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Extreme heat in Darwin

The number of days over 35°C in Darwin has increased from 5.6 per year to 22.2 per year. CSIRO modelling estimates that without climate action this could rise to 132 days per year in 2030 and 275 days per year in 2070. Such extreme heat would have profound effects on human health, industries and ecosystems. Given the NT's vulnerability to climate change, development of emission-intensive oil and gas reserves are not in the Territory's interests.

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Summary

Temperatures above 35^{o}C with 70% humidity are considered 'extremely dangerous' by government agencies such as the US Government National Oceanic and Atmospheric Administration. The number of days over 35^{o}C per year in Darwin has increased fourfold from an average of 5.6 days per year in the early 20th century to over 20 days per year in the last five years.

This increase is especially pronounced throughout the September to December "build-up" to the wet season. Combined with the humidity of this season, the resultant heat stress risk is being pushed to an extremely dangerous level.

Alarmingly, CSIRO climate models project that without drastic reductions in greenhouse gas emissions, the number of days over 35 degrees each year in Darwin will increase dramatically to 132 days per year by 2030, 187 days per year by 2050 and 275 days per year by 2070.

Temperature increases of this magnitude are dangerous. Severe health impacts and heat-related deaths would increase. Increased hot days would reduce productivity in important Territory industries such as agriculture, construction and tourism. Ecosystems would be severely damaged and the standard of living of all Territorians would be greatly reduced.

Exploiting shale oil and gas in the Territory is completely incompatible with the steps we need to avoid these impacts.

Introduction

Extreme heat is dangerous for human health, for ecosystems and agriculture. As the climate warms, the number of extremely hot days is forecast to increase. While Darwin is known for its consistent warm weather, the number of extremely hot days - days over 35^{o}C - has generally been low. The number of extremely hot days in Darwin has increased through the last century and is forecast to increase dramatically without a strong policy response to climate change.

Animals and plants have an upper limit for heat tolerance. While flora and fauna in the tropics are adapted for the relatively high temperatures of their environment, the temperature ranges they experience in tropical regions are very narrow compared to temperate climate zones. Tropical flora and fauna struggle to survive temperatures outside the range they are accustomed to, such as extreme heat.[1]

The human body copes with a wider temperature range via complex thermoregulatory system. In hot climates, the body cools itself primarily through sweating.[2] Evaporation of sweat transfers heat from the body to the atmosphere. However, when the surrounding air is hot and humid, heat loss stalls, and the body temperature rises. This creates discomfort and further heat gain brings a cascade of health impacts, from mild to severe, and can ultimately be fatal without intervention. Familiarity with heat allows the body to acclimatize, but this too has upper limits.[3]

Temperature and humidity are often combined into a heat index figure to provide a simple indicator of the body's ability to cool itself. Of a number of indices available, one of the most important is published by the US Government National Oceanic and Atmospheric Administration (NOAA).

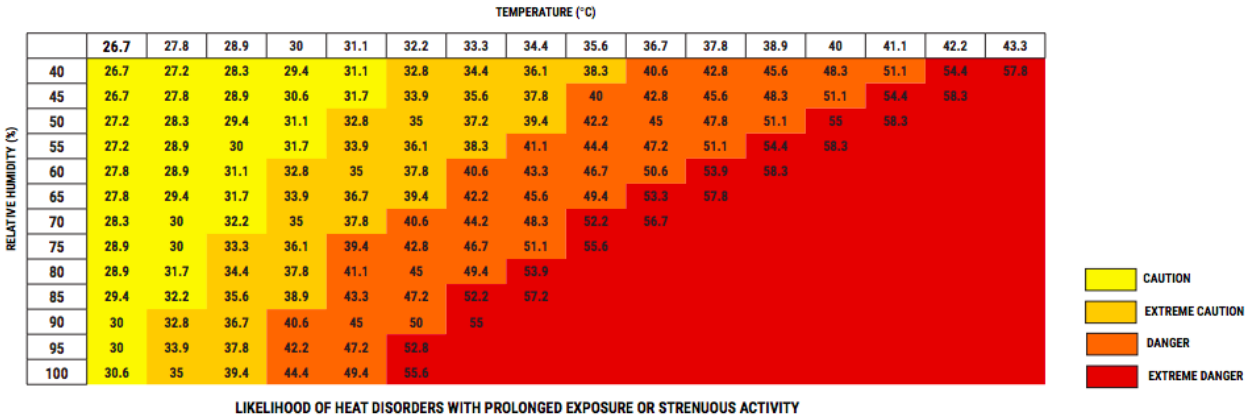
As shown in the NOAA heat stress chart in Figure 1 below, the combination of centigrade temperatures in the low thirties with high humidity are considered "dangerous" to human health.

[1] Khaliq I, Hof C, Prinzinger R, Bohning-Gaese K, Pfenninger M. (2014) Global variation in thermal tolerances and vulnerability of endotherms to climate change. Proc Biol Sci. 2014; 281 (1789): 20141097.

[2] Hanna EG, Tait PW. Limitations to thermoregulation and acclimatisation challenges human adaptation to global warming. Int J Environ Res Public Health (2015) ; 12 (7): 8034-74.

[3] Hanna EG, Tait PW. Limitations to thermoregulation and acclimatisation challenges human adaptation to global warming (2015) Int J Environ Res Public Health 2015; 12 (7): 8034-74.

Figure 1. NOAA Heat Stress Index



	26.7	27.8	28.9	30	31.1	32.2	33.3	34.4	35.6	36.7	37.8	38.9	40	41.1	42.2	43.3
40	26.7	27.2	28.3	29.4	31.1	32.8	34.4	36.1	38.3	40.6	42.8	45.6	48.3	51.1	54.4	57.8
45	26.7	27.8	28.9	30.6	31.7	33.9	35.6	37.8	40	42.8	45.6	48.3	51.1	54.4	58.3	
50	27.2	28.3	29.4	31.1	32.8	35	37.2	39.4	42.2	45	47.8	51.1	55	58.3		
55	27.2	28.9	30	31.7	33.9	36.1	38.3	41.1	44.4	47.2	51.1	54.4	58.3			
60	27.8	28.9	31.1	32.8	35	37.8	40.6	43.3	46.7	50.6	53.9	58.3				
65	27.8	29.4	31.7	33.9	36.7	39.4	42.2	45.6	49.4	53.3	57.8					
70	28.3	30	32.2	35	37.8	40.6	44.2	48.3	52.2	56.7						
75	28.9	30	33.3	36.1	39.4	42.8	46.7	51.1	55.6							
80	28.9	31.7	34.4	37.8	41.1	45	49.4	53.9								
85	29.4	32.2	35.6	38.9	43.3	47.2	52.2	57.2								
90	30	32.8	36.7	40.6	45	50	55									
95	30	33.9	37.8	42.2	47.2	52.8										
100	30.6	35	39.4	44.4	49.4	55.6										

Source: http://www.nws.noaa.gov/os/heat/heat_index.shtml

As shown in Figure 1, NOAA's heat stress index rises to "Extreme Danger" when temperatures pass 35°C with 70% humidity. Darwin's current climate already sees relative humidity levels approach and even exceeds 70%. From March 2017 to February 2018 there were 60 days with a relative humidity of 70% or above at 3pm in Darwin. 46 of these days occurred during the months of January, February and March.[4]

A future that combines such high humidity levels with a large increase in days over 35 degrees represents a serious threat to the wellbeing of Darwin's population. Under such conditions even short period of exposure, particularly in combination physical exertion, can lead to serious heat disorders and even the risk of death.

Heat stress indices inform the International Standards Organization guidelines for work-rest ratios to limit the risk of overheating and avoid deaths [5]. Temperatures are recorded in the shade, so the additional heat generated by sunlight adds further to the risk. According to these guidelines, gentle exercise, such as walking in the sun at 3pm in Darwin for more than 15 minutes per hour, from September to December (during the build-up season) already presents dangerous risks of heat stress. [6]

Projections about future humidity are mixed. Humidity levels are projected to remain largely unchanged in the Monsoonal North West of Australia up to 3 degrees of warming. Over 3 degrees there is thought to be a 34% chance of a small decrease in

[4] BOM Daily Weather Observations. http://www.bom.gov.au/climate/dwo/IDCJDW8014.latest.shtml

[5] ISO / DIS 7243. Ergonomics of the thermal environment -- Assessment of heat stress using the WBGT (wet bulb globe temperature) index. Geneva: International Standards Organization; 2015 18th June .p. 16. Available from: http://www.iso.org/iso/home/store/catalogue_ics/catalogue_detail_ics.htm?csnumber=67188. [cited 30th July 2016].

[6] Davis C, Hanna (2016) EG. Temperature and rainfall trends in Northern Australia 1911-2013: implications for human activity and regional development. Climate Research. 2016; 71 (1): 1-16.

humidity (-1 to-10%).[7] However, warm air can hold more water vapour, an extra 7% for every 1^{o}C.[8] In a warming world people's ability to regulate temperature through sweating may be hampered.

[7] CSIRO Climate Change in Australia, Climate Futures Tool, RCP 8.5, 2017. Accessed 15/3/18, https://www.climatechangeinaustralia.gov.au/en/climate-projections/climate-futures-tool/projections/

[8] Coumou D, Rahmstorf S. A decade of weather extremes. Nature Clim Change. 2012; 2 (EPub 25 March): 491–6.

Increasing temperatures in the Top End

Bureau of Meteorology temperature records are available for Darwin from 1911. On average there were 5.6 days per year over 35°C for the 30-year period from 1911 to 1940. This almost doubled to 10.1 days per year for the years between 1961 and 1990, as shown in Table 1 below:

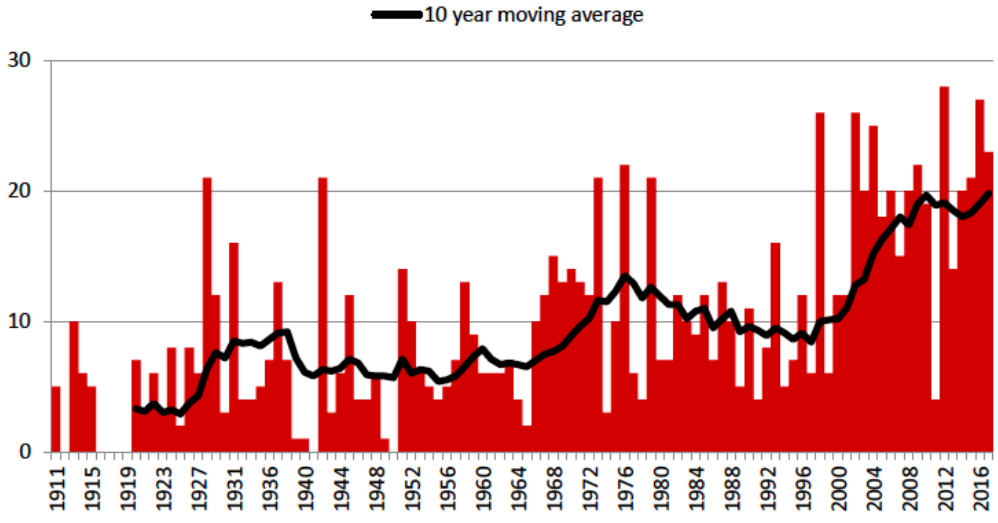
Table 1: Average number of days per year above 35°C, Darwin

Year	Average days over 35°C
1911-1940	5.6
1961-1990	10.1
2008-2017	19.8
2012-2017	22.2

Source: Bureau of Meteorology http://www.bom.gov.au/climate/data/index.shtml

As shown in Table 1 above, the 10 years to 2017 have seen days over 35°C double again to 19.8 days per year. Since 2012, the maximum daily temperature has reached 35°C on average over 22 days per year, representing a fourfold increase since the first half of the 20th century. The Bureau of Meteorology data back to 1911 is represented in Figure 2 below:

Figure 2: Annual number of days over 35°C Darwin, 1911-2016



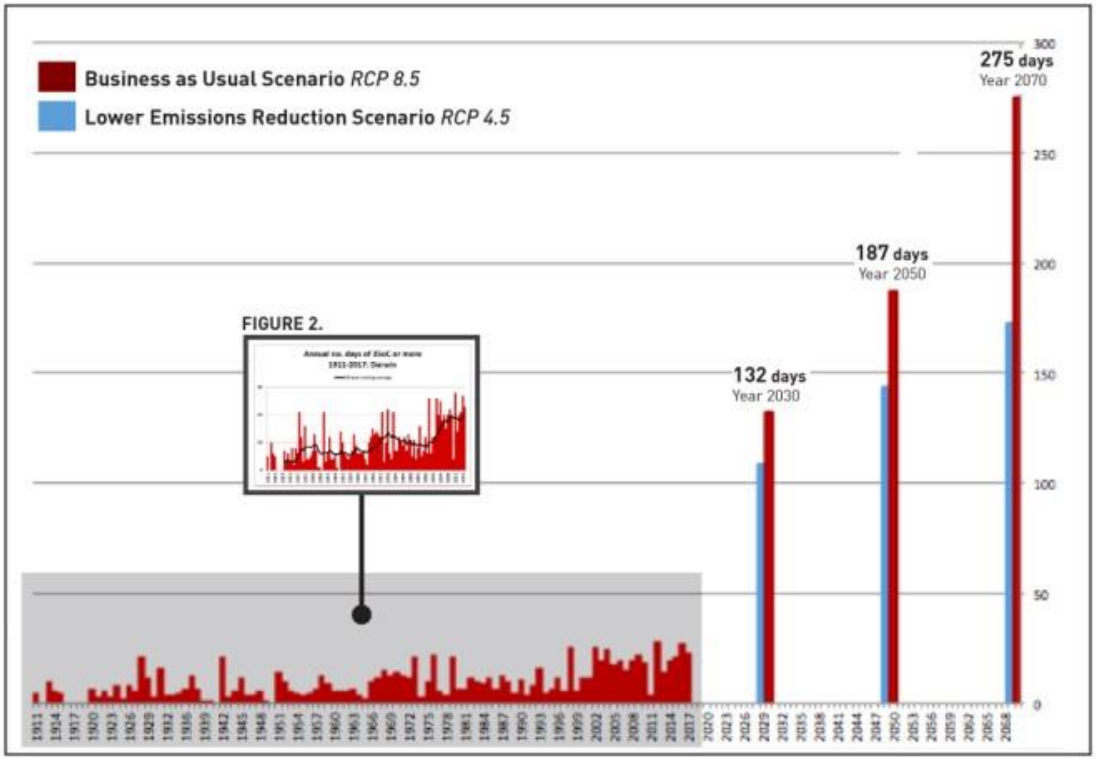
Source: Analyzed by C. Davis from BoM Acorn_Sat data set.

This recent increase in very hot days has significant implications for human health, productivity and the quality of life of people living in Darwin. Furthermore, the projected increase over the following decades will significantly exacerbate these challenges.

Projected increases in days over 35°C

The number of extremely hot days in Darwin will increase dramatically in the coming decades under CSIRO climate modelling. Under a business as usual scenario on greenhouse emissions, the CSIRO estimates Darwin could experience days 132 days over 35°C per year in 2030, 187 days per year by 2050 and 275 days per year in 2070. Figure 3 below combines the Bureau of Meteorology's data on days over 35°C from 1911 with CSIRO predictions out to 2070:

Figure 3: Darwin days over 35°C per year historic and CSIRO future modelling



Source: CSIRO Climate Change in Australia, Climate Thresholds Calculator. Using HadGEM2 RCP 8.5. Accessed 13/3/18 https://www.climatechangeinaustralia.gov.au/en/climate-projections/explore-data/threshold-calculator/#

These projections are based on the IPCC Representative Concentration Pathways (RCPs) which are scenarios of various levels of concentrations of greenhouse gases in the atmosphere. Here we have used RCP 8.5, which is the highest of the four scenarios of global emissions outlined by the IPCC in their 2014 Fifth Assessment. It reflects the Business as Usual (BAU) scenario, which most closely resembles the current global trajectory as emissions still continue to increase [9].

[9] Le Quere C, Andrew RM, Friedlingstein P, Sitch S, Pongratz J, Manning AC, et al. Global carbon budget 2017. Earth Syst Sci Data. 2017; 8 (13 November): 605–49.

Figure 3 also shows the projected number of hot days using the RCP 4.5 scenario where strong emission reduction is achieved. The RCP 4.5 pathway requires decisive reduction in emissions. If this is achieved, the CSIRO expects number of days over 35°C per year for Darwin to be significantly lower than in BAU trajectory, with 108 days over 35°C per year in 2030, 143 days per year in 2040 and 178 days per year in 2070. While these figures carry significant inherent risk, substantial additional harm could be avoided.

The number of days per year over 35°C under the most ambitious scenario (RCP 2.6) is not shown in Figure 3 as the CSIRO no longer provides these projections. Limiting warming to below 2° C is still possible but would require rapid reductions and deep and profound decarbonization of the global economies(2).[10] Insufficient political appetite has been shown thus far to achieve this goal as agreed in Paris in 2015.[11] However, it is the only way the Northern Territory can avoid the devastating impacts of dangerous climate change.

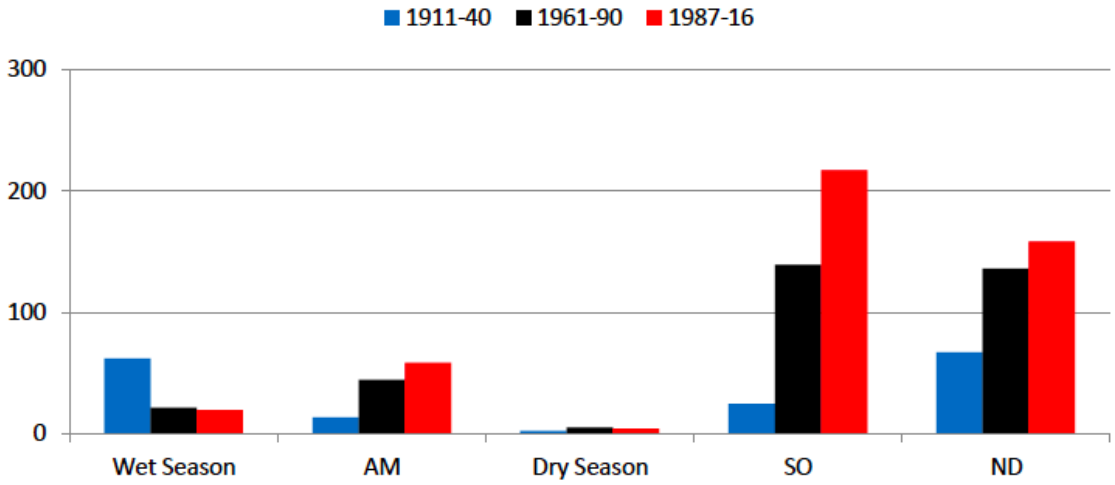
[10] Raftery AE, Zimmer A, Frierson DMW, Startz R, Liu P. (2017) Less than 2 °C warming by 2100 unlikely. Nature Climate Change. 2017; 7: 637.

[11] UNEP. The Emissions Gap Report 2017. A UN Environment Synthesis Report. Nairobi: United Nations Environment Programme (UNEP); 2017 31st October p. 116. Available from: https://wedocs.unep.org/bitstream/handle/20.500.11822/22070/EGR_2017.pdf?sequence=1&isAllowed=y. [cited 1st November 2017].

Distribution of extreme heat days

An indication of the likely timing of extreme heat days throughout the year can be gained from examining trends from 1911 over the various seasons. As shown in Figure 4, the increase in days over 35°C per year is concentrated in the shoulder seasons, the "build-up" to the wet season and the transition from the wet to the dry.[12] The high humidity of these seasons combined with the significant increase in extreme heat days already occurring make this period already dangerous to human health and wellbeing.

Figure 4: Distribution of days over 35°C by season



Note: AM=April-May, SO= Sept-Oct, ND= Nov-Dec. Source: Analyzed by C. Davis from BoM Acorn_Sat data set.

Note, in Figure 4, the number of days refers to the total over the time period represented, not the annual average.

Further increase in days over 35 severely increase these impacts. Extreme heat days can also be expected to increase in other seasons as the total number of extreme heat days exceeds the amount of days currently making up the shoulder seasons.

[12] Davis C, Hanna EG. Temperature and rainfall trends in Northern Australia 1911-2013: implications for human activity and regional development. Climate Research. 2016; 71 (1): 1-16.

Consequences of increases in extreme heat days

There will be a range of consequences from more frequent days of extreme heat, including increased intensity of storms, increasing rainfall extremes, changes to mosquito populations and the way infectious diseases spread.

Severe impacts on human health would result, including increased rates of heat-related deaths. Heat interrupts sleep patterns and reduces capacity and willingness to exercise. Both carry broad ramifications, such as increased accident risk,[13] avoidance of general life tasks, for example cooking healthy foods, and sedentary life style induced diabetes and cardio vascular disease.[14] Europe, Russia, India and Pakistan have all experienced heat waves resulting in mass death events where thousands of people died sitting in their homes. [15,16]

Irritability also increases with heat. Darwin experiences strong seasonal patterning in domestic violence and assaults which peak during the build-up season.[17] Exacerbations of these incidences would have far reaching effects. The trauma is shocking for victims and their families, and spikes in these violent attacks stretches response capacity of hospital and police services. They also have profoundly negative bearing on social amenity by disrupting community cohesion, sense of safety and attractiveness to visitors and tourists.

Recent analysis of decadal climate systems suggests it is possible that the world could breach 1.5^{o}C warming as early as 2026.[18] If this happens, within the next decade, Darwin is likely to witness increasingly severe impacts on human health and many more heat related deaths. The ability of the human body to continue to be physically active throughout the day time, for 6 or more months of the year will be significantly curtailed.

Later this decade, the number of highly dangerous months could extend to 8 or 9. Many industries such as tourism, construction and agriculture would face challenges just to continue

[13] Kjellstrom T, Kovats RS, Lloyd SJ, Holt T, Tol RSJ. The Direct Impact of Climate Change on Regional Labor Productivity. Archives of Environmental & Occupational Health. 2009; 64 (4): 217-27.

[14] WHO. Preventing noncommunicable diseases (NCDs) by reducing environmental risk factors. Geneva; 2017.p. 16. Report No.: WHO/FWC/EPE/17.1. Available from: http://apps.who.int/iris/bitstream/10665/258796/1/WHO-FWC-EPE-17.01-eng.pdf?ua=1. [cited 26th September 2017].

[15] Wang H, Horten R. Tackling climate change: the greatest opportunity for health The Lancet Climate Change and Human Health Commission. 2015;DOI: http://dx.doi.org/10.1016/S0140-6736(15)60854-6(June): 1-2.

[16] Hass A, Ellis K, Reyes Mason L, Hathaway J, Howe D. Heat and Humidity in the City: Neighborhood Heat Index Variability in a Mid-Sized City in the Southeastern United States. International Journal of Environmental Research and Public Health. 2016; 13 (1): 117.

[17] Purtill J. Mango madness: Tropical seasonal affective disorder linked to stress and depression, research finds Melbourne: ABC News; 2014 [updated 9 Oct Available from: http://www.abc.net.au/news/2014-10-07/mango-madness-mental-illness-tropical-wet-season-build-up/5795852

[18] Henley BJ, King AD. (2017) Trajectories toward the 1.5°C Paris target: Modulation by the Interdecadal Pacific Oscillation. Geophysical Research Letters. 2017; 44 (9): 4256–62

operating. In those industries productivity would be impacted, as work-rest ratios will impinge on financial viability. Alternative strategies to facilitate sustained physical exertion outdoors, such as cooling vests and cool rooms will add to costs but are likely to be a necessary feature across Australia's tropical north.

Conclusion

Given the vulnerability of Darwin and the rest of the Northern Territory to climate change, further development of its fossil fuel resources is not in the Territory's interests. Such development is incompatible with Australia's carbon budget and commitments under the Paris agreement to limit warming to less than 2 degrees. It has been calculated that two thirds of **existing** fossil fuel reserves need to remain in the ground in order to have even a 50% avoid 2 degrees warming.[19]

Despite this, the Draft Report of the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory examines a gas production scenario that could result in an increase of 5% of Australia's national emissions. A submission from the Northern Territory Department of Primary Industries and Resources presents an oil and gas production scenario that would represent an increase of over 20% of Australia's total annual emissions. Incredibly, the draft report lists the consequences of these changes in emissions as "low" and the risk as "medium".[20]

Darwin residents are already experiencing the consequences of global warming. Northern Territory shale oil and gas is a very large potential source of carbon emissions which should not be developed.

[19] McGlade and Ekins (2015) The geographical distribution of fossil fuels unused when limiting global warming to 2 °C, accessed 15/3/18, https://www.nature.com/articles/nature14016

[20] Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (2017) *Draft Final Report*, https://frackinginquiry.nt.gov.au/inquiry-reports/draft-final-report