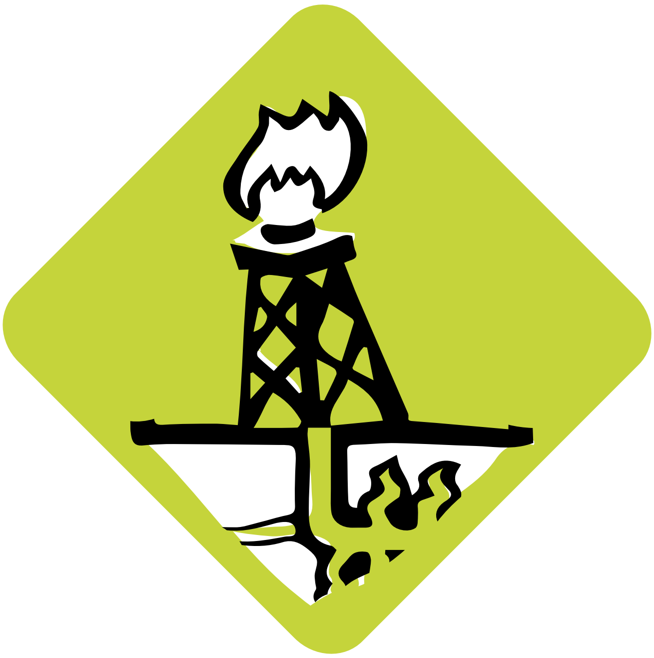


SHALE GAS (TIGHT GAS)

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.

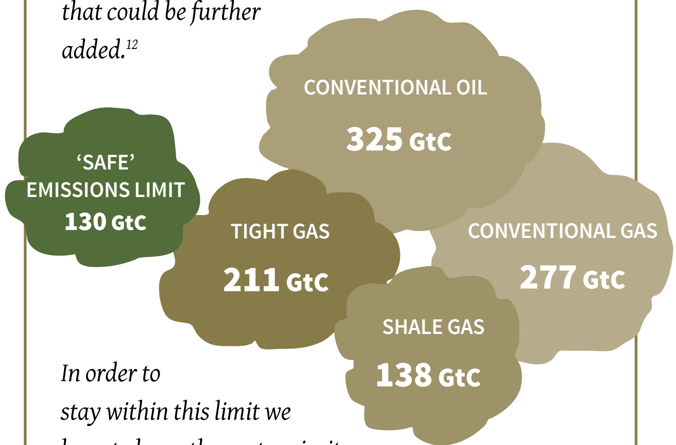
There is a lot of debate about how much gas escapes as fugitive methane emissions in the process of extracting and transporting natural gas. The gas industry is particularly reluctant to investigate this, which is partly why it is hard to find reliable figures. However various studies have found significant 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]

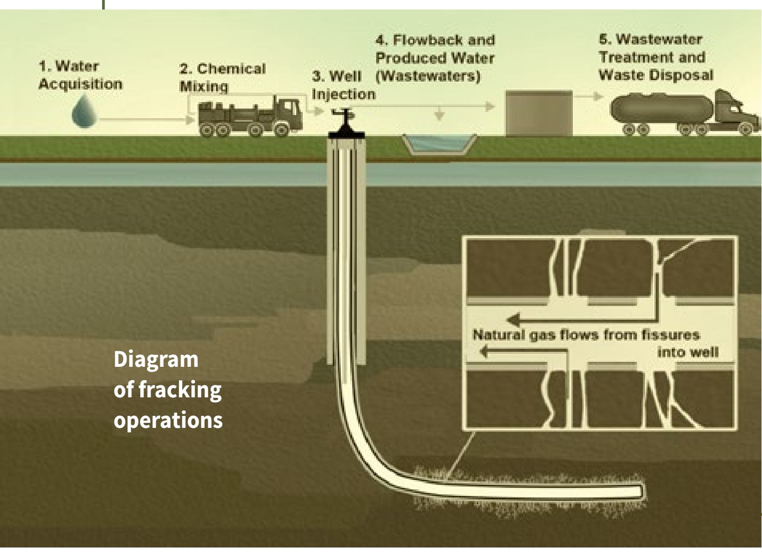


Diagram of fracking operations

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]

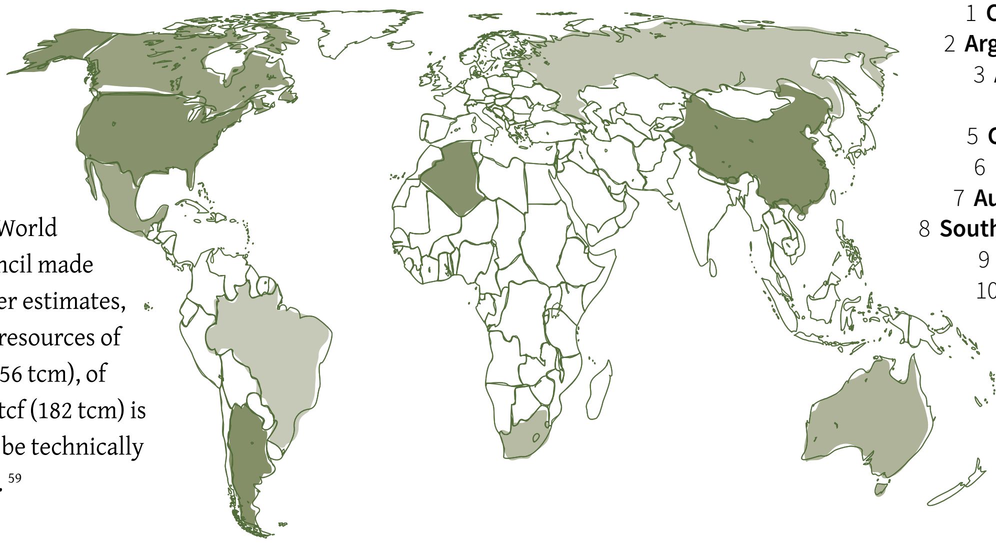
In the US, which is largely isolated from the world gas market due to transport issues, the shale gas boom has coincided with a recession, which has led to a reduction in energy demand and gas prices. This has actually made it uneconomical to produce shale gas, and has stalled drilling. Well production 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.

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)

ENDNOTES

1 Broderick, J., and K. Anderson. 'Has US shale gas reduced CO2 emissions? Examining recent changes in emissions from the US power sector and traded fossil fuels (Technical Report)'. *Manchester: Tyndall Centre* (2012).‹http://tyndall.ac.uk/publications/technical-report/2012/has-us-shale-gas-reduced-co2-emissions›

2 Howarth, R. W., R. Santoro, and A. Ingraffea. 'Methane and the greenhouse gas footprint of natural gas from shale formations'. *Climatic Change Letters* (2011), DOI: 10.1007/s10584-011-0061-5. ‹http://link.springer.com/article/10.1007%2Fs10584-011-0061-5›

3 (estimates also within the 3.6% to 7.9% range) Pétron, G. *et al. J. Geophys. Res.* 117, D04304 (2012)

4 (estimates also within the 3.6% to 7.9% range) 'Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010' (Chapter 3: Energy). US EPA (2012). ‹http://epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2012-Chapter-3-Energy.pdf›

5 Howarth, Robert W., Renee Santoro, and Anthony Ingraffea. 'Venting and Leaking of Methane from Shale Gas Development: Response to Cathles et Al.' *Climatic Change* 113, no. 2 (1 February 2012): 537–549. doi:10.1007/s10584-012-0401-0. ‹http://www.eeb.cornell.edu/howarth/publications/Howarthetal2012_Final.pdf›

6 'New Study Shows Total North American Methane Leaks Far Worse than EPA Estimates'. *DeSmogBlog*. Accessed 28 February 2014. ‹http://www.desmogblog.com/2014/02/14/new-study-shows-total-north-american-methane-leaks-far-worse-epa-estimates›

7 Karion, Anna, Colm Sweeney, Gabrielle Pétron, Gregory Frost, R. Michael Hardesty, Jonathan Kofler, Ben R. Miller, et al. 'Methane Emissions Estimate from Airborne Measurements over a Western United States Natural Gas Field: CH_4 EMISSIONS OVER A NATURAL GAS FIELD'. *Geophysical Research Letters* 40, no. 16 (28 August 2013): 4393–4397. doi:10.1002/grl.50811. ‹http://onlinelibrary.wiley.com/doi/10.1002/grl.50811/abstract›

8 Tollefson, Jeff. 'Methane Leaks Erode Green Credentials of Natural Gas'. *Nature* 493, no. 7430 (2 January 2013): 12–12. doi:10.1038/493012a. ‹http://www.nature.com/news/methane-leaks-erode-green-credentials-of-natural-gas-1.12123#/b1›

9 Peischl, J., T. B. Ryerson, J. Brioude, K. C. Aikin, A. E. Andrews, E. Atlas, D. Blake, B. C. Daube, J. A. de Gouw, E. Dlugokencky, G. J. Frost, D. R. Gentner, J. B. Gilman, A. H. Goldstein, R. A. Harley, J. S. Holloway, J. Kofler, W. C. Kuster, P. M. Lang, P. C. Novelli, G. W. Santoni, M. Trainer, S. C. Wofsy, D. D. Parrish. 'Quantifying sources of methane using light alkanes in the Los Angeles basin, California'. *J. Geophys. Res. Atmos.*, doi:10.1002/jgrd.50413, 2013. ‹http://www.esrl.noaa.gov/csd/news/2013/140_0514.html›

10 Alvarez, R. A., Pacala, S. W. Winebrake, J. J., Chameides, W. L. & Hamburg, S. *P. Proc. Natl Acad. Sci. USA* 109, 6435–6440 (2012). ‹http://www.pnas.org/content/109/17/6435›

11 Hansen, James, Pushker Kharecha, Makiko Sato, Valerie Masson-Delmotte, Frank Ackerman, David J. Beerling, Paul J. Hearty, et al. 'Assessing "Dangerous Climate Change": Required Reduction of Carbon Emissions to Protect Young People, Future Generations and Nature'. Edited by Juan A. Añel. *PLoS ONE* 8, no. 12 (3 December 2013): e81648. doi:10.1371/journal.pone.0081648. ‹http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0081648›

12 Ibid

13 Ibid

14 ‹http://www.corporatewatch.org/uff/carbonbudget›

15 Elliot, T. R., and M. A. Celia. 'Potential Restrictions for CO_2 Sequestration Sites Due to Shale and Tight Gas Production'. *Environmental Science & Technology* 46, no. 7 (3 April 2012): 4223–4227. doi:10.1021/es2040015.‹http://pubs.acs.org/doi/abs/10.1021/es2040015›

16 Verdon, J. P., J.- M. Kendall, A. L. Stork, R. A. Chadwick, D. J. White, and R. C. Bissell. 'Comparison of Geomechanical Deformation Induced by Megatonne-Scale CO_2 Storage at Sleipner, Weyburn, and In Salah'. *Proceedings of the National Academy of Sciences* 110, no. 30 (8 July 2013): E2762–E2771. doi:10.1073/pnas.1302156110. ‹http://www.pnas.org/content/early/2013/07/03/1302156110.abstract›

17 Gan, W., and C. Frohlich. 'Gas Injection May Have Triggered Earthquakes in the Cogdell Oil Field, Texas'. *Proceedings of the National Academy of Sciences* 110, no. 47 (4 November 2013): 18786–18791. doi:10.1073/pnas.1311316110. ‹http://www.pnas.org/content/early/2013/10/31/1311316110›

18 Cooley, H, Donnelly, K. 'Hydraulic Fracturing and Water Resources: Separating the Frack from the Fiction'. *Pacific Institute* (June 2012). ‹http://www.pacinst.org/wp-content/uploads/2013/02/full_report35.pdf›

19 'Draft Plan to Study the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources'. *US EPA.* (Feb 2011).‹http://yosemite.epa.gov/sab/sabproduct.nsf/0/D3483AB445AE61418525775900603E79/$File/Draft+Plan+to+Study+the+Potential+Impacts+of+Hydraulic+Fracturing+on+Drinking+Water+Resources-February+2011.pdf›

20 'A Texan tragedy: ample oil, no water'. *Guardian website* (Retrieved Feb 2014). ‹http://www.theguardian.com/environment/2013/aug/11/texas-tragedy-ample-oil-no-water›

21 'Chemicals used in hydraulic fracturing'. *United States House of Representatives, Committee on Energy and Comerce Minority Staff* (April 2011). ‹http://democrats.energycommerce.house.gov/sites/default/files/documents/Hydraulic-Fracturing-Chemicals-2011-4-18.pdf›

22 Colborn, Theo et al. 'Natural Gas Operations from a Public Health Perspective'. *International Journal of Human and Ecological Risk Assessment*. September-October 2011, p. 11. ‹http://cce.cornell.edu/EnergyClimateChange/NaturalGasDev/Documents/PDFs/fracking%20chemicals%20from%20a%20public%20health%20perspective.pdf›

23 'Toxic Chemicals in the Exploration and Production of Gas from Unconventional Sources'. *National Toxics Network* (April 2013). ‹http://www.ntn.org.au/wp/wp-content/uploads/2013/04/UCgas_report-April-2013.pdf›

24 Fontenot, Brian E., Laura R. Hunt, Zacariah L. Hildenbrand, Doug D. Carlton Jr., Hyppolite Oka, Jayme L. Walton, Dan Hopkins, et al. 'An Evaluation of Water Quality in Private Drinking Water Wells Near Natural Gas Extraction Sites in the Barnett Shale Formation'. *Environmental Science & Technology* 47, no. 17 (3 September 2013): 10032–10040. doi:10.1021/es4011724. ‹http://pubs.acs.org/doi/abs/10.1021/es4011724›

25 'EPA Releases Draft Findings of Pavillion, Wyoming Ground Water Investigation for Public Comment and Independent Scientific Review'. *US EPA* press release (12/08/2011). ‹yosemite.epa.gov/opa/admpress.nsf/20ed1dfa1751192c8525735900400c30/ef35bd26a80d6ce3852579600065c94e!OpenDocument›

26 'Canadian authorities: Fracking operation contaminated groundwater'. *National Resource Defence Council website* (Posted December 20, 2012). ‹http://switchboard.nrdc.org/blogs/amall/canadian_authorities_leaked_fr.html›

27 Myers, Tom. 'Potential Contaminant Pathways from Hydraulically Fractured Shale to Aquifers'. *Ground Water* 50, no. 6 (November 2012): 872–882.doi:10.1111/j.1745-6584.2012.00933.x.‹http://onlinelibrary.wiley.com/doi/10.1111/j.1745-6584.2012.00933.x/abstract›

28 'Inside the Censored EPA Fracking Water Study'. *Counterpunch.org* (August 06, 2013). ‹http://www.counterpunch.org/2013/08/06/inside-the-censored-epa-pennsylvania-fracking-water-contamination-study ›

29 Jackson, R. B., A. Vengosh, T. H. Darrah, N. R. Warner, A. Down, R. J. Poreda, S. G. Osborn, K. Zhao, and J. D. Karr. 'Increased Stray Gas Abundance in a Subset of Drinking Water Wells near Marcellus Shale Gas Extraction'. *Proceedings of the National Academy of Sciences* 110, no. 28 (24 June 2013): 11250–11255. doi:10.1073/pnas.1221635110. ‹http://www.pnas.org/content/110/28/11250.full ›

30 Osborn, S. G., A. Vengosh, N. R. Warner, and R. B. Jackson. 'Methane Contamination of Drinking Water Accompanying Gas-Well Drilling and Hydraulic Fracturing'. *Proceedings of the National Academy of Sciences* 108, no. 20 (9 May 2011): 8172–8176. doi:10.1073/pnas.1100682108. ‹http://www.pnas.org/content/108/20/8172.long›

31 Jackson RB, et al. 'Research and policy recommendations for hydraulic fracturing and shale-gas extraction'. *Durham, NC: Duke University, Center on Global Change* 2011. ‹http://www.nicholas.duke.edu/cgc/HydraulicFracturingWhitepaper2011.pdf›

32 'Wellbore Leakage Potential in CO2 Storage or EOR'. *Fourth Wellbore Integrity Network Meeting, Paris, France*. March 19, 2008. ‹http://www.ieaghg.org/docs/wellbore/Wellbore%20Presentations/4th%20Mtg/19.pdf›

33 'From Mud to Cement—Building Gas Wells '. *Oilfield review* (Autumn 2003) ‹http://www.slb.com/~/media/Files/resources/oilfield_review/ors03/aut03/p62_76.pdf›

34 'Environmental water and air quality issues associated with shale gas development in the Northeast'. *Environmental water and air quality working group, NYS Water Resources Institute, Cornell University*. ‹http://wri.eas.cornell.edu/MSARC%20Env%20H2O%20Air%20Group%20Revised%20071012.pdf›

35 McKenzie, Lisa M., Roxana Z. Witter, Lee S. Newman, and John L. Adgate. 'Human Health Risk Assessment of Air Emissions from Development of Unconventional Natural Gas Resources'. *Science of The Total Environment* 424 (May 2012): 79–87. doi:10.1016/j.scitotenv.2012.02.018. ‹http://cogcc.state.co.us/library/setbackstakeholdergroup/Presentations/Health%20Risk%20Assessment%20of%20Air%20Emissions%20From%20Unconventional%20Natural%20Gas%20-%20HMcKenzie2012.pdf›

36 McDermott-Levy, By Ruth, Nina Kaktins, and Barbara Sattler. 'Fracking, the Environment, and Health:' *AJN, American Journal of Nursing* 113, no. 6 (June 2013): 45–51. doi:10.1097/01.NAJ.0000431272.83277.f4. ‹http://lgdata.s3-website-us-east-1.amazonaws.com/docs/350/860804/Article_4.pdf›

37 Witter RZ. 'Use of health impact assessment to help inform decision making regarding natural gas drilling permits in Colorado'. *Glenwood Springs, CO: Garfield County (CO) Board of County Commissioners*; 2010 Oct 4. ‹http://www.garfield-county.com/public-health/documents/BOCC_Draft_HIA_Presentation_10_4_10%5B1%5D.pdf›

38 R Witter, Colorado School of Public Health. 'Use of Health Impact Assessment to Help Inform Decision Making Regarding Natural Gas Drilling Permits In Colorado'. *Presentation to, Board of County Commissioners, Garfield County* (October 4, 2010). ‹http://www.garfield-county.com/public-health/documents/BOCC_Draft_HIA_Presentation_10_4_10%5B1%5D.pdf›

39 Mielke E, Anadon LD, Narayanamurti V. 'Water Consumption of Energy Resource Extraction, Processing, and Conversion'. *Harvard Kennedy School, Belfer Center for Science and International Affairs*. October 2010. ‹http://belfercenter.ksg.harvard.edu/files/ETIP-DP-2010-15-final-4.pdf›

40 'Statement on Preliminary Findings from the Southwest Pennsylvania Environmental Health Project Study'. Press Release, Concerned Health Professionals of New York (27 Aug 2013) ‹http://concernedhealthny.org/statement-on-preliminary-findings-from-the-southwest-pennsylvania-environmental-health-project-study/ ›

41 Steinzor N, Septoff A. 'Gas Patch Roulette, How Shale Gas Development Risks Public Health in Pennsylvania'. *EarthWorks* (Oct 2012). ‹http://www.earthworksaction.org/library/detail/gas_patch_roulette_full_report#.UwzG187xHSe›

42 Slatin, Craig, and Charles Levenstein. 'An Energy Policy That Provides Clean and Green Power'. *NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy* 23, no. 1 (1 January 2013): 1–5. doi:10.2190/NS.23.1.a. ‹http://www.prendergastlibrary.org/wp-content/uploads/2013/03/New-Solutions-23-1-Binder.pdf›

43 Draft Scoping Document for Horizontal Drilling and High Volume Hydraulic Fracturing to Develop Shale and Other Low Permeability Gas Reservoirs. *New York Sate Department of Environmental Conservation, Division of Mineral Resources* (Sep 2009). ‹ftp://ftp.dec.state.ny.us/dmn/download/OGdSGEISFull.pdf›

44 'UK shale gas no "get out of jail free card"'. *Bloomburg New Energy Finance* (21 February 2013). ‹http://about.bnef.com/press-releases/uk-shale-gas-no-get-out-of-jail-free-card/›

45 'Revised Draft SGEIS on the Oil, Gas and Solution Mining Regulatory Program (September 2011)' *New York State Department of Environmental Conservation* (2011). ‹http://www.dec.ny.gov/energy/75370.html›

46 'How many tanker trucks does it take to supply water to and remove waste from a horizontally drilled and hydrofracked wellsite'. *un-naturalgas.org*. ‹http://www.un-naturalgas.org/Rev%201%20Truckloads+to+service+a+well+pad+-+DJC.pdf›

47 'Fracking and Earthquake Hazard', *British Geological Survey website* (accessed Feb 2014). ‹http://earthquakes.bgs.ac.uk/research/earthquake_hazard_shale_gas.html›

48 'Man-Made Earthquakes Update' *US geological survey website* (Posted on 17 Jan, 2014). ‹http://www.usgs.gov/blogs/features/usgs_top_story/man-made-earthquakes/›

49 Van der Elst, N. J., H. M. Savage, K. M. Keranen, and G. A. Abers. 'Enhanced Remote Earthquake Triggering at Fluid-Injection Sites in the Midwestern United States'. *Science* 341, no. 6142 (11 July 2013): 164–167. doi:10.1126/science.1238948. ‹http://www.sciencemag.org/content/341/6142/164.abstract›

50 'Exaggerating the Employment Impacts of Shale Drilling: How and Why' Multi-State Shale Research Collaborative (Nov 2013). ‹http://www.multistateshale.org/shale-employment-report›

51 Hughes D J. 'Drill, Baby, Drill: Can Unconventional Fuels Usher in a New Era of Energy Abundance?'. *Post Carbon Institute* (Mar 2013). ‹http://www.postcarbon.org/drill-baby-drill/›

52 'Shale Grab in U.S. Stalls as Falling Values Repel Buyers'. *Bloomberg*. Accessed 25 February 2014. ‹http://www.bloomberg.com/news/2013-08-18/shale-grab-in-u-s-stalls-as-falling-values-repel-buyers.html›

53 Jaramillo, Paulina, W. Michael Griffin, and H. Scott Matthews. 'Comparative Life-Cycle Air Emissions of Coal, Domestic Natural Gas, LNG, and SNG for Electricity Generation'. *Environmental Science & Technology* 41, no. 17 (September 2007): 6290–6296. doi:10.1021/es063031o. ‹http://pubs.acs.org/doi/abs/10.1021/es063031o›

54 Op.Cit. (Hughes et al. 2013)

55 Ibid

56 'Fracking and the Shale Gas "Revolution"'. *Global Research website*. Accessed 25 February 2014. ‹http://www.globalresearch.ca/fracking-and-the-shale-gas-revolution/5345815›

57 D Rogers. 'Shale and wall street: was the decline in natural gas prices orchestrated?'. *Energy Policy Forum* (Feb 2013). ‹http://shalebubble.org/wall-street/›

58 'Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States'. *U.S. Energy Information Administration* (June 2013). ‹http://www.eia.gov/analysis/studies/worldshalegas/pdf/overview.pdf›

59 'World Energy Resources: 2013 Survey'. *World Energy Council* (2013). ‹http://www.worldenergy.org/publications/2013/world-energy-resources-2013-survey ›

60 'China's 2013 Shale Gas Output Rises to 200 Million Cubic metres'. *Bloomberg*. Accessed 25 February 2014. ‹http://www.bloomberg.com/news/2014-01-08/china-s-2013-shale-gas-output-rises-to-200-million-cubic-metres.html›