IN THE HIGH COURT OF SOUTH AFRICA

(WESTERN CAPE DIVISION, CAPE TOWN)

CASE NO: 5/6/76/2024

In the matter between

THE GREEN CONNECTION NPC	First Applicant
NATURAL JUSTICE	Second Applicant
and	
MINISTER OF FORESTRY, FISHERIES AND THE ENVIRONMENT	First Respondent
MINISTER OF MINERAL RESOURCES AND ENERGY	Second Respondent
DIRECTOR GENERAL: DEPARTMENT OF MINERAL RESOURCES AND ENERGY	Third Respondent
TOTAL ENERGIES EP SOUTH AFRICA BLOCK 5/6/7 (PTY) LTD	Fourth Respondent

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EXPERT AFFIDAVIT OF MARK NEW

I, the undersigned,

MARK NEW

do hereby make oath and state:

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1. I am a professor in the Department of Environmental and Geographical Science at the University of Cape Town and the previous director of the African Climate and Development Initiative (2011 - 2023).

2. The facts contained in this affidavit fall within my own personal knowledge, except where I indicate otherwise and are, to the best of my knowledge, true and correct. To the extent that I rely on information supplied by others, I believe that such information is true and correct.

3. I have over twenty-five years of experience in climate change research, teaching and project management. My qualifications and experience are set in my curriculum vitae, a copy of which is attached marked '**MN1**'. By virtue of my qualifications, training and experience, I submit that I am qualified to give expert evidence on the issues traversed in this affidavit.

4. In order to arrive at a balanced assessment of whether or not the exploration for, and production of, gas in Block 5/6/7 is socially, environmentally and economically sustainable, it is necessary to consider, assess and evaluate the social, economic and environmental impacts of those activities, including disadvantages and benefits. In this affidavit, I set out the basic science underpinning concerns about climate change and the global and national efforts to arrest this phenomenon, and some of the considerations relevant to deciding whether or not to authorise gas exploration and production within Block 5/6/7. I point out that authorising those activities would be at odds with South Africa's climate change policies and its international commitment to dramatically reducing greenhouse gas emissions. It would also exacerbate climate change

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and thereby contribute to very significant adverse impacts on people (especially women, vulnerable people and future generations) and the environment.

Paris Agreement limits

5. As a party to the United Nations Framework Convention on Climate Change ("**UNFCCC**") and the Paris Agreement, South Africa has agreed to collaborate with the other Parties to limit the increase in the global average temperature to well below 2°C above pre-industrial levels, and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels. This requires South Africa to do its "fair share" of reductions in the emissions of greenhouse gasses ("**GHGs**"). South Africa has acknowledged this in its first (2016) and updated (2021) Nationally Determined Contribution ("**NDC**") submissions to the UNFCCC, where (in the latter) it states it has committed "to ultimately moving towards a goal of net zero carbon emissions by 2050, which will require various interventions to reduce greenhouse gas emissions".

6. Climate change is already having very significant negative impacts on people and ecosystems throughout the world, including in South Africa. The significance of the Paris Agreement target of 1.5°C above pre-industrial levels is that it reflects a global consensus that the level of risk to humanity becomes unacceptably high once that threshold is crossed. Those include the risk of extremely high impact "tipping point" changes in the climate which I discuss below.

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Proven oil and gas reserves far exceed what can be combusted

7. I have prepared the report attached to this affidavit, marked '**MN2**', and confirm that to the best of my knowledge and belief the contents of that report are true and correct.

8. As I explain in that report, as a matter of scientific fact, the total proven oil and gas reserves globally exceed by some margin what it would be possible to combust while still implementing the global GHG emissions reductions necessary to limit the increase in global average temperatures to no more than 1.5°C above pre-industrial levels. Investing in more oil and gas exploration and new resource discoveries will inevitably lead to greater production and greater GHG emissions at a time when it is critical to reduce emissions.

9. The abovementioned report uses data collated and analysed in 2020 and 2021. In the intervening period emissions of GHG have continued to increase, apart from a slight downturn in 2020 during COVID (2020: 50.632 Gt CO_2-eq; 2021: 53.056 Gt CO_2-eq; 2022 53.786 Gt CO_2-eq; 2023: 54.861 Gt CO_2-eq; 2024: 55.958 Gt CO_2-eq [projected as of Sept 2024]). As a result, the available GHGs available to burn has decreased by over 200 Gt CO_2-eq over the last four years, and the discovered reserves available to burn have not decreased, and have likely increased. Therefore, today, the extent to which discovered reserves exceed what can be burned while keeping global temperature increases below 1.5°C has only increased.

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Tipping points

10. It is important to appreciate that climate change is not linear, and its impacts not necessarily reversible. Non-linear impacts of climate change have been termed "tipping points". A climate tipping point occurs when change in one or more large parts of the climate system change rapidly (or "tip") once a particular global warming threshold is exceeded. Once such a tipping point has been passed, the change will continue regardless of how humans respond, causing so-called "irreversible" climate change.

11. An example of a climate tipping point is melting of the Greenland Ice Sheet. At somewhere between 1.5 and 2.0 °C global warming, summer melting will exceed winter accumulation of the ice sheet, and its mass balance starts to decrease. As its mass decreases, the elevation of the ice sheet (currently up to 3,300m above sea level) decreases, and surface temperatures become warmer due to this lower elevation (the lapse rate effect). Even if global warming is reversed, the lower elevation and warmer temperatures ensure that melting continues in a positive feedback loop. Complete melting of the Greenland Ice Sheet will cause ~6m of sea level rise, inundating nearly all coastal settlements, including those in South Africa, such as Cape Town and Durban.

12. Some tipping points can act to increase GHG emissions, further accelerating climate change. For example, the Amazon forest is projected to collapse and transform into a savanna landscape somewhere around 2.0 °C. The carbon stored in the forest vegetation and soils will be released into the atmosphere as GHGs, adding to those from fossil fuels, and the capacity of this new savanna

ecosystem to act as a sink for CO_2 will be much lower than the forest it replaced. This creates "positive CO_2 feedback" which causes the change to accelerate and become self-perpetuating.

13. An article titled "*Exceeding 1.5°C global warming could trigger multiple climate tipping points*" published by leading climate change scientists in Science on 9September 2022[1] states the following:

> "*Potential causal interactions among tipping elements are such that overall tipping of one element increases the likelihood of tipping others, possibly risking a "tipping cascade" of impacts that may further amplify global warming. In the worst-case scenario, interactions might produce a global CTP.*"
>
> "*The Earth may have left a safe climate state beyond 1°C global warming. A significant likelihood of passing multiple climate tipping points exists above ~1.5°C, particularly in major ice sheets. Tipping point likelihood increases further in the Paris range of 1.5 to <2°C warming. Current policies leading to ~2 to 3°C warming are unsafe because they would likely trigger multiple climate tipping points. Our updated assessment of climate tipping points provides strong scientific support for the Paris Agreement and associated efforts to limit global warming to 1.5°C.*"[2]

Natural Gas, Methane, CO_2 and GHG Warming

14. Methane is the main component of natural gas found underground (i.e. the gas which Total is exploring for). The amount of methane in raw natural gas varies, but is typically between 70% and 97%, and on average around 95%. The

[1] Armstrong McKay et al. 'Exceeding 1.5°C global warming could trigger multiple climate tipping points' Science 377, 1171 (2022) p.1
[2] Armstrong McKay et al. 'Exceeding 1.5°C global warming could trigger multiple climate tipping points' Science 377, 1171 (2022) p. 8.

second most abundant gas in raw natural gas is ethane, which is also a GHG. Natural gas affects climate through two pathways: (i) during its production and transport so called fugitive emissions arise from releases methane, ethane and other gases directly into the atmosphere (e.g., from leakages in pipelines); and (ii) during combustion, CO_2 is produced, in a similar manner to burning of oil and coal.

15. Methane (from fugitive emissions and other sources such as agriculture) is a powerful GHG. Although it breaks down in the atmosphere faster than CO_2, its Global Warming Potential ("**GWP**") is ~80 times greater than that of CO_2 when measured over a 20 year period, and ~28 times greater when measured over a 100 year period[3].

16. The magnitude of natural gas production on GHG warming depends strongly on the level of fugitive emissions (gas that escape into the atmosphere during production and transport, and is therefore not burnt for energy production). At zero fugitive emissions, production natural gas for electricity results in emissions of of ~258 g CO_2-eq/kWh_{el}, while 10% fugitive emissions increase the GHG forcing to ~1439 g CO_2-eq/kWh_{el}. Here, CO_2-eq refers to the combined GHG warming effect of all gases emitted from production to burning, re-expressed as the equivalent concentration of CO_2, while kWh_{el} refers to electricity energy produced. Actual fugitive emissions across different natural gas production systems typically fall towards the upper level of this range. In many cases, the net GHG effect of natural gas use is greater than that of oil or

[3] Global warming potential (GWP) is a measure of a molecule of a given GHG's warming power, relative to a molecule of CO_2, over a given time period, typically 20, 50 or 100 years. GWP is a function of both a molecule's instantaneous warming power and its lifetime in the atmosphere.

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coal, because of these fugitive emissions. Therefore, the argument that natural gas is a lower impact "transition fuel" that should be exploited in place of oil and gas is untrue in most gas production cases to date.

17. Carbon dioxide (CO_2) is causing about three quarters of global warming and can take thousands of years to be fully absorbed by the carbon cycle. South Africa's carbon emissions are relatively high and the Union of Concerned Scientists estimated that in 2018 South Africa was the world's 13th biggest emitter of CO_2, and the largest in Africa. South Africa's per capita emissions of GHGs are also high by African standards. According to Climate Watch, South Africa's per capita emissions are 9.01 tonnes of carbon dioxide equivalent ("**CO_2-eq**") and while Nigeria's is 1.83 tonnes CO_2-eq.

Remaining Carbon Budget

18. The cumulative "stock" of GHGs (particularly CO_2) in the atmosphere is the primary driver of long-term global warming. This means that even if all human-caused GHG emissions ceased immediately, Earth's climate would still heat up by several tenths of a degree Celsius because the GHGs which are already in the atmosphere will continue warming in the Earth's climate for more than a century.

19. The Remaining Carbon Budget is the amount of CO_2 (or total GHG, expressed as CO_2-eq) that can be emitted in the future, while still keeping human-induced warming below 1.5 °C. The Remaining Carbon Budget is not a single number, but a range of budgets each of which corresponds to a specific likelihood of keeping global warming below 1.5 °C. For example, the IPCC's Sixth Assessment Report published in March 2023 estimated that in order for there

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to be a 50% likelihood of limiting warming to 1.5°C, the remaining carbon budget from the start of 2020 was 500 Gt (Gigatonnes) CO_2.

20. However the Remaining Carbon Budget is shrinking fast. The Indicators of Global Climate Change ("**IGCC**") initiative produces estimates for key climate indicators that are consistent with the IPCC's Sixth Assessment Report.[4] The IGCC's updated assessment has reduced the remaining carbon budget from 500 Gt CO_2 at the start of 2022 to 200 Gt CO_2 as of September 2024. This is largely due to the annual emissions of around 55 Gt CO_2 per year over the last four years. This means that the window of opportunity within which humanity can take measures to avoid overshooting the 1.5 °C and 2.0 °C thresholds for dangerous, and perhaps catastrophic, climate change, is closing fast.

21. The Summary for Policy Makers, which the IPCC published with its Sixth Assessment Report on global warming, was approved by government signatories to the UNFCCC, including South Africa. It recorded that human activities are causing an increase in the Earth's temperature, and this poses a risk to health, livelihood, food security and water supply, among others. The following extracts are relevant.

> *"In the near term, every region in the world is projected to face further increases in climate hazards (medium to high confidence, depending on region and hazard), increasing multiple risks to ecosystems and humans (very high confidence). Hazards and associated risks expected in the near term include an increase in heat-related human mortality and morbidity (high confidence), food-borne, water-borne, and vector-borne diseases (high confidence), and mental health challenges[36] (very high*

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[4] See Current Remaining Carbon Budget and Trajectory (climatechangetracker.org)

confidence), flooding in coastal and other low-lying cities and regions (high confidence), biodiversity loss in land, freshwater and ocean ecosystems (medium to very high confidence, depending on ecosystem), and a decrease in food production in some regions (high confidence). Cryosphere-related changes in floods, landslides, and water availability have the potential to lead to severe consequences for people, infrastructure and the economy in most mountain regions (high confidence). The projected increase in frequency and intensity of heavy precipitation (high confidence) will increase rain-generated local flooding (medium confidence). {Figure 3.2, Figure 3.3, 4.3, Figure 4.3} (Figure SPM.3, Figure SPM.4)"[5]

"Risks and projected adverse impacts and related losses and damages from climate change will escalate with every increment of global warming (very high confidence). They are higher for global warming of 1.5°C than at present, and even higher at 2°C (high confidence). [...]"[6]

22. The IPCC's Synthesis of its Sixth Assessment Report calculates that to have a 50% probability of limiting global warming to 1.5°C, with no or limited overshoot, countries must collectively reduce GHG emissions (from 2019 emission levels) by 43% by 2030 and 60% by 2035.[7].

23. The IPCC's reports also shows that reducing emissions is no longer sufficient, and that it will also be necessary to remove some of the carbon that is already in the atmosphere, or will be in the atmosphere in the years to come.

"From a physical science perspective, limiting human-caused global warming to a specific level requires limiting cumulative CO_2 *emissions, reaching at least*

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[5] B2.1

[6] B2.2.

[7] Synthesis Report of the Intergovernmental Panel on Climate Change Sixth Assessment Report, Summary for Policymakers IPCC AR6 SYR (March 2023) at Table 3.1, Figure 2.5, Box SPM.1 p. 21.

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*net zero CO_2 emissions, along with strong reductions in other greenhouse gas emissions. Reaching net zero GHG emissions primarily requires deep reductions in CO2, methane, and other GHG emissions, and implies net negative CO2 emissions39. Carbon dioxide removal (**CDR**) will be necessary to achieve net negative CO_2 emissions [...].*"[8]

24. South Africa's remaining carbon budget, if it were to meet its self-defined fair share contribution to net zero global GHG emissions by 2050 is in the range of 6-9 Gt CO_2-eq[9]. At current annual emissions of ~455 Mt CO_2-eq, this budget will be exhausted within between 13 and 20 years (2037 - 2044). Thus, the country is already challenged to not exceed its nationally defined remaining carbon budget.

25. If a gas field in Block 5/6/7 were to be developed as a deep water (700+ m depth) field, and over a 10-to-15 year period it produced between 5 Tcf[10] and 10 Tcf of gas (approximately the minimum viable reserve size for offshore exploration at these depths), the combustion of that gas would release between 258 (5 Tcf) to 564 (10 Tcf) Mt CO_2-eq.

    25.1. Those emissions will consume part of the remaining global carbon budget. By way of illustration, if the total amount produced were to be combusted in South Africa, this would consume a significant amount (3-9%) of South Africa's remaining carbon budget, meaning that other GHG emitting activities would have to be restricted more severely.

[8] B.5.1

[9] Marquard, Andrew, et al. (2023). Exploring net zero pathways for South Africa - An initial study. University of Cape Town. Report. https://doi.org/10.25375/uct.22189150.v2.

[10] Tcf = trillion cubic feet of gas

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25.2. If such a field were developed, it is reasonable to assume that it would not start producing gas until about 2035. Extremely steep reductions in emissions will be necessary well before this date to meet the goal of net-zero emissions by 2050, meaning that it is extremely unlikely that the field could operate and be consistent with South Africa's 2050 net-zero commitment.

Impacts

26. It is virtually certain that the world will overshoot 1.5 °C within the next few years and enter a zone of very significant risk. Current implemented and planned emissions reduction policies from countries will result in an overshoot of 2.0 °C, most likely to between 2.1 and 2.5 °C[11], increasing the severity of impacts and the likelihood of tipping points being reached. Failure to implement planned emissions reductions will result in overshoots higher than 2.5 °C.

27. Climate change is having, and will continue to have, disproportionately severe impacts on Africa, and on poor and marginalised communities, women, children and future generations. The South Africa government acknowledges this. For example, the Just Transition Framework states:

"South Africa is in a part of the world that is severely impacted by climate variability. The country frequently experiences droughts, floods, and other extreme weather events, with evidence that the frequency and intensity of such events are increasing because of climate change (IPCC 2022). These events have already caused enormous damage to infrastructure, ecosystems, lives, and livelihoods, and displaced thousands of people, and continue to be a stark reminder that it is poorer communities—women and young people, the

[11] https://climateactiontracker.org/global/cat-thermometer [accessed 09 October 2024].

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unemployed, those living in informal settlements— that are most vulnerable to climate change."

MARK NEW

I hereby certify that the deponent has declared that he knows and understands the contents of this Affidavit and that to the best of his knowledge and belief it is the truth, which Affidavit has been signed to and affirmed to before me at CLAREMONT on this the 10TH day of OCTOBER 2024.

COMMISSIONER OF OATHS

LISA KATE WOOD (SZÖKE)
COMMISSIONER OF OATHS
PRACTISING ATTORNEY
FIRST FLOOR, UNIT C
4 ASCOT ROAD, KENILWORTH
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PROFESSOR MARK NEW

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Publications: 133
h-index: 51
h5-index: 13
Citations: 23,480
Policy citations: 962

PROFILE

Mark New has thirty years' experience in climate research, teaching and public outreach, thirteen of which were as director of the African Climate and Development Initiative, a cross-faculty interdisciplinary research institute at UCT. He is also Director of the ARUA (African Research Universities Alliance) Centre of Excellence for Climate and Development, in which UCT partners with the University of Ghana and Nairobi University, to drive pan-African research and teaching on climate change in Africa. Mark is internationally recognised as a leading researcher in climate change detection, attribution, impacts and adaptation. He is a recipient of the 2023 Frontiers Planet Prize, which recognises research the offers solutions to planetary environmental challenges and the 2020 Piers Sellers Prize for exceptional climate change research. He has served on several international bodies, most recently as a member of the World Adaptation Science Programme Scientific Committee, as Coordinating Lead Author for the IPCC 6th Assessment Report, and as a member of the World Climate Research Programme Working Group on Event Attribution.

RELEVANT EXPERTISE

- Climate change detection, attribution, impacts and adaptation research.
- Research project management on over 20 research grants since 2010.
- Strategic planning, large-institute management, interdisciplinary leadership and practice
- Systematic reviews, including as a senior author of GAMI (Global Adaptation Mapping Initiative)
- Leading science-policy assessments, including IPCC AR6, WGII, Chapter 17 coordinating lead author
- Adaptation tracking, including the TSITICA project mapping of adaptation projects in RSA, Kenya, Ghana
- Policy-oriented research, such as development of South Africa's adaptation research agenda prioritisation

EDUCATION AND QUALIFICATIONS

10/1993 – 09/1996: PhD, Geography, Cambridge University, UK (graduated 1999).
09/1991 – 07/1992: MPhil, Environment and Development, Cambridge University, UK (graduated 1992).
02/1987 – 11/1987: BSc Hons, Geology, University of Cape Town, RSA, (graduated 1987).
02/1984 – 11/1986: BSc, University of Cape Town, RSA (graduated 1986).

EMPLOYMENT AND EXPERIENCE

07/2023 – present: Professor, Department of Environmental & Geographical Science, University of Cape Town
07/2011 – 06/2023: Professor & Director, African Climate and Development Initiative, University of Cape Town
09/1999 – 07/2011: Lecturer / Professor in Climate Science, School of Geography & Environment, Oxford University
04/1996 – 09/1999: Senior Research Associate, Climatic Research Unit, University of East Anglia
02/1988 – 03/1991: Exploration Geologist, Southern Oil Exploration Corp., Cape Town

SELECTED AWARDS, RECOGNITION AND EXTERNAL POSTIONS

2024-2024: Royal Society Wolfson Visiting Professor Fellowship, University of Bristol, UK
2024-2026: University of Cape Town – Bristol University Joint Professorship
2023-2024: Fulbright Visiting Scholar Fellowship to University of California Santa Barbara, USA
2023: Frontiers Planet Prize (with co-authors Dr Petra Holden, et al.)
2022-present: Science Review Board, UK Met Office Hadley Centre
2018-present: World Adaptation Science Programme Science Committee

SELECTED RELEVANT PUBLICATIONS

Carlson, C., et al, incl. **M. New** (2024). Detection & Attribution of Climate Change Impacts on Human Health [version 1; not peer reviewed]. Wellcome Open Research. London, Wellcome Trust. 9:245.

Wood, R. A., et al, incl. **M. New** (2023). A Climate Science Toolkit for High Impact-Low Likelihood Climate Risks. *Earth's Future* 11(4): e2022EF003369.

Taylor, A., et al, incl. **M. New** (2023). Operationalising climate-resilient development pathways in the Global South. *Current Opinion in Environmental Sustainability*, 64: 101328.

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New, M. et al. (2022). Decision Making Options for Managing Risk. In: *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK.

Berrang-Ford, L., et al incl. **M.New** (2021). A systematic global stocktake of evidence on human adaptation to climate change [Article]. Nature Climate Change, 11(11), 989-1000.

Ziervogel, G., et al. incl., **New, M.** (2022). Climate change in South Africa: Risks and opportunities for climate-resilient development in the IPCC Sixth Assessment WGII Report, *South African Journal of Science,* vol. 118, no. 9-10.

Sibanda, D, et al. incl. **New, M** (2024). Tracking adaptation and mitigation projects in South Africa, Ghana and Kenya. In review.

Ofoegbu, C., & **New, M.** (2022). Evaluating the effectiveness and efficiency of climate information communication in the African agricultural sector: a systematic analysis of climate services. *Agriculture*, 12(2), 17.

SELECTED POPULAR SCIENCE PUBLICATIONS

Rebello, A. D., K. J. Esler, P. Holden and **M. New** (2022). Removing alien plants can save water: we measured how much. In: *The Conversation.*

Holden, P., **M. New**, et al (2022). Clearing alien trees can help reduce climate change impact on Cape Town's water supply. In: *The Conversation.*

Perumal, L., M. New, W. Liu and M. Jonas (2021). Africa's growing road network may affect ecosystems: we reviewed the evidence. In: *The Conversation.*

Odoulami, R. C. Trisos, and **M. New** (2020). "Dimming the sun could reduce future drought risk in Cape Town – but there's a catch." In *The Conversation.*

New, M (2019). "Climate explained: how much of climate change is natural? How much is man-made?" In *The Conversation.*

New, M (2018). "What the latest assessment on global warming means for southern Africa." In *The Conversation.*

New, M, Wolski, P. and Otto, F. (2018). "Global warming has already raised the risk of more severe droughts in Cape Town." In *The Conversation.*

RECENT MAJOR RESEARCH PROJECTS

PI: *Frontiers Planet Prize.* [Frontiers Foundation, 2024-2028, CHF 1.0 M].

The Frontiers Planet Prize is awarded for world leading, solutions-oriented research addressing one of more Planetary Boundaries. The award is to be used to deepen and/or scale out research by the winner and their lab. In my case, I and my team will be expending our work in joint attribution methodologies to (i) pilot operational impacts attribution and (ii) use attribution methods to assess effectiveness of disaster risk reduction adaptations.

PI: *Building African climate-health attribution data, digital tools and capacity.* [Welcome Trust, 2025-2027, UKP 3.0 M].

AFRIVERSE aims to address the lack of evidence on climate-health impacts in Africa by developing new African climate and health data, digital tools for data access, analysis and visualisation, and human capacity, in parallel with delivering several Africa-focused attribution studies undertaken by teams of African scientists hosted at ASCEND, the University of Cape Town's new climate and development science synthesis centre.

PI: *Heat Adaptation Benefits for Vulnerable Populations in Africa.* [Welcome Trust, 2023-2027, UKP 2.0 M].

HABVIA aims to work with four vulnerable urban and rural communities in South Africa and Ghana to co-design and implement affordable housing and workplace heat adaptation and to assess the social and health effectiveness of these adaptations. The project is a collaboration between the Universities of Cape Town, Ghana, Kwame Nkrumah, Bristol, and also the South African Medical Research Council.

PI: *South Africa Flanders Adaptation Research and Training Programme.* [UKRI GCRF, 2020-2024, EURO 2.4 M].

SAF-ADAPT brings together three South African universities - Cape Town, Fort Hare and Venda - with a consortium of Belgian universities - led by KU Leuven - to: (i) train a cohort of twenty MSc, PhD and Post-doctoral researchers; (ii) fill key adaptation knowledge gaps through student research; (iii) develop knowledge products and data that supports national adaptation practice needs; (iv) provide professional training in adaptation to technical staff in government and civil society.

Co-PI: *TSITICA - Transforming social inequalities through inclusive climate actions.* [UKRI GCRF, 2020-2023, UKP 2.0 M].

TSITICA is a collaborative research project between the Universities of Cape Town, Ghana, Nairobi, Bristol, LSE and East Anglia, which aims to build the evidence base on how climate risk intersects with poverty and inequality, and how national climate actions mandates under the UNFCCC and the Nationally Determined Contribution process can be targeted and reduction of multi-dimensional poverty and inequality.

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Evidence that current proven reserves of oil and gas exceed CO_2 budgets consistent with the Paris Agreement temperature targets

Mark New
African Climate and Development Initiative (ACDI), University of Cape Town
07 March 2022

Summary

1. The Paris agreement of the UN Framework Convention on Climate Change, to which South Africa is a signatory, has the goal of keeping human-induced global warming to well below 2.0°C, ideally below 1.5°C.

2. While the net emissions that are consistent with the Paris targets have considerable uncertainties due to biogeochemical and geophysical uncertainties about the earth system, *net* emissions from today need to be below 400 Gt CO_2 to have a 50% likelihood of keeping below 1.5°C, and 800 Gt to keep "well below" 2.0°C.

3. Emissions from fossil fuels greater than 400 and 800 Gt will require substantial carbon dioxide removal (CDR) to meet the Paris temperature targets. Questions remain as to the viability of large-scale CDR, especially up to 2050 when net zero emissions are required.

4. The CO_2 budgets for oil and gas within any overall emissions budget vary depending on assumptions on the future mix of coal, oil and gas. The least-precautionary estimates of budgets for oil and gas consistent with 1.5°C are 248 and 121 Gt CO_2, respectively.

5. CO_2 budgets that are consistent with keeping well below 2.0°C are 396 and 194 Gt CO_2 for oil and gas, respectively.

6. Proven reserves of oil and gas, if burned, would produce *at least* 543 and 350 Gt CO_2, respectively.

7. The emissions from burning already proven oil and gas will substantially exceed the budget available to meet the 1.5°C target, by at least 210% and 290%, respectively

8. Emissions of CO_2 from burning proven oil reserves will also substantially exceed the "well below 2.0°C" oil and gas emissions budgets, by at least 137% and 194%, respectively.

Background context: the Paris agreement

The "Paris Agreement" is a legally binding international treaty on climate change, adopted by 196 Parties to the UNFCCC at COP 21 in Paris, on 12 December 2015 and entered into

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force on 4 November 2016[1]. South Africa is a signatory to the Paris Agreement. One of the goals of the agreement is to limit global warming to well below 2.0 degrees Celsius, preferably to 1.5 degrees, compared to pre-industrial levels.

This report assesses whether proven global reserves of oil and gas – if burned – would lead to greenhouse emissions that cause warming in excess of the Paris Agreement global temperature targets.

Greenhouse gas emissions budgets to meet the 1.5°C and 2.0°C targets

The 2018 IPCC Special Report on 1.5 Degrees (SR15)[2] specifically assesses the greenhouse gas emission reduction pathways that will keep global warming below the Paris Agreement 1.5°C and 2.0°C targets.

There are a range of possible future emission pathways that meet these targets, but as a rule, the sooner global emissions peak the less steep subsequent reductions are needed. Pathways that peak late and decline slowly will either cause greater warming, possible overshooting 2.0°C, or will need carbon dioxide removal to reduce GHG concentrations to levels consistent with the 1.5°C and 2.0°C targets.

Uncertainties in carbon cycle feedbacks and climate sensitivity mean that any emissions pathway could lead to a range of possible future warming levels. Therefore, scientific literature often presents a likelihood of a particular emissions pathway meeting a given target (e.g. 50%, 66%, 90%). A higher likelihood threshold (a more precautionary approach) will reduce the allowable future emissions.

A common approach to summarising the emissions reduction challenge is to estimate a remaining CO_2 budget (the cumulative total of emissions into the future) that meets the 1.5 or 2.0°C target. In 2018, the IPCC estimated that budget to be 580 Gt CO_2 to have a 50% likelihood of keeping below 1.5°C, and 420 Gt CO_2 for a 66% likelihood[4]. The budget for keeping below 2.0°C was 1500 and 1170 GtCO_2 for 50% and 66% likelihoods, respectively. Given global emissions of CO_2 since 2018 have been approximately 80Gt, the current remaining budget for 1.5 degrees can be adjusted down to 500 and 340 Gt CO_2 (50% and 66% likelihood) and similarly, the 2.0 degrees budget to 1420 and 1090 Gt CO_2. Different estimates of this budget are shown in Table 1. The latest IEA world energy outlook report adopts a budget of 500Gt for 1.5°C, based on similar logic[3].

How a future CO_2 budget could be distributed between different sources (coal, oil, gas, others) depends on the mix of these sources into the future. Table 1 presents estimates of the total CO_2 budget consistent with 1.5°C and 2.0°C from the IPCC SR15 (which itself summarises underlying literature), along with a breakdown of fossil fuel components of that

[1] UNFCCC (2015). Paris Agreement to the United Nations Framework Convention on Climate Change, Dec. 12, 2015, T.I.A.S. No. 16-1104, United Nations Treaty Collection.

[2] IPCC (2018). Summary for Policymakers. Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. V. Masson-Delmotte, P. Zhai, H. O. Pörtner et al. Cambridge, United Kingdom, and New York, NY, USA, Cambridge University Press: 1-32.

[3] IEA (2021), Net Zero by 2050, IEA, Paris https://www.iea.org/reports/net-zero-by-2050

budget between coal, oil and gas, under different emissions reduction scenarios in line with 1.5°C. Although IPCC does not provide a breakdown for other temperature targets, we estimate the budgets by scaling the 1.5°C budgets for the other warming targets. All scenarios assume that coal phases out more quickly than gas and oil, and the higher budgets assume significant carbon dioxide removal (CDR; see Box 1). In addition, scenarios with higher oil budgets are offset by lower gas budgets and vice versa. For oil and gas, the remaining *maximum* 1.5°C budgets (assuming these two energy sources are preferred to coal, and 50% likelihood) for each that do not depend on large-scale CDR are 248 and 121 Gt CO_2 respectively. The combined maximum budget across scenarios is 369 and 468 Gt CO_2, assuming minor and significant CDR, respectively.

If one adopts the recommendation of Matthews et al[4] that the Paris target of "well below" 2.0°C equates to 1.75°C, with a likelihood of 66%, the maximum budgets for oil and gas scale to 396 and 194 Gt CO2, without significant CDR.

*Table 1. Remaining emissions of CO_2 consistent with a 1.5 and 2.0°C warming targets, from the IPCC SR15, adjusted to take account of the 80Gt CO_2 emitted up to 2020. Net emissions represent the difference between emissions and CDR. The IPCC P1-P4 scenarios show total actual emissions that deliver the net emission target, with increasing levels of CDR from P1 to P4. *Note that emissions breakdown for P1-P4 for 2.0°C and 1.75°C are estimates arrived at by scaling 1.5°C estimates by the net emissions estimate.*

	Current Emissions (1)	**Emission Budget for Temperature Target / Likelihood of Meeting Target (Gt CO2)**					
Emission Source	2019	1.5°C / 50%	1.5°C / 66%	1.75 / 50%	1.75 / 66%	2.0°C / 50%	2.0°C / 66%
Total Net Emissions	36.45	500	340	1040	800	1420	1090
IPCC Scenario		*P1 P2 P3 P4*	*P2* P4**	*P1* P2* P3* P4**	*P2* P4**	*P1* P2* P3* P4**	*P2* P4**
Coal	14.36 (39.4%)	63 139 105 116	43 71	132 288 219 242	222 186	225 492 373 413	302 253
Oil	12.36 (33.9%)	152 248 235 491	103 160	315 515 489 1022	396 786	538 879 835 1745	540 1071
Gas	7.62 (20.9%)	102 121 233 195	70 159	213 253 485 406	194 313	363 431 828 694	265 426

(1) Current emissions from Friedlingstein (2020)[5] as reported by Our World in Data

Box 1: Carbon-dioxide removal as a climate mitigation option

[4] Matthews, H.D., Tokarska, K.B., Nicholls, Z.R.J. et al. Opportunities and challenges in using remaining carbon budgets to guide climate policy. Nat. Geosci. 13, 769–779 (2020). https://doi.org/10.1038/s41561-020-00663-3.

[5] Friedlingstein, P., et al., (2020). Global carbon budget 2020. *Earth System Science Data*, *12*(4), pp.3269-3340.

Carbon-dioxide removal (CDR) refers to the "process of removing CO_2 from the atmosphere" so as to achieve "negative emissions"[6,7]. There are two broad categories of CDR, natural and artificial. Examples of natural CDR include afforestation and land restoration, where plants (especially trees) are used to take up CO_2 via photosynthesis and this is then stored in living plant mass and later as dead material on and within the soil. Artificial methods, called "direct air capture and carbon storage" (DACCS), use mostly yet to be proven engineered processes to capture atmospheric CO_2 for subsequent geological storage. A hybrid approach called "bioenergy with carbon capture and storage" (BECCS) utilises biomass for energy, capturing the CO_2 emissions and similarly to DACCS, storing them geologically. Land-based approaches such as afforestation and BECCS frequently will involve trade-offs with use of land for other purposes, especially food production, and their feasibility depends strongly on transformations in the global food system towards low-meat diets. The storage of CO_2 in BECCS and DACCS require substantial geological storage sites, and these are not always close enough to where the CO_2 is captured, for example at a power plant. Overall, (i) some CDR methods have been shown to be feasible, but there are doubts as to whether they can be deployed at scale without major negative side-effects; (ii) the remaining CDR methods are yet to be proven; (iii) nearly all CDR methods are expensive, at much greater than US$ 100 per tonne of CO_2, adding considerably to the full cost of burning fossil fuels.

Proven reserves of coal, oil and gas, and their combustion CO_2 emissions

Estimates of proven fossil fuel reserves vary widely between studies, due to different definitions of what constitutes proven, how such reserves are estimated, whether conventional or unconventional sources are considered, and which geographic regions are included (e.g., OPEC versus non-OPEC; Arctic included or excluded)[8]. Table 2 shows a range of estimates from different sources, summarised by McGlade and Ekins[10] and other sources. The upper and lower ranges from these studies are 1,300-2,300 billion barrels of oil, 186-2,200 trillion cubic metres of gas, and 850-1,069 billion tons of coal, respectively.

The combustion emissions of CO_2 from different fossil fuel sources is dependent on several factors, including the characteristics of the raw resource (e.g., heavy versus light crude oil), the refining process and end product (e.g. gasoline versus diesel), and the efficiency of the eventual burning for energy. Estimates of future CO_2 emissions from fossil fuels are therefore dependent on assumptions about how these fuels are used. The most conservative estimates from the literature suggest that the *minimum* emissions from combustion of already discovered oil, gas and coal will be 543, 350 and 1,540 Gt CO_2 respectively (Table 2). If the reserves or emissions per unit fossil fuel are higher, then these values increase.

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6 IPCC (2018). FAQ 4.2 What are Carbon Dioxide Removal and Negative Emissions? In: *Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.* Eds: V. Masson-Delmotte, et al Cambridge, United Kingdom, and New York, NY, USA, Cambridge University Press: 1-32.

7 Royal Society and Royal Academy of Engineering (2018). Greenhouse Gas Removal Policy briefing DES5563_1. https://royalsociety.org/topics-policy/projects/greenhouse-gas-removal.

8 McGlade, C. and Ekins, P. (2015) The geographical distribution of fossil fuels unused when limiting global warming to 2 °C. *Nature*, 517, 187–190. https://doi.org/10.1038/nature14016.

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Table 2. Estimates of known global reserves of oil, gas and coal, and associated estimated emissions of CO_2 from their combustion (emission factors from McGlade and Ekins[5]). Gb = billions of barrels; Tcm = trillion cubic metres; Gt = billions tonnes.

Source	Oil (Gb)	Oil-CO_2 (Gt)	Gas (Tcm)	Gas-CO_2 (Gt)	Coal (Gt)	Coal-CO_2 (Gt)
BGR	1,600	661	195	388	1,000	1,756
IEA	1,700	700	190	379	1,000	1,756
GEA	1,500-2,300	621- 936	670-2,000	1,229-3,584	850-1,000	1,540-1,756
ME	1,300	543	190	379	1,000	1,756
HO	1,688	626.9	186	350.4	892	1,756.9
BP (2020)	1,734	644*	199	375*	1,069	2,379*

BGR = Federal Institute for Geosciences and Natural Resources[9]; IEA = International Energy Agency[10]; GEA, Global Energy Assessment[11]; ME = McGlade and Ekins[10]; HO = Heede & Oreskes[12] using reserve data obtained from BP (2014)[13]; BP = Authors' own calculations for emissions based on reserve data from BP (2020)[14] using the methodology reported in Heede & Oreskes[14].

Comparison of Paris CO_2 budgets and emissions from proven reserves

Based on the IPCC estimates of oil and gas CO_2 emissions budgets consistent with the more ambitious 1.5°C Paris Agreement target, the least precautionary (maximum) budget (50% likelihood of meeting target) requires net emissions of 500 Gt in total, and around 248 and 121 Gt for oil and gas, respectively. This compares to emissions from burning of the lowest estimates of proven oil and gas of 543 and 350 Gt CO_2, respectively. There is already sufficient proven oil to supply over double the emissions consistent with 1.5°C, while for gas, proven reserves are nearly three times the 1.5°C CO_2 budget. These broad figures are consistent with a similar analysis undertaken by Welsby et al (2021)[15] who estimate that

[9] Federal Institute for Geosciences and Natural Resources (BGR). Energy Study 2012. Reserves, Resources and Availability of Energy Resources. http://www.bgr.bund.de/DE/Gemeinsames/Produkte/Downloads/DERA_Rohstoffinformationen.

[10] International Energy Agency (IEA) (2013). World Energy Outlook. http://www. worldenergyoutlook.org/publications/weo-2013.

[11] Rogner, H.-H. et al. (2021) in: Global Energy Assessment —Towards a Sustainable Future. Ch. 7, 423–512, Cambridge University Press.

[12] Heede, R. and Oreskes, N. (2016). Potential emissions of CO2 and methane from proved reserves of fossil fuels: An alternative analysis. *Global Environmental Change*, *36*, pp.12-20.

[13] BP (2014 & 2013). Statistical Review of World Energy. London, www.bp.com/statisticalreview.

[14] BP (2020). Statistical Review of World Energy. London, www.bp.com/statisticalreview.

[15] Welsby, D., J. Price, S. Pye and P. Ekins, 2021: Unextractable fossil fuels in a 1.5°C world. *Nature*, **597**(7875), 230-234, doi:10.1038/s41586-021-03821-8.

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nearly 60 per cent of oil and methane, and 90 per cent of coal must remain unextracted to keep within a 1.5 °C carbon budget, with a 50% likelihood.

Emissions budgets are more generous for the 2.0°C target. The least precautionary budget (2.0°C at 50% likelihood) allows for net emissions of 1420 Gt CO_2, of which oil and gas could make up 538-879 and 363-431 Gt (without significant CDR). However, many have argued that the Paris objective of keeping "well below 2.0°C" would require a more precautionary approach in setting these budgets, for example by choosing a 66% likelihood of keeping below 1.75°C[6]. In this case, the net emissions budget is 800 Gt CO_2 in total, of which oil comprises 396 Gt CO_2 and gas 194 Gt CO_2 (without significant CDR). Therefore, emissions of 543 and 350 Gt CO2 from burning proven oil and gas reserves would thus result in significantly exceeding this "well below 2.0°C" carbon budget for both oil and gas. It is only in the case of the least precautionary emissions scenarios, with a high risk of overshooting 2.0°C, that emissions from oil and gas are less than those from proven reserves.

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