Submission
No 14

INQUIRY INTO THE IMPLEMENTATION OF THE RECOMMENDATIONS CONTAINED IN THE NSW CHIEF SCIENTIST'S INDEPENDENT REVIEW OF COAL SEAM GAS ACTIVITIES IN NEW SOUTH WALES

Organisation: Doctors for the Environment Australia

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Submission on the implementation of the recommendations contained in the NSW Chief Scientist's Independent Review of Coal Seam Gas Activities in New South Wales

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Healthy planet, healthy people.

Parliament of New South Wales, the implementation of the recommendations contained in the NSW Chief Scientist's Independent Review of Coal Seam Gas Activities in New South Wales.[1]

Executive Summary

Doctors for the Environment Australia (DEA) is pleased to see that NSW Parliament has recognised the need to review the NSW Chief Scientific Officer’s recommendations from 2014 and their implementation. This is particularly important because the Chief Scientist report is now six years old and based only on research findings up to early 2013. At that time there were approximately 160 publications available regarding environmental and health impacts.

By the end of 2018, just five years later, nearly 1,800 papers were published on the topic, according to the Physicians and Scientists for Healthy Energy (PSE) (Figure 1).

This submission particularly responds to Terms of Reference 1(c), to support the Parliamentary Committee’s consideration of *whether any other inquiry findings or other major reports relating to unconventional gas in Australia or the east coast gas market published since the release of the Chief Scientists are relevant to the suitability or effectiveness of the Chief Scientists recommendations.*

In this submission, we review the substantial growth in evidence regarding the safety of unconventional gas mining to human health and vital ecosystem services necessary for continued health into the future via:

- air pollution
- risks to water quality, safety and quantity
- risks to food safety and security
- intensive psychosocial and community distress, and climate change.

This evidence has added substantial strength to DEA’s continued call for application of the precautionary principle in unconventional gas decisions. That means – to cease further expansion of the gas industry until there is sufficient evidence to demonstrate that human health is not placed at risk from the above-listed industry impacts.

While research on the public health risks and impacts associated with unconventional gas mining research in the United States has progressed, with a substantive proportion funded independently from industry, minimal parallel health-focused research has occurred in Australia.

The majority of the Australia research has been funded by GISERA – an alliance involving the Gas Industry – which has largely ignored human health. Furthermore, the Australia Institute has examined the potential for conflict of interest within this funding arrangement and concluded that GISERA is an "inappropriate organisation to undertake research to evaluate the social and environmental impacts of unconventional gas development"[2].

Thus, five years after the NSW Chief Scientist's report, and a decade into a massive expansion of coal seam gas mining in Queensland, we see a clear failure of governments to meet the recommendations that DEA made in 2013 to the Chief Scientist:

- Require Health Impact Assessment for all unconventional gas project assessments under nationally developed guidelines - including long-term cumulative health and social benefits and costs.

- Develop and implement a protocol for health surveillance of persons living, working, or attending school in proximity to CSG development. Regularly report on surveillance outcomes.

- Promote and financially support research, such as long-term longitudinal health studies and research on potential health effects, social impacts, and other aspects relating to unconventional gas development.

As a result, we are left with little independent, peer-reviewed evidence pointing to the safety of the CSG industry to Australia's people, water supplies, biodiversity and the climate. The amplification of the highly complex and expansive industry activities in NSW would only increase the probability and severity of risks borne by people and their environment.

Compared to our understanding in 2013, there is no doubt that the NSW government must urgently prioritise the protection of water and climate above all other considerations if it intends to take responsibility for the health of its people.

This submission presents detailed evidence drawn from our recent review, "The implications for human health and wellbeing of expanding gas mining in Australia"[3].

DEA urges the NSW government to ban new coal seam gas mining developments and expansions in order to protect the health and wellbeing of its citizens. Particularly given our climate emergency, this is an industry that cannot be regulated to safety.

Comments on the NSW Chief Scientific Officer's recommendations and their implementation

Recommendation 1

The NSW Government has not clearly articulated the rationale/need for CSG extraction nor a mechanism for the community or research organisations to work closely with the CSG industry. From our current submission, it is clear that CSG extraction poses significant risks to the environment, human health and will accelerate global warming. In contrast, there is growing evidence of the capacity of renewable energies to meet Australia's energy needs at similar cost with substantially less environmental and climate impacts. Consequently, there is no rationale or need for the expansion of CSG extraction – an argument that becomes substantially clearer when the externalities eg costs to health, costs to the environment and climate borne by the community, are added. Similarly, further health research, as recommended by Vaneckova and Bambrick (as commissioned by the NSW Chief Scientific Officer) which would provide baseline data on community health, have not been done.

We strongly recommend that the NSW government advance renewable energy developments without delay and embrace the Step Change Scenario as proposed by the Australian Energy Market Operator (AEMO)[4]. This is the only model that appropriately responds to the urgent need to reduce emissions rapidly and directs rapid reduction of gas usage in the electricity grid.

Recommendation 2

There has not been "clear and open communication" from the government on CSG matters.

Recommendation 3

Compensation mechanisms are not in place for people impacted by CSG extraction. Our current submission outlines the evidence regarding health impacts from unconventional gas extraction, including effects on foetuses, children and adults. Although the full extent of these impacts have not been defined, as time goes on, more associations with potential health impacts are being confirmed. Consequently, it is imperative that adequate compensation mechanisms are created to compensate the adverse health impacts from CSG extraction.

Recommendation 10

As far as DEA is aware, a Whole-of-Environment Data Repository which incorporates health data has not been created. There is an open data set available – Sharing and Enabling Environmental Data (SEED)which incorporates some environmental data regarding CSG. However, this database has limited value. It certainly does not allow for health data or citizen data to be included.

Recommendation 11

DEA is not aware of a centralised “Risk Management and Prediction Tool” to ascertain cumulative impacts from CSG or other extractive industries. If a tool was developed it would need to be agile enough to incorporate the growing evidence of adverse health impacts from CSG extraction in order to give an accurate assessment of risk.

It would need to ensure its focus includes impacts on psychosocial wellbeing and mental health, including the distress caused to children and adults as a result of continued mining of fossil fuels in the face of the climate and health emergency which most Australians are well aware of. It would also need to include the additional stresses and worries about water quality and security due to CSG mining operations in the face of the extreme drought currently devastating rural NSW.

Recommendation 12

An expert advisory body on CSG has not been established. Of biggest concern is the lack of public health and medical expertise in the ongoing assessment and development of CSG. DEA once again re-iterates its opposition to further CSG development due to the increasing evidence of significant health risks and impacts.

Recommendation 15

Managing legacy issues is a massive problem which does not appear to be addressed by the NSW Government. Even legacy issues managing water bores does not appear to be addressed.

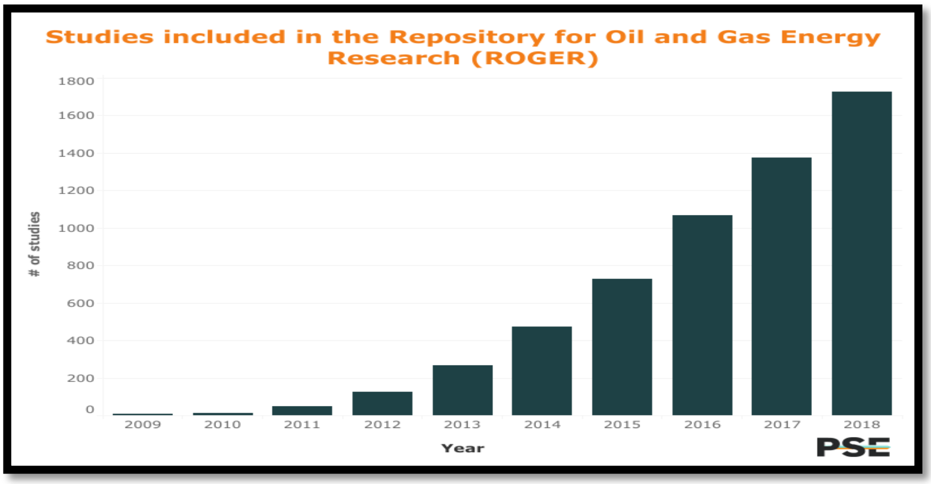


Figure 1. Cumulative number of studies examining environmental and health concerns associated with oil and gas production (Physicians and Scientists for Health Energy, 2019; https://www.psehealthyenergy.org/our-work/shale-gas-research-library/).

The evidence

Because of the complexities of unconventional gas mining, and the multiple chemical, physical and social stressors involved, a full analysis of potential public health hazards must include all steps of the process, starting from community awareness and reactions to development proposals, to site preparation and construction, materials transport, drilling, flowback and produced water collection and handling, hydraulic fracturing, gas production, storage and transport and decommissioning and monitoring of spent wells. The broader implications of the industry on water, food and climate security have stimulated a wide and vigorous response around Australia and the world.

In this submission, we review the evidence of Global, Regional and Local risks and impacts of unconventional gas mining, then examine the responses of medical and public health professionals.

Global impacts: Greenhouse Gas Emissions

Human use of fossil fuels is the primary cause of both global warming and ambient air pollution, resulting from the release of greenhouse gases (carbon dioxide and methane) and other pollutants (particulate matter, nitrogen oxides and other gases) into the atmosphere during mining and combustion[5, 6].

Atmospheric levels of methane, which accounts for an estimated 17- 25% of the increase in the trapping of heat in the atmosphere (causing global warming), have increased steady and substantially in the atmosphere since 2008. Worden and colleagues (2017) have demonstrated that oil and gas production is responsible for between 48% and 75% of the total methane emissions from all human activities, i.e. 12 to 19 of the total 25 terograms (trillion grams) released each year.

These pollutants cause direct and indirect impacts on human health. Climate change caused by increasing atmospheric greenhouse gas concentrations is described by the Lancet Commission on Climate Change and Health as the greatest health threat of the 21st Century, with unprecedented implications for human health and wellbeing[7, 8].

Addressing both global warming and air pollution demands coordinated global efforts to rapidly transition away from the use of fossil fuels. The Paris Agreement emerged from the COP21 United Nations Framework Convention on Climate Change (UNFCCC) in 2015 with commitments from 175 countries to take responsibility for reducing greenhouse gas emissions and assist in limiting global warming to 2°C, or preferably to 1.5°C.

At the latest UNFCCC COP24 in December 2018, both the IPCC and the World Health Organization focused specifically on the health, biodiversity and environmental benefits of limiting warming to 1.5°C. Furthermore, additional emphasis was given to the dual requirement for rapid reductions in both CO_2 and short-lived climate pollutants (methane is the most important one) in order to success in controlling global warming. This is because of the high potency, even if comparatively short-lived, of methane, as it traps 86 times more heat energy in the atmosphere than CO_2 over 20 years, warming the atmosphere much more quickly than an equivalent amount of CO_2.

In order to meet the minimum target limiting to 2°C of global warming[9], estimated that one third of oil reserves, half of gas reserves and over 80 per cent of current coal reserves must remain unused and warned that "any increase in unconventional oil production is incommensurate with efforts to limit average global warming to 2°C". Seeking a target of 1.5°C in order to protect human health means that far more than half of the known gas and oil reserves will need to be left in the ground.

Despite this clear warning, exploration and exploitation of fossil fuel resources continue unabated and/or are expanding in Australia for both domestic consumption and for generating export revenue. In 2019, there are many reasons to be seriously concerned about the climate change implications of continued reliance on and expansion of gas production for energy purposes. Unfortunately, early claims that using unconventional gas for energy will have positive impacts on greenhouse gas emissions are no longer justified.

When the entire life cycle of gas production, transportation and combustion is taken into consideration, fugitive (leaking) methane emissions that are not combusted to form CO_2 before release into the atmosphere, means that the claimed climate ‘advantage’ of gas over coal is greatly diminished[10, 11, 12].

It is now clear that the impacts of gas emissions have been significantly underestimated for a number of reasons, for example:

Compared to what was initially expected, higher proportions of the extracted gas escapes as fugitive emissions[13]. This occurs for reasons of well-casing failures, or leaky pipes and infrastructure or, possibly, fracking-induced channels for gas flow from underground to surface.

Methane’s short-term impact on warming is 86 times more potent than carbon dioxide over 20 years[11, 14, 5, 12], which is much more important to consider than the frequently used 100 year average potency of 25 (because it breaks down over time).

Modelling suggests that abundant supply of natural gas in the United States has competed against, rather than bridged to, renewable energies and delayed urgent transitions to a decarbonised energy system to limit global warming[15,10].

The enormous impact of accidents involving well blowouts and leakage from methane storage sites, as exemplified by the 2016 Aliso Canyon disaster (Figure 2) and potentially occurring at similar sites in future[16].

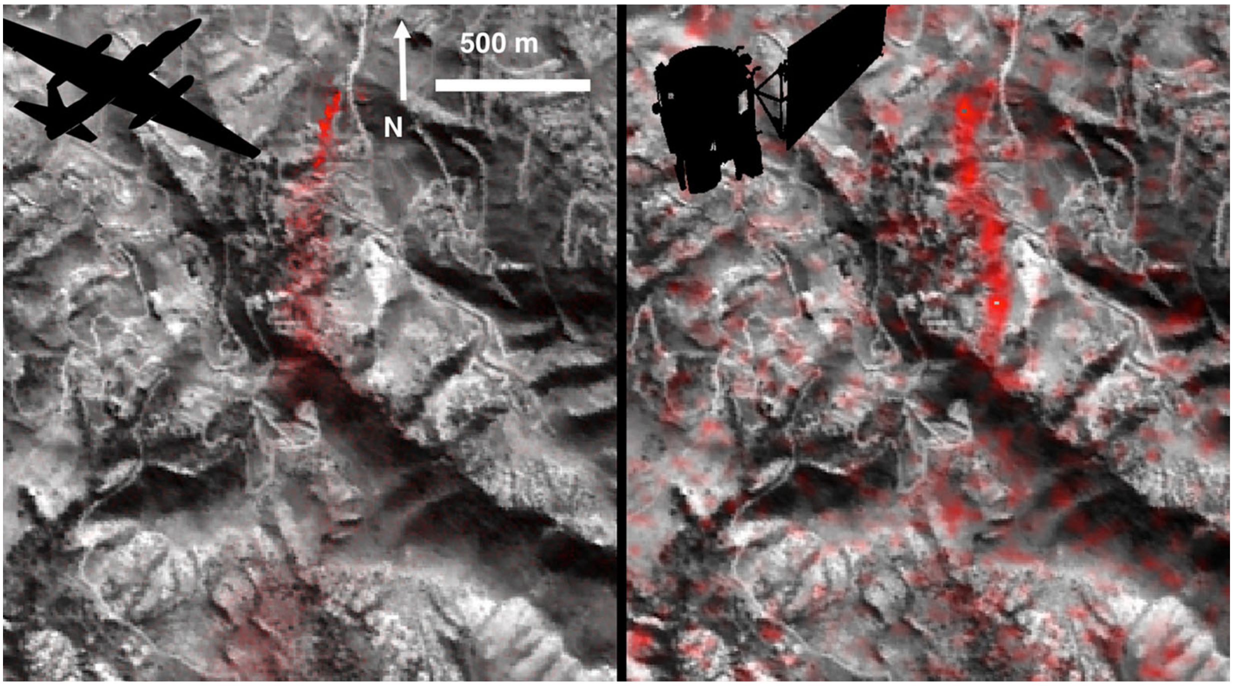
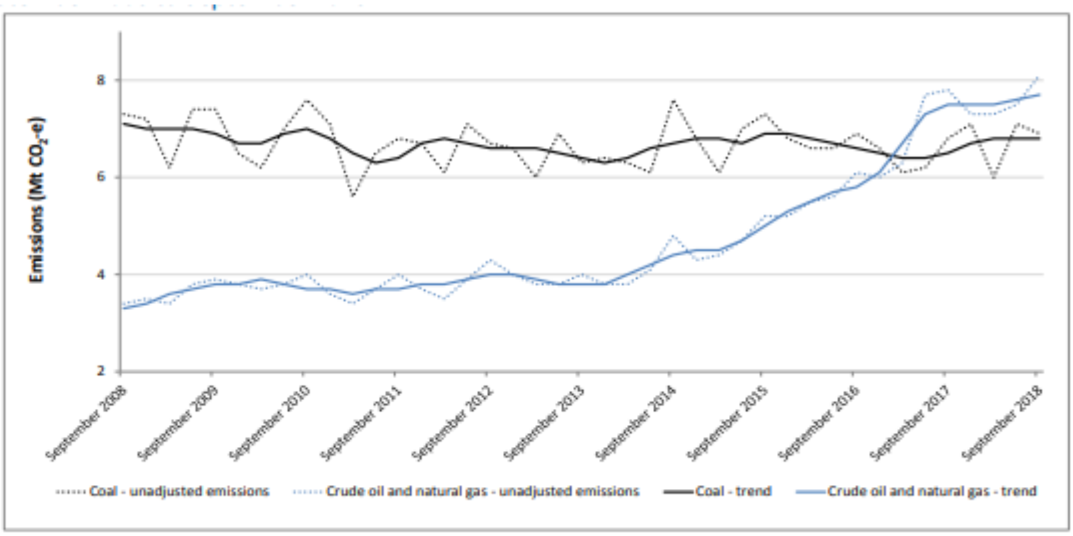


Figure 2. NASA photograph showing for the first time a single point methane leak at Aliso Canyon in June 2016, three days after a major accident which led to the release of an estimated 97,100 metric tons of methane. Left hand side is from aircraft at 6.6 kilometre height, right hand side is a satellite image. (Image credit: NASA/JPL-Caltech/GSFC; *https://photojournal.jpl.nasa.gov/figures/PIA20716_fig1.jpg*).

Because the world's nations have failed to stabilise and sharply reduce greenhouse gas emissions over the last decade there is insufficient time left for a slow and gradual transition towards decarbonisation of energy supply. Hence even if a switch to gas did provide a significant reduction of CO_2 emissions as claimed, this reduction would not be sufficient to avoid exceedance of the 1.5 or 2°C carbon budget[6].

The National Pollutant Inventory figures from Queensland, the only Australian state with a well-established unconventional gas mining industry, suggested that Queensland emitted 29% of Australia's total emissions in 2016; with fugitive emissions from gas fields being among the top 5 sources of emissions and steadily increasing by year[17].

The September 2018 Quarterly report on Australia's National Greenhouse Gas inventory suggested that national fugitive emissions from gas and crude oil production more than doubled in just four years, from 4 megatons of CO_2 equivalents in 2014 to approximately 9 megatons of CO_2 equivalents in 2018 and surpassing methane emissions from coal mining (Figures 3 and 4).



Source: Department of the Environment and Energy

Figure 3. Fugitive emissions by quarter, sub-sector, unadjusted and trend emissions, Australia, September 2008 to September 2018. . Source: Department of the Environment and Energy; from the Quarterly Update of Australia's National Greenhouse Gas Inventory: September 2018, Commonwealth of Australia 2018, p 8[18].

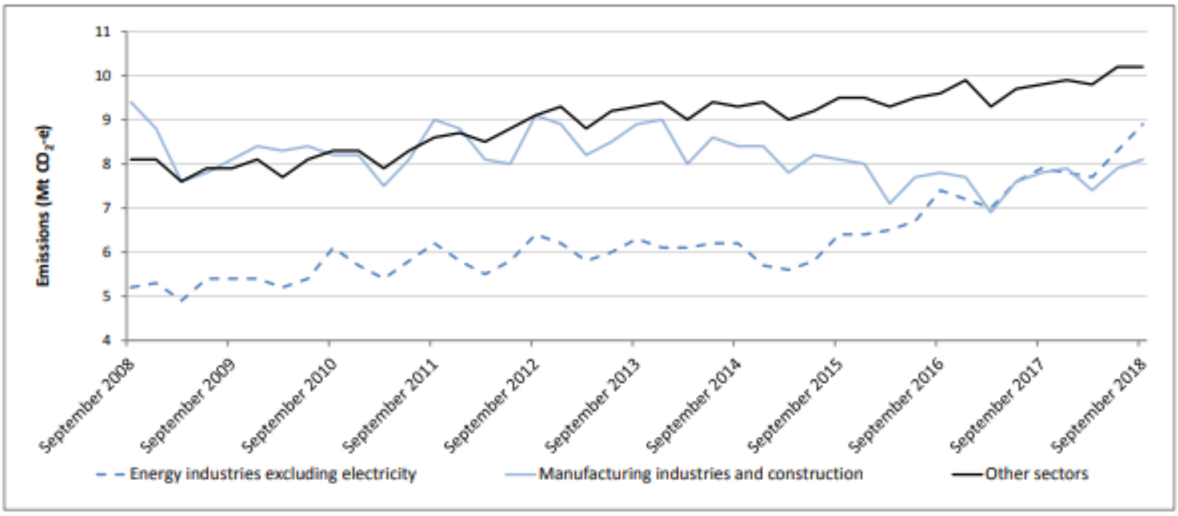
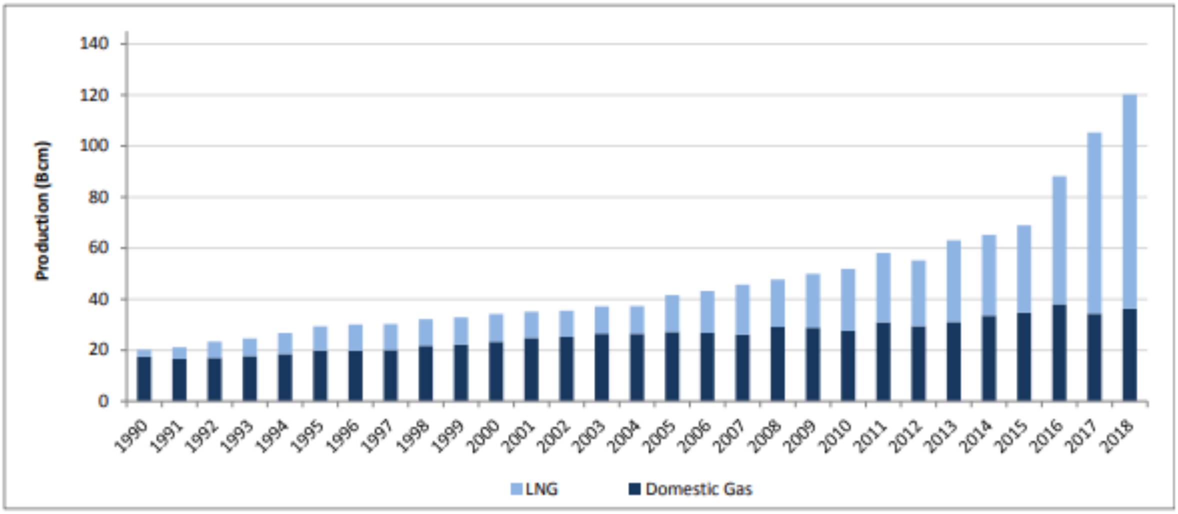


Figure 4. Stationary energy excluding electricity by sub-sector, quarterly, 'unadjusted' emissions, Australia, September 2008 to 2018. *Source: Department of the Environment and Energy; from the Quarterly Update of Australia's National Greenhouse Gas Inventory: September 2018, Commonwealth of Australia 2018, p 13*[18].

According to the report "This was driven primarily by an increase of 19.7 per cent in LNG exports in 2018" (*Quarterly Update of Australia's National Greenhouse Gas Inventory: September 2018, page 13*[18]).

LNG production increases have mainly come from offshore developments in Western Australia, the Northern Territory and from Queensland's coal seam gas developments, from approximately 25 billion cubic metres in 2014 to about 80 BCM in 2018 (Figure 5).



Sources: Department of Industry, Innovation and Science (2018), Resources and Energy Quarterly

Figure 5. Natural gas production, financial years, Australia, 1990 to 2017 and forecast data for 2018. Source: Quarterly Update of Australia's National Greenhouse Gas Inventory: March 2018, Commonwealth of Australia 2018, p 13[18].

If other states and the Northern Territory pursue extensive unconventional mining industry developments, these upward trends are likely to amplify substantially in future years.

While these figures are concerning enough, they are mainly based only on reports and modelling, not actual measurements. A detailed analysis of potential greenhouse gas emissions from coal seam gas mining conducted by the Melbourne Energy Institute[19] identified multiple uncertainties that could potentially yield significantly underestimated emissions figures.

LaFleur et al.[19] questioned the adoption of a markedly low emissions factor (0.5% of fugitive emissions relative to total gas production), compared to that estimated in multiple studies in the United States suggesting much higher levels (2-17%). The authors highlighted a lack of confirmation by satellite or atmospheric measures and a lack of monitoring of all potential emission points where methane could be leaking in gas field operations. Extensive monitoring is particularly important because it is known that shale gas mining can create 'super-emitting' points that emit extremely high quantities of methane, which must be identified for accurate measurement (and mitigation). Little is known about the variation in fugitive methane emissions between wells in coal seam gas mining. Furthermore, there is little understanding of potential 'migrating emissions' that may occur at considerable distances away from the well site. The authors stated, "there has been no comprehensive, rigorous and independently-verifiable audit of gas emissions"[20].

Another significant concern is that the current abundance of gas on the global market may not be acting as a bridging fuel towards renewable energies but may instead be competing against the adoption of renewable energies, because of a belief that gas produces substantially fewer emissions than coal. Like coal however, prices paid for gas do not include the many externalities – costs borne by communities – resulting from environmental loss, climate impacts, health loss and social conflicts and tensions between those gaining and those losing from developments in their midst.

In much of Australia, gas production is predominantly geared towards export markets; and the proportion exported may further increase with pipelines, processing facilities and access to shipping ports. Thus while some states are transitioning to low carbon domestic energy sources, the much larger contribution of Australian gas to the international market may be driving down prices, placing an economic deterrent against other nations' efforts towards decarbonisation and phasing out fossil fuel energy usage, as has been observed in the United States[15, 10].

Local and Regional Environmental and Public Health Risks and Concerns

The following sections review the evidence regarding potential risks mediated via water, land and air pollution, as well as psychosocial impacts. A comprehensive database, ROGER (Repository of Oil and Gas Energy Research, was used to assist in accessing published papers for this section[21].

Chemical Concerns: Overview

Research and assessment of health concerns associated with unconventional gas mining has been dominated by the use of a wide range of chemical additives and materials required for the procedure, plus the large number of naturally occurring chemicals brought to the surface within large quantities of wastewater generated at various stages. Many chemicals of both types have the potential to harm humans and the environment. Where data exists, it is clear that leaks and spills are common events in unconventional gas mining, although a lack of reporting prevents clear estimates of frequency of contamination of land and waters[22, 23 24]

As of March 2019, 122 peer-reviewed publications on examining flowback and produced wastewater and 48 on chemical additives were listed on the ROGER database; with nearly all pertaining to shale and tight gas operations. Some examined potential impacts on health and are described below.

In contrast, there are few published studies on the composition of wastewater derived from coal seam gas mining in Australia or overseas. In Australia, the most significant work thus far has been done by NICNAS (National Industrial Chemicals Notification and Assessment Scheme)[25].

However, it is important to acknowledge the limitations of this work. For example, only chemical additives (not naturally occurring chemicals present in wastewater) used in coal seam gas mining (not shale or tight gas mining) that were identified voluntarily by the industry (not mandated disclosure) were studied. Furthermore, the assessment focused solely on the (surface) above-ground handling of the chemicals, limiting information on environmentally mediated exposures to workers and communities.

Some findings of this work are discussed below.

Water Concerns with potential health impacts

Harm to water resources through contamination and/or depletion is often cited as a primary concern in Australia, especially because most developments are planned or occurring in rural agricultural areas[26].

Introduced chemicals

Local disposal of produced water, muds or drill-debris mediates the local dispersal of the chemicals they contain. Many of these have not been assessed for human health safety, while others are known to have detrimental human and/or environmental impacts.

As stated above, there has been very little peer-reviewed research investigating chemicals used in coal seam gas mining in Australia or elsewhere. The Australian government body, NICNAS[25], conducted an analysis of 113 chemicals used in CSG mining. It is not clear if this represents all chemicals used, or a subsample or voluntarily disclosed chemicals used by companies, and which additional chemicals are now being used that were not in use when the study began.

NICNAS[25] found that 44 chemicals out of the 113 examined were potentially harmful to workers in the case of exposure during an industrial accident. Twelve were found to have the potential to harm workers during mixing and dilution of highly concentrated chemicals if adequate protection methods were not used.

Considering public health, NICNAS identified that 40 chemicals used in CSG mining had the potential to harm the community should people become exposed to the chemical by swimming or drinking water contaminated by spills during transport or leakage from a waste-water pond.

Companies are expected to abide by the *Environment Protection and Biodiversity Conservation Act 1999*, as well as state and national regulations and Codes of Practice in the handling and transport of dangerous goods. They are also expected to have emergency preparedness plans and reporting procedures in the event of an accident or leak.

A large number of chemicals are used in the hydraulic fracturing process for gas mining that may not have been examined in the NICNAS study. These include surfactants, acids, bactericides, glycol and many substances not revealed under “commercial in confidence” agreements. In an August 2018 stakeholder update, NICNAS announced its intention to invite companies ‘*to apply to protect a chemical's identity as confidential business information (CBI). If approved, we [NICNAS] will mask its* *identity by using a generic chemical name. These will be known as AICIS approved chemical names (AACNs) once the reforms come into effect*'. Thus, it is not clear, as in some States in the United States, whether or not medical practitioners will be able to gain information needed for medical treatment of patients who may have been exposed to specific chemicals.

The greatest occupational health concern identified thus far in the United States for unconventional oil and gas workers is excessive exposure to silica – large quantities of 'frac sand' required for hydraulic fracturing[27, 28].

Furthermore, little is published about the chemicals used in conventional gas mining, which does not involve hydraulic fracturing, but does use drilling muds and chemical additives, as well as conferring potential exposure to naturally occurring chemicals in air and wastewater[29].

From a human health perspective, there are significant concerns if chemicals enter the air, groundwater or aquifers, and, in the long term, have the potential to affect food and water safety for crops, humans and animals.

Naturally occurring chemicals

There is significant concern about naturally occurring chemicals in the saline wastewater produced in unconventional gas mining[30, 31, 32, 33].

Volatile organic compounds, including BTEX (Benzene, Toluene, Ethylene and Xylene), which occur naturally in the shale or coal seam, and evaporate from the flowback wastewater after fracking may pose health risks, as does the flaring excess gas. Benzene contamination of ground water was a frequent consequence of 77 surface spills that were reported in a 12-month period in a Colorado county with intense shale gas mining activity[34].

Polycyclic aromatic hydrocarbons (PAHs), heavy metals and naturally occurring radioactive materials (NORMs) have the potential to damage the health of people who are exposed. Radioactive materials, such as uranium, thorium, radium and their decay products, can be found in unconventional gas wastewater, and are concentrated and brought to the Earth's surface in extraction and waste disposal process[35]. The waste containing these materials is called TENORMS or technologically enhanced naturally occurring radioactive materials. If present at significant levels, workers and nearby residents may be at risk of exposure through air and water[36, 37].

A few studies have characterised constituents of wastewater produced during coal seam gas mining[22]. Untreated produced water contains high levels of sodium and bicarbonate, often with suspended solids, iron, silica and barium[22, 38, 39]. Heavy metals, boron, fluoride, organic compounds and ammonia may also be present[40].

NICNAS and CSIRO commissioned important laboratory-based leaching experiments using samples from different sources of coal exposed to conditions roughly simulating those of hydraulic fracturing[41]. Findings for a range of potentially hazardous metals, radioactive materials and organic compounding existing in the coal leachate were then compared where possible with existing water quality benchmarks for aquatic ecosystems and stock watering systems used in Australia. The authors highlighted the following inorganic chemicals released from the coal samples out of a total of 60 identified as priorities for further investigation: aluminium, arsenic, beryllium, boron, cadmium, chromium, cobalt, copper, gallium, lead, manganese, nickel, selenium, silver, thallium, uranium, vanadium, and zinc. Among the organic coal contaminants retrieved were phenols, cresols and low molecular weight total recoverable hydrocarbons. An additional 14 organic chemicals, including alkanes, alcohols, aldehydes and polycyclic aromatic hydrocarbons were also present, but their origin in the coal and/or in the added chemicals is unclear[41].

Concentrations of radionuclides, namely radium, thorium and uranium, were deemed below concern. However, the authors pointed out that these materials could potentially be concentrated during procedures, such as in crust formations in pipework, filters and on reverse osmosis membranes used in water treatment[41].

Concentrations of many additional chemicals found in the coal leachate, such as barium, could not be assessed due to a lack of guidelines or regulations available for drinking water or aquatic water systems[41]. The authors called for additional research to extend these findings to actual hydraulic fracturing activities in coal seam gas mining.

Wastewater from both coal seams and shale strata is mildly to extremely saline. Treatment by reverse osmosis or other disposal methods produces enormous quantities of salt, creating a serious environmental hazard for both ecologically significant areas and agricultural regions, impacting on soil fertility[22, 33]. Saline leakage from the water handling processes can also mobilise naturally occurring chemicals in soil, such as arsenic and uranium, transporting them into groundwater aquifers. One such incident caused by a leak in a wastewater holding pond liner in Santos' Pilliga Forest CSG operations has been reported[42].

Interactions between chemicals

The comprehensive systematic literature review by Saunders et al.[43] highlighted a major gap in our understanding of the interactions between the many chemicals in wastewater from hydraulic fracturing. Interactions are not considered in risk assessments because there is still little or no understanding of this complex area. The use of experimental studies in animals and bioanalytical assays is recommended, progressing beyond identification of individual toxicological profiles constituents to better understand the potential negative consequences of exposure to unconventional gas wastewater[22].

Chemicals in wastewater with carcinogenic, neurological, reproductive and developmental toxicity

A study by Elliott et al.[31] examined the carcinogenicity data on a total of 1,177 chemicals in fracking fluids and wastewater (US EPA) and 143 chemicals identified in scientific papers published before 2016 on air pollutants. The researchers found that over 80% of these chemicals were not evaluated for carcinogenicity. Among the 119 chemicals that were evaluated, 49 water and 20 air pollutants were possible, probable or known carcinogens and 20 were associated with leukemia/lymphoma, including benzene, 1,3-butadiene, cadmium, diesel exhaust and PAHs.

Elliott et al.[44] also examined the reproductive and developmental toxicity of 1,021 chemicals identified in fracturing fluid, wastewater or both. Information on toxicity was lacking for 781 (76%). Among the 240 that had been evaluated, 103 were known to have the potential for reproductive toxicity and 95 for developmental toxicity.

Evidence of endocrine-disrupting activity in surface and groundwater in areas with unconventional gas mining raises concerns[45, 46, 47]. These chemicals can interfere with endocrine function at very low concentrations, sometimes without any overt signs or symptoms.

A systematic review of 45 peer-reviewed publications examined links between conventional gas extraction processes and the presence and potential impacts of endocrine-disrupting activity[29].

Moderate evidence was found of an increased risk of preterm birth, miscarriage, birth defects, decreased semen quality, and prostate cancer that could result from disruption of the oestrogen, androgen, and progesterone receptors by chemicals associated with (mostly conventional) oil and gas production. The researchers postulated that unconventional gas mining posed more potential risks to reproductive health than conventional gas operations given the many endocrine-disrupting chemicals involved in the hydraulic fracturing process.

No studies have examined potential endocrine-disrupting chemical activity in wastewater from CSG extraction.

Webb et al.[48] reviewed existing evidence regarding air and water pathways through which infants and children could potentially become exposed to and experience neurological and neurodevelopmental impacts associated with oil and gas mining emissions. Five chemical groups were identified, including particulate matter, polycyclic aromatic hydrocarbons, volatile organic compounds, endocrine disrupting chemicals and heavy metals.

Water security

Unconventional gas mining raises concerns for both water quality, as discussed above, and a sufficient and secure supply of water for drinking, food production and other human and ecosystem services[49, 50]. Already many areas of the world, including the United States and Australia, face significant water stress, which will worsen as climate change progresses. A global analysis reported that 31-44% of shale deposits are located in areas of the world likely to be affected by water stress; 20% are in areas where groundwater is already depleted and 30% underlie irrigated lands[50]. These authors warned of likely competition between unconventional gas production, food and other human uses of water.

Shale gas mining uses large quantities of water (4 to 24 million litres) in each hydraulic fracturing event[51], which can be applied many times per well across hundreds to thousands of wells in an area. Contamination of aquifers and surface waters may also render them unusable for human consumption.

It has recently been discovered that as shale gas and oil mining has expanded in the United States, the amount of water used per well to produce a unit of gas (water-use intensity) increased substantially[52]. This was associated with longer lateral drilling distances and increased intensity of hydraulic fracturing that occurred in 2014-2015, simultaneously with a reduction in drilling of new wells as oil and gas prices fell. High intensity production also resulted in an even greater increase in wastewater production per well. Examining water usage records across four shale gas mining regions in the United States, Kondash et al.[52] reported increased water-use intensity (lower water efficiency) and waste-water production across all areas. The increase was as high as 770% in water usage per well and 1440% in wastewater production in the Permian and Eagle Ford Basins, located in semiarid Texas and New Mexico over a five-year time period.

These concerns are likely to be applicable to many areas of Australia where coal seam gas and shale gas deposits are found. Water stress is already experienced by local farmers and communities in existing developments in the Darling Downs, Queensland and Narrabri, NSW. Similarly, water availability is a pressing challenge for farmers and communities near to proposed sites for exploration and mining in the Northern Territory and Western Australia.

Evidence of harm to water resources

A seminal report by the U.S. EPA (2016), "*Hydraulic Fracturing for Oil and Gas: Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources*"[23], was released in December 2016. This long-awaited report confirmed that, despite some 300,000 unconventional gas wells being drilled, hydraulically fractured and operating in the United States, the safety of the operation to drinking water resources has not been demonstrated.

The Executive Summary stated:
EPA identified cases of impacts on drinking water at each stage in the hydraulic fracturing water cycle. Impacts cited in the report generally occurred near hydraulically fractured oil and gas production wells and ranged in severity, from temporary changes in water quality, to contamination that made private drinking water wells unusable.

As part of the report, EPA identified certain conditions under which impacts from hydraulic fracturing activities can be more frequent or severe, including:

Water withdrawals for hydraulic fracturing in times or areas of low water availability, particularly in areas with limited or declining groundwater resources;
Spills during the management of hydraulic fracturing fluids and chemicals or produced water that result in large volumes or high concentrations of chemicals reaching groundwater resources;
Injection of hydraulic fracturing fluids into wells with inadequate mechanical integrity, allowing gases or liquids to move to groundwater resources;
Injection of hydraulic fracturing fluids directly into groundwater resources;
Discharge of inadequately treated hydraulic fracturing wastewater to surface water resources; and
Disposal or storage of hydraulic fracturing wastewater in unlined pits, resulting in contamination of groundwater resources.

…Data gaps and uncertainties limited EPA's ability to fully assess the potential impacts on drinking water resources both locally and nationally. Generally, comprehensive information on the location of activities in the hydraulic fracturing water cycle is lacking, either because it is not collected, not publicly available, or prohibitively difficult to aggregate. In places where we know activities in the hydraulic fracturing water cycle have occurred, data that could be used to characterize hydraulic fracturing-related chemicals in the environment before, during, and after hydraulic fracturing were scarce.

Because of these data gaps and uncertainties, as well as others described in the assessment, it was not possible to fully characterize the severity of impacts, nor was it possible to calculate or estimate the national *frequency of impacts on drinking water resources from activities in the hydraulic fracturing water cycle."*

Experience to date suggests that the same circumstances are present in Australia. RMIT hydrogeologist and geochemist, Dr Matthew Currell, recently highlighted a serious lack of appropriate baseline data and insufficient resources available for monitoring and compliance to ensure that water resources can be sufficiently protected by Santos in their Narrabri operations[53]. Currell provided detailed recommendations in a public submission to the NT Hydraulic Fracturing Inquiry[54].

Further unknowns and uncertainties regarding water

At times, 'solutions' to problems can actually cause further problems and may not be subject to research before implementation. For example, the siting of multiple wellheads on the same pad, and drilling multi-directionally may both reduce surface footprint. However, as fully demonstrated by Kondash et al.[52] and discussed above, the wellheads may not be placed in optimal positions for the location of the 'sweet spots' of gas in each direction. This has meant longer distance drilling, and larger water requirements, greater pressures for hydraulic fracturing and greatly enhanced volumes of wastewater requiring safe handling. Effects can also occur at considerable distance from drilling and can be difficult to trace back to the source of disruption.

Furthermore, the reuse of flowback water after fracking for additional fracking (recycling) may result in increasingly high concentrations of hazardous chemicals, elevating risks in handling and ultimate disposal. According to Webb et al.[55], recycling wastewater is not often used because of the increased concentrations of hazardous chemicals. An analysis by Parker et al.[56] revealed multiple challenges in the treatment and management of fracking-affected water, which are also very expensive.

Any such proposed 'adaptive management' changes should be accepted only after extensive consideration of the potential complications and risks they may pose. Additionally, contamination risks to water in agricultural areas should also be seen as potential food safety concerns, as livestock and produce may be affected. There has been little research on these issues.

Impacts on land use and food security concerns

Contamination of soils and competition for land use carries significant human health risks, especially when considering cumulative impacts of hundreds of wells over decades.

As stated by Haswell and Bethmont[26], the link between food safety and security and unconventional gas has received less research interest, but it is a critical concern for farmers for whom livestock health and water rights are paramount, especially with increased droughts predicted in Australia and globally[57, 5]. These concerns were highlighted in exceptionally drought-stricken California in 2015 where some farmers irrigated crops with unconventional oil wastewater with unknown consequences[58].

The long-term safety of insufficiently treated water in farming remains uncertain, as toxins may transfer into food chains[59] and increased soil salinity may reduce productivity[60]. Furthermore, irrigation of crops with saline wastewater can also mobilise heavy metals already present in the soil, such as cadmium and uranium[61].

Negotiations between water and energy sectors face conflicting views and complexity, increasing with climate change and population growth[62]. Prospects for successful coexistence between farming and gas mining are further challenged by roads and mining infrastructure on agricultural land, pollution risks, livestock disturbance and economic uncertainties surrounding unconventional gas mining[58, 59, 62, 63].

Air Emissions with potential direct health impacts

Potential Exposure pathways

Chemicals reach the atmosphere from flaring, venting, holding tanks, ponds, compressors and other infrastructure. While initially the focus of most public health concern was on risks to water, the US experience to date has indicated that health risks associated with air pollution are at least as serious to the health of people living nearby as the risks mediated through water contamination[64, 65].

Residents living near gas wells and infrastructure and industry workers may be exposed to air-borne pollutants directly, e.g. through diesel exhaust from extensive truck movements, drilling, compressors and other machinery used in the process, flaring and from gases from the coal seam or shale deposits released during well completion and other phases [66, 67, 68]. Some gases form secondary atmospheric pollutants such as ground level ozone. Other exposure pathways involving inhalation of potentially harmful substances occur through the movement of volatile compounds from contaminated water into the air, and some toxins may return to contaminate soil and water bodies through subsequent rainfall, falling on waterways and livestock pastures.

Airborne chemicals of health concern

Webb et al.[55] detailed the toxins associated with unconventional oil and gas operations of greatest concern – many of which can affect unborn and developing children at low doses. The authors state:

"Unconventional oil and gas (UOG) operations have the potential to increase air and water pollution in communities located near UOG operations. Every stage of UOG operation from well construction to extraction, operations, transportation, and distribution can lead to air and water contamination. Hundreds of chemicals are associated with the process of unconventional oil and natural gas production… Many of the air and water pollutants found near UOG operation sites are recognized as being developmental and reproductive toxicants; therefore there is a compelling need to increase our knowledge of the potential health consequences for adults, infants, and children from these chemicals through rapid and thorough health research investigation." (Webb et al., [55], p 307)

People living near unconventional and conventional gas operations can be at elevated risk of exposure to organic compounds (like benzene), poly-aromatic hydrocarbons, heavy metals and radioactive materials in the air as well as water. These can affect the respiratory, endocrine, nervous and cardiovascular systems, and some have the potential to cause cancer, at sufficient levels of exposure[30, 69, 70].

Endocrine disrupting chemicals associated with the industry may also be airborne[71]. Bolden and colleagues[72] reviewed 48 air quality studies associated with shale gas mining and identified 106 chemicals with endocrine disruption potential, including estrogenic and androgenic activity, chemicals capable of altering steroid formation.

Finally ground level ozone, that forms from mixtures of pollutants emitted during unconventional gas mining is also of significant concern and can travel large distances, acting at a regional level, potentially capable of causing exacerbations of asthma among residents.

Communities close to unconventional gas operations can experience a major increase in heavy vehicle traffic. This brings a loss of amenity, increased risk of traffic accidents among workers[73] and residents[74] and increased exposure to diesel engine exhaust[75]. Diesel exhaust from trucks and heavy machinery contains particulate matter, nitrogen oxides and volatile organic compounds and is classified as a Group 1 carcinogen by the International Agency for Research on Cancer[76]. Silica, handled in very large quantities in the drilling and hydraulic fracturing processes, has the potential to pose serious risks to the respiratory health of exposed workers, causing silicosis decades later[27, 28].

Studies measuring health risks and impacts associated with residence near gas wells.

Risk assessments and health studies

Many studies are now underway in the US to measure concentrations of potentially harmful chemicals in ambient air and water, assess likely levels of exposure to children and adults living in nearby communities to estimate their potential to cause or contribute to disease and compare disease frequencies among those close to and further from gas mining operations[69, 44].

An evaluation of potential impacts associated with shale gas operations in the Barnett Shale region of the United States by Bunch et al.[77] used routine measurements of a range of volatile organic compounds in over 7,500 assessments. These authors concluded that there was no evidence that any of the assessed compounds posed significant human health risks.

In contrast, health risk assessments of toxic air emissions conducted by McKenzie et al.[69] suggested that people living within 0.8km of shale gas wells experience significantly increased risk of sub-acute non-cancer hazards, particularly those with neurological, haematological and respiratory health impacts. This study also suggested a higher cancer risk to those living closest to the wells.

The latter risk assessment adds weight to frequent anecdotal reports and findings of a recent community study that found significantly higher prevalence for self-reported respiratory (39% vs 18%) and skin (19% vs 3%) conditions among people living within 1 km compared to those living more than 2 km from shale gas wells in Pennsylvania[78]. People living near unconventional gas wells throughout the world, including near CSG gas wells in the community of Tara in the Darling Downs region of Queensland, have anecdotally reported similar symptoms, as well as headaches, nosebleeds and numbness and tingling sensations[79, 80].

While no spatial community-level health studies have been done in Australia, there have been two limited single time-point studies. One by Queensland Health[81] with low community participation and few reports of physical symptoms at a one-day clinic, did not identify likely links between existing air emission data and symptoms reported at the clinic. In contrast, many community members reported a range of signs and symptoms potentially related to CSG activities in a house-to-house survey conducted by local General Practitioner, Dr Geralyn McCarron[79]. While their results on the prevalence of physical symptoms were conflicting, the findings of both studies support Queensland Health's statement that:

"the available data were insufficient to properly characterise any cumulative impacts on air quality in the region, particularly given the

anticipated growth of the industry. It is necessary to assess those impacts according to health-based standards which are relevant to long-term exposure" (Queensland Health, p18[81]).

Also, in the Darling Downs, Queensland, where increasingly extensive unconventional gas mining and production of coal seam gas has occurred to date, McCarron[82] reported substantial rises in hospitalisation rates of 133% for acute circulatory and 142% rises in acute respiratory conditions between 2007 and 2014. Annual analysis of hospitalisations demonstrated that the rates were largely constant between 2007 and 2009, then climbed steeply from 2010 onwards; simultaneously with sharp rises in gas production and accompanying annual atmospheric emissions of nitrogen oxides, volatile organic compounds, $PM_{2.5}$ and PM_{10}, formaldehyde and sulphur dioxides that were reported by the companies and published in the National Pollutant Inventory. There is an urgent need to further investigate these coincidental increases in hospitalisations and pollution emissions[82].

A further step examining temporality between air quality and symptoms was conducted in the US by Macey et al.[83] in four US states with substantial oil and gas production. This involved community members receiving training and utilising a grab air sampling procedure when individuals felt normal, and at times when they felt sick or sensed pollution from the nearby gas operations through taste or smell. This novel method enabled the community to identify numerous excursions above federal guidelines that were particularly frequent for air-borne toxins, notably formaldehyde, 1,3-butadiene, hydrogen sulphide, mixed xylenes and n-hexane, above health-based risk levels.

Importantly these measured exceedances had not been detected and/or reporting in routine air monitoring, raising questions about the sensitivity of existing data in ensuring protection of health. Indeed, atmospheric research in a variety of circumstances has revealed significant underestimations in emissions of methane and other hydrocarbons based on ground level measurements and modelled predictions[66, 65, 14].

Workers may also be exposed to unsafe levels of fine silica due to the large volumes of sand used, increasing the risk of silicosis[36].

Public health studies on unconventional gas mining are gaining in maturity and rigour, and each year brings new understandings[84, 43, 85, 26]. These studies collectively address the challenges on how to measure complex risks, assess impacts and respond to knowledge from studies of human health.

Studies attempting to measure health impacts of the industry remain relatively few but are increasing and are mostly limited to physical health consequences.

To summarise, negative health outcomes that have been found to occur more often in groups of residents with greater exposure to shale gas mining, compared with groups with lower exposure, include:

Hospitalisations - for cardiological and neurological disorders and for those with existing asthma conditions (emergency department visits, inpatient stays) and for cancers, genitourinary presentations (kidney and urinary tract infections and urinary stones) and immune related diseases[86, 87, 88, 89, 90].

Symptoms – migraine headaches, chronic nasal and sinus irritation, fatigue, nausea, skin rashes, eye irritation, nosebleeds, and asthma worsening requiring medication changes[79, 86, 91].

Sexually transmitted infections – increased incidence rates of chlamydia and gonorrhoea infections which are associated with changes in sexual behaviour that can be associated with mobile workers coming in to depressed areas[92, 93, 94].

Special Risks to foetuses, infants and children

Of particular concern among research findings are studies that have identified developmental problems during pregnancy and infancy – lower birth weight, small for gestational age, higher frequency of preterm (especially severely pre-term) births and specific birth defects[95, 96, 97, 98,99, 88,100].

Since 2013, there has been an increasing focus on the likely vulnerability of developing foetuses and children to environmental hazards as compared to adults. The complex developmental processes that occur during gestation are exquisitely sensitive to chemicals and signals in the uterine environment. There is a growing understanding of the negative impacts of various exposures to the mother during pregnancy on birth outcomes, for example air pollution ($PM_{2.5}$) on birth weight and preterm births, as well as drugs on brain development. Many of the chemicals involved in unconventional gas mining have potential reproductive and developmental toxicity[55, 101, 31, 44].

Confirming previous studies suggesting an association between birth weight and exposure to unconventional gas mining mentioned above, Currie et al.[99] found a 25% increased risk of low birth weight infants among mothers living within 1 km of a hydraulically fractured well, and smaller but detectable elevated risks at 2 and 3 kilometres distance. Using these findings, it was estimated that 29,000 infants born in the United States each year were at increased risk of low birth weight; which has significant implications for their subsequent health.

Detailed studies by Hill[100] controlled for a wide range of relevant maternal and geographical characteristics and examined birth weight outcomes of infants of mothers living within and beyond 2.5km of one or more shale gas wells in Pennsylvania. This work revealed a 7% increase in the frequency of low birth weights, a 5g reduction in the average full-term birthweight and a 3% increase in preterm births for each well located closer than 2.5km. This affect was only observed for residence near active wells during gestation.

Further work has indicated that unconventional gas mining is also associated with increased risk and severity of preterm birth, especially when exposures to mining activity occurs in the first trimester of pregnancy[88].

A regional study involving 124,832 infants in Colorado reported positive links between the incidence of congenital heart disease, and possibly neurotubular defects, and increasing numbers of shale gas wells within 10 miles (16kms) of residence in the infant's birth year [97]. Low birth weight, in contrast, was negatively correlated with numbers of wells in this study.

Infants and children continue to face higher risks compared to adults from toxic exposures after birth due to their higher metabolic and respiration rates, their smaller body size and smaller and immature organs, including the liver, lungs and kidneys that deal with or store many toxins that enter the body. Children also experience exposure to toxins in the environment through outdoor play activities. Conversely it is also concerning if children do not feel safe to play outside, as lack of physical activity is also associated with poorer physical and mental health. It is very important to recognise that infant and child wellbeing is highly sensitive to psychosocial and community stressors, including noise, heavy traffic, negative emotions expressed by others and witnessing aggression and conflict (discussed below), and, potentially, fear of pollution.

Higher rates of childhood hematologic cancers among children living close to oil and gas developments compared to areas without such developments have been observed in areas producing shale gas in the United States[102]. Similarly, higher hospitalisation rates for children with neoplasms (9% higher [95% CI 2-16%]) and blood/immune diseases (14% higher [95% CI 2-27%]) were reported by Werner et al.[103] in the coal seam gas mining areas of the Darling Downs, Queensland compared to a rural agricultural area without coal or coal seam gas mining. Age-specific comparisons of hospitalisation rates revealed that living within areas with coal seam gas mining activity was associated with significant increases in hospitalisations for respiratory diseases among very young (0-4 years) and 10-14 year old children (ranging from 7-11% higher) and a 467% increase in blood/immune diseases among 5-9 year olds, when compared with children in areas without coal seam gas mining activity[104].

Children living in areas where shale gas mining activities were introduced (by zip code) were found to experience a 25% increase in hospitalisations due to asthma (Odds ratio 1.25 (1.07-1.47)) within 3 months after commencement. In contrast, children living in comparison areas without of drilling activity did not experience a change in asthma hospitalisations[105].

Studies of longer-term impacts, such as cancers and chronic disease, are extremely limited to date because insufficient time has elapsed since commencement of potential widespread exposure to gas activities.

In summary, the relatively small literature specifically examining potentially harmful exposures to air- and water-borne pollutants and stressors associated with unconventional gas mining for foetuses, infants and children is consistently building evidence of significant concern in both the United States and Australia.

Social and mental health impacts

There are many avenues through which the unconventional gas industry can harm mental health and individual and community wellbeing[106, 107, 108, 109, 110, 111, 112, 113, 114, 115]. Prior to commencement, impacts may include distress, anxiety, fear of the unknown and social disharmony due to disagreements that split the community into those who support the industry and those who oppose it[116, 113]. In the 'boom' phase tight-knit communities can feel inundated with strangers coming in, burdening health and other services[106, 113]. Crime may also increase[117] (; James and Smith, 2017). Such impacts are detrimental to the social cohesion and for some, the moral character, of the community[116, 112, 111, 115]. In the post-construction phase, jobs may decline and housing demand drops. Production continues, with drilling and fracking, with its 24-hour lights, noise, privacy invasion, odours, tree clearing and truck movements - causing some people to feel a deep sense of loss of control, loss of place, anger, powerless and loss of peace and a feeling of being trapped and unable to escape[111, 112, 113]. All the phases may exacerbate the risk of depression and anxiety and suicidal ideation[116, 109, 113].

While the 'boom' phase may appear to bring positive social change, impacts on residents are uneven and most feel uncertainty in how communities will cope with the post-construction phase[118, 119]. A survey by Australia's Commonwealth Scientific and Industrial Research Organisation of 390 residents found that 48.5% felt their community was 'only just coping', 'not coping' or 'resisting' the industry. While 51.5% felt their community was adapting, just 11.4% of this group saw the change as 'into something different but better'[119]. Disturbance of place attachment as a result of unconventional gas development may contribute to loss of wellbeing[111, 112].

The New South Wales Parliament Legislative Council Inquiry into Coal Seam Gas (2012) found widespread concern about CSG developments from rural, urban and indigenous communities. Some inquiry participants were concerned about poor behaviour by CSG companies and contractors, the pace of development and fear of loss of land and livelihood.

A recent study by Casey et al.[120] found a strong positive association between symptoms of depression and living in close proximity to greater numbers of unconventional gas wells in Pennsylvania.

In southern Queensland, 239 landholders, community and service representatives attending workshops linked psychosocial, health service, housing and financial stressors and negative mental health impacts with coal and UCG mining[106]. Participants urged greater protection of mental health and increased health and psychological services in mining areas.

Augmenting the Edinburgh Farming Distress Inventory to include stressors linked to CSG mining, Morgan et al.[109] found that concerns about CSG mining contributed to overall stress burdens and odds of experiencing depression and anxiety, especially among farmers directly affected by mining activities.

The suicide of an Australian farmer in 2015 who, according to a family statement[121], resisted pressure and experienced the consequences of unconventional gas mining and underground coal gasification on his farmland for over 10 years adds gravity to the findings of these studies. This death stimulated a national Senate Select Committee Inquiry on Unconventional Gas Mining[122] but, after an interim report, the Inquiry was suspended due to the 2016 Australian election. Doctors for the Environment Australia made a submission to this inquiry[123].

There are particularly important concerns when considering the potential psychosocial and spiritual impacts of unconventional gas mining on Aboriginal people and communities. Aboriginal people are highly overrepresented in the rural and remote areas where most developments are proposed, especially in the Northern Territory and Western Australia. Aboriginal people already experience substantially higher burden of morbidity, hospitalisation and mortality from the negative health conditions associated with exposure to unconventional gas mining, such as higher prevalence and severity of heart and respiratory tract conditions (including asthma and chronic obstructive airway disease), low birth weight, some cancers, mental health illnesses and traffic accidents. The environmental health conditions that Aboriginal people living remotely experience are often substandard, and water supplies difficult to monitor and maintain. While there are no specific research publications to date, a submission to the draft Final Report of the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory by the Aboriginal Medical Services Alliance NT[124] concluded, *"imposing fracking against the wishes of large sections of the Aboriginal community is likely to worsen health and wellbeing through increased community discord, and heightened levels of depression and anxiety with subsequent effects on physical health and wellbeing. Aboriginal health is connected to the health of the land and water- so threatening the physical environment directly affects Aboriginal wellbeing. Aboriginal people already suffer unacceptable rates of mental health issues and chronic disease. The benefits in terms of employment are likely to be limited and short term. AMSANT considers fracking to be an unacceptable risk to the health and wellbeing of Aboriginal people in the NT with the risks clearly outweighing the benefits".*

Interpreting these Studies

Understanding uncertainty in causative association – what adds strength to health studies?

There are many challenges hampering the ability to establish that gas mining is the cause of the higher frequencies of health problems associated with living close to mining activities[84]. While many studies have demonstrated associations between unconventional gas activity and adverse outcomes, further research is necessary to provide more direct causal evidence of effects. For example, the link between tobacco smoking and lung cancer took many years to be established. However, despite these difficulties, evidence is accruing, as studies are increasingly demonstrating for example:

Plausibility – There are logical links between the health problems being experienced and the kinds of chemicals used based on their known properties and distressing experiences associated with living near industry operations;
Dose-dependence – Many studies demonstrate higher frequencies of problems among those with higher likely exposure (closer distance to wells, higher densities of wells, more intense gas production);
Time relationship – Many studies show that the detected increases in health problems began only after commencement of industry activities in the areas;
Associations are still evident after considering other causes - for example, controlling for the potential contribution of smoking, socioeconomic status, community age profiles, legacies of other industrial activities in the area, etc.

Views of Professional Health Organisations

Inadequate and unproven regulatory framework

For adequate protection of health and the environment, it is critical to also consider that risk management approaches are sufficient only where the technical capacity to alleviate all risks exists and is clearly and sufficiently demonstrated. Relying on risk management approaches also requires certainty that a sufficient level of regulation, monitoring, early detection, correction and preventative actions can be operationalised, paid for by appropriate bodies, and sustained over time.

Experience documented in the US EPA Final Report regarding impacts of hydraulic fracturing in the United States shows that such a level of assessment, monitoring, detection and correction has not occurred, making it impossible to estimate on a wide scale how much contamination of water supplies has resulted from the industry. This raises serious questions about the extent to which people have been exposed to undetected contaminants in water they have consumed.

It should be noted that while fugitive emissions can be reduced during production, the processes are not cost effective for industries without a carbon pricing mechanism in place, and therefore continual legislation and monitoring is required to ensure compliance.

Furthermore, the Physicians for Social Responsibility and Concerned Health Professionals of New York (2016) have compiled four extensive editions of "*Compendium of scientific, medical and media findings demonstrating risks and harms of fracking*"[125] (Unconventional oil and gas extraction) in the United States. The authors argued that, based on this extensive experience, "regulations have not prevented significant harms; and that some harms are not preventable through regulatory opportunities".

Little has been published regarding the effectiveness of regulatory frameworks in Australia. This is despite significant reference to the ability of regulation to mitigate the many environmental, health and wellbeing concerns raised by the industry. For example, the Scientific Inquiry into Hydraulic Fracturing of Onshore Unconventional Reservoirs in the Northern Territory released in March 2018 concluded that, although there were significant risks and concerns associated with the industry, the application of 134 recommendations was deemed to be sufficient to ensure safety.

Even if risk elimination were theoretically possible, all governments should be asking whether their regulatory agencies have – and will continue to have - the capacity to adequately monitor and respond to the many potentially hazardous chemical, social, mental and physical health risks posed by large numbers of producing and depleted wells. The future security of these regulations depends on the commitment of future government leadership to place the protection of human health above that of industry demands, where conflicts exist.

Precautionary Principle and unconventional *gas mining*

Good health is highly cherished. Australian citizens generally believe that their state and national governments make responsible decisions that protect their health above other considerations, even where there is uncertainty. Thus many people probably assume that the government would take preventive action in the face of uncertainty; that proponents of a proposed activity, rather than the community, are required to demonstrate its safety; that governments will explore a wide range of alternatives to possibly harmful actions; and that the government would encourage public participation in decision making[126].

However, the unconventional gas boom has been described as an uncontrolled worldwide health experiment due to the incomplete disclosure of chemicals, combined with non-disclosure agreements in the US and in some cases in Australia[127]. Finkel and Hays[64] provide historical and current context to activities conducted by the unconventional gas industry in interactions with communities and the US Environmental Protection Agency, emphasising the risks of allowing the industry to go ahead without clear knowledge of risk. The effectiveness of regulations imposed on industries with the aim of increasing public safety has also been questioned. An interesting comparison between Kovats et al.[128] and Hill[129] highlights differing views on the potential versus the actual ability of regulation to protect human health from contaminants associated with shale gas mining. In a paper directed at the United Kingdom policy regarding the industry, Hays et al.[130] urged governments to make policy decisions based on evidence of risk and *measured effectiveness* of harm reduction based on actual experience - and not on theoretical solutions that have not been demonstrated.

Many Australian public health and medical organisations including DEA, the Public Health Association of Australia (PHAA), the Climate and Health Alliance (CAHA) and the National Toxics Network (NTN), collectively representing many doctors, public health practitioners, and allied health professionals, have expressed serious concern about the lack of evidence of safety to human health.

Doctors for the Environment Australia[131] joins the Union of Concerned Scientists[132] and many other health and medical organisations, in concluding that actions taken to prolong the continued use of gas as an energy source, such as continued exploration, production of any new gas resources and the new development and expansion of unconventional gas operations, pose unacceptable risks to the climate and hence, human health and wellbeing.

In its submission on the draft Final Report of The Scientific Inquiry into Hydraulic Fracturing in the Northern Territory, the Aboriginal Medical Service of the NT[124] emphasised that when uncertain risks are involved, "the choice of action should be the result of a participatory process" and unbiased information about the risks must be publicly available. AMSANT (2018) stated:

There is also a critical distinction between being consulted and being able to engage and make one's views heard, especially when there is such a critical power imbalance between disadvantaged, impoverished populations and dominant economically and politically backed mining lobby groups and governments, particularly when, as pointed out by the report, the regulatory mechanisms are inadequate.

In submissions to the NSW Chief Scientist and Engineer's examination of the public health and safety of coal seam gas mining in 2013 and in subsequent government submissions and communications, these groups, as well as the Australian Medical Association, have publicly called for application of the Wingspread Declaration on the Precautionary Principle. This can be summarised as: *'When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not established scientifically. In this context the proponent of the activity, rather than the public, should bear the burden of proof'* (Science and Environmental Health Network, 2016).

Coram, Blashki and Moss[133] reviewed the comparatively small body of evidence that had accumulated at the time and argued, "*The uncertainty over the health implications of unconventional gas is greater than that surrounding any other energy choice, and suggests that adopting an attitude of precaution – such as that employed with the introduction of a new drug – is justified on the basis of health risks alone".* The research conducted since that time has only added evidence of harm, not evidence of safety.

In her paper entitled, "Regulating Coal Seam Gas in Queensland: Lessons in an Adaptive Environmental Management Approach", Dr Nicola Swayne, cautioned: "*Most significantly, a truly adaptive environmental management approach must be able to embrace the hard decisions that go with "learning by doing" including the ultimate decision of ceasing CSG activities in Queensland in the face of significant information gaps and/or an unacceptably high risk of cumulative adverse impacts*".

The British Medical Journal[134] published a joint letter with similar sentiments signed by 18 leading medical scientists, stating: *"The arguments against fracking on public health and ecological grounds are* *overwhelming. There are clear grounds for adopting the precautionary principle and prohibiting fracking"*.

Concluding their review of 156 peer-reviewed publications on exposure pathways [air, water], seismicity, and health, economic and social and climate change impacts associated with unconventional gas mining, Saunders et al.[43] state:

As the available evidence does not enable a definitive public health judgment, a position shared by the US Centers for Disease Control (Centers for Disease Control and Prevention), we have a duty to pursue and assess that evidence while ensuring that, in the meantime, communities are not exposed to unacceptable risks. Several countries and North American states have banned, or imposed moratoria on, hydraulic fracturing including France, Bulgaria, Germany, Scotland, Wales, New York, Nova Scotia, Newfoundland, Quebec and New Brunswick[135].

… Considering the uncertainties surrounding the health, environmental, social, global warming potential and economic implications of unconventional gas within this internationally recognised framework, it would seem prudent to incentivize further research across all the domains of UNGD related impact, and delay any proposed developments until the products of this investment have been peer-reviewed and assessed.

The Australian Medical Association stated simply, *"If in doubt, turn CSG off"*[136].

vii. Conclusion

This submission has provided an extensive review of the evidence on the complex array of potential direct and indirect impacts on human health and wellbeing associated with the rapidly expanding gas and oil mining industries.

All of these findings should be taken into consideration in the review of the Chief Scientists recommendations made in 2013 – which were made at the very early stages of our understanding of the environmental and health risks linked to unconventional gas mining.

While evidence is growing of wide ranging and serious risks to many basic environmental determinants of health (clean and secure supply of water, air and food), arguably the most important implication of continuing and expanding gas mining in Australia and globally is its carbon footprint. Substantial research has highlighted the gas industries' major contribution to fugitive methane and CO_2 emissions during clearing, exploration, production, storage, transportation and combustion with special concern regarding major accidents and poorly understood super-emitting wells. In

Australia where there is no price on carbon, and no external auditing of gas emissions, it can be presumed that efforts to legislate, monitor and enforce will be difficult to commence and even more difficult, if not impossible, to sustain, with little optimism for success.

We conclude that for this reason alone, widespread development of new gas resources is a very dangerous gamble that humans should not be subjected to.

The accumulating evidence in other areas indicates that the many predictable concerns about, and impacts associated with, unconventional oil and gas mining are not only well founded, but also being increasingly measured and reported from various locations in the United States, Australia and elsewhere. These concerns include the wide range of potentially harmful chemicals being used which require transport, dilution and application; the large and increasing quantities of water used for gas extraction; the even larger volumes of waste water produced which contains both introduced chemicals and those brought to the surface and into the atmosphere; stress experienced by many directly affected; the disruption of community life from social changes and loss of physical amenity; and alarming contributions to increased greenhouse gas emissions at this crucial time.

This review has reported research, which has helped characterise these risks, identify the potential avenues of entry of chemicals into the environment and of human exposure, and quantify increasing rates of symptoms and exacerbations of illnesses. Particularly concerning to health and medical professionals and affected communities are associations found in many studies between living close to gas operations and increased hospitalisation for a range of serious health problems, increased stresses impacting on physical, social and mental wellbeing, and increased risk of poorer birth outcomes.

We conclude that the safety of gas and oil mining to the environment and to people is not confirmed by current research. While no study is wholly conclusive on its own, when the evidence is considered comprehensively, it becomes clear that the industry places significant risks to the health of people, especially developing foetuses and babies, and to the environmental determinants of health (climate, water and food security) on which we depend.

From these findings, we broadly recommend that in the short term, existing and already developed gas reserves should be used judiciously to assist in the rapid transition away from coal and gas fired power stations towards clean energy resources, i.e. wind, solar, hydroelectric energy where existing and agricultural biomass energy for extenuating circumstances.

However, as clearly demonstrated in the most recent Intergovernmental Panel on Climate Change report6 report, if we are to limit global warming to 1.5°C or even 2°C, the use of gas should curtail as quickly as possible, allowing renewable energies take over the powering of Australia and the world. To participate appropriately in this global urgency, Australia should urgently assist developing countries to transition away from gas power, instead of developing an industry that would continue to supply vast quantities of gas on the world market.

We point out that the cost and feasibility of such transitions has been repeatedly demonstrated through research across the world, including Australia[137, 138, 139]. Political will is a critical requirement. We urge the NSW government to take the necessary steps to lead Australia away from fossil fuel production and into a clean energy future that can support the health and wellbeing of current and future generations all over the world.

We strongly urge the NSW government embrace the Step Change Scenario as proposed by the Australian Energy Market Operator (AEMO)[4]. This is the only model that appropriately responds to the urgent need to reduce emissions rapidly and directs rapid reduction of gas usage in the electricity grid.

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Burden of Proof: a comprehensive review of the feasibility of 100% renewable-electricity systems. *Renewable and Sustainable Energy Reviews* 92: 834-847.

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Appendix

Unconventional gas mining; Doctors for the Environment Australia submissions to Governments 2011-2018

Independent Scientific Panel Inquiry into Hydraulic Fracture Stimulation in Western Australia 2018
March 2018
https://www.dea.org.au/wp-content/uploads/2018/03/Inquiry-into-Hydraulic-Fracture-Stimulation-in-Western-Australia-2017-Submission-03-18.pdf

Scientific Inquiry into Hydraulic Fracturing in the Northern Territory in Response to the Draft Final Report 2018
February 2018
https://www.dea.org.au/wp-content/uploads/2018/02/Scientific-Inquiry-into-Hydraulic-Fracturing-in-the-NT-02-18.pdf

Supplementary Submission to the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory
October 2017
https://www.dea.org.au/wp-content/uploads/2017/10/Supplementary-Submission-to-the-Scientific-Inquiry-into-Hydraulic-Fracturing-in-the-NT-10-17.pdf

Narrabri Gas Project
May 2017
https://www.dea.org.au/wp-content/uploads/2017/05/Narrabri-Gas-Project-Submission-Final-05-17.pdf

Scientific Inquiry into Hydraulic Fracturing in the Northern Territory
April 2017
https://www.dea.org.au/wp-content/uploads/2017/04/Scientific-Inquiry-into-Hydraulic-Fracturing-in-the-NT-Submission-04-17.pdf

Jemena Northern Gas Pipeline EIS
October 2016
https://www.dea.org.au/wp-content/uploads/2017/02/Jemena-Northern-Gas-Pipeline-EIS-submission-10-16.pdf

Inquiry into Hydraulic Fracturing of Unconventional reservoirs onshore within the NT 2016 (ToR)
October 2016
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Select Committee on Unconventional Gas Mining
March 2016
https://www.dea.org.au/wp-content/uploads/Select_Committee_on_UG_Mining_Submission_03-16.pdf

Inquiry into Unconventional Gas in Victoria
July 2015
https://www.dea.org.au/wp-content/uploads/2017/04/Unconventional-Gas-VIC-submission-07-15.pdf

Inquiry into Unconventional Gas (Fracking) – South Australia
January 2015
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Review of Hydraulic Fracturing (Fracking) in Tasmania
December 2014
https://www.dea.org.au/wp-content/uploads/2017/04/Review-of-Hydraulic-Fracturing-Fracking-in-Tasmania-12-14.pdf

Certain Aspects of Queensland Government Administration related to Commonwealth Government Affairs
November 2014
https://www.dea.org.au/wp-content/uploads/2017/03/Certain-Aspects-of-QLD-Government-Administration-Submission-11-14.pdf

Presentation to the Planning and Assessment Commission regarding the Narrabri Coal Seam Gas Mining Project Australia
June 2014
https://www.ipcn.nsw.gov.au/resources/pac/media/files/pac/projects/2014/05/dewhurst-gas-exploration-and-pilot-expansion-project-ssd6038/public-meeting--presentations-tabled/42-dr-melissa-haswell--doctors-for-the-environmentpdf.pdf

Hydraulic Fracturing Inquiry Northern Territory Submission
May 2014
https://www.dea.org.au/wp-content/uploads/2017/04/DEA-Hydraulic-fracturing-in-NT-inquiry-final.pdf

Implications for Western Australia of Hydraulic Fracturing for Unconventional Gas
September 2013
https://www.dea.org.au/wp-content/uploads/2017/04/WA-Inquiry-into-Hydraulic-Fracturing-UG-Submission-09-13.pdf

Amendments to the NSW State Environmental Policy Plan (SEPP) on Mining, Petroleum Products and Extractive Industries Amendment (Resource Significance) 2013
August 2013
http://dea.org.au/images/uploads/submissions/NSW_Mining_SEPP_Submission_08-13_.pdf

Draft significant impact guidelines: Coal seam gas and large coal mining developments – impacts on water resources
July 2013
http://dea.org.au/images/uploads/submissions/CSG_and_large_coal_mining_impacts_on_water_resources_submission_07-13.pdf

NSW Government Planning Review – White Paper
June 2013
http://dea.org.au/images/uploads/submissions/NSW_Planning_Review_White_Paper_submission_06-13.pdf

Management of the Murray Darling Basin – impact of mining coal seam gas
June 2011
https://www.dea.org.au/wp-content/uploads/2017/05/MDB_CSG_Senate_submission_June_2011.pdf