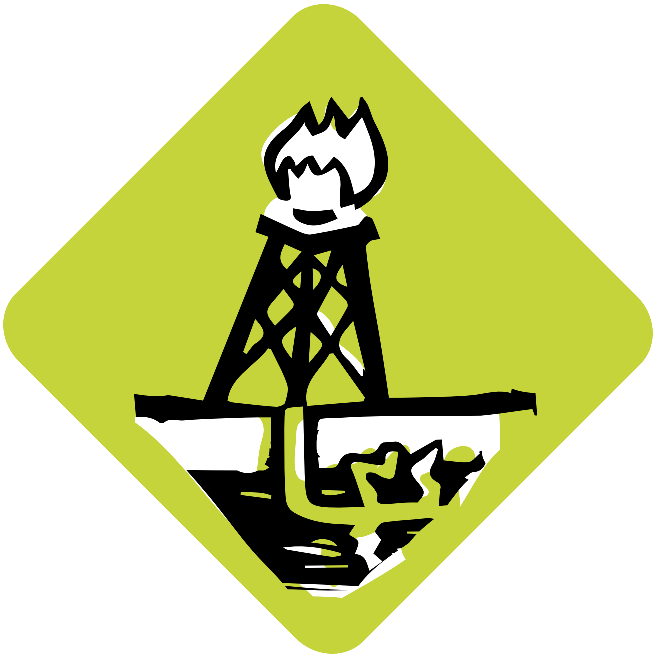


COALBED METHANE

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.

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.

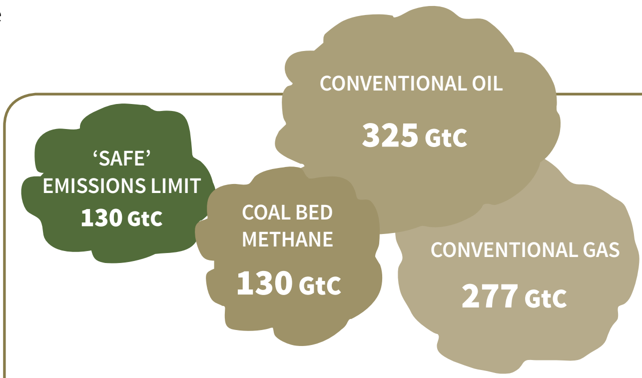
When comparing fuel types it is important to use lifecycle GHG emissions, the total GHG emissions generated by developing and using the fuel. In the case of CBM these include direct CO_2 emissions from end-use consumption (e.g. from burning gas in power plants), indirect CO_2 emissions from fossil fuel 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

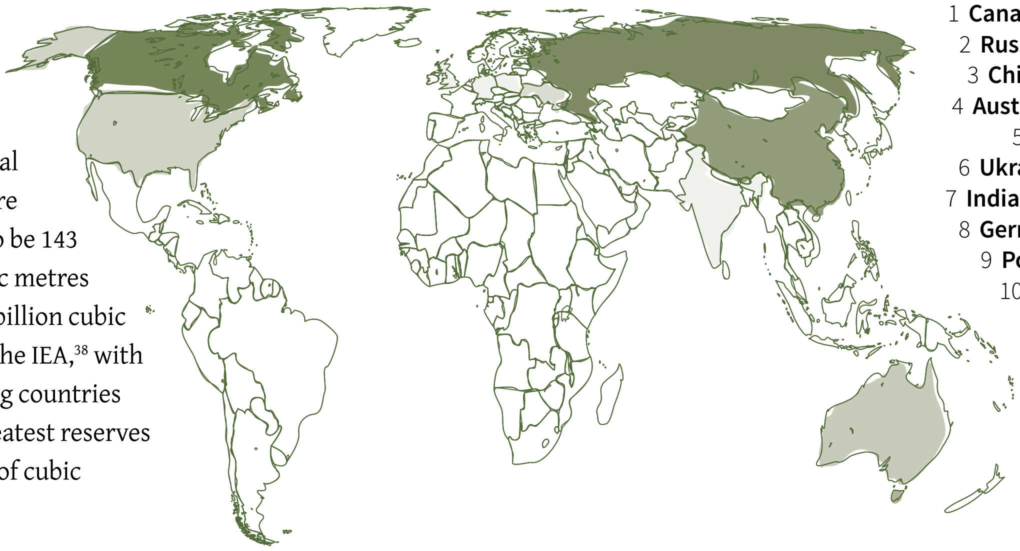
Despite industry claims of it being a safe, controlled process, countries that have carried out CBM activities have experienced numerous blow-outs, spillages and other accidents.[34] [35]These have resulted in serious ground and surface water contamination.

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)

ENDNOTES

1 'Coalbed methane development: Boon or bane for Rural Residents' Factsheet, *Western Organization of Resource Councils (WORC)* (2003).<http://www.worc.org/pdfs/CBM.pdf>

2 'World Energy Resources: 2013 Survey'. *World Energy Council* (2013). <http://www.worldenergy.org/publications/2013/world-energy-resources-2013-survey >

3 Larry Thomas. 'Coal Geology' (West Sussex, England: John Wiley & Sons Ltd.), 2002

4 Rogers, R.E. 'Coalbed Methane: Principles and Practice', 345. (Englewood Cliffs, New Jersey: Prentice Hall) 1994

5 'Oil and Gas Production Activities'. Accessed 25 February 2014. <http://teeic.anl.gov/er/oilgas/activities/act/index.cfm>

6 'Australian Scientists Find Excess Greenhouse Gas near Fracking'. *Los Angeles Times*. Accessed 25 February 2014. <http://articles.latimes.com/2012/nov/17/world/la-fg-wn-australia-fracking-leakage-20121116>

7 'Fugitive Greenhouse Gas Emissions from Coal Seam Gas Production in Australia'. CSIRO (Feb 2013). <http://www.csiro.au/Outcomes/Energy/Fugitive-Greenhouse-Gas-Emissions-from-Coal-Seam-Gas-Production-in-Australia.aspx>

8 Alvarez, R. A., S. W. Pacala, J. J. Winebrake, W. L. Chameides, and S. P. Hamburg. 'Greater Focus Needed on Methane Leakage from Natural Gas Infrastructure'. Proceedings of the National Academy of Sciences 109, no. 17 (9 April 2012): 6435–6440. doi:10.1073/pnas.1202407109. <http://www.pnas.org/content/109/17/6435>

9 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>

10 Ibid

11 Ibid

12 See <www.corporatewatch.org/uff/carbonbudget>

13 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>

14 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>

15 '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>

16 'The Basics of Salinity and Sodicity Effects on Soil Physical Properties'. Accessed 25 February 2014. <http://waterquality.montana.edu/docs/methane/basics_highlight.shtml>

17 Atkinson, C.M. 'Environmental Hazards of Oil and Gas Exploration'. Report prepared for *National Parks Association NSW* Inc (August 2002)

18 'Oil and Gas Production Wastes'. Radiation Protection. *US EPA*. Accessed 25 February 2014. <http://www.epa.gov/radiation/tenorm/oilandgas.html>

19 Fisher, J. B., A. Santamaria. 'Dissolved Organic Constituents in Coal-Associated Waters and Implications for Human and Ecosystem health'. *9th Annual International Petroleum Environmental Conference*, 2002 October 22-25

20 'Coalbed Methane Extraction: Detailed Study Report (4.3.2.)'. *United States Environmental Protection Agency* (Dec 2010) <http://water.epa.gov/scitech/wastetech/guide/304m/upload/cbm_report_2011.pdf>

21 Ibid (see 4.1 to 4.3)

22 Ibid [see 3.4)

23 John Wheaton, John Metesh. Potential Groundwater Drawdown and Recovery from Coalbed Methane Development in the Powder River Basin, Montana. *US Bureau of Land Management* (May 2003). <http://www.mt.blm.gov/mcfo/cbm/eis/CBM3DGWReport.pdf>

24 Ibid

25 Lloyd-Smith M, Senjen R. 'Hydraulic Fracturing in Coal Seam Gas Mining: The Risks to Our Health, Communities, Environment and Climate'. *National Toxics Network* [Internet]. 2011. Accessed July 2013. <http://ntn.org.au/wp/wp-content/uploads/2012/04/NTN-CSG-Report-Sep-2011.pdf >

26 'Report Details Health Concerns for Residents Affected by CSG'. *Sunshine Coast Daily*. Accessed 25 February 2014. <http://www.sunshinecoastdaily.com.au/news/report-details-health-concerns-residents-affected-/1862076/>

27 Tim Jones '(draft) Wyong hydrogeological report'. *Northern Geoscience* (Jan 2005). <http://wage.org.au/documents/doc-41-wyonghydrogeologicalreport.pdf>

28 '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>

29 '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>

30 'Northern San Juan Coal Basin Methane Project Draft Environmental Impact Statement. Appendix E. "Well Field Development Activities Common to All Alternatives," p. E15.'. *Bureau of Land Management* (June 2004)

31 Jenkins, C.D. and Boyer, C.M. 'Coalbed- and shale-gas reservoirs. Distinguished Author Series'. *Journal of Petroleum Technology*, February Issue, 92-99, SPE 103514 (2008)

32 '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>

33 M.A. Habermehl. 'Summary of Advice in Relation to the Potential Impacts of Coal Seam Gas Extraction in the Surat and Bowen Basins, Queensland'. *Geoscience Australia* (29 September 2010). <http://www.environment.gov.au/epbc/notices/pubs/gladstone-ga-report.pdf>

34 'Contaminated-sites-and-accidents-related-specifically-to-CSG-in-Australia'. *coalseamgasnews.org*. Accessed 25 February 2014. <http://coalseamgasnews.org/wp-content/uploads/2012/10/Contaminated-sites-and-accidents-related-specifically-to-CSG-in-Australia.pdf >

35 'CSG Myth Busting - Lock the Gate Alliance'. Accessed 25 February 2014. <http://www.lockthegate.org.au/csg_myth_busting >

36 'Coalbed Methane: Clean Energy for the World'. Oilfield Review, Vol. 21, Issue 2 (06/01/2009). <http://www.slb.com/~/media/Files/resources/oilfield_review/ors09/sum09/coalbed_methane.pdf >

37 'Coal Bed Methane Market – Global Industry Size, Market Share, Trends, Analysis, and Forecast, 2010 – 2018'. Transparency Market Research. <http://www.transparencymarketresearch.com/coal-bed-methane-market.html>

38 IEA Clean Coal Centre 2005 <http://www.iea-coal.org.uk/site/2010/publications-section/cct2005?>.