]

Industrialisation of countryside

As shale is impermeable the oil cannot easily flow through it and wells are needed wherever there is oil. This means that, unlike conventional oil, exploiting tight oil requires large numbers of wells to be be drilled. In the US tens of thousands of shale wells have been drilled leading to widespread industrialisation of the landscape in some states.

It has been estimated that fracking requires 3,950 truck trips per well during early development of the well field.[19] A single well pad could generate tens of thousands of truck journeys over its lifetime[20] In addition to these increases in traffic for transportation of equipment, waste water and other materials the site itself creates significant noise, light pollution and direct impact on local wildlife and ecosystems.

Earthquakes

Underground fluid injection has been proven to cause earthquakes, and there are instances in the UK where fracking has been directly linked to small earthquakes.[21] The injection of waste water from fracking back in to wells has also been shown to cause earthquakes.[22] Although these earthquakes are usually relatively small, they can still cause minor structural damage and of particular concern is the possibility of damaging the well casings thus risking leakage. This did in fact happen after the earthquake at Cuadrilla's site in Lancashire, UK. The company failed to report the damage and were later rebuked by the then UK energy minister, Charles Hendry, for not doing so.

Occasionally larger earthquakes are triggered. A 2013 study in prestigious journal Science linked a dramatic increase in seismic activity in the midwestern United States to the injection of waste water. It also catalogues the largest quake associated with waste water injection, which occurred in Prague on November 6, 2011. This measured 5.7 on the Richter scale, and destroyed fourteen homes, buckled a highway and injured two people.[23] It should be noted that mining and conventional gas and oil extraction can also cause earthquakes.

Jobs

In practice much of the employment for oil shale developments are from outside the area in which the oil is extracted, and any boost to the local economy is relatively short lived as the industry moves on once wells are depleted. This undermines the argument, often used by those trying to promote the industry, that it will generate large-scale employment.

Economic issues

It is sometimes argued that shale oil can be used as a 'bridging fuel' in the short term while renewables are developed.[24] However, estimates of reserves containing so many years' worth of a country's oil supply ignore the fact that it will take many years and thousands of wells drilled before production rates rise sufficiently to provide significant amounts of fuel.

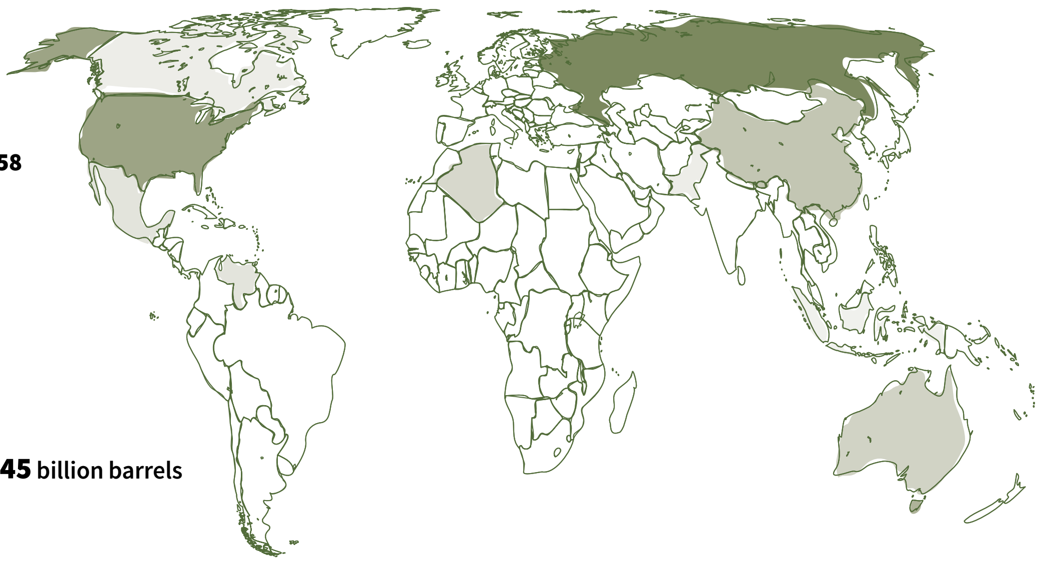
In addition, as the most productive shale plays and their 'sweet spots' are used up first, it becomes increasingly more expensive, both in terms of money and energy, to maintain production levels and there are various predictions that the shale oil boom in the US may be short lived.[25] Concerns that the same kind of financial practices that led to the US housing bubble were used to provide investment (with the prospect of profitable merger and acquisition deals attracting the financial sector) are leading some to predict that the financial bubble behind the US shale boom will burst, possibly even risking another global economic crisis.[26]

WHERE AND HOW MUCH?

According to the International Energy Agency,[27] economically recoverable shale oil reserves around the world are as follows (in billions of barrels):

1 Russia **75**
2 United States **48-58**
3 China **30-35**
4 Australia **27**
5 Libya **26**
6 Venezuela **13**
7 Mexico **13**
8 Pakistan **9**
9 Canada **9**
10 Indonesia **8**

World Total **335-345** billion barrels



However, these figures are only for shale rather than other tight oil formations, and do not include most of the Middle East or Russia, which is estimated to have the largest shale oil resources in the world.

In the United States, where the industry has undergone rapid development over the last ten years or so, the Bakken, Eagle Ford, Niobrara and Permian fields hold large resources of shale oil. At least 4,000 new shale oil wells were brought online in the United States in 2012.[28] Canada also has an advanced shale oil industry.

Other countries are also now beginning to consider exploiting their shale oil resources. In particular China, Mexico and Argentina are aggressively pursuing shale oil extraction. China and Mexico have been hampered by lack of expertise and difficulties with national oil and gas companies. In Argentina the industry is set to rapidly expand with a deal between the national oil and gas company YPF S.A. and Chevron to produce both shale gas and shale oil from the Vaca Muerta (Dead Cow) basin, believed to hold as much as 23 billion barrels of oil equivalent.[29]

Russia has the largest shale oil resources, but seems unlikely to exploit them in the near future, as it still has large reserves of other, easier to extract fossil fuels.[30]

COMPANIES INVOLVED

In the US multinational super-major corporations such as Exxon, Shell and Total do not dominate the shale oil industry. Mostly the work is undertaken instead by American companies, ranging in size from tiny start-ups to mid-sized companies worth tens of billions. Notable US shale companies include Chesapeake Energy, Continental Resources, Occidental Petroleum, Pioneer Natural Resources, Apache, Whiting Petroleum, Hess, EOG Resources, ConocoPhillips and Chesapeake.

Often small companies carry out the initial exploratory drilling and testing in places where the industry is in a fledgling stage. If the process is proved economically viable these companies are often bought up by larger companies. In this way, the bigger companies are protected from any loses, should the testing prove unsuccessful.

RESISTANCE

There has been widespread resistance to fracking wherever it has been conducted. The most active national movement is in the US, and many have been inspired by the film Gaslands. Protests have spurred various countries, including France, Bulgaria, Romania and the Czech Republic to adopt moratoriums or outright bans on fracking.[31]

Protesters in a number of countries have used direct action and civil disobedience to oppose fracking. The 'Lock the Gate' movement in Australia saw environmental activists and local communities linking together, using blockades in their attempts to prevent exploration.

In the village of Pungesti, in Romania, the local community have managed to remove and sabotage Chevron's equipment to test fracking, despite receiving violent police repression for doing so. Similarly, indigenous Elsipogtog First Nation and other local residents blocked a road near Rexton, New Brunswick in Canada successfully preventing South Western Energy from carrying out tests at a potential fracking site. In the UK there have been community blockades of potential fracking sites, for instance at Balcombe in Sussex and Barton Moss in Lancashire.

For more information on resistance see the Corporate Watch website (corporatewatch.org/uff/resistance)

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TO THE ENDS OF THE EARTH

A GUIDE TO UNCONVENTIONAL FOSSIL FUELS

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