Submission to:
Scientific Inquiry into Hydraulic Fracture Stimulation in WA 2018

Submission from:

Patricia McAuliffe
[redacted]

[redacted]

On behalf of
Buddhists for the Environment WA (BFEWA)

Preamble

I am a concerned member of the public, a mother and grandmother who cares deeply about leaving a habitable planet for the next generations.

I have been a member of a group 'No Fracking Way' since its inception in 2011, when many were appalled by the potential of great harm being inflicted on various parts of the world. An imminent threat to the West Australian landscape was cause for further concern.
.
I, however, am now submitting this submission on behalf of 'Buddhists for the Environment WA.'

This organisation was recently formed by Buddhist practitioners who are concerned with many aspects of environmental sustainability: a healthy, balanced ecosystem is essential for all of life. High on our list of concerns is the impact of hydraulic fracture stimulation for gas on biodiversity in all its forms our land, water, air and health.

I have largely based this submission on independent, peer reviewed scientific research, of which there is an abundance highlighting serious risks – more than I could possibly include in this paper.

I would like to draw your attention to two visual references**:**
Fractured Country - An Unconventional Invasion: an Australian film by Lock the Gate, which includes the personal testaments from people directly affected by this industry, including farmers and their families, a vigneron and a traditional owner.

https://www.youtube.com/watchy=Dxis-vYGM_M : A video clip on 'well failure' and 'well integrity,' by industry insider Anthony Ingraffea (PHD) from Cornell University School of Civil and Environmental Engineering in the US.

The table of contents will show you the extent of coverage of relevant issues in this paper.

Scientific Inquiry into Hydraulic Fracture Stimulation in WA 2018

By

Patricia McAuliffe

[redacted]

on behalf of

Buddhists for the Environment WA (BFEWA)

Table of Contents

1 Introduction

This inquiry is welcomed, even though it is somewhat late, given the huge area of Western Australia already under exploration for unconventional gas. It allows concerned individuals and groups to express their grave concerns about this high risk, under researched unconventional gas industry, to an independent panel. This is essential prior to giving a potential green light to what could be described as a 'fracking frenzy', as observed elsewhere in Australia and worldwide.

Existing industry research has focused on the economic benefits and technicalities of gas extraction to achieve the most efficient and cost-effective results. However, a great deal of independent, peer reviewed research has been published in reputable scientific journals that contra-indicate the 'horizontal hydraulic slick-water fracturing' practice. Given that unconventional shale and tight gas production is relatively new to Western Australia, the experience in the eastern states and overseas is used largely in this submission.

Unconventional gas fracking licences have been granted extensively in WA, even during the period in which there is a moratorium and a ban. This has flown under the radar before there has been a meaningful assessment of this industry. Exploration licences allow companies to drill and check for potential gas flow, regardless of the considerable damage to land and property caused during exploration. Questions must be raised about these processes occurring whilst an inquiry is proceeding.

Whilst landowners do not own the resources below a certain level, it must be said that the people of Australia do own them. Our elected representatives must diligently protect the resources of the state, for the people of the state. Thus, governments and industry bodies should act accordingly.

Having attended public talks on hydraulic fracturing for unconventional gas by the Department of Mines and Petroleum, I have noted their uncompromising support of this industry, which exposes a conflict of interest and a lack of independence. Misinformation by senior spokespersons from the DMP, is evidence of collusion with the industry. To state, "Fracking has been occurring safely for more than 60 years," is an example of a patently misleading statement. Furthermore, 'Horizontal hydraulic slick-water fracturing is necessary for the extraction of unconventional gas and has only been in commercial operation since the late 1990s,' again demonstrates this collusion. Referring to conventional gas drilling is misleading, as is the statement that, 'it is much cleaner than coal in terms of greenhouse gas emissions, and it is therefore a good transition fuel.' Studies clearly show that the whole process (upstream, midstream and downstream sections) of unconventional gas mining must be considered, not just the 'burning end point.' Methane emissions over time contribute more to global warming than CO2, which is released when any hydrocarbon, like natural gas, is burned. (Howarth et al 2011); (Stephensona et al 2012)

DMP, as a government department, should consider independent peer reviewed scientific sources of information, rather than repeating website information of industry bodies such as APPEA. They should also consider the broader implications of addressing climate change**.**

In summary, this assault on our state should not proceed, contrary to what industry, government, and government departments have previously proclaimed. I will endeavour to show the serious risks posed by this industry to populations living close to gas fields as well as beyond, through the pollution of our water, air, soil, and more. I aim to support my submission with scientific research and individual experiences.

1.2 Community opposition to unconventional gas fracking

In the film, '*A fractured country: an unconventional invasion'* (*http://www.lockthegate.org.au/our_films*), families living in the Darling Downs area of Queensland discuss how their health, drinking water and livelihoods have been devastated due to living close to gas fields. Contrary to industry claims, they recount the contempt with which they have been treated by the gas companies. Similar stories abound for those living close to unconventional gas operations in NSW.

Across Australia, there have been 450 communities who have declared themselves 'gas-field free' with close to 20 being from WA. The voices of those affected should be given equal weight to those wishing to push this industry onto their lives.

2 Choosing where to drill

It is my understanding that through seismic surveys and core sampling, petroleum geologists/scientists seek where the most productive or 'sweet' target formations lie. From an industry economic viewpoint this is a logical practice.

Seismic surveys, which often proceed prior to drilling, are in themselves, destructive. I have observed the marking out of a large seismic survey area in a prolific wildflower region close to Eneabba. Huge seismic vibreosis vehicles thumped in a grid pattern, across a fragile river, as well as any wildlife and precious vegetation.in their path. I observed seriously threatened black cockatoos feeding in the designated area; this habitat would have been in the path of destruction.

UGF needs to be close to adequate water resources (necessary in huge amounts for the fracking process.) Decisions about where to locate well sites are predicated on reasons other than conservation, ecological fragility, nature reserves and national parks, Aboriginal heritage, threatened species, agricultural farm land and livestock, essential aquifer systems, rivers and streams, iconic tourist attractions, or even proximity to human habitation. These are the economic backbone of Western Australia, that rely on healthy, uncontaminated soil, water and air. We too are reliant on these essential elements.

3 Land owner rights

Ease of access to land, and resources which lie beneath, are key considerations for mining corporations. Land owners must have their rights clearly spelled out by these companies, councils and the government, so that any bullying tactics and threats regarding confidentiality contracts can be put in to perspective. Phrases such as ’minimal impact’, or ‘minor adverse effects,’ should be clearly defined. Hence, industry insurance coverage for adverse effects such as gas leaks, bore water contamination, health effects and property damage should be provided. Nearby landowners risk the loss property value, and many find they cannot be insured if they are located close to gas fields.

Moreover, once written approval to an activity is given by landowners, those persons can no longer be considered as ‘affected persons.’ This undermines the rights, safety and compensation for potential parties affected. Although landowners and occupiers do not own the oil and gas under their land, they must have the right to deny access by not signing access arrangements proposed by companies. This needs to be made clear to land owners**,** who may be vulnerable to bullying tactics.

4 Establishing the well site

Consents for land use, water take and discharge, may be granted elsewhere by regions or councils or government authorities. This can be without consideration of the cumulative effects of the different activities consented to, and the real impacts on the environment and nearby landowners. Examples include permission to discharge emissions into the air through venting, emissions of CO_2 through flaring, air pollution of toxic chemicals from returned frack fluids in waste evaporation ponds, and discharge of contaminants to water or land. Pipelines criss-crossing their land, may considerably hamper the movement of livestock, and the normal workings of farm life. Gas leaks are more common than the industry admits to, as will be shown in the next sections.

There is an apparent paucity of research and risk assessment of the cumulative or synergistic effects of so many unconventional gas related activities in a small area over the short to long term.

5 Drilling and constructing the well

5.1 Well integrity

Current engineering capacity cannot guarantee well integrity in the short or long term**,** despite industry claims to the contrary**.** Even strict regulations cannot avoid such failures. Studies have shown that approximately 5% of all oil and gas wells leak immediately because of well integrity issues, with increasing rates of leakage over time. In a period of 20 years, over half of the wells will leak. (Ingraffea 2012) With the proposed number of wells expected, this problem is neither negligible nor preventable with current technology. Pressures under the earth, temperature changes, ground movement from the drilling of nearby wells, and shrinkage crack and damage to the thin layer of brittle cement that is supposed to seal the wells, are all current concerns. Ensuring the integrity of the cement as the drilling goes horizontally into shale is extremely challenging. Once the cement is damaged, repairing it many metres underground is expensive and often unsuccessful.

Regarding well integrity, Lustgarten (2012) noted (in the US) a review of well records, case histories, and government summaries from “more than 220,000 well inspections…found that structural failures inside injection wells are routine," and that "from late 2007-2010" there was "one integrity violation…issued for every six deep injection wells examined- more than 17,000 violations nationally… more than 7,000 wells showed that their walls were leaking." There is nothing to ensure that old wells that are being re-drilled will have the required strength and integrity to withstand a 'second life' of production, possibly several years later.

Nikiforuk (2014) reported on a University of Waterloo study, which claimed that Canada had 500,000 leaky wells. Such massive amounts of methane in the atmosphere could have grave implications at a national and state level, in terms of impacts on climate change.

5.2 Fault seal analysis

Mullen and Archer (2018) compared two shale gas wells in the North Perth Basin for their fault stability; Arrowsmith 2 and Woodada Deep. They found that Woodada Deep had more critically stressed faults that were leaking significant volumes of gas, including methane, short chain alkanes and petroleum vapours into deep aquifers. The deep aquifers proximal to the shale gas target were also low in salinity. These findings show that environmental risks can be considerable. The question must be asked as to why fault seal analysis is not assessed routinely prior to drilling. In the Arrowsmith region, the Kockatea shale has low permeability and is a regional seal. (Plampton W. 2017) The aquifer underlies the shallower target formation. Given that it is both a seal and a target for unconventional gas, it seems incomprehensible that this important seal could be fractured and blasted by UGF processes, potentially also reactivating existing faults.

6 Fracking the well

6.1 Environmental and health impacts of fracking chemicals

There are now multiple peer-reviewed studies that have demonstrated the serious risks involved in fracking, and the many pathways for water contamination to occur. Air pollution associated with flaring, venting, and evaporation ponds are also implicated. (Coborn 2011; Bamberger 2012; McKenzie 2012) Many of these studies have pointed out the need for more detailed research, baseline studies, and public disclosure, especially in the area of health impacts from exposure to fracking chemicals.

At present, little is known about many of the chemicals, and the cumulative and synergistic effects they may have on humans, animals and soil or water quality. Many of the chemicals have not even been assessed, and some have undisclosed constituents, making it impossible to assess or monitor. Many of the chemicals are known to be toxic at concentrations near or below detection limits eg. glutaraldehyde, ethylene glycol. monobutyl ether, 2.2-dibromo-3-nitrilopropionamide, as well as methanol, formaldehyde and sulfuric acid. Other chemicals used include known carcinogens such as xylene, toluene and ethylbenzene which may have been currently banned, however, they are released from the rock during the fracking process and returned as waste with the flowback alongside the introduced chemicals. Many of the chemicals are self-assessed by companies and approved under groupings as additives, process chemicals, and raw materials. It is questionable that the regulatory agencies have the technical capacity and resources to assess this. Shonkoff et al (2014) notes that there is a lack of basic scientifically based contaminant levels known or disclosed. This makes it more difficult to quantify health risks. The industry claims that the number of chemical additives is very small, being somewhere between 0.5% and 2%. However, in a typical 15 million litre fracturing operation, this would range from 80 to 330 tons of chemicals - not an insignificant amount! The industry is prone to comment for public consumption that many of these chemicals can be found in household and food products. This is very misleading as are other industry myths. Whilst it might be true of a small number of ingredients in minute amounts, people would not consume the amounts or combinations that the industry uses.

6.2 Seismic risks and monitoring

UGF is known to induce micro earthquakes, though in the USA, seismic monitoring capabilities in many areas are not capable of detecting small earthquake activity, and quakes of M<3 are not always documented. Yet small earthquakes have the potential to cause damage to well casings and associated infrastructure, creating links between previously unconnected sub-surface ground layers such as fractured zones and aquifers (Ellsworth 2013; Keranen 2013)

In an exhaustive literature review, Watson (2016) found that seismic activity in six US states, was found to be caused by waste water injection as well as the fracking itself. He concluded that the courts should impose strict liability on the companies concerned.

In 2016, Atkinson et al, a Canadian team of researchers found earthquake swarms in Western Canada were due to the actual fracking operations. They found that this "has far reaching implications for the assessment of seismicity hazards."

Groningen Province in Holland which has had numerous gas extraction earthquakes, is currently seeking damages for 900 affected homes. (2018) http://www.france24.com/en/20180112-dutch-hasten-plans-pay-damages-after-gas-field-quake

The above research should also be of great concern in WA. Fracture lines and faults are not all known or documented in our vast state, although seismic activity has been historically recorded here.

7 Flowback and transitioning into production

7.1 Fugitive emissions

Methane escapes during the initial drilling process; well head problems including corrosion are a source of methane leakage; flaring of gas is frequently permitted and can take place close to human habitation without regard to health consequences; venting (non-captured methane) is forbidden in many jurisdictions and is, never the less, estimated to occur more frequently than flaring; (Howarth et al 2012) Compressor stations are a big source of fugitive emissions and consequent air pollution and have exploded at times; gas pipes also are subject to aging, corrosion, leaks and explosions.

Ingraffea (2016) identifies the extent of well failure even in many new wells, that increases dramatically over time in an informative video.

7.2 Groundwater contamination

Groundwater contamination can occur via a number of routes, including pre-existing fractures and faults, as well as those caused through the hydraulic fracturing process. (Meyers 2012; Warner 2012; Gross 2013; Adams 2011; Osborn 2011) The fracturing of target formations not only releases the sought-after methane gas, but many other organic compounds that have been safely locked in the rocks for eons. However, in WA, the highly toxic and carcinogenic b-tex chemicals have been reportedly banned from the chemical injection fluids; they never the less are naturally occurring within the rock.

Once fracked, the surface area of the rock is multiplied many times. Its porosity is increased to release the methane. This means that these chemicals and chemical compounds are much more readily available to contaminate whatever they come in contact with. About 50% of the injected water and fracking chemicals, now mixed with the many other organic compounds, are returned to the surface. The remainder stay underground. There is growing evidence that, despite the thick layers of rock above the target formation, toxic waste substances can make their way through not fully understood means, into overlying aquifers. (Lustgarten 2012)

Hildenbrand et al (2015) found extensive contamination or drying up of private drinking water wells in Pennsylvania (240) over a seven-year period, as a result of drilling and fracking operations. They also found a similar situation in the Barnett shale region of northern Texas, where 550 water samples taken, were contaminated.

7.3 Water abstraction

From fracking to production, a substantial amount of water is required. Every fracked well may require up to 20 million litres of fresh water, 4,000 tons of proppants, and up to 200,000 litres of chemicals. (IEA 2012a:27: IEA 2012b:33)

This is of great concern in Australia, the driest state on the driest habitable continent, at a time when inundation is decreasing, and temperatures are rising. The mining industry competes with the water needs of agriculture, of urban and regional populations, and the sustainability of our natural environment.

In Barnhart, Texas, The Guardian (13.8.13) headline reads***, "A Texan Tragedy: Ample Oil, No Water*** - Fracking sucks away precious water from beneath the ground, leaving cattle dead, farms bone-dry, and people thirsty." The local wells and main water supply to the town have dried up.

7.4 Potential for recycling produced water

The vast amount of water used in hydraulic fracturing is a concern to the many citizens who are aware of this problem. A lack of public debate in this state, leaves the public uninformed. Therefore, serious questions must be posed and thoroughly researched.

Frack fluid in the initial injection phase contains many hazardous chemicals, which are not yet known in the public domain. Added to this, is the return fluid; there are NORMs (naturally occurring radioactive material) and sand and brine, which is much saltier than sea water. Lutz (2013) conducted research into waste water in the Marcellus shale region, stating that waste water is overwhelming disposal options, and could have a range of environmental and health impacts if not properly managed. He says, with unconventional gas, this waste is difficult to deal with. Removing dissolved salts requires expensive distillation and reverse osmosis. Drillers found it more cost effective to invest in mobile waste water treatment for re-use in fracking rather than discharging it into the environment.

In addition, large amounts of water were trucked to deep wells for injection under high pressure. In some cases, this had the effect of causing seismic events. The practice was temporarily stopped, before tighter controls could be applied, resulting in additional costs.

Major concerns remain about ground and surface water contamination, and human exposures to this. The re-use of fracking fluid in subsequent fracking operations is also fraught. It means that the injection fluid will be much more concentrated and will have the NORMs included. This intensifies the risk to aquifers and ground water in the case of leakages, migration and other forms of contamination.

Guy Pearse, in his book 'Big Coal' (P. 110, 2013) notes that, "Rio Tinto is funding irrigation infrastructure for farmers", and in Chinchilla, Queensland, "The Queensland Gas Corporation has gifted pipelines and a treatment plant to supply un-potable water to supplement local agricultural water supplies". This is very concerning as using questionable industrial waste water for agriculture without much more research being done, is dangerous.

Adams (2011) also reported on a stand of trees in West Virginia which were damaged after fracking waste was sprayed on them.

7.5 Radio-nuclides and contamination risks

Christopher Busby, the Scientific Secretary of the European Committee on Radiation Risk, and an expert on the health effects of ionizing radiation, has written extensively on this topic. (Busby 2013) Among the most concerning of the released materials are part of the uranium chain; Naturally Occurring Radioactive Material (NORMs). Human activities such as gas exploration can expose people to this ionising radiation. Notably Radium 226 is one of one chemical released. When this reaches air, it becomes radon gas. It has been detected in greater quantities around gas fields and is highly carcinogenic. NORMs can also attach as scale to pipes and other mining equipment such as the trucks used for transporting waste. All of these materials then become hazardous radioactive waste which is very difficult to dispose of safely. The waste water can also be radioactive.

Rich and Crosby (2013) analysed for the presence of TENORMs (technologically enhanced naturally occurring radioactive waste through anthropogenic means) in the soil and water (sludge) in an active and a vacated waste reserve pit in unconventional gas mining operations. They analysed for the total Gamma, Alpha, Beta radiation for 13 radio nuclides, investigating the potential impact on the environment, occupational workers and the general public. They were concerned about the oversight and exemption of TENORM in the State and Federal regulations.

“Once you have a release of fracking fluid into the environment you end up with a radioactive legacy.” (Vengosh 2014)

7.6 Health issues

There are many studies identifying serious risks to public health through the life cycle of shale gas development. This can be through water, soil and air contamination. (Gross 2013; Lustgarten 2012; Litovitz 2013)

Shonkoff et al (2014), argue there is a need for more epidemiological studies to assess risk factors between air and water pollution, and health outcomes among populations living close to shale gas operations. There is a growing body of evidence pointing to this need.

Hays and Shonkoff (2016) reviewed 700 peer reviewed scientific studies on the relationship of unconventional gas developments and public health and found 84% of them to show risks. Likewise, Saunders et al (2016) found multiple potential hazards to human health from exposures to harmful air and water pollutants associated with unconventional gas mining.

Dr G McCarron (2018) published a paper looking at a large increase in air pollutants from 2007-2014 in Queensland from unconventional gas emissions. These were nitrogen oxide (489%) carbon monoxide (800%), pm10 (6000%), and formaldehyde (from 12kg to over160 tons). There were significant increases in hospitalisations of people suffering with acute circulatory and respiratory conditions of which the said toxins were known causal factors.

A health assessment of exposure to air emissions from shale gas development in Colorado found that residents who live within ½ mile of well pads are at greater risk of developing cancer and non-cancer health effects (McKenzie 2012).

Studies have shown that shale gas production is associated with raised atmospheric concentrations of tropospheric or ground level ozone, whereby nitrogen oxides, volatile organic compounds, and sunlight interact to produce hazardous respiratory irritants that increase risks of morbidity and mortality. (Schnell 2009; Jerrett 2009; Olaguer 2012; Petron et al 2012)

Diesel trucks emit health damaging particulate air pollutants that contribute to cardiovascular and respiratory diseases, atherosclerosis, and premature death (Carb 2008; EPA 2011). German cities can now instigate bans on diesel vehicles that don't meet euro 6 emission standards. Government figures have shown that about 6000 people in the country die prematurely each year because of nitrogen oxides. (NOx) ABC News 28 Feb 2018

Crystalline silica (frac sand) is a significant hazard for workers and other populations in close geographical proximity. Illnesses include silicosis, lung cancer, chronic obstructive pulmonary disease, chronic kidney diseases and a variety of auto immune diseases (NIOSH/CDC2012; NTP 2012).

Given the serious nature of health issues relating to unconventional gas operations, baseline studies should be carried out by industry funds, for populations living close to proposed gas developments as well as comprehensive epidemiological population studies.

7.7 Noise pollution

This is not an insignificant problem for local communities both for stress and mental health issues for many who are used to a slower paced and peaceful rural lifestyle. Noise and light pollution occurs 24 hours per day, and there is a constant stream of trucks carrying chemicals, water, sand or silica, and toxic waste material. The diesel trucks are also a source of pollution, emitting diesel particulates. In addition, there is onsite activity including infrastructure, transporting and building in the construction phase. Compressor stations are very noisy and operate 24 hours a day. Flaring is also loud. Broomfield (2012) estimates that **"…**each well-pad (assuming 10 wells per pad) would require 800 to 2,500 days of noisy activity during pre-production, covering ground works and road construction as well as the hydraulic fracturing process."

7.8 Land footprint

Overhead pictures of gas fields are well known. Ever expanding networks of multi-well pads; intersecting access roads; gas and water pipelines criss-cross the landscape; treatment plants; compressor stations and toxic waste water ponds transform previously productive, fertile and picturesque land, including nature reserves and national parks, as well as farms, into vast industrial wastelands. It disrupts the natural ecology, removing trees and vegetation that support life, changing the landscape to polluting entities destructive of life. Broomfield (2012) estimates that approximately 50 shale gas wells may be needed to give a similar yield as one North Sea gas well. He also compares the surface well installation during the fracturing and completion periods as approximately 3.6 hectares per pad compared with conventional drilling which needs approximately 1.9 hectares.

Even though gas companies are more recently positing the use of deviated wells in multiple directions from a single well head, this means that though the land surface may show a lesser surface number of well heads, the underground footprint is still huge. Additionally, these underground well constructions may go under the land of non-consenting land owners. The risk to their land, their water bores and the diminished water may impact them markedly.

8 Handling the waste

8.1 Air and soil contamination

Many particulates and chemicals are released into the atmosphere including sulphuric oxide, nitrogen, volatile organic compounds, benzene, toluene, diesel particulates, hydrogen sulphide, and radon gas. The drilling sludge, which is brought to the surface during the drilling process, contains fracking fluid, drilling mud, and radioactive material from the target formation, hydrocarbons, metals, and volatile organic compounds. The sludge is often left to dry out (evaporate) in surface waste pits. Alternatively, it may be removed to waste disposal sites (not always hazardous waste sites) or it may be tilled into the soil in ‘land farms’. These practices raise the risk of contaminating soil, air, and surface water, as a result of the fine dust becoming air-born. (Finkel & Law2011)

Kort et al (2016) used air born carbon data collected over the North Dakota section of the Bakken shale in 2014. They found the equivalent of 1-3% of total global sources of Ethane. Ethane is the second most abundant atmospheric hydrocarbon, which reduces the atmosphere's oxidative capacity. "The large source from one location illustrates the key role of shale oil and gas production in rising global ethane levels."

Allred et al (2015) in an interdisciplinary US study, documented the failure of plant and soil systems disturbed by drilling and fracking activities to return to pre-drilling conditions following rehabilitation, even after 20-50 years. They demonstrated that the accumulating land degradation of the unconventional gas industry measured in the amount of carbon absorbed by plants and accumulated as biomass essential to food production, biodiversity, and wildlife habitat, was "…likely long lasting and potentially permanent".

8.2 Land farming

Land spreading (also known as land farming, land disposal and land treatment) is the process whereby drilling wastes are disposed of via application to land. The aim is to attempt to remediate the soil's naturally occurring microbial populations, to degrade drilling waste constituents, particularly hydrocarbons and other organic compounds.

In terms of science, there is not enough information to ensure that this practice is safe over the long term. Fracking waste has been spread on land in Taranaki New Zealand, but no studies on the outcome were found. A Taranaki Land council technical report (Oct 2011) - drilling waste (not fracking waste) was reviewed after 3 years. The results did not reach any definitive conclusion. No New Zealand studies investigated the potential impacts on wildlife, livestock or food products.

In the USA, this practice has had adverse effects. (Adams 2011)

Further research is needed into how this practice may affect the environment, soil health, animal health and food safety, especially the synergistic effects in the long term.

With fracking waste, this caution is doubly important due to the toxic and known carcinogenic chemicals used. Should this be a proposal for West Australia, definitive research must be conducted into the long-term outcomes in countries where this has occurred, prior to any consent being given to explore or drill.

Waste disposal is a major problem for energy companies engaged in fracking practices, and they grasp at any possibilities for disposing of the toxic waste. Once disposed of in unsafe ways, it then becomes the community's long- term problem.

Given that well pipes and underground structures will remain after well abandonment, a landscape extensively perforated by pipes going deep into the earth, often directly through aquifers, becomes a perpetual environmental issue.

The potential to leak toxins into the water, ground and air renders the possibility of these structures returning the land to productive use as unfeasible.

8.3 Deep well injection

A process of injecting waste water and materials into deep wells (such as abandoned mining wells) is often used by the industry. Fluid must be injected at high pressure which has been known to cause earthquakes. Whilst these quakes might be small, they have been suspected of triggering larger earthquakes over time. (Ellsworth 2013) Western Australia has had significant earthquakes in the past, and the fault systems, major or minor, have not been fully mapped.

Lustgarten (2013) writes that more than 30 trillion gallons of toxic waste have been estimated to have been injected into thousands of wells across America in 'invisible dumping grounds'. Growing records are now showing that these wells have repeatedly leaked, sending dangerous chemicals and waste gurgling to the surface, and at times seeping into shallow aquifers. It had previously been assumed that these wastes would be entombed beneath the deep layers of rock forever.

Pro Publica (2012) quoted interviews with several key experts who acknowledged that the idea of injection being safe rests on science that has not kept pace with reality. It quotes Mario Salazar, an engineer who worked for 25 years as a technical expert with the EPA's underground injection program in Washington as saying, "In 10-100 years we are going to find that most of our groundwater is polluted. A lot of people are going to get sick, and a lot of people may die."

9 The reclamation of land that has been hydraulically fractured

9.1 Reclamation planning prior to drilling

Reclaiming planning prior to drilling involves numerous steps that should begin with initial site selection. It is necessary to choose an optimal site, says Bloomfield (2012), in order “to minimise adverse impacts on sensitive receptors.” Assessment of baseline information regarding the site contours, vegetation, wildlife habitat and land function, prior to being given a licence to drill, are essential. It should be independent regulators that assess these details rather than the drilling companies, thus ensuring successful environmental restoration can be determined after the event (Parkland Institute). Where mature, native trees, necessary for bird habitation among other things, are removed, it is difficult to see how these can be replaced in the short term.

Developer liability for water and soil contamination as well as inadequate land restoration should be determined before any leases or agreements are signed, as well as what steps will be taken to return the land to its original state. (Skausen 2011)

Broomfield (2012) notes that,” The evidence suggests that it may not be possible fully to restore sites in sensitive areas following well completions or abandonment, particularly in areas of high agricultural, natural or cultural value. Over a wider area with multiple installations, this could result in a significant loss or fragmentation of amenities or recreational facilities, valuable farmland or natural habitats.”

See also sections 8.1 and 8.2 for evidence regarding the poor prospects for land rehabilitation.

9.2 Soil compaction and topsoil removal

Soil compaction because of heavy machinery on the drill site and access roads needs to be addressed by tillage to at least 80-centimetre depth prior to top soil re-application, to optimise water filtration and revegetation. Even so, there has been a decline in filtration on the land after a 3 year period (Chong 1997).

Careful topsoil removal and storage for subsequent land restoration must be a requirement by the drilling companies. Skausen (2011) says that at least 2 feet and preferably 4 feet of topsoil should be salvaged for later restoration. It should be seeded with a vegetation cover if the stockpile is to remain for more than 6 months. It should be stored safely away from potential contamination operations and substances. Pipeline disturbances need the same attention.

9.3 Removal of mining equipment and well abandonment

Removal of mining equipment is another area of concern. The waste ponds must be safely emptied without contamination of the site or surrounding land or water. It must be safely removed to hazardous waste facilities. The lining should also accompany this and not be buried on site, or on convenient nearby land.

Well abandonment is an under-researched area of concern. Lustgarten (2011 and 2013) wrote of EPA's initial serious concerns about contamination from abandoned wells, and again reported on the back flip of the EPA. This had initially promised peer reviewed research as a follow up. Eventually the EPA handed over the responsibility of the research to the likely offender in the industry, Encana. Thus, "effectively disengaging from any research that could be perceived as questioning the safety of fracking or oil drilling."

In WA, wells are supposed to be monitored after abandonment for 2 years. After this time, the company is no longer responsible for their integrity. This will leave the government departments responsible both for ongoing monitoring and potential contamination costs into the future. The alternative to ongoing monitoring of abandoned wells is to leave and ignore them. Thus, when contamination occurs down the track, possibly away from the original well site, traceability of the source of contamination, and any remediation will be either seriously hampered, too expensive or impossible to remediate.

Whilst wells are supposed to be plugged with concrete at the end of their active life, their integrity and permeability are unknown. Cement deteriorates over time, and the pipes which go deep into the ground and through aquifer systems, can corrode. This would both connect below levels of strata with the aquifers, and pose serious risks of contamination, both of the aquifers and the surface level soil and structures. Given that approximately 50% of waste water remains under the ground, this should be a major concern.

The vertical pathways of wells that have deteriorated over time can allow oil, gas and brine to contaminate ground water, reported the International Association of Hydrogeologists in 2015, in their report to the Hawke Inquiry.

Old wells have been known to cave in, again connecting differing geologic layers with the surface. In a New York study (Bishop 2012) found that in the last 25 years, the oil and gas industry consistently neglected to plug most (89%) of its depleted wells, and the rate has increased since the year 2000. This indicates a culture of neglect and avoidance of responsibility. Whether or not plugged with cement (which itself deteriorates and cracks with time) the leakage of methane and other toxicities continue to occur without due oversight.

Whilst investigating oil and gas challenges in Colorado, Finley (2015) found that companies could shut down active wells in response to decreasing prices or oil and gas, which complicated their oversight. In the case of abandoned wells, restoration fell on the state where owners could not be located. This was the case with most of the 83 sites known to the regulator. It was also known that many companies do not fully restore the land for years after the cessation of production. Advanced planning was seen as crucial, requiring management and stewardship of landscapes.
“The state requires oil and gas companies to restore all sites completely - to reduce erosion, loosen compacted soil, prevent dust storms and control invasions of noxious weeds,” he reported. However, the state didn’t set a timetable or time period for companies to complete the required work.

9.4 Feasibility of land restoration

Broomfield (2012) questions that full restoration of sensitive ecological sites is possible for hydraulic fracturing shale gas well projects.

When one looks at the extent of shale gas mining activities and the very large land footprint, covering highly sensitive areas of sensitive ecosystems; unique flora; endangered species; habitat loss (especially mature trees); the arid and drought prone nature of much of the Western Australia, already threatened with significant global warming; the huge amount of water used for the process; the well documented and serious contamination risks to diminishing water supplies; the complex, expensive, and in some cases impossible task of achieving appropriate restoration; serious doubt about the viability of hydraulic fracturing for shale gas in this state is posited. **10**

Regulation

10.1 Industry self-regulation; external monitoring; penalties for non-compliance; financial responsibility for accidents and clean-ups.

There is a continuing complaint from the oil and gas mining companies that their industry is over regulated, and that self-regulation would minimise costs and speed up processes.

The Commonwealth Government 'Task Force on Industry Self-Regulation' (2000) outlined a checklist whereby self-regulation by industry should be considered where:

- there is no strong public interest concern, in particular, no major public health and safety concern;
- the problem is a low risk event, of low impact/significance, in other words the consequences of self-regulation failing to resolve a specific problem are small; and
- the problem can be fixed by the market itself, in other words there is an incentive for individuals and groups to develop and comply with self-regulatory arrangements (e.g. for industry survival, or to gain a market advantage).

Given the above guidelines, it is clear that there is strong public concern, and the risks are significant. Serious incidents have occurred where horizontal hydraulic slick-water practices in shale gas projects have occurred. (Bishop 2012; Drajen 2013). Self-regulation for this industry is strongly counter indicated according to these sensible guidelines. The unconventional gas industry faces serious problems of methane leakages, fugitive emissions, well failure, explosions, and soil and air contamination. The failure of any government or government department to be advocating for the most stringent of regulations on behalf of the populations they serve is irresponsible. To claim the industry cannot make adequate profits by observing such safety measures gives no reason to bend to their wishes. Political decisions are ultimately answerable to the will and rights of the people who elect the politicians.

A tighter regulatory system is needed, with meaningful penalties for remediation and clean-up. As many companies are multi-national and continually buying and selling operations or declaring themselves bankrupt, it can be a huge and expensive task to pursue compensation after accidents or misdemeanours occur. They may be catastrophic and irreversible, given the volatile nature of the products they are working with. Well known examples of catastrophic events in offshore drilling, where the companies have claimed best practice, include BP's Deepwater Horizon in the Gulf of Mexico in 2006 and PTTEP's Montara oil spill off the north coast of Australia in 2009. They claimed to have followed 'best practice,' as do all on-shore shale gas drilling operations. Blow outs do occur, and although they may be locally confined, deaths, injuries and ecological damage are known to take place. These 'fraccidents' have been scattered across the USA, with some mapped regularly by 'Frack Alert'.

In West Australia, as in other places, the powerful oil and gas sector appear to dictate the parameters under which they will operate. There is a culture of secrecy, cost cutting, lack of transparency and avoidance of responsibility, other than to their shareholders. An imbalance occurs between the industry and the needs and rights of the populations that are affected adversely by their operations.

Companies must be liable for compensation for environmental damage. Questions of how this could be assessed or calculated should be predetermined, and not left to chance. As many of these companies are global in their reach, international legal solutions must be understood by our governments. An example of this is the asbestos mining industry which fled once the financial implications of their responsibility became publicly known. The cigarette industry is another example of the cost afforded to our health system, and their consistent cries of foul play when attempts are made to limit their promotional rights.

Extensive risk assessments should be conducted before the green light is given to the commencement of unconventional gas production in this state. The fact that exploration licences are granted over extensive areas of Western Australia, is not a reason to allow the sector to proceed before appropriate risk assessments are carried out. The overseas adverse experiences must be taken into serious account when doing these assessments.

Baseline studies are vital for the health of surrounding populations, as well as water quality, toxicity and aquifer depletion rates. Similarly, these studies should extend to monitoring the health of the land, air and soil. The costs of conducting such analysis would need to be considered prior to the operations proceeding.

It is essential that cost benefit analysis is compulsory. Decision makers must address all aspects of the unconventional gas industry; health. air land and water degradation, risks of the pollution of our aquifers and waterways, water loss impacts on our drying climate and loss of biodiversity.

Moratoriums or bans on the industry have been enacted in several countries, some US states, and some Australian states. These are serious red lights for those contemplating further exposure to our fragile ecosystem with such aggressive assaults.

Self-regulation has been rorted by many international companies, with responsibility for accidents and leaks being taken only after the facts have become public. For the industry to proceed further in West Australia, it can only be with serious oversight. Government regulatory bodies must be fully resourced with enough scientifically trained personnel to fully monitor operations at all stages.

10.2 Conflict of interest

Whilst the Environmental Protection Authority (EPA) endeavours to assess potential environmentally damaging projects, this resource has been underused.

- Section 5 of the Environmental Protection Act 1986 (West Australia) provides that it has primacy over other laws, including the Department of Mines legislation:
- Section 5. Inconsistent Laws: Whenever a provision of this Act or of an approved policy is inconsistent with a provision contained in, or ratified or approved by, any other written law, the provision of this Act or the approved policy, as the case requires, prevails.

The EPA, therefore, should be far more prominent in decisions and oversight relating to the environment, and not secondary to The Department for Mines and Petroleum which currently conducts much of its assessment behind closed doors.

The EPA was discredited in its approval for the proposed James Price Point Gas Hub in the Kimberley. The conflict of interest of 3 of the 4 decision makers, who had gas mining shares in their personal portfolios, evidenced what might be a serious problem with many high-ranking decision makers. Full disclosure of conflicts of interest should be mandatory before appointments are made, and not incidentally discovered later by the investigation of those with counter interests.

The DMP has a questionable role in its industry promotion. A DMP Executive Director was, in my presence, described by the chairperson from CSIRO at a public lecture, as being a fervent advocate of unconventional gas mining in Western Australia. I attended two public talks presented by him, that upheld this pro-industry bias. He was dismissive of any objective criticism of the industry. This is in itself is a real conflict of interest, leading to poor and biased decision making within a department that influences government policy. It excludes fair and open public debate on this matter. This person has since left the department, but the bias remains.

Adam Lucas, Senior Lecturer in Science and Technology at the University of Wollongong, in a timely article in The Conversation ((4 March 2018) revealed the extent of job-swapping between public servants and fossil fuel lobbyists. It outlined serious non-compliance in ministerial and staffer codes of conduct, in terms of job interchange with the resource and energy sector, favourable treatment in return for generous political donations, and the consequent dire predictions about planetary boundary breaches.

10.3 Economic considerations

There is a growing number of experts questioning the ongoing viability of unconventional gas production. (Nafeez 2013; Economy Watch. 26August 13)

Once the most productive areas (sweet spots) have been exploited, the companies must forever expand. energy expert Bill Powers (2013) describes this as 'the drilling treadmill.' Companies continually seek more possibilities, much of which cover less productive sites and give ever diminishing returns. This wreaks further havoc on the environment.

Once the money runs out, these leases may be on sold to unsuspecting buyers, or abandoned altogether. Extensive infrastructure, including roads and un-usable land is left for the public purse to deal with, and shareholders are left stunned as the gas bubble bursts. Meanwhile, other essential industries such as food and agriculture may be considerably diminished by the unconventional gas fracking industry.

11 Climate change and alternatives to fossil fuels

Howarth et al (2011) note, in comparing CO2 emissions, methane's lifetime is shorter in the atmosphere, but the comparative impact on climate change is over 20 times greater than CO2 over a 100- year period. It is much more efficient at trapping heat. Given that climate change is now a given by most published scientists throughout the world, and our time line for avoiding catastrophic change and reducing our hydrocarbon emissions has almost passed, it is hard to comprehend why governments are not heeding these warnings.

Turner et al (2016) used evidence from atmospheric and ground observations which showed that methane emissions in central US climbed 30% between 2002 and 2014. This coincided with the rapid development of the unconventional gas industry in the same area.

A review published by the Melbourne Energy Institute (25.10.2016), commissioned by the Australia Institute, made the following findings:

- Several major potential sources of methane emissions are assumed to be zero under Australia's accounting and reporting of unconventional gas.

- Methane measurements at US unconventional gas fields have found leakage rates in the order of 10-25 times higher than the Australian Government reports to UNFCCC, and up to 170 times those claimed by the gas industry.

- If leakage rates comparable to those found in the US are found in Australian unconventional gas fields, it will have serious implications for Australia meeting its emission reduction commitments under the Paris Agreement.

Building new coal and natural gas power plants remains a counter-productive lock-in of scarce resources needed elsewhere to avert catastrophic global warming. In our rapidly drying climate, particularly in the South West of WA, all aquifers need to be reassessed in terms of their future use, and not dismissed as saline or non-potable by the oil and gas industry.

Whilst unconventional gas is being falsely proclaimed as a necessary transitional fuel, the great potential that Australia, in particular, has for renewable energy, is being delayed to appease the hydrocarbon industries. Australian scientists and engineers involved in Beyond Zero Emissions have put together two substantial reports, outlining how 100% renewable energy is achievable and affordable in a 10year transformational period, (BZE 2010) and also how we could be world leaders technologically in this field. (BZE 2012)

12 Summary

Transparency and public debate is of utmost importance with regards to shale gas exploration in Western Australia. To date, the abundance of independent peer reviewed scientific research into the potentially devastating effects on our water, air quality, soil, ecosystems and biodiversity, water quality and depletion, health, agriculture, tourism, culture and amenity have not been heeded by the regulators. Baseline studies are also missing from the equation, making it more difficult to assess potential negative impacts. The unconventional gas industry produces vast amounts of toxic waste, for which there is no proven safe disposal procedures. Their practice lags considerably behind the available science. Added to this, is the industry's demand for more and more self-regulation, to which economically strapped governments tend to readily comply. In the past, self-regulation has proved to be disastrous in risk fraught industries.

Monitoring and supervision costs, and the number of qualified government personnel required to oversee this industry, are seen as prohibitive. The public-sector work force, which is currently targeted for cuts, exposed the potential for a lack of supervision in an industry which threatens our water and food security. Such an important role should not be out-sourced to the private sector and, in particular, should not be undertaken by the UGF industries themselves.

With a shale gas industry looming, Western Australian tax payers should be protected from potential disaster clean-ups by companies that leave, on-sell or declare bankruptcy. Penalties for misdemeanours and accidents across the world have shown to be non-existent or totally inadequate. Should our aquifers be adversely affected, there is no known remedy. It is a risk we cannot contemplate.

Short sighted and short term economic gains should not lead to an economic burden, diminished lifestyle and amenity for future generations. The general population is largely unaware of the practices of this industry, however, over time, there is potential for all of the above to become more widely known. As the industry progresses and the deleterious effects become real, greater opposition will be expressed. This is clearly evident in the eastern states.

Whilst I have detailed a long list of serious risk factors inherent in this industry, it is my belief that it would only take one serious incident to have calamitous repercussions. This is particularly pertinent with regard to our valuable water resource. Fault seal analysis before fracking should be mandatory to minimise risks of toxic substances seeping into our aquifers. They must be protected more systematically as they are critically important to our future survival.

As a mother, grandmother and concerned citizen, I feel it is incumbent on all of us to consider our future generations. In doing so, our government will ensure it is not seduced by short term economic gains.

13 Recommendations

The first recommendation reflects a sensible approach and is my preferred choice. However, I also recognise that this industry has well-funded lobbying powers, which promotes a mythology unsustained in real science, and which appears to have the attentive ear of governments. I have therefore added constraints in the subsequent recommendations which may limit the industries unfettered **approach to unconventional gas mining and the serious risks it poses.**

1. **A ban of the UGF in WA** is the most obvious and desirable and sensible course of action.

2. **Failing a ban, a moratorium must be placed on the industry**, **for the whole of WA**, until the science catches up with the practice. The science should include health issues, predetermined planning for land restoration, full analysis of chemicals used by the industry, long term implications of excessive water usage in our drying climate, and a full cost benefit analysis of this industry, including all of the foregoing.

3. **Site selection** should be determined on the least interference with natural ecosystems, farming, tourist destinations, and should not occur over or through our potable aquifers. Noise levels, compressor stations and associated venting, flaring, storage tanks and pipelines should not be located near human habitation. The selected sites should be fully mapped and contoured before exploration, with a determination of how it will be restored to a balanced ecosystem that serves the local communities and

the natural habitat and wild life that will have been displaced. Sites that are of cultural significance and or ownership to indigenous peoples must be avoided.

4. **Landowner rights including aboriginal ownership and important cultural sites** must be respected in relation to refusal of access to their land, pre-determined contracts fully outlining risks, adequate compensation for use should permission be given, and eventual appropriate restoration to former land function. Funds by the companies should be made in advance, as an insurance for this.

5. **Prompt violations or accident reporting** should occur for remediation, and with adequate pre-determined consequences applied, especially in the case of non-reporting of such events. This should be facilitated by having independent and adequately funded monitors and regulators**.**

6. **Fracking chemicals disclosure** should occur in each individual operation, with this knowledge available for public scrutiny if requested.

7. **Fracking chemical testing** should be scientifically analysed to determine individual and synergistic effects on water, soil and air, as well as on human and animal life if ingested, inhaled, or made contact with. This knowledge should be publicly available.

8. **Analysis of faults and fractures** on all land should be independently pre-determined, and where they are shown to be critically stressed through **fault seal analysis**, drilling should not take place.

9. **Baseline studies** should be instigated for water aquifer levels and for water, soil and air quality prior to the commencement of drilling. Also, baseline health data on workers and nearby populations should be conducted at the cost of the industry.

10. **Water extraction** from aquifers and other natural water sources that replenish the aquifers must meet priority needs of resident populations, food production needs, and maintenance of the ecology including wildlife, trees and other natural vegetation.

11. **Toxic waste disposal** including produced water and sludge, with particular attention to radioactive constituents. This includes waste pond liners, disused piping and other contaminated equipment, and contaminated soil. All toxic waste disposal methods must be assessed and pre-determined for their capabilities in handling the significant

radioactive and highly toxic chemical components of fracking waste. Practices such as spraying toxic waste onto farmlands, roads, and into streams and rivers, or burying waste in non-disclosed sites so commonly documented elsewhere, must be totally prohibited, with serious pre-determined penalties for violations. Recycled water should not be sprayed on land as this method is in its infancy, with long term outcomes unknown.

12. **Deep well injection** has been shown to be hazardous for earth precipitation and for waste migration into aquifers. This should be prohibited.

13. **Abandoned wells** are not able to be secured in the long term and pose serious risks to water, soil and air over time. For those that do exist, they must be mapped and monitored, with companies being contractually responsible for them into the long-term future. Adequate costs should be pre-determined and a significant bond deposited with the government for this purpose.

14. **Regulation of all the processes** of the unconventional gas industries from exploration to completion must be monitored by independent government bodies, with those companies being held to account for breaches and dangerous outcomes. Bonds should apply to cover any potential risks, especially where companies may move off shore to avoid penalties or restoration costs.

15. **EPA Act 1986** must allow the EPA to resume its primary role in assessment and monitoring in accordance with its purpose to protect the environment, and must be sanctioned to over-ride the DMP in its decision-making processes where appropriate. Funding and staffing for this should be made available.

16. **Conflicts of interest** must be fully disclosed by all elected government representatives and employees of government departments responsible for policy decision making about this highly controversial and potentially dangerous industry. Transparency must be paramount, and open for public debate and challenge. The extent of corporate lobbying must also be made transparent.

17. **Cost benefit analysis** should be conducted, including social amenity, increased health costs, food production, air, water and soil quality and the remediation costs of all of these. Water usage must be a major component of this, and the costs for alternative sources such as desalination, and expensive water recycling processes. Our limited and irreplaceable natural aquifer systems may be irremediable should serious contamination occur.

18. **Aquifers need to be fully analysed and assessed** in terms of their potential potability for our future use They cannot be treated cavalierly by an industry which might easily either over use or put them at risk through contamination.

19. **Climate change and global warming** is occurring according to an overwhelming majority of climate scientists. The science must be heeded by all governments, and priority action pursued to increase renewable energy targets. Continued use of fossil fuels contributes enormously to climate change, and in particular, fracking for unconventional gas. Methane emissions have a greater impact on global warming than CO_2. Ethane emissions should also be factored in. Measurements of these gases in the atmosphere must be more accurately reported for national and international purposes.

20. **Hazards of fire and explosions from gas, flooding of toxic waste ponds, and reduced water availability** because of the greater availability of gas in the air and landscape, unpredictable floods, prolonged droughts and reduced inundation, must be taken into account, and publicly prepared for. With unconventional gas fracking, these are particularly relevant.

21. **Renewable energy** is important for the future. Temporary job losses in the fossil fuel industry would be offset by those provided by the renewable energy sector.

<u>References</u> (in alphabetical order by lead authors)

- <u>Land application of hydro-fracking fluids damages a deciduous forest stand in West Virginia</u>
  Journal of environmental quality **(July 2011)**
  Adams M B

- <u>Ecosystem services lost to oil and gas in North America</u>
  Science, 348 (6233), 401-402 **(2015)**
  Allred, BW. Kolby Smith W. Tridwell D. Haggerty JH. Running SW. Naugle DE. Fuhlendorf SD.

- <u>Hydraulic fracturing and seismicity in the Western Canada Sedimentary Basin</u>
  Seismological Research Letters, 87(3), doi: 10.1785/0220150263 **(2016)**
  Atkinson G.M. Eato , D.W. Ghofrani H. Walker D. Cheadle B. Schultz R. Kao H.

- <u>Impacts of gas drilling on human and animal health</u>
  New Solutions. **(Jan 2012)**
  Bamberger M. Oswald R.E

- <u>Zero Carbon Australia Stationary Energy Plan</u>
  Beyond Zero Emissions: Collaborative research by Australian scientists and Engineers. (June 2010)

- <u>Laggard to Leader: How Australia can lead the world to zero carbon prosperity</u>
  Beyond Zero Emissions. Ibid (July 2012)

- <u>History of oil and gas well abandonment in New York</u>
  Chemistry and Biochemistry Department SUNY College, Oneonta**. (2012)**
  Bishop R E.

- <u>Support to the identification of potential risks for the environment and human health arising from operations involving hydraulic fracturing in Europe: A report Commissioned by Director General for Environment, European Commission</u>
  ED57281-Issue Number 17 **(August 10, 2012)**
  Broomfield M.

- <u>Fracking the Earth: Fracking has grave radiation risks few talk about</u>
  Scientific Secretary of European Commission on Radiation Risk
  August 28, 2013
  Busby C.

- <u>Methodology for estimating premature deaths associated with long-term exposure to fine particulate matter in California,</u>
  California Air Resources Board, (CARB) Sacramento California (2008)

- Infiltration in re-claimed mined land ameliorated with deep tillage treatments
  Soil Tillage Research vol.44 issue 3-4 pp 255-264 **(December 1997)**
  Chong S. Cowsert P. T.

- Natural gas operations from a public health perspective
  Human and Ecological Risk Assessment: An International Journal **(20.9.2011)**
  Colborn T. Kwiatkowski C. Schultz K. Bachran M.

- Taskforce on Industry Self-Regulation
  Commonwealth Government of Australia (June 2000)

- Fracking tied to drinking water damage by EPA regional official
  Insurance Journal **(31 July 2013)**
  Drajen M.

- Has the Shale Bubble Already Burst?
  Economy Watch. 26 August 2013

- Injection Induced Earthquakes
  Science Vol 341 N. 6142 DOI : 10.1126/Science 1225942 (**12 July 2013)**
  Ellsworth W. L.

- The rush to drill for natural gas: A cautionary tale
  American Journal of Public Health 101 (5) pp 784-5 **(May 2011)**
  Finkel M. L Law A.

- Marcellus shale's drilling impact on the dairy industry in Pennsylvania: A descriptive report
  New solutions vol.23(1) pp 189-201 **(2013)**
  Finkel M. L. Selegean J. Hays J. Kondamudi N.

- Colorado land impact of oil and gas boom. Scars spread and stay
  The Denver Post
  Finley B. (28.2.15)

- Analysis of BTEX groundwater concentration from surface spills associated with hydraulic fracturing operations
  Journal of the Air and Waste Management Association (**14.3.2013)**
  Gross S.A. Avens H.J. Banducci A.M. Sahmel J. Panko J.M. Tvermoes B.E.

- Toward and understanding of the environmental and public health impacts of unconventionsl natural gas development: A categorical assessment of the peer-reviewed scientific literature, 2009-2015
  Plos one **(2016)**
  http//journals.plos.org/plosone/article?id= 10.1371/journal.pone.015416
  Hays J. Shonkoff B.C.

- A comprehensive analysis of groundwater quality in the Barnett shale region
  Environmental Science and Technology49(13), 8254-62.doi: 10.1031/acs.est.5601526 **(2015)**
  Hildenbrand Z.L. Carlton D.D. Fontenot B.E. Meil J.M. Walton J.T. Shug K.A.

- Should fracking stop? Extracting gas from shale increases the availability of this resource, but the health, environmental risks may be too high
  Nature **(15.9.2011)**
  Howarth R.W. Ingraffea A. Engelder T.

- Methane and the greenhouse-gas footprint of natural gas from shale formations
  Climate Change Letters. vol.106, number 1**.(14.4.2011)**
  Howarth R.W. Santo W.R.

- Video. Well Failure. *https://www.youtube.com/watch?y=Dxis-vYGM_M*
  Ingraffea A. R.(2016)

- Submission to the Hawke Inquiry
  https://fracking inquiry.nt.gov.au/other-australian-inquiries/2014-northern territory-inquiry-terms-of-reference?a=389206
  International Association of Hydrogeologists. (2015)

- Fugitive emissions from the Bakken shale illustrate the role of shale production in the global ethane shift
  Geophysical Research Letters, 43, 4617-4623. doi: 10.1002/2016GL068703
  Kort EA. Smith ML. Murray LT. Ghakharia A. Brandt AR. Peischi J. Travis K. (2016)

- Long-term ozone exposure and mortality
  New England Journal of Medicine, Vol.360, no.11 pp. 1085-1095 **(2009)**
  Jerret M. Burnett R. T. Arden Pope C. et al.

- Potentially induced earthquakes in Oklahoma, USA:links between wastewater injection and the 2011 Mw 5.7 earthquake sequence
  Geology **(26.3.2013)**
  Keranen K.M. Savage H.M. Abers G.A Cochran E.S.

- Estimation of air-quality damages from Marcellus shale natural gas extraction in Pennsylvania
  Environmental research letters **(31.3.2013)**
  Litovitz A. Cartwright A. Abramzon . Burger N. Samaras C.

- *Fractured Country:An Unconventional Invasion*
  http://lockthegate.org.au/our_films
  Lock the Gate

- Revealed: The extent of job swapping between public servants and fossil fuel lobbyists
  The Conversation **(5 March 2018)**
  Lucas, A, Senior Lecturer Science and Technology. University of Wollongong.

- EPA finds compound used in fracking in Wyoming aquifer
  Pro Publica (**10 Nov. 2011)**
  Lustgarten Abrahm

- Are fracking wastewater wells poisoning the ground beneath our feet?
  Scientific American, (**June 21, 2012)**
  Lustgarten Abrahm

- EPA's abandoned Wyoming fracking study-one retreat of many
  Pro Publica (**3 July 2013)**
  Lustgarten Abrahm

- Air pollution and human health hazards: compilation of air toxins as acknowledged by the gas industry in Queensland's Darling Downs
  International Journal of Environmental Studies, Vol. 757 **(2018**) Issue 1 Energy and Natural resources
  McCarron G.

- A review of current and future methane emissions for Australian production
  Melbourne Energy Institute. 25 October 2016

- Human health risk assessment of air emissions from development of unconventional natural gas resources
  Science of the Total Environment (**17.4.2012)**
  McKenzie L.M. Witter R.Z. Newman L.S. Adgate J.L.

- Relation between fracture stability and gas leakage in the North Perth Basin
  University of Auckland. Hydrogeology Journal in prep**. 2018**
  Mullen F*. Archer R. (affiliation)

- Potential contaminant pathways from hydraulic shale to aquifer groundwater
  Groundwater **(17.4.2012)**
  Myers. T.

- Canada's 500,000"leaky energy wells: Threat to Public
  The Tyee retrieved from http://www.thetyee.ca/News/2014/06/05//Canada-Leaky-Energy-Wells
  Nikolforuk A .(June 2014)

- Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing
  Proceedings of the National Academy of Science. (14 April 2011)

- Cold Hungry and in the Dark: Exploding the Natural Gas Supply Myth
  New Society Publishers. **(2013)**
  Powers Bill (energy expert)

- Shale Gas Won't Stop Peak Oil, but Could Create an Economic Crisis
  The Guardian **26 June 2013**
  Nafeez Ahmed (Ex director of The Institute for Policy Research and Development)

- The potential near-source ozone impacts of upstream oil and gas industry emissions
  Journal of Air and Waste Management Association. (**August 2012)**
  Olaguer E.P.

- Big Coal- Australia's Dirtiest Habit
  Newsouth Publishing, University of New South Wales, Sydney **2013**
  Pearse G. McKnight D. Burton B.

- Hydorcarbon emissions characterization in the Colorado front range- a pilot study
  Journal of Geophysical Research DOI. 10. 1029/2011 JDO16360 **(2012)**
  Petron G. et al

- The Perth Basin- What do we know and what's to learn.
  IHS Markit
  Plampton W. (14 Dec. 2017)

- Analysis of Reserve Pit Sludge from Unconventional Natural Gas Hydraulic Fracturing and Drilling Operations for the Presence of Technologically Enhanced Naturally Occurring Radioactive Substances (TENORM)
  New Solutions: A Journal of Environmental Health Policy. 23(1) pp 117-135
  (April 2013)
  Rich A. Crosby E.C.

- A review of the public health impacts of unconventional gas development.
  Environmental Geochemistry and health, DOI 10.1007/s10653-9898-x (**2016)**
  Saunders P.J. McCoy D. Goldstein R. Saunders A.T.

- Rapid photochemical production of ozone at high concentrations in a rural site during winter
  National Geoscience 2. pp 120-122 (**2009)**
  Schnell R.C. Ottmans J. Neely R. R. Endres M. S. Molenor J. V. White A. S.

- Environmental Public Health dimensions of Shale and Tight Gas Development
  Environmental Health Perspectives; DOI:10.1289/ehp.1307866
  Shonkoff, Hays and Finkel (2014)

- The critical decade 2013: climate change science, risks and responses.
  Climate Commission Secretariat, Commonwealth of Australia**, (2013)**
  Steffen W. Hughes L.

- The reclamation of Marcellus drilling sites in West Virginia
 University of West Virginia (**August 22 2011)**
 Skausen J. Ziemkiewicz P.

- Greenwashing gas: might a 'transitional fuel' legitimize carbon-intensive natural gas development
 Energy Policy. **(30.4.2012)**
 Stephensona E. Doukasa A. Shaw K.

- Land farming of drilling wastes impacts on soil biota within sandy soils in Taranaki
 Taranaki Regional Council New Zealand technical report (Oct 2011)

- A Texan Tragedy: Ample Oil, No Water
 The Guardian. (13 August 2013)

- Reclamation Illusions in Oil Sands Country: lack of legislation, financial preparedness undermined reclamation efforts
 The Parkland Institute. University of Alberta. (undated)

- A large increase in U>S> methane emissions over the past decade inferred from satellite data and surface observation Geophysical Research Letters, volume 43, Issue 5.
 Turner A. J. Jacobs D.J Beumergui J. (March 2016)

- Report on carcinogens
 National Toxicology Program (NTP) **(2012).** 12th ed.
 US Dept Health and Human Services, Public Health Services.

- A critical review of the risk to water resources from unconventional shale gas development and hydraulic fracturing in The United States
 Environmental Science and Technology vol.48 issue 5pp. 36-52
 Vengosh A. Jackson R.B. Warner N. Darrah T.H. Kondash A. (2014)

- Geo-chemical evidence for possible natural migration of Marcellus formation brine into shallow aquifers in Pennsylvania.
 PNAS. **(9.6.2012)**
 Warner N.R. Jackson R.B. Darrah T.H. Karguang Z. White A. Vengosh A.

- Fracking and cracking: strict liability for earthquake damage due to wastewater injection and hydraulic fracturing. Texas Journal Oil, Gas, and Energy law 11 (1)
 Watson B,A. (2016)

- Environmental Protection Act 1986
 West Australian Government