THE RISKS OF OIL AND GAS DEVELOPMENT FOR HUMAN HEALTH AND WELLBEING: A SYNTHESIS OF EVIDENCE AND IMPLICATIONS FOR AUSTRALIA

Professor Melissa Haswell, Mr Jacob Hegedus,
Emeritus Professor David Shearman

We respectfully acknowledge the Jinibara, Peramangk, Gadigal, Turrbal and Yugara, Gubbi Gubbi, Bundjalung, Gumbaynggirr Lands as those our primary work for the report was hosted. We pay respect to all the Aboriginal and Torres Strait Islander Nations and Peoples of Australia.

We pay respect to their Elders past, present and emerging and acknowledge these Lands were never ceded but havebeen mistreated to our collective detriment.

We acknowledge the strength and leadership of Aboriginal and Torres Strait Islander people across the nation in protecting the health and beauty of the Land we now call Australia. This leadership is based on science built over many millennia and must play a crucial role in helping us navigate an uncertain future.

Report authors are Professor Melissa Haswell and Mr Jacob Hegedus, Office of the Deputy Vice Chancellor (Indigenous Strategy and Services), University of Sydney and Emeritus Professor David Shearman, University of Adelaide.

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About the authors

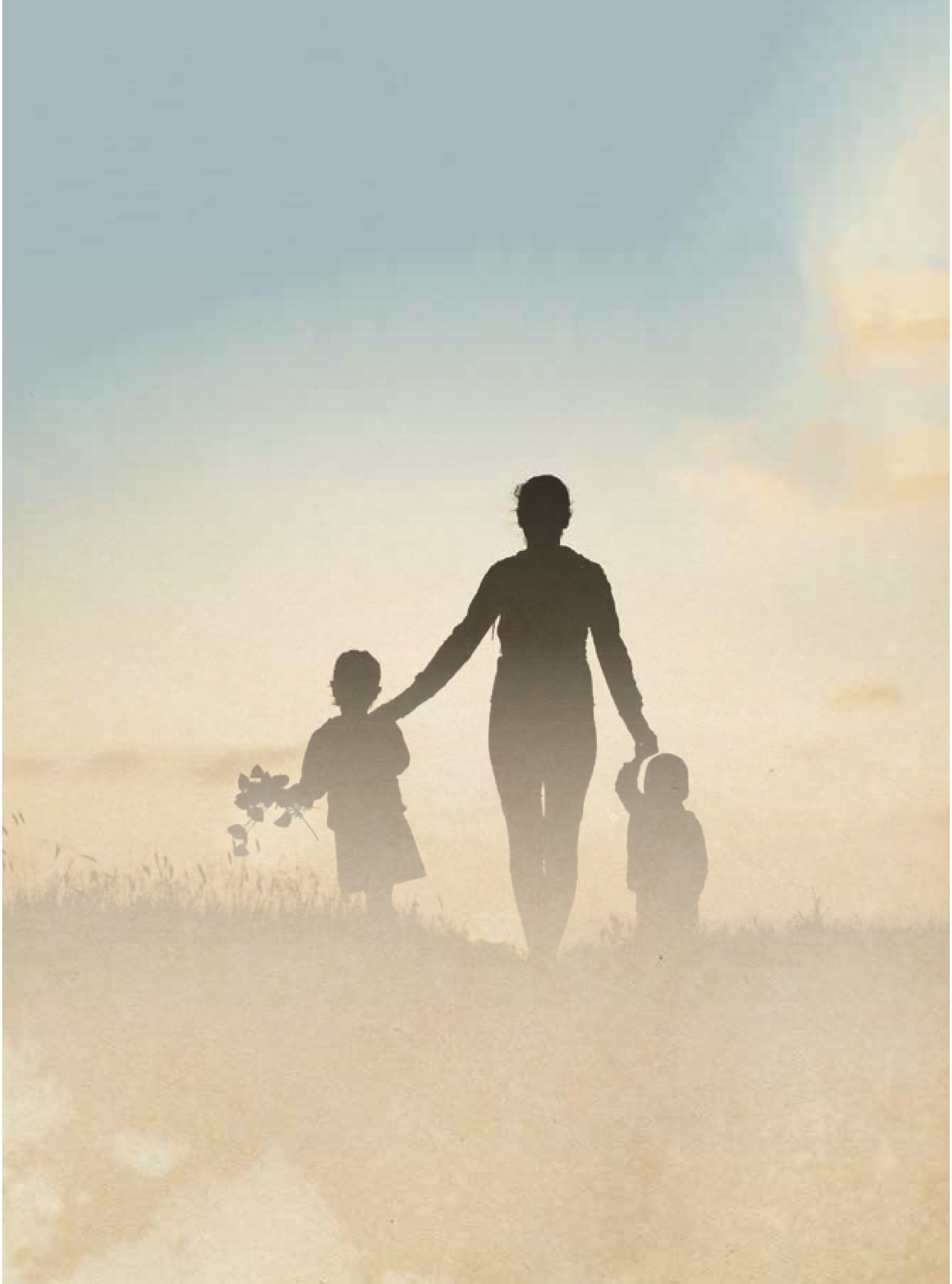
Melissa Haswell MSc PhD is Professor of Practice (Environmental Wellbeing) in the Deputy Vice Chancellor (Indigenous Strategy and Services) Portfolio and Honorary Professor in the School of Geosciences at the University of Sydney. She is also Professor and former Discipline Lead of Health, Safety and Environment in the School of Public Health at Queensland University of Technology. Melissa obtained her PhD in the Department of Pure and Applied Biology at Imperial College, University of London. She previously held academic positions at Queensland Institute of Medical Research, The University of Queensland and the University of New South Wales. She was the first appointed environmental epidemiologist at the National Research Centre for Environmental Toxicology (enTOX), a collaboration between three Brisbane universities.

Melissa has published in the fields of epidemiology, pathogenesis and control of infectious diseases, immunology, carcinogenesis, heavy metals, empowerment, mental health and social and emotional wellbeing. She teaches extensively in Indigenous health and community development, climate change, pollution and sustainability. She has applied her multidisciplinary and wholistic health and wellbeing knowledge to communicate extremely pressing planetary health issues in media articles and government assessments and parliamentary inquiries the Northern Territory, South Australia, Western Australia and NSW. Melissa strongly feels that decisions on the expansion of fossil fuel mining and extraction in Australia must be made with clear understanding of the full available evidence regarding direct and indirect impacts on human social, emotional, physical and spiritual health, as well as the stability of the climate and environmental assets upon which we all depend.

Jacob Hegedus is a proud Gumbaynggirr man from Grafton, Northern New South Wales. Jacob recently completed a Bachelor of Property Economics at the Queensland University of Technology, whilst working as a Research Assistant, studying Indigenous collaboration and integration within governance and decision making models in business. After starting his professional career in funds management at the Queensland Investment Corporation, Jacob returned to academia, starting a Master of Business Administration (Finance) at the Australian Institute of Business and commencing a role as a Research Assistant at the University of Sydney. Jacob has a strong passion for social justice and fair economic opportunity, and continues to embody these commitments every day, in all aspects of his work and study.

Professor David Shearman AM MB, ChB, PhD, FRACP, FRCPE was Professor of Medicine at The University of Adelaide from 1975–1997, and Emeritus Professor thereafter. He previously held senior positions at Edinburgh and Yale Universities. He is both medical doctor and scientist. He is the author of many books relating to climate change, its science, consequences, and democratic international and economic implications. His most cited work is *The Climate Change Challenge and the Failure of Democracy* co-authored with Joseph Wayne Smith and written for the Pell Center for International Relations and Public Policy at Salve Regina University in Rhode Island.

Emeritus Professor Shearman served on the International Panel on Climate Change for two terms on the health and scientific sections. He has been President of the Conservation Council of South Australia and, with the late Professor Tony McMichael, he founded Doctors for the Environment Australia in 2001 and was the Honorary Secretary from 2001 to 2018. He is author and co-author of several hundred scientific and medical papers, and he writes frequently for the media. He was appointed a Member of the Order of Australia (AM) in 2015 for service to medicine and to climate change.



Executive summary

The purpose of this report is to provide the Australian community and decision makers with a synthesis of the now extensive evidence demonstrating multiple direct and indirect health and wellbeing risks from oil and gas developments. It responds to a request from deeply concerned paediatricians about proposed shale gas development of the Beetaloo Basin and processing facilities at the proposed Middle Arm Precinct in Darwin Harbour.

The report identifies and discusses an extensive body of recent, peer-reviewed scientific and public health literature on five areas of extreme concern, namely:

- 1: the procedural risks posed by oil and gas operations to biodiversity, water and food security,
- 2: contributions to the climate emergency,
- 3: the vast array of potentially harmful chemicals involved,
- 4: contamination pathways into water and air and
- 5: resulting physical, social, emotional, spiritual health losses associated with extensive disruption of life near oil and gas fields and its sprawling infrastructure.

Threats to climate: Extensive research shows that oil, gas and LNG production and burning contribute substantially to extremely steep rises in atmospheric CO_2 and methane gas (86 times more potent over 20 years) and, consequently, to global heating. Queensland's coal seam gas industry has already driven a 14.1% and 27.4% rise in national fugitive and stationary emissions excluding electricity respectively, over 2005 levels. Besides comparing extremely poorly with wind and solar, substantial research and new life cycle analysis has dismissed the supposed climate advantage of gas over coal. This analysis indicated that leakage of methane more than 1% of production levels *eliminates climate benefits* over coal. Thus, the 49 new oil and gas projects planned for Australia directly conflict with our commitment to the Global Methane Pledge to reduce emissions by 30% by 2030 and other climate commitments.

Threats to water: Besides climate damage, the industry uses vast quantities of fresh water, often much greater than anticipated, posing water security threats to arid areas. Furthermore, each step of the gas production creates multiple opportunities for chemical contamination of surface and ground water. There is extensive documentation of contamination via spilling, leaking, flooding, overflows and deliberate environmental application through so-called 'beneficial uses', especially in handling the vast quantities of toxic wastewater. This wastewater contains hundreds of naturally occurring and added drilling and hydraulic fracturing chemicals. These can include heavy metals, phenols, barium, volatile organic compounds including benzene, toluene, ethylene and xylene, radioactive materials, fluoride, polyaromatic hydrocarbons, salt and many chemicals of unknown toxicity.

Threats to air quality: The review found that a vast array of chemicals are released into the air during all steps of the process, including volatile organic compounds, polyaromatic hydrocarbons, nitrogen oxides, radioactive materials, diesel fumes, hydrogen sulfide, acrolein and heavy metals. A cocktail of additional chemicals form in the atmosphere, including formaldehyde, particulate matter from aerosols and ground level ozone, which travel long distances damaging health and agriculture.

Chemical threats: Extensive research has shown that these chemicals can cause cancer, tissue damage, reproductive harms, impairment of normal human growth and development, birth defects, respiratory and cardiovascular disease and deaths. Furthermore, a poorly understood group of chemicals, endocrine disrupting chemicals, act at extremely low concentrations to interfere with the body's communication system of hormones that regulate growth, behaviour, metabolism and reproductive function.

Health and wellbeing consequences: A substantial quantity of increasingly rigorous research evidence has accumulated from studies across oil and gas basins, especially in the United States. Each gas basin is different in its geography, hydrogeology (underground rock and water systems), chemistry (different mixtures of added and naturally occurring chemicals), weather and air flow characteristics, legislative regimes and regulatory compliance, and social and cultural diversities. Despite these variations, there is a consistency across locations in finding a greater burden of health loss among those most exposed to oil and gas operations and infrastructure.

Reported health risks include increased severity of asthma in children demonstrated by elevated incidences of exacerbations requiring medical treatment, crises requiring emergency department visits and hospitalisations. Research shows higher hospitalisation and death rates due to heart attacks, heart failure, respiratory diseases and some cancers associated with oil and gas operations and/or predicted from air pollution exposure in many studies across whole populations. Higher injury and fatality rates from increased large truck traffic volumes, higher incidences of depression, anxiety, social withdrawal among young females and higher prevalences of sexually transmitted infections have been linked to the impacts of oil and gas operations on home and community life. Furthermore, multiple studies have detected interference with normal development of unborn babies. This includes higher risk of low birth weight, pre-term delivery and spontaneous abortion, severe birth defects and risk of acute lymphoblastic leukemia.

Many studies have demonstrated that these outcomes occurred after, not before, gas development commenced, while others have shown that these outcomes specifically occur downwind and/or downstream (groundwater flow) of gas operations. Most studies have controlled for a wide range of potential confounders (other explanations for the observed differences).

The report also highlights the cultural and spiritual harms reported by Aboriginal Australians in the alleged poor adherence to the right to free, prior and informed consent to these operations on their Traditional Lands. Finally, the report issues a loud warning about the risks of sexual violence that have been suffered by First Nations Americans and Canadians associated with oil and gas activities interfering with their remote communities. These risks have been completely ignored in all government assessments of potential consequences borne by Australian people.

Conclusion: This wide-ranging review including recent academic and research insights has only strengthened long-standing concerns regarding the multiple, complex risks of serious harm to human health and wellbeing associated with oil and gas development. New studies are emerging regularly, with deepening fears that reproductive consequences and increased cancer rates may be revealed in the future, with longer duration of human exposure to these multiple and unchecked potential harms. In addition to direct health risks, human health and wellbeing is threatened by the risks of contamination of air and water with a wide array of harmful chemicals, the excessive use of limited freshwater resources and substantial contributions to climate change should the proposed new developments progress. Human safety and security is also at risk.

Unfortunately, Australians are very ill informed about the research and evidence presented in this report, and only sparse health research has assessed impacts in Western Queensland where many farmers and residents struggle to cope with approximately 15,000 coal seam gas wells.

The Report concludes with an urgent plea to all Australian governments to recognise the full extent of risk that this industry brings to our nation at a time when the dangers of climate change demand rapid reduction, not expansion, of fossil fuels to preserve our future.

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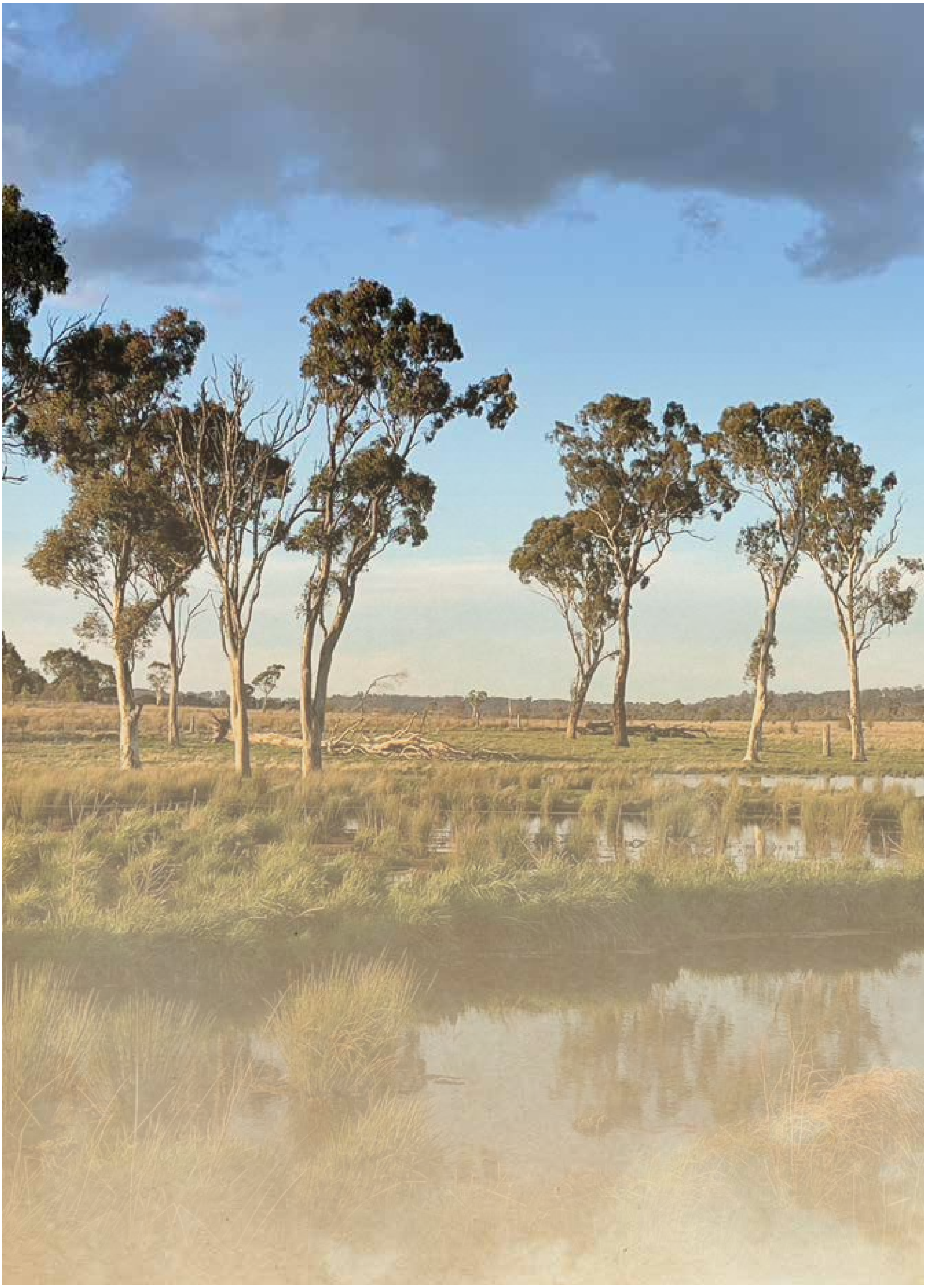

1. Overview and purpose of the report

Good health requires not merely the absence of disease, but also clean air, a safe and sufficient supply of clean water and nutritious food, a safe and stable climate and a strong and supportive social, cultural and spiritual environment. These are the foundational pillars of human health.

Human activities, particularly since the Industrial Revolution, have both enhanced and diminished our continuing access to these fundamental requirements. Major global efforts mobilised by the United Nations Millennium Development Goals brought about improvements in human health and wellbeing. However, we now recognise that achieving these economic development goals by individual nations came largely at the expense of the environment. Global efforts now being guided by the Sustainable Development Goals aim to work in harmony with national commitments to the 2015 Paris Agreement on Climate Change to achieve "Dignity, prosperity and peace on a healthy planet" by 2030.

Much of the responsibility for realising the vision of the Paris Agreement, to achieve "Dignity, prosperity and peace on a healthy planet" by 2030 lies at the feet of individual nations, who face difficult decisions to ensure a sustainable future for current and coming generations. According to the Intergovernmental Panel on Climate Change (IPCC, 2023), a major determinant of future health and prosperity is how quickly the world can move away from fossil fuels – coal, gas and oil – and embrace the remarkable economic, environmental and health opportunities offered by renewable energies.

As the late Professor Will Steffen, groundbreaking climate and planetary scientist and communicator, legacy Climate Councillor and Executive Director of the Australian National University Climate Change Institute, and author and reviewer of five Intergovernmental Panel on Climate Change Reports spanning eighteen years reminded us, "Failure is not an option: After a lost decade on climate action, the 2020s offer one last chance" (Steffen, 2021; Climate Council, 2023).

Australia is one of the world's wealthiest nations with one of the largest *per capita* global footprints and greenhouse gas emissions. Australia is also already among the world's top exporters of both coal and liquified methane gas (LNG) derived from coal seams and offshore drilling. Remarkably, Australia is rapidly moving to implement extensive plans for commencement of ***a new export industry*** using shale gas extraction, with developments in the Beetaloo Basin in the Northern Territory only the first in a series of major new gas initiatives aimed at increasing export volumes.

These expansion plans run counter to pleas from the United Nations Secretary General to cease new developments. They put Australia's commitment to net zero greenhouse gas emissions by 2050 in jeopardy and risk failure in meeting our National Determined Contribution obligations under the Paris Agreement. Moreover, expanding exports of methane to other countries, which are expected to account for the emissions resulting from this Australian product, appears to contravene the spirit of many articles of the Paris Agreement. Instead, developed countries like Australia are expected to take the lead by undertaking absolute economy-wide reduction targets [not only offsets] (Article 4); keep our fossil fuels and their potential greenhouse gases securely in the ground (Article 5) and support the efforts of developing countries to build clean, climate-resilient futures (Articles 9, 10 and 11).

The Paris Agreement also invites all citizens (non-Party stakeholders) to address and respond to climate change and "recognises the need to strengthen the knowledge, technologies and practices and efforts of local communities and Indigenous Peoples".

Our report ***"The risks of oil and gas development for human health and wellbeing: A synthesis of evidence and implications for Australia"*** is a response to that invitation. It was initiated at the request of paediatricians practicing in the Northern Territory, where national and territory governments accelerated approvals to introduce, for the first time, an export industry for unconventional gas extraction from shale deposits.

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Extensive research has indicated that gas developments, in addition to contributing to climate change, can threaten water supplies with overextraction and contamination and cause multiple health outcomes in local and regional populations. By mid-2022, more than 2000 peer-reviewed papers, reflecting rapidly expanding research efforts in the United States, have examined health-related concerns (Physicians, Scientists and Engineers for Healthy Energy, 2023). These include papers on toxic chemicals added and brought to the surface, air and water contamination, direct health and developmental impacts, climate change, community change, seismicity, infrastructure and regulation.

Because of the complexities of unconventional gas mining, and the multiple chemical, physical and social stressors involved, a full assessment of potential public health hazards must encompass all steps of the process, from community awareness of and reactions to development proposals and implementation, 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 for water, food and climate security stimulated a wide and vigorous response around Australia between 2012 and 2019 when proposals were raised to start or expand coal seam gas extraction in NSW, including near urban areas such as Camden, Western Sydney, Sydney Park (Saint Peters), and Sydney Water Catchment Area (Helensburgh), as well as rural locations including the Northern Rivers, the Pilliga Forest (Narrabri) and New England. South Australians also rejected shale gas fracking in Mt Gambier and Kalangadoo. With stiff community opposition, many of these plans, with the exception of the Western Queensland and the Pilliga Forest, were discontinued. Many may have thought that the struggle to stop further expansion of gas extraction across Australia was over.

Despite major sprawling development across Western Queensland, the Australian literature on health impacts of coal seam gas remains limited. In the United States, a wide array of major research teams from numerous universities have received substantial funding independent of the gas industry to grow the now considerable evidence base of concerns. In contrast, Australian research is solely focused on coal seam (not shale gas) operations and most is provided through the Gas Industry Social and Environment Research Alliance with the Commonwealth Science and Industry Research Organisation (CSIRO, 2023). According to their website, this has culminated in a health study design framework and a 69 page final synthesis report focusing on chemicals, lights, noise and dust (Keywood et al., 2018; Huddlestone-Holmes and Dunne, 2023). The latter identified 25 chemicals used in coal seam gas extraction which warrant further investigation and other studies are in progress.

This report builds on our previous work (Haswell and Shearman, 2019) to provide a comprehensive source of information to assist people, especially those working to inform decision-makers about how individuals, communities and their environmental assets may be impacted by unconventional oil and gas developments. It aims to help Australians to be aware of and gain access to the large body of evidence of the multiple direct and indirect physical human health impacts of the mature and diverse shale gas industry in the United States, where it co-exists with a solid public health and environmental research community.

This new report is issued in response to a health emergency, not only about climate change, but also about the overall impacts of an industry that state, territory and federal governments in Australia are again fast-tracking with approvals and direct funding. State-wide pushes to expand unconventional gas production in Queensland, New South Wales, West Australia and the Northern Territory are undeterred by knowledge about widespread harmful impacts experienced in the United States.

This report also urges leaders to pay attention to the extensive foundation of evidence, including new evidence since earlier inquiries, which documents the actual experiences of climate, environmental, social and physical health losses due to the now enormous gas industry in the United States. As new published information on health losses emerges regularly, the full extent of these harms is still unknown.

Every day in the United States, an estimated two billion tons of fracking chemicals and water are forced under high pressure into shale deposits, over an enormous land footprint. Water containing both introduced and naturally occurring chemicals is then brought to the surface for treatment, dispersion into the environment for 'beneficial' purposes or reinjection into the ground. In that country, an estimated 17.6 million people live within a mile of an oil or gas well that has been hydraulically fractured – a number that would have been unthinkable just 20 years ago as the developments got underway. The resulting cost of air pollution impacts alone to the American community was an estimated US$77 billion in health care costs in 2016, including 410,000 additional episodes of asthma treatment for children, and 7500 deaths (Buonocore et al., 2023). Very few Australians are aware of this data – and even fewer understand what it could mean for our health and wellbeing should the industry progress.

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In summary, this Report is based on extensive review and synthesis of the literature on and actual experience of the impacts of the shale gas industry in other countries, especially the United States. The large body of research reviewed reflects studies across multiple states in the US, with greatly varying policies, regulations, population distributions and chemical makeup of both naturally occurring and deliberately introduced chemicals. While specific variations in exposures and impacts no doubt occur across these settings, there is substantial consistency in detecting evidence that harms can and do affect people, their communities and their water, air and climate.

We urge readers to recognise that we can only truly understand the wide array of potential impacts of such a complex and sprawling industry by learning from careful research-based assessments using quantitative and qualitative inquiry with communities at risk. While some circumstances will be very different between Australia and the US, and within different sites in Australia, this is clearly an industry that brings many complex chemical, psychosocial, environmental, cultural and climate stressors. Rigorous Health Impact Assessment informed by extensive science, lived experience and the voices of people who would be directly and/or indirectly affected, helps us to understand that ***all*** of these stressors impact synergistically to threaten health. This is a much more powerful way to predict health losses people may experience. Only with this information can we make wise decisions about what kinds of industries we need to invite and grow in our country to help us meet future challenges.

We urge leaders and decision makers to take notice of the evidence and fully comprehend the risks and documented harms involved at a time of unprecedented environmental instability. We urge full attention, resources and human capacity to be directed towards the safest and healthiest future – the science makes it clear that this can only be secured by winding down fossil fuel developments and responsibly embracing new clean energy opportunities.

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2. Background information on the processes and risks in unconventional oil and gas extraction

This section provides a brief overview of the multiple steps involved in unconventional oil and gas exploration, extraction, transportation and processing, and highlights risks and problems that can and have arisen. This section focuses largely on the processes of shale oil and gas production, with less reference to coal seam gas production. This is because, in contrast to coal seam gas, Australia has had very little experience in shale gas extraction as a major export industry and many in the community are largely unaware of the differences. Furthermore there is a wealth of peer-reviewed published information from many research teams examining the risks and consequences experienced in diverse circumstances and regulatory regimes across the United States. The information is important for Australia to learn from in its own decision-making about the industry. Attention in this section is on land and water use change and potential risks to water and food security and biodiversity; while further sections examine contributions to climate change (Section 3), loss of air and water quality (Section 4) and risks to physical, psychosocial, First Nations' justice and women's and children's safety (Section 5).

This section first describes broad differences between conventional and unconventional methods for gas and oil extraction. We then briefly describe the major steps involved and identify some of the known risks and hazards that accompany each step. We draw attention to the very large quantities of water used in the hydraulic fracturing process and cite an important paper which revealed alarming, unexpected upward trends in water usage per well and wastewater production, particularly in arid areas of the United States. Associated water, food and biodiversity security concerns have yet to be fully investigated but are clearly of extreme relevance in the context of the already stressed water supply in parts of Australia with a prominent agricultural industry and an extreme biodiversity crisis.

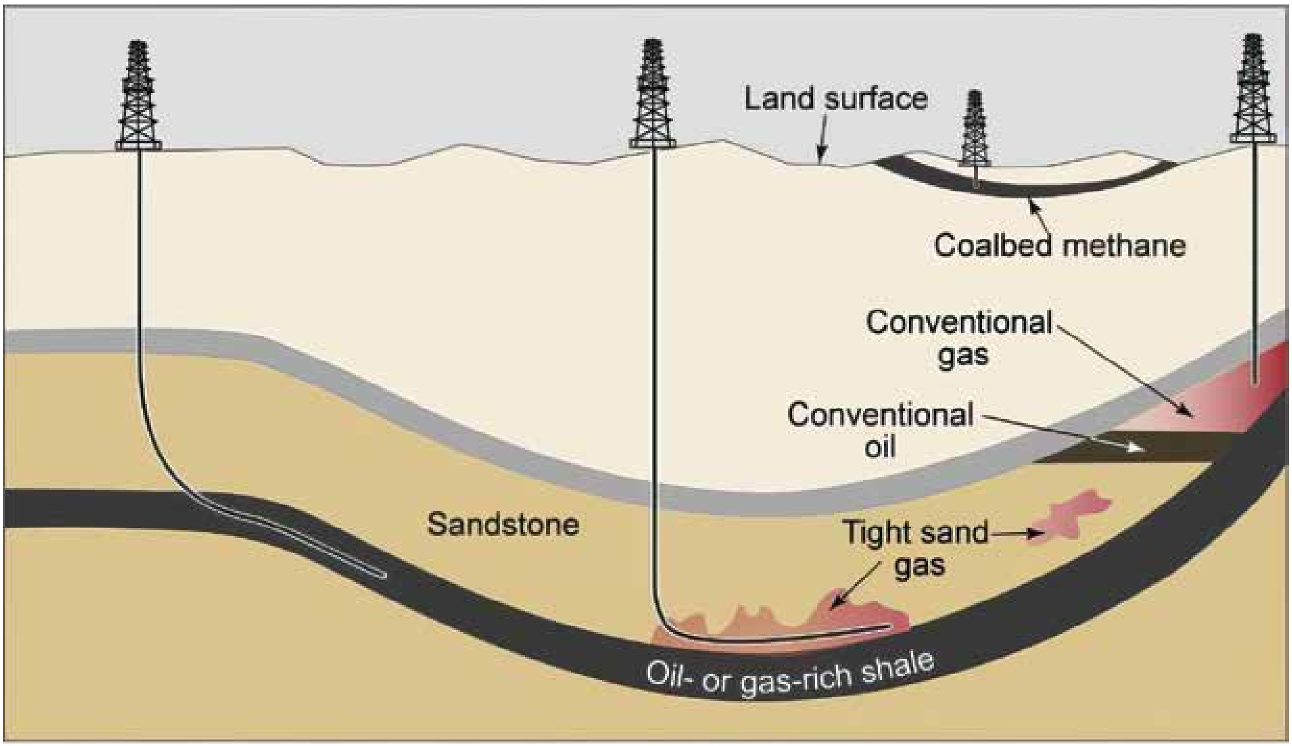
What is unconventional gas and oil and how is it different from conventional?

Easily accessible, concentrated land-based 'conventional' deposits of methane gas (also referred to as 'natural' gas, 'fossil' gas or coalbed methane) have met domestic needs in Australia for decades at costs well below the international market price. However, these conventional reserves are increasingly depleted, not only in Australia, but also globally. Hence, 'unconventional' techniques that harvest gas that is distributed underground over widespread areas at commercially viable cost have been developed and have proliferated across the United States, in Queensland and in other parts of the world.

Unconventional oil and gas operations refer to the site preparation, drilling, extraction, transportation and processing of methane gas that is held tightly in shallow deposits of coal (coal seam gas or coalbed methane), sandstone and limestone (tight gas) and deep shale deposits (shale gas). For export purposes, Australian gas is turned into a liquid (liquefied natural gas [LNG]) and shipped to trading partners. The extraction of coal seam, tight and shale gas often requires invasive techniques, such as removal of fluid from the coal seam (dewatering) and horizontal or deviated drilling and hydraulic fracturing (Figure 2.1). All unconventional oil and gas extraction requires an extensive large scale industrial footprint.

Because unconventional gas is widely dispersed, the continuous drilling and hydraulic fracturing of hundreds to thousands of wells spread across entire regions are required to maintain supply and ongoing

Figure 2.1: Conventional and unconventional oil and gas reservoirs



Sources: U.S. Energy Information Administration and U.S. Geological Survey (U.S. Government Accountability Office from Washington, DC, United States, Public domain, via Wikimedia Commons)
https://commons.wikimedia.org/wiki/File:Figure_1-_Conventional_and_Unconventional_Oil_and_Gas_Reservoirs_(8080671862).jpg

Figure 2.2: Tower for drilling horizontally into the Marcellus Shale Formation for natural gas in Lycoming County, Pennsylvania, USA

Source: Ruhrfisch, CC BY-SA 3.0, via Wikimedia Commons 2009
https://commons.wikimedia.org/wiki/File:Marcellus_Shale_Gas_Drilling_Tower_1_crop.jpg

commercial viability. The need for multiple wells across large areas, plus horizontal drilling and hydraulic fracturing to release the gas, are activities that distinguish unconventional from conventional oil and gas production.

To date (2023), unconventional extraction in Australia has been largely limited to the rapidly expanding coal seam gas operations in Western Queensland and in some parts of New South Wales. The vast majority of coal seam gas produced is exported. So far minor quantities of shale gas for the domestic market only have been produced through hydraulic fracturing of shale, but that is the only experience that Australia has had with this industry thus far. However, multiple proposals for shale gas developments are now being considered in many parts of Australia, with the Beetaloo Basin in the Northern Territory recently prioritised for acceleration, along with further expansions of coal seam gas production.

Oil may also be produced from shale in a similar way to gas. Where profitable oil deposits are available, oil and gas production in the US often overlap through the same wells. The progression from unconventional gas to unconventional oil – and from conventional to unconventional oil – raises a new set of environmental concerns. As Deborah Gordon (2012) of the Carnegie Endowment for International Peace warned:

> *Many new breeds of petroleum fuels are nothing like conventional oil. Unconventional oils tend to be heavy, complex, carbon laden, and locked up deep in the earth, tightly trapped between or bound to sand, tar, and rock. Unconventional oils are nature's own carbon-capture and storage device, so when they are tapped, we risk breaking open this natural carbon-fixing system. Generally speaking: the heavier the oil, the larger the expected carbon footprint.*

These issues are also relevant to predicting fugitive methane emissions from shale gas basins, because the proportion of methane lost during the production of 'dry' gas (i.e., with almost no oil contaminants), such as the coal seam gas in the Queensland Surat Basin, tends to be lower than in basins that produce 'wet' gas containing higher levels of oil contaminants (Neininger et al., 2021; see Section 3).

The components of unconventional gas production processes and their potential negative environmental impacts are briefly described below. The information was accessed from the US Department of Labor Occupational Safety and Health Administration (OSHA) (2018). Occupational health and safety hazards and examples of incidents that have occurred in the United States are also described on the OSHA website.

Application and approval processes

Prior to any action, there is a long and, for communities, often stressful process while the government considers the development. Steps in this process include submission of proposals, review of the proposals by various state and territory agencies, granting of exploration licences, seismic testing, and exploratory drilling. Applications to proceed with full production are then submitted with voluminous Environmental Impact Statements, and assessment and final determinations are made. Sections 5.2 and 5.3 describe some of the psychosocial impacts of these preparatory steps, which can induce feelings of conflict, distress, anger, worry and fear in affected communities and Aboriginal people.

Transportation

Each stage of development brings major increases in large-truck traffic for the transport of personnel, drilling rigs and components, heavy equipment, on site vehicles, chemicals and wastewater. In addition to potential injuries and deaths among oil and gas truck drivers, the increased truck movements affect drivers from other industries, such as cattle, and pedestrians and drivers in nearby communities (described in Sections 5.1, 5.2 and 5.4).

Seismic testing, site preparation and well pad construction

The first steps in new gas exploration and production include seismic testing, the construction of roads and access tracks to the well drilling and other operational sites; the cleaning, leveling and construction of the well pad; and the digging of pits and trenches for disposing of water, drilling fluids, muds and other discharge. Seismic testing is performed to identify the optimal place to site the future wells as well as the size of the target gas or oil reservoir. These activities, including seismic testing alone, can require substantial land clearing and community disturbance with potentially major problems for farmers and habitat and ecosystem integrity. As exploratory drilling in Australia requires fewer approvals than drilling for oil and gas production, it can lead to problems with legacy and abandoned wells that may not be well documented or monitored (McCarron and Dougall, 2021). Proceeding to the next steps also requires the installation of high tensile power, telemetry and telecommunications infrastructure. All of these activities are noisy, dusty and may cause biosecurity risks for the ecosystems or agricultural industry upon which these activities and sites are often located.

As substantial numbers of fly in–fly out (FIFO) workers are required to undertake the construction, drilling and production activities, temporary accommodation quarters, often called 'man camps', are built nearby (Section 5.3; 5.4).

Drilling

Well pads can house one or more wells. A drilling rig is placed into upright position and the drill parts assembled on site. Large drills, lubricated by special 'muds', penetrate the ground. Muds are composed of lubricant and protective agents mixed with other chemical additives. Muds with contaminants also return to the surface during drilling. Muds are reused but may be buried in onsite surface pits when no longer useable.

Multiple casings (steel pipes) are placed down into the drilled hole to line the well and contain the fluids and gas that will be placed into and drawn up from the drill hole. For shale gas, and increasingly for coal seam gas in Western Queensland, the drilling proceeds downwards to the shale, then turns horizontally (horizontal drilling) or deviates (slants) from the straight down vertical path (deviated drilling), producing tunnels along the shale or coal layer for over 3 km (Hossain and Al-Majed, 2015).

Drilling may provide a short and long-term pathway for potentially harmful chemicals, including salt, to migrate upwards and to reach local aquifers that have been drilled through (Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development, 2014). Handling and disposal of waste muds, drill cuttings and chemical additives can pose risks to groundwater and adjacent land and to the atmosphere through evaporation from waste ponds.

Old and aging wells for both conventional and unconventional gas and oil mining are susceptible to wear-out failures caused by rusting, electrolytic corrosion and dissolution of metals and concrete by acids. Breaching of well integrity can result in long-term low-level fugitive methane emissions, groundwater contamination and surface seepage and spills of toxic chemicals.

Analysis of 1144 violation notices issued from 3533 wells in Pennsylvania found 85 instances of cement and casing failures and six cases of blowouts and gas venting between 2008 and 2011 (Considine et al., 2013). Other violations, comprising nearly 90% of notices issued, included major and minor land spills, surface water contamination and site restoration.

A further review of well barrier and integrity failures of unconventional and conventional oil and gas wells estimated that about four million onshore wells had been drilled globally as of 2014 (Davies et al., 2014). The authors estimated that approximately 6.3% of shale gas wells drilled in Pennsylvania had well integrity issues, most of them were cement or casing failures. Globally, the authors found a widespread lack of well monitoring and of clearly defined responsibility for 'orphaned' wells, where the company that originally drilled the well no longer exists or transfers assets to another company. They concluded that concerns regarding well integrity and barrier maintenance for conventional gas wells apply equally to unconventional gas wells, hence suggesting that these issues are an important cause of methane leakage from wells.

Kiren et al. (2017) reviewed the literature investigating the wide array of chemical, mechanical and operational causes of well integrity failure worldwide. These authors similarly found the leading causes to be cement degradation, casing corrosion, pressure and temperature stress, and insufficient plugging and abandonment operations once a well has been decommissioned.

Drilling may provide a short and long-term pathway for potentially harmful chemicals, including salt, to migrate upwards and to reach local aquifers that have been drilled through…Handling and disposal of waste muds, drill cuttings and chemical additives can pose risks to groundwater and adjacent land and to the atmosphere through evaporation from waste ponds.

Hydraulic fracturing (fracking)

Once a well has been drilled, a process called "well completion" follows. This involves placing and cementing a final production well casing into the well and then punching holes through the casing to allow for fluids and chemicals to be discharged into the shale or coal seam and for wastewater to be collected. Gas also flows up to the surface into the pipe, or through smaller tubes inserted into the pipe to speed the flow of gas to the surface.

The first step in coal seam gas production is the removal of water (dewatering) that has been in contact with the coal for millennia. This so-called "produced water" is highly saline and contains many naturally occurring chemicals, many of which are toxic to humans (see Section 4). The removal of water and gas can cause subsidence on the surface of the land, which causes significant difficulty for agricultural activity (Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development, 2014c).

Extracting oil and gas from shale and often from coal seam deposits requires hydraulic fracturing for the gas to flow sufficiently. Each well may undergo multiple applications of hydraulic fracturing. This procedure involves detonating small explosives placed along the well casing and then injecting high volumes of pressurised hydraulic fracturing fluid. The fluid contains silica sand, which keeps cracks made in the shale or coal open for gas to

Figure 2.3: Natural gas flaring

Source: Photo by Tod baker, (CC BY-SA 2.0) Retrieved from https://www.flickr.com/photos/todbaker/9148692 flow, along with many chemicals, including lubricants, biocides (to kill bacteria), gelling agents, and anticorrosive agents as described in Section 4.

Hydraulic fracturing:

- uses very large amounts of local water, reducing availability for local farmers and communities (Jiang et al., 2014);
- requires drilling at multiple sites to achieve full access to the gas-bearing strata – resulting in hundreds of wells over large land areas and compounding the risks associated with each well;
- carries the risk of seismic activity from the forceful injection and/or lubricating effect of hydraulic fracturing into geological fault lines, as has been observed in some locations (Bau and Eaton, 2016; Eaton and Schultz, 2018).

The chemicals used in hydraulic fracturing in the US and in Australia are described in Section 4. Water and food security concerns that arise from the use of large volumes of water for these processes and their application for agricultural purposes are discussed below.

Wastewater production and management

Oil and gas wells produce varying amounts of unwanted water from the strata containing the fossil fuels or from fracking itself. This water may contain chemicals, including naturally occurring radioactive materials, arsenic, mercury and volatile organic compounds – many of which are harmful to human and animal life – as well as chemicals added during drilling and extraction (see Section 4).

Recycling of wastewater, i.e. using it repeatedly in hydraulic fracturing operations, is favoured in some jurisdictions, especially where water is scarce. However, the reuse of flowback water after fracking for additional fracking results in increasingly high concentrations of hazardous chemicals in the fluids being handled, elevating risks for workers and in accidents, spills and ultimate disposal. According to Webb et al. (2014), recycling of wastewater is not common because of these increased hazards. Parker et al. (2014) also analysed multiple challenges encountered in treating and managing fracking water, which are also very expensive.

One method of wastewater disposal, namely injection back into the ground, can induce seismic activity in some locations. For example, a 900-fold increase in seismic activity was recorded in Oklahoma following the commencement of wastewater reinjection (Ellsworth, 2015; Keranen et al., 2014). Weingarten et al. (2015) confirmed that wastewater injection from oil and gas operations were the sole cause of the unprecedented increase in earthquakes, from 1–7 (1970s) to 75 to 190 (2011 to 2013) to over 650 in 2014, experienced across the central United States between 2009 and 2014. These can be reduced by reinjecting lower volumes.

Another method used is centralised wastewater treatment where wastewater is collected and transported from the well to a specific treatment facility. Those used for shale oil and gas extraction involve several steps, including separation and air and gas flotation to remove gels, dissolved gases, oil, sand, polymers and suspended solids; precipitation of metals; activated carbon filtration with aerobic degradation to remove organic compounds; and reverse osmosis to remove salts (Butkovskyi et al., 2018; Easton, 2013; Jiang et al., 2014). In Australia, coal seam gas wastewater is treated first by reverse osmosis in order to remove the large quantities of salt and other contaminants (Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development, 2014a), but organic compounds and heavy metals may remain in the treated water. This water is then used for various 'beneficial uses'.

Other methods of dealing with wastewater include evaporation from large holding ponds, spraying onto roads or nearby paddocks, and discharging into rivers, all of which disperse residual chemicals into the local environment (Jiang et al., 2014). Section 4 also discusses the environmental and health risks arising from so-called 'beneficial uses' of untreated wastewater, such as for dust suppression, road construction and de-icing of roads in the winter. The use of wastewater for agricultural purposes, such as watering cattle, also raises concerns, with some examples described below. Some of the emerging concerns, for example regarding heavy metals and endocrine disrupting chemicals as described in Section 4, are not yet fully understood (Davies et al., 2015). Thus, proposed 'adaptive management' techniques should be viewed with scepticism and accepted only after extensive consideration of the potential complications and risks they may pose.

However, despite or perhaps partly because of the many options being used, the actual safety and sufficiency of wastewater management as practiced remains unclear. Furthermore, there is no long-term solution for the disposal of salt waste in inland areas, which when not managed well may threaten the ecological health and productivity of rivers, soil and vegetation (Davies et al., 2015). In Queensland there are very large volumes of extremely concentrated salt brine that is currently stored in large holding ponds waiting for an effective strategy for safe disposal. Among possibilities being considered is a commercial salt industry or dumping into the ocean (Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development, 2014a).

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Oil and gas processing

Crude oil and gas flowing from wells may contain toxic and equipment-damaging chemicals, such as acids, heavy metals (mercury and arsenic) and volatile organic compounds (such as benzene). These contaminants can be removed through a number of chemical and physical processes, for example by incineration (flaring), biofiltration and adsorption through acid gas treatment. These processes represent a significant expense to the industry, especially as they require constant application to multiple wells and gas infrastructure in order to be effective.

Flaring, venting and fugitive emissions

Flaring is a deliberate process used to burn excess methane in a controlled way, breaking it down from a highly explosive and potent greenhouse gas (see Section 3) into a much less potent greenhouse gas, namely CO_2, before release into the atmosphere. It is performed in order to relieve pressure and prevent explosions in gas and oil wells, pipelines and during gas processing and maintenance, sometimes lasting for several days or weeks.

Flaring that does not achieve complete combustion of methane or when the gas also contains contaminants, the process not only emits carbon dioxide, but can also release volatile organic compounds, polycyclic aromatic hydrocarbons, black carbon, heavy metals, carbon monoxide, nitric oxide, nitrogen dioxide and sulfur dioxide. Excess methane and other volatile organic compounds are also deliberately released directly into the atmosphere through a process called venting. This is performed multiple times during the completion and production phase. These can have negative health and environmental and health consequences, contribute to climate change, acid rain and respiratory illnesses.

Methane is also released through leakage at every step and is called 'fugitive emissions'. During extraction, processing and distribution of oil or gas, accidents, normal wear and tear and improperly constructed infrastructure all permit direct loss of methane gas into the atmosphere. This includes from gas and oil wells, machinery, storage tanks, compressors and dehydrators on the well pad, during processing, from pipelines and at transmission compressor stations, during underground storage if necessary, during transfer at its destination and with the end users within households, commercial properties and industrial plants (Lafleur et al., 2016; Weller et al., 2020; Department of Climate Change, Energy, the Environment and Water, 2023).

Until recently, there have been few research-based estimates of fugitive emissions occurring from municipal pipelines delivering gas to end users. Using data from an advanced mobile methane leak detection system, Weller et al. (2020; 2021) estimated that there are over 659,000 pipeline leaks in the United States local gas distribution systems. These leaks released an estimated 0.69 (95% CI 0.25-1.23) million tonnes of methane into the atmosphere each year, which is approximately 5 times greater than reported by the US Environmental Protection Agency's greenhouse gas inventory. To our knowledge, similar research-based estimates are not available for Australia's major LNG importers, China, Japan and South Korea.

Finally, as we describe in Section 3, major and minor accidents, such as the Alysso Canyon disaster, have occurred in storage locations which have released enormous quantities of methane directly into the atmosphere. Other gases present with the methane caused a significant health emergency for people living nearby.

Other processes

There are other processes associated with unconventional oil and gas operations that also pose potential health and environmental risks. These include the extensive mining of silica sand and manufacture of hazardous chemicals used in vast quantities in hydraulic fracturing, the management of very large quantities of salt if wastewater is treated by reverse osmosis. Liquifying methane to produce liquified natural gas before shipping is extremely energy intensive (See Section 3).

Finally, the new and unproven technology of carbon capture and storage proposed to assist in reducing the greenhouse gases emitted for these extensive procedures carries an extensive environmental footprint. The IPCC's 2022 Climate Change Mitigation Report (Pathak et al., 2022) found that, globally, carbon capture and storage has been slower than anticipated to deploy, has very limited capacity to contribute to net emission reduction, supports far fewer Sustainable Development Goals and is substantially more expensive that wind, solar and battery energy system development.

All these problems have been experienced throughout the Gorgon carbon capture and storage project in Western Australia, which after six years of operation has only running at one third capacity in capturing emissions from its large-scale gas fields (Mercer, 2023). Oil and gas industry leaders insist that the technology is proven and effective, but IPCC scientists do not agree.

Serious threats associated with these operations: Water security, food security and biodiversity

Water security at risk

Each hydraulic fracturing event for shale gas production uses 5.7 to 60.6 million litres of water (American Geosciences Institute, n.d.), which can be applied many times per well across hundreds to thousands of wells in an area (Vengosh et al., 2014; Jiang et al., 2014). Kondash et al. (2018) reported that the median amount used per well in 2016 was 28 million litres in the Marcellus, 42 million litres in the Permian and 21 million litres in the Bakken regions of the United States. While wastewater that returns to the surface is sometimes reused, challenges in water reuse are discussed below.

This use of valuable freshwater raises concerns for water security in some locations. Water security is defined as having a sufficient and secure supply of water for drinking, food production and other human and ecosystem services (Entrekin et al., 2018; Rosa et al., 2018). Already many areas of the world, including in the United States and Australia, are facing significant water stress, which will worsen as climate change progresses. A global analysis reported that 31–44% of the world's known shale deposits are located in areas likely to be affected by water stress; 20% are in areas where groundwater is already depleted and 30% underlie irrigated lands (Rosa et al., 2018). These authors warned of likely competition between unconventional gas production and food and other human uses of water.

Substantial concerns have been raised by modelling conducted for the Office of Groundwater Impact Assessment on the extensive use of water by the coal seam gas industry in Queensland (Underground Water Impact Report, 2018; McCarron and Dougall, 2021). The modelling predicts future pressure drops in groups of freshwater springs and loss of 571 private and licensed stock and domestic water bores. The Office has already reported significant declines in water levels and loss of trees and ecological health of springs in areas of coal seam gas activity.

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) has also risen substantially (Kondash et al., 2018). This was associated with longer lateral drilling distances and greater intensity of hydraulic fracturing in 2014–2015, simultaneously with a reduction in drilling of new wells as oil and gas prices fell. High-intensity production also resulted in even more wastewater produced per well. Kondash et al. (2018) examined water usage records across four shale gas mining regions in the United States and reported increased water-use intensity (lower water efficiency) and wastewater production across all four. 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, respectively, over a five-year period.

Sometimes, 'solutions' to problems can actually cause further problems and may not be adequately researched before implementation. For example, the siting of multiple wellheads (up to 12) on the same pad and multi-directional drilling was anticipated to reduce surface footprint. However, as demonstrated by Kondash et al. (2018) and discussed above, the wellheads may not be placed optimally to locate the 'sweet spots' of gas in each direction. This then has meant longer distance drilling, larger water requirements, greater pressures for hydraulic fracturing and greatly enlarged volumes of wastewater requiring safe

Contamination and deterioration of soils and competition for water and land use carry significant human health risks, especially considering the cumulative impacts of hundreds of wells over decades.

handling. After a decade of drilling, according to research by Jacquet et al. (2018), multi-well pads have not been widely used; a majority of pads housed only one (45.7%) or two wells (15.2%), for an average of 3.2 wells per pad in Pennsylvania and 2.2 in West Virginia.

Food security at risk

Concerns over water security are clearly directly connected to concerns for the agricultural industry and food security (Hitaj et al., 2020). These concerns are likely to apply 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 already a pressing challenge for farmers and communities near proposed sites for exploration and mining in the Northern Territory and Western Australia. In addition, oil and gas operations, and the mining of sand for hydraulic fracturing, damages the health of soil, through direct contamination with an array of chemicals, through soil heating, impacts on watershed, increased salinity, pH changes and nutrient availability which can reduce crop yields (Allred et al., 2015 and Moran et al., 2017).

Contamination and deterioration of soils and competition for water and land use carry significant human health risks, especially considering the cumulative impacts of hundreds of wells over decades. Haswell and Bethmont (2016) noted that the link between soil health, food safety and security and unconventional gas has received insufficient research interest even though it is a critical issue for Australian farmers. Livestock health and water rights are paramount concerns for these farmers, especially with increasing drought conditions predicted in Australia and globally (Collins et al., 2013; IPCC, 2022) and likely in 2023 with forecast El Nino conditions.

Very few studies have examined impacts on agricultural products and yields. Finkel et al. (2013) identified substantial reductions in both dairy cow numbers and milk production in areas of Pennsylvania with heavy drilling activity. Hoy et al. (2018) examined changes in agriculture associated with drilling in the Marcellus shale region compared with communities in New York where drilling was banned. They found little difference in many of the agricultural variables they examined; however, they noted an increase in average farm size, reflecting a reduction in the number of smaller farms, likely through amalgamation, and a decline in beef farms in drilling areas.

Negotiations between water and energy sectors are rife with conflicting views and complexity and increasingly so with climate change and population growth (Hussey et al., 2013). Prospects for successful coexistence of farming and gas mining are further challenged by new roads and mining infrastructure on agricultural land, heightened pollution risks, livestock disturbance, lack of attention to legislated occupational health and safety rights as gas developments operate in farmers' workplaces, landscape changes and economic uncertainties surrounding the impacts of unconventional gas mining in Australia and elsewhere (Freyman, 2014; Bamberger and Oswald, 2015; Hussey et al., 2013; Chen and Randall, 2013; Dougall, 2019; McCarron and Dougall, 2021; Bressan and Deshaies, 2023). Psychosocial impacts experienced by farmers are described in Section 5.2.

Biodiversity at risk

Biodiversity is essential for healthy ecosystems, which in turn are essential for human health. Biodiversity protects human access to clean air and water and a secure food supply. In forested areas and other ecologically sensitive sites, these activities as well as clearance for pipelines and infrastructure causes substantial tree clearing, habitat fragmentation and loss, and stress and disturbance of wildlife (Langlois et al., 2017; Black et al., 2021). Ensuing steps in the processes of gas development, including air pollution and surface water pollution, threaten aquatic ecosystems, vegetation and wildlife (Meng, 2017). There is a growing literature demonstrating how these disruptions are changing habitat choices, migration and reproductive patterns and species loss (Northrup et al., 2015; Barton et al., 2016; Juliusson & Doherty 2017).

Australia and the world are facing a global biodiversity crisis which comes with grave concerns for human health and wellbeing.

Summary

This section has provided a brief scaffold to build understanding of the multiple, complex activities involved in unconventional oil and gas operations and the risks they pose to people and the environment. While some activities are shared with conventional methods which also carry risk, two aspects set shale and coal seam gas production apart. First, to overcome the more difficult task of harvesting dispersed oil and gas over vast areas, unconventional oil and gas production requires hundreds to thousands of well pads creating a very large land footprint. Secondly, the difficulty in releasing oil and gas from shale and coal deposits often requires multiple applications of hydraulic fracturing.

This technique requires the use of many chemicals, silica sand and very large quantities of fresh water and results in large quantities of wastewater containing even more toxic chemicals returning to the surface and requiring management and disposal. The literature documents spills and accidents, well integrity failures, wastewater management challenges and methane leaks. Combined with land clearing, noise and disturbances from seismic testing, networks of roads, high power energy infrastructure, truck traffic and potential exacerbation of water scarcity in dry areas, it is not surprising to see emerging evidence of negative impacts that unconventional oil and gas operations bring to water security, food security and biodiversity, as well as to people.

These screenshots were taken of the Pilliga Forests on the Homeland of the Gomeroi People. Covering 500,000 hectares, it is the largest continuous remnant forest in the eastern side of Australia and a National Biodiversity Hotspot. In December 2022, despite an outpouring of public opposition, the NSW government approved the construction of 850 coal seam gas wells in the forest.

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3. Climate implications: Why we must keep Australia's methane (aka 'natural' gas) in the ground to secure our future

This Section provides an analysis of the substantial contribution of oil and gas production, transportation, processing and combustion on the dangerous and precarious state of our climate. We first describe the causes, the severity and the imperative of rapid action to stop producing and burning fossil fuels. We then discuss the key role that methane – the product of unconventional gas developments – is contributing to climate change.

We then identify the many reasons why methane is not a 'low-carbon fuel' and how continued production and export of gas from Australia is exacerbating climate change. We review a range of evidence that destroys some of the 'myths' about gas compared to coal and urge direct transition to much cheaper and much safer renewable energies. We also look at some of the trends in our National Greenhouse Gas reporting that show the substantial contribution of coal seam gas and LNG exports to the increases in both stationary energy (excluding electricity) and fugitive emissions since 2005.

We then focus on Australia's responsibility as a wealthy nation, with a very high per capita carbon footprint but significant potential to support the enormous global transition required to protect the health and wellbeing of current generations and the future of our children.

We are now living in a climate health emergency.

What is happening to our climate?

According to the world's most eminent scientists, Earth's climate is changing rapidly, with signals across virtually every human dimension pointing to the role of human activity in pushing towards much more dangerous planetary conditions. The resulting impacts of global warming, are now clearly playing out in front of us, with devastating impacts on livelihoods across the globe, and on global health (IPCC, 2022; 2023). There is almost universal understanding among scientists that the major human activity contributing to this change is the continuing choice to burn fossil fuels – coal, oil and gas – to power our lives.

The Sixth Intergovernmental Panel on Climate Change (IPCC) Final Synthesis Report, released in March 2023 (IPCC, 2023), and, the Impacts, Adaptation and Vulnerability Report released in March 2022 (IPCC, 2022), clearly articulate the urgency for change and the consequences of failing to change:

> *Human activities, principally through emissions of greenhouse gases, have unequivocally caused global warming.... Global greenhouse gas emissions have continued to increase, with unequal historical and ongoing contributions arising from unsustainable energy use, land*

use and land-use change, lifestyles and patterns of consumption and production across regions, between and within countries, and among individuals (high confidence).

Human-caused climate change is already affecting many weather and climate extremes in every region across the globe. This has led to widespread adverse impacts and related losses and damages to nature and people (high confidence). Vulnerable communities who have historically contributed the least to current climate change are disproportionately affected (high confidence).

Risks and projected adverse impacts and related losses and damages from climate change escalate with every increment of global warming (very high confidence). Climatic and non-climatic risks will increasingly interact, creating compound and cascading risks that are more complex and difficult to manage (high confidence).

Some future changes are unavoidable and/or irreversible but can be limited by deep, rapid and sustained global greenhouse gas emissions reduction. The likelihood of abrupt and/or irreversible changes increases with higher global warming levels. Similarly, the probability of low-likelihood outcomes associated with potentially very large adverse impacts increases with higher global warming levels (high confidence).

The Sixth Assessment reported that because of the greenhouse gases already emitted, even if fossil fuel use ceased today, we will witness increasing harms to the Earth's physical and ecological systems, and consequently to human health and wellbeing, until 2030. The modelling indicates humanity can still limit harms to that level with strong and committed global decarbonisation from 2030 onwards, limiting warming as close as possible to a 1.5°C increase above pre-industrial temperatures (IPCC 2022; 2023).

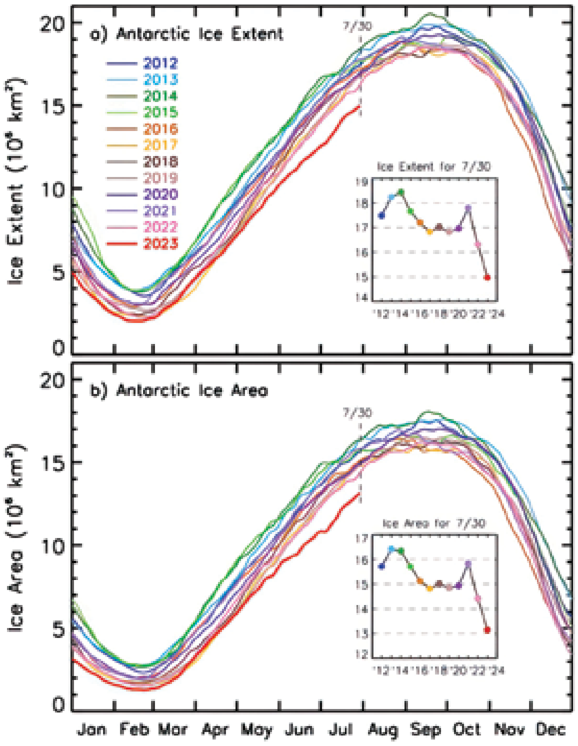
However, if global action now is not sufficient, we will see rapidly escalating changes well beyond what we have already experienced. As noted above, the likelihood of catastrophic (abrupt and irreversible) global impacts will increase with steady deterioration of planetary conditions. Current global policies are leading to a 2.7°C rise, which is beyond catastrophic (IPCC, 2023). According to The Lancet Countdown on health and climate change, under conditions of catastrophic climate change it will no longer be a question of whether we can adapt, but one of fighting for survival, as 'hothouse' Earth no longer provides the basic necessities, such as safe, clean and sufficient food, water and air (Costello et al., 2023).

Australia is highly sensitive to climate change, as we have already witnessed the beginning of this deterioration in recent unprecedented bushfires, heatwaves and floods. In 2023, we are moving from wet and cooler La Nina conditions into heat and drought extremes of El Nino conditions. For seven days in a row, July 2023 temperatures were above all previous global records. These are now impacting on all aspects of human life, with an estimated 61,672 excess deaths among Europeans during the 2022 heat waves (Ballester et al., 2023). Simultaneously, the loss of sea ice in the Antarctic in 2023 (see red line in figure below) has also been unprecedented, potentially bringing forward inundation of Australian coastal cities and islands. These observations in the first seven months of 2023 alone, combined with those gathered over decades, confirm what many climate scientists (including the late Professor Will Steffen) have already pointed out – that our earth systems are now approaching tipping points from which there will be no return (Steffen et al., 2021).

Figure 3.1 is taken directly from the National Aeronautics and Space Agency (July 29, 2023) "Seasonal cycle of Southern Hemisphere sea ice extents (a) and areas (b). given as daily averages, for the years 2012 through 2023.

The vertical line represents the last data point plotted Seasonal cycle of Southern Hemisphere sea ice extents (a) and areas (b). given as daily averages, for the years 2012 through 2023. The vertical line represents the last data point plotted [July 26]" (Comiso et al., 2023).

Figure 3.1: Seasonal cycles



Source: National Aeronautics Space Agency
https://earth.gsfc.nasa.gov/cryo/data/current-state-sea-ice-cover

Role of fossil fuels, focusing on methane

Fossil fuels – coal, oil and methane gas –are the source of 80% of all greenhouse gas emissions from human activity, driving both global warming and indoor and outdoor air pollution. Greenhouse gases (carbon dioxide, methane and nitrous oxide) and other pollutants (particulate matter, ground level ozone, oxides of nitrogen and other gases) are released into the atmosphere from mining/ extraction, processing, transport and combustion (IPCC, 2013; 2018; 2022).

Methane, commonly called 'natural gas', is the product of hundreds of millions of years of carbon removed from the atmosphere into the shells of sea creatures, into plants through photosynthesis and onto rocks. Vast quantities of carbon were safely stored in layers of shale formed where oceans once were, in coal deposits fossilised from ancient vegetation and forests and in some types of rock. In the last 30 years, humans have brought massive quantities of carbon to the surface through coal mining and oil and gas extraction. The three types of gas extraction reflect the places where carbon was stored and methane formed, being shale gas (3–5 kilometres below the surface), coal seam gas, (held in place along the surface of coal by natural water) and tight gas (in rock deposits) (see Section 2).

When coal, oil and gas are burned for heat and energy, most of the carbon is released into the atmosphere as carbon dioxide. However, methane that escapes into the atmosphere without being burned, as it does during coal mining and oil and gas extraction, transportation and processing, will remain in the atmosphere for 12–20 years and is very potent in trapping energy from the sun.

Essentially then, global warming has largely resulted from the reintroduction of this naturally-stored carbon back into the atmosphere as carbon dioxide and methane as a result of human activities. The rate of change in atmospheric chemistry from mining, extraction and burning is orders of magnitude faster than any non-human process (for example volcanic activity). Hence within decades, human activity has increased the concentration of CO_2 from 280ppm to 420ppm (National Oceanic and Atmospheric Administration, 2022).

Concerningly, as human activities have caused some planetary warming, other natural processes of carbon sequestration are also starting to break down. Some examples include release of methane previously trapped under Arctic ice, warmer oceans releasing CO_2 rather than absorbing it, loss of reflective polar sea ice increasing the absorption of heat into land and water, and carbon released from unprecedented forest fires in drought-stricken forests. In turn the loss of forest means that less carbon is being taken out of the atmosphere through photosynthesis by trees and vegetation. These are examples of the 'positive feedback' that occurs when a human-induced change triggers changes in the natural world that then amplify the damage.

Potency and rise in atmospheric methane

Methane is the second largest contributor, after carbon dioxide, to global warming. Methane is the most important of the 'short-lived climate pollutants', a group of very potent greenhouse gases that also includes other gases emitted during gas production operations, such as black carbon (derived from gas flaring), ground level ozone (described in Section 4) and oxides of nitrogen.

The IPCC Sixth Assessment Report on Impacts, Adaptation and Vulnerability (IPCC, 2022) emphasises the dual requirements for rapid reductions in CO_2 and in short-lived climate pollutants (most importantly methane) in order to limit global warming. Methane, even if comparatively short-lived, traps 86 times as much heat energy, warming the atmosphere much more rapidly than equivalent levels of CO_2 over 20 years.

Methane now accounts for an estimated 45% (IPCC, 2023) of the increase in the trapping of heat in the atmosphere (causing global warming). Atmospheric levels of methane have increased steadily and substantially since 2008. In October 2021, the World Meteorological Organisation (WMO) reported the biggest annual increase in methane concentration since the start of systematic measurement in 1983. At that point, methane levels were 2.62 times higher than pre-industrial levels.

Contribution of oil and gas production to methane levels

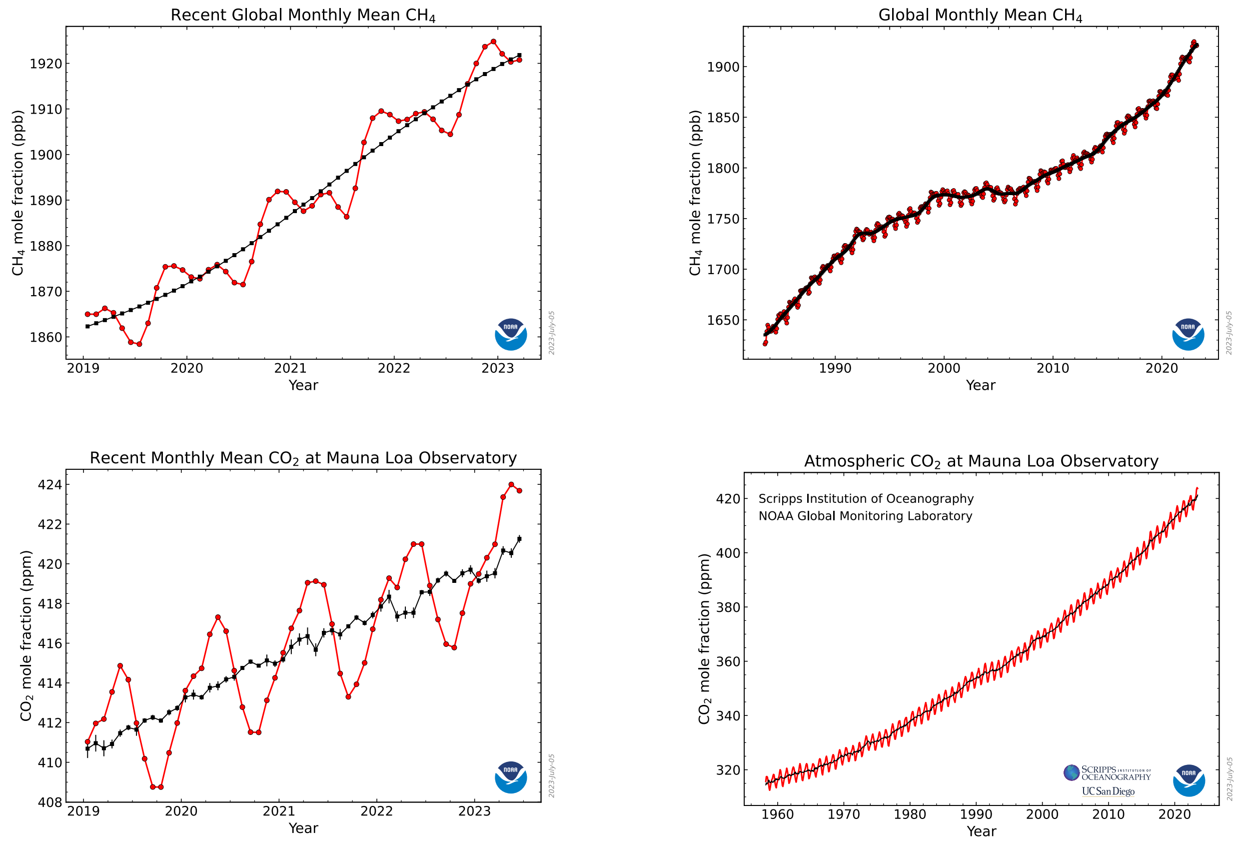
The International Energy Agency's plan (2021) to achieve global energy decarbonisation argues that there is no need for new fossil fuel developments. The UN Secretary General has urged all nations to cooperate as global citizens to stop fossil fuel expansion and to assist developing nations which do not have the resources to move quickly enough in their transition to renewable energies without external support.

Despite this clear warning, however, exploration and exploitation of fossil fuel resources continue unabated and/or are expanding, both globally and in Australia (see Section A1). In 2023, 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 is a bridge or 'transition' to lower greenhouse gas emissions are not justified. When the entire life cycle of gas production, transportation and combustion is taken into consideration, fugitive (leaking) methane emissions (not combusted to form CO_2 before release into the atmosphere) means that the claimed climate 'advantage' of gas over coal is greatly diminished at best and more potent than coal at worst (Shearer et al., 2014; Staddon and Depledge, 2015; Voiland, 2016; IEA, 2017; Smillie et al., 2022; Gordon et al., 2023).

It is now clear that the impacts of gas emissions have been significantly underestimated, and its climate benefits over coal overestimated, for many reasons. Some of these are discussed below.

Methane's oversized short-term impact on warming compared to carbon dioxide (i.e., the fact that a molecule of methane traps approximately 86 times more energy than a molecule of carbon dioxide) over 20 years (Voiland, 2016; NASA, 2016; IPCC, 2023) is

Figure 3.2: Recent global monthly mean CH_4 and CO_2 readings



Source: CH_4 – NOAA Global Monitoring Laboratory: https://gml.noaa.gov/ccgg/trends_ch4/#:~:text=Global%20CH4%20Monthly%20Means,Last%20updated%3A%20Jul%2005%2C%202023
CO_2– NOAA Global Monitoring Laboratory: https://gml.noaa.gov/ccgg/trends/

far more important than the frequently used 100-year average potency of 28 times that of CO_2. As we approach potential tipping points, near term impacts (occurring within 10 to 20 years) have become extremely important. However, some modelling, including that used in the Australia's National Greenhouse Gas accounting, continues to use the 100-year figure for estimating CO_2 equivalents of fugitive methane.

Fugitive emissions account for higher proportions of the extracted gas escapes than were initially expected (Howarth, 2014; Gordon et al., 2023). Leaks occur for reasons of well-casing failures, or leaky pipes and infrastructure or, possibly, fracking-induced channels for gas flow from underground to surface. Extensive modelling by Gordon et al. (2023) indicated that leakage over 0.2% of the total methane production volume before combustion calls into question the benefit of 'natural' gas over coal as an energy source.

The most comprehensive study of methane emissions from coal seam gas production in the Surat Basin in Queensland indicated that 0.4% of production volume is lost as fugitive emissions (Neininger et al., 2021). This estimate is 2 to 3 times higher that of previous estimations in the Surat Basin which did not account for a range of factors, but similar to levels found for other 'dry gas' fields (gas without contamination with oil) in the US and The Netherlands. Although this is within the low range compared to unconventional gas produced in other regions of the world, it calls into question the significance of its advantage over coal based on Gordon et al. (2023).

Importantly Shearer et al. (2014) pointed out that switching from coal to renewable energies, rather than to gas, completely avoids those concerns since the much larger known net gain in life cycle emissions reduction with wind and solar energy does not depend on methane leakage rates.

When methane is exported (the vast majority of gas produced in Australia is exported), it is transported by pipeline propelled by compressor stations to processing stations. This infrastructure and processes may emit both methane and other air pollutants which are immediately harmful (Buonocore et al., 2023). For shipment, the gas is then liquified at -160°C, producing liquefied natural gas (LNG), which is extremely energy intensive.

While proposed oil and gas developments may pledge to use solar or wind energy to drive these processes and help reduce their carbon footprint, this would need to be carefully assessed to ensure that these developments do not divert Australia's already over-stretched renewable energy transition skills and resources away from developments designed to benefit households, services and businesses (Knight, 2023).

Once the oil and gas is exported by ship (which is also fossil energy intensive), the LNG is then reverted back to methane gas and placed into supply networks in our export partner nations, currently China, Japan and South Korea. As in Australia, methane may leak from these networks and in households before the point of combustion.

In addition to its direct effect on global heating, methane can also be converted into the highly potent greenhouse gas, tropospheric (ground level) ozone, which also damages human health and agricultural production (see Section 4). Being highly reactive in the atmosphere, methane also enhances stratospheric water vapour and influences aerosols and the lifetimes of extremely potent greenhouse gases, the hydrochlorofluorocarbons and hydrofluorocarbons (IPCC 2013, O'Connor et al., 2021; Szopa et al., 2021).

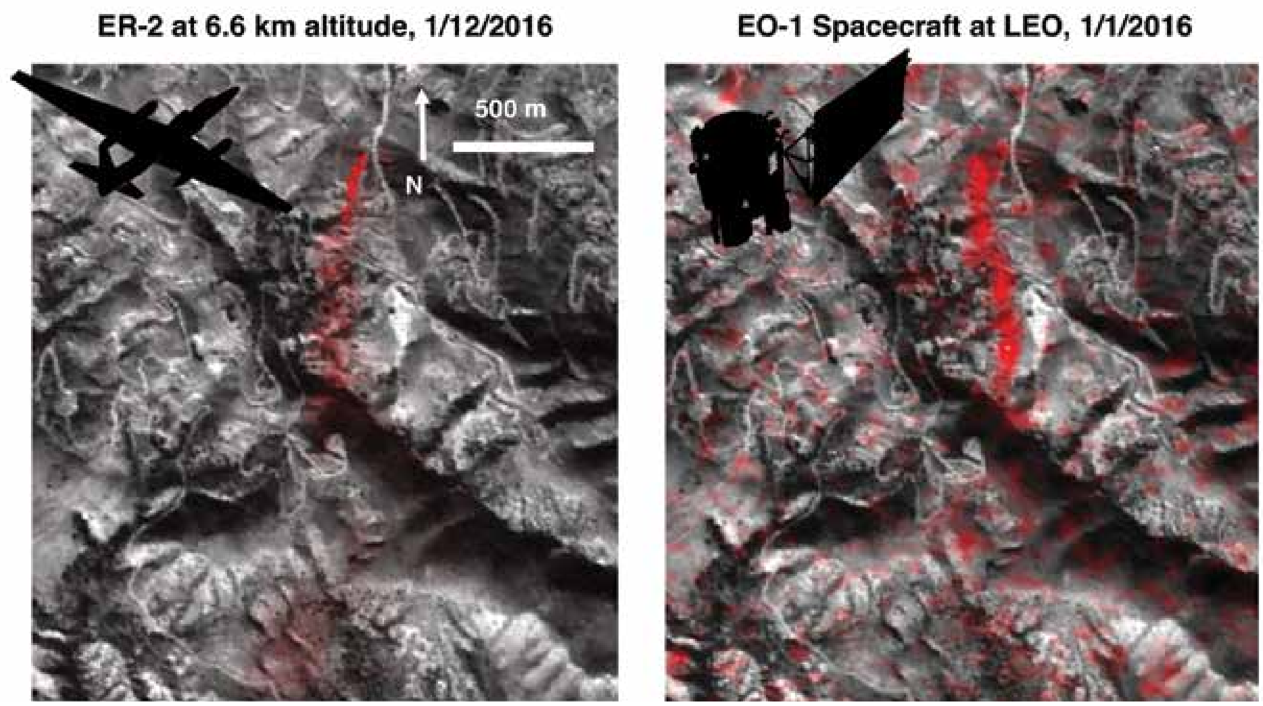
Modelling suggests that abundant supply of natural gas in the United States has competed against, rather than bridged to, renewable energies and delayed urgent transitions to a decarbonized energy system to limit global warming (Shearer et al., 2014; McJeon et al., 2014; Staddon and Depledge, 2015). Similarly, Smillie et al. (2022) found in modelling the international market effects of increasing LNG exports from the US that "the increased supply of lower cost gas will not only drive fuel switching from coal but also lower energy prices leading to increased energy consumption overall." Estimates of purported gains from the switch from gas to coal were substantially reduced by these market forces.

Despite extensive research, claims that gas is a 'low carbon' fuel persist in media, advertising and government discussions, obstructing honest and open discussion about the best ways to avoid climate catastrophe.

Methods of large-scale carbon capture and offsets to 'make up for' emissions from continued fossil fuel expansion are not proven to do so. While methane capture from existing oil and gas production activities around the world is highly desirable (United Nations Environment Programme/Climate and Clean Air Coalition, 2022), this does not mean that new oil and gas developments are acceptable. The United Nations urges technology and funding to reduce emissions from current installations that are adding to increased methane levels in the atmosphere, not to produce more gas.

Accidents involving well blowouts and leakage from methane storage sites, as exemplified by the 2016 Aliso Canyon disaster (Figure 3.3), have happened, with staggering impacts, and may occur at similar sites in the future (Conley et al., 2016).

Figure 3.3. 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 kilometer height, right hand side is a satellite image.



Source: NASA/JPL-Caltech/GSFC; https://photojournal.jpl.nasa.gov/figures/PIA20716_fig1.jpg

Finally, 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 the energy supply. Hence even if a switch to gas did provide a significant reduction in CO_2 emissions as claimed, this reduction would not be sufficient to avoid exceeding the 1.5 or 2° C carbon budget (IPCC, 2018).

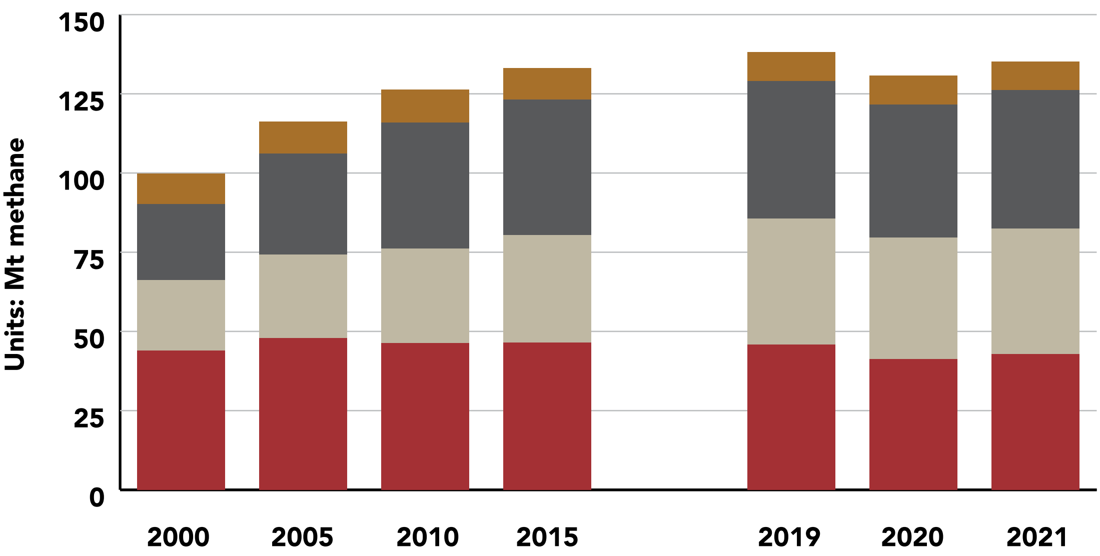
Worden and colleagues (2017) estimated that oil and gas production is responsible for between 48% and 75% of the total methane emissions from all human activities, i.e. 12 to 19 of the total 25 million tonnes released each year.

The Global Methane Assessment 2030 Baseline Report (United Nations Environment Programme/Climate and Clean Air Coalition (2022) presents the results of extensive modelling and states that:

> *Without serious reduction efforts, global baseline methane emissions will continue increasing through 2030. By 2030, methane emissions are projected to increase by between 20–50 million tonnes per year above current levels… Emissions in the fossil fuel sector are expected to increase over the decade to 10 million tonnes per year by 2030 (ranging between 4 and 23 million tonnes) within the oil and gas sector (especially gas).*

To draw attention to and monitor the alarming increase in atmospheric methane, the International Energy Agency (2022) developed Methane Tracker 2021 to improve the accuracy of measurement of methane emissions from energy activities. This work shows that emissions from gas increased between 2015 and 2019 and remained steady from 2019 to 2021. Little change was observed during the COVID-19 pandemic.

Figure 3.4: Global methane emissions from the energy sector over time 2000–2021



Source: International Energy Agency (2022)
https://www.iea.org/reports/global-methane-tracker-2022/overview

Australia's role and responsibility as a wealthy country and leading gas exporter

As discussed above, science has provided unequivocal evidence of the severity, the causes and the consequences of further inaction. Action must be taken immediately to protect future generations.

The Lancet Commission on Climate Change and Health describes the impacts of increasing atmospheric greenhouse gas concentrations on human health and wellbeing as the greatest health threat of the 21st century (Woodward et al., 2014; Watts et al., 2017). The majority of the loss of health, life, livelihood and property from climate change to date has been borne by the developing world, which has contributed least, but suffered the most, from climate change, mostly driven by developed countries directly and indirectly through export of their fossil fuels. This same concept is even more evident within countries (Chancel et al., 2023). The wealthiest 10% of the global population, including low, middle and high income countries, is responsible for 48% of total emissions, experiences the least relative losses and have the greatest capacity to finance global action on climate change if they chose to.

The greatest injustices, however, will be borne by children born today and all future generations if we fail to act now. They will bear the greatest suffering from catastrophic climate change, having had no choice or voice in its progression and left with few resources to deal with it.

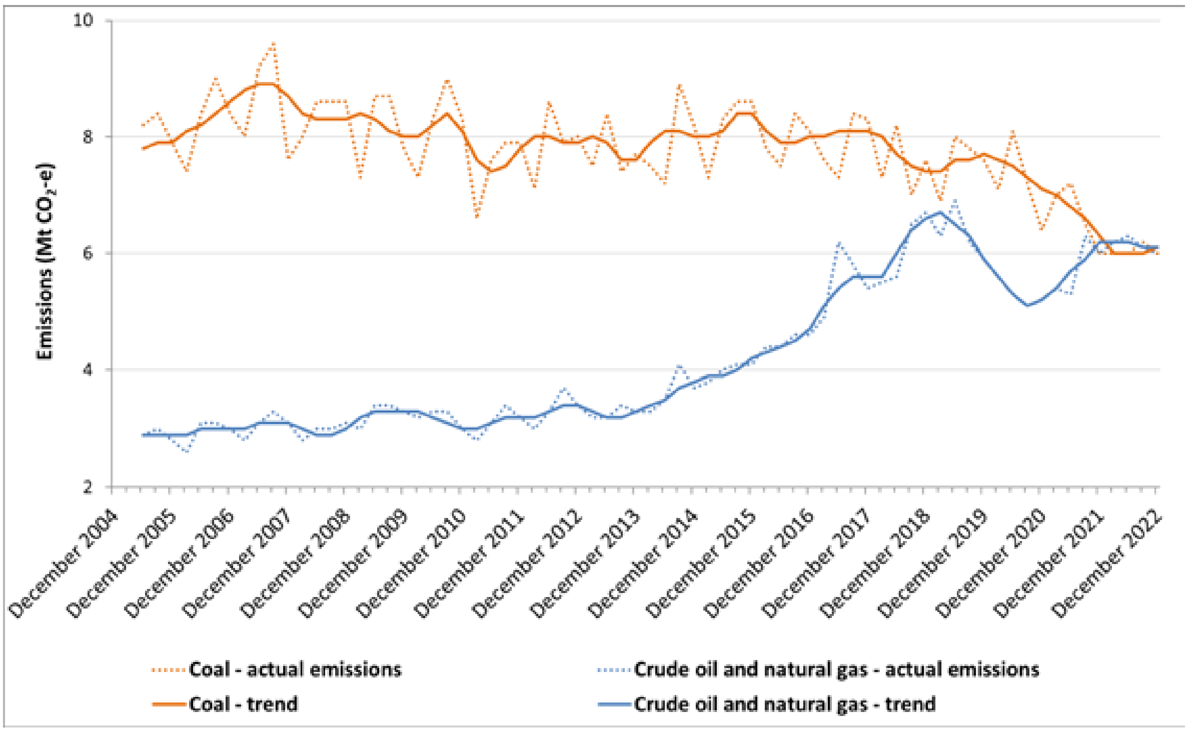
As Australia is one of the world's wealthiest nations with one of the largest *per capita* greenhouse gas footprints, the changes Australia must undertake cannot be clearer – and are already outlined in international agreements we have committed to, particularly the Paris Agreement and recently the Global Methane Pledge, which Australia signed in October 2022.

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, and preferably to 1.5 °C. To date, Australia has reportedly been heavily criticised by international governments and health leaders for its lack of commitment and action (Smith, 2021; Beggs et al., 2022).

Domestically, Australia has demonstrated its commitments to reduce domestic electricity emissions through the Australian Energy Market Operator's 2022 Integrated System Plan (AEMO, 2022). This Plan operationalises its Step Change scenario through a 30-year electricity market roadmap. The map forecasts the nearly complete phaseout of coal and existing gas generators by 2040, with an ongoing but minor role for 'peaking gas' in exceptional circumstances. These models play close attention to the cost and stability of the transition process, and market adjustments required to achieve net zero. The Quarterly Update of Australia's National Greenhouse Gas Inventory demonstrates this progress with electricity emissions decreasing 21.4% between June 2005 and December 2022 due to domestic renewable energy penetration (Department of Climate Change, Energy, the Environment and Water, 2023).

In sharp contrast, Australia's rapid increase in LNG exports since 2015 are singled out as the main driver of a 27.4% increase in stationary energy (excluding electricity) emissions from direct burning of fuel in heating and industrial processes, such as liquifying gas for export. Similarly, a 14.1% increase in fugitive emissions since June 2005 is attributed to the extraction, production, processing and transportation of natural gas and oil, including leakage, evaporation and storage losses, flaring and venting of carbon dioxide, methane and nitrous oxide.

Figure 3.5: Fugitive emissions, actual and trend, by sub-sector, by quarter December 2004 to December 2022



Source: Department of Climate Change, Energy, the Environment and Water

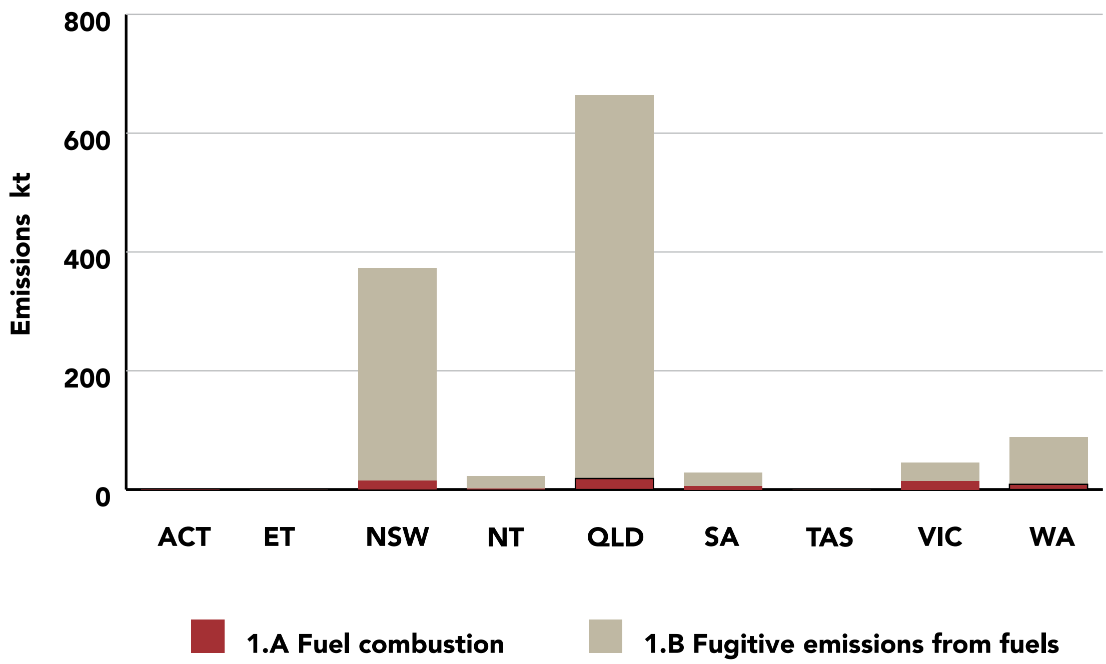
These increases in fugitive emissions from gas fields are clearly evident in Queensland, where emissions from fuels far exceed those of other states and territories.

In October 2022, the Hon Chris Bowen MP, Minister for Climate Change and Energy, signed the Global Methane Pledge which commits countries to reduce global methane emissions across all sectors by at least 30% below 2020 levels by 2030 (Australian Government, 2022). While this is positive news, it is challenging to see how this could possibly be achieved, given the above emissions trends from existing gas production, let alone with the enormous expansions being planned.

Australia is fast-tracking extensive plans to increase gas production, including the commencement of a major new shale gas export industry (Office of the Chief Economist, 2022). With 49 new gas initiatives and 69 new coal mines planned as of 2022, plus the accelerated development of the Beetaloo Basin in the Northern Territory (hailed as Australia's equivalent to the Marcellus Shale plan, the largest US Basin), it is hard to understand how major rises in emissions will be avoided. Estimates of carbon emissions from these 118 new initiatives have been estimated at 4.8 billion tons of greenhouse gases (CO_2-equivalents) by 2030 (Denniss, 2023). Suggestions that carbon capture and storage will be able to solve this problem are not consistent with research (Grubert and Sawyer, 2022).

Furthermore, these developments are operating without taking responsibility for Scope 3 emissions – that is, those that occur in the countries importing the product. Expanded

Figure 3.6: State and territory reported emissions of methane gas from fuel combustion and fugitive emissions from fuels in 2020



Source: https://greenhouseaccounts.climatechange.gov.au
NB some data was either not available or was confidnetial (eg ACT and TAS)
ET: External Territories

export volumes of methane to other countries, who are expected to account for the emissions resulting from this Australian product, appears to contravene the spirit of many articles of the Paris Agreement (United Nations Climate Change, n.d.), for example:

- Developed countries should take the lead by undertaking absolute economy-wide reduction targets [not only offsets] (Article 4);
- Parties should conserve and enhance as appropriate, sinks and reservoirs of greenhouse gases [for example, keep methane secure within shale and coal seams] (Article 5);
- Voluntary cooperation among Parties is encouraged to promote more ambitious targets, contribute to the mitigation of GHG emissions and support sustainable development (Article 6);
- Developed countries have obligations to support the efforts of developing country parties to build clean, climate-resilient futures, while encouraging voluntary contributions to other Parties (Articles 9, 10 and 11).

Summary

In summary, this Section has highlighted the difficult reality that all scientific assessments of our planet indicate that we are clearly living in the onset of a planetary health emergency of previously unseen proportions. We explored the current and perilous state of the Earth's climate, highlighting how the mining/extraction and combustion of coal, oil and gas have returned vast amounts of carbon previously stored safety underground and under ice by natural processes into the atmosphere and oceans. This has already had major consequences on the health of people and the environment we depend on, including extraordinary extremes experienced in the first seven months of 2023. The Sixth Intergovernmental Panel on Climate Change reports clearly warn us of the rapidly closing window to stop emitting greenhouse gases, especially CO_2 and methane from fossil fuels, to avoid catastrophic impacts that will be suffered by current and especially future generations.

We then demonstrated the particular importance of methane – the product of unconventional gas operations – in driving rapid global heating that requires immediate and effective attention. We presented multiple lines of research evidence which discredits the suggestion that gas is safer for the climate than coal. We observed, in Queensland in particular, how the rapid expansion of coal seam gas mining and liquefied natural gas production has increased both stationary energy (excluding electricity) and fugitive emissions since 2005. We ask, how in the world is our current government going to honour our Methane Pledge to reduce methane emissions by 30% given the additional burden of emissions from enormous oil and gas development projects in the planning pipeline.

Beyond the critically important Methane Pledge, we also highlight the crucial responsibility, accepted by Australia like all signatory nations to the Paris Agreement, to do better, not worse, in helping the world to achieve the necessary decarbonisation to avoid catastrophic consequences. Approving and progressing oil and gas developments on a scale unprecedented in Australia is unconscionable.

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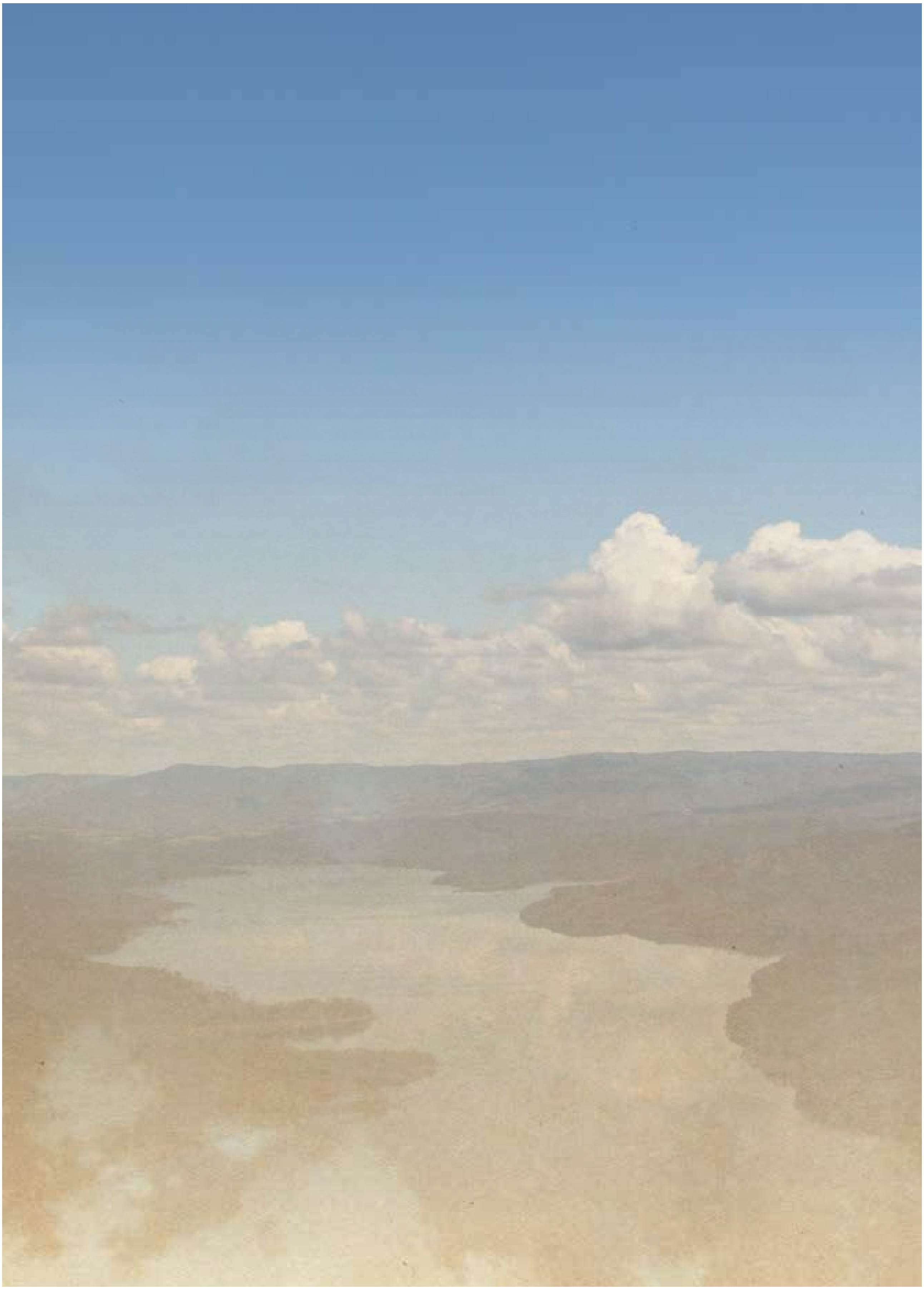


4. Water and air quality implications: Migration routes and chemicals of concern

This Section describes some of the key evidence to date of the many pathways of exposure and the many introduced and naturally occurring chemicals resulting from the unconventional gas industry that are known to be potentially harmful to humans and the environment. Section 3 provides examples of contamination incidents that have been reported in the United States so frequently that regulatory agencies and researchers have not been able to keep up with investigation of even the most significant events.

The evidence presented in this Section was extracted from a title and abstract scan of 527 publications identified through the comprehensive research database Scopus using key words 'unconventional gas' and 'health'. In addition, 204 peer reviewed publications (as of July 2023) examining flowback and produced wastewater, and 75 on chemicals and additives identified through the Repository of Oil and Gas Energy Research (ROGER), were title screened for their relevance to health and reviewed. From this search, over 50 papers were read, have been analysed and are cited in this section.

Potential exposure pathways

Research on, and assessment of, health concerns associated with unconventional gas mining have mainly focused on the wide range of chemical additives and materials that are required for the procedure. The role of the large number of naturally occurring chemicals that are mixed with added chemicals and brought to the surface within the large quantities of wastewater generated at the various stages is more complex and less understood, but even more relevant to the assessment of human health risks (Colborn et al., 2011; Elliot et al., 2017; Vidic et al., 2013; Maloney et al., 2017, 2018).

As discussed in Section 3, there is now greater awareness of the numerous pathways by which harmful chemicals, gases and salt can migrate into shallow aquifers and other drinking water supplies through leaking wells and subsurface flows. Spills, leaking wastewater from holding pond liners, flooding and overflow of ponds during heavy rain and other accidents and disposal of inadequately treated wastewater onto the ground or into creeks and other water bodies all threaten surface water and surrounding soil

… there is now greater awareness of the numerous pathways by which harmful chemicals, gases and salt can migrate into shallow aquifers and other drinking water supplies through leaking wells and subsurface flows

(Vengosh et al., 2014; Maloney et al., 2017; 2018; Carey et al., 2009; Rossi et al., 2023). The salinity of spilled fluids can dissolve toxic chemicals, such as uranium, within the soil and contaminate aquifers and surface waters, as was observed in Narrabri, NSW (Carey et al., 2009).

Maloney et al. (2017) examined 6422 reported spills across four states in the US from 2008 to 2014. They found that wastewater, crude oil, drilling waste, and hydraulic fracturing fluid were most often spilled in volumes ranging from 100 to 10,000 litres. More recently, Rossi et al. (2023) found widespread underreporting of the location of spills, lack of follow-up testing of groundwater for contamination and underestimation of spill volumes among 1029 produced water spill incidents in 2018–2020 in the official California database.

The deliberate practice of using untreated produced wastewater and sludge from oil and gas wells for maintenance and de-icing of roads and as a dust suppressant to reduce harmful particulate matter (PM10) exposure was legalised in 13 states in the USA. Recent research has demonstrated that wastewater is not only inferior as a dust suppressant (Stallworth et al., 2021), it raises many concerns about harm to the environment and human health. Tasker et al. (2018) identified radium, strontium, barium, inorganic salts and organic matter contaminants in oil and gas wastewaters applied to roads in Pennsylvania, where an estimated 130 million litres were applied annually from 2008 to 2014. They conclude that this deliberate practice released 200 times more of the known radioactive carcinogen radium into the environment than reported spills:

> *In Pennsylvania, we found that radioactivity associated with radium released to the environment via road spreading exceeds the radioactivity of radium released by spill events* [200 times more] *or wastewater treatment plants* [four times more]*. The spreading of O&G wastewaters on roads could be a significant contributor of inorganic and organic micropollutants to the environment and has been largely ignored in environmental studies on O&G development.*
>
> (Tasker et al., 2018, p 7089).

A growing number of studies provide evidence suggesting that pressure changes due to dewatering, multiple hydraulic fracturing and/or reinjection of fluids into wells and through natural and induced cracks in the strata can, and have, led to drinking water contamination, including from abandoned wells (Warner et al., 2012; Jackson et al., 2013; Kharak et al., 2013; Kassotis et al., 2014; Lefebvre, 2017; Stanish et al., 2021; Perra et al., 2022; Jellicoe et al., 2022; Warner et al., 2012). These studies add weight to concerns long expressed by geohydrologists and imply that even in the absence of errors and infrastructure failures, contamination of water can occur through the 'normal' or 'usual' processes of hydraulic fracturing and wastewater disposal and is therefore not preventable.

In Queensland, Navi et al. (2014) discussed similar possible contamination pathways into surface waters associated with the handling of vast quantities of coal seam gas wastewater, as well as in some practices currently in use for 'beneficial purposes', including irrigation of crops, livestock watering, dust suppression, aquaculture and a trial injection of treated coal seam gas water into drinking water aquifers. The authors raised potential concerns regarding salt accumulation, crop productivity, reduced permeability of soil, lower nutrient availability due to excess sodium and bioaccumulation of heavy metals, as well as additional concerns regarding the safety of farmers applying this water through inhalation of contaminated aerosols. They also questioned the use of coal seam gas water for cattle and for aquaculture, given the possibility of contaminants entering the meat or fish and being transferred to humans upon consumption.

Chemicals also reach the atmosphere from flaring (Figure 4.1), venting, holding tanks, ponds, compressor stations and other infrastructure. While initially most public health concern focused on risks to water, the US

Figure 4.1: Decommissioned coal seam gas well, Pilliga Forest

Credit: Lock the Gate Alliance

experience to date indicates that health risks associated with air pollution are at least as serious for human health as water contamination (Finkel and Hays, 2013; Brown et al., 2014). This includes gases, such as methane and co-occurring volatile organic compounds that escape through the gas extraction process and from faulty and leaky wells. Harmful airborne chemicals may escape directly from wells during production and volatilise (evaporate) from contaminated water into the air.

Residents living near gas wells and infrastructure and industry workers may be exposed to airborne 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 (Petron et al., 2012; Adgate et al., 2014; Field et al., 2014). Besides toxic gases directly emitted during these processes, it is important to recognise secondary atmospheric pollutants that form when two or more reactive chemicals come together in the atmosphere in the presence of sunlight and heat.

Humans can also be exposed when airborne chemicals return through rainfall on waterways and livestock pastures to contaminate soil and bodies of water and potentially be transferred to livestock and fish.

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 through impacts on soil fertility (Khan and Kordek, 2014; Davies et al., 2015). Saline leakage from 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 Pilliga Forest CSG operations has been reported (Carey et al., 2014).

A significant occupational health concern for unconventional oil and gas workers is excessive exposure to silica – large quantities of 'frac sand' required for hydraulic fracturing (OSHA, 2012; Esswein et al., 2013). Mining of this sand also causes substantial ecological damage. An extensive study of the effects of inhaling hydraulic fracturing sand dust suggested that while the pulmonary effects may be less severe than those of crystalline silica, the frac sand was more toxic to other organ systems besides the lungs (Investigative Team, 2020).

In Australia, gas 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 place in the event of an accident or leak. Section 2 examines some of the limitations of these regulations.

Chemicals of concern in hydraulic fracturing fluids and wastewater from shale oil and gas extraction

Hundreds of chemicals of concern are purposely added to or occur naturally in water that has been in contact with gas-containing material (that is, shale, coal or granite) for millions of years underground (Colborn et al., 2011; Elliot et al., 2017; Vidic et al., 2013; Davies et al., 2015). Shale gas chemicals have been most intensely studied. Findings are presented from some of the key research examining the presence of these chemicals and their potential effects on exposed humans, including neurological and neurodevelopmental harms, harms to the reproductive and other organ systems, radioactivity and carcinogenicity and endocrine disruption.

Naturally occurring chemicals, chemicals in drilling muds and those emitted from machinery and diesel combustion engines pose a risk in gas extraction without hydraulic fracturing (conventional gas extraction). Unconventional gas extraction carries these risks, plus the many additional chemicals specifically used in the hydraulic fracturing procedure. These include surfactants, acids, bactericides, glycol and many substances not revealed under "commercial in confidence" agreements.

A systematic review by Antial et al. (2022) identified potential hazardous chemicals in drilling muds, lubricants, additives, drill cuttings and naturally occurring chemicals in vast quantities of wastewater. The 109 reviewed papers showed evidence of the presence of heavy metals such as cadmium, chromium, arsenic and lead, as well as toxic elements such as barium, radium and strontium in the wastewater. Furthermore, volatile organic compounds (VOCs) such as benzene, toluene, ethylene and xylene, and poly-aromatic hydrocarbons were frequently present. These chemicals can have multiple health effects, including birth defects, cancer, cardiovascular and respiratory disease. The authors recommended handling these materials with extreme caution.

Elliott et al. (2017b) examined the carcinogenicity data on a total of 1177 chemicals in fracking fluids and wastewater (US EPA) and 143 chemicals identified in scientific papers published before 2016 on air pollutants. They found that over 80% of these chemicals had not been evaluated for carcinogenicity. The 119 chemicals that had been evaluated included 49 water and 20 air pollutants that were possible, probable or known carcinogens, and 20 that were associated with leukemia/ lymphoma, including benzene, 1,3 butadiene, cadmium, diesel exhaust and polyaromatic hydrocarbons (PAHs).

A systematic assessment of the carcinogenicity of 1,173 chemicals present in hydraulic fracturing fluid alone (1,039), wastewater alone (97) or both (37) was performed by Xu et al. (2019). Information was not available for 989 (84.3%) of the chemicals in two prominent databases. Only 104 had been evaluated by the International Agency for Research on

Cancer, and 48 were found to be definitely (14), probably (7), or possibly (27) carcinogenic. The Carcinogenic Potency Database identified 66 that were potentially carcinogenic in animal models. The authors concluded that exposure to these chemicals, especially in flowback water, may increase cancer risk.

PAHs, heavy metals, naturally-occurring radioactive materials (NORMs) and a wide array of known and unknown chemicals used in drilling and hydraulic fracturing fluid have the potential to damage the health of workers and community residents who may be exposed through contact with water that has been contaminated during the handling of the large quantities of chemicals and wastewater involved (Esswein et al., 2014). 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 surface during extraction and waste disposal (US EPA, 2018). If these technologically enhanced naturally occurring radioactive materials, or TENORMS, are present at sufficient levels, workers and nearby residents may be at risk of exposure through air and water (Esswein et al., 2014; Geltman and LeClair, 2018; US Environmental Protection Agency, 2023).

Volatile organic compounds, including BTEX (benzene, toluene, ethylene and xylene), which occur naturally in shale, can contaminate groundwater and enter the atmosphere from the flowback wastewater after fracking and during flaring of excess gas. Benzene contamination of groundwater 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 (Gross et al., 2013).

Elliott et al. (2017a) looked at the reproductive and developmental toxicity of 1021 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

Volatile organic compounds, including BTEX which occur naturally in shale, can contaminate groundwater and enter the atmosphere from the flowback wastewater after fracking and during flaring of excess gas.

toxicity. Webb et al. (2018) reported numerous neurodevelopmental and neurological effects of many chemicals associated with gas operations, focussing particularly on risks to children. Some of these developmental impacts are likely to be mediated by endocrine disrupting chemicals.

Evidence of endocrine-disrupting activity in surface and groundwater in areas with unconventional gas mining raises significant concern (Kassotis et al., 2014; 2016a; 2016b; 2016c; 2018a; 2018b; 2019a; 2019b; 2020; He et al.; 2018) because these chemicals can interfere with endocrine function at very low concentrations, sometimes without overt signs or symptoms. Because of their complexity and the lack of fundamental understanding in Australia, these chemicals are discussed in further depth on pages 42–46.

To our knowledge, independent research on the safety of chemicals that would be used in proposed new shale gas exploration and production in Western Australia, South Australia and the Northern Territory is lacking, with no peer-reviewed publications available. By contrast, American researchers have published at least 75 peer-reviewed papers on chemicals/additives applied in gas extraction, many of which raise concerns about their potential health impacts (Repository for Oil and Gas Energy Research, 9 July 2023).

In an August 2018 stakeholder update, the Australian Industrial Chemicals Introduction Scheme, formally the National Industrial Chemicals Notification and Assessment Scheme (NICNAS), announced its intention to invite CSG 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.

It is not clear how constituents used for shale gas operations protected under 'trade secret' legislation in the United States might be handled in Australia. Most importantly it remains unclear how this may impact access by medical practitioners to information needed for medical treatment of patients who may have been exposed to those chemicals through operations in Australia. It is also unclear how the many new chemicals that may be used in shale gas extraction will be assessed, especially if there is no information from the United States on those used and brought to surface in wastewater.

Chemicals used and produced in coal seam gas extraction in Australia

As most of the research on chemicals has examined shale gas production, fewer studies have characterised constituents of wastewater produced during gas extraction from coal seams, the predominant unconventional gas extraction method in Australia to date (Khan and Kordek, 2014). Untreated produced water contains high levels of sodium and bicarbonate, often with suspended solids, iron, silica and barium (Khan and Kordek, 2014). Heavy metals, boron, fluoride, organic compounds and ammonia may also be present (Volk et al., 2011).

The most significant work thus far on coal seam gas (CSG) has been done by NICNAS and the Commonwealth Science and Industrial Research Organisation (CSIRO), with fourteen reports on the risks to human health and environment of exposures to 113 chemicals used in drilling and hydraulic fracturing for CSG in Australia (NICNAS and CSIRO, n.d.). NICNAS and CSIRO (n.d.) found that 44 of the 113 chemicals examined were potentially harmful to workers in the event 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. With regard to public health, NICNAS identified 40 chemicals used in CSG mining that had the potential to harm the community should people become exposed by swimming in or drinking water contaminated by spills during transport or leakage from wastewater ponds.

NICNAS and CSIRO found that 44 of the 113 chemicals examined were potentially harmful to workers in the event of exposure during an industrial accident.

CSIRO also commissioned laboratory-based leaching experiments using samples from various sources of coal exposed to conditions roughly simulating those of hydraulic fracturing (Apte et al., 2017). 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. The organic coal contaminants retrieved included 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 was unclear (Apte et al., 2017).

Concentrations of radionuclides, namely radium, thorium and uranium, were deemed below concern. However, the authors pointed out that these materials could become concentrated during certain procedures, such as getting trapped in crust formations in pipework, on filters and on reverse osmosis membranes used in water treatment (Apte et al., 2017).

Concentrations of many additional chemicals found in the coal leachate, such as barium, could not be assessed due to a lack of available guidelines or regulations for drinking water or aquatic water systems (Apte et al., 2017). The authors called for additional research to extend these findings to actual hydraulic fracturing activities within CSG mining.

It is important to acknowledge the limitations of this work. For example, only chemical additives (not naturally occurring chemicals present in wastewater) used in CSG mining (not including additives used in shale and 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 other environmentally mediated exposures to workers and communities.

Navi et al. (2014) identified a wide range of potentially hazardous naturally occurring substances in water drawn from coal seams that have been reported in the global literature, including salts, barium, fluoride, boron, arsenic, lead, cadmium, chromium and organic compounds including phenols, biphenyls and PAHs. Many of these compounds have been reported in CSG water withdrawn in Queensland, in some cases in substantially higher concentrations than Australian Drinking Water guidelines.

Air emissions with potential direct health impacts

Human exposure to air pollutants is difficult to measure for a number of reasons: monitoring methods and stations are often not designed for or located in places suited for the most accurate capture of the human exposure; the dispersal of pollutants is affected by wind and weather conditions; there are extreme fluctuations of released pollutants over time related to industry activities; there are differences in housing quality that promote or impede the intrusion of ambient air pollution; and human activities, such as children playing and adults exercising outdoors, have varying impacts on the inhalation rate and depth of breathing (Brown et al., 2014).

Nevertheless, harmful chemicals in air are as concerning as those in contaminated water as a source of potential harm to communities near gas and oil operations These exposures come from drilling operations and diesel-powered machinery and trucks as well as from wastewater handling, especially when the wastewater is stored in open air ponds and holding tanks.

For detailed analysis, readers may consult the extensive review of hazardous air pollutants associated with oil and gas development done by Garcia-Gonzales et al. (2019). Their review identified stage-specific pollutants that had been reported in the literature and underlined the importance of the production phase, as opposed to the hydraulic fracturing stage as expected, in contributing to air pollution. This is because of its long duration, the larger number of pollutants and the occurrence of episodes of very high emissions. The review named BTEX chemicals, formaldehydes and acetaldehyde, hydrogen sulfide and acrolein as the chemicals likely to be of greatest concern in airborne emissions (Garcia-Gonzales et al., 2019).

Other research on air pollution linked to gas extraction has examined volatile organic compounds (like benzene), polyaromatic hydrocarbons, heavy metals, radioactive materials, fine particulate matter (PM2.5), endocrine disrupting chemicals and secondary organic aerosols and ground level (trophospheric) ozone (Lloyd-Smith & Senjen 2011; Fann et al., 2018; Helmig, 2020, Li et al., 2020). These chemicals can affect the respiratory, endocrine, nervous and cardiovascular systems and some, notably benzene and radioactive chemicals, can cause cancer (Colborn et al., 2011; ATSDR 2007; McKenzie et al., 2012).

The combination of chemicals in the produced wastewater (flowback) that become volatile varies according to the fracking fluid additives used and those naturally occurring in the coal seam or shale. Details of chemicals present in these fluids may not be known or are difficult to access from companies. Many have not been assessed for toxicity to humans or the environment (Colborn et al., 2011; McCarron & King 2014).

Pollack and colleagues (2021) found that oil and gas operations contributed significantly to benzene, ethane and hexane levels, with concentrations in production regions often far exceeding those in major urban areas.

A study by Li et al. (2020) added weight to concerns about radioactive particles emitted during unconventional, but not conventional, gas mining, with raised concentrations of airborne radioactive particles detected as far as 20 km downwind of operations. These particles have been linked to increased blood pressure and inflammatory markers and decreased lung function.

Diesel engines and trucks carrying chemicals and waste emit particulate matter, nitrogen oxides, diesel fumes and volatile organic compounds, many of which are known or suspected carcinogens.

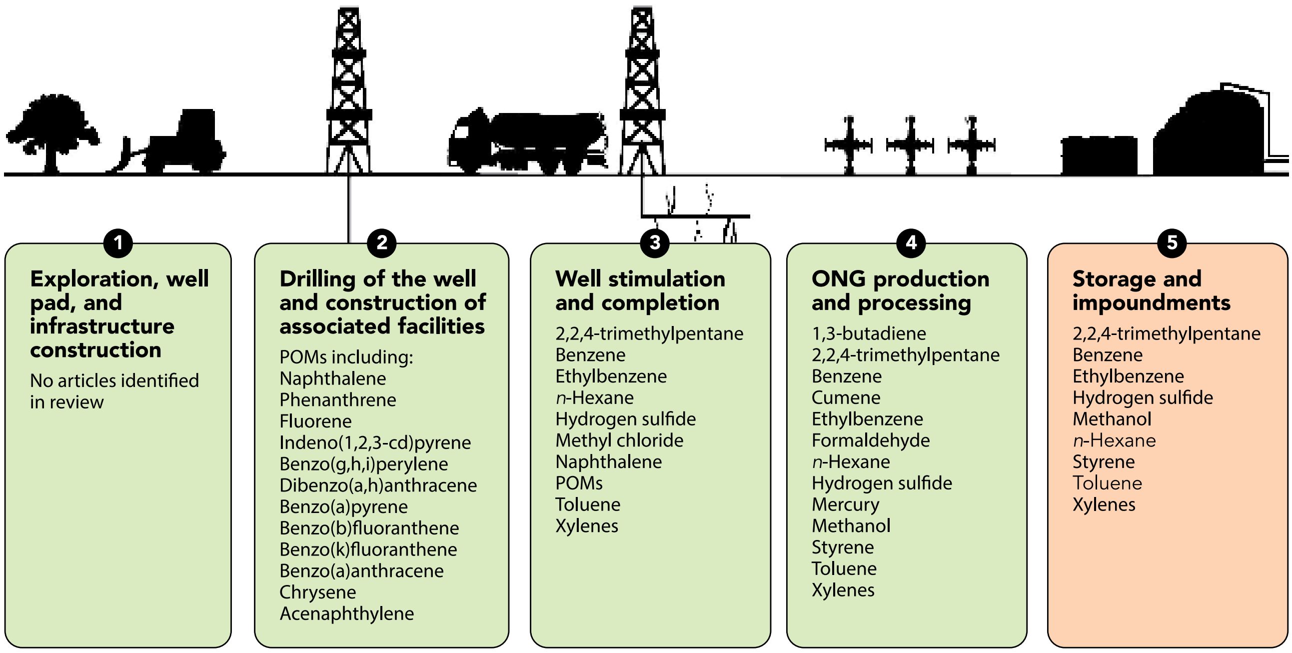
Chemicals of particular concern: Endocrine disrupting chemicals in air and water

As described above, there are many opportunities for harmful chemicals to move from the extraction site to the surrounding environment through air and water. The wide array of endocrine disrupting chemicals (EDCs) and the amount of EDC activity that reaches the environment deserve much more attention than they have yet received in Australia. Despite the rapidly growing literature in the United States on these chemicals, as well as recent experiences across Australia with one family of EDCs, namely PFAS, they have rarely even been mentioned in risk assessments and documents guiding decision-making on gas production expansion in the country, and few Australians understand the threat of these chemicals to human health.

The endocrine system, together with the nervous system, regulates and coordinates communication between cells, organs and systems. This extremely important and delicate role in human bodily function is achieved through the secretion of a complex array of hormones. Hormones direct the development, reproductive functions, metabolism and normal functioning of the body.

EDCs are defined as individual or mixtures of chemicals that can interfere with any aspect of the ways in which hormones – these major messengers produced by the endocrine system – act in the body (Di Pietro et al., 2023). They act by interfering with the attachment of hormones to receptors on cells, by blocking the signals that hormones stimulate within cells for normal functioning, by interfering with signals for cells to stop growing and/or by preventing the production, breakdown or movement of hormones around the body (Di Pietro et al., 2023). Furthermore, and particularly worryingly, EDCs can also alter the

Figure 4.2: Hazardous air pollutant (HAP) compounds collected through primary measurements and recategorized. Abbreviations: ONG, oil and natural gas; POMs, polycyclic organic matter



Source: Garcia-Gonzales et al., 2019

folding of DNA, preventing the expression of genes and the production of required proteins at the right time. This means that some of the damage caused by EDCs before or soon after birth (ie damage to the foetus from the mother's bloodstream or when breast feeding) can be expressed in adult life and transmitted to the next generation without further exposure (Nagel et al., 2020).

By interfering with hormones, EDCs have the capacity to cause a wide array of health and developmental problems. While this field of research is in its infancy, studies have already linked exposure to EDCs to numerous serious health disorders (discussed below).

Three further characteristics of EDCs make them especially relevant in recognising the risk of environmental contamination and hence human exposure:

- EDCs can have profound impacts on health at very low concentrations – much lower than some other types of toxic chemicals;
- EDCs are rarely tested for, as the testing is costly and highly technical, often requiring sophisticated assays; and
- EDCs are highly persistent in the environment and are often called "Forever Chemicals" because once present, they remain as a continuing source of harm.

Finally, strategies to prevent contamination and to reduce the risk of exposure are difficult to implement, because highly specialized research is required to link impacts of EDCs to their source.

However, there is now evidence that emissions from oil and gas mining operations have a real potential to expose humans, livestock and wildlife to a wide range of chemicals with endocrine disrupting activity through contamination of both air and water. Balise et al. (2016) reviewed 45 peer-reviewed publications that examine links between conventional gas extraction processes and the presence and potential impacts of endocrine-disrupting activity. They found moderate evidence 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 likely poses more potential risks to reproductive health than conventional gas operations given the many endocrine-disrupting chemicals involved in the hydraulic fracturing process. Bolden and colleagues (2018) reviewed 48 air quality studies associated with shale gas production and identified 106 chemicals with endocrine disruption potential, including estrogenic and androgenic activity and alteration of steroid formation.

Multiple studies by Kassotis and colleagues (2014; 2016a; 2016b; 2016c; 2018a; 2018b; 2019a; 2019b; 2020; He et al., 2018) have revealed the presence (by chemical analysis) and bioactivity (ie activity tested on living cell cultures) of wastewater and in ground and surface water in areas with moderate and high drilling activity. The quantities detected are known to be capable of causing harm to aquatic organisms. Further effects of early life exposure to these chemicals found in experimental models have included interference with mammary gland development (Sapoukey et al., 2018), reproductive function (Balise et al., 2019), immune system functioning and anti-viral immune responses (Boule et al., 2018; Robert et al., 2019).

A very recent study by Breitmeyer et al. (2023) examined potential sources of 33 per- and poly-fluorinated alkyl substances (PFAS), a well-known family of endocrine disrupting chemicals, in surface waters in Pennsylvania. PFAS chemicals are thought to be highly disruptive at very low exposure levels and very persistent, and they are now widespread in human beings globally from many sources. They are the target of substantial and expensive clean-up operations across the USA and in Australia at airports and military installations. Breitmeyer et al. (2023) found elevated levels of PFAS (8.42 ng/s/km^2) in surface water associated with combined sewage outflows (mixed municipal sewage and oil and gas wastewater) in the seven sites sampled in areas with a high density of oil and gas wells (median 1548 wells, compared to a median of 10 wells across the whole sample). The authors noted that PFAS chemicals are effective in enhancing the recovery of petroleum hydrocarbons (oil), and thus petroleum recovery operations may have been a source of the PFAS found in the combined sewage outflows into surrounding streams.

Although there is no expectation that PFAS would be used in Australian shale gas production, there are many endocrine disrupting chemicals of concern that are likely to be in the gas wastewater produced that may pose risks to people, livestock and ecological systems in future developments. In contrast to the significant body of literature summarised above on shale gas, we are aware of only one study exploring endocrine disruption activity associated with gas operations in Australia, and very little is known about EDC activities in coal seam gas wastewater (Bain and Kumar, 2018).

Ground level ozone impacts on regional health

The toxic air pollutant ground level ozone is not directly emitted from oil and gas mining operations, but forms from mixtures of pollutants emitted during unconventional gas operations, especially in the presence of sunlight and heat. While some other chemicals, such as volatile organic compounds, remain relatively localised, ground level ozone and fine particulate matter travel large distances and can harm wildlife, agriculture (livestock and plant production) and people in affected regions. The damage caused by ozone to the agricultural industry, and therefore food security, has long been recognised and scientifically modelled (Adams et al., 1989). New methods for examining the impacts of rising ozone levels simultaneously with rising CO_2 concentrations are improving the prediction of combined damage to crop yields (Tai et al., 2021).

Helmig et al. (2020) conducted an extensive analysis of air quality data in relation to oil and natural gas operations in Colorado. They synthesised evidence from 50 studies demonstrating that oil and gas operations contribute significantly to levels of volatile organic compounds (VOCs) and ozone production in the atmosphere forming from VOCs, methane and particulate matter. Ozone, unlike VOCs, is transported in the atmosphere away from the site of gas extraction operations; daytime peak ozone levels were often found to be tens of kilometres away. Given the significant harms associated with unsafe levels of ozone, the authors concluded that:

> *These downwind air quality impacts from O&NG industries should be a strong consideration in the design of monitoring networks and decision-making on regulating existing and new O&NG development in the region.*
>
> (Helmig et al., 2020, p. 25).

The study also found that levels of ozone pollution from oil and gas operations were sufficiently high to significantly damage ecosystems and agricultural productivity in the region and argued that these losses should be quantified and farmers compensated accordingly (Helmig et al., 2020). Globally, economic damage to staple crops due to ozone is estimated at US$14–26 billion per year; hence efforts to lower ozone formation by reducing methane and nitrogen oxide emissions is also an urgent food security challenge (Emberson, 2020).

An in-depth study by Pozzer et al. (2020) examined the specific contribution of oil and gas operations to summer and winter ozone levels, the number of days exceeding safe ozone levels, and the estimated number of excess premature deaths due to exposure across the United States. The authors estimated that the ozone footprint from oil and gas operations is likely to have caused 320 (95% CI 298–344) excess premature deaths per year in the United States (Pozzer et al., 2020). Adding similar estimates of premature deaths linked to fine particulate matter emitted from oil and gas operations (Fann et al., 2018) indicates the industry causes over 600 premature deaths per year.

Finally, Francoeur et al. (2021) used an improved fuel-based oil and gas industry technique to demonstrate that emissions of methane, non-methane volatile organic compounds and oxides of nitrogen from oil and gas basins are two to three times higher than previous estimates. These chemicals are precursors of both ground level ozone and formaldehyde.

As described in Section 5.1, Buonocore et al. (2023) more fully modelled the likely health impacts and health costs of air pollutants associated with oil and gas operations in the United States. This work estimated that three main pollutants, nitrogen oxides, ground level ozone and PM2.5, resulted in 410 000 asthma exacerbations, 2200 new cases of childhood asthma and 7500 excess deaths in the year 2016. Associated health costs were estimated at US$77 billion. The industry has since expanded significantly, likely further increasing the annual costs to people and the economy.

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This work clarifies once again the substantial, underestimated contribution of natural gas production (from fugitive methane released and from the formation of ozone; both are very potent greenhouse gases) to the seemingly relentless progression of global warming as well as to human disease and death in the United States.

Summary

This Section has reviewed research that has been undertaken to understand the very large number and cumulative quantities of both introduced and naturally occurring harmful chemicals involved in unconventional gas production, transportation and processing. We present evidence indicating the many ways that these chemicals can and have entered into the broader environment via air and water through both accidental and deliberate actions and potentially through underground migration processes stimulated by oil and gas operations. The combination of some of these chemicals and their resulting by-products can also accumulate and persistent indefinitely in the environment or be taken up and concentrated by plants and animals and ultimately enter the food chain, as discussed in Section 2.

We also described studies which have identified that these complex mixtures can include many chemicals that:

- **have the potential to cause cancer (carcinogens);**
- **directly damage tissue and organs in the body;**
- **interfere with the reproductive system;**
- **interfere with normal human development, including those capable of causing birth defects and impairing neurodevelopment (teratogens and neurodevelopmental toxins); and**
- **may interfere with metabolism through disruption of the endocrine system (endocrine disrupting chemicals).**

Particularly concerning among these chemicals is ground level ozone, which is formed in the atmosphere from chemicals released during gas production activities and, together with fine particulate matter (PM2.5), travels long distances, putting regional human health, agricultural production and wildlife health at risk. Ozone damages the respiratory system and is also a highly potent greenhouse gas.

Also concerning is evidence of endocrine disrupting chemicals found in wastewater and in ground and surface waters associated with unconventional oil and gas drilling activity. These are harmful to both human and aquatic organisations. Due to the extremely low concentrations required to cause significant health impairments, there is an urgent need to protect both people and the environment from any exposure to these chemicals.

If exposed, foetuses (through their pregnant mother's bloodstream), infants (through inhalation, drinking and through their mother's breastmilk), children, elderly people and people with chronic illnesses are often the most at risk of harm from these chemicals. The reasons for this vulnerability are complex and include increased exposure due to age-specific behaviours, sensitivity associated with developmental stages especially in utero and the additional stress put on already impaired organs and systems due to age or disease.

Section 5 presents evidence from research that has examined the potential risks and impacts on human health and wellbeing that have been associated with oil and gas developments.

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5. Effects on health and wellbeing: Physical, social, emotional, cultural and spiritual

This section examines the existing evidence of direct impacts of oil and gas production operations on people across four key areas of health and wellbeing:

5.1 Physical health risks and impacts on adults and children;

5.2 Social and emotional impacts on individuals, families and communities;

5.3 Additional concerns and losses faced by Aboriginal people;

5.4 Risk of sexual violence, especially against women and children in remote areas.

Sections 5.1 and 5.2 are consolidated evidence from the now large body of peer-reviewed publications; Sections 5.3 and 5.4, by necessity, also include some "grey" literature from major government inquiries and other reputable sources. Very few peer-reviewed studies or formal research has been done in the latter two areas, and much more is needed to arrive at a comprehensive understanding of the specific risks and impacts on the safety, wellbeing and spiritual health of Aboriginal people associated with unconventional gas and oil developments. Evidence to date indicates that it would be severe.

5.1 Health risks and impacts associated with the unconventional gas industry

The research evidence presented so far paints a clear picture of multiple potential risks and measurable outcomes of exposure to complex mixtures of air- and water-borne chemicals that accompany unconventional gas operations. Before turning to the influence of social, emotional, cultural and spiritual factors, we describe here in more detail the evidence linking unconventional gas developments to symptoms, illnesses, hospitalisations, interference with foetal development and deaths across many regions in the United States with diverse geological, chemical and regulatory conditions. Where available, peer reviewed health studies associated with coal seam gas developments in Australia are included, but these are significantly limited to date.

Methodology notes

This is a comprehensive review, not a systematic review, of relevant publications with an inclusive scope. It builds upon the continuous monitoring and communication of the literature on health and wellbeing risks associated with oil and gas developments since 2011 by authors Haswell and Shearman. The papers for this Section include previous publications accessed frequently over 12 years. Added to this are papers identified from the database Scopus using terms *unconventional gas AND *health as well as those obtained from the Repository of Oil and Gas Energy Research (Physicians, Scientists and Engineers for Healthy Energy) over the period 2019 to 2023. Snowballing of reference lists within papers was also conducted to gain more specific understanding of information raised in the text of the publications.

The methodologies leading to each individual studies' findings are not reported to increase ease of understanding among non-specialists. However, as with most highly complex topics in environmental epidemiology, there has been a steady increase in the rigour and sensitivity of studies that has continuously built upon previous studies, reinforcing the finding of a wide array of negative impacts on health and wellbeing. Further discussion about the strengths and limitations of the body of work is provided in Section 6.

Studies assessing health risks and impacts

A large number of studies have now reported health effects among children and adults living in proximity to oil and gas operations that may result from both chemical exposures and chronic distress. These include (see Table 5.1 pp 56–59 for further detail):

- Symptoms and markers of disease: migraine headaches, chronic nasal and sinus irritation, fatigue, nausea, skin rashes, eye irritation, nosebleeds, asthma exacerbation requiring medication changes and cardiovascular disease indicators (McCarron, 2013; Rabinowicz et al., 2015, Rasmussen et al., 2016; Tustin et al., 2017, McKenzie et al., 2019; Blinn et al., 2020; Weisner et al., 2023).
- Higher hospitalisation rates among adults for heart disease, including heart attacks and heart failure; for respiratory and neurological disorders; for those with existing asthma conditions (emergency department visits, inpatient stays); and for some childhood cancers and immune deficiency disorders (Rasmussen et al., 2016; Jemielita et al., 2015; Werner et al., 2017; Whitworth et al., 2018; McCarron, 2018; McKenzie et al., 2017; McAlexander et al., 2020; Blinn et al., 2020; Denham et al., 2021; Blundell and Kokoza, 2022; Buonocore et al., 2023).
- Asthma exacerbations and hospitalisations among children (Willis et al., 2018; 2020; Bushong et al., 2020; Buonocore et al., 2023).
- Increased deaths and reduced life expectancy from cardiovascular and respiratory diseases and some cancers (Denham et al., 2021) and from all causes (Apergis et al., 2021; Li et al., 2022; Buonocore et al., 2023).
- More frequent traffic and pedestrian injuries and fatalities (Retzer et al., 2013; Graham et al., 2015; Blair et al 2018; Xu and Xu, 2020).

The following findings relating to psychological and social stressors are discussed in Section 5.3:

- Higher incidence of mental health conditions: depression and anxiety (Casey et al., 2016; 2018; 2019; Akers et al., 2022) and new onset of internalising disorders (anxiety, depression, social withdrawal, fatigue) among adolescent females seeking treatment in Pennsylvania (Gorski-Steiner et al., 2022).
- Increased incidence of sexually transmitted infections such as chlamydia and gonorrhoea, resulting from changes in sexual behaviour that can be associated with an influx of mobile workers in depressed areas (Mabey and Mayaud, 1997; Komarek and Cseh, 2017; Deziel et al., 2018).

Some examples of each health outcome investigated are briefly described to facilitate understanding of the nature of this complex research.

Symptoms linked to potential chemical exposures

Many studies have linked closeness to gas extraction operations with self-assessed symptoms at the community level. For example, Rabinowitz et al. (2015) found significantly higher prevalence of self-reported respiratory (39% vs 18%) and skin (19% vs 3%) conditions among people living within 1 km of shale gas wells in Pennsylvania compared to those living more than 2 km away. People living near unconventional gas wells worldwide, including near coal seam gas wells in the community of Tara in the Darling Downs of Queensland, have reported similar symptoms, as well as headaches, nosebleeds, numbness and tingling sensations (McCarron 2013; McCarron and King, 2014).

Weisner et al. (2023) examined a Colorado county where extensive gas production rapidly commenced following the development of a large, multi-well unconventional oil and gas site. The county adopted a variety of best practice management policies to try to mitigate negative environmental impacts on the relatively wealthy and healthy population. Despite these interventions, such as closed loop feedback systems designed to reduce emissions of volatile organic compounds, extensive air quality monitoring detected frequent significant emissions of these chemicals during pre-production operations (Weisner et al., 2023). Sound barriers were also found to be ineffective at reducing noise levels. A survey of nearly 4000 households in the area identified higher frequencies of upper respiratory, lower respiratory, gastrointestinal and acute symptoms among respondents living within 1.6 km of the extraction site compared to respondents living more than 2 miles away. Frequent symptoms included nosebleeds, nausea, vomiting and shortness of breath, consistent with known responses to exposure to volatile organic compounds.

Studies assessing health risks and impacts

Symptoms and markers of disease: migraine headaches, chronic nasal and sinus irritation, fatigue, nausea, skin rashes, eye irritation, nosebleeds, and asthma worsening requiring medication changes and cardiovascular disease indicators

Hospitalisations for heart disease including acute heart attacks and heart failure, respiratory and neurological disorders and for those with existing asthma conditions (emergency department visits, inpatient stays) and for some cancers and immune related diseases

Asthma exacerbation and hospitalisations among children

Increased deaths and reduced life expectancy from cancers, cardiovascular and respiratory disease and all causes

More frequent traffic and pedestrian injuries and fatalities

Mental health conditions: depression and anxiety and new onset of internalising disorders (anxiety, depression, social withdrawal, fatigue) among adolescent females

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

Table 5.1 Cardiovascular, cardiovascular and respiratory (combined) and respiratory health effects

Author and Illness Studied	Location and Year	Methodology	Sampling Size and Age Range	Main Findings and Health Outcomes	
Denham, Willis, Croft, Liu, & Hill, 2021 Acute myocardial infarction (AMI)	2005 to 2014 Pennsylvania and New York counties that overlay the Marcellus Shale	Observational longitudinal study: analysing the relationship between age- and sex-specific county-level acute myocardial infarction (AMI) hospitalization and mortality rates and three unconventional natural gas development drilling measures.	N = 2840 county-year-quarters 45+ years	Cumulative unconventional natural gas development is associated with increased AMI hospitalization rates among middle-aged men, older men and older women as well as with increased AMI mortality among middle-aged men. Heart attack hospitalizations increased 1.4–2.8%, depending on age and sex. Heart attack mortality increased 5.4% in middle-aged men.	CARDIOVASCULAR
McAlexander et al., 2020 Heart failure	2008 to 2015 Pennsylvania	Case-control study: evaluating associations between unconventional natural gas development activity and hospitalization among heart failure (HF) patients, stratified by both ejection fraction (EF) status (reduced [HFrEF], preserved [HFpEF], not classifiable) and HF severity.	9,054 (5,839 cases and 3,215 controls) mean age 71.1 ± 12.7 years	Three of 4 phases of UNGD activity were associated with increased hospitalization for heart failure in a large sample of patients with HF in an area of active UNGD, with similar findings by HFrEF versus HFpEF status. Older patients with HF seem particularly vulnerable to adverse health impacts from UNGD activity. Associations of most UNGD metrics with hospitalization were stronger among those with more severe heart failure at baseline.	CARDIOVASCULAR
McKenzie et al., 2019 Cardiovascular disease indicators including: augmentation index, systolic and diastolic BP, Interleukin-1β, Interleukin-6, Interleukin-8, and Tumor Necrosis Factor-α	October 2015 to May 2016 Northeastern Colorado	A cross-sectional study: evaluating associations between indicators of CVD and the intensity of O&G development and production activity within 16 km (10 miles) of a participant's home.	97 adults (28 male and 69 non-prepregnant female) ≥ 18 years	Evidence supported an association between the intensity of O&G activity and several indicators of cardiovascular disease. The results support associations between O&G activity and augmentation index, SBP, DBP, IL-1β, and TNF-α. Our study was not able to elucidate possible mechanisms or environmental stressors, such as air pollution and noise.	CARDIOVASCULAR
Apergis, Mustafa, & Dastidar, 2021 Mortality rates, cancer, cardiac, respiratory	1998 to 2017 Oklahoma	The analysis estimates the long-run relationship between the health profile and its determinants using the Common Correlated Effects (CCE) method. The empirical setup allows for cross-sectional dependence and accounts for both observed and unobserved heterogeneity.	Not applicable 37 to 55 years old	UNGD activities have negative effects on human health-related outcomes across all counties in Oklahoma. Specifically, an increase in the number of (unconventional) wells has a positive impact on mortality rates, and incidences of cancer, cardiac, and respiratory diseases in communities in close spatial proximity, and a negative impact on life expectancy.	CARDIOVASCULAR and RESPIRATORY

Author and Illness Studied	Location and Year	Methodology	Sampling Size and Age Range	Main Findings and Health Outcomes	
Blinn, Utz, Greiner, & Brown, 2020 Sore throat headache, difficulty speaking itchy or burning eyes, stress, shortness of breath, anxiety, fatigue, sinus infection	2012 to 2017 Southwest Pennsylvania	A novel approach to comparing estimates of exposure was taken. Generalized linear modelling was used to ascertain the relationship between symptom counts and estimated UOGD exposure, while Threshold Indicator Taxa Analysis (TITAN) was used to identify associations between individual symptoms and estimated UOGD exposure. Authors used three estimates of exposure: cumulative well density (CWD), inverse distance weighting (IDW) of wells, and annual emission concentrations (AEC) from wells within 5 km of respondents' homes. Taking well emissions reported to the Pennsylvania Department of Environmental Protection, an air dispersion and screening model was used to estimate an emissions concentration at residences.	104 ≥ 18 years old median age of 57	Results suggested that living in proximity to oil and gas wells may be associated with more frequent and more complex health symptoms. However authors suggested that more complex analyses of symptoms was needed.	CARDIOVASCULAR and RESPIRATORY
Buonocore et al., 2023 Premature deaths, asthma, respiratory, heart attacks	2016 United States	Authors assessed air quality and human health impacts associated with ozone, fine particulate matter, and nitrogen dioxide from the oil and gas sector in the US in 2016.We Authors used an integrated geospatial model framework that links emissions inventories from O&G production to changes in air quality and health in exposed populations.	Whole population, United States	Estimated that air pollution in 2016 from the oil and gas sector in the US resulted in 410 000 asthma exacerbations, 2200 new cases of childhood asthma and 7500 excess deaths, with $77 billion in total health impacts. NO_2 was the highest contributor to health impacts (37%) followed by ozone (35%), and then PM2.5 (28%). • Asthma exacerbations: 410,000 cases • Childhood asthma: 2,200 new cases • Asthma hospitalizations: 53 cases • Asthma Emergency department visits: 530 • Heart attacks: 270 cases.	
Jemielita et al., 2015 All cause hospitalizations for cardiovascular, respiratory and others	2007 to 2011 Pennsylvania	An ecological study: Zip-specific inpatient counts from 2007–2011 were used. The study assessed the link between inpatient rates, well count per zip code, and well density (quantiles) using fixed-effects Poisson models for overall and 25 medical categories.	92,805 hospitalisations. Age median 43.4 to 45.9	Hydraulic fracturing as determined by well number or density had a significant association with cardiology inpatient prevalence rates, while well density had a significant association with neurology inpatient prevalence rates.	

Author and Illness Studied	Location and Year	Methodology	Sampling Size and Age Range	Main Findings and Health Outcomes	
Li et al., 2022 All-cause mortality	2001 to 2015 All major US unconventional exploration regions	For each beneficiary's ZIP code of residence and year in the cohort, we calculated a proximity-based and a downwind-based pollutant exposure. Authors analysed the data using two methods: a Cox proportional hazards model and a difference-in-differences design which shows changes occurred after commencement of drilling and controls for many potential confounding variables.	15,198,496 The study relied on a nationwide cohort of over 15 million Medicare beneficiaries. Medicare beneficiaries; >95% over age 65	Evidence of a statistically significant higher mortality risk associated with living in proximity to and downwind of unconventional oil and gas wells. Results suggest that primary air pollutants sourced from unconventional oil and gas exploration can be a major exposure pathway with adverse health effects in the elderly.	CARDIOVASCULAR and RESPIRATORY
McCarron, 2018 Cardiovascular and respiratory	2007 to 2014 Darling Downs, Queensland, Australia	Ecological study of regional hospitalization data was compared before commencement of a coal seam gas industry in the region and after commencement, in association with the air pollutant inventory.	Admissions of patients for both cardiovascular and respiratory diseases.	Increased cardiopulmonary hospitalisations are coincident with the rise in pollutants known to cause such symptoms.	
Werner et al., 2017 All cause, disease of blood, circulatory and respiratory, perinatal, congenital	1995 to 2011 Queensland, Australia	This study analyzed hospitalization rates in relation to coal seam gas development in Queensland Admissions were linked to coal seam gas well numbers, indicating development intensity. Time series models estimate hospitalization rate changes during "low", "medium", "high", and "intense" activity versus a "very low" activity period.	238,457 0 to 65+	Hospitalisation rates for "Blood/immune" conditions generally increased for both sexes. Female and male hospitalisation rates for "Circulatory" conditions decreased with increasing coal seam gas activity. Hospitalisation rates were generally low for reproductive and birth outcomes; no clear associations were observed.	
Blundell & Kokoza, 2022 Respiratory-related hospital visitation	2007 to 2015 North Dakota	Authors assessed the impact of flared natural gas on respiratory health by using quasi-random variation in upwind flaring generated by the interaction of wind patterns and natural gas processing capacity. Specifically, they construct a novel dataset to estimate the causal effect of increased upwind flaring on the monthly respiratory-related hospital visitation rate by using the number of upwind wells that are connected to a capacity-constrained natural gas processing facility as an instrument for monthly upwind flaring.	180,000 <1 to ≥65	A 1% increase in the amount of flared natural gas in North Dakota would increase the respiratory-related hospital visitation rate by 0.73%. More than 32,000 total respiratory-related hospital visits for the 30-mile range alone.	RESPIRATORY

Author and Illness Studied	Location and Year	Methodology	Sampling Size and Age Range	Main Findings and Health Outcomes	
Bushong, McKeon, Regina Boland, & Field, 2022 Asthma hospitalization admission rates	2001 to 2014 Pennsylvania	Authors constructed regression models to investigate the association between UNGD and asthma hospitalization admission rates (HAR), using HAR as a proxy for severe asthma exacerbation.	N/A N/A	Models were robust enough to confirm an expected association of asthma hospitalization admission rates with urban areas, PM2.5, income, and racial disparities using public data only. N/A	RESPIRATORY
Rasmussen et al., 2016 Asthma exacerbations	2005 to 2012 Pennsylvania	A nested case-control study comparing asthma patients with exacerbations to asthma patients without exacerbations.	35,508 5 to 90 years old	Residential UNGD activity metrics were statistically associated with increased odds of mild, moderate, and severe asthma exacerbations.	
Tustin et al., 2017 Chronic rhinosinusitis (nasal and sinus) Migraine headache Fatigue	2014 Pennsylvania	A cross-sectional study: Authors used residential addresses and information about Pennsylvania unconventional gas wells to create UNGD activity metrics for four time-varying well development phases. They evaluated the associations between UNGD activity and CRS, migraine headache, and fatigue symptoms.	7,785 ≥ 18 years old 55.3 ± 16.1 (mean ± sd)	UNGD was associated with Chronic rhinosinusitis, migraine headache, and fatigue symptoms in a large population-based survey. Associations were stronger in patients with two or more outcomes. 11.7 % (909) reported that they have received medical assistance.	
Weisner et al., 2023 Upper respiratory, lower respiratory, mental health, neurological, gastrointestinal symptoms	2020 to 2021 Broomfield, Colorado	Cross-sectional: To assess whether residents near multi-well UOGD sites (within 1 mile) reported more health symptoms than those further away (> 2 miles), we used linear regression to test links between UOGD distance and summed Likert scores for health symptoms.	427 18 to ≥75	Results indicate that people living within 1 mile of multi-well unconventional oil and natural gas sites more frequently report upper respiratory and acute (e.g., nosebleeds, nausea, shortness of breath) symptoms than people living more than 2 miles from the sites. N/A	
Willis, Hystad, Denham, & Hill, 2020 Asthma hospitalizations	2000 to 2010 Texas	Authors examined associations between natural gas development and paediatric asthma hospitalizations, where our primary outcome is 0 vs ≥1 hospitalization. They used quarterly production reports to assess additional drilling-specific exposures at the zip code-level including drilling type, production and gas flaring.	24,333 (not exposed to NGD) + 48,589 (patients exposed to at least one NGD site) 1 to 17 years old	Conventional drilling, compared with no drilling, is associated with odds ratios up to 1.23 [95% confidence interval (CI): 1.13, 1.34], whereas unconventional drilling is associated with odds ratios up to 1.59 (95% CI: 1.46, 1.73). Increasing production volumes are associated with increased paediatric asthma hospitalizations in an exposure-response relationship, whereas associations with flaring volumes are inconsistent.	

No community-level health studies based on closeness to specific gas operations have been done in Australia, but there have been two limited, single-time-point studies. One undertaken by Queensland Health (2013) with low community participation and few reports of physical symptoms at a one-day clinic, did not identify any links between air emission data and symptoms. In contrast, many community members reported a range of signs and symptoms potentially related to gas production activities in a house-to-house survey conducted by local General Practitioner, Dr Geralyn McCarron (2013). 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, 2013, p. 18).

Macey et al. (2014) examined the timing of the relationship between poor air quality and the presence of symptoms in four US states with substantial oil and gas production. Community members were trained to use air sampling devices to obtain samples of the air they were breathing at times when they felt normal, and at other times when they felt sick or sensed pollution from the nearby gas operations by taste or smell. This novel method enabled the community to identify numerous excursions above federal guidelines that were particularly frequent for toxins in the air they were breathing, notably formaldehyde, 1,3-butadiene, hydrogen sulphide, mixed xylenes and n-hexane. Strikingly, these excessive readings had not been detected and/or reported in routine air quality monitoring, raising questions about the sensitivity of existing data to enable issuance of alerts for the protection of health. Indeed, atmospheric research in a variety of circumstances has revealed significant underestimations of emissions of methane and other hydrocarbons based on ground level measurements and modelled predictions (Pétron et al., 2012; Brown et al., 2014; NASA, 2014).

Public health studies on unconventional gas operations continue to advance in depth, reach and rigour, and each year brings enhanced understanding (see reviews by Werner et al., 2015; Saunders et al., 2018; Hays and Shonkoff, 2016; Haswell and Bethmont, 2016; Deziel et al., 2020). These studies collectively strive to address the challenges involved in measuring complex exposures and risks, assessing impacts and responding to new knowledge.

Studies using chemical risk assessment to predict disease outcomes

Bunch et al. (2014) evaluated potential air pollution impacts associated with shale gas operations in the Barnett Shale region of the United States using routine measurements of a range of volatile organic compounds in over 7500 assessments. They concluded that there was no evidence that any of the assessed compounds posed significant risks to human health. In contrast, assessments of toxic air emissions in Colorado conducted by McKenzie et al. (2012) suggested that people living within 0.8 km of shale gas wells experienced a significantly increased risk of sub-acute non-cancer hazards associated with trimethylbenzenes, xylenes and aliphatic hydrocarbons at levels capable of causing neurological, haematological and respiratory health impacts. This study also suggested a higher cancer risk due to benzene levels among those living closest to the gas wells.

Heart disease

In the same study mentioned above, McCarron (2018) also found a simultaneous rise in hospitalisations for acute circulatory conditions (133%) amid substantial company-reported emissions of multiple chemicals associated with coal seam gas production in Queensland, many of which are known to promote acute cardiovascular events.

McKenzie et al. (2019) observed significant positive associations between the intensity of gas development and production near place of residence in Colorado and markers/predictors of cardiovascular disease, including stiffness of the arteries, elevated systolic and diastolic blood pressure and the presence of inflammatory markers in the blood. Comparing rates of acute myocardial infarctions (heart attacks) and deaths between areas of New York State (where fracking is banned) and Pennsylvania (where it has continued), Denham et al. (2021) quantified significant increases in hospitalisations among middle-aged men and women linked to gas extraction intensity in Pennsylvania. These increases were not observed in New York counties across the state border. For every 100 wells added per square mile, there was a 5% increase in heart attack deaths among resident males aged 45 to 50. Hospitalisations of patients with severe heart failure increased between two- and four-fold at every stage of gas production from pad development, drilling, fracking and production, and to a lesser extent during the production phase for patients with less severe disease in Pennsylvania (McAlexander et al., 2020).

Respiratory disorders

A number of hospitalisation studies have also reported increases in other respiratory conditions among adults living in proximity to oil and gas operations (Apergis et al., 2021). More detailed information has emerged showing strong links with asthma exacerbations and hospitalisations among children. Modelling exposures to airborne chemicals known to be linked to asthma exacerbation and emitted at all stages of oil and gas operations, Buonocore et al. (2023) estimated that 410,000 additional episodes occurred, mostly among American children and 1500 respiratory hospitalisations in 2016 (more details below).

Children living in areas where shale gas mining activities were introduced (by zip code) experienced a 25% increase in hospitalisations due to asthma (OR 1.25 (1.07-1.47)) within 3 months after activity commencement (Willis et al., 2018). Children living in comparable areas without drilling activity did not experience a change in asthma hospitalisations.

Willis et al. (2020) also observed a 59% (confidence interval 46-73%) increase in the likelihood of hospitalisation for asthma among children living in zip codes in Texas with intense unconventional gas extraction activities compared to those with no drilling activities. The increase occurred after, not before, commencement of drilling and was positively correlated with production volumes but not with flaring intensity. Similar findings were reported by Bushong et al (2022) in Pennsylvania, with higher asthma hospitalisation rates associated with higher gas well density.

McCarron (2018) reported a 142% rise in acute respiratory conditions between 2007 and 2014 in the Darling Downs, Queensland, which now has extensive production of coal seam gas (coalbed methane). Hospitalisations, largely constant between 2007 and 2009, climbed steeply from 2010 onwards, simultaneously with sharp rises in gas production and accompanying atmospheric emissions of nitrogen oxides, volatile organic compounds, PM2.5 and PM10, formaldehyde and sulphur dioxides reported by the gas companies and

A number of hospitalisation studies have also reported increases in other respiratory conditions among adults living in proximity to oil and gas operations

published in the National Pollutant Inventory. These data signal the urgent need to further investigate and address co-occurring increases in hospitalisations and pollution emissions (McCarron, 2018).

All-cause mortality and reduced life expectancy

Three landmark studies have been completed in the last three years providing evidence of higher all-cause mortality and reduced life expectancy associated with living in areas with greater exposure to oil and gas developments.

In Oklahoma, Apergis et al. (2021) found that a 1% increase in the number of hydraulically fractured wells is associated with a 4.2% reduction in life expectancy among residents of exposed communities, reflecting positive associations between proximity of residence to wells and deaths due to cancer, cardiovascular disease and respiratory disorders.

Li et al. (2022) investigated the all-cause death rate among 15,198,496 Medicare beneficiaries over age 65 who had lived at least 2 years over a 15-year period (2001 to 2015) in all gas development regions of the United States, for a total of 136,215,059 person-years. They also obtained records of the location, construction dates and production records of over 2.5 million oil and gas wells. They then assessed the intensity of exposure to gas wells (low, medium-low, medium-high and high) of the individuals and whether they lived in postcodes upwind or downwind of wells. Using difference-in-differences methodology (controlling for time before and after gas production activities) and controlling for timing to the onset of illnesses and socioeconomic variables, the study demonstrated a highly statistically significant, linear (dose-dependent) increase in mortality according to intensity of exposure. Furthermore, the increase was observed more strongly among those living downwind, compared to upwind, of gas developments. The increased mortality among those living upwind was suggested

Three landmark studies have been completed in the last three years providing evidence of higher all-cause mortality and reduced life expectancy associated with living in areas with greater exposure to oil and gas developments.

to result from surface or groundwater contaminants; increased traffic, noise, light pollution and lifestyle disruption; and/or shifts in wind direction. The higher mortality rates among those living downwind of wells were suggested to be the result of greater exposure to air pollutants emitted by the wells in addition to the exposures experienced by those living upwind.

Buonocore et al. (2023) applied advanced methodologies to previous estimates of the total health burden of air pollution from the oil and gas industry in the United States in 2016 (Fann et al., 2018). The study used national emissions inventories of PM2.5, oxides of nitrogen, VOCs, ammonia and sulfur dioxide from stages and components of oil and gas processes, including exploration, well pad development, drilling rigs, production, compressor stations, flaring, venting, processing, pipeline transportation and service stations. Highly sophisticated air pollution modelling (CMAQ) was used to model the impacts of these emissions across the continental United States. Census data and hospitalisation, morbidity and mortality data from the Centers for Disease Control and from research publications were used to model health impacts and the contributions of oil and gas emissions relative to other emission sources from natural and human causes. The authors also estimated the costs of health care and the social cost of greenhouse gases based on impacts of climate change on health.

The modelling produced from this extensive national dataset revealed that oil and gas emissions were likely to have caused 7,500 premature deaths, 410,000 asthma exacerbations, 2200 new cases of asthma, 1500 respiratory hospitalisations, 530 asthma emergency department visits, 53 hospitalisations for asthma and 270 heart attacks in 2016. The monetary losses due to oil and gas operations in 2016 from premature deaths and morbidity were estimated at US$77 billion (equivalent to $103 billion in Australian dollars in 2016).

Most of the study limitations identified by the authors were more likely to result in underestimation rather than overestimation of health losses, including, for example, underreporting of levels of non-methane volatile organic compounds and of the number of compressor stations emitting these gases and incomplete inclusion of important air pollutants. In addition, the costs due to mental health issues and productivity losses were not able to be included in the modelling analysis and would likely add substantially to the estimated figures.

Mortality associated with truck traffic

Oil and gas developments in the US have been linked to significant increases in truck movements and in fatal truck-on-car traffic accidents, especially at the hydraulic fracturing stage of extraction (Retzer et al., 2013; Graham et al., 2015; Blair et al., 2017; Xu and Xu, 2020). Using highly sensitive and specific methods to analyse data from North Dakota, Xu and Xu (2020) found that each hydraulic fracturing event on a well was associated with 6,790 one-way truck trips hauling wastewater to disposal sites and an 8% increase in fatal crashes compared to times when hydraulic fracturing had not taken place. Although the rate of traffic accidents per trip in the area did not change, the authors attributed the increase in deaths to the higher volume of truck movements and the higher front end and heavier body structure of trucks associated with servicing the hydraulic fracturing industry.

Oil and gas developments in the US have been linked to significant increases in truck movements and in fatal truck-on-car traffic accidents, especially at the hydraulic fracturing stage of extraction

Graham et al. (2015) proposed that higher levels of road surface degradation known to result from heavy vehicle traffic may also contribute to more accidents and road deaths. The cost of these additional road fatalities was estimated to be US$197 million per year, which greatly exceeded the revenue received by the state from the industry over several years (Xu and Xu, 2020). The higher accident rate also led to increased costs for vehicle insurance in the region.

It should be noted that rates of hospitalisation and death due to transport injuries are already far more common in outer regional (354 hospitalisations and 13 deaths per 100,000 population per year), remote (465 and 19) and very remote (482 and 25) areas of Australia where gas developments are planned, compared to urban (205 and 2.8) and inner regional (313 and 8.8) areas (AIHW, 2023). Furthermore, the risk of being killed is nearly three times higher for Aboriginal and Torres Strait Islander people than non-Indigenous people (Henley and Harrison, 2019; AIHW, 2023).

Evidence of impacts on foetuses and infants associated with their mothers' exposures to oil and gas during pregnancy

Since 2013, there has been an increasing focus on the likely vulnerability of foetuses to environmental hazards experienced by their mothers during gestation. Foetuses are uniquely sensitive to damage, developmental errors and altered hormonal signalling that may be caused by inappropriate chemical exposures in the uterine environment, and the outcomes can be severe. There is a growing understanding of the potential negative impacts of various exposures of the mother during pregnancy on birth outcomes; for example, air pollution (PM2.5) may influence birth weight and preterm births, and chemical exposures (teratogens) through the mother's bloodstream may cause birth defects.

Both pregnancy outcomes and infant and child wellbeing are highly sensitive to psychosocial and community stressors, including mental health stresses on parents, noise, heavy traffic, negative emotions expressed by caregivers, witnessing aggression and conflict (discussed in Section 5.3), and, potentially, fear of pollution.

Therefore, it is not unexpected that negative birth outcomes have been found to be more frequent in pregnancies spent in proximity to gas wells and, very recently, in areas with gas flaring. Several studies have documented lower birth weights and higher incidences of small-for-gestational-age and preterm births associated with mothers' exposure to gas operations in both the US and Canada (Hill, 2018; Whitworth et al.,2017; Caron-Beaudoin et al, 2021; Cairncross et al., 2022). Some of these studies are described below.

Measured pre-natal risks associated with maternal exposures to gas operations

Three conditions of pregnancy that can affect birth outcomes have been shown more frequently in pregnant women living closer to active gas well, namely antenatal depression and anxiety (Casey et al., 2016; 2018; 2019; Akers et al., 2022), hypertension (5% increase) and pre-eclampsia (26% increase) (Willis et al., 2022).

Negative birth outcomes include:

- Reduced average birth weight and small for gestational age (Stacy et al., 2015; Currie et al., 2017; Hill, 2018; Deziel et al., 2020; Hill and Ma, 2020; Tran et al., 2020; Willis et al., 2020; Caron-Beaudoin et al., 2021; Cairncross et al., 2022);
- Higher incidence of low-birthweight babies (Currie et al., 2017; Hill, 2018; Hill and Ma, 2020);
- Higher frequency of pre-term and extreme pre-term deliveries and spontaneous abortions (Casey et al., 2016; Hill et al., 2018; Whitworth et al., 2018; Cushing et al., 2020; Deziel et al., 2020; Hill and Ma, 2020; Gonzales et al., 2020; Caron-Beaudoin et al., 2021);
- Birth defects, including congenital heart valve defects, anencephaly, spina bifida and gastroschisis (McKenzie et al., 2014; Janitz et al., 2019; Tang et al., 2021; Cairncross et al., 2022; Willis et al., 2023; Gaughan et al., 2023; Han et al., 2023);
- Higher incidence of blood cancers, especially acute lymphoblastic leukemia (Werner et al., 2016; 2018; McKenzie et al., 2017; Clark et al., 2022).

All these outcomes can be caused by chemical exposures of mothers during pregnancy and can have lasting impacts on future health. Preterm birth is associated with infant mortality and long-term health problems, and lower birthweight, even within the normal range above 2.5 kilograms, is associated with a higher risk of type 2 diabetes and cardiovascular and renal disease (Barker, 2006).

Confirming previous studies suggesting an association between birth weight and exposure to unconventional gas mining mentioned above, Currie et al. (2017) found a 25% increased risk of low-birthweight infants among mothers living within 1 km of a hydraulically fractured well, and smaller but detectable elevated risks at 2 and 3 km 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 carries significant implications for their subsequent health.

Detailed studies by Hill (2018) using difference-in-differences methodology controlled for a wide range of relevant maternal and geographical characteristics when examining birth weight outcomes of infants of mothers living within and beyond 2.5 km of one or more shale gas wells in Pennsylvania. This work showed a 7% increase in the frequency of low birth weights, a 5 g reduction in average full-term birthweight and a 3% increase in preterm births for each well located closer than 2.5 km. This affect was only observed for residence near active wells during pregnancy.

Further work has indicated that unconventional gas mining is also associated with increased risk and severity of preterm birth, especially when exposures to oil and gas extraction activity occurs in the first trimester of pregnancy (Whitworth et al., 2018). Similarly, Gonzales et al. (2020) found an 8-14% increase in the odds of delivering at less than 31 weeks associated with high exposure to well sites among Hispanic and Black women.

Cushing et al. (2020) specifically examined the association between gas flaring and birth outcomes, identifying increased odds of pre-term birth (OR 1.50; 95% CI 1.23-1.83) and shorter gestation (OR -1.9; 95% CI -2.8 to -0.9) among Hispanic women living in places with high levels of nightly flaring compared to those without such exposure. No trend was observed for non-Hispanic white women. The authors suggested that the greater vulnerability of Hispanic women to these circumstances may have been related to higher stress levels, a phenomenon that has been observed with exposures to other air pollutants, such as PM2.5 (Westergaard et al., 2017).

Higher incidence of severe birth defects

A regional study of 124,832 infants in Colorado reported positive links between the incidence of congenital heart defects (and possibly of neurotubular defects) and increasing number of shale gas wells within 10 miles (16 km) of residence in the infant's birth year (McKenzie et al., 2014). Low birth weight, in contrast, was negatively correlated with numbers of wells in this study.

More recently, Tang and colleagues (2021) found significantly (up to three times) higher frequency of infants born with anencephaly (missing large parts of the brain and skull structure), spina bifida (defective spinal cord), gastroschisis (where intestines are located outside the body at birth), and aortic valve and pulmonary valve defects (narrowed or blocked) when the mother lived near gas wells during pregnancy. In Canada, Cairncross et al (2022) examined 34,873 pregnancies in rural Alberta. After controlling for multiple variables, they found a 31% increase in major congenital abnormalities and a 12% increase in small-for-gestational-age babies among those whose mothers lived within 10 km of a hydraulically fractured well. Note that this study suggests the presence of an effect at a substantially farther distance from gas operations than previously recognised. Willis et al. (2023) examined 86,315 congenital anomalies among 2.2 million births in

… it was estimated that 29,000 infants born in the United States each year were at increased risk of low birth weight, which carries significant implications for their subsequent health.

Texas. Interestingly, they found that the increased odds of any anomaly associated with gestational residence within 5 km of unconventional gas wells (OR 1.20; 95% CI 1.17–1.23) and a produced water holding site (OR 1.17; 95% CI 1.14–1.20) were greater than for oil wells (OR 1.08; 95% CI 1.04–1.12).

In 2023, Gaughan et al. added substantial weight to these studies with a detailed analysis of 965,236 live birth records in Ohio. These researchers found a 13% increase in the presence of any birth defect (CI 0.98–1.30 95%), a 57% increase in neural tube defects (CI 1.12–2.19 95%), a 99% increase in defects to the limbs (CI 1.18–3.35 95%) and a 93% increase in spina bifida (CI 1.25–2.98 95%) associated with living within 10 km of an active oil and gas well. Han et al. (2023) identified increases in some heart defects and total birth defects associated with annual gas production in several counties across Texas.

Increased incidence of and hospitalisations for blood cancers and asthma

Higher rates of childhood hematologic cancers among children living close to oil and gas developments compared to those in areas without such developments have been observed in shale gas producing regions in the United States (McKenzie et al; 2017). Similarly, Werner et al. (2016) reported higher hospitalisation rates for children with cancer (9% higher; 95% CI 2–16%) and blood/immune diseases (14% higher; 95% CI 2–27%) 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 production activity was associated with significant increases in hospitalisations for respiratory diseases among very young (0 to 4 years) and 10- to 14-year-old children (ranging from 7 to 11% higher) and a 467% increase in blood/immune diseases among 5- to 9-year olds, when compared with children in areas without coal seam gas mining (Werner et al., 2018).

Two additional studies examined whether children growing up near unconventional gas wells are experiencing greater incidences of cancers, including acute lymphoblastic leukemia (McKenzie et al., 2017; Clark et al., 2022). This severe disease causes painful and frightening symptoms, and treatment requires hospitalisation and extensive chemotherapy over a long time period. In Colorado, McKenzie et al. (2017) reported a 4.3-fold (95% CI 1.1–16) increased odds of having lived within 16.1 km of 33 or more active gas and oil wells among 5- to 24-year-olds with acute lymphoblastic leukemia compared to controls with other types of cancer.

Consistent findings were reported in Pennsylvania by Clark et al. (2022). Also using a registry-based case control design, this research revealed a 2.35-fold (95% CI 0.93–5.95) increase in the odds of developing the disease among children aged 2 to 7 whose mothers had lived within 2 km of at least one gas well during the period from three months before their conception to their birth, compared to age-matched children without any cancer. Furthermore, this work used a measure called a "[ground]water-pathway specific metric" linked to the home address. The results supported the hypothesis that chemicals contaminating the groundwater are involved in the disease pathway.

Studies of longer-term impacts, such as the likelihood of developing adult cancers and chronic diseases, are limited to date because not enough time has elapsed since the beginning of potential widespread exposure to gas activities for these diseases to arise. Remarkably, it has taken just over two decades of unconventional gas development in the United States for more than 17.6 million Americans to be located within a mile of at least one oil or gas well.

Summary

Taken together, many studies reviewed here have identified significantly higher frequencies of health and developmental problems associated with living close to unconventional gas wells and other production activities that are potential sources of exposure to damaging chemicals (Werner et al., 2015; Dezeil et al., 2020). Some have provided evidence of causation via polluted water, and some have modelled already known effects of known pollutants emitted via the air. Others have identified known hazards that we don't yet have research methods to understand and quantify.

As a body of research, this evidence provides a compelling case for direct harms of the oil and gas industry across the lifespan on individuals – from foetal development, to infancy and childhood, to young and pregnant women to adulthood and elderhood. Pre-birth and childhood impacts, and impacts on mothers, fathers and extended family members, can have whole of life consequences. The complex diversity of chemicals and modes, timing and patterns of possible exposures and the added influence of varying social, emotional, economic and spiritual stressors would be expected to produce a diversity of findings and outcomes across studies. With Australia's substantially smaller pool of public health researchers and resources, it is difficult to imagine research of this scale and magnitude to be possible to reveal how communities are impacted should a major American-style industry be established here.

This section highlighted the three outstanding studies that have substantially increased our understanding of all-cause mortality (7500 premature deaths) and the enormous health losses and economic costs (AUS$103 billion dollars per year) associated with air pollutant emissions from a mature oil and gas industry (Li et al., 2022; Apergis et al., 2021; Buonocore et al., 2023). While morbidity and mortality are higher in heavily developed oil and gas regions, the analysis also demonstrated the spread of ozone, PM2.5 and oxides of nitrogen from these regions to others, including into neighbouring states. Another critical factor not included is morbidity due to deteriorating mental health, which has been less extensively studied.

There are more critical health impacts that have not yet been included in large modelling studies so those so far are underestimations. These include morbidity and decreased productivity to the loss of psychosocial wellbeing and mental health, which has not been as extensively studied but described in the next section. Furthermore, the contribution of oil and gas developments and the leakage and combustion of their products to the acceleration of climate change has vast health implications.

The strengths and challenges of this body of literature, along with other studies reviewed in this Report, are discussed in Section 6.

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5.2 Global and local psychological, social and mental health impacts

Mental health is of enormous importance to Australia's national wellbeing. Climate change and fossil fuel projects, including gas and oil developments, impact on mental health causing decreases to productivity and overall health. In this section we outline the major losses we currently face from poor psychosocial wellbeing and mental health within the overall health burden and loss of productivity of Australia. The rising importance and mixed emotions that arise from climate anxiety are briefly identified, not only due to fear of the consequences of climate change but also due to the moral injury caused by governments that are still rapidly expanding oil and gas developments despite pleas from the world's people to stop.

The section then looks specifically at the plethora of psychological, social stresses and losses experienced by people and communities living in the midst of the oil and gas industry. Brief descriptions of the local and regional impacts of the pre-development, the brief boom and the production phases involved in oil and gas expansions are provided from research studies. This is followed by an overview of studies that have measured associations between oil and gas developments and mental health in the community, in adults and in one study with adolescents.

This is the first of three Sections that focus on the losses experienced among those impacted directly and indirectly from oil and gas development of social, emotional, cultural and spiritual wellbeing. It is important to note that impacts described are ***additive and compounding*** – that is, these stresses are occurring in addition to the risks of chemical exposures through air, water and food, of loss of ecological values, water quality and security, and of unabated climate change progression.

These stressors and resulting poor mental health most likely contribute significantly to illnesses, such as asthma exacerbations, respiratory and cardiovascular emergencies and impairment of infants' healthy start to life. The stress of dealing with these health crises feeds directly back onto the mental health burden carried by the family.

Section 5.3 examines further burdens borne by Aboriginal people from expansive oil and gas development and Section 5.4 highlights the serious known risks to safety of women and children from major FIFO development.

Burden of mental ill health in Australia

Loss of personal, family and community wellbeing and poor mental health makes an enormous impact on the health of the Australian population, both directly and indirectly. An estimated one in five Australians (20%) experienced anxiety, depression and/or substance use disorders in 2020/21 (Australian National Mental Health and Well-being Survey, ABS, 2022). Together, the health burden of dealing with a mental illness (for example anxiety, depression and substance abuse) and musculoskeletal disorders (back pain) contributed almost equally to 48% of Australia's total (non-fatal) health burden in 2018 (AIHW, 2021). Furthermore, the leading cause of death among 15–24 year olds and 25–44 year olds between 2019 and 2021 was suicide, which is at least twice as frequent among young Aboriginal and Torres Strait Islander Australians than among non-Indigenous young people (AIHW, 2023). Suicide was also fifth leading cause of death among children aged 5 to 14 years.

The Productivity Commission (2020) estimated the total economic cost of mental ill health and suicides in Australia at $200 to $220 billion per year, with direct costs of $16 billion for mental healthcare and support services and $39 billion in productivity losses due to reduced employment opportunities, absenteeism and presenteeism. Rural and remote areas are particularly underserviced, for example less than 2% of Northern Territorians outside Darwin and Alice Springs and 3% of people living in rural and remote areas of Queensland accessed mental health services in 2016. Suicide rates between 2013 and 2017 tended to be higher in remote areas (twice the national average). Beyond these figures, there is an additional largely unquantified burden from loss of psychosocial wellbeing which is not measured, either because it does not meet mental illness criteria, no services are available or the person does not access help.

Climate anxiety among Australian youth: Oil and gas development as a moral injury

Of particular importance to this discussion, but largely ignored so far in national studies, is the growing evidence of climate anxiety with emotions of worry, fear, anger, grief, despair, guilt and shame that often impact on their daily lives (Wu et al., 2020; Hickman et al., 2021). These feelings are especially prevalent among children and young people, who may struggle to see their future in a climate changed world.

The results of a survey answered by over 3,000 Victorians and 700 Victoria healthcare professionals (Sustainability Victoria, 2020) reported that:

> *The health impacts of climate change are more front-of-mind for young people and this demographic is potentially at higher risk of developing climate change-related mental health conditions. Around half of young Victorians report extreme feelings of frustration, fear, sadness and outrage. Also of note is that four out of five healthcare professionals (79 per cent) report feeling "overwhelmed" when thinking about the future impacts of climate change.*

A similar survey by Mission Australia found that 67% of Australian youth are concerned about climate change, with 26% feeling very or extremely concerned (Gao et al., 2023). This 26% also experienced substantially more concern about their ability to cope with stress, lower personal wellbeing and mental health conditions, compared with their peers who were less concerned about climate change.

Many young people feel a deep sense of betrayal from government inaction and failure to take the necessary urgent steps to protect their future (Hickman et al., 2021). In Australia, this is best demonstrated by continued plans to expand, rather than contract, fossil fuel developments when scientists globally (IPCC, 2021) and the UN Secretary General António Guterres are calling for rapid cessation of new fossil fuel projects at a time of climate crisis:

> [This is] *code red for humanity… greenhouse gas emissions from fossil-fuel burning and deforestation are choking our planet and putting billions of people at immediate risk, and many of the changes are becoming irreversible.*

In the British Medical Journal, Rao and Powell (2021) state:

> *For the eco-anxious, more concerning than even this apocalyptic news is the extraordinary level of indifference and banality with which the climate crisis is treated by many others, including those in positions of influence.*

Hickman et al. (2021) calls such actions 'moral injury' – akin to stoking a fire in a burning house – and a critical contributor to the high prevalence of climate anxiety identified in their global survey:

> *By endangering and harming fundamental human needs, the climate crisis is also a human rights issue. Legal bodies recognise an intersection between human rights, climate change, and climate anxiety. Subjecting young people to climate anxiety and moral injury can be regarded as cruel, inhuman, degrading, or even torturous.*

Local and regional psychosocial stressors from oil and gas developments

Beyond the inter-generational mental health impacts of continuing expansion of new fossil fuel developments, there is also a wide spectrum of local and regional impacts of gas developments on psychosocial and mental health, including and especially of children and young people. While not as extensively examined as direct physical health impacts, there are many avenues, in addition to climate anxiety discussed above, through which both immediate and distant exposure to the unconventional gas industry has been linked to increased stress, feelings of disempowerment and negative impacts on mental health and wellbeing (Adgate et al., 2014; Hossain et al., 2013; Ferrar et al., 2013; Powers et al., 2014; Kriesky, 2012; Morgan et al., 2016; NSW Parliament, 2012; Sangaramoorthy et al., 2017; Lai et al., 2017; Fisher et al., 2018; Hirsch et al., 2018). Very little work has explored experiences and impacts of these developments on young people.

Australian studies predominantly relate to coal seam gas extraction in the Western Downs of Queensland, while US studies relate to shale gas developments; both settings mostly impacting farmers and previously small and relatively quiet communities. Importantly, there is a significant further literature that examines sociological change, power imbalance, social license and attitudes to gas developments in the US and Australia that is not included in this review. This information builds theoretical understanding of the trends discussed below.

Three phases of gas development

To assist in understanding these impacts, the characteristic events and impacts that occur during the three phases of oil and gas developments are described. Shared features across the whole experience are then discussed in the next subsection.

The experience of communities affected by gas developments is often described as three phases, prior to and preparation for development, the construction or boom phase and the post-boom phase, a typical pattern for resource extraction undertaken in non-urban areas.

Prior to commencement, impacts on individuals and communities 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 (Moffatt and Baker, 2013; Hirsch et al., 2018). This has been observed in many communities in New South Wales, including places where gas developments did not progress (the Northern Rivers, Gloucester, Helensburg, Medowie) and in Narrabri and the Pilliga Forest where it has progressed despite substantial community opposition. Feelings often intensify as seismic surveys and exploration begins, noise increases and social hazards associated with disruptions to the local social fabric become apparent and communities come to realise the extent of change ahead.

Box 5.2.1 provides an insider perspective from a rural psychiatrist, Dr Steve Robinson, on how intense the impacts of the threat of a gas development and commencement of exploration wells were in an otherwise close-knit rural community. Multiple chronic mental health risks can be identified in his account, namely anxiety, uncertainty, confusion, secrecy, division, conflict, property damage, loss of peace and quiet, noise, loss of place, loss of identity as a community, loss of financial security and assets, loss of dreams and aspirations, insecurity, poor employment outlook, strangers and fear. His submission to a Senate Select Committee Inquiry on Unconventional Gas Mining (Parliament of Australia, 2016) also emphasises how the additional distress leads to recurrences of mental illnesses among the most vulnerable in the population, including depression and anxiety. Dr Robinson also highlighted some new cases of depression among those who had not been previously affected, particularly associated with "stresses that continue for a very long time, involving a powerful opponent and having no apparent solution promote feelings of helplessness and hopelessness". In addition, he observed occurrences of "angry outbursts, single episodes of antisocial behaviour and interpersonal disharmony" and highlighted the tremendous sense of injustice felt by residents.

BOX 5.2.1: CASE STUDY: A rural psychiatrist/resident perspective

An excerpt from a submission to the NSW Parliamentary Enquiry on Coal Seam Gas by retired psychiatrist, Dr. Steve Robinson, describes an insider's experience with his own community in the Hunter Valley when the CSG exploration began.

"Exploration is when the psychological stresses are first noticed in the community. Exploration maps are placed in the local newspaper but they are difficult to decipher and individual landholders are not notified. This uncertainty starts to generate community anxiety. Some individual landholders are approached and offers are made mostly for access but with agreements that include confidentiality clauses. Individuals don't know if they are being treated fairly.

The community starts to divide between the few who see it as an opportunity for an additional income and the larger number who hear the risks and see little in the way of benefits. The local council has a sharp pro-mining versus anti-mining divide leading to a spill of one mayor. The letters page in the local newspaper has amply echoed this divide for the past 5 years.

Seismic surveys come and go with some damage to paddocks, heavy vehicle traffic ruining country roads, and noise. Drilling occurs with the same complications. The town takes on a different look with mining vehicles being prominent and drilling teams from interstate coming and going. The visual impact is slowly increasing.

A few properties are purchased for good prices, other houses close-by cannot be sold and their value drops. Lifetime plans are put on hold or cancelled. Property development in the area declines as a result of the general uncertainty. Rental property is more expensive. The tourism industry is threatened and wealthy prospective city retirees look to other beautiful areas not impacted by mining. The gas company employs very few locals.

Exploration wells are fracked to optimize the flow and the wells are flared for months. There is no explanation of the risks and precautions taken in these fracking and flaring operations. There is no publicity given to any air or water testing. There have been at least two separate unpredicted explosions locally due to gas migration known to the community from just a dozen exploration wells and even more dramatic events elsewhere from gas mining. This results in understandable anxiety about safety risks. [This community is in] this first phase has taken 5 years so far and production has yet to commence."

https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Gasmining/Gasmining/Submissions

Aboriginal communities may feel disempowered and voiceless when they have not been afforded the right to prior, free and informed consent and to prepare themselves to witness industrialisation of their Lands, more truck movements, and people coming onto their Country (Jumbunna Institute for Indigenous Education and Research, n.d.). Section 5.3 explores this further.

Once decisions are made, the construction (or boom) stage begins. In the 'boom' phase, tight-knit communities can feel inundated with strangers coming in, taking the new jobs, disrupting housing affordability and availability and burdening health and other services (Hossain et al., 2013; Hirsch et al., 2018; McTaggart et al., 2018; Carrington and Periera, 2011). Crime and intimate partner abuse may also increase (Carrington et al., 2011; Lockie, 2011; Bartik et al., 2017; James and Smith, 2017; Ruddell et al., 2014). Several studies have linked the male domination of the mining industry to the promotion of patriarchal culture which marginalises and isolates women and enhances their vulnerability to subordination and abuse (Sharma and Rees, 2007).

Such impacts are detrimental to the social cohesion and for some, the moral character, of the community (Moffatt and Baker, 2013; Sangaramoorthy et al., 2017; Lai et al., 2017; James and Smith, 2017; Fisher et al., 2018; McTaggart et al., 2018). Attempting to deal with conflict, loss of social cohesion and added stress burden of these changes has been associated with increase substance abuse and domestic violence (Measham et al., 2016). Increases in domestic violence and adult substance abuse are adverse childhood experiences with strong evidence of links to poorer long-term mental health and functional outcomes (Mathews et al., 2023).

Several authors have identified increased incidence rates of sexually transmitted infections, chlamydia and gonorrhoea, which they attribute to changes in sexual behaviour that can be associated with mobile workers coming in to depressed areas (Mabey and Mayaud, 1997; Komarek and Cseh, 2017; Deziel et al., 2018). While this may reflect partnering and consensual or commercial sexual relations, it could also be influenced by increased risks of sexual violence and disempowerment of women associated with the large influx of men into oil and gas development regions as discussed in Section 5.4.

The New South Wales Parliament Legislative Council Inquiry into Coal Seam Gas (2012) found widespread concern about coal seam gas developments in rural, urban and indigenous communities. Submissions from the public described concerns about poor behaviour by coal seam gas companies and contractors, the pace of development and fear of loss of land and livelihood.

In the post-construction phase, jobs may decline and housing demand drops. Production, gas and oil transport through pipelines with compressor stations every 50 to 100 kilometres and, as local processing continues, with drilling and fracking, with its 24-hour lights, flaring, noise, privacy invasion, odours, tree clearing and truck movements –all cause 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 (Lai et al., 2017; Sangaramoorthy et al., 2017; Hirsch et al., 2018). This phase may continue for years as a long-term feature of the industry's constant and visible impact on the community, for some a constant reminder of what they have lost (Willow, 2014; Eaton and Kinchy, 2016; Richard and Slagley, 2019).

The literature on employment in mature (post-boom) communities in shale gas regions of the United States shows mixed results. Some studies observe no measurable impact on employment, while others report modest gains (Jacquet et al., 2018; Hoy et al., 2018). Notably, an in-depth comparison of employment between counties in Pennsylvania with substantial drilling of the Marcellus shale and New York State which banned shale gas development, analysis observed an increase in employment in construction and resource sector, but an equivalent decrease in employment in the manufacturing sector after, but not before drilling began. Thus, there was no statistically significant net change in employment linked to the gas operations over 12 years (Cosgrove et al., 2015). While Komarek (2016), reported an early increase in total employment and wages of 7% and 11% in the Marcellus drilling region, this lasted for three years and then declined markedly.

There are a host of additional studies demonstrating sociological and economic impacts of mining on communities. Hajkowicz et al. (2011) compared selected quality of life indicators including socio-economic factors, communications, housing, education, employment and life expectancy of 71 local government areas with national indicators. Their study found that mining towns scored higher on these indicators, however, they did not suggest that their study demonstrated a causal relationship. They also pointed out they did not consider indicators related to health, family life, sense of community or the impact of FIFO – Fly In Fly Out work on aspects such as alcohol and drug misuse, and family violence and breakdowns. These impacts on whole communities have been described as 'collective trauma' (Perry, 2012, Hirsh et al, 2018). Conversely, the conditions of FIFO work, stress on relationships and the feeling of being an outsider also has negative consequences on oil and gas workers' mental health (Hirsch et al., 2018).

A few questions included in a survey by Australia's Commonwealth Scientific and Industrial Research Organisation of 390 residents across five communities impacted by coal seam gas extraction in Queensland may have reflected those critical aspects of community wellbeing (Walton, McCrea and Leonard, 2016). The key question among many asked was how they felt their community was coping with the industry and found that nearly half (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' (Walton et al., 2014). Similar findings were revealed when the survey was repeated in 2016; 51% reporting 'only just coping' or worse.

Specific changes highlighted by the authors were the significant drop in community attitudes towards 'employment and business opportunities' that dropped as economic activity declined within the two year interval, 2014–2016. While personal safety, community wellbeing and community spirit, cohesion and trust scored highest in both surveys, communities repeatedly scored environmental management, planning and leadership, being informed, having a voice and trust in the coal seam gas companies and state government scored lowest in both surveys.

Within the same Queensland region, Marcos-Martinez et al. (2019) observed a 7% increase in household income associated with coal seam gas development compared to areas without development. However, they observed no difference in employment levels between the areas and no evidence of the so-called 'indirect employment multiplier effect' even in the early phase of coal seam gas development.

Overall, while the 'boom' phase may appear to bring some positive social change to residents seeking employment opportunities, impacts on residents are uneven and most feel uncertainty in how communities will cope with the post-construction phase (Rifkin 2015; Walton et al., 2014).

Solastalgia, loss of place and disempowerment

Disturbance of place attachment as a result of the sprawling industrial footprint of unconventional gas development may contribute to the condition of solastalgia – an intense longing for lost environmental qualities of a place that previously had deep meaning to one's sense of identity and continuity of past, present and future possibility. This mental health vulnerability comes from Glenn Albrecht (2005) who named and described the concept of 'solastalgia' after examining the impact of open cut coalmines in the Hunter Valley. Albrecht defined 'solastalgia' as:

> *the pain experienced when there is recognition that the place where one resides and that one loves is under immediate assault … a form of homesickness one gets when one is still at 'home'.*

Solastalgia as a specific and important form of wellbeing loss has received increasing attention in the literature (Lai et al., 2017; Sangaramoorthy et al., 2017; Huth et al., 2017) and was recognised in Queensland Health's small project in coal seam gas regions in 2013.

Working with residents impacted by open-cut coal mines in the Hunter region of NSW, Connor, Albrecht, Higginbotham, Freeman, Smith and others (2004) established the critical importance of sense of place and belonging, and the reality of deep distress and sense of powerlessness that results from the loss of place. The team developed the Environmental Distress Scale (Higginbotham et al., 2007) to help measure levels of distress.

The work of this team also identified the critical importance of promoting recovery from solastalgia through taking protective and restorative environmental action. This approach, which includes exercising the right to protest against environmental damage has also been endorsed by many researchers as a method of coping with climate anxiety and distress from environmental damage available to young people, parents and all citizens (Hickman et al., 2016; Ogunbode et al., 2022).

Using the Environmental Distress Scale developed by Higginbotham et al (2006), Elser and colleagues (2020) reported significant concerns among a sample of West Texas residents about foul-smelling air, heavy vehicles, noise, vibrations, loss of cultural heritage and environmental damage affecting future generations. Nearly 50% of respondents report symptoms of solastalgia – worries about polluted air, water and scenery (Elser et al., 2020).

An ethnographic analysis of the impact of the oil and gas industry in Bradford, Pennsylvania by Simona Perry (2012) of Rensselaer Polytechnic Institute revealed the profound loss felt by the community as captured in a focus group with community members:

> *They expressed the feeling that the shale gas industry had forever altered the connections they had with their family histories, childhood memories, their lands, their neighbors and communities, the past, and the present. These sentiments were expressed by everyone interviewed regardless of their opinions about whether the shale gas developments were having an overall positive or negative impact in the county. As one landowner put it, "That's why we're feeling this death-feeling because change is a-coming. It's like you want to hold onto it and you know it's not going to be there…. one participant noted, "the dread I feel in the pit of my stomach" in slowly realizing as they talked about the photographs they had taken and what was most important to them—their land, their water, their farm, their children's health—that those things could so easily be destroyed forever, and made the comment, "It feels like we're losing our love. The things we love the most may be taken away. That's what we're all saying with this.*

Disempowerment, vulnerability (loss of safety) and deep loss is also a dominant theme through this literature. Willow (2014) provides a powerful analysis of the consistency of these feelings shared between First Nations Canadian Anishinaabe peoples who suffered massive deforestation and mercury contamination of their land and waters, Yonngom people living downstream from the environmentally disastrous Ok Tedi mine in New Guinea and White middle-class people who became anti-fracking activists in Ohio felt devastated by the immense change brought by shale gas development. The author states:

> *For Ohioans who oppose shale energy development, landscapes that until recently provided the promise of sustenance, stability, renewal, and relaxation have, in the face of apparently uncontrollable and unknowable environmental changes, been replaced by landscapes of disempowerment and vulnerability.*
>
> (Willow, 2014).

Reflecting on a protest in Mexico saying 'we are all Indigenous', the author states:

> *When they evoke the analogy of the miner's canary— the caged bird that alerts coal miners to the presence of poisonous gasses—Native North American scholars convey a similar message: While indigenous people may be among the first to suffer, the devastating results of environmental degradation are certain to spread.*
>
> (Weaver 2010; as cited in Willow, 2014).

Another qualitative study was conducted with rural people in Saskatchewan and Pennsylvania who remain quiet and elect not to take action against the unwelcome changes brought by gas developments (Eaton and Kinchy, 2016). Residents of both locations raised many grievances, but many struggled with the notion that 'progress' requires social, environmental and health sacrifices. They felt that they had to accept the negative impacts that upset them

Solastalgia … the pain experienced when there is recognition that the place where one resides and that one loves is under immediate assault … a form of homesickness one gets when one is still at 'home'.

as part of perceived benefits to their region, and hence felt they had no right to protest. Others felt powerless against the dominance of the industry, while others vented through individual action, such as voicing complaints to show their anger and opposition. However, those residents felt unable to unite and seek greater control over their situations through collective coordinated action.

The author recorded a quotation from an elderly multi-generational landowner in Pennsylvania:

> *It's changed from being a rural area to being a semi-industrial area. Especially when you are on the roads….I just [feel] like, wow, they've – they've taken this over, this is no longer ours. …This is not ours anymore.*

Urging more emphasis on listening to communities which do not openly protect against the industry, the authors concluded:

> *At times our interviewees expressed profound feelings of powerlessness, seeing their mere selves as structurally ineffective against the corporate oil and gas industry, and the distant and bureaucratic power of the state.*

Antecedents and associations with clinically diagnosed mental health disorders

Thus, substantial evidence has identified that all phases of gas development can bring disempowerment and loss to community residents. This includes those with initial high hopes disappointed by a lack of perceived long-term opportunities, those who unsuccessfully resisted the industry and those impacted by the loss of loved ecological qualities of their environment. These feelings of disempowerment and solastalgia, especially when constantly reminded of the changes brought by the industry, may in turn exacerbate the risk of clinical depression and anxiety and suicidal ideation (Moffatt and Baker 2013; Morgan et al., 2016; Hirsch et al., 2018).

Malin (2020) analysed 75 in depth interviews with people living in areas of intensive gas production in Colorado. She reported that the ***industrialisation of communities caused people chronic stress, negative mental health outcomes and depression***. Many people spoke in depth about the stress of uncertainty regarding risks and impacts on their health [as verified by research], feelings of powerlessness in the face of extensive environmental change and lack of trust in government regulations and monitoring.

In southern Queensland, 239 landholders, community and service representatives from 12 communities attending workshops discussed their lived experience with psychosocial, health service, housing and financial stressors and negative mental health impacts with coal and coal seam gas extraction (Hossain et al., 2013). Most alarming was a sense of disempowerment, isolation and pessimism. Participants urged greater protection of mental health and increased psychological services.

The suicide of an Australian farmer in 2015 who, according to a family statement (Bender family, 2015), resisted pressure and experienced the consequences of unconventional gas operations and underground coal gasification on his farmland for over 10 years adds gravity to the findings of these studies. This death stimulated the abovementioned national Senate Select Committee Inquiry on Unconventional Gas Mining (Parliament of Australia, 2016; Box 5.2.1) but, after an interim report, the Inquiry was suspended due to the 2016 Australian election and the Inquiry was not completed.

The Australian Office of the Chief Economist (2015) expressed concerns about the stress and anxiety experienced by farmers who are forced to accommodate coal seam gas operations on their land and workplace. Augmenting the Edinburgh Farming Distress Inventory to include stressors linked to CSG mining, Morgan et al. (2016) confirmed these concerns. Their work found that a significant proportion of farmers surveyed had many concerns, not only about the direct impact of CSG operations on their farming business (on farm concerns), but also larger worries about deteriorating community values, threats to their health and the future of their children (off-farm concerns). These worries contributed significantly to overall stress burdens and odds of experiencing depression and anxiety, especially among farmers directly affected by mining activities.

…industrialisation of communities caused people chronic stress, negative mental health outcomes and depression … spoke in depth about the stress of uncertainty regarding risks and impacts on their health … feelings of powerlessness in the face of extensive environmental change and lack of trust in government regulations and monitoring.

There have been only three studies which have examined possible direct links between proximity to oil and gas operations and mental health disorders. Casey et al. (2018) explored relationships between disordered sleep and symptoms of depression and proximity to active oil and gas wells in Pennsylvania. These authors found an 18% increase (4–34%) in the likelihood of experiencing symptoms of depression among those living in close proximity to both larger wells and greater numbers of unconventional gas wells in Pennsylvania. However, no associations were observed for disordered sleep. Casey et al. (2019) further explored whether anxiety and stress among pregnant women associated with living near oil and gas wells might be associated with adverse birth outcomes such as described in Section 5.1. While this study did again demonstrate a higher (4.3%, 1.5–7%) frequency of anxiety and depression among pregnant women living close to oil and gas wells, no relationship between these presentations and adverse birth outcomes was observed (Casey et al., 2019). However, childhood mental health outcomes are known to be impacted by prenatal depression and anxiety, with increases in childhood anxiety disorders and behavioural problems with attention and aggression (Park et al., 2014; Donnici et al., 2021).

In perhaps the only epidemiological study of mental health impacts on young people of living in high intensity oil and gas regions, Gorski-Steiner et al. (2022) observed a 15% (6–25%) increased likelihood of experiencing new onset internalising disorders among females living near high intensity, compared to low intensity, oil and gas operations. Internalising disorders include anxiety and depression, and associated experiences of distress, social withdrawal, loss of interest and fatigue.

These impacts are particularly important when considering the potential psychosocial and spiritual impacts of unconventional gas developments on Aboriginal people and communities.

Clearly there is insufficient literature which understands these multiple, complex and often profoundly negative impacts of life within oil and gas production regions from a mental health and wellbeing perspective. Most of the research done has considered these stressors as social impacts, rather than health concerns with significant implications for both physical and mental health. Furthermore, while there is a wealth of information on psychosocial stressors, there is extremely little literature on how these stressors impact on the mental health and wellbeing, aspirations and life opportunities of young people. This impact stretches from the immediate environment where extraction is occurring to global harms to the wellbeing of young people.

These impacts are particularly important when considering the potential psychosocial and spiritual impacts of unconventional gas developments on Aboriginal people and communities. While there are no research publications to date, many Aboriginal and Torres Strait Islander people are leading efforts to protect the environment and health in the face of challenges from gas developments and climate change (See Section 5.3).

Summary

To summarise this literature, unconventional oil and gas developments have been associated with:

- **Mental health conditions – Depression and anxiety (Casey et al., 2018; 2019; Hirsch et al., 2018) and new onset of internalising disorders (anxiety, depression, social withdrawal, fatigue) among adolescent females seeking treatment in Pennsylvania (Gorski-Steiner et al., 2022)**
- **Demoralisation and anxiety that the government is not transitioning away from fossil fuels despite the climate imperative (Hickman, 2021; Sustainability Victoria, 2020; Ogunbode et al., 2022).**
- **Distress and division within and between families and communities who support and are opposed to oil and gas developments (Ferrar et al, 2013)**
- **Disempowerment, loss of control, hopelessness, loss of livelihood, loss of belonging and isolation, particularly of women (Sharma and Rees, 2015; Kriesky 2012; Perry, 2012; Moffatt & Baker, 2013; Hossain et al., 2013; Eaton and Kinchy, 2016; Lai et al., 2017; Fisher et al., 2018)**
- **Crime and loss of moral character of community (Carrington et al., 2011; Carrington and Periera, 2011; Sharm and Rees, 2015; Sangaramoorthy et al., 2016; James and Smith, 2017)**
- **Solastalgia and anxiety from destruction of nature, farmlands and industrialisation of landscapes, loss of identity (Albrecht, 2005; Connor et al., 2004; Willow et al., 2014; Morgan et al., 2016; Elser et al., 2020)**
- **Disturbances from lights, noise, traffic, reduced property values, fear of future (Allhouse et al., 2019; Richburg and Slagley, 2019)**
- **Traffic and pedestrian injuries and fatalities (Retzer et al., 2013; Graham et al., 2015; Blair et al 2017, Xu and Xu, 2020).**
- **Local, regional & broader unfavourable economic changes, boom bust cycles (Walton et al., 2014; Rifkin 2015)**
- **Fear for one's own and children's health and future (Morgan et al., 2016)**

As oil and gas operations are also contributing substantially to the acceleration of global warming, the many mental health impacts and losses associated with climate change will also accelerate. A detailed review of 114 studies and meta-analysis of 19 studies by Thompson et al. (2023) revealed significant increases in suicide rates, hospital attendance and admissions for mental illness associated with hotter weather, which is, in turn, increasing with climate change. Extreme heat is already increasing throughout Australia, especially across northern regions which, if current climate policies remain unchanged and climate action is not sufficient, may become uninhabitable by 2080 (Lenton et al., 2023).

Further potential impacts of expanded gas production in Australia on social, emotional, cultural and spiritual health of Aboriginal people and increased exposure to sexual violence and crime of particular concern to residents of remote communities are discussed in Section 5.3 and 5.4, respectively.

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5.3 Additional physical, cultural and spiritual impacts of gas industry on Aboriginal communities and people in Australia

This Section does not seek to speak for Aboriginal people on the challenges faced by oil and gas developments on their Country. Rather we echo some of the voices that have spoken publicly, from consultations and analysis in formal documents, in open letters and in submissions to government inquiries. Those voices have spoken the enduring science of this Land for millennia. Many of the voices express outrage, fear of harms to Country, to water and to their health. They also express frustration and continued defiance about the processes that have been forced upon them, the lack of free, prior and informed consent, and impacts that all aspects of gas development would have on their lives. These are in addition to all the risks described in Sections 5.1, 5.2 and 5.4. This section provides a small snapshot of Aboriginal people's voices regarding the challenges that they have had to face in protecting their Lands, cultures and identities.

For over 65 thousand years, Aboriginal and Torres Strait Islander people have nurtured the health and diversity of ecosystems of their Country, including the Lands, inland waters, coasts and sea. This is a tradition of science that is now being recognised. Social, spiritual and physical connection to these systems, knowledge of their importance and a profound sense of responsibility for the protection of their integrity is embedded within Indigenous cultures worldwide.

This section provides a small snapshot of Aboriginal people's voices regarding the challenges that they have had to face in protecting their Lands, cultures and identities.

Threads of this wisdom are echoed in some of the foundational pillars of global health and wellbeing, such the Ottawa Charter for Health Promotion (World Health Organization, 1986), the Sustainable Development Goals and in Climate Change 2022: Impacts, Adaptation and Vulnerability (IPCC, 2022).

In 2023, Aboriginal and Torres Strait Islander People continue to lead strident efforts to protect Country against inappropriate developments and climate change inaction. This is despite bearing much cultural and spiritual loss from the devastation of social, linguistic, ecological, geological and biological diversity which commenced in 1788 and continues today. The State of the Environment Australia 2021 (Department of Climate Change, Energy, the Environment and Water, 2021) reports:

> *There has been devastation of cultural practices since European colonisation began. Indigenous land and sea management has been greatly impacted. Colonisation continues to interrupt many cultural practices and the intergenerational transmission of our knowledge needed to keep us and Country strong.*
>
> *The continuing legacy of colonial management of Country has disenfranchised and marginalised Indigenous peoples in their stewardship of Country. Legislative regimes, and rights to land and sea, vary across the states and territories, perpetuating inequity for Indigenous peoples. Access to Country has been impacted. Indigenous peoples' rights have been impacted.*
>
> *Our knowledge of Country, developed through scientific practice, careful observation and interaction over millennia, has been portrayed as myth and legend. People were taken from Country and treated as outsiders. There have been limited rights*

for heritage, water, land and seas – and we have often been powerless to protect our totems, plants and animals.

Sadly, many Australians have little awareness that the impact of this history and the continuing circumstances of environmental and social injustice continue to drive challenges for the health and wellbeing of Aboriginal and Torres Strait Islander peoples today. Perhaps most distressing is that many leaders and decision-makers in Australia are still not listening and, as shown in Section 3, time is running out. Again, the State of the Environment reports:

> *Future management of Country must be premised on Indigenous-led approaches to strengthening and sharing our knowledge of caring for Country. Sharing of knowledge must recognise our Indigenous cultural and intellectual property and respect the ancestors who gave us the knowledge.*
>
> *Management practices should be about revitalising and strengthening cultural practice and enable reconnecting to Country and kin, which delivers healing and rehabilitation of Country. Support for intergenerational transfer of customary knowledge and practices, and respect for cultural authority and customary law, are vital.*
>
> *Self-determination is a key focus, having people employed in and leading data collection and monitoring projects as well as providing evidence of how to heal Country. There must be nothing about us without us. We must not just be given a seat at the table; we must set the menu. Empower us and you empower yourselves – no group of people are more invested in caring for the environment and keeping it healthy than Indigenous peoples.*

Physical and mental health concerns

There are additional concerns when considering the potential physical, cultural and spiritual impacts of unconventional gas developments 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, and would clearly be disproportionally affected by disturbance of their lives and their communities and all of the potential harms from the gas developments.

A seminal paper by former Aboriginal and Torres Strait Islander Social Justice Commissioner Mr Tom Calma (2007) summarised a human rights-based approach to promoting the social determinants and health of Indigenous Australians. He emphasises:

> *the right of self-determination includes the right of peoples to freely 'dispose of their natural wealth and resources' and that 'in no case may a people be deprived of its own means of subsistence … supporting traditional culture – including customary law and governance structures – is likely to help improve the health status of people living in remote communities. In practice, this also means ensuring Indigenous peoples have access to their traditional lands. While Indigenous commentators have highlighted the social and culturally related health benefits of access to land, many possible positive health impacts are likely including improved diet, exercise, and the reconnection of Indigenous peoples with their traditional economic bases.*

Because of the historical and contemporary impacts of colonisation and losses described by Calma (2007) and above, Aboriginal people already experience substantially higher burden from all of the health conditions that have been associated with exposure to unconventional gas developments (Section 5.1). These conditions include heart and respiratory conditions (including asthma and chronic obstructive airway disease), low birth weight, some cancers, mental health challenges and traffic accidents (Australian Indigenous Health InfoNet, 2023). The environmental health conditions that Aboriginal people living remotely experience are often substandard and not protective against air pollution and extreme

Because of the historical and contemporary impacts of colonisation and losses … Aboriginal people already experience substantially higher burden from all of the health conditions that have been associated with exposure to unconventional gas developments

heat, and water supplies are difficult to monitor and maintain (Water Services Association of Australia, 2022; Quilty et al., 2022; Australian Indigenous Health InfoNet, 2023).

There are no specific research publications on the impacts of gas developments on Aboriginal peoples' health to date. However, 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 (AMSANT, 2018) 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.*

These sentiments expressed by AMSANT were also recorded in consultations undertaken for the Independent Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2018) which stated:

> *Aboriginal people from regional communities who made submissions to the Panel almost universally expressed deep concern about, and strong opposition to, the development of any onshore shale gas industry on their country…*
>
> *The Panel received an abundance of evidence that the broader Aboriginal community was not being appropriately informed about fracking or the potential for an onshore shale gas industry more broadly.*
>
> *The responses to the presentation by the Panel at community consultations on the processes involved in fracking for onshore shale gas suggests that the knowledge of the likely impacts of this industry within the Aboriginal community in the Beetaloo Sub-basin, and more widely, is wholly inadequate.*

An Open Letter to Parliament from Traditional Owners with over 35,000 signatures (Knowles 2021) stated:

> *Our connections to Country have been established and proven time and time again by the white man's law. We hold the Native Title and Land Rights — a system that is meant to protect and enforce our rights. These have been denied to us… For years, we have been told lies by the gas and oil corporations. That there would be no damage to the Country or poison in our waters. These companies won't even answer the most basic of questions — where they plan to drill or how many wells they want to build.*

The Traditional Owners noted the lack of respect shown to them by gas corporations, saying they have failed to *"follow proper process in consultation with us, failed to acquire consent, failed to provide transparency in their dealings with us, and have systemically excluded our voices from the decision-making process for activities on our Country."*

The letter to Parliament also noted their feelings regarding the behaviour of the Federal Government. *"This Federal Government coming in over the top of what little processes we have undermines our land rights as Northern Territory Traditional Owners,"* and *"The same Government who has never come out to our communities to sit with us or meet with us. They are failing to represent us."*

The statements are supported in a literature review commissioned by The Jumbunna Institute for Indigenous Education and Research (n.d.). This review examined whether the principles of free, prior and informed consent were met in the determinations with Traditional Owners that led to the current progression of plans for oil and gas development in the Northern Territory. Examining documentation of the circumstances of the processes used in communicating with Traditional Owners, the review concluded:

> *Given these findings, and from the findings and recommendations of the Pepper Inquiry, there is adequate information to form the conclusion that most, if not all, exploration permits issued in the Northern Territory for unconventional gas were issued in the absence of FPIC, as it is conceived of under international law.*

In 2009 Australia formally committed our nation, including state and territory governments, to all the principles embedded in the UN Declaration on the Rights of Indigenous Peoples (United Nations, 2007; Australian Human Rights Commission, n.d). In signing, Australian government committed to *"recognising the urgent need to respect and promote the inherent rights of Indigenous peoples which derive from their political, economic and social structures and from their cultures, spiritual traditions, histories and philosophies, especially their rights to their lands, territories and resources"*. Among many references to rights to health, Land and custodianship, the Declaration specifies that:

> *Indigenous peoples have the right to the lands, territories and resources which they have traditionally owned, occupied or otherwise used and acquired (Article 26(1))*

> *Indigenous peoples have the right to conservation and protection of the environment and the productive capacity of their lands, territories and resources. States shall establish and implement assistance programmes for Indigenous peoples for such conservation and protection, without discrimination.*

Twelve years after signing the UN Declaration on the Rights of Indigenous Peoples a report on "Implementing UNDRIP" from the Australian Human Rights Commission (2021) showed that the Australian Government has not taken steps to implement UNDRIP into law, policy and practice; has not negotiated with Indigenous peoples a National Action Plan to implement the UNDRIP; and has not audited existing laws, policies and practice for compliance with the UNDRIP.

What has been observed in the Northern Territory, the Kimberley, Narrabri and across the country where unconventional gas operations have threatened or commenced, is that the obligations of governments and industries to respect the rights committed to in UN Declaration have been contravened. These harms impact on the physical, social, emotional and spiritual wellbeing of Aboriginal people even before the processes of road building, site preparation, drilling, hydraulic fracturing, gas production, wastewater retrieval, transportation and handling and compressor stations begin proliferating across their lands. Despite these deep wounds, Aboriginal people who are against these developments are maintaining leadership in the battle to protect their Country. To proceed with these invasive impacts on Country against Traditional Owners wishes is likely to have devastating impacts.

> ***There is an urgent need for evidence from Indigenous peoples' perspectives, and investments in Indigenous knowledges in science, energy use and caring for Country, especially because these uphold cultural protocols of intergenerational transfer of knowledge and supporting young people as leaders of the future who inherit climate crises.***

Professor Megan Williams, personal communications

Summary

This Section has brought forward just a few voices from the countless Aboriginal and Torres Strait Islander people who have stood up to protect their Lands and waters from harmful development for over 230 years. Some Traditional Owners have spoken out about the lack of respect for their right to self-determination and to make decisions over their Lands with free, prior and informed consent that they have experienced with proponents of the oil and gas industry. These rights are enshrined in the UN Declaration for the Rights of Indigenous Peoples which Australia committed to in 2009. In addition to the risks and harms to physical, psychosocial and mental health and safety described in Section 5.1 and 5.2, the oil and gas developments clearly threaten the cultural and spiritual health of many Aboriginal Australians.

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5.4 Sexual violence: Threats to the safety of girls and women with evidence from the United States, Canada and Australia

Globally, the introduction of gas and oil extractive industries into remote areas with a transit and fly in-fly out workforce has brought many safety risks and disturbances to local populations, including increased crime rates, antisocial behaviour, truck traffic and accidents as discussed in Section 5.2. For example, Ruddell et al. (2014) reported higher crime rates and an 18.5% increase in violent crime reported between 2006 and 2012 in communities impacted by oil extraction, and a decrease of 25.6% in a matched sample of counties that had no oil or gas production.

However, the most disturbing of these are accounts of sexual and related violence. This Section first describes this based on reports prepared by First Nations Canadians and Native Americans on how their people are subjected to workforces conducting extreme extraction in remote areas. The Section then describes how the circumstances that enable such behaviour and suffering are clearly evident in Australia.

Most relevant of these to Australia is the identified association between oil and gas industry operations in the US and Canada and sexual violence as described within their Missing and Murdered Women and Girls research and investigations.

The submission documents the connection between extreme extraction and sexual violence against Native women...

First Nations People's experience in the US and Canada

An article and artwork published in *Indian Country Today* (2015) depicts what is widely seen in Canada as an epidemic of sexual violence.

The publication reports:

On April 21, 2015, a coalition of Native American and women's organizations filed a submission to the United Nations Expert Mechanism on the Rights of Indigenous Peoples to be tabled in the Fourteenth Session of the UN Permanent Forum on Indigenous Issues. This submission requested UN intervention in the epidemic of sexual violence brought on by extreme fossil fuel extraction in the Great Lakes and Great Plains region (Indian Country Today, 2015).

The submission documents the connection between extreme extraction and sexual violence against Native women in the Bakken oil fields of western North Dakota and eastern Montana, and the Tar Sands region of Alberta, Canada, where vast "man camps" of temporary labor have become lawless hubs of violence and human trafficking. It also contextualizes this epidemic within the history of colonization, genocide and systemic violence against Indigenous peoples, which has always disproportionately affected women and girls.

Four years later, "Reclaiming Power and Place: The Final Report of the National Inquiry into Missing and Murdered Indigenous Women and Girls in Canada" (2019) recorded many similar statements and stories regarding the unsafe circumstances created through extractive industries, particularly oil and gas, and suffering among Indigenous women and children. For example:

> *The industrial system of resource extraction in Canada is predicated on systems of power and domination. This system is based on the raping and pillaging of Mother Earth as well as violence against*

> *women. The two are inextricably linked. With the expansion of extractive industries, not only do we see desecration of the land, we see an increase in violence against women. Rampant sexual violence against women and a variety of social ills result from the influx of transient workers in and around workers' camps.*

(Statement by Melina Laboucan Massimo, of the Lubicon Cree First Nation. page 586)

The Report concluded:

- "There is substantial evidence of a serious problem demonstrated in the correlation between resource extraction and violence against Indigenous women, girls, and 2SLGBTQQIA+ people. Work camps, or "man camps," associated with the resource extraction industry are implicated in higher rates of violence against Indigenous women at the camps and in the neighbouring communities.
- This increased rate of violence is largely the result of the migration into the camps of mostly non-Indigenous young men with high salaries and little to no stake in the host Indigenous community.
- Industries that create "boom town" and "man camp" environments are implicated in increased rates of drug and alcohol-related offences, sexual offences, domestic violence, and gang violence, as well as sex industry activities in the host communities. These occurrences disproportionately impact Indigenous women, girls, and 2SLGBTQQIA+ people.
- The influx of people as a result of "man camps" near or within Indigenous, remote and rural communities further results in stress on already limited social infrastructure, such as policing, health, and mental health services".

A lack of reporting of sexual violence and, in some cases, police vigilance regarding missing and harmed women hampers quantification and effective response to these crimes, however mixed methods research using both qualitative and quantitative approaches are starting to document trends and linkages.

Martin et al. (2019) compared changes in frequencies of violence in the Bakken region of North Dakota before and after shale oil extraction began, and in a similar region without oil or gas developments. They reported 70% increases in rates of reported violent victimisation, 44.8% increase in unlawful sexual contact, and 47% increases in serious domestic and stranger violence during shale oil extraction, while decreases were evident in regions without extractive operations.

First Peoples Worldwide (2019; 2020), University of Colorado at Boulder, disaggregated these data by ethnicity and found that violent victimisation of Blacks and Native Americans occurred at 2.5 times that of white residents. Unlawful sexual contact, particularly statutory rape cases, increased 53% among Native women in the extraction region. These findings support earlier work demonstrating higher rates of violent victimisation among Native women (Martin et al, 2012; Finn et al., 2017; Jayasundara et al., 2018; Grisafi, 2020). The report also emphasised the serious underreporting of these crimes, especially among Indigenous people, due in part to mistrust of government agencies and fear of reprisal.

There are clear similarities in the circumstances present in these North American settings and many of the locations under Gas Exploration Licenses and slated for development through the 'gas-led recovery' scheme in Australia. All contributing factors to these circumstances are highly present in these regions: from FIFO workforces, sharp economic disparities, over-representation of Aboriginal communities in the impacted areas, privilege and power imbalances, patriarchal social forces embedded in the remote context, enduring impacts of colonisation, higher background levels of domestic and family violence as a result of colonisation, to underpolicing and poor service access. As remote communities in Australia often struggle to meet basic needs, women can be vulnerable to sexual exploitation for money, food or addictive substances.

Evidence of risk in Australia

While no direct data are available regarding sexual violence and gas developments in Australia, there is now substantial evidence of sexual harassment and abuse against women working within the FIFO mining environment.

In its Fifth National Survey on Sexual Harassment in Australian workplaces, the Australian Human Rights Commission (2022) found a high prevalence of sexual harassment in the mining industry, with 62% of the females and 25% of males in the workforce affected within the previous five year period, compared with 31% across all workforces.

The reality and details of these behaviours within the FIFO mining setting are revealed in a landmark Report published in June 2022 entitled "Enough is Enough: Sexual Harassment against women in the FIFO mining industry" in Western Australia. The Report described high levels and detailed experiences of sexual harassment and sexual assault by male workers towards their female colleagues which shocked the Members of the Inquiry Committee, as described by the Chairperson:

> *Our first line of questioning was to establish how prevalent sexual harassment is across the sector. The shocking conclusion we had to draw was that sexual harassment has long been and continues to be prevalent across the industry. This was in line with what the Australian Human Rights Commission identified in 2020 – that mining was one of the worst five performing industries. What we were not prepared for, and what we only learned because so many brave individuals shared their stories with us, was the appalling range of behaviours that women have endured in this industry* (p xiii).

The Committee described their experience as "*We heard a staggering range of abuse, harassment and assault.*" (p 11)

Please note: readers who are concerned about the impact of these stories might choose to skip the following quoted section.

In her Forward to the Enough is Enough Report, the Chair summarised:

> *There were stories of sex dolls put in front of women's dongas, and sex toys hung on their doors. Stories of unsolicited and unwelcome sexual attention, stalking, texting of explicit and lewd material, and horrifying stories of sexual assault. We heard details of unwanted touching, sexual comments, provocative photo requests and grooming. We heard of powerplay behaviour known as 'shovelling' where iron ore would be dumped on the cab of trucks operated by women if they didn't comply with sexual requests. These stories and the others we heard illustrate the full range of behaviours that make up sexual harassment and sexual assault as well providing examples of general incivility – which is well-recognised as a precursor to worse behaviour.*

Other comments made by informants included:

> *There was 'an expectation that the few woman [i.e. other workers] that these men encounter on remote exploration sites will be available to have sex with them.*

One witness compared the situation to "*witnessing bloodhounds on the trail*".

> *This is a culture on a mine site; it is normal. You walk in and you know what you are getting yourself into, you just do not realise how bad it is, that these guys in a lot of ways are grooming these young girls. We are talking young apprentices, young wannabe digger operators, stuff like that.* (p 23)

The Committee found that:

- The West Australian FIFO industry embodies the main risks to sexual harassment
- The culture of mining has perpetuated poor behaviour
- Underreporting is endemic as reporting such experiences are often negative to the victim and ineffective at impacting the perpetrator.
- There is clearly a power imbalance in the mining and resources sector.

Although the report does not attempt to quantify the proportion or suggest that 'most' men working in the industry commit sexual harassment and sexual violence, the Committee confirmed acceptance of a culture and circumstances where this can flourish. The very high proportion of women working in the industry who experience this behaviour demonstrates the widespread harms caused by those that do. The Committee made an important point when stating that male workers who say they are "unaware of" or "have never seen" these behaviours present in their workplace is not evidence that it is not occurring. These findings are consistent with theoretical understandings of sexual violence against women in male dominated settings (DeKeseredy and Donnermeyer, 2022).

Twenty four recommendations were made to address this often criminal behaviour and to help women workers in the mining industry feel and be safe and also be heard when an incident of sexual harassment or abuse is perpetrated upon them.

However, there is no mention in the Report about women and children living in communities nearby mining sites, and those living in communities along trucking routes. While enhanced rights and protections of women working in the industry are important, there appears to be no equivalent effort to protect women and children impacted by this culture who do not work in the industry. It is plausible that a perpetrator may perceive the risk of losing their job or facing legal consequences is lower for sexual violence crimes committed in a nearby community rather than in the workplace, especially if the workplace recommendations of the Inquiry are implemented. This is especially true for a community trying to cope with the immense disruption of their lives from being in a gas field zone where, for example, law enforcement agencies and assault services become overstretched (Carrington et al., 2011; Ruddell et al., 2014; Jayasundara et al., 2018).

Twenty-four recommendations were made to address this often criminal behaviour and to help women workers in the mining industry feel and be safe and also be heard when an incident of sexual harassment or abuse is perpetrated upon them.

Lockie (2011) explored intimate partner abuse and its impact on women's health in the Bowen Basin, considered Australia's premier coal mining region, near the regional city of Mackay in Central Queensland. Police records for the two statistical divisions in the region revealed a substantially higher rate of reported sexual offences (361 and 430 per 100,000 people) compared to the rest of Queensland (169 per 100,000). A survey completed with 532 women living in the region revealed a range of factors influencing the likelihood of women experiencing physical, psychological or financial abuse, including growing up in a mining town and partnering with men in the mining profession.

As suggested above, women and children in remote areas may face enhanced vulnerability due to factors such as lack of resources, ongoing impacts of colonization and transgenerational trauma, fear of reporting to authorities and lack of adequate services for their protection.

Mass truck movements through communities

There is a lack of studies on the impact of long-haul truck drivers on individuals and communities along their routes, especially related to any role they may play in the spread of drugs and direct or indirect sexual violence in vulnerable communities. McCree et al. (2010) described the circumstances involved and evidence of risky sexual behaviour, often associated with drug addictions, among commercial sex networks accessed by truck drivers in New Mexico. Similar circumstances are described among truckers in Florida (Stratford et al. (2002) and Arizona (Apostolopoulos et al., 2012).

Equivalent studies are not apparent in Australia, where research has focused on truck drivers' health. A national cross-sectional survey of 1320 truck drivers in Australia by van Vreden et al. (2022) revealed a high prevalence of multiple physical and mental health problems, including moderate and severe levels of distress especially among younger drivers. Participants in the Driving Health Study described a wide range of circumstances contributing to distress, including being away from home, experiencing break up and divorce as a result, unrealistic demands, and lack of respect and support systems (Pritchard et al., 2020). More research is needed, especially among truck drivers specifically associated with the remote area mining industry.

Exceptionality and invisibility of these risks

The instruments and reports used in Australia to assess the health impacts of the gas industry on people living in nearby communities contain no evidence of an intention to protect women and children. The concerns for these communities subjected to the massive influx and passage of FIFO workers in the proposed gas developments and the associated rampant and appalling behaviours are rendered completely invisible (Scientific Inquiry into Hydraulic Fracturing in the Northern Territory, 2018; Regional Report: Strategic Regional Environmental and Baseline Assessment for the Beetaloo Sub-basin, 2022; Environmental Health Baseline Report: Population Health, 2022).

For example, in the 327 page Regional Report: Strategic Regional Environmental and Baseline Assessment for the Beetaloo Sub-basin (SREBA) (used by the NT government to green light the development), the word 'sexual' is mentioned eight times, all followed by sexually 'transmitted diseases' (Department of Environment, Parks and Water Security, 2022). The words 'assault' and 'violence' are mentioned zero and two times, respectively. Furthermore, the full Environmental Health Baseline Report for the SREBA published by Flora and Fauna Division of the Department of Environment, Parks and Water Security (Jacobs 2022) mentions the word 'sexual' 10 times in the phrase 'sexually transmitted disease', 'assault' zero times and 'violence' only once.

Besides the oversights which potentially contravene obligations under the United Nations Declaration of the Rights of Indigenous Peoples, Article 22 specifically requires signatories (including Australia) to protect the Safety of Women and Children (Article 22(1&2). Section 1 states that "*Particular attention shall be paid to the rights and special needs of Indigenous elders, women, youth, children and persons with disabilities in the implementation of this Declaration*". Section 2 requires that "States shall take measures, in conjunction with Indigenous peoples, to ensure that Indigenous women and children enjoy the full protection and guarantees against all forms of violence and discrimination".

Furthermore, the UN Women (2020) have prepared a Programme brief entitled, Extractive industries, gender and conflict in Asia Pacific to address the harms that women can experience as a result of male dominated processes. The oversight of women's and children's safety both within FIFO mining operations and in affected communities across the risk assessment documentation on Australia's gas expansion plans is also consistent with the findings identified in this Brief, for example:

> *Gender-blind policies and practices create contexts where women are routinely denied access to and control over the benefits of mining, while their needs and interests are excluded from decision-making processes… Not only do women receive fewer of the benefits from extractive industries, they are also more adversely affected by their negative impacts, as shown by an increasing number of studies.*

(UN Women, 2020, p3).

These gender-specific problems are duly compounded by the overall lack of free, prior informed consent raised by Aboriginal people whose Traditional Lands would be affected by gas operation processes and infrastructures (Jumbunna Institute for Indigenous Education and Research, n.d.).

Interestingly, the Department of Foreign Affairs and Trade's Child Protection Guidance Note on Extractive Industries (2017), reported:

> *Often, in-migration causes or escalates the sexual abuse and exploitation of children (including prostitution and trafficking), the rate of teenage pregnancy, and the spread of communicable diseases. When companies transport materials by truck, the abuse and exploitation of children along transport routes can increase.*
>
> *Mining sites can attract children and young people (to sell market goods, for employment as housekeepers, to look at machinery, to get sweets and gifts from labourers) thus allowing opportunities for children and young people to be exploited and abused.*

However, no such considerations are raised in deliberations about the health and safety impacts and risks to children in Australia's remote communities.

The oversight of this serious threat to the health and wellbeing of women in the vicinity of remote gas operations opens the door to the extreme mental health consequences and lifetime, and often transgenerational, impacts of sexual violence on a child's or woman's life. To summarise, these include depression, anxiety and intense fear of repeated attacks, pregnancy and sexually transmitted diseases, post-traumatic stress disorder, poor educational attainment, difficulty in partner and parental attachment, sexual promiscuity, victim-perpetrator cycles, alcohol and drug addiction, low self-esteem and self-worth, restricted social activities, view of the world as unsafe and dangerous, incarceration and suicide (ODDONE Paolucci, 2001; Boyd, 2011; Phoenix Australia, n.d.).

Furthermore, research on the body's response to severe trauma, such as sexual violence, is revealing how hormones induced by traumatic stress cause long term impacts on the endocrine, central nervous and immune systems in the body. Persistent emotions, such as humiliation, guilt, fear, and self-blame, may promote suicidal thoughts and feelings of 'unbearable secrecy' which prevent help-seeking and resolution (Sigurdardottir and Halldorsdottir, 2021). This ongoing suffering can program the body towards inappropriate inflammatory responses, which enhance the development of mental and physical health problems, such as depression, anxiety, suicidal thoughts, chronic pain and back problems, eating disorders, diabetes and heart disease (Sigurdardottir and Halldorsdottir, 2021; Kuhlman et al., 2017).

While appropriate therapeutic support is vital for recovery, this is rarely available in remote Australian settings. These settings are the most likely to experience the risks known to be associated with major gas developments, especially amongst Indigenous people as revealed by the US and Canadian experience.

Governments must exercise duty of care to prevent circumstances that are clearly known to foster and enable these kinds of crimes, most often committed against women and children, sometimes even within the mining workplace itself.

Summary

Evidence has been presented that highlights the particular risks and occurrence of sexual harassment and violence that has been perpetrated in the United States and Canada, particularly of First Nations women and children. Evidence from Australia about disregard for women's safety within the FIFO mining workforce suggests that these same risks would equally apply in the Australian context. The West Australian Inquiry demonstrated the high proportion of women experiencing harassment and violence, the enabling work culture and circumstances, the diversity of both sexual harassment and violence behaviours among the FIFO workforce, lack of accountability for punishing perpetrators and the reasons for non-disclosure borne by women working in Australia's mines. With no acknowledgement of the likelihood that this dangerous situation will harm communities nearby these operations, it appears that governments are not recognizing their responsibility for the protection of women and children in their jurisdiction subjected to these harms outside the mining setting. The massive truck movements through the developing areas during and after the boom phase (described in 5.3) are likely to amplify these risks.

The behaviour of the gas industry and approving governments in Australia ignoring these risks or considering them to be 'exceptional' rather than sources of immense pain, physical and mental harm and loss, often compounding immense grief and loss, is consistent with that found globally (Togalagba, 2020). To consider only sexually transmitted disease (Jacobs 2022), rather than also considering the possibility of these diseases having occurred because of heinous crimes and deep wounds against women and children, exposes a serious problem in health impact assessment and baseline monitoring. Regardless of attitude, the government's relentless push to create circumstances known to enable this harm in areas where women and children are particularly vulnerable, must be addressed in any assessment of the industry's severe psychosocial and physical health costs.

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6. Discussion and conclusions

This Report brings together and reviews the extensive body of research on the breadth and magnitude of potential direct and indirect risks to human health and wellbeing associated with gas and oil developments. The research has helped to identify, characterise and quantify these risks. Our ability to understand and document the various avenues for potential chemical contamination of air and water and consequent human exposure has improved as studies have identified a wide array of potential toxicities of chemicals used in hydraulic fracturing and those naturally occurring in produced wastewater. This work clearly indicates that these complex mixtures of chemicals have the capacity to cause negative health outcomes in exposed infants, children and adults.

Health practitioners, medical professionals and affected community members are particularly concerned by the rapidly accumulating evidence of associations between proximity to high intensity gas extraction activities and the incidence of asthma exacerbations and respiratory hospitalisations, sinus conditions, depression and anxiety and hospitalisations for heart attacks and heart failure. Studies on infants have associated lower birth weights and higher pregnancy complications, birth defects and blood cancers with their mothers' residence near oil and gas developments during pregnancy. While most of these studies have been conducted in the United States, exploratory hospital-based studies comparing regions with and without coal seam gas mining suggest that similar trends in these outcomes may be emerging in Queensland. These health and developmental effects may appear disparate, but they are all known potential manifestations of exposure to volatile organic compounds, ground level ozone, oxides of nitrogen and other chemicals linked to oil and gas operations.

We have special concerns about infants and children, who face higher risks than adults from toxic exposures after birth due to their higher metabolic and respiration rates (breathing in more toxins), smaller body size and smaller and immature organs, including the liver, lungs and kidneys that deal with or store toxins entering the body. Children are also exposed 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.

The American Academy of Pediatrics' Policy Statement on Ambient Air Pollution: Health Hazards to Children (Brumberg et al., 2021) identified the significant contribution of oil and gas operations to airborne hazards affecting American children. Similarly, the Academy's Policy Statement on Drinking Water from Private Wells and Risks to Children (Woolf et al., 2023) highlighted the significant potential for unconventional gas operations to introduce toxins into groundwater resources and potentially impact drinking water wells in the United States. Serious concern was also expressed about the potential for other health effects not yet characterised.

The lifetime impacts of antenatal and childhood exposures are unknown. Studies of longer-term impacts, such as the likelihood of developing adult cancers and chronic diseases, are limited because not enough time has elapsed since the beginning of potential widespread exposure to oil and gas activities for these diseases to manifest.

Like most complex scientific research, these studies have progressed in both volume and sophistication as funding and research opportunities have grown. First to emerge were risk assessments based on measurements of pollutants being emitted from industry activity, along with small community assessments of symptoms being experienced relative to closeness to wells. These initial findings were then followed by larger regional studies using routinely collected health data to compare disease rates before and after, close to and further away from and/or in high and low density oil and gas production areas. Increasing numbers of publications are now modelling health harms and health care costs due to air pollution impacts of the now mature, but still growing, unconventional gas industry. The most recent of these publications presented detailed estimations of deaths, morbidity and health costs in the United States associated with air pollution exposures. Difference-in-differences methodology, which reduces the chances for confounding effects (by studying the same population before and after drilling) and demonstrates temporality (indicating that exposure to active wells came before the detected health outcome measured), has also yielded increasingly precise findings. As the literature has grown, there has been no indication that the associations observed in initial studies have disappeared; rather, newer research has consistently added more extensive, robust and refined evidence supporting potential causation.

The accumulating evidence from areas outside the the United States corroborates and extends the findings regarding the many predictable concerns about, and impacts associated with, unconventional oil and gas developments. Chief among these concerns are the wide range of potentially harmful chemicals being used; the large and increasing amounts of water used for gas extraction and of wastewater produced; the stress placed on affected individuals and communities disrupted by social changes and loss of physical amenities; and the alarming contributions to increased greenhouse gas emissions at this critical time.

We are deeply concerned about the cultural and spiritual wounds that are already being felt and would be further afflicted on Australia's Aboriginal people by large developments threatening to destroy the integrity of their Lands and corrupt their waters. The report revealing poor adherence to free, prior and informed consent protocols in industry and government interactions with Traditional Owners in the Beetaloo planning process is not acceptable and has caused much pain. The risk of sexual violence against women and girls has been all but ignored in oil and gas development planning. The experiences of First Nations Canadian and Native American women and the shocking findings from the Western Australian Inquiry into the sexual harassment against women in the fly in-fly out workforce have demonstrated the seriousness of this risk.

We conclude that current research does not confirm that gas and oil developments are safe for the environment and for people. While no study is wholly conclusive on its own, the large body of work that has accumulated makes a strong case that the industry enhances 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.

The limitations of this work include the possibility that some research findings may have been missed, that study quality was not individually assessed, and that the economic impacts of the industry, which may have influenced health and wellbeing, were generally omitted. It is considered likely that socioeconomic status will have advanced for some people, and declined for others, especially in Australia where landholders do not own the rights to underground minerals.

Arguably the most important implication of continuing and expanding oil and gas developments in Australia and globally is its vast carbon footprint. Substantial research has highlighted the industries' major contribution to fugitive methane and CO_2 emissions during clearing, exploration, production, storage, transportation and combustion. Particularly in remote Australia, it can be presumed that efforts to legislate, monitor and enforce over hundreds to thousands of wells will be difficult to initiate and even more difficult to sustain as the industry is allowed to grow.

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, and hydroelectric energy. Domestic gas may play a small role in extenuating circumstances for some years before being phased out. Our Australian Energy Market Operator has a plan, and we must strive to adhere to it in our domestic lives. The International Energy Agency also has a global plan that shows no need for new fossil fuel expansion, and we must support it in our export policies and decisions. State, territory and federal governments need to demonstrate that they hear the voices, especially of Indigenous people and young people, who fear the future that is advancing upon us all.

As clearly demonstrated in the most recent Intergovernmental Panel on Climate Change report (IPCC, 2018), if we are to limit global warming to 1.5°C or even 2°C, the use of gas must be curtailed as quickly as possible and give way for renewable energies to take over the powering of Australia and the world. To participate appropriately in the face of this global urgency, Australia should do all in its power to assist developing countries to transition away from gas power, rather than developing an industry that would continue to push vast quantities of gas onto 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 (Diessendorf and Elliston, 2018; Brown et al., 2018; Institute for Energy Economics and Financial Analysis, 2018). Political will is a critical requirement. We urge the Australian government to take the necessary steps to lead Australia away from fossil fuel production and into a clean energy domestic and export future that can support the health and wellbeing of current and future generations all over the world.

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