GRASPING FOR GAS: WHY CLIMATE GOALS AND GAS ARE INCOMPATIBLE

A Research Study Done By The Green Connection

GRASPING FOR GAS

Why climate goals and gas are incompatible

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The Green Connection

1. Introduction

Predictions are that world oil consumption has peaked [1] and oil and gas companies are emphasising gas as a clean energy alternative. The concept of natural gas as a transition energy source, filling the gap between fossil fuels and renewable energy is being mooted by both the South African government[2] and the oil and gas industry[3].

This brief report seeks to investigate the veracity of the claims and to consider the potential impacts of the continued use of natural gas.

2. Natural Gas

There are two general types of natural gas, defined by their methane content, that reflect differences in the formation processes:

- Biogenic gas (± 95% methane), or "dry" gas, which was formed by bacterial decay at shallow depth.
- Thermogenic gas (<95% methane), or "wet" gas, which is a lower quality gas formed at high temperatures. Wet gas may contain compounds such as ethane and butane, in addition to methane.

Natural gas as extracted from conventional and unconventional plays consist of combination of different gases of which methane (CH_4) constitutes the greatest portion. Natural gas (also called fossil gas) is a naturally occurring hydrocarbon gas mixture consisting primarily of methane, but commonly including varying amounts of other higher alkanes, and sometimes a small percentage of carbon dioxide, nitrogen, hydrogen sulphide, or helium water vapor. Natural gas also contains smaller amounts of natural gas liquids (NGL) and nonhydrocarbon gases with methane making up 70-90%[4].

In the process of converting natural gas into cleaner fuel for consumption many by-products are extracted like propane, ethane, butane, carbon dioxide, nitrogen etc, which can be further used[5]

[1] https://www.bloomberg.com/graphics/2020-peak-oil-era-is-suddenly-upon-us/
[2] http://www.energy.gov.za/IRP/2019/IRP-2019.pdf
[3] https://www.iea.org/reports/the-role-of-gas-in-todays-energy-transitions
[4] https://group.met.com/energy-insight/what-is-natural-gas/2
[5] https://economictimes.indiatimes.com/definition/natural-gas

The natural gas that is delivered to downstream users is gathered from the wellhead in pipelines called gathering lines and transported to processing plants, which separate the various hydrocarbons and fluids from the pure natural gas, to produce what is known as 'pipeline quality' dry natural gas.

Processing involves four main processes to remove the various impurities and to extract by-products:

- Oil and Condensate Removal
- Water Removal
- Separation of Natural Gas Liquids
- Sulphur and Carbon Dioxide Removal

Gas is then transported through pipelines via feeders to distribution centres or stored. In some cases, gas is cooled down to liquid form (LNG) for ease and safety of non-pressurized storage or transport to end users.

3. Methane as a Greenhouse Gas

Methane (CH_4) is a fossil fuel and when burned emits carbon dioxide (CO_2). Methane contributes 50 to 60% less CO_2 to the atmosphere than coal when combusted and 30% less than oil. Methane also contains less nitrogen oxide, sulphur dioxide, carbon monoxide, and total unburned hydrocarbons when compared to other fossil fuel.

The energy released by burning one barrel of oil is the equivalent of burning 58ccf (hundred cubic feet) methane and the carbon dioxide coefficient for natural gas is 5,307kg/ccf. Therefore, to compare the carbon emission values, one barrel of oil will generate 426kg of CO_2 and to obtain an equivalent amount of energy, gas will produce 307kg of CO_2.

CH_4 is more efficient at trapping radiation than CO_2 and the Intergovernmental Panel on Climate Change[6] estimates that over a 20-year time frame, methane will trap 86 times more heat than carbon dioxide and over a 100-year period has a carbon equivalence of 34. It is known that the CH_4 molecule is broken down to carbon dioxide and hydrogen over a period of approximately 120 years in the stratosphere. Carbon dioxide has a longer residence time and molecules of the gas will remain present in the atmosphere for about 300 to 1000 years.

For the 2003–2012-decade, global methane emissions were 558 teragrams per year, with 60 percent of global methane emissions attributed to anthropogenic sources of all kinds and with a significant contribution (likely at least 39 percent) from oil and gas production operations[7] [8].

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[6] IPCC. (2013). *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T. F., D. Qin, G.-K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex & P. M. Midgley (eds.)]. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

[7] Saunois, M., Bousquet, P., Poulter, B., Peregon, A., Ciais, P., Canadell, J. G., … Zhu, Q. (2016). The global methane budget 2000–2012. *Earth System Science Data, 8,* 697–751.

[8] Saunois, M., Jackson, R. B., Bousquet, P., Poulter, B., & Canadell, J.G. (2016). The growing role of methane in anthropogenic climate change. *Environmental Research Letters, 11,* 120207.

During the past decade, meaningful debate has been conducted and numerous studies have been concluded that have investigated climate change consequences due to methane gas emissions. This has been largely brought about with the advent of the shale gas boom experienced in the USA and the extensive use of flaring, venting and fugitive methane emissions associated with oil and gas production.

Methane escapes to the atmosphere from all parts of the extraction, processing, and distribution system, all the way to the end user. In Texas, methane emissions have been shown to be 50 percent higher than the US Environmental Protection Agency (EPA) estimates[9] while shale gas operations and associated infrastructure contributed 71-85 percent of the methane emissions in the region. A recent analysis of methane leaks from the U.S. oil and gas supply chain found leakage rates were 60 percent higher than reported by the EPA[10], and a 2019 study in Pennsylvania found shale gas emissions that were underreported by a factor of five when compared to EPA estimates[11].

4. Summary of relevant studies

A few relevant peer reviewed research findings that have been published during the past decade are summarised below. The catalogue of papers that have been reviewed is by no means complete and represents an overview of the current thinking and conclusions.

It is immediately apparent that current research emanates primarily from the USA and was initially focused on fugitive methane emissions from shale gas installations. As the concept of gas becoming a transitional source of energy, research emphasis changed to include studies of intentional and fugitive gas emissions from all gas installations.

i. In a major study[12] conducted by Stanford University, Massachusetts Institute of Technology, and the U.S. Department of Energy in 2014 found that methane leaks negate any climate benefits of natural gas as a fuel for vehicles, and that the EPA is significantly underestimating methane in the atmosphere. Brandt et.al (2014) concluded that *"Switching from diesel to natural gas, is not a good policy from a climate perspective."* The study also found that the US national methane leakage rate is likely between 3.6 and 7.2 percent of production.

ii. In an assessment of the heat-trapping potential of greenhouse gases, a study conducted by Edwards and Trancik (2014)[13] revealed that methods of accounting fugitive gas concentrations

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[9] Barkley, Z. R., Davis, K. J., Feng, S., Balashov, N., Fried, A., DiGanji, J., . . . Halliday, H. S. (2019). Forward modelling and optimization of methane emissions in the south-central United States using aircraft transects across frontal boundaries*. Geophysical Research Letters, 46,* 13,564-13,573.
[10] Alvarez, R. A., Zavala-Araiza, D., Lyon, D. R., Allen, D. T., Barkley, Z. R., Brandt, A. R., . . . Hamburg, S. P. (2018). Assessment of methane emissions from the U.S. oil and gas supply chain. *Science, 361*(6398): 186-188.
[11] Howarth, R. W. (2019). Ideas and perspectives: Is shale gas a major driver of recent increase in global atmospheric methane? *Biogeosciences, 16,* 3033-3046.
[12] Brandt, A. R., Heath, G. A., Kort, E. A., O'Sullivan, F., Petron, G., Jordaan, S. M., . . . Harriss, R. (2014). Methane leaks from North American natural gas systems. *Energy and Environment, 343*(6172), 733-735.
[13] Edwards, M. R., & Trancik, J. E. (2014). Climate impacts of energy technologies depend on emissions timing. *Nature Climate Change, 4*, 348-352

underestimate the climate-damaging impact of methane pollution from all sources, including drilling and fracking operations.

iii. An influential study carried out by Busch and Gimon (2014)[14] analysed the level of greenhouse gas emissions attributable to electricity from natural-gas-fired power plants and coal-fired power plants and conclude that, over short time frames and at high rates of leakage, natural gas offers little benefit compared to coal and could exacerbate global warming. Acknowledging that natural gas offers some reductions in greenhouse gas emissions over longer time frames, they point out that such reductions are not large enough for natural gas to play an expanded role in efforts to manage emissions. They conclude that under the best of circumstances, natural gas-fired electric power offers a modest benefit toward abating climate change, while if poorly developed (i.e., with extensive methane leaks, estimated by these authors to be on the order of 4 percent or higher), or if used to displace energy efficiency or renewable energy, natural gas could seriously contribute to increased greenhouse gas emissions.

iv. A similar study by Zhang et al (2014) [15] in which coal and natural gas were compared for power generation. They concluded that over time, natural gas plants can produce some reduction in near-term warming, but only if life cycle methane leakage rates are low and power plant efficiency is high. Relative to coal, there is the potential that *"…deployment of natural gas power plants could both produce excess near-term warming if methane leakage rates are high and produce excess long-term warming."*

v. Howarth (2015) [16] summarized and analysed the evidence documenting the magnitude of methane emissions related to oil and gas development in the United States since 2007. With estimated emission rates ranging from 3.8-12 percent, the high radiative forcing of methane over a twenty-year period prevents natural gas from serving as a bridge fuel. Instead of further investments in natural gas, the study recommended a rapid transition to electric powered vehicles for transportation, high-efficiency heat pumps for space and water heating, and imposition of a methane tax. Howarth (2015) also noted that the EPA has seriously underestimated the importance of methane emissions in general and from shale gas in particular.

vi. In a paper published by Turner et.al (2016)[17] in which both satellite retrievals and surface observations were used to determine that methane emissions in the United States increased by more than 30 percent over the previous twelve years. The findings contradict the 10

[14] Busch, C. & Gimon, E. (2014). Natural gas versus coal: Is natural gas better for the climate. *The Electricity Journal, 27*(7), 97-111.
[15] Zhang, X., Myhrvold, N. P., & Calideira, K. (2014). Key factors for assessing climate benefits of natural gas versus coal electricity generation. *Environmental Research Letters, 9.*
[16] Howarth, R. W. (2015). Methane emissions and climatic warming risk from hydraulic fracturing and shale gas development: implications for policy. *Energy and Emission Control Technologies, 3,* 45-54.
[17] Turner, A. J., Jacob, D. J., Benmergui, J., Wofsy, S. C., Maasakkers, J. D., Butz, A., . . . Biraud, S. C. (2016). A large increase in U.S. methane emissions over the past decade inferred from satellite data and surface observations. *Geophysical Research Letters, 43.*

percent decline reported by the EPA and suggest that the United States could be responsible for 30-60 percent of the global spike in atmospheric methane.

vii. The CSIR (2016) report on Shale Development in the Central Karoo[18] was compiled for the Strategic Environmental Assessment into the potential impacts of introducing shale gas extraction in the Karoo. Drawing from many of the studies cited above, the assessment concluded that leaks amounting to a few percent can offset the benefit that accrues from the higher energy yield per unit CO_2 emitted when gas is used in the place of coal. The GHG no-benefit threshold occurs at between 1.9 to 3.2% leakage under the gas production scenarios assumed in the study.

viii. In an analysis of methane leaks from the U.S. oil and gas supply chain, Alvarez et al (2018)[19] found that natural gas is just as damaging as coal for the climate over a 20-year time frame. This study combined terrestrial measurements of leaks at selected facilities (bottom-up methods) with data collected from the atmosphere via aircraft (top-down methods). Based on the results, the authors estimated that roughly 2.3 percent of all the natural gas extracted in the United States escapes into the air. This estimated level of leakage was 60 percent higher than the EPA's estimate of 1.4 percent.

ix. The Groningen natural gas field in the northern Netherlands is one of Europe's major gas fields where extraction, gas processing, and gas storage take place. It is also a region with intensive agriculture and cattle operations. An international research team[20] investigated methane emissions there with the intent of distinguishing between methane from fossil fuel sources and methane arising from livestock, wetlands, and agriculture. Using both ground and aircraft measurements, the researchers determined that emissions from oil and gas operations account for 20 percent of regional methane, with the remainder from biogenic sources. That figure for fossil fuel sources is ten times higher than the 1.9 percent that was estimated by previous inventories. Ground-based measurements showed that wells with no production still had emissions.

x. Nisbet et al (2019)[21] together with an international team of atmospheric scientists confirmed a sharp rise in global atmospheric methane that began in 2007 and has accelerated since 2014. The causes for the increase are not fully understood, however, Nisbet el al (2019) also documented that over the same period, a shift in the carbon isotope ratio, which may signal a shift in the relative proportions of emissions from different sources. (These various methane sources include gas leaks, microbes, livestock, landfills, biomass burning.) Ongoing increase in

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[18] Scholes, R., Lochner, P., Schreiner, G., Snyman-Van der Walt, L. and de Jager, M. (eds.). 2016. Shale Gas Development in the Central Karoo: A Scientific Assessment of the Opportunities and Risks. CSIR/IU/021MH/EXP/2016/003/A, ISBN 978-0-7988-5631-7

[19] Alvarez, R. A., Zavala-Araiza, D., Lyon, D. R., Allen, D. T., Barkley, Z. R., Brandt, A. R., . . . Hamburg, S. P. (2018). Assessment of methane emissions from the U.S. oil and gas supply chain. *Science, 361*(6398): 186-188.

[20] Yacovitch, T. I., Neininger, B., Herndon, S. C., Denier van der Gon, H., Jonkers, S., Hulskotte, J., . . . Zavala-Araiza, D. (2018). Methane emissions in the Netherlands: The Groningen field. *Elementa: Science of the Anthropocene, 6*(57).

[21] Nisbet, E. G., Manning, M. R., Dlugokencky, E. J., Fisher, R. E., Lowry, D., Michel, S. E., . . . White, J. W. C. (2019). Very strong atmospheric methane growth in the four years 2014-2017: Implications for the Paris Agreement. *Global Biochemical Cycles, 33*(3), 318-342.

global methane concentrations was not predicted by the future greenhouse gas scenarios that were incorporated into the targets of the Paris Agreement and the goals of the treaty could be out of reach. The study concluded that *"…there is an urgent need to reduce methane emissions, especially from the fossil fuel industry… anthropogenic methane emissions are relatively large and thus offer attractive targets for rapid reduction, which are essential if the Paris Agreement aims are to be attained."*

xi. According to Australia's National Greenhouse Gas Inventory[22], Australia's Liquid Natural Gas (LNG) export industry contributed significantly to rising carbon emissions from that country in the 12 months prior to September 2018. Emissions from power plants fell during this same period as the result of a 31 percent jump in renewable energy serving eastern Australia. These declines, however, were more than offset by increases in industrial and fugitive emissions from Australia's LNG plants. LNG exports rose by one fifth in 2018 and this escalation represents the third consecutive year of rising greenhouse gas emissions from Australia. The expansion in LNG production and export was identified as the major contributor to this trend.

xii. In a study conducted by Jackson et al (2019)[23] the growing dependency on fossil fuels around the globe was examined. They determined that the ongoing natural gas boom is serving a major barrier to rapid decarbonization. Natural gas is the fastest growing fossil fuel in the world and has displaced coal as the preferred fossil fuel. The use of natural gas has grown at a rate that the methane emissions from burning it have more than offset the decline in carbon dioxide emissions from the reduced use of coal. The result is that carbon dioxide equivalent emissions from fossil fuels grew each year from 2017-2019. The low costs of natural gas, and new methods for transporting it, such as LNG tankers, are keeping the use of fossil fuels high even as renewable energy sources are also growing. As a result, the carbon intensity of global energy production has remained essentially unchanged since 1990. The study calls for *"…accelerated energy efficiency improvements and reduced consumption, rapid deployment of electric vehicles, carbon capture and storage technologies, and a decarbonized electricity grid, with new renewable capacities replacing fossil fuels,"*

xiii. Ingraffea et al (2020)[24] used mechanical inspection reports to determine that methane emissions from abandoned and active wells were at least 15 percent higher than previously thought. The researchers used 589,175 reports on methane leaks from both fracked and conventional oil and gas wells. Extrapolating these findings to the USA, where over three million wells are in operation, they were able to show that methane escaping from oil and gas wells undermine efforts to address climate change.

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[22] Commonwealth of Australia Department of Environment and Energy. (2018). *Quarterly update of Australia's National Greenhouse Gas Inventory: September 2018*. Retrieved from https://www.environment.gov.au/climate-change/climate-science-data/greenhouse-gas-measurement/publications/quarterly-update-australias-national-greenhouse-gas-inventory-sept-2018

[23] Jackson, R. B., Friedlingstein, P., Andrew, R. M., Canadell, J. G., Le Quéré, C., & Peter, G. P. (2019). Persistent fossil fuel growth threatens the Paris Agreement and planetary health. *Environmental Research Letters, 14.*

[24] Ingraffea, A., Wawrzynek, P. A., Santoro, R., & Wells, M. (2020). Reported methane emissions from active oil and gas wells in Pennsylvania, 2014–2018. *Environmental Science & Technology, 54*(9), 5783-5789.

5. How much gas can we use?

Using reports from countries and companies with proved reserves of recoverable oil, natural gas, and coal, an analysis by Heede & Oreskes (2015)[25] showed that full production of these resources would use up 160 percent of the world's estimated remaining carbon budget, designed to restrict anthropogenic climate change to equal to or less than 2^{o}C. With approximately 76 percent of reserves owned by states or state entities. The relatively smaller number of reserves owned by investors pose the greater immediate threat, since those companies are more likely to produce, refine, and deliver fossil fuels to global markets in the near term. However, exploitation of existing proved reserves controlled by the private sector alone will not lead to warming above the 2^{o}C limit ***if it is not accompanied by exploration for and development of new reserves***. Future considerations of fossil fuel use should therefore focus not only on reducing private sector contributions but also on reducing contributions from countries that have historically dominated or currently dominate emissions, and especially nation-states with large undeveloped reserves.

The estimates of leakage worldwide are in the range 1.5 to 2.3%, but recent literature showing that much of the emission comes from a few "super emitters" locations suggests that the true range may be 2.2 to 4.1 and even as much at 12%[26].

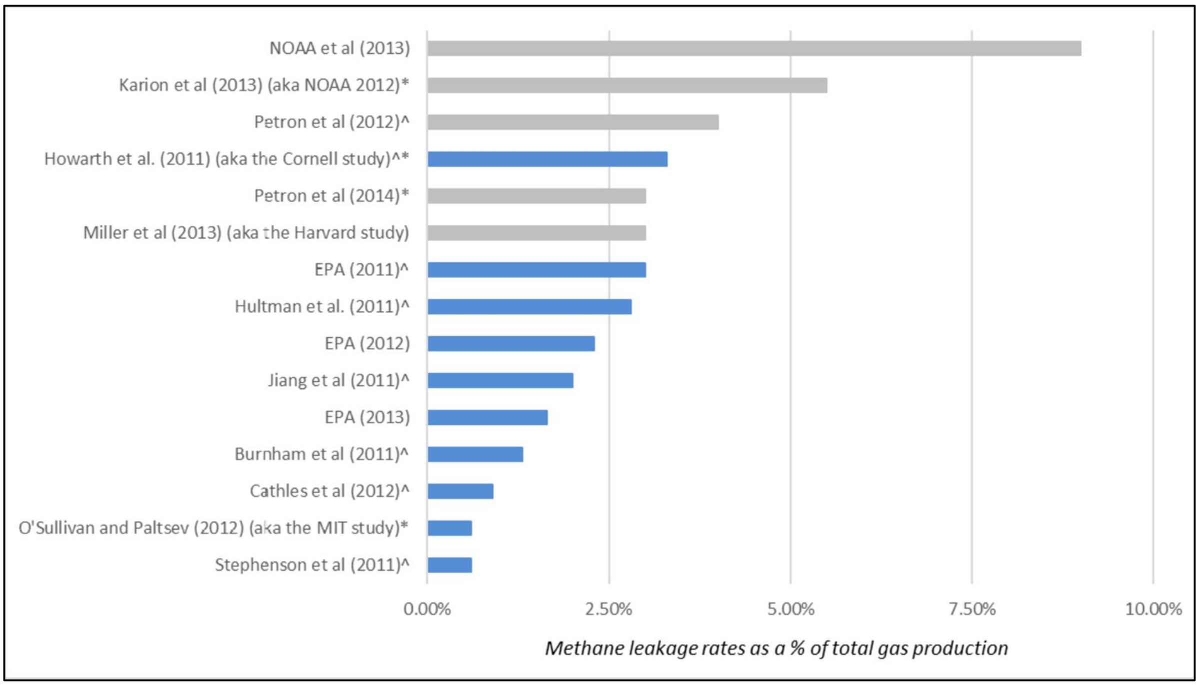

Figure 1. Estimate of methane leakage rates in literature, with both bottom-up and top-down approaches. (from Scholes et al (2016).[27])

[25] Heede, R., & Oreskes, N. (2015). Potential emissions of CO2 and methane from proved reserves of fossil fuels: An alternative analysis. *Global Environmental Change, 36.*

[26] Howarth, R. W. (2015). Methane emissions and climatic warming risk from hydraulic fracturing and shale gas development: implications for policy. *Energy and Emission Control Technologies, 3,* 45-54.

[27] Scholes, R., Lochner, P., Schreiner, G., Snyman-Van der Walt, L. and de Jager, M.

In addition, worldwide proved fossil fuel reserves reported in British Petroleum's Statistical Review of World Energy[28] with CO_2 emission factors from the IPCC yields 3,600 Gt of CO_2 emissions. This implies that only one twelfth or 8% of known fossil fuels reserves can be utilised to limit global warming to 1.5°C.

Although being heavily skewed by the inclusion of known coal reserves, table 1 below clearly demonstrates that South Africa and the world cannot afford to exploit the countries hydrocarbon reserves without gravely impacting on the global climate change aspirations.

Source	Fossil Fuel reserves	CO_2 equivalent Gt	2021 CO_2 eq remaining carbon budget for a two-thirds chance of limiting warming to 1.5°C	
South Africa's estimated gas reserves[29]	60tcf	3.2	Global remaining carbon budget[30]	South Africa's remaining carbon budget[31]
South Africa's estimated oil reserves	9bbl	3.9	300Gt	12Gt
Coal[32]	53Gt	151.6		
Total		158.7		
Percentage emission contributed by SA fossil fuel reserves			53%	1322%

Table 1. Estimated GHG emissions in the event of South Africa's know hydrocarbon reserves being used.

6. Gas Power Ships

The South African government is currently advocating gas as a clean "bridging" source of energy, transitioning the gap between coal and renewable energy. Considering this stance, the country is aggressively promoting exploration off the South African coast for conventional oil and gas resources as well as unconventional terrestrial resources which include shale gas, coal bed methane and in-situ gasification. Furthermore, the government has also announced the acceptance of the EIA for the construction of a gas pipeline network that will provide gas to downstream end users which include gas powered power stations that will be located at along the coast as well as inland in Gauteng and Mpumalanga.

(eds.). 2016. Shale Gas Development in the Central Karoo: A Scientific Assessment of the Opportunities and Risks. CSIR/IU/021MH/EXP/2016/003/A, ISBN 978-0-7988-5631-7

[28] https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2020-full-report.pdf

[29] Department of Environment, Forestry and Fisheries, 2019. Strategic Environmental Assessment for the Development of a Phased Gas Pipeline Network in South Africa. CSIR Report Number: CSIR/SPLA/EMS/ER/2019/0077/B. ISBN Number: ISBN 978-0-7988-5649-2. Stellenbosch and Durban.

[30] https://www.ipcc.ch/sr15/chapter/chapter-2/

[31] http://awsassets.wwf.org.za/downloads/understanding_carbon_budgets_final.pdf

[32] http://www.energy.gov.za/IRP/2019/IRP-2019.pdf

These developments are in accordance with the Integrated Resource Plan (2019)[33] prepared by the Department of Energy and Minerals, which indicates that 6380 MW of gas and diesel fuelled power will be included in the energy mix by 2030.

In addition to the commitments included in the IRP (2019), the South African government has also recently announced the approval of three power ships that will be berthed at Richards Bay, Coega and Saldanha Bay. The Risk Mitigation IPP Procurement Programme (RMIPPPP) is intended to alleviate the countries current energy deficit and it is proposed that the floating gas fired power stations will provide 1220MW of power to the electrical grid for a period of 20 years .

The volume of CO_2 emissions that will result from the commissioning of the three power ships as well as the government's current indicated commitment to the use of gas as a bridging fuel is shown in table 2 below

	Karpower ships	Gas and Diesel (IRP 2019)	Coal (IRP 2019)
Capacity MW	1220	6380	33364
Emission CO_2 Mt/yr	4.5	33	306.2
Fugitive Gas CO_2 equivalent Mt/yr (4%)	4.5	33	
Total Mt CO^2eq/yr	381.2		

Table 2. Anticipated emissions from hydrocarbon powered electricity

7. Global Carbon Budget

Adopting a carbon budget approach, which is defined as a tolerable quantity of greenhouse gas emissions that can be emitted in total over a specified time. The budget needs to be in line with what is scientifically required to keep global warming and thus climate change "tolerable"[34] Several different models have been applied to determine the global carbon budget and various working groups within the IPCC are debating the application of a single appropriate model, the proverbial "one size fits all".

Based on a Threshold Avoidance Budget (TAB) model Rogelj et. al[35] were of the opinion that for a >66% chance of limiting warming below the internationally agreed temperature limit of 2 °C relative to pre-industrial levels, the most appropriate carbon budget estimate is 590–1,240 $GtCO_2$ (the lower and upper figures represent the 10 and 90 percentile confidence limits) from 2015 onwards.

[33] http://www.energy.gov.za/IRP/2019/IRP-2019.pdf
[34] http://awsassets.wwf.org.za/downloads/understanding_carbon_budgets_final.pdf
[35] Rogelj, J, Schaeffer, M., Friedlingstein, P. et. al (2016) Differences between carbon budget estimates unravelled. Nature Climate Change. Vol 6. March 2016 www.nature.com/natureclimatechange

The carbon budget is a scarce resource to be divided up between countries, giving each country its own carbon budget which it must not exceed. Although still subject to debate and agreement, a "fair share" carbon budget allocation for South Africa (2009 to 2050) is considered to be 9 to 16Gt CO_2 equivalent.

In 2018 the IPCC suggested that a remaining budget of about 420 Gt CO_2 exists for a two-thirds chance of limiting warming to 1.5°C (current 2021 estimate is 300Gt budget remaining). From this analysis indications are that South Africa's proposed continued use of current estimated reserves of oil and gas and the continued use of coal, albeit a reducing dependency, will have a significant impact on the world carbon budget.

8. South Africa's Intended Nationally Determined Contribution (INDC).

As a signatory to the Paris Agreement set out at COP 21 in 2015, South Africa is obliged to communicate its Intended Nationally Determined Contribution (INDC) of GHG to the United Nations Framework on Climate Change (UNFCC) every 5 years. INDCs are the primary means for governments to communicate internationally the steps they will take to address climate change in their own countries. INDCs reflect each country's ambition for reducing emissions, taking into account its domestic circumstances and capabilities. The climate actions communicated in these INDCs largely determine whether the world achieves the long-term goals of the Paris Agreement: to hold the increase in global average temperature to well below 2°C, to pursue efforts to limit the increase to 1.5°C, and to achieve net zero emissions in the second half of this century.

South Africa submitted its first INDC in November 2016 and committed itself to following a Peak, Plateau and Decline (PPD) trajectory, with green house gas emissions peaking in 2025, plateauing between 2025-2035 and declining from 2035 that expressed as trajectory range of 398 to 614 Mt CO2eq.

In 2018, South Africa's CO_2 emissions were 478.6 Mt or 1.31% of the world's total emissions. Using the assumptions presented in table I, if South Africa should exploit the estimated domestic oil and gas resources and continue use coal although at a reduced rate as indicated in the IRP (2019) the country will consume approximately 4.42% of the worlds remaining carbon budget. In a simplified comparison South Africa has approximately 0.7% of the world's population and will consume about 4.4% of the planets carbon budget.

However, Climate Action Tracker (CAT)[36], an independent scientific analysis produced by three research organisations tracking climate action, rates South Africa's NDC as "highly insufficient". This means its INDC pledge is outside a "fair share" of the emissions cuts needed to meet the goals of the Paris Agreement, and "not at all" consistent with limiting global warming to less than 2C or 1.5C. If all governments had similar targets, global temperature rise would likely reach 3-4°C by 2100. Under its currently implemented policies and assuming continued low economic growth, South Africa will reach the upper end of its 2030 emission reduction targets in 2020 and 2025. By 2030, emissions would breach of South Africa's current NDC pledge, with emissions around 27MtCO2e higher than the upper end of the target.

[36] https://climateactiontracker.org/countries/south-africa/

In April 2021 the Department of Environment (DEF) recently released South Africa's draft NDC[37] submission to UNFCCC for public comment. The country *"…warmly welcomed the IPCC's special report on global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways"* and commitment itself to be *"…consistently been guided by science and equity"*.

Within the realms of these noble endeavour's the countries proposed update to the initial INDC submitted in 2016, a PPD emission trajectory is maintained with maximum emissions of 398-510 $MtCO_2$ eq being reached by 2025 and reducing to 398-440Mt CO_2 eq by 2030. The upper end of the target range in 2025 represents a reduction over the NDC (2016) pledge of 17%, and the upper end of the target range in 2030 is a reduction of 28%.

In terms of the CAT rating the current upper limit of the draft pledge remains in the "insufficient" category and the is 2025 and 2030 upper limit of 510 and 440Mt CO2 eq respectively. It is however critical to consider the lower limit of the countries INDC of 398 Mt CO2 eq, which has not been adjusted and is rated "compatible with a 2°C warming" and is not consistent with the Paris Agreement.

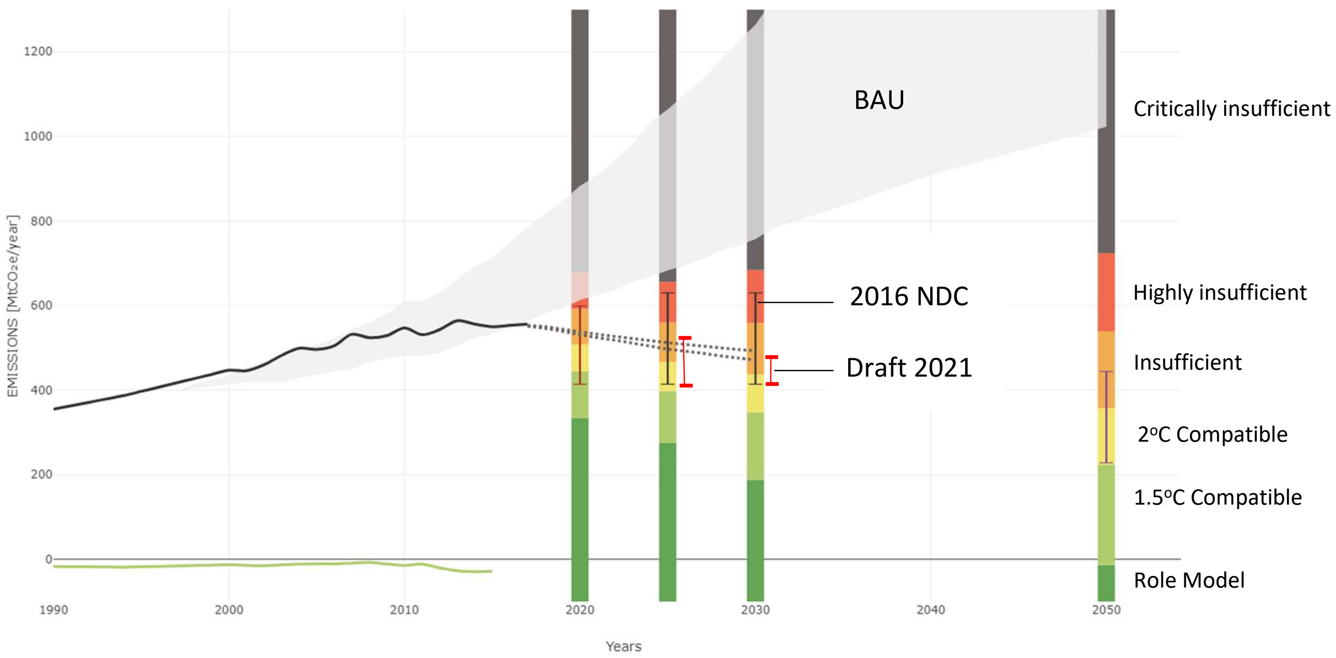

Figure 2. South Africa's emissions trajectory based on 2016 INDC and 2021 draft INDC (adapted from Climate Action Tracker)

With the current indications that the government intends to adopt gas as a transition fuel it is appropriate to evaluate Souths Africa's INDC against the Paris Agreements target of restricting the planet to an average temperature increase to well below 2 and preferably to 1.5°C. It is envisioned that the decarbonization of the South African economy will focus primarily on the electricity sector in the 2020's and moving the transport sector towards low emission vehicles in the 2030's [38].

[37] https://www.environment.gov.za/mediarelease/creecy_indc2021draftlaunch_climatechangecop26
[38] https://www.environment.gov.za/mediarelease/creecy_indc2021draftlaunch_climatechangecop26

Applying loose calculations to the IRP (2019) it is realistic that the country will emit 381Mt CO2 eq per year by 2030 from electricity generation only. With all other GHG emitting sectors in the South African economy accounting for 231 MtCO2 eq emissions in 2016, to which no significant amendments have been considered in the draft INDC, it is apparent that the country will be hard pressed to achieve its INDC by 2030. Strong and more decisive policies must be implemented that will divert the country away from the continued use of coal as a source of energy and the realisation that gas cannot be considered to be a bridging fuel.

9. Conclusion

A significant proportion of methane leaks are not preventable through engineering fixes, and some represent intentional venting and flaring during routine maintenance or during attempts to control pressure and prevent explosions during malfunctions. Venting takes place at all points along the supply chain, from well pads, pipelines, and compressor stations to liquefied natural gas (LNG) export terminals. A 2018 analysis of methane emissions from the U.S. oil and gas supply chain[39] found leakage rates 60 percent higher than reported by the EPA and concluded that natural gas is just as damaging as coal for the climate over a 20-year time frame. Collectively, a range of studies disprove the claim that natural gas is a transitional "bridge" fuel that can lower greenhouse gas emissions while renewable energy solutions are developed[40]. As documented from many studies, fugitive methane emissions from oil and gas exploration operations, production facilities that include storage, and ancillary infrastructure are much higher than previously supposed. The science is settled on these facts. Other lines of research have shown that expanded use of natural gas impedes rather than encourages investments in, and deployment of, renewable energy infrastructure.

Orthofer et al (2019)[41] studied the economic advantages in which various scenarios of utilising gas in the energy mix as well considering the introduction of a carbon tax were considered. This research assumed that the cost of externalities such as effects on climate change and other environmental impacts are accounted for by the carbon tax rate. The authors concluded that at a carbon price of 10 USD/tCO_2 and above, gas-fired power stations will not only economically out-compete coal power plants but also crowd out renewables, therefore displacing both technologies. The current carbon tax rate is 9.37 USD per ton of CO_2e (exchange rate April 2021) and the new carbon tax includes a number of mechanisms that includes a 60 percent allowance for all emissions and an additional 10 percent allowance for process and fugitive emissions[42]. It is therefore apparent that the introduction of gas as an energy feedstock will delay the introduction of renewable energy at a significant cost to South Africa's climate change commitments.

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[39] Alvarez, R. A., Zavala-Araiza, D., Lyon, D. R., Allen, D. T., Barkley, Z. R., Brandt, A. R., . . . Hamburg, S. P. (2018). Assessment of methane emissions from the U.S. oil and gas supply chain. *Science, 361*(6398): 186-188

[40] Concerned Health Professionals of New York, & Physicians for Social Responsibility. (2020). Compendium of scientific, medical, and media findings demonstrating risks and harms of fracking (unconventional gas and oil extraction) (7th ed.).

[41] Orthofer CL, Huppmann D and Krey V (2019) South Africa After Paris—Fracking Its Way to the NDCs? Front. Energy Res. 7:20. doi: 10.3389/fenrg.2019.00020

[42] https://www2.deloitte.com/za/en/pages/tax/articles/what-the-new-carbon-tax-means-for-SA-industry.html

In conclusion, the continued utilisation of gas as a transition fuel as proposed by the oil and gas industry as well as by the Department of Minerals and Energy, is incompatible with climate stability and the goal of rapid decarbonization that is required.

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