Submission to the scientific inquiry into hydraulic fracturing in the Northern Territory.

Dimitri Lafleur

19th of January 2018

Introduction:

I welcome the opportunity to provide comments to the scientific inquiry into hydraulic fracturing in the Northern Territory.

I am a PhD student at the Australian-German climate and energy college finalizing my PhD on the climate impacts of methane emissions of unconventional gas. I have a MSc in Geology/Geophysics from the University of Utrecht, the Netherlands, and have worked in the oil and gas industry for 11 years, 8.5 of them at Shell. For Shell, I worked on onshore and offshore gas fields in the Netherlands and the U.K. as a geophysicist and project lead and as a geophysical advisor on the gas fields offshore West Australia.

I mainly address aspects of chapter 9 of the draft report. The first section addresses the possible size of the industry, the possible emissions from hydraulic fracturing, shale oil and shale gas and the impact on national emissions. It includes why emissions could be higher based on the measured methane emissions from U.S. shale oil and gas developments and analysis from global data. The second section deals with the unorthodox comparisons that the draft report makes between the presumed methane emissions of shale gas in the Northern Territory, the global budget and other industries. The third section deals with the impacts on the global carbon budget and the risk of carbon lock-in for other nations. This is followed by some remarks on the future electricity mix and why shifting to away from coal to gas may not reduce emissions as expected. I then address the emissions mitigation proposals for monitoring and emission reduction standards. I conclude with some closing remarks.

Contents

Summary:

The risk assessment of the upstream emissions and climate change from a new shale gas field is underestimating the consequences of upstream emissions and life cycle emissions of shale gas and shale oil for the domestic and global emission budget, respectively. The impact on the domestic emission budget is large – based on the reference gas field – but can be much larger. It is unwise to introduce such large emission increases given the significant challenges to reduce emissions domestically. Moreover, the draft report sees little opportunity to reduce downstream (combustion) emissions and advocates to focus on mitigation of upstream emissions. The draft report unacceptably dismisses this part of the emissions and its consequences, while stating that the inquiry will assess the scientific evidence to determine the nature and extend of cumulative impacts. The knowledge that the downstream emissions will significantly contribute to future CO_2 emissions, reducing the remaining carbon budget even further, makes Australia partly morally responsible for supplying the fossil fuels in the first place.

1. Emissions from hydraulic fracturing, shale oil & gas and impact on domestic emissions

The best estimates of technical recoverable shale gas resources for Northern Territory's sedimentary basins are estimated at 90,000 PJ [1]. There is little data on the technical recoverable shale oil resources, but there is an estimation of 17.5 Billion barrels, of which 5.7 Billion barrels is in the Northern Territory [2]. It depends how 'wet' the shale gas is, but the presence of oil may well make or break the economics of a project [1], similarly to the U.S. shale gas development which initially was all about the oil. It is surprising that the inquiry does not presume oil exploration and production to play a part in the shale gas developments. It is well possible that the reason for exploration and production is the prospectiveness in oil, not gas, since it has a higher value and truly is a global commodity. Therefore, it is possible that emissions could be much higher based on gas developments alone, as oil may be a separate development. Parts of the U.S. have seen very high methane venting and flaring levels, at times close to 40% of the gas production [3]. It is possible that this was due to the absence of a gas market, as the initial goal was oil. A similar example was the oil and gas developments in Nigeria, where between 50 and 80% of the gas was flared or vented in the period 1980-2000 [4].

In this light, it is unlikely that only a single gas field of 365PJ/y would be developed. This is taken as a reference in the draft report. Based on 90,000 PJ technically recoverable resources, an annual production of 1800 PJ/y is possible over a timeframe of 50 years – towards the year 2070, well into the second half of this century. Similarly, the reference methane emissions are assumed to be 2%. It is unclear to me where this number comes from, but it is 4 times higher than the current Australian

---

[1] Cook, P., Acola, 2013, Engineering Energy - Unconventional gas production, and conversions 1 Tcf = 28.3 Bcm, 1 Bcm = 37.6 PJ. Best estimates of recoverable gas resources in the ground for the Amadeus, Beetaloo and Georgina basin are 17,000 PJ (453 Bcm), 20,000 PJ (538 Bcm) and 53,000 PJ (1415 Bcm) respectively.

[2] EIA, 2013, Technically Recoverable Shale Oil and Shale Gas Resources - An Assessment of 137 Shale Formations in 41 Countries Outside the United States. Beetaloo: 4.7Bilion bbls, Georgina: 1.0 Billion bbls

[3] North Dakota flared periodically more than 35% of its gas production (2009-2014). EIA, 2016, https://www.eia.gov/todayinenergy/detail.php?id=26632

[4] OPEC, 2014, Annual Statistical Bulletin, Oil and gas data, Table 3.8: Natural Gas Production in OPEC Members, http://www.opec.org/library/Annual%20Statistical%20Bulletin/interactive/current/FileZ/XL/T38.HTM

estimate for methane emissions from oil and gas [5], and 20 times higher than the estimates given in original coal seam gas environmental impact assessments [6]. I interpret this assumption as an acknowledgement that methane emissions from unconventional oil and gas are likely to be much higher than the reported emissions in the Australian greenhouse gas emissions inventory. I would welcome more information for the basis of this number.

A booming shale oil and gas industry in Australia undeniably comes with methane emissions. When the coal seam gas industry started developing for LNG exports, annual reported methane emissions in Queensland in 2014, 2015 and 2016 were 11, 8 and 7 times higher than the 2005-2012 average [7]. The draft report expects that emissions from natural gas production in the Northern Territory are 3% of Australia's inventory methane emissions. Regardless of whether the 3% is an accurate and prudent estimate given the outline above, the progress of Australia's emission reduction since the start of the first period of the Kyoto protocol has shown how difficult cutting 3% of emissions is. Australia's emissions including and excluding land use changes have been going up since 2013 [8], while Australia's commitment to the Paris agreement is to reduce greenhouse gas emissions by 26 to 28% below 2005 levels by 2030. The Paris agreement itself is not sufficient to limit global warming to 2°C, hence more ambitious targets will be necessary in the near future.

Furthermore, the 3% figure is based on the entire Australian greenhouse gas emissions inventory: it would be more insightful to compare it to the methane emission from the fossil fuel inventory, i.e. 1.37Mt/y [9]. If the best estimates of recoverable gas resources are extracted, at a methane emission level used in the draft report of 2% of gas production (0.7Mt CH_4/y [10]), this would constitute 51% of Australia's current methane emissions from fossil fuels (or more than 3 times the current reported methane emissions from the oil and gas sector alone [11]).

The draft report also presumes that any new onshore gas field in the Northern territory (365 PJ/y) would contribute around 5% of Australian GHG emissions and on a global basis 0.05% of global GHG emissions [12]. As stated above, it is quite likely that the emissions are much higher in a fully

---

[5] Total CH4 emissions from oil and gas production, 2014: 5.453 Mt CO2e (or 0.218Mt CH4, using GWP_{100} CH_4=25), Australian Government, Department of Environment and Energy, 2016, National Inventory Report 2014 (revised) Volume 1. Gas production, 2014: 68,183Mcm (426.2PJ, 49.8Mt CH4), from Australian Government, DIIS, 2017, Australian Energy Statistics 2015-2016 table Q. Ratio is 0.44% of gas production.

[6] Lafleur et al., 2016, and references therein: Clark, et al. (2011), Prior (2011), Hardisty et al. (2012)

[7] Queensland government, 2018, https://data.qld.gov.au/dataset/petroleum-gas-production-and-reserve-statistics

[8] Quarterly Update of Australia's National Greenhouse Gas Inventory: June 2017, http://www.environment.gov.au/system/files/resources/62506dca-2cb1-4613-82cd-fa46c7a0df42/files/nggi-quarterly-update-june-2017.pdf . Australia's emissions including land use in 2016 were 543Mt CO2e. As stated in the draft report this is 2.0% below 2000 and 10.2% below 2005. However, emissions including land use changes have been going up since 2013. The reason that the Australian Government is using this metric is due to negotiation successes during UNFCCC negotiations (the Australia Clause art3.7 of the Kyoto Protocol: https://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/pubs/BN/~/link.aspx?_id=C5066CCDFBF2437BAFEB744911ADEA67&_z=z). Excluding land use emissions, emissions have been steadily rising since 1990, and rose 0.7% in 2016-2017 to 549.8Mt CO2e.

[9] National Greenhouse Gas Inventory Total, Methane Emissions, 2015, Kyoto Accounting. Australia's methane emissions for year 2015: 4.36Mt CH4/y, methane emissions from fuels: 1.37Mt CH4/y. http://ageis.climatechange.gov.au/#

[10] 1800 PJ/y = 48 Bcm/y. 2% of 48Bcm/y = 0.96Bcm/y = 0.7Mt CH4.

[11] Australian Government, Department of Environment and Energy, 2016, National Inventory Report 2014 (revised) Volume 1. Methane emissions from the oil and gas sector: 5.453 Mt CO2e/y or 0.21Mt CH4/y.

[12] It is not entirely clear from the report whether the reference 'global GHG emissions' and 'Australian GHG emissions' refer to annual or cumulative emissions. I assume this to be annual emissions.

developed shale gas industry. Given the struggle to cut 5% of national emissions, it would make meeting Australian emissions reduction targets very difficult if emissions increase by 5%, if not more, coming from a new industry. A full development of the shale gas resources (excluding oil) could increase Australia's emissions by 25% [13].

In the next 50 years Australia's emissions need to reduce significantly. An increase in CH_4 and CO_2 emissions on this scale is detrimental to Australia's Intended Nationally Determined Contributions (INDC) [14] for the Paris agreement.

The U.S. shale oil and gas development as an analogue is useful but dangerous

There are several reasons why the U.S. shale gas revolution has not been replicated yet, anywhere in the world. One of the issues that Australia is facing is the intraplate geological stress field. The Australian craton is characterised by a compressional stress regime [15]. The compressional regime has hampered the pioneering geothermal industry in the past [16], although the targets were at greater depths. Observed stress regime in the Bowen and Sydney basins show both reverse and strike slip stress [17]. The Cooper basin shale exploration is significantly affected by a reverse stress regime [18]. Variations in in-situ stress regimes have influenced hydraulic fracturing orientations in the Surat basin [19]. The complexity of the in-situ stress regime of the Australian plate may mean the at depth reverse stress regime could hamper effective hydraulic fracturing. There are few measurements in the Northern Territory, implying there are uncertainties as to how it varies with depth. If prospective oil and shale gas regions are governed by a reverse stress field, hydraulic induced fractures will propagate horizontally. The horizontal to vertical permeability ratio in shales can be 10:1 [20], which means that gas is more mobile along the bedding than across. Presuming the bedding is more or less horizontal, this means that vertical fracks are therefore much more efficient in increasing the gas recovery per well than horizontal fracks. Hence, there is a significant risk that more energy is needed to enhance or to create effective fractures. It may impact well type and well spacing. This will increase associated emissions and overall shale development costs. There is also greater uncertainty around the ability to control the injection fluid, which could impact the risk assessment on aquifer contamination. (It is noted that Falcon's Amungee NW-1H horizontal well in the Beetaloo basin was

---

[13] The 365PJ/y (9.69Bcm) equals to 5% methane emissions. Production of the technically recoverable gas resource (90,000PJ/y) spread over 50 years would be 1800PJ/y, which is 5 times the reference production. If market competition would see 5 operators build 5 LNG facilities, there is little synergy to collaborate and the reference emissions (5%) would increase with a factor 5. Projects could be phased in time, but this too will counter the emission reductions required or achieved elsewhere in the economy.

[14] Australia's INDC: "Under a Paris Agreement applicable to all, Australia will implement an economy - wide target to reduce greenhouse gas emissions by 26 to 28 per cent below 2005 levels by 2030" http://www4.unfccc.int/Submissions/INDC/Published%20Documents/Australia/1/Australias%20Intended%20Nationally%20Determined%20Contribution%20to%20a%20new%20Climate%20Change%20Agreement%20-%20August%202015.pdf

[15] Coblentz, et al., 1995, The origins of the Australian stress field. Cloetingh and Wortel, 1985, Stress in the Indo-Australian plate. Denham, et al., 1979, stresses in the Australian crust.pdf

[16] Huddlestone-Holmes, CSIRO, 2014; https://arena.gov.au/assets/2017/02/Geothermal-Energy-in-Australia.pdf

[17] Hillis, R. et al., 1999, In-situ stress field of Eastern Australia

[18] E&P Magazine, 2014, https://www.epmag.com/difference-between-us-australian-shale-plays-tectonic-stress-764421#p=full

[19] Flottmann, T., et al., 2013, Influence of in Situ Stresses on Fracture Stimulation in the Surat Basin, Southeast Queensland

[20] Schön, 2011, Physical properties of rocks; Bjørlykke, 2015, Petroleum Geoscience; from sedimentary environments to rock physics

hydraulically fractured but it is not clear if fractures were vertical or horizontal [21]. Falcon's Beetaloo-1 well confirms the search for oil.)

This may make hydraulic fracturing much more difficult in the attempt to replicate the U.S. analogue. This may lead to unintended consequences such as the need to drill significantly more wells (and therefor more hydraulically fracturing), which will lead to significantly higher methane emissions. In a worst-case scenario, it could also lead to not being able to meet international gas contracts, and the need to purchase the gas domestically from elsewhere (which happened to the coal seam gas industry in Queensland), perhaps increasing domestic gas prices.

The U.S. has extensive experience with shale gas and in general, it is useful to look at scientific peer-reviewed literature that explain methane measurements, emission factors and analogues from the U.S. as it includes shale gas. Various scientific studies [22] have shown that within a specific sedimentary basin methane, emissions can be much higher than the reported average percentage of production. The maximum number stated (e.g. 17% of production[23]) is indeed not representative of the methane emissions of the oil and gas industry. Studies have shown that global constraints exclude global average emissions of higher than 5-6% [24]. Other reasons for much higher methane emissions are possible due to e.g. no access to a gas market [3], an immature oil and gas industry or poor regulation. Scientific studies have argued that fossil fuel emissions have declined on a global scale, and that the increase in CH_4 concentration is due to biogenic (e.g. agricultural, wetlands) emissions, based on $\delta^{13}C$ CH_4 data [25]. Others concluded that fossil fuels emissions have gone up [26], based on atmospheric ethane and propane concentrations. By updating and revising biomass burning emissions (that have declined twice as fast as previously thought), simulations of $\delta^{13}C$ CH_4 have now reconciled this contradiction [27]. These simulations have shown that both biogenic emissions and fossil fuel emissions are going up. Fossil fuel emissions are now estimated to emit an additional 12-19Mt/y CH_4 than previously thought, bringing the total to around 120Mt CH_4/y. This means that scientific studies that have targeted specific sedimentary basins or plays cannot be discounted based on the conclusions of Schwietske et al.[24]

2. Comparisons to other sectors and global budgets

The draft report makes a few comparisons to global CH_4 and CO_2 budgets, and one to another industry sector. The report argues that the impact of emissions on the global scale is low, and the risk assessment takes this input into consideration. The comparison to global budgets is unorthodox and potentially misleading and makes impacts look small. As an example: Australia's territorial emissions are roughly 1% or the global budget. Although this may seem a small number, there are only 15 countries emitting more, all of them with a much higher population. Per capita emissions are

---

[21] Falcon, 2017, Activity 2017 to 2014. http://www.falconaustralia.com.au/overview

[22] Lafleur et al., 2016, and references therein (e.g. Peischl et al. (2015), Kort et al. (2014), Schneising et al. (2014), Pétron et al. (2014), Caulton et al. (2014), Karion et al. (2013))

[23] Caulton et al. (2014)

[24] Schwietske et al. , 2014, Natural gas methane emissions rates constrained by global atmospheric methane and ethane

[25] Nisbet et al, 2016; Schaefer et al., 2016; Schwietzke et al., 2016. Schwietzke et al. indeed concluded that methane emissions from natural gas as a fraction of production had declined from approximately 8% to 2% over the past three decades.

[26] Helmig et al., 2016; Franco et al., 2016; Hausmann et al., 2016.

[27] Worden, et al., 2017

similar to those of the U.S., 1.6 times larger than the OECD average, and 2.4 times higher than the European Union [28]. There are almost 7 Billion people who emit less, on a capita basis [28,29].

A first example is the comparison of methane emissions from fossil fuels to the entire global methane budget. On a 558Mt [30] CH_4 budged, 59% is anthropogenic (328Mt CH_4). Of the 328Mt, 105Mt [30] comes from fossil fuels, representing 32% of the total anthropogenic budget. It is potentially misleading to compare methane emissions from fossil fuels of the entire global methane budget. Mathematically the comparison is correct (19%), but humanity is responsible for the anthropogenic emissions. Moreover, the numbers used are averages from the 2003-2012 decade. Emissions have grown since and it is well possible that the contribution is now larger [31].

A second example is the comparison of the estimated climate effect of the global annual methane emissions to the annual added anthropogenic CO_2 greenhouse effect over a decade. The mathematical calculation is correct [32] and would indicate that methane's estimated climate effect is 2.3% of the annual added anthropogenic carbon dioxide greenhouse effect over the decade. This is however a misleading statement. One cannot argue the climate effect of CH_4 based on the share that CH_4 growth has as proportion of CO_2 growth, without acknowledging what the greenhouse gas is doing in the atmosphere on a decadal timeframe. While the GWP metric on its own overstates CH4's impact, a simple mass balance understates methane's importance. One could argue that on a decadal timeframe one should use a GWP_{10} CH_4, which is around 110 [33], making the climate effect 7% of the annual anthropogenic CO_2 effect over a decade. If one would use the radiative forcing as measure, this would increase the annual climate effect of methane to over 6%, based on the difference between the additional radiative forcings of CO_2 and CH_4 in 2015 and 2016 [34]. The report also states that CH_4 contribution to is estimated to account for 21% of the radiative forcing [35]. Updated values show that the contribution of methane has increased by 25% and will likely be higher than the referenced 21% [36].

---

[28] Worldbank, 2014, CO2 Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee, U.S. http://api.worldbank.org/v2/en/indicator/EN.ATM.CO2E.PC?downloadformat=csv

[29] U.N., 2017, World Population prospects 2017, https://esa.un.org/unpd/wpp/DVD/Files/1_Indicators%20(Standard)/EXCEL_FILES/1_Population/WPP2017_POP_F01_1_TOTAL_POPULATION_BOTH_SEXES.xlsx

[30] Annual average 2003-2012, Saunois, 2016, table 2.

[31] From Saunois, 2016, table 2. For the year 2012, anthropogenic emissions equate to 61% (347Mt) of the total budget (568Mt) and fossil fuel CH4 emissions (112Mt) represent 32% of that. However, this is just one year.

[32] Annual growth in atmospheric CO2 growth is 15.8Gt CO2/y (over 2004-2013, Le Quéré, et al., 2015, Global Carbon Budget 2015). Annual CH4 growth is 10Mt (Saunois, M., et al., 2016, The global methane budget 2000–2012), hence 360Mt CO2e based on $GWP_{100}=36$. This is 2.3% of 15.8Gt.

[33] IPCC, 2013, Climate change 2013: The physical science basis, chapter 8, figure 8.29

[34] NOAA, 2017. http://www.esrl.noaa.gov/gmd/aggi/AGGI_Table.csv The difference in additional radiative forcing between 2015 and 2016 for CO2 and CH4 is 1.985-1.938 = 0.047 Wm^{-2} and 0.507-0.504=0.003 Wm^{-2} respectively. The ratio gives 6.4%. Or similarly in 2016 the annual CO2, CH4 and N2O concentration increases were (404.21-400.83)=3.38ppm, (1843-1834)=9ppb and (329.415-328.708)=0.7066ppb respectively. Based on the radiative forcing equations from IPCC (1990) and IPCC (2001), $\Delta F(CO2) = \alpha \ln(C/Co)$, $\Delta F(CH4) = \beta(M½ - Mo½) - [f(M,No) - f(Mo,No)]$ and $\Delta F(N2O) = \varepsilon(N½ - No½) - [f(Mo,N) - f(Mo,No)]$, the CO2, CH4, N2O concentration increase are responsible for additional radiative forcing of $0.0499Wm^{-2}$, $0.0032Wm^{-2}$ and $0.0021Wm^{-2}$ respectively. This is equivalent to 89.4, 6.4 and 4.2% of the radiative forcing addition, excluding the CFCs.

[35] Based on the relative radiative forcing contribution from methane of 0.48 W/m2 to the net anthropogenic radiative forcing function of 2.29 W/m2 (IPCC, 2013, p 698).

[36] Etminan, et al., 2016, Radiative forcing of carbon dioxide, methane, and nitrous oxide - A significant revision of the methane radiative forcing. The contribution of CO2 and CH4 to the radiative forcing for 1750-2015 are

A third example is the comparison of methane emissions from natural gas production to the annual anthropogenic greenhouse warming effect of carbon dioxide, based on the climate effect of methane (2.3% mentioned above), the share of methane emissions from fossil fuels (19%, mentioned above) and the estimate the 1/3 of methane emissions from the fossil fuels comes from gas production. Attributing 1/3 to gas I believe may lead to underestimating the CH_4 emissions. Based on the bottom-up measurements of CH_4 emissions, fossil fuel emissions account for 134Mt CH_4/y [37]. Coal mining accounts for 46Mt (34%), oil and gas from 88Mt [37,38] (66%). There is no known split between oil and gas production share. One could argue both should be taken as shale oil is part of the opportunity. Taking 1/3 from 105Mt mentioned above gives 35Mt CH_4/y, which is equivalent to 10.7% of anthropogenic methane emissions. Furthermore, a comparison between of methane emissions from natural gas production to the annual anthropogenic greenhouse warming effect of carbon dioxide without acknowledging that part (18.2%) [39] of the CO_2 emissions are caused by the same gas production is an incomplete comparison.

The fourth comparison with enteric fermentation of livestock in the Northern Territory could be better formulated: “methane emissions from one new gas field in the NT (365 PJ/y) would be similar to the methane emissions from the entire enteric fermentation of livestock in the NT [40]. This statement and the statement in the draft report both show however, how large methane emissions from oil and gas would be.

3. Impact on global emissions and carbon lock-in

While the TOR stipulates the assessment of “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”, the consequences of CO_2 combustion emissions of the shale oil and shale gas developments are part of cumulative impacts. The reference gas field (365PJ/y) emits 20.5Mt CO_2/y when combusted. A full-scale shale gas industry could produce 1812PJ/y (which is not far of the 1240PJ/y development scenario in the report by Department of Primary Resources) for 50 years. This represents 1.35% (101.7Mt CO_2) of the global annual CO_2 emissions from gas combustion [41]. The development of the best estimate of

---

now 1.95Wm^{-2} and 0.62Wm^{-2},. The update increase methane’s contribution by 25%. Given not all GHG are analysed, an updated total net anthropogenic radiative forcing is not mentioned.

[37] Annual average 2003-2012, Saunois, 2016, table 2.

[38] Another estimate is 76Mt from oil and gas operations (IEA, 2017. World Energy Outlook 2017. https://www.iea.org/newsroom/news/2017/october/commentary-the-environmental-case-for-natural-gas.html)

[39] Annual CO2 emissions from fossil fuels, cement, land-use change = 41.07Gt CO2/y. Gas production 2016 = 3552Bcm (BP, 2017). 1 Bcm = 0.90Mt oil equivalent. 1Mt oil equivalent of gas emits 2.35Mt CO2. 3552 Bcm emits 7.51Gt CO2. Therefore 7.51/41.07=18.2% is from gas combustion. The fact that 46% of CO2 emissions=18.9Gt CO2 is retained in the atmosphere doesn’t change the ratio. (based on 2000-2015 average, http://cdiac.ess-dive.lbl.gov/ftp/Global_Carbon_Project/Global_Carbon_Budget_2016_v1.0.xlsx).

[40] Number of heads of cattle: 2.24 million (ABS, 2016, Agricultural census, http://www.ausstats.abs.gov.au/ausstats/subscriber.nsf/0/4B070279C6B4969DCA25815500129042/$File/australia,%20state%20and%20territory%20summary%20information%20sheets.pdf . Methane emissions of livestock equals 60kg/head/year. This would equate to 0.1344 Mt CH4 for NT cattle livestock (this is equivalent to the numbers in references of chapter 9)

[41] The global gas production is 134,000 PJ/y (3552Bcm, BP,2017). 1800 PJ/134,000Bcm=1.34%. 1 Bcm = 0.90Mt oil equivalent. 1Mt oil equivalent of gas emits 2.35Mt CO2 (BP, 2015).

technically recoverable shale gas alone would emit 5Gt CO_2 which is 0.4-0.85% of the remaining carbon budget [42]. Including the best estimate of technically recoverable oil would add 2.4 Gt CO_2 [43] or 0.20-0.40%. In total the oil and gas of a full development of the best estimates of technically recoverable shale and oil in the Northern Territory would emit 0.6 to 1.25% of the remainder carbon budget if global warming is limited to 2°C. It will represent a significant larger proportion of the remaining CO_2 budget if global warming is limited to 1.5°C.

The impact of supplying these kinds of production volumes have the real possibility to drive other nations further into fossil fuel lock-in, in particular nations that currently have no, or very limited gas infrastructure. These are nations where the largest growth could be materialised. But in reality, these are the nations who have the opportunity to bypass fossil fuels and power themselves with renewables, since there is no incumbent fossil fuel energy market. Australia is partly and will become more morally responsible for emissions elsewhere, since it is part of the chain that results in emissions.

4. Future electricity mix and the shift from coal to gas

The draft report elaborates on the role of gas and the future electrification mix. If, as suggested by the report, the proportion of domestic gas fired electricity generation is going to fall, one has to question the reason to open up an entire new industry. Companies will be attracted to a shale play with the intent to export oil and gas, not to supply the domestic market.

While gas can complement the baseload electricity that renewables will provide in the future (and are providing already at present), the scale of gas production can affect the future capacity that renewables can provide. Gas prices currently are high in Australia; globally however the market is oversupplied [44]. More gas means lower international gas commodity prices, which is in turn will stimulate use of gas for the economy. This will increase the chance that renewable energy will compete with a fossil fuel energy to supply a nation’s energy rather than complement it. If this means that a nation locks itself into a 50-year infrastructure, this renders Australia partly morally responsible for the opportunity costs of other nations. More gas and lower prices and hence more demand, also means more emissions, as people tend to use more energy when the costs are low [45].

The idea that gas is a transition fuel that may play a role in the future global energy mix comes from the notion that it can shift energy consumption from coal to gas. While 1PJ of gas emits 60% CO_2 of 1 PJ of coal, this does not hold true if the shift from coal to gas means that more gas demand is created while coal demand is not displaced. If the growth rate in gas demand is larger than the decline rate of coal, the benefit is less that the 60% usually quoted. Moreover, the benefit will drop further if the methane emissions go up.

---

[42] Rogelj, J., et al., 2016, Differences between carbon budget estimates unravelled. Remaining CO2 budget with >66% change to limit global warming to and not exceed 2°C: 590-1240Gt CO2. This is the CO2 only budget, but had accounted for non-CO2 gasses using the stringent mitigation scenarios from the IPPC AR5 Scenario database.

[43] 1 barrel = 0.1364t of oil. 1 t oil emits 3.07t CO2 (BP, 2015). 5.7Billion barrels emit 2.4Gt CO2

[44] IEA, 2017, World Energy Outlook 2017. Based on the gas growth forecasted, additional gas is needed by the mid 2020s.

[45] McJeon, H., et al., 2014, Limited impact on decadal-scale climate change from increased use of natural gas

There is an argument to be made that gas is necessary for aluminium production or for industries that require very high heat energy. Given the mineral resources that the world needs, one could argue for a role for Australia. There is however also research that targets technological innovation around high heat generation by renewables [46]. One could advocate that Australia should champion the race to run aluminium smelting and steel production on renewable energy.

5. Monitoring and regulation

While I think that the risk assessment in the draft report underestimates the impact of shale oil and gas in the Northern Territory, I'd like to provide some comments on monitoring and regulation of a shale oil and gas industry. Good regulation and mitigation around methane emissions may reduce the impact on the domestic emissions, it will do nothing for the CO_2 emissions that will impact the global carbon budget.

I commend the panel on the strong intentions and rigorous standards on baselines, repeat surveys, monitoring funded by the industry, and audits by an independent regulator. Mitigating the risk by implementing a U.S. EPA New Source Performance Standards of 2012 and 2016 may help, but good regulation is determined by what falls under the standard and who verifies and signs off on the measurements and reporting. It has already been stated that a regulator needs to be up to speed with the specifics of shale oil and gas production, and unconventionals in general [47]. As noted, this is important if players are companies with limited experience in shale unconventionals.

I full subscribe to the statement that baseline monitoring of methane levels in the soil and atmosphere in the vicinity of any new onshore shale gas development needs to be undertaken before any natural gas production commences. The coal seam gas industry was allowed to start without baselines, and it will be very difficult to determine what the full impact will be of this industry over the next century. Natural methane seepage can lead to elevated methane concentrations in the ambient air and in the soil, but natural seepage is more prevalent in areas with shallow reservoirs such as the coal seam reservoirs [48]. Shale gas is usually much deeper, with less chance of natural seepage.

Baseline surveys should however be conducted a year prior to exploration. A year prior to production, it is quite likely hundreds of wells will have been drilled (and hydraulically fractures and completed), while construction of a LNG facility is being finalised. Completion of wells is a large source of methane (21% of shale gas field emissions) [49]. Delineation (or appraisal) of a field can include dozens of wells, which all will need to be completed and/or tested. A monitoring network can identify these sources, but it needs to be put in place prior to exploration and appraisal. Monitoring networks using multiple towers, some 10-20 km apart can assist in identifying sources within the area of the network by solving for potential sources using inverse modelling and weather

---

[46] ARENA, 2016, https://arena.gov.au/projects/integrating-concentrating-solar-thermal-energy-into-the-bayer-alumina-process/

[47] Cook, et al., 2013, p.182

[48] The draft report mentions methane in water bores. Elevated methane levels in water bores in NSW and Queensland are in the coal seam gas development area, with the source rocks (the coal seams) relatively close to the surface.

[49] In this report, p. 195 from Skone et al., 2016.

forecasting models. The main cost in such networks are the spectrometers to analyse atmospheric methane concentrations.

It is not impossible – as suggested in the draft report – to distinguish between the many sources of emissions when considering the results from 'top-down' investigations. $\delta^{13}C$ CH_4 isotopic composition data allows to distinguish between thermogenic (fossil fuels), biogenic (e.g. agriculture) and pyrogenic (biomass burning). This will greatly benefit monitoring networks in NT, as prescribed biomass burning is common and the cattle industry is large. Hence other industries (agriculture and prescribed savannah burning) will benefit from baseline and repeat surveys. Therefor it should be standard and best practice that isotopic analysis is included in every regional scale survey. This is the key dataset that will assist in distinguishing thermogenic methane (methane emissions from shale oil and shale gas) from biogenic and pyrogenic methane.

The finding that further research is required to accurately detect methane concentrations, conversion of these emissions into a flow rates (fluxes), and assigning them to particular sources, is a good reason why Australia should invest in knowledge and instruments to enable identification of methane from different sources. There are a lot of techniques that can provide datasets that complement each other and can assist in identifying different methane sources [50]. Also, if, as stated, 19% of all upstream methane emissions fall into an 'unassigned' or 'super emitter' category [51], it merits to invest in knowledge and instruments that could identify super emitter on a more regular basis and in a timelier manner. Real-time airborne imaging spectroscopy has been shown to successfully identify and characterise methane point sources [52]. The detection threshold of 2-5kg/h will pick up even small sources. A shale gas industry can potentially be a big influence on the Australian economy, as is the coal seam gas industry. The reliance on emission factors carries an inherent risk that emissions are underestimated. This is an opportunity to invest in best practice monitor networks that have been deployed successfully in the U.S.

6. In conclusion

Underestimation of the environmental risks of hydraulic fracturing in the Northern territory effectively means underestimation of the impact of exploration of shale oil and shale gas in Australia. Exploration can lead to a very large industry including oil production and LNG exports. Upstream and downstream emissions from shale oil and shale gas developments in the Northern Territory have wide implications. An industry at the scale of the coal seam gas industry in Queensland could see very large impacts on Australia's annual emissions, on Australia's international commitments and on the global carbon budget. Underestimating the possible emissions from methane emissions from shale oil and shale gas, concluding that there is little opportunity to mitigate downstream (combustion) emissions and therefore arguing that the focus should be on mitigating methane emissions is underestimating the moral responsibility for fossil fuel supply in the 21st century. It is unacceptable to dismisses this large part of the emissions and its consequences,

---

[50] See Lafleur, et al., 2016, A review of current and future methane emissions from Australian unconventional oil and gas production. See Day, et al., 2015, Characterisation of Regional Fluxes of Methane in the Surat Basin, Phase 2

[51] Littlefield et al. 2017.

[52] Frankenberg, C. et al., 2016, Airborne methane remote measurements reveal heavy-tail flux distribution in Four Corners region

while stating that the inquiry will assess the scientific evidence to determine the nature and extend of cumulative impacts.

Considering the emissions reduction roadmap that is locked in by the Paris agreement, in particular for the second half of the century, emissions of a new fossil fuel industry in Australia do have global consequences. Australia needs to accept that it is partly morally responsible for all emissions of the resources in extracts and supplies. The argument that the consumer (or foreign nation) is entirely responsible for its emissions is flawed, akin to the partial responsibility that the tobacco industry, the sugar industry or the arms industry bear by supplying consumer goods. The given that Australia supplies fossil fuels implies that Australia is partly morally responsible for the emissions it causes, domestically or elsewhere.

A way of dealing with this responsibility and mitigating the risk of upstream and downstream emissions, is stopping new gas exploration and by acknowledging that the environmental risk of hydraulic fracturing, shale gas and shale oil developments is too high. Countries need to make transitions. Supplying more gas, lowers commodity prices, which encourages people to use more, which comes at the expense of the necessary emission reductions.