PO Box 173 Bangalow
NSW 2479 Australia
info@ntn.org.au

Hydraulic Fracturing in Coal Seam Gas Mining:

The Risks to Our Health, Communities, Environment and Climate

Prepared by:
Dr Mariann Lloyd-Smith and Dr Rye Senjen
June 2011

Hydraulic Fracturing in Coal Seam Gas Mining: The Risks to Our Health, Communities, Environment and Climate

A Moratorium on Hydraulic Fracturing Chemicals

The National Toxics Network (NTN) calls on federal and state governments to implement a moratorium on the use of drilling and fracturing chemicals ('fracking chemicals') used in coal seam gas and shale gas extraction, until these chemicals have been fully assessed for their health and environmental hazards by the Australian industrial chemicals regulator, the National Industrial Chemical Notification and Assessment Scheme (NICNAS).

NTN's review of chemicals used by the industry has found that only 2 out of the 23 most commonly used fracking chemicals in Australia have been assessed by NICNAS. Neither of these 2 chemicals has been specifically assessed for their use in drilling and hydraulic fracking fluids.

NTN demands the following :

- that a comprehensive hazard assessment is carried out for all fracking chemicals used in Australia, including their impacts on human health, their ecotoxicology and environmental fate (air emissions; releases to groundwater and watercourses).
- a comprehensive health and environmental assessment of all chemical impacts associated with CSG activities including gas flaring, intentional venting, fugitive emissions, diesel use, waste water management; and
- a full cost-benefit analysis to investigate the long-term impacts of the industry in terms of cleanup and remediation of contaminated areas, treatment of wastewater, and increased landfill capacity to dispose of waste products created by CSG.

What is Hydraulic Fracturing?

Hydraulic fracturing or 'fracking' is the practice of using high-pressure pumps to inject a mixture of sand, water and chemicals into bore wells in order to fracture rocks and to open cracks ('cleats') present in the coal seams thereby releasing natural gas in the process. A well can be repeatedly 'fracked' and each gas field incorporates many wells.

The social and environmental impact of fracking is an emerging issue of concern around the world, including Australia.[1] It has received widespread community attention in the USA, particularly since the release of the documentary film Gasland[2] and it is also emerging as an important issue in Europe. The social and environmental impacts of fracking cut across many issues including: climate change;

[1] Stop Coal Seam Gas Now http://www.youtube.com/watch?v=93hRPRxXFg4&feature=related
[2] See www.gaslandthemovie.com and www.gasland.com.au

sustainable/renewable energy; hazardous waste disposal; air, soil and water pollution; and land and water use.

Coal Seam Gas Exploration and Extraction in Australia

With the realities of climate change upon us, the scramble for sustainable energy sources is rapidly expanding. One potential source of energy in the Australian context is the extraction of gas from coal seam gas (CSG), shale gas, basin-centered gas and tight gas (collectively known as unconventional gas).

Until recently this these types of gas were too expensive to extract and too difficult to produce, but technological innovations such as 'fracking' have made this gas accessible and commercially viable. Some commentators have compared this 'unconventional' gas extraction to a new gold rush and a way to ensure our energy future. It's estimated that up to 80% of all natural gas wells in the next 10 years will use fracking.[3]

CSG largely consists of methane and is bonded to the surface of coal particles. In comparison, natural gas is found in the space between grains of sandstone or similar types of rock.[4] Coal seams are generally filled with water, and it is the pressure of the water that keeps the gas adsorbed as a thin film on the surface of the coal. CSG typically contains very small amounts of other hydrocarbons (propane, butane).

While the interest in CSG stems from its high content of methane, it can also contain carbon dioxide (CO_2), and the amount of CO_2 can vary dramatically. For instance, the Illawarra Coal Measures in NSW may even contain predominantly carbon dioxide.[5] This raises critical questions about CSG and its validity as a 'clean' source of energy for the future.

Australia's coal basin deposits, particularly in Queensland and NSW, contain large resources of CSG. Explorations are also occurring in the Perth and Tasmanian basins. It is estimated that together, these deposits will be larger than the combined conventional gas deposits of Bass Strait, the Cooper Basin and the North West Shelf.[6]

There are already a number of coal seam gas projects underway in Australia, chiefly in the Surat-Bowen basin in Queensland and also in NSW. To give an indication of the scale of the proposed operations up to 20,000 - 40,000 wells could be drilled in the Surat and Bowen Basins in the next 20 years alone.[7,8]

---

3 Hydraulic Fracturing for Natural Gas Development, Investor Environmental Health Network 2011 IEHN http://iehn.org/overview.naturalgashydraulicfracturing.php

4 Clark, A. (Dec 2010). Millionaires: not in our backyard. Australian Financial Review (AFR). Available at: http://www.afr.com/p/national/millionaires_not_in_our_backyard_E3sB01Jq0IRg0cYNsu4zvI

5 Coal bed methane- factsheet, Australian Mining Atlas. Available at http://www.australianminesatlas.gov.au/education/fact_sheets/coal_bed_methane.jsp

6 Ibid.

7 Queensland Government announces gas enforcement team. ABC Rural 23/11/2010. Available at http://www.abc.net.au/rural/news/content/201011/s3074371.htm

8 Growing concern over coal gas seam plant. ABC Tropical ABC Tropical 23/11/2010. Available at: http://www.abc.net.au/news/stories/2010/11/23/3073726.htm?site=tropic

By October 2010 there were a reported 72 mining projects at an advanced stage, an increase of 21% since May 2010. Not all of these are CSG deposits, but they do include the development of BG Group's $15 Billion Queensland Curtis Island LNG facility, which draws on CSG deposits.[9] The plant will take coal seam gas from the Surat Basin and pipe it to Gladstone to be super-cooled to create Liquefied Natural Gas (LNG).[10]

Another project in Gladstone was approved in November 2010. The Australia Pacific LNG project is a joint venture between Origin and ConocoPhillips and is also proposing a coal seam gas (CSG) to liquefied natural gas (LNG) plant. It will involve the construction of a 450km gas transmission pipeline from the coal seam gas fields to an LNG plant in Gladstone, which will have a processing capacity of up to 18 million tonnes per annum.[11]

The financial, political and environmental stakes are high. In November 2010 the federal Minister for Sustainability, Environment, Water, Population and Communities approved $35 billion worth of coal gas seam projects in Queensland alone, despite his own Department voicing concerns about the potential serious environmental implications of the projects to the Great Artesian Basin and the Murray-Darling basin.[12,13] The Water Group expressed significant concerns about "the general level of uncertainty associated with these proposals, and the inability of proponents to accurately quantify their individual and collective impacts over the life of their projects." **(***For a list of companies actively exploring and/or extracting CSG in Australia see Appendix 1.***)**

Shale Gas

Shale gas is another unconventional gas and is the type of gas that has fuelled the natural gas boom in the USA in the past decade. Interest in this type of gas has spread worldwide with exploration and drilling occurring in Asia, Europe and also Australia. Shale gas is also produced by fracking. Shale is a fine-grained, sedimentary rock, which is essentially a mix of flakes of clay minerals and tiny bits of other minerals, especially quartz and calcite. The environmental issues associated with shale gas production are similar to CSG fracking. Beach Petroleum has commenced exploratory drilling for shale gas in the Cooper Basin, South Australia.[14]

---

[9] Clark, A. (Dec 2010). Millionaires: not in our backyard. AFR Available at: http://www.afr.com/p/national/millionaires_not_in_our_backyard_E3sB01Jq0IRg0cYNsu4zvI

[10] BG Group and Coal Seam Gas. Available at: http://www.bg-group.com/OurBusiness/OurBusiness/Pages/BGGroup_and_CoalSeamGas.aspx

[11] Media Release, Australian Pacific LNG project. Available at: http://www.originenergy.com.au/files/APLNG_EIS_20101109.pdf

[12] WATER GROUP ADVICE ON EPBC ACT REFERRALS (QGC referral - 2008/4399, Santos-Petronas referral - 2008/4059 and comments on AP LNG referral - 2009/4974 September 201; Also see http://www.smh.com.au/environment/energy-smart/windsor-plans-new-coal-seam-gas-rules-to-protect-water-20101205-18lej.html

[13] Clark, A. (Dec 2010). Millionaires: not in our backyard. AFR Available at: http://www.afr.com/p/national/millionaires_not_in_our_backyard_E3sB01Jq0IRg0cYNsu4zvI

[14] See www.beachenergy.com.au

Is CSG a Sustainable Source of Energy?

The real environmental and social costs of CSG extraction have not been thoroughly assessed. According to a recent Cornell University assessment, "Natural gas obtained by the controversial technique of hydraulic fracturing may contribute significantly to greenhouse gas emissions and so should not be considered as a cleaner alternative to coal or oil."[15] (*For further information on CSG and climate impacts see Appendix 2.)*

This US finding has direct relevance to the situation in Australia. The methods of extraction of unconventional gas both here and in the US are the same and both countries face the impacts of methane emissions, chemical contamination, water depletion and waste water management.

In neither country have the fracking chemicals been adequately assessed for their health and environmental effects and there is a growing concern that they may have significant negative impacts on the environment and surrounding communities. For instance, toxic spills can occur, and air, soil and water may also be polluted with fracking chemicals as a by-product of the CSG extraction process. Contamination of drinking and irrigation water and the destruction of productive farmland are also significant issues that concern the community.

What is BTEX?

In October 2010, traces of BTEX chemicals were found at an Arrow Energy fracking operation in Queensland. Arrow Energy confirmed that benzene, toluene, ethylbenzene and xylene (BTEX) had been found in well water associated with its coal-seam gas operation at Moranbah, west of Mackay.[16]

An underground coal gasification project, a joint venture between Origin and the multinational ConocoPhillips, near Kingaroy Queensland, was also temporarily shut down when benzene and toluene were detected.[17] Queensland has since banned the use of BTEX chemicals in fracking fluids. The NSW Government announced it would examine banning the use of BTEX chemicals in 'situations, which may pose risk to groundwater'.[18]

BTEX chemicals are commonly found in the products used in the drilling stage of hydraulic fracturing. BTEX chemicals are also components of the volatile compounds found naturally in the coal gas seams. The fracking process itself can release BTEX from the natural-gas reservoirs, which may allow them to disperse into the groundwater aquifers or to volatilise into air. As a consequence, people may be

---

[15] Robert Howarth (2010) Preliminary Assessment of the Greenhouse Gas Emissions from Natural Gas obtained by Hydraulic Fracturing, http://www.damascuscitizens.org/GHGemissions_Cornell.pdf
[16] Contamination fear fails to stop project, http://www.theaustralian.com.au/national-affairs/contamination-fear-fails-to-stop-project/story-fn59niix-1225950389968
[17] Cancer chemical found at western Queensland gas site, http://www.couriermail.com.au/business/cancer-chemical-found-at-gas-site/story-e6freqmx-1225940922665
[18] Tough New Rules for Coal Seam Gas Exploration 19.12.2010 News Release, Premier of NSW

exposed to BTEX by drinking contaminated water, breathing contaminated air or from spills on their skin.[19] BTEX compounds can contaminate both soil and groundwater. BTEX chemicals are hazardous in the short term causing skin irritation, central nervous system problems (tiredness, dizziness, headache, loss of coordination) and effects on the respiratory system (eye and nose irritation). Prolonged exposure to these compounds can also negatively affect the functioning of the kidneys, liver and blood system. Long-term exposure to high levels of benzene in the air can lead to leukemia and cancers of the blood.[20]

Are Fracking Fluids Safe?

"Chemicals are used at most stages of the drilling operation to reach and release the natural gas from gas coal seams – to drill the bore hole, to facilitate the actual boring, to reduce friction, to enable the return of drilling waste to the surface, to shorten drilling time, and to reduce accidents. After drilling has been completed, hydraulic fracturing is used to release the trapped gas by injecting approximately 2.5 million litres or more of fluids, loaded with toxic chemicals, underground under high pressure."[21]

Fracturing fluids or 'fracking fluids' consists of water, sand and chemicals that are combined and injected into the coal seam at high pressure. The fracking fluid includes chemicals and additives that aid the fracturing process (e.g. viscosifiers, surfactants, pH control agents) as well as biocides that inhibit biological fouling and erosion.

The US Ground Water Protection Council and Interstate Oil and Gas Compact Commission describe the contents of fracking fluids;

"The addition of friction reducers allows fracturing fluids and sand, or other solid materials called proppants, to be pumped to the target zone at a higher rate and reduced pressure than if water alone were used. In addition to friction reducers, other additives include: biocides to prevent microorganism growth and to reduce biofouling of the fractures; oxygen scavengers and other stabilizers to prevent corrosion of metal pipes; and acids that are used to remove drilling mud damage within the near wellbore area. These fluids are used to create the fractures in the formation and to carry a propping agent (typically silica sand) which is deposited in the induced fractures to keep them from closing up." [22]

While companies argue that the full identity and composition of fracking fluids cannot be publicly disclosed as the information is a trade secret and involves commercial-in-confidence data, the identity of the types of chemicals used in fracking fluids is

---

[19] Agency for Toxic Substances and Disease Registry (ATSDR). 2004. Interaction Profile for Benzene, Toluene,Ethylbenzene and Xylene (BTEX). U.S. Department of Health and Human Services, Public Health Service.

[20] Agency for Toxic Substances and Disease Registry (ATSDR). 2004. Interaction Profile for Benzene, Toluene,Ethylbenzene and Xylene (BTEX). U.S. Department of Health and Human Services, Public Health Service.

[21] Theo Colborn, Carol Kwiatkowski, Kim Schultz, Mary Bachran, Natural Gas Operations from a Public Health Perspective, *International Journal of Human and Ecological Risk Assessment,* September 4, 2010. Available at:http://www.endocrinedisruption.com/files/NaturalGasManuscriptPDF09_13_10.pdf

[22] http://fracfocus.org/chemical-use/what-chemicals-are-used Fracfocus is joint project of the Ground Water Protection Council and the Interstate Oil and Gas Compact Commission

publicly available.[23] (*See Appendix 3 for a comprehensive list of chemicals used in fracking fluid products identified by the US Ground Water Protection Council and the Interstate Oil and Gas Compact Commission).*

A recent review on the use of chemicals in fracking[24] lists nearly a thousand products involved in natural gas operations (including CSG and shale gas) in the USA. Only a small percentage of these chemicals have CAS Registry Numbers [25] listed on their Material Safety Data Sheets (MSDS). Without a CAS number it is very difficult to search for specific health and environmental data about a chemical.

MSDS are a limited source of information on chemical hazards as they often provide only rudimentary human health data and little, if any, information on the environmental fate of the chemical or its effects on the environment and ecosystems. (*For more information on MSDS see Appendix 4.)*

A review of 980 chemical products used in the gas industry in the USA found that [26]:

- A total of 649 chemicals were used in the 980 products. Specific chemical names and CAS numbers could not be determined for 286 (44%).

- Less than 1% of the total composition of the product was reported on the MSDS for 421 of the 980 products (43%), less than 50% of the composition was reported for 136 products (14%), and between 51% and 95% of the composition was reported for 291 (30%) of the products. Only 133 products (14%) had information on more than 95% of their full composition.

The issue of lack of disclosure of the full chemical identity on product MSDS is similar in Australia. In 2010, it is reported that a coal seam gas-drilling site near Lismore NSW, run by Metgasco, was permitted to use fracking after supplying only a generic list of hazardous materials safety guidelines.[27]

A review of MSDS provided by the CSG companies and verified by industry sources[28], provides a general list of the type of chemicals used in fracking fluids in Australia. *(See Table 1)*

---

[23] http://fracfocus.org/chemical-use/what-chemicals-are-used

[24] Theo Colborn, Carol Kwiatkowski, Kim Schultz, Mary Bachran, Natural Gas Operations from a Public Health Perspective, *International Journal of Human and Ecological Risk Assessment,* September 4, 2010. Available at:http://www.endocrinedisruption.com/files/NaturalGasManuscriptPDF09_13_10.pdf

[25] CAS registry numbers are unique numerical identifiers assigned by the Chemical Abstracts Service to every chemical described in the open scientific literature.

[26] Chemicals in Natural Gas Operations, Health Effects Spreadsheet and Summary TEDX 2011, Available at http://www.endocrinedisruption.com/chemicals.multistate.php.The Endocrine Disruption Exchange (TEDX) maintains a publicly available database of the potential health effects of chemicals used during natural gas operations. It is available for download in an Excel file format for easy searching and sorting

[27] http://www.smh.com.au/environment/toxins-found-at-third-site-as-fracking-fears-build-20101118-17zfv.html

[28] Australian Petroleum Production & Exploration Association Ltd (APPEA), Chemicals that may be used in Australian fracking fluid Available at http://www.appea.com.au

Table 1. Types of Chemicals Commonly Used in Fracking Fluids in Australia

Note: This summary of chemicals and their uses was consolidated from the MSDS provided by the CSG companies and verified by industry sources in Australia.

Additive Type	Main Compound(s)	Purpose
Diluted Acid	Hydrochloric Acid, muriatic acid	Dissolves minerals
Biocides	Glutaraldehyde, Tetrakis hydoxymethyl phosphonium sulfate,	Eliminates bacteria in water that produce corrosive products
Breaker	Ammonium persulfate/ sodium persulfate	Delayed break gel polymer
Corrosion Inhibitor	n,n-dimenthyl formamide, methanol, naphthalene, naptha, nonyl phenol, acetaldhyde	Prevents corrosion of pipes
Friction Reducer	Mineral oil, polyacrylamide	Reduces friction of fluid
Gel	Guar gum	Thickens water
Iron Control	Citric acid, thioglycolic acid	Prevent metal oxides
KCl	Potassium chloride	Brine solution
pH Adjusting Agent	Sodium or potassium carbonate	Maintains pH
Scale Inhibitor	Ethylene glycol	Prevents scale deposits in pipe
Surfactants	Isopropanol, 2-Butoxyethanol	Affects viscosity of fluid
Crosslinker	Ethylene glycol	Affects viscosity of fracking fluid

Are Fracking Chemicals 'Household Chemicals'?

Industry representatives claim that fracking chemicals are safe because they are similar to 'food additives' and are used in 'household products'. NTN believes these claims are misleading for several reasons. A number of the chemicals used in fracking fluids would never be permitted as food additives or household products due to their toxicity. As well, there has been no comprehensive hazard assessment of the chemical mixtures used in fracking fluids nor their impacts on the environment or human health.

A US analysis of chemicals used in fracking based on health data obtained from the MSDS as well as government toxicological reports, and the medical literature for the 362 chemicals with CAS numbers found: [29]:

- Over 78% of the chemicals are associated with skin, eye or sensory organ effects, respiratory effects and gastrointestinal or liver effects. The brain and nervous system can be harmed by 55% of the chemicals. Symptoms include burning eyes,

[29] Chemicals in Natural Gas Operations, Health Effects Spreadsheet and Summary TEDX 2011, Available at http://www.endocrinedisruption.com/chemicals.multistate.php.The Endocrine Disruption Exchange (TEDX) maintains a publicly available database of the potential health effects of chemicals used during natural gas operations. It is available for download in an Excel file format for easy searching and sorting

rashes, coughs, sore throats, asthma-like effects, nausea, vomiting, headaches, dizziness, tremors, and convulsions.

- Between 22% and 47% of the chemicals were associated with possibly longer-term health effects such as cancer, organ damage, and harm to the endocrine system.

- 210 chemicals (58%) are water-soluble while 131 chemicals (36%) are volatile; i.e., they can become airborne. Because they can be inhaled, swallowed, and also reach the skin, the potential for exposure to volatile chemicals is greater.

- Over 93% of the volatile chemicals can harm the eyes, skin, sensory organs, respiratory tract, gastrointestinal tract or liver, 86% can cause harm to the brain and nervous system, 72% can harm the cardiovascular system and blood, and 66% can harm the kidneys.

In May 2011, the US House of Representatives Committee on Energy and Commerce released their report identifying 750 chemicals that were used in fracking fluids between 2005 and 2009.[30] They stated:

'Some of the components used in the hydraulic fracturing products were common and generally harmless, such as salt and citric acid. Some were unexpected, such as instant coffee and walnut hulls. And some were extremely toxic, such as benzene and lead.'

They noted that the most widely used chemical in hydraulic fracturing as measured by the number of compounds containing the chemical was methanol. Methanol was used in 342 hydraulic fracturing products, and is a hazardous air pollutant and on the candidate list for potential regulation under the *Safe Drinking Water Act* due to its risks to human health.

Other widely used chemicals were isopropyl alcohol (used in 274 products), 2-butoxyethanol (used in 126 products), and ethylene glycol (used in 119 products). Between 2005 and 2009, hydraulic fracturing products contained 29 chemicals that were either known or possible human carcinogens, regulated under the *Safe Drinking Water Act* for their risks to human health, or listed as hazardous air pollutants under the *Clean Air Act*. These 29 chemicals were components of more than 650 different products used in hydraulic fracturing.[31]

Lack of Australian Assessment of Fracking Chemicals

In Australia, a review of a selection of CSG companies' environmental authorisations identified 23 compounds commonly used in fracking fluids (*See Table 2*). Australia's

[30] United States House of Representatives Committee On Energy And Commerce, Minority Staff, April 2011 Chemicals Used In Hydraulic Fracturing http://democrats.energycommerce.house.gov/sites/default/files/documents/Hydraulic%20Fracturing%20Report%204.18.11.pdf

[31] United States House of Representatives Committee On Energy And Commerce, Minority Staff, April 2011 Chemicals Used In Hydraulic Fracturing http://democrats.energycommerce.house.gov/sites/default/files/documents/Hydraulic%20Fracturing%20Report%204.18.11.pdf

industrial chemical regulator, the National Industrial Chemical Notification and Assessment Scheme (NICNAS) has assessed only 2 out of the 23. Yet, hydraulic fracturing in Australia involves very large quantities of fracking fluids.
Environmental authorisations by Queensland regulators identified that in one CSG operation, approximately 18,500kg of additives were to be injected during the hydraulic fracturing process in each well, with only 60% of these recovered and up to 40% of the hydraulic fracturing fluid volume remaining in the formation, corresponding to 7,400kg of chemicals per injection well.[32]

The fluids that return to the surface within a specified length of time are referred to as *'flowback'*. As well as the original fluid used for fracturing, flowback may also contain other fluids, chemicals and minerals that were present in the fractured formation such as heavy metals and hydrocarbons. [33]

Table 2. NICNAS Status of Chemicals Used in Fracking Fluids
Note: The following list of chemicals and CAS numbers was compiled from MSDS provided by three CSG companies based in Queensland and NSW.

Chemical	**CAS RN**	**AICS Status***
Tetramethylammonium Chloride	75-57-0	Pub/NA
Potassium carbonate	584-08-7	Pub/NA
Methanol	67-56-1	Pub/NA
Isopropanol	67-63-0	Pub/NA
Propargyl alcohol	107-19-7	Pub/NA
Formamide	75-12-7	Pub/NA
Ethoxylated 4-nonylphenol	26027-38-3	Pub/NA
Heavy aromatic naphtha	64742-94-5	Pub/NA
Pine oil	8002-09-3	Pub/NA
Naphthalene	91-20-3	Pub/NA; PEC Candidate list
Citric acid anhydrous	77-92-9	Pub/NA
Hemicellulase Enzyme Concentrate	9025-56-3	Pub/NA
Tetrakis(Hydroxymethyl) Phosphonium Sulphate	55566-30-8	Pub/NA
Sodium persulfate	7775-27-1	Pub/Ass; Declared PEC
Guar gum	9000-30-0	Pub/NA

[32] Coal Seam Hydraulic Fracturing Fluid Risk Assessment. Response to the Coordinator-General Requirements for Coal Seam Gas Operations in the Surat and Bowen Basins, Queensland. Golder Associates 21 October 2010
[33] http://fracfocus.org/chemical-use/what-chemicals-are-used

Ethylene glycol	107-21-1	Pub/NA
Sodium hydroxide	1310-73-2	Pub/NA
Diethylene glycol	111-46-6	Pub/NA
2-Bromo-2-nitro-1,3-propanediol	52-51-7	Pub/NA
Alcohols, C12-14	80206-82-2	Pub/NA
Tris(2-hydroxyethyl) amine	102-71-6	Pub/NA; PEC Candidate list
2-Butoxyethanol	111-76-2	Pub/Ass; Declared PEC
Cristobalite (silica)	14464-46-1	Pub/NA

*AICS = Australian Inventory of Chemical Substances; Pub = public AICS; NA = not assessed; Ass = assessed; PEC = priority existing chemical

Other chemicals commonly listed in fracking chemical products but without CAS numbers include the following. Without CAS the identity of the chemical cannot be assured:

- Alkanes / Alkenes (Multiple CAS)
- Oxylalkylated alcohol(s)
- Fatty alcohol
- Oxylalkylated alkanolamine(s)
- Silicone(s)
- Surfactant(s)

Health and Environmental Risks of Some Fracking Chemicals

Note: The following information was compiled from publically available sources including International Program on Chemical Safety, INCHEM, www.inchem.org, US Agency for Toxic Substances & Disease Register, www.atsdr.cdc.gov, Material Safety Data Sheets and NICNAS literature.

Health data and sources for 560 fracking chemicals is available for download at http://www.endocrinedisruption.com/chemicals.multistate.php

Tetrakis (hydroxymethyl)phosphonium sulfate (THPS)

Tetrakis(hydroxymethyl)phosphonium sulfate (THPS) acts as a biocide, that is a chemical that is toxic to microorganisms and is used as anti-fouling agent. THPS has shown mutagenic potential (in vitro) and cancer potential in rats (No Observable Adverse Effect Level (NOAEL) 3.6 mg/kg). Repeated skin exposure to THPS resulted in severe skin reaction and caused skin sensitization in guinea pigs. THPS was also identified as a severe eye irritant in rabbits. [34] Little is known about the effects of the break down products of THPS. The reported acute toxicity values for algae are less than 1 mg/litre (No Observable Effect Concentration (NOEC) of 0.06mg/litre). No exposure information is available for either humans or organisms in the environment; hence no quantitative risk assessment has been made.[35]

[34] NTP Study Reports, Abstract for TR-296 - Tetrakis(hydroxymethyl)phosphonium sulfate (THPS) (CASRN 55566-30-8) and Tetrakis(hydroxymethyl)phosphonium chloride (THPC) (CASRN 124-64-1

[35] Environmental Health Criteria 218 Flame Retardants: TRIS(2-BUTOXYETHYL) PHOSPHATE, TRIS(2-ETHYLHEXYL) PHOSPHATE and TETRAKIS(HYDROXYMETHYL) PHOSPHONIUM SALTS United Nations

Sodium Persulfate

Exposure to sodium persulfate via inhalation or skin contact can cause sensitization, i.e., after initial exposures individuals may subsequently react to exposure to very low levels of that substance. Exposure to sodium persulfate causes skin rashes and eczema as well as allergies that may develop after repeated exposures. Sodium persulfate is irritating to eyes and respiratory system and long-term exposure may cause changes in lung function (i.e. pneumoconiosis resulting in disease of the airways) and/or asthma.

Ethylene Glycol

Exposure to ethylene glycol via inhalation or skin contact can irritate the eyes, nose and throat. It is a human respiratory toxicant. Among female workers, exposures to mixtures containing ethylene glycol were associated with increased risks of spontaneous abortion and sub-fertility.[36] Ethylene glycol is a teratogen (i.e., an agent that causes malformation of an embryo or foetus) in animal tests. Ethylene Glycol is on the U.S. EPA list of 134 priority chemicals to be screened as an endocrine disrupting substance (EDC).

2-Butoxyethanol

2-butoxyethanol was declared a Priority Existing Chemical (PEC) under Australia's regulatory National Industrial Chemicals Notification and Assessment Scheme.[37] The assessment of 2-butoxyethanol shows that it is highly mobile in soil and water and has been detected in aquifers underlying municipal landfills and hazardous waste sites in the US. It is recommended that waste 2-butoxyethanol not be disposed of to landfill because of its high mobility, low degradation and its demonstrated ability to leach into and contaminate groundwater.

While high doses of 2-butoxyethanol can also cause reproductive problems and birth defects in animals, it is not known whether 2-butoxyethanol can affect reproduction or cause birth defects in humans. Animal studies have shown exposure to 2-butoxyethanol can cause hemolysis (destruction of red blood cells that results in the release of hemoglobin). The International Agency for Research on Cancer has not classified 2-butoxyethanol as to its human carcinogenicity as no carcinogenicity studies are available.

Ethoxylated 4-nonylphenol

Ethoxylated 4-nonylphenol (NPE) is a persistent bioaccumulative endocrine disruptor, which has been detected widely in wastewater and surface waters across the globe. Canada classified NPE metabolites as toxic.[38] The European Union classifies

---

Environment Programme, the International Labour Organisation, and the World Health Organization, and produced within the framework of the Inter-Organization Programme for the Sound Management of Chemicals. World Health Organization Geneva, 2000

36 Adotfo Correa, Ronald H. Gray, Rebecca Cohen, Nathaniel Rothman, Faridah Shah, Hui Seacat and Morton Com, Ethylene Glycol Ethers and Risks of Spontaneous Abortion and Subfertility, American Journal of Epidemiology Vol. 143, Issue 7 Pp. 707-717.

37 Declared Priority Existing Chemical (PEC). Full report at www.nicnas.gov.au/Publications/CAR/PEC/

38 Environment Canada 2001 Nonylphenol and its Ethoxylates: Priority Substance Lists Assessment Report. Minister of Public Works and Government Services

nonylphenol as very toxic to aquatic organisms, which may cause long-term adverse effects in the aquatic environment.[39] In the aquatic environment, NPE metabolites can cover organisms with a soap-like coating that inhibits them from moving and causes the organism to become stupefied and lose consciousness. NPE also disrupt normal hormonal functioning in the body and thus are considered endocrine disrupting chemicals. NPE mimics the natural hormone estradiol and binds to the estrogen receptor in living organisms. Exposure to NPE changes the reproductive organs of aquatic organisms.[40] Sexual deformities were found in oyster larvae exposed to levels of nonylphenol (NP) that are often present in the aquatic environment.[41] A 2005 study found that exposure to NP increases the incidence of breast cancer in lab mice.[42] The intermediary chemicals formed from the initial degradation of NPE are much more persistent than the original compound.

Naphthalene

Based on the results from animal studies, which demonstrated nasal and lung tumours in lab animals, the International Agency for Research on Cancer (IARC) concluded that naphthalene is a possible human carcinogen, and the US Department of Health and Humans Services (DHHS) concluded that naphthalene is reasonably anticipated to be a human carcinogen.

Naphthalene causes lung toxicity in mice, either by injection or inhalation. Naphthalene can cause cataracts in humans, rats, rabbits and mice. Animal studies suggest that naphthalene is readily absorbed following oral or inhalation exposure. Although no data are available from human studies on absorption of naphthalene, the detection of metabolites in the urine of workers indicates that absorption does occur, and there is a good correlation between exposure to naphthalene and the amount of 1-naphthol excreted in the urine.

Humans accidentally exposed to naphthalene by ingestion develop haemolytic anaemia (damage or destruction of red blood cells). Symptoms of hemolytic anemia include fatigue, lack of appetite, restlessness, and pale skin. Exposure to large amounts of naphthalene may also cause nausea, vomiting, diarrhea, blood in the urine, and a yellow color to the skin.

Methanol

Methanol is a volatile organic compound, which is highly toxic to humans. Methanol causes central nervous system depression in humans and animals as well as degenerative changes in the brain and visual system. Chronic exposure to methanol, either orally or by inhalation, causes headache, insomnia, gastrointestinal problems, and blindness in humans and hepatic and brain alterations in animals. Methanol is highly mobile in soil. In water, the degradation products of methanol are methane and carbon dioxide. Methanol also volatilizes from water and once in air, exists in the

---

[39] European Union 4-Nonylphenol (branched) and Nonylphenol Risk Assessment Report. Institute for Health and Consumer Protection, European Chemicals Bureau Volume 10,

[40] Gray, M., and C. Metcalfe. 1997.Induction of Testis-Ova in Japanese Medaka (Oryzias Latipes) Exposed to p-Nonylphenol. *Environmental Toxicology and Chemistry*, No. 16, Issue 5, p. 1082.

[41] Nice, H., D. Morritt, M. Crane and M. Thorndyke. 2003. Long-term and Transgenerational Effects of Nonylphenol Exposure At a Key stage in the Development of Crassostrea gigas. Possible Endocrine Disruption? *Marine Ecology Progress Series,*Vol. 256, p. 293.

[42] Acevedo, R., P. Parnell, H. Villanueva, L. Chapman, T. Gimenez, S. Gray, and W. Baldwin. 2005. The Contribution of Hepatic Steroid Metabolism to Serum Estradiol and Estriol Concentrations of Nonylphenol Treated MMTVneu Mice and Its Potential Effects on Breast Cancer Incidence and Latency. *Journal of Applied Toxicology* Volume 25, Issue 5, pages 339–353, September/October 2005

vapor phase with a half-life of over 2 weeks. The chemical reacts with photochemically produced smog to produce formaldehyde and can also react with nitrogen dioxide in polluted air to form methyl nitrite. [43]

Isopropanol

Isopropanol is reproductive toxin and irritant. It is a central nervous system depressant and prolonged inhalation exposure of rats can produce degenerative changes in the brain.[44]

Formamide

Formamide is a teratogen with the potential to affect the unborn child. The substance is irritating to the eyes and the skin and may cause effects on the central nervous system. It can be absorbed into the body by inhalation, through the skin and by ingestion. It is harmful by all exposure routes.

Drilling Chemicals

CSG activities also require the use of drilling chemicals. Chemicals commonly used at Australian drill sites include calcium sulfate, anionic surfactants, ethylene glycol monobutyl ether, polyacrylamide polymers and petroleum distillate flocculants. Drilling fluid additives are generally claimed as trade secrets and their contents are typically described as carrier fluids, anionic water-soluble polymers, activators, emulsifiers and neutralizers. Hydrocarbons are also used at the drill sites and surrounding areas and include lubricants, rod grease, petrol and diesel for small plant equipment.[45]

Pollution Threats to Australia's Water Resources

CSG activities involve considerable quantities of water as the extraction of gas from coal seams relies on reducing the ground water pressure that keeps the gas absorbed between layers of coal. The amount of water extracted from a CSG well varies depending on the type and depth of the coal seam, but is reported by industry to range between 0.1 megalitres per day (ML/d) and 0.8 ML/d.[46]

When contaminated with the byproducts of the hydraulic fracturing process, this wastewater is referred to as *'produced water'*. Produced water can be contaminated with fracking and drilling chemicals, heavy metals (eg arsenic, mercury, lead, cadmium and chromium IV), other minerals, hydrocarbons like BTEX which occur naturally in coal seam water as well as radioactive elements like uranium. Coal seam water also contains salt. While the amount of salt depends on the location and age of the coal seam, it is typically between five and eight tonnes (5000kg-8000kg) for every megalitre (one million litres) of water. [47]

---

[43] EPA 749-F-94-013a CHEMICAL SUMMARY FOR METHANOL prepared by OFFICE OF POLLUTION PREVENTION AND TOXICS U.S. ENVIRONMENTAL PROTECTION AGENCY, August 1994

[44] International Agency for Research on Cancer (IARC) - Summaries & Evaluations ISOPROPANOL

[45] For more information see http://www.amcmud.com/amc-drilling-fluids-and-products.html

[46] CSG and water: quenching the industry's thirst, Gas Today Australia — May 2009

[47] Arrow Energy: Salt Management http://www.arrowenergy.com.au/icms_docs/95251_Salt_Management.pdf

Managing Produced Waste

Produced water is either stored in evaporation ponds, reinjected into the aquifer or 'treated' and then released into waterways or sold on to farmers for irrigation. While the Queensland Government prohibits the use of evaporation ponds as the primary disposal means for produced water (unless there is no feasible alternative)[48] NSW still permits them.

Evaporation ponds can cover large areas, for example Metgasco estimates that water by-products from its Casino wells will require approximately 12 hectares of pond area.[49] The water is typically saline and should the ponds fail (e.g. leak) surrounding soil quality and vegetation could be compromised or in the worst case destroyed. If ponds are flooded (for instance due to rain), their contaminants are released to surface water. Evaporative ponds inevitably result in the transfer of volatile or semivolatile chemicals into the atmosphere and evaporation ponds also need to be remediated and rehabilitated.

Some CSG companies in Australia are either developing and/or operating plants to treat the produced water using reverse osmosis and to on sell it to farmers for irrigation, domestic drinking water supply or cooling of power stations. However, reverse osmosis filtration has significant limitations [50] and cannot remove all contaminants, particularly organic compounds with low molecular weight.[51] Reverse osmosis involves forcing water through a semi-permeable membrane, which filters out a select number of water contaminants, depending on the size of the contaminants. In general, if the contaminants are larger in size than water molecules, those contaminants will be filtered out. If the contaminants are smaller in size, they will remain in the water.

The Queensland Gas Company (QGC) is opening a water treatment facility in the Western Downs region in October 2011. The $350 million facility will treat 100 megalitres of water used at the Chinchilla gas processing plant. It is unknown what the company will do with the 200 tonnes of salt produced a day, but a company representative has said, "Dumping it will be a last resort".[52]

Permits to Release Waste Water into Waterways

Permits are provided for the release of wastewater produced in association with the fracking process. In one authorisation for one CSG company,[53] the release of treated water into the Condamine River was authorised for a period of 18 months at a maximum volume of 20 megalitres (ML) per day. Over 80 chemical compounds as

[48] Coal Seam Gas Water Management Policy, Dept of Environment & Resource Management June 2010
[49] Appendix G METGASCO LIMITED, CASINO GAS PROJECT HYDROGEOLOGICAL ASSESSMENT http://www.planning.nsw.gov.au/asp/pdf/06_0217_rvps_cgp_ea_appendixgpt1.pdf
[50] See A. Bbdalo-Santoyo, J.L. Gbmez-Carrasco, E. Gbmez-Gbmez, M.F. Maximo-Martin, A.M. Hidalgo-Montesinos Spiral-wound membrane reverse osmosis and the treatment of industrial effluents. Desalination 160 (2004) 15 l-l 58: Also see Lianfa Song, J.Y. Hu, S.L. Ong, W.J. Ng, Menachem Elimelech, Mark Wilf, Performance limitation of the full-scale reverse osmosis process. Journal of Membrane Science 214 (2003) 239–244
[51] http://www.industry.qld.gov.au/documents/LNG/csg-water-beneficial-use-approval.pdf
[52] Farms to get treated coal seam gas water, Sam Burgess and Fidelis Rego ABC News 2911/2010 Available http://www.abc.net.au/news/stories/2010/11/29/3079368.htm
[53] Schedule C, Australian Pacific LNG Pty Ltd Environmental Authority (petroleum activities) No. PEN100067807

well as radionuclides[54] were listed in the permit and included a range of persistent, bioaccumulative toxic substances such as nonylphenols, Bisphenol A (BPA), chlorobenzenes, bromides, lead, cadmium, chromium, mercury, BTEX). There was no requirement for an assessment of the cumulative load or the potential to contaminate sediment, plants, aquatic species and /or animals prior to release.

While release limits were included for the listed compounds, the majority of these were not based on the ANZECC water guidelines [55] as many of the chemicals were not listed in the ANZECC guidelines or were marked as having insufficient data to set a water quality guideline. [56]

Follow up monitoring was required by the authorisation but this did not include assessment of the cumulative load. This is in contradiction of the current National Water Quality Management Strategy (NWQMS) [57] which recommends moving away from relying solely on chemical specific water monitoring to a more integrated approach using direct toxicity assessments (toxicity bioassays which assess overall toxicity of the water) and biological monitoring to fully assess the cumulative (additive and synergistic) impacts of the mixture of chemicals on the environment including plants and animals

Table 3 provides volumes and quantities of a selection of compounds permitted for release into the Condamine River over an 18 month period.

Table 3. Waste Water Permit

Chemical compound	**Release rate/day**	**Total** **(release rate x 20ML x 547.5 days / 18 months)**
BPA	200g/ML	2,298KG (2.298 tonnes)
Bromide	7,000g/ML	76,650KG (76.65 tonnes)
Total Chlorobenzenes	1,840g/ML	20,148KG (20.148 tonnes)
Monochloramine	3,000g/ML	32,850KG (32.85 tonnes)
Nitrate	50,000g/ML	5,475,000KG (5,475 tonnes)

[54] Radionuclides occur naturally as trace elements in rocks and soils as a consequence of the "radioactive decay'' of uranium-238 (U-238) and thorium-232 (Th-232). When radioactive atoms release or transfer their extra energy, it is called decay. The energy they release is called ionizing radiation, which may be alpha particles, beta particles, or gamma rays. When ionizing radiation strikes a living organism's cells, it may injure the organism's cells. There are about 650 radionuclides with half lives longer than 60 minutes. Of these, about 339 are known from nature. For more information see http://www.epa.gov/radiation/radionuclides/; Also see http://www.nesc.wvu.edu/pdf/dw/publications/ontap/2009_tb/radionuclides_DWFSOM45.pdf

[55] http://www.mincos.gov.au/publications/australian_and_new_zealand_guidelines_for_fresh_and_marine_water_quality

[56] The authors note that the Australian Centre for Mining Environmental Research, an industry consultancy has published their own list of TRIGGER VALUES FOR TOXICANTS in the document; Batley, GE, Humphrey CL, Apte SC and Stauber JL (2003). A Guide to the Application of the ANZECC/ARMCANZ Water Quality Guidelines in the Minerals Industry. (Australian Centre for Mining Environmental Research: Brisbane). However, the document is not in the public domain hence the trigger values, the data used or the methodology cannot be assessed.

[57] http://www.environment.gov.au/water/policy-programs/nwqms/

Uranium	20g/ML	219KG
Toluene	800g/ML	8,760KG (8.76 tonnes)
Xylene	600g/ML	6,570KG (6.57 tonnes)
Ethylbenzine	300g/ML	3,285KG (3.285 tonnes)
Benzene	1g/ML	10.95KG
Cyanide	80g/ML	876KG
Lead	10g/ML	109.5KG

CSG Impacts on Groundwater

'The drawdown of ground water heads within coal seam gas aquifers is a necessary process and an unavoidable impact associated with the depressurisation of the coal seam.' [58]

CSG drilling and fracking activities can impact the groundwater in different ways. There can be significant losses in pressure within the aquifer or in overlying and underlying aquifers and impacts may be experienced well beyond the perimeter of the gas fields. Industry predicts groundwater drawdown for the Arcadia Valley and Fairview CSG fields within the Bowen Basin, Queensland of up to 15 metres by 2013 and 65 metres by 2028. For the 4 bore wells situated in and around the fields, it was estimated they would experience 7 to 25 metres drawdown in the groundwater level by 2028.

For the Roma CSG field in the Surat Basin, industry predicted minor inter-aquifer transfer and only a 3 metre drawdown at the edge of the gas field.[59] Drill holes or fractures may intersect with one or multiple aquifers potentially mixing groundwater from different strata or altering the groundwater chemistry through exposure to the air, gas, fracking chemicals and drilling fluids or the release of natural compounds like BTEX.[60]

Methane Water Contamination

Methane can also contaminate bores and water wells near gas wells.[61] An analysis of 60 water wells near active gas wells in the US, found most were contaminated with

[58] Groundwater (Deep Aquifer Modeling) for Santos GLNG Project – Environmental Impact Statement 31/3/2009
[59] Groundwater (Deep Aquifer Modelling) for Santos GLNG Project – Environmental Impact Statement 31/3/2009 http://www.glng.com.au/library/EIS/Section%206/06%2006%20Groundwater%20(Section%206.6)%20FINAL%20PUBLIC.pdf
[60] Shenhua Watermark Coal Pty Ltd, Review of Environmental Factors Exploration Drilling and Associated Activities -EL 7223 February 2011 GHD-RPT-EXP-DRL-007 [1] Revision 1
[61] Osborn, SG, A Vengosh, NR Warner, RB Jackson. 2011. Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing. Proceedings of the National Academy of Sciences, U.S.A. doi: 10.1073/pnas.1100682108. http://www.nicholas.duke.edu/cgc/pnas2011.pdf

methane at levels well above US federal safety guidelines for methane. The majority of water wells situated one kilometre or less from a gas well, contained water contaminated with 19 to 64 parts per million of methane. Wells more than a kilometre from active gas had only a few parts per million of methane in their water. The study used chemical and isotopic analyses to identify the high levels of methane in well water as being produced in the deep shale, released by gas drilling activities. The low-level, background methane from the more distant water wells came from methane-generating bacteria living in shallow rock.

Other Risks Associated with CSG Fracking

There are other health and environmental risks associated with the extraction and production of CSG and shale gas. These include:

Flare stacks and flare pits

Gas flare or flare stacks are used in gas wells (and chemical plants, landfills, oil wells etc.) to 'dispose' of waste gas. Flares act as a safety system to manage excess gas pressure and can be used to burn off excess gas. Gas flares contribute significantly to local air pollution and flares are a significant global contributor to greenhouse gas emissions (0.5% of all anthropogenic carbon dioxide emissions).[62] Over 250 toxins have been identified as being released from flaring including carcinogens such as benzopyrene, benzene, carbon di-sulphide (CS2), carbonyl sulphide (COS) and toluene; metals such as mercury, arsenic and chromium; sour gas with H2S and SO2; nitrogen oxides (NOx); carbon dioxide (CO2); and methane (CH4) which contributes to the greenhouse gases.[63]

Flare pits are the earthen pits constructed beneath the flare stacks to contain any fluids produced from the flaring of the gas associated liquid hydrocarbons and brine water. The soil surrounding these pits is typically hydrocarbon and salt contaminated. These fluids mix with other toxic chemicals and are hazardous to birds and wildlife. Wildlife may die from the inhalation of toxic hydrogen sulphide gas (if the flare igniter is faulty), or by direct incineration in the flare stack. At minimum, anti-perching devices for birds should be installed.[64]

Ozone

Ozone is produced by fugitive emissions mixing with nitrogen oxides from the exhaust of diesel-driven, mobile and stationary equipment to produce ground-level ozone. Ozone combined with particulate matter less than 2.5 microns produces smog (haze). Gas field produced ozone in the USA has created a serious air pollution problem similar to that found in large urban areas, and can spread large distances (up

---

[62] Global, Regional, and National CO2 Emissions. In Trends: A Compendium of Data on Global Change, Marland, G., T.A. Boden, and R. J. Andres, 2005, Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tennessee.

[63] Canadian Public Health Association, Background to 2000 Resolution No. 3 Available at http://www.climatelaw.org/cases/country/nigeria/cases/casedocuments/nigeria/report/section7/doc7.1.pdf

[64] See Contaminant Issues - Oil Field Waste Pits. US Fish and Wildlife Services Available at http://www.fws.gov/mountain prairie/contaminants/contaminants1f.html

to approx. 300km) beyond the immediate region where gas is being produced.[65]

Hazardous waste disposal

Concentrated hazardous wastes from evaporation ponds (and water treatment plants) need to be disposed of to an appropriate licensed facility. This will add significant demands on regional waste management capacity (e.g. landfills).

Radioactive tracers

Radioactive tracers are used with various types of proppants that include resin coated sand and man-made ceramics (eg polymers, nanomaterials) which can be retained in the produced water.

Assessing the Risks

Many of these and other chemical risks associated with CSG and hydraulic fracturing. are not comprehensively assessed. For instance, the Queensland Environmental Protection Act of 1994 (S310D) calls for companies to provide a complete inventory of chemicals, full toxicity data including mixture toxicity and a risk assessment. Yet, the relevant authorities acknowledge that not all chemicals can be assessed because some are commercial secrets, and even those that are disclosed, have very little data available.

In a review of Australian industries risk assessments of CSG activities, the following were not adequately assessed:

- air emissions from evaporative ponds;
- emissions and releases from gas flares/pits
- impact of the release of BTEX from the coal seam;
- impact of potential break down products fracking chemicals intermediates;
- endocrine disrupting potential (of concern as impacts occur at very low levels); and
- the combined effect of the complex mixture of chemicals on the environment, especially water contamination.

[65] The Endocrine Disruption Exchange http://www.endocrinedisruption.com/chemicals.introduction.php

APPENDIX 1: Companies actively exploring and/or extracting CSG in Australia include: *Note: this is an indicative list of companies at the time of writing. Companies may cease exploration or expand exploration as required.* [66,67]

- Santos Ltd - Surat and Bowen Basins
- Origin Energy - Surat and Bowen Basins
- Westside corporation (http://www.westsidecorporation.com/) - Bowen Basin.
- Queensland Gas Company - Surat Basin
- Sunshine Gas Ltd - Surat and Bowen Basins
- Arrow Energy NL **-** Surat and Bowen Basins, Clarence-Moreton Basins
- Molopo Australia Ltd - Gloucester, Bowen and Clarence-Moreton Basins
- Blue Energy Pty Ltd - Bowen, Surat and Maryborough Basins
- Magellan Petroleum Australia - Maryborough Basin
- Red Sky Energy - Clarence-Moreton Basins
- Metgasco Ltd - Clarence-Moreton Basin
- AGL(agl.com.au): Glouchester Basin
- Sydney Gas Ltd - Sydney Basin
- Eneabba Gas Ltd - Perth Basin
- Pure Energy Resources Ltd - Bowen, Duaringa, Surat and Tasmania Basins
- Comet Ridge Ltd - Bowen, Galilee and Gunnedah Basins
- Planet Gas Ltd - Gippsland, Eromanga, Wilochra, Gunnedah and Otway Basins
- Eastern Star Gas – Otway Basin, Gunnedah Basins (Narabi Coal Seam project)
- Westralian Gas and Power Ltd - Perth, Collie and Wilga Basins
- Central Petroleum Ltd - Pedirka Basin
- Rey Resources Ltd - Canning Basin
- Red Sky Energy – numerous basins In NSW, Northern Territory and Queensland are being explor

[66] Coal bed methane- factsheet, Australian Mining Atlas Available at http://www.australianminesatlas.gov.au/education/fact_sheets/coal_bed_methane.jsp
[67] Coal Seam Gas Factsheet. Australian Mining Atlas Available at http://www.australianminesatlas.gov.au/education/fact_sheets/coal_seam_gas.jsp

APPENDIX 2: Coal Seam Gas and climate impacts

Industry and government frequently contend that natural gas is a ‘transition’ fuel and when used in tandem with renewable energy can play a complementary role in reducing carbon emissions.[68] At first glance, natural gas looks beneficial when compared with coal at the point of combustion: 80% less acid rain (sulphur dioxide), 60% less greenhouses gases (CO2) and no mercury or particulates (soot).[69]

In Australia, greenhouse gas emissions from the external processing and power generation activities for Liquid Natural Gas (LNG) are reported as significantly lower than for coal. Overall, industry claim coal delivery and power generation activities produce 43% more greenhouse gas emissions than LNG per GJ (gigajoule) of energy delivered. Diesel and fuel oil produce approximately 10-15% more greenhouse gas emissions than LNG, and hence sit between coal and gas in terms of emissions.[70] However, it must be acknowledged that the predicted advantage of natural gas over coal holds only when it is burned in modern and efficient plants.

Nevertheless, to effectively assess the impact of natural gas obtained from CSG or shale gas activities compared to other forms of energy production, it is essential to quantify and assess the total greenhouse gas emissions ie ‘*carbon footprint’*, rather than look only at the point of combustion.

US research demonstrates that the energy required for the liquefaction, transport and regasification in LNG, may add up to 20% additional CO2 to natural gas production.[71] Furthermore, coal seam gas cannot be assumed to have an emissions profile that is similar to conventional natural gas. In fact, there are indications that when measured across the entire lifecycle, CO2 emissions from unconventional gas sources such as CSG are higher than from conventional gas sources. Due to the paucity of emission records and research, just how much higher the CO2 emissions might be is a contested issue.

A key factor when assessing greenhouse emissions from an energy source is how the lifecycle analysis has been performed for example, what assumptions have been used and what is the quality and origin of the input data. Currently there is only very limited publicly available information for an in-depth life cycle assessment of CSG versus other forms of natural gas extraction.

The difference in the overall emissions associated with CSG versus conventional natural gas over the lifecycle of the fuel will principally depend on the attributes of the reservoir and the extraction method used. CSG not only differs from conventional gas extraction in terms of drilling (horizontal) and extraction processes (hydraulic

---

[68] Australia Pacific LNG Project, Volume 5: Attachment 30: Greenhouse Gas Assessment – Gas Fields and Pipeline

[69] Fulton,M, Mellquist, N and S. Kitasai, (2011)Comparing Life Cycle Greenhouse Gas Emissions from Natural Gas and Coal, March 14, Deutsche Bank, Climate Change Advisors http://www.dbcca.com/dbcca/EN/_media/Comparing_Life_Cycle_Greenhouse_Gas.pdf

[70] Australia Pacific LNG Project, Volume 5: Attachment 30: Greenhouse Gas Assessment – Gas Fields and Pipeline

[71] Paulina Jaramillo, W. Michael Griffin, H. Scott Matthews, “Comparative Life Cycle Carbon Emissions of LNG Versus Coal and Gas for Electricity Generation” (paper presented at Green Design Reading Group at Carnegie Mellon University, Pittsburgh, PA, February 12, 2005), http://www.ce.cmu.edu/~gdrg/readings/2005/10/12/Jaramillo_LifeCycleCarbonEmissionsFromLNG.pdf

fracturing), but additional emissions are generated from transportation of water and chemicals, as well as the removal of waste products.

The principle emissions during extraction of CSG which need to be accounted for in a thorough life cycle analysis, can be divided into:

- Use of fossil fuels for the engines of the trucks, drills, pumps and compressors used to extract the gas onsite, and to transport equipment, resources and waste on and off the well site;
- Fugitive emissions of natural gas that escape unintentionally during the well construction and production stages;
- Methane emissions from leaking wells; and
- Intentional vented emissions expelled during the extraction process and flaring.

The documents relied on by the Australian industry for their assessments of comparative carbon footprints, readily admit that greenhouse emissions from the extraction, processing and product transport for LNG are higher than for coal, and confirms that *"resources for unconventional sources such as shale formations, tight sands, and coal bed methane are generally more costly and energy intensive to develop due the need for advanced drilling techniques, such as horizontal drilling, and are also often characterized by smaller concentrations and steeper decline rates."* [72]

A report by the University of Manchester's Tyndall Centre, which assessed the climate impacts of shale gas, indicates that between 4,300 and 6,600 truck visits occur during preproduction for a 6 pad well arrangement. To produce 10% of the UK gas production would result in a total of 2-4 million truck visits.[73]

Another key question to be examined is the extent of fugitive emissions, especially methane. Methane is a powerful greenhouse gas, with a global warming potential 72 times more powerful than that of carbon dioxide over a 20 year horizon and 25 times more powerful than that of carbon dioxide over a 100 year horizon.

The Australian gas industry acknowledges that methane is the most important greenhouse gas fugitive emission (e.g. pipe leaks, leaking wells) in CSG projects, but also claims that the emissions of methane are relatively minor.[74]

It is this issue of fugitive methane emissions that lead a team of researchers from Cornell University to the conclusion that the greenhouse gas footprint of natural gas obtained by high-volume hydraulic fracturing from shale formations, which in many aspects is similar to CSG, is at least 30% more, and perhaps even twice as great as those from conventional gas.[75] They concluded that the carbon footprint of shale gas

[72] Life Cycle Assessment of GHG Emissions from LNG and Coal Fired Generation Scenarios: Assumptions and Results Prepared for: Center for Liquefied Natural Gas(CLNG) Feb 3, 2009 http://www.energy.ca.gov/lng/documents/2009-02-03_LCA_ASSUMPTIONS_LNG_AND_COAL.PDF

[73] Wood. R., et al: 2011, *Shale gas: a provisional assessment of climate change and environmental impacts.* A report commissioned by the Cooperative and undertaken by researchers at the Tyndall Centre, University of Manchester

[74] Australia Pacific LNG Project, Volume 5: Attachment 30: Greenhouse Gas Assessment – Gas Fields and Pipeline

[75] Robert W. Howarth, Renee Santoro, and Anthony Ingraffea, Methane and the Greenhouse-Gas Footprint of

is comparable to coal when compared over 100 years. The Cornell research put the size of the methane fugitive emission at up to 7.9% over the life-time of a well, with much of the leakage during initial drilling, completion and during transmission, storage and distribution. This figure is hotly contested by industry, which claims that methane leakage is minimal, despite the fact that the US EPA has recently revised its methane emissions estimations upwards. For instance, estimates for well venting were increased by a factor of 11 and well completion by a factor of 172.[76] Given these new figures, the Cornell research figures seem much more realistic.

The experience of landowners with wells on their properties also puts claims of minimal methane leaks in doubt. Wells have been seen to leak with bubbling gas being clearly evident around the well-head. CSG engineers also admit there are small leaks all along pipeline, but dismiss them as ‘tiny’.

Using conservative estimates the Tyndall Centre research states that if half of all the shale gas resources on earth were exploited, the additional cumulative emissions over the time period 2010-2050 would be between 46-183 giga tons of CO2, equating to an additional atmospheric concentration of CO2 of 3-11ppm.[77]

The assumption that natural gas from CSG can act as a transition fuel also needs to be challenged. Rather than substituting for coal, it is likely that CSG will simply satisfy increasing energy demand and hence, increase associated emissions and contribute to further reducing our ability to keep global temperature changes below 2C. The Tyndal research went as far as contending that the investment required for the exploitation of unconventional gas sources could further delay rapid carbon reductions, because this *‘investment would be much more effective if targeted at genuinely zero- (or very low) carbon technologies.’*

When the overall lifecycle of CSG and shale gas is taken into account acknowledging all the uncertainties, including the accuracy of emissions factors for fugitive methane released during extraction, processing and transportation then the view that this form of gas provides an effective transitional fuel to a cleaner, greener future is definitely in doubt.

Natural Gas from Shale Formations, *Climatic Change Letters* In press April 2011

[76] EPA, “Greenhouse Gas Emissions Reporting from the Petroleum and Natural Gas Industry, Background Technical Support Document, 30th November 2010
http://www.epa.gov/climatechange/emissions/downloads10/Subpart-W_TSD.pdf

[77] Wood. R., et al: 2011, Shale gas: a *provisional assessment of climate change and environmental impacts.* A report commissioned by the Cooperative and undertaken by researchers at the Tyndall Centre, University of Manchester

APPENDIX 3: *Chemicals used in fracking fluid products identified by the US Ground Water Protection Council and the Interstate Oil and Gas Compact Commission*

Chemical Name	CAS	Chemical Purpose	Product Function
Hydrochloric Acid	007647-01-0	Helps dissolve minerals & initiate cracks in rock	Acid
Glutaraldehyde	000111-30-8	Eliminates bacteria that produces corrosive by-products	Biocide
Quaternary Ammonium Chloride	012125-02-9	Eliminates bacteria in the water that produces corrosive by-products	Biocide
Quaternary Ammonium Chloride	061789-71-1	Eliminates bacteria in the water that produces corrosive by-products	Biocide
Tetrakis Hydroxymethyl-Phosphonium Sulfate	055566-30-8	Eliminates bacteria in the water that produces corrosive by-products	Biocide
Ammonium Persulfate	007727-54-0	Allows a delayed break down of the gel	Breaker
Sodium Chloride	007647-14-5	Product Stabilizer	Breaker
Magnesium Peroxide	014452-57-4	Allows a delayed break down the gel	Breaker
Magnesium Oxide	001309-48-4	Allows a delayed break down the gel	Breaker
Calcium Chloride	010043-52-4	Product Stabilizer	Breaker
Choline Chloride	000067-48-1	Prevents clays from swelling or shifting	Clay Stabilizer
Tetramethyl ammonium chloride	000075-57-0	Prevents clays from swelling or shifting	Clay Stabilizer
Sodium Chloride	007647-14-5	Prevents clays from swelling or shifting	Clay Stabilizer
Isopropanol	000067-63-0	Product stabilizer and / or winterizing agent	Corrosion Inhibitor
Methanol	000067-56-1	Product stabilizer and / or winterizing agent	Corrosion Inhibitor
Formic Acid	000064-18-6	Prevents the corrosion of the pipe	Corrosion Inhibitor
Acetaldehyde	000075-07-0	Prevents the corrosion of the pipe	Corrosion Inhibitor
Petroleum Distillate	064741-85-1	Carrier fluid for borate or zirconate crosslinker	Crosslinker
Hydrotreated Light Petroleum Distillate	064742-47-8	Carrier fluid for borate or zirconate crosslinker	Crosslinker
Potassium Metaborate	013709-94-9	Maintains fluid viscosity as temperature increases	Crosslinker
Triethanolamine Zirconate	101033-44-7	Maintains fluid viscosity as temperature increases	Crosslinker
Sodium Tetraborate	001303-96-4	Maintains fluid viscosity as temperature increases	Crosslinker
Boric Acid	001333-73-9	Maintains fluid viscosity as temperature increases	Crosslinker
Zirconium Complex	113184-20-6	Maintains fluid viscosity as temperature increases	Crosslinker
Borate Salts	N/A	Maintains fluid viscosity as temperature increases	Crosslinker
Ethylene Glycol	000107-21-1	Product stabilizer and / or winterizing agent.	Crosslinker
Methanol	000067-56-1	Product stabilizer and / or winterizing agent.	Crosslinker

Polyacrylamide	009003-05-8	“Slicks” the water to minimize friction	Friction Reducer
Petroleum Distillate	064741-85-1	Carrier fluid for polyacrylamide friction reducer	Friction Reducer
Hydrotreated Light Petroleum Distillate	064742-47-8	Carrier fluid for polyacrylamide friction reducer	Friction Reducer
Methanol	000067-56-1	Product stabilizer and / or winterizing agent.	Friction Reducer
Ethylene Glycol	000107-21-1	Product stabilizer and / or winterizing agent.	Friction Reducer
Guar Gum	009000-30-0	Thickens the water in order to suspend the sand	Gelling Agent
Petroleum Distillate	064741-85-1	Carrier fluid for guar gum in liquid gels	Gelling Agent
Hydrotreated Light Petroleum Distillate	064742-47-8	Carrier fluid for guar gum in liquid gels	Gelling Agent
Methanol	000067-56-1	Product stabilizer and / or winterizing agent.	Gelling Agent
Polysaccharide Blend	068130-15-4	Thickens the water in order to suspend the sand	Gelling Agent
Ethylene Glycol	000107-21-1	Product stabilizer and / or winterizing agent.	Gelling Agent
Citric Acid	000077-92-9	Prevents precipitation of metal oxides	Iron Control
Acetic Acid	000064-19-7	Prevents precipitation of metal oxides	Iron Control
Thioglycolic Acid	000068-11-1	Prevents precipitation of metal oxides	Iron Control
Sodium Erythorbate	006381-77-7	Prevents precipitation of metal oxides	Iron Control
Lauryl Sulfate	000151-21-3	Prevent formation of emulsions in fracture fluid	Non-Emulsifier
Isopropanol	000067-63-0	Product stabilizer and / or winterizing agent.	Non-Emulsifier
Ethylene Glycol	000107-21-1	Product stabilizer and / or winterizing agent.	Non-Emulsifier
Sodium Hydroxide	001310-73-2	Adjusts the pH of fluid	pH Adjusting Agent
Potassium Hydroxide	001310-58-3	Adjusts the pH of fluid	pH Adjusting Agent
Acetic Acid	000064-19-7	Adjusts the pH of fluid	pH Adjusting Agent
Sodium Carbonate	000497-19-8	Adjusts the pH of fluid	pH Adjusting Agent
Potassium Carbonate	000584-08-7	Adjusts the pH of fluid	pH Adjusting Agent
Copolymer of Acrylamide, Sodium Acrylate	025987-30-8	Prevents scale deposits in the pipe	Scale Inhibitor
Sodium Polycarboxylate	N/A	Prevents scale deposits in the pipe	Scale Inhibitor
Phosphonic Acid Salt	N/A	Prevents scale deposits in the pipe	Scale Inhibitor
Lauryl Sulfate	000151-21-3	Used to increase the viscosity of the fracture fluid	Surfactant
Ethanol	000064-17-5	Product stabilizer and / or winterizing agent.	Surfactant

Naphthalene	000091-20-3	Carrier fluid for the active surfactant ingredients	Surfactant
Methanol	000067-56-1	Product stabilizer and / or winterizing agent.	Surfactant
Isopropyl Alcohol	000067-63-0	Product stabilizer and / or winterizing agent.	Surfactant
2-Butoxyethanol	000111-76-2	Product stabilizer	Surfactant

APPENDIX 4: MSDS Supplementary Information

To download *The National Code of Practice for the Preparation of Material Safety Data Sheets* go to: www.safeworkaustralia.gov.au/AboutSafeWorkAustralia/WhatWeDo/Publications/Pages/CP2003MaterialSafetyDataSheets2ndEdition.aspx

Material Safety Data Sheets (MSDS)

The MSDS National Code

The National Occupational Health and Safety Commission (NOHSC) has produced *The National Code of Practice for the Preparation of Material Safety Data Sheets*, 2nd Edition 2003, which has been adopted as a Code of Practice under some state legislation. The application of the code is the prerogative of that State or Territory. MSDS are controlled by the hazardous substances and dangerous goods Acts in each state and territory.

(*The Workplace Health and Safety Regulation 2008* and the *Workplace Health and Safety Act 1995* provide a framework for managing health and safety risks in Queensland workplaces. The regulation sets out the legal requirements to prevent or control certain hazards, which might cause injury or death in the workplace.)

While an MSDS is not required for substances not classified as hazardous, there is often a legislative requirement to provide hazard information.

Hazardous Substances

The Code applies to hazardous substances and dangerous goods.

“A material is classified as hazardous and/or dangerous if it is:

(a) classified as hazardous according to the latest edition of the NOHSC *Approved Criteria for Classifying Hazardous Substances* [NOHSC:1008] and is above the cut-off concentration criteria for being classified as a hazardous substance;

(b) specified in the NOHSC *List of Designated Hazardous Substances* [NOHSC:10005];

(c) classified for physicochemical hazards according to the ADG Code (including class(es), subsidiary risk(s), Packing Group, Proper Shipping Name and UN Number); and/or

(d) specified as dangerous in the ADG Code or determined by the Competent Authorities. “

Under the code, Australia MSDS are based on 16 part data sheet, all sections of an MSDS need to be completed. Where information relevant to a particular section is not available, the MSDS should state ‘Not available’.

Acceptability of Overseas MSDS

Currently, MSDS prepared overseas are accepted by Commonwealth, State and Territory legislation if they meet the following requirements:

The MSDS is prepared in accordance with this code including the provision of the following information:

(i) Australian contact details – name of supplier, address and telephone number, including emergency contact details (see section 6.1);

(ii) classification in accordance with the Australian hazardous substance and Dangerous Goods regulatory framework

(iii) ingredient disclosure as required by Commonwealth, State and Territory legislation (see section 6.3);

(iv) national exposure standard value if available (see section 6.8); and

(v) relevant additional Australian regulatory information (see section 6.15).

New Zealand is in the process of harmonizing their MSDS with Australia. Their MSDSs also adhere to the 16 sections and are based on the UN GHS classification. Overall, they are a much more detailed and useful documents.

MSDS must be updated or reviewed:

- whenever there is new information on changes to hazardous properties of the product;
- whenever there is a formulation change;
- often enough to keep it up to date; and
- at least every five years.