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Submission regarding aspects¹ of
the Draft Final Report of the
Scientific Inquiry into Hydraulic Fracturing
in the Northern Territory

19 January 2018

The author

I am a chemical engineer and independent energy advisor with over 35 years of experience in petrochemicals, oil, gas, electricity, and energy efficiency. I have worked with organisations including ExxonMobil, BHP Billiton, and Jemena. My roles included petrochemical technology manager, LNG plant engineering design team manager, facilities and operations advisor with the Esso/BHP Bass Strait oil and gas joint venture, and commercial manager of the Queensland Gas Pipeline.

I also worked at the Australian Energy Market Operator (AEMO) where I was Gas Planning Principal responsible for the publication of AEMO's Gas Statement of Opportunities (GSOO). I subsequently led AEMO's research into powering eastern Australia with 100% renewable energy.

More recently as Energy Advisor at the University of Melbourne (working with the Melbourne Energy Institute and the Australian-German College of Climate and Energy Transitions), I published leading research reports covering topics such as pumped hydro energy storage, methane emissions from unconventional oil and gas production, eastern-Australian electricity and gas demand trends, and the economic advantages of alternatives to gas.

I have published numerous articles about his University of Melbourne research at The Conversation, Renew Economy, ReNew Magazine, Climate Spectator (The Australian), The Fifth Estate, and elsewhere. My work has been widely reported in print and online media and in numerous radio and television interviews and articles.

I have presented his research to state and territory government inquiries in Melbourne, Sydney, and Darwin (this Inquiry), to federal Members of Parliament in Canberra, and at industry conferences, community meetings, and other fora.

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¹ Time did not permit me to further extend my comments on the Inquiry's report.

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1). THE INQUIRY REPORT UNDERSTATES THE CONSEQUENCES AND RISKS ASSOCIATED WITH GREENHOUSE GAS EMISSIONS – IN PARTICULAR, HUMAN DEATHS

The Inquiry has chosen to use a risk assessment process to assess the risks inherent in producing unconventional oil and gas in the Northern Territory (NT). However, the Inquiry has understated the consequences and risks associated with further climate disruption that will occur if Northern Territory oil and gas production expands.

Scientific research has found that greenhouse-gas induced climate change is not only a future concern but is already **causing damage now** - including loss of human life, human injury, and property damage. The January 2018 Bulletin of the American Meteorological Society featured 21 papers that “identified climate change as a significant driver” of extreme events. Three of those papers conclude that

“the extreme magnitude of a particular weather event was not possible without the influence of human-caused climate change”².

Most acutely, greenhouse gas emissions have disrupted our Earth’s climate to the extent that people have already been killed by heat stress caused by climate change. A January 2018 study found that

“in India, at least 580 people were killed by the heat waves from March to May” (2016).

This study further found that...

“... the 2016 extreme warmth across Asia would not have been possible without climate change”³.

A July 2017 World Health Organisation (WHO) assessment⁴...

... “taking into account only a subset of the possible health impacts, ..., concluded that climate change is expected to cause approximately 250,000 additional deaths per year between 2030 and 2050; 38,000 due to heat exposure in elderly people, 48,000 due to diarrhoea, 60,000 due to malaria, and 95,000 due to childhood undernutrition. All populations will be affected by climate change, but some are more vulnerable than others. People living in small island developing states and other coastal regions, megacities, and mountainous and polar regions are particularly vulnerable. Children - in particular, children living in poor countries – are among the most vulnerable to the resulting health risks and will be exposed longer to the health consequences. The health effects are also expected to be more severe for elderly people and people with infirmities or pre-existing medical conditions. Areas with weak health infrastructure – mostly in developing countries – will be the least able to cope...”

² Herring, S. et. al. “Explaining extreme events of 2016 from a climate perspective.”, Special Supplement to the Bulletin of the American Meteorological Society, January 2018.

³ Imada, Y. et. al., ‘Climate change increased the likelihood of the 2016 heat extremes in Asia’, American Meteorological Society. January 2018. <http://www.ametsoc.net/eee/2016/ch19.pdf>

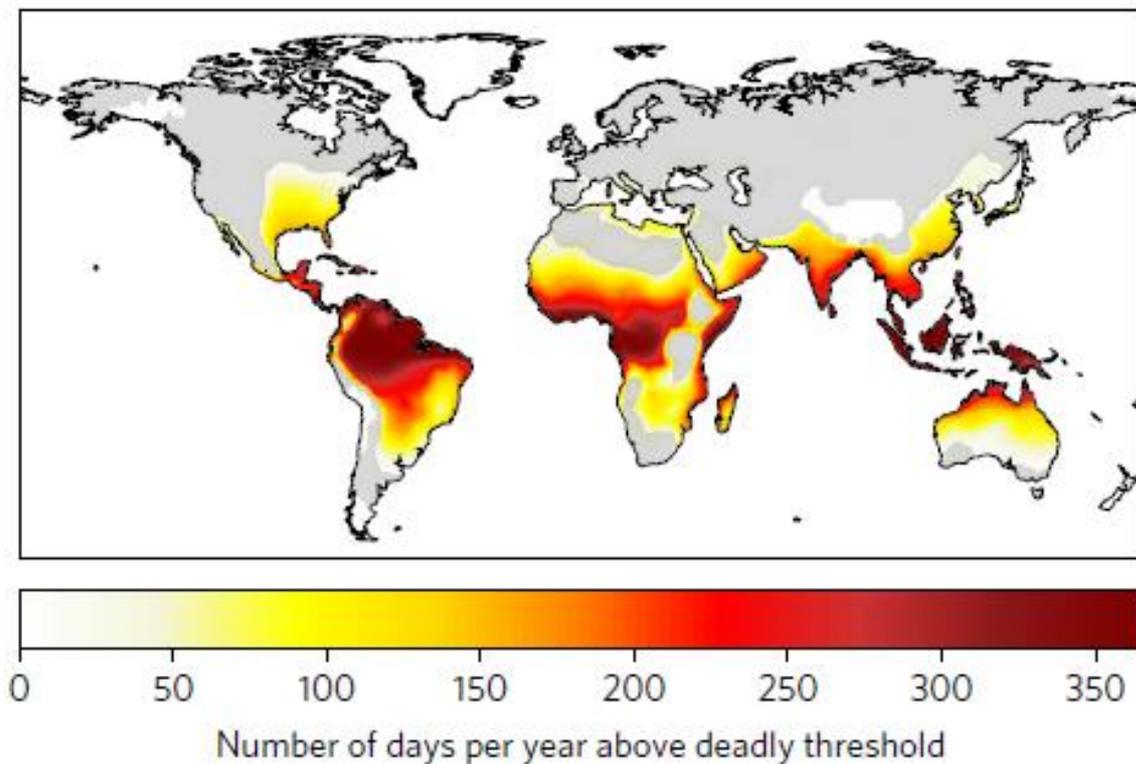
⁴ World Health Organisation. “Climate Change and Health”, Updated July 2017. <http://www.who.int/mediacentre/factsheets/fs266/en/>

Rephrasing part of the above, taking into account only a subset of possible health impacts, the World Health Organisation expects climate change to cause the premature deaths of approximately 5,000,000 people between 2030 and 2050. (Note, the Inquiry’s report describes scenarios where development of Northern Territory shale gas occurs over “the next 25 years”, i.e. from now until the year 2043.)

Another recent (July 2017) study⁵ underscored heat stress risks with the statement...

“... the current and increasing threat to human life posted by climate conditions that exceed human thermoregulatory capacity”.

The Inquiry should please note the use of the word “current”. This study went on say “that today nearly one-third of the world’s population is regularly exposed to climatic conditions surpassing this deadly threshold.” This includes some people living in the Northern Territory, as shown on the map below.



⁵ Mora, C. et. al., “Global risk of deadly heat”, Nature Climate Change, July 2017.

Yet another recent study, published in June 2017 ⁶, found a ...

“... 146% increase in the probability of heat-related mortality events...”

had occurred in India over the period 1960 to 2009, a period over which mean temperatures had increased by 0.5 deg C. Indian heat waves occurring in 2013 and 2015...

“... killed more than 1,500 and 2,500 people across the country, respectively”.

The most intense Indian heat wave in recorded history occurred in May 2016 when maximum temperatures reached 52.4 deg C.

Reflecting that climate change is already causing damage now, the City of New York recently announced a lawsuit against oil and gas producing companies BP, Chevron, ConocoPhillips, Exxon Mobil, and Royal Dutch Shell for billions of dollars of damages, in part for damages

“... already seen...” ⁷.

Producing more oil and gas, and therefore adding more greenhouse gas to our Earth’s atmosphere, and consequently further exacerbating climate disruption, will result in an increasing number of premature human deaths.

The scale of greenhouse gases that may be released into our Earth’s atmosphere because of Northern Territory oil and gas developments is very large. The Inquiry reports that total shale gas resources “are estimated to be 257,276 PJ”⁸, and as will be shown below, the U.S. Energy Information Administration (EIA) estimated the volume of technically recoverable NT shale oil to be 4.7 billion barrels.

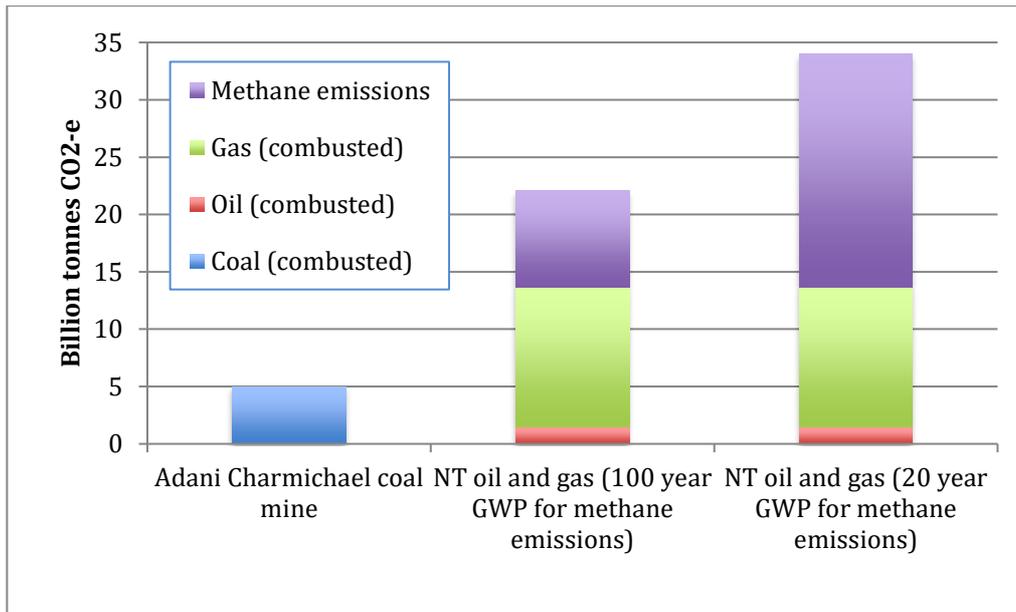
The chart below compares the greenhouse gas emissions potential from NT oil and gas with the well-known proposed Adani Charmichael coal mine in Queensland. Potential global greenhouse gas emissions from the Adani mine are reported to be 5 billion tonnes, which is approximately equal to nine-years-worth of Australia's emissions (recently reported to be 0.55 billion tonnes per year).

Northern Territory shale oil and gas is one of Australia’s largest potential sources of greenhouse gas emissions. As shown on the following chart, the potential global greenhouse gas emissions from NT shale oil and gas could be approximately 4 to 7 times larger than the potential total emissions from the Adani coal mine.

⁶ Mazdiyasi, O. et. al., “Increasing probability of mortality during Indian heat waves”, Environmental Science, 7 June 2017.

⁷ City of New York, "Climate Action: Mayor, Comptroller, Trustees announce first-in-the nation goal to divest from fossil fuels, 10 January 2018. <http://www1.nyc.gov/office-of-the-mayor/news/022-18/climate-action-mayor-comptroller-trustees-first-in-the-nation-goal-divest-from#/0>

⁸ Inquiry report, Section 6.3.



Comparing potential global greenhouse gas emissions from NT shale oil and gas with Adani Charmichael coal mine potential.
5% emission of NT gas (methane) to atmosphere assumed.

These volumes can be compared with Australia's annual domestic emissions of 0.55 billion tonnes per year.

The Inquiry's report describes how greenhouse gases cause the Earth to warm. The Inquiry then devotes only a single six-line paragraph⁹ to describe the consequences of this warming. The Inquiry's report cites impacts such "changing precipitation", species shifting "their geographic ranges", and "changes in many extreme weather and climate events" and that "both observed temperature and sea-level rise are tracking at or near the top of the envelope of model predictions". However, the Inquiry's report does not explicitly mention that people **are already dying**, and will continue to prematurely die, as a result of climate change.

Possibly because the Inquiry does not explicitly recognise that climate change is already causing premature human deaths, the Inquiry has assessed the risks associated with greenhouse gases as "medium"¹⁰. The Inquiry has assessed the consequences of increasing greenhouse gas emissions as merely "low", rather than "severe or catastrophic"¹¹. The Inquiry then describes ways that the risks associated with greenhouse gas emissions can be "mitigated to achieve an acceptable level" of risk¹².

⁹ Inquiry report Section 9.1.4.

¹⁰ Inquiry report Section 9.9.

¹¹ Inquiry report Tables 9.3 and 9.5.

¹² Inquiry report Section 9.9.

Another possible reason why the Inquiry has rated the climate change consequences as “low” and risks as “acceptable” is because the Inquiry uses in its analysis the technique known as “salami slicing”¹³. Ways in which the Inquiry has “sliced the salami” are described below:

- The Inquiry has assessed the climate change risks of “excessive” or “abnormal” emissions, but has not assessed the risks of the base level of emissions.
- The Inquiry has assessed individual risks to our climate from parts of the oil and gas field development life-cycle (e.g. emissions from abandoned wells), but did not assess the full risks of the full development cycle.
- The Inquiry has assessed the climate change consequences from the development of any single “new gas field”¹⁴ but not the consequences of developing multiple new Northern Territory oil and gas fields.
- The Inquiry has not acknowledged, at all, the climate change consequences of producing oil (hydrocarbon liquids) from NT shales (see the following section of this submission).

To summarise, by using the technique of “salami slicing”, the Inquiry has concluded that the consequences of greenhouse gas emissions that ultimately occur from bringing NT shales into oil and gas production are:

“**low**, given that greenhouse gas emissions (from any new shale gas field) will contribute a very low proportion of net global greenhouse gas emissions.”¹⁵

Using the above-described “salami-slicing” methods is inconsistent with the Inquiry Terms of Reference that require a full assessment of “cumulative” impacts¹⁶.

Considering the evidence presented in the recently-published scientific literature references described above, and if the full risks of climate change are considered, it is clear that no scientific inquiry can responsibly approve a fossil fuel development. These recent scientific references show that it can no longer be claimed, as the Inquiry implies, that there is a safe level of greenhouse gases that can be added to our Earth's atmosphere. The consequences of adding large volumes of greenhouse gas to our atmosphere cannot be said to be “low” when people are already dying as a result.

¹³ “Salami slicing refers to a series of many small actions, ..., that as an accumulated whole produces a much larger action.” https://en.wikipedia.org/wiki/Salami_slicing

¹⁴ Inquiry report Appendix 3.

¹⁵ Inquiry report Appendix 3.

¹⁶ Inquiry report Appendix 1.

Climate change is already killing people. Because the Inquiry accepts that NT fossil fuel developments will cause large amounts of additional greenhouse gases to be released into our Earth's atmosphere, the Inquiry must recognise that it follows that the climate change consequences of NT fossil fuel developments are not "low". Rather, NT fossil fuel developments will cause additional people to die sooner than they otherwise would have died.

I recommend that the Inquiry recognise that recent scientific literature has now established that greenhouse gas emissions are already causing human deaths, and that greenhouse gas emissions will cause millions of people to die prematurely. The Inquiry should then recognise that the development of the very large Northern Territory fossil fuel deposits, if allowed, will result in premature human deaths. Given these consequences, the Inquiry's scientific risk assessment must conclude that shale oil and gas development should not proceed in the Northern Territory.

Considering the recent New York City lawsuit mentioned above, I also recommend the Inquiry report on the legal risks faced by parties that would approve oil and gas development in the Northern Territory.

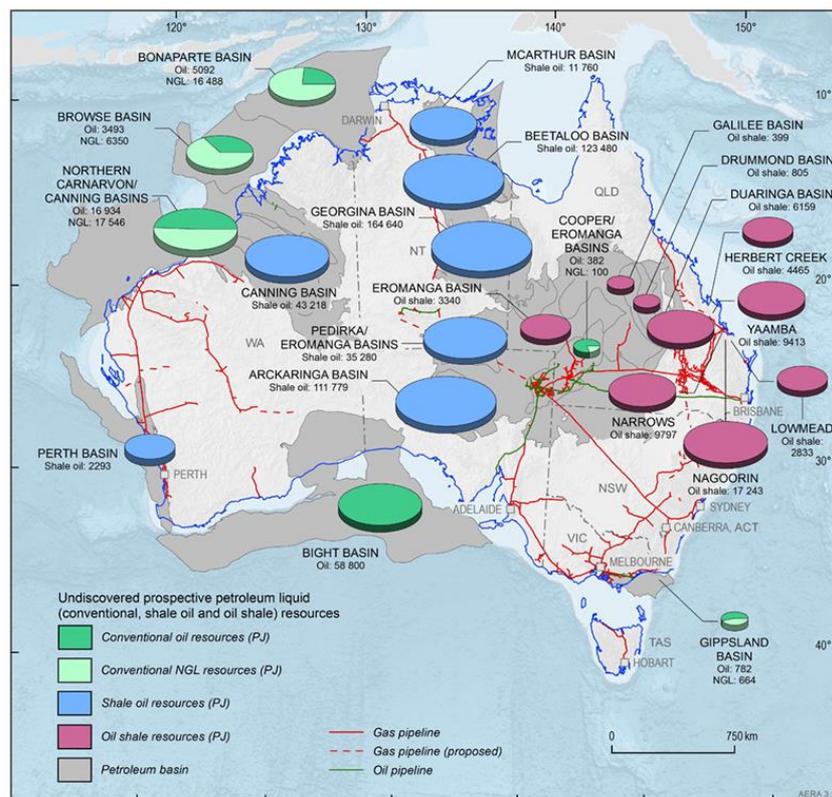
For completeness, below I provide further comments on the Inquiry's report. However, further commentary nearly seems unnecessary considering the impact of climate change on human life described above.

Fossil fuel development should not be allowed to proceed in the Northern Territory on the basis of scientifically-evident climate change risks alone.

2). OIL PRODUCTION IS THE KEY DRIVER FOR DEVELOPMENT OF NT BASINS, BUT THE RISKS ASSOCIATED WITH PRODUCING OIL HAVE NOT BEEN ASSESSED BY THE INQUIRY

The Inquiry's report focuses on the risks associated with gas production. Unfortunately, the Inquiry's draft report is, to date, silent on the risks associated with producing oil (i.e. hydrocarbon liquids). This is despite Geoscience Australia clearly highlighting that "the possibility of producing oil is the key driver ... in basins ... such as the Georgina Basin (Northern Territory / Queensland), and the Beetaloo Sub-basin in the Northern Territory"¹⁷.

Geoscience Australia has identified prospective petroleum liquid (shale oil) resources of 123,480 PJ in the Beetaloo Basin alone¹⁸. (See the following figure.)



Source: Geoscience Australia, Encom GPInfo, a Pitney Bowes Software (PBS) Pty Ltd. Whilst all care is taken in the compilation of the field outlines by PBS, no warranty is provided re the accuracy or completeness of the information, and it is the responsibility of the Customer to ensure, by independent means, that those parts of the information used by it are correct before any reliance is placed on them. Accurate at July 2015.

Undiscovered prospective petroleum liquids.

Geoscience Australia (GA), Australian Energy Resource Assessment

<http://www.ga.gov.au/aera/oil>

The Inquiry's report includes the corresponding GA chart for gas¹⁹, but does not include information about or discussion of hydrocarbon liquids.

¹⁷ Geoscience Australia, "Old rocks prove their exploration potential", 29 May, 2013. <http://www.ga.gov.au/news-events/news/latest-news/old-rocks-prove-their-exploration-potential2>

¹⁸ Geoscience Australia, "Australian Energy Resource Assessment (AERA)", <http://www.ga.gov.au/aera/oil>

¹⁹ Inquiry report Figure 6.1.

The U.S. EIA has identified 4.7 billion barrels of “technically recoverable” oil²⁰ in the Northern Territory. This is a very large amount of potentially recoverable oil. To present an idea of scale, the EIA’s figure is equivalent to a volume of up to 64 million ten-tonne road tankers, were that amount of oil to be moved by road.

Overseas and in the Northern Territory, oil and gas companies target hydrocarbon-liquids-bearing shale zones, in order to maximise economic return²¹. In the NT, the oil and gas producing company Origin has highlighted the Kyalla formation in the Beetaloo Basin as being liquids-rich²².

The following chart shows that for liquids-rich shales, the value of the liquids can be far greater than the value of the gas. Indeed, gas can have zero value if markets are not found for the gas nor infrastructure put in place to collect, process, and transport the gas. Liquid hydrocarbons (including oil), on the other hand, have greater intrinsic value and are easier to transport and store.

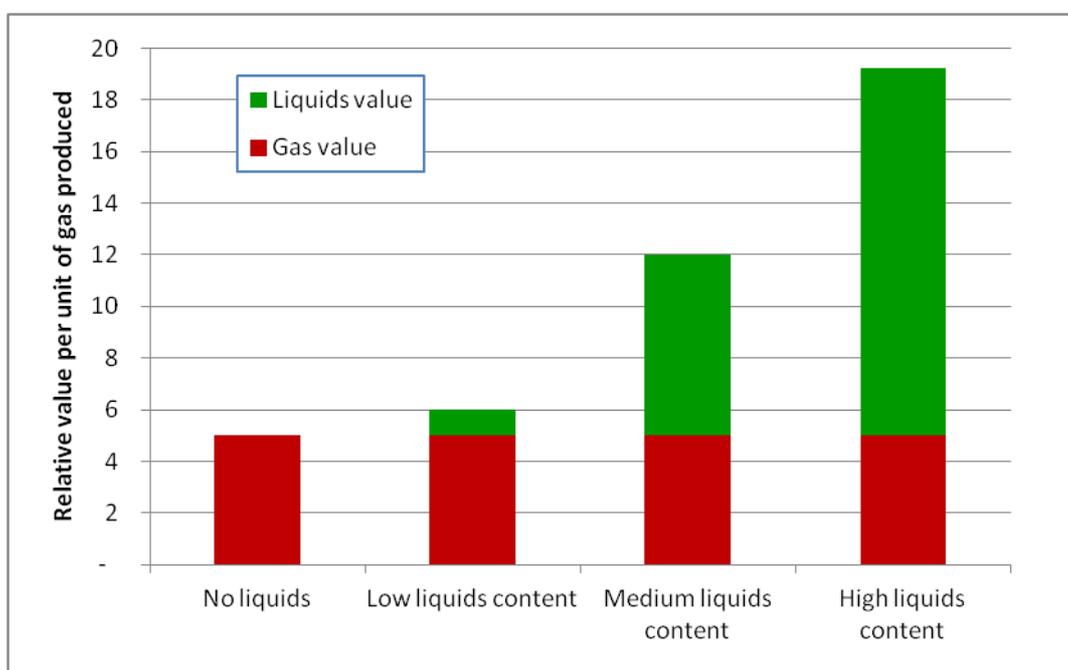


Illustration of relative gas and liquid hydrocarbon values.
(Gas valued at \$5/GJ and liquids at \$50/bbl.)

²⁰ U.S. Energy Information Administration (EIA), "Technically recoverable shale oil and shale gas resources: An assessment of 137 shale formations in 41 countries outside the United States", June 2013. <https://www.eia.gov/analysis/studies/worldshalegas/pdf/overview.pdf>

²¹ Udland, M., "Australian Mining Giant BHP is shutting down 40% of its U.S. shale wells", Business Insider Australia, 21 January 2015. <https://www.businessinsider.com.au/bhp-shuts-shale-operations-2015-1?r=US&IR=T>

²² "Origin sitting on Beetaloo shale gas bonanza," The Australian, 19 July 2017. <http://www.theaustralian.com.au/business/mining-energy/origin-sitting-on-beetaloo-shale-gas-bonanza/news-story/b0df8be0415702284a6c5a8c23832285>

The production of oil (hydrocarbon liquids) involves greater and additional risks versus the risks related only to gas production that the Inquiry as documented so far. Examples of oil-related risks include contaminating land and water with spilled oil²³, contaminating air with volatile and toxic hydrocarbon components²⁴, and increased methane emissions in situations where oil is the primary target and there is limited investment in gas-recovery infrastructure²⁵. The production of large amounts of oil will, of course, also significantly increase greenhouse gas emissions when this oil is eventually burned. The Inquiry Terms of Reference²⁶ state:

“The Inquiry will assess the scientific evidence to determine the nature and extent of the environmental impacts and risks, including the **cumulative impacts** and risks, associated with hydraulic fracturing of unconventional reservoirs and the Associated Activities in the Northern Territory.”

Clearly the cumulative impacts of producing oil - as well as gas - will be greater than the impacts of producing gas alone.

I recommend that the Inquiry investigate and report not only on the risks associated with gas production and transportation, but also on the risks associated with producing hydrocarbon liquids (including oil) in remote Northern Territory locations and transporting hydrocarbon liquids from these locations.

²³ Chow, L. "Massive North Dakota oil spill not cleaned up 3 years later. EcoWatch. 19 December 2016. <https://www.ecowatch.com/tesoro-pipeline-spill-2156083859.html>

²⁴ Warneke, C., et. al., "Volatile organic compound emissions from the oil and natural gas industry in the Uintah Basin, Utah: oil and gas well pad emissions compared to ambient air composition", Atmospheric Chemistry and Physics, 20 October 2014. <https://www.atmos-chem-phys.net/14/10977/2014/>

²⁵ Macpherson, J., "North Dakota oil output cut back to meet gas capture rules", St Louis Post Dispatch, 16 January 2018. http://www.stltoday.com/business/north-dakota-oil-output-cut-back-to-meet-gas-capture/article_0aee4db3-9df7-512d-857f-3e5b209a7eca.html

²⁶ Inquiry report Appendix 1.

3). FRACKING HAS NOT MADE THE U.S. A NET ENERGY EXPORTER

Page 5 of the Inquiry's report states "...the 'shale gale' gas revolution turned the US from an energy importer into an energy exporter."

This statement is unclear, may be incomplete, and potentially misleads. It is unclear what this statement, placed in this scientific inquiry report, is intended to achieve. The Inquiry should be aware that this incorrect / incomplete statement could indicate unscientific bias and could be seen as an attempt to stir enthusiasm for shale fracking.

What is the source for this statement? Often it is reported in the U.S. and international media that "thanks to fracking", the U.S. no longer imports oil, or that the U.S. exports more oil than it imports (i.e. is a net oil exporter) ²⁷. Such media statements are incorrect. As reported by the U.S. Energy Information Administration (EIA) the U.S. continues to rely heavily on **imported** oil (petroleum) ²⁸.

Even considering not just petroleum but all sources of traded energy (e.g. coal, uranium), the U.S. continues to be a "net" energy **importer**. The U.S. EIA has published some scenarios where the U.S. in future does become a net energy exporter, but likewise the EIA has published scenarios where the U.S. **never** becomes a net energy exporter ²⁹.

I recommend that this sentence containing the claim that "the shale gale gas revolution" has turned the U.S. from an energy importer to an energy exporter be removed from the Inquiry's report.

²⁷ Hanson, V. D., Dallas News, "Why fracking deserves our gratitude", 6 July 2017.
<https://www.dallasnews.com/opinion/commentary/2017/07/06/fracking-industry-deserves-gratitude>

²⁸ U.S. Energy Information Administration,
https://www.eia.gov/energyexplained/index.cfm?page=oil_imports,

²⁹ U.S. Energy Information Administration, <https://www.eia.gov/todayinenergy/detail.php?id=29433>

4). SHALE GAS IS NOT AN “IMPORTANT SOURCE OF ENERGY IN THE AUSTRALIAN ENERGY MARKET”

Part of the Inquiry Report Section 9.1.1 reads: “Shale gas is a form of natural gas and is an important source of energy in the Australian energy market.”

Considering that to date very little gas has been produced from shales in Australia, and that it is not known how much gas ever will be produced from shales in Australia, this statement is incorrect. At present, shale gas is not an "important source" of energy in the Australian energy market.

I recommend that this statement be deleted from the report because it is incorrect and may indicate unscientific bias.

The subject paragraph then goes on to broadly recap the role of gas in the Australian energy market. This recap is out of place in Chapter 9, which covers greenhouse gas emissions.

5). OIL AND GAS PRODUCERS WILL NOT FIND IT ECONOMIC TO DRIVE METHANE EMISSIONS TOWARD ZERO

Part of Section 9.4 of the Inquiry's report reads: "fugitive methane emissions from a new onshore shale gas field ... are estimated to be worth \$72 million per year". This is the Inquiry's estimate of the value of 7.3 PJ/yr of produced gas (2% of 365 PJ/yr) that might be lost to the atmosphere. ($0.02 * 365 \text{ PJ/yr} * \10 GJ). The Inquiry uses this figure of \$72 million per year to illustrate that there are "economic incentives for gas companies to reduce methane emissions".

Unfortunately, the economic benefits that might result were methane emissions reduced toward zero are unlikely to be realised. If, because of releasing methane into our atmosphere, the producing company finds that they fall 2% short of meeting production targets (to use the Inquiry's example), then, considering the potentially vast scale of the NT shale gas resource, the producing company will likely find it more economic to maintain the required gas production rate simply by drilling 2% more wells. The approach of drilling more wells may be cheaper than expending significant operational and maintenance effort addressing a large number of methane emission points.

An illustration of the above-described gas-field operating philosophy is the continuously vented methane found in the Queensland coal seam gas fields^{30, 31}. (See images below.) At the design phase for this coal-seam-gas facility, financially-driven decisions were made that allow this produced gas to be released into the atmosphere. Today during the operations phase for this coal seam gas facility, it would be very expensive to retrofit facilities to reduce these emissions. High methane emissions reported in the U.S. is further illustration of the lack of economic drivers to improve methane recovery³².

³⁰ Forcey, T., "Infrared video-recording methane emission in the Queensland Coal Seam Gas Fields", February 2016.
https://d3n8a8pro7vhmx.cloudfront.net/lockthegate/pages/3861/attachments/original/1495068484/FLIR_Report_FINAL_20170501_Small.pdf?1495068484

³¹ Long, S. "Methane emissions from coal seam gas development raise climate change concerns". ABC News.

³² Lafleur, D, Forcey, T., Sandiford M., Saddler, H., "A review of current and future methane emissions from Australian unconventional oil and gas production", University of Melbourne Energy Institute, October 2016.



Visual and infrared images of continuous methane venting in the Queensland coal seam gas fields.
February 2017

The Inquiry suggests that \$72 million per year is a substantial sum. However, considering that the 365 PJ/yr gas field would be producing revenue of \$3,528 million per year (using the Inquiry's \$10/GJ gas valuation), producing company management might find it uneconomic to prioritise limited operations and maintenance resources on gaining "only" some tens of millions of dollars per year of lost gas. (Note: \$3,528 million per year includes gas value only and ignores the value of co-produced hydrocarbon liquids. Based on U.S. experience, hydrocarbon liquids value is likely to exceed the value of the produced gas.)

Unless a very high "carbon price" is set on methane-related greenhouse-gas emissions, gas companies operating in large and remote gas fields are unlikely to find it profitable to reduce methane emissions toward zero. For example, a carbon price of \$A 50/tonne-CO₂-equivalent applied to (the Inquiry's example of) 7.3 PJ/yr of methane emissions lost to the atmosphere - results in an impost of \$236 million/yr (100 year methane GWP = 36) or \$572 million/yr (20 year methane GWP = 87). These sums are substantially larger than the \$72 million/yr of lost-gas value alone. However at this time in Australia or in the Northern Territory, no attempt is made to limit greenhouse gas emissions by mechanisms such as a carbon price.

The Inquiry's hopeful characterisation of the \$72 million/yr leak-reduction incentive indicates a lack of understanding about how gas companies, operating in large and remote gas fields, will make financial judgements and set operational and maintenance budgets and priorities.

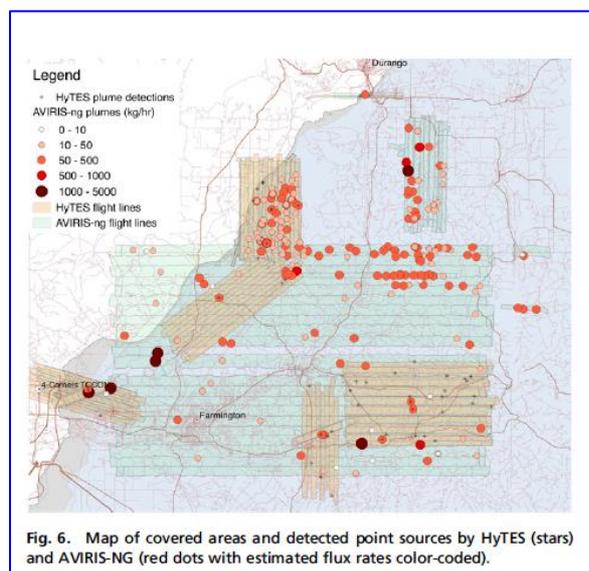
I recommend that this part of the report be deleted unless a more informed understanding of gas-field business decision-making and opportunity prioritisation can be presented.

6). SOPHISTICATED TOP-DOWN METHANE-EMISSION-FLUX QUANTIFICATION METHODS ARE AVAILABLE NOW AND SHOULD BE DEPLOYED IN AUSTRALIA

Regarding top-down methane emission measurement techniques, the Inquiry's report states in Section 9.4.1 that "it is difficult if not almost impossible, to distinguish between the many sources of emissions when considering the results from 'top-down' investigations". The Inquiry report goes on to state that "...measuring methane flux levels from a gas field is difficult and the results unreliable"³³.

These statements are incorrect. Technology is available now that can, over a large geographical area, rapidly identify multiple methane emissions sources and quantify large and small methane fluxes.

For example, as I presented previously to the Inquiry in August 2017³⁴, Frankenberg et.al.³⁵, working in the Four Corners region of the United States, used "top-down" airborne infrared imaging to identify 250 individual methane plumes and to quantify methane emission rates ranging from **as little as two kilograms per hour** to five tonnes per hour. This research, funded by National Aeronautics and Space Administration (NASA) and the National Oceanographic and Atmospheric Administration (NOAA), used a "next-generation Airborne Visible/Infrared Imaging Spectrometer (near-infrared)" and a "Hyperspectral Thermal Emission Spectrometer (thermal infrared)" mounted in a fixed-wing aircraft. The researchers measured methane plumes at one-to-three metre spatial resolution across an area 80 kilometres x 40 kilometres. The figure below illustrates the study area and the methane emissions sources identified.



Map of airborne methane investigations in the Four Corners region of the United States, from Frankenberg et. al. Emission sources shown as coloured dots.

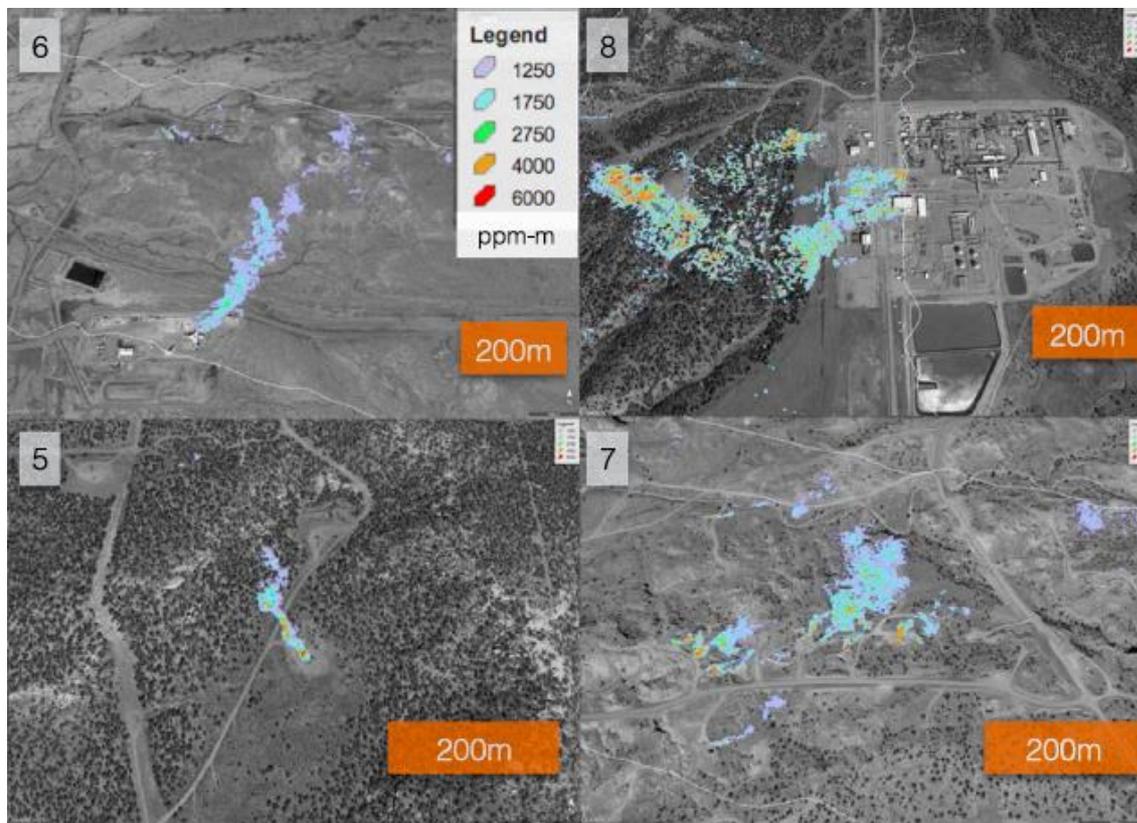
³³ Inquiry report Section 9.9, footnote 196.

³⁴ Tim Forcey August 2017 submission to the Inquiry. <https://frackinginquiry.nt.gov.au/?a=445695>

³⁵ Frankenberg, C. et al., "Airborne methane remote measurements reveal heavy-tail flux distribution in Four Corners region", PNAS 2016. <http://www.pnas.org/content/113/35/9734.full>

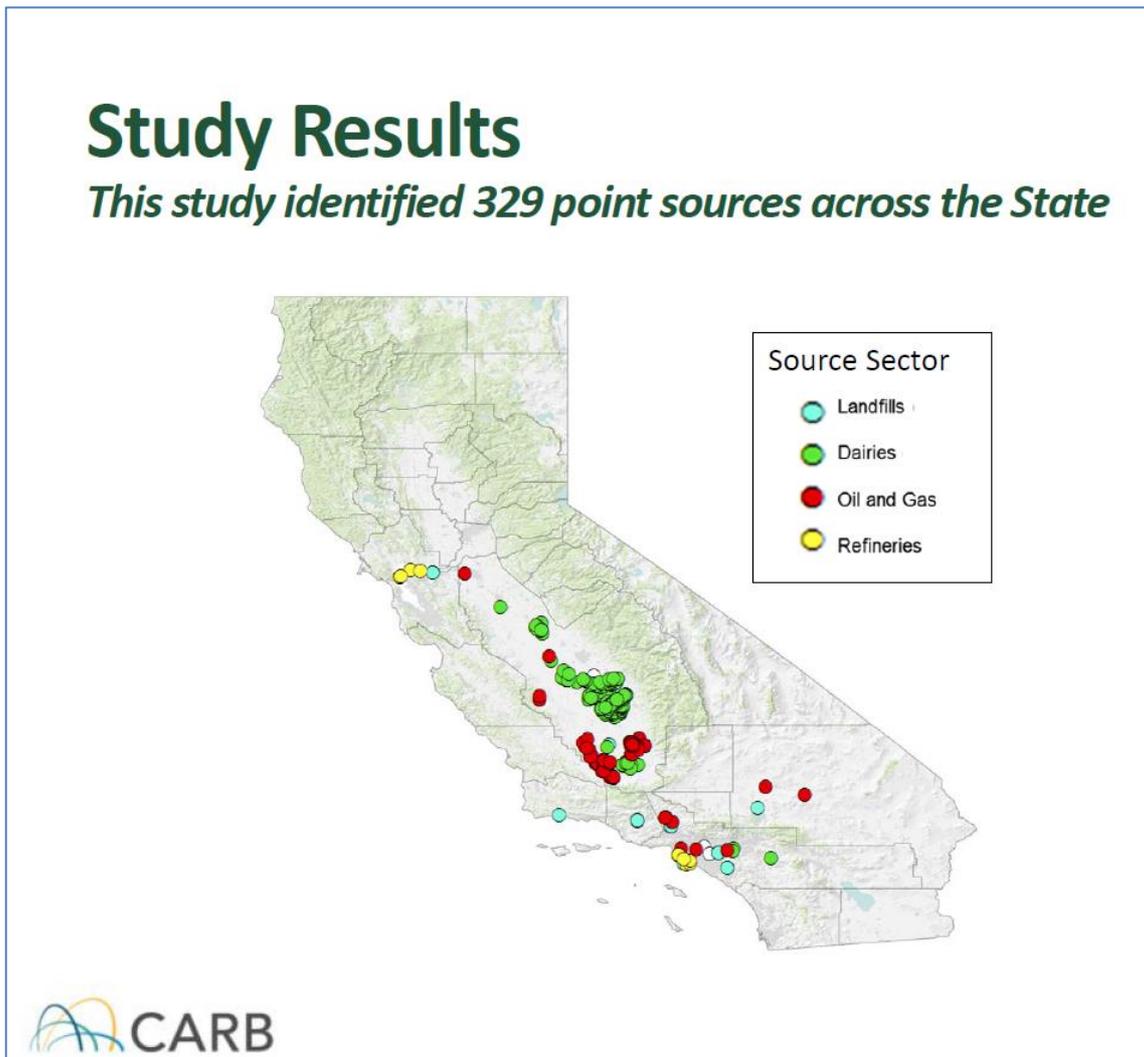
The table and images below show results for four of the 250 methane-emissions sources identified by Frankenberg et.al.

Image number	Emission source	Emission rate (kilograms / hour)	Emission rate (tonnes / day)
5	well pad	500	12
6	coal mine venting shaft	1,100	26
7	sources undetermined, located near well-completion site	1,200	29
8	gas processing plant	5,000	120



Imaging and quantifying methane emissions in the "Four Corners" region of the south-western United States.

Following on from Frankenberg et. al., recent top-down studies in California³⁶ were able to identify 329 methane emission point sources and to distinguish between landfills, dairies, oil and gas production facilities, and refineries, as shown by the following figure³⁷.



³⁶ California Air Resources Board AB 1496 Research Program.

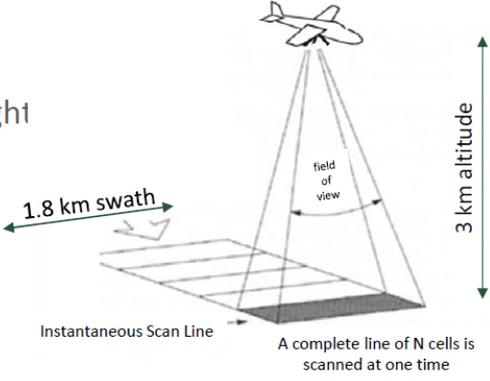
https://www.arb.ca.gov/research/methane/ab1496_research.htm

³⁷ <https://www.arb.ca.gov/board/books/2017/092817/17-9-5pres.pdf>

The following figure illustrates the top-down method employed by the researchers in California.

Technology Overview

- Airborne methane imaging with JPL's AVIRIS-NG instrument
 - "Pushbroom" sensor measures reflected solar radiation along the flight path
 - Infrared absorption by methane to detect plumes
 - Point source detection within meters
 - Quantifies methane in kg for each plume
- Different airborne approach than used for CARB's Aliso Canyon quantification



1.8 km swath

3 km altitude

field of view

Instantaneous Scan Line

A complete line of N cells is scanned at one time



With the methane emission detection and flux-quantification technology now available, the Inquiry is not correct in stating that "the reporting of facility wide emissions ... will continue to rely substantially on emissions factor calculations".³⁸

I recommend that throughout Chapter 9 and in the Inquiry's recommendations, the Inquiry call for the use of state-of-the art "top-down" methane emission detection and methane flux-quantification techniques.

³⁸ Inquiry report Section 9.5.6.

7). MIS-ACCOUNTING OF AUSTRALIAN METHANE EMISSIONS FROM UNCONVENTIONAL OIL AND GAS PRODUCTION STILL NEEDS TO BE FIXED

In August 2017 I presented to the Inquiry our 2016 University of Melbourne research into methane emissions from unconventional oil and gas production³⁹. Key findings of that research included:

- “No baseline methane-emission studies were completed prior to the commencement of the Australian CSG-LNG industry
- There is significant uncertainty about methane-emission estimates reported by oil and gas producers to the Australian government, and by the Australian government to the United Nations. The United Nations has requested that Australia improve its methodologies.
- Australian methane-emission reporting methodologies rely to a significant extent on assumed emissions factors rather than direct measurement
- The assumptions used to estimate methane emissions include some that are out-dated, and some that lack demonstrated relevance to the Australian unconventional oil and gas industry
- Despite Australian Government greenhouse-gas reporting requirements having been established in 2009 and Australia's unconventional gas industry operating at significant scale since 2010 and rapidly expanding since, there has as yet been no comprehensive, rigorous, independently-verifiable audit of gas emissions. Indeed, to quote CSIRO, "reliable measurements on Australian oil and gas production facilities are yet to be made." ⁴⁰
- If methane emissions from unconventional oil and gas production are being significantly under-reported, this could have a large impact on Australia's national greenhouse accounts.”

In February 2017 I travelled to the Queensland coal seam gas fields with a sophisticated infrared-video camera capable of recording methane being continuously vented from water pipelines⁴¹. (See images on page 14). This is an example of a class of methane emissions that are ignored by the current accounting practices of gas companies and the Australian Government.

The Inquiry's report states that “further research is required to explain or reduce” discrepancies in methane accounting⁴². I agree and continue to call on the Australian Government to ensure methane emissions from oil and gas production, transport, and use are correctly measured and reported.

³⁹ Lafleur, D, Forcey, T., Sandiford M., Saddler, H., “A review of current and future methane emissions from Australian unconventional oil and gas production”, University of Melbourne Energy Institute, October 2016.

⁴⁰ Day, S., Dell'Amico, R. et. al., “Field measurements of fugitive emissions from equipment and well casing in Australian coal seam gas fields.” 2014

⁴¹ Forcey, T., "Infrared video-recording methane emission in the Queensland Coal Seam Gas Fields", February 2016.

https://d3n8a8pro7vhmx.cloudfront.net/lockthegate/pages/3861/attachments/original/1495068484/FLIR_Report_FINAL_20170501_Small.pdf?1495068484

⁴² Inquiry report Section 9.4.2.