



Expert report at the request of the law firm Simonsen Vogt Wiig in case 24-036810ASD-BORG/02

2 September 2025

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Dr Rupert Stuart-Smith – biographical detail

Deputy Director & Senior Research Fellow in Climate Science and Law, Oxford Sustainable Law Programme, University of Oxford

Education

- DPhil (PhD) in climate science from the School of Geography and the Environment, University of Oxford. BA (Hons) in Geography from the University of Oxford.

Expertise

- Climate change impacts on health, glaciers, extreme weather events.
- Climate change mitigation: emission reductions required to meet global climate goals.
- Research regularly published in leading scientific journals, recent publications in *Science*, *Nature Geoscience*, *Nature Climate Change*, *Climatic Change*. Over 1,200 scholarly citations.
- Co-Principal Investigator of two multi-million GBP research grants from the Wellcome Trust on the health impacts of climate change, with particular focus on under-studied regions including Africa and Latin America.
- Co-led, with Prof. Kristie Ebi (University of Washington) and Prof. Sir Andy Haines (London School of Hygiene and Tropical Medicine), the drafting of community guidelines for quantifying attributable impacts of climate change on human health with over fifty leading researchers in the field.



Questions asked by Simonsen Vogt Wiig

As addressed in expert report

1. Is there an established method to quantify climate change impacts from project-level greenhouse gas emissions?
2. Using established scientific methods, could you quantify some climate change impacts of the project-level emissions from Breidablikk (107 MtCO₂), Tyrving (12 MtCO₂), and Yggdrasil (365 MtCO₂) including on sea levels and economic losses?
3. Can you assess these emissions against the remaining global carbon budget for limiting warming to 1.5°C with 50%, 67% and 83% likelihood, accounting for the emissions of other global fossil fuel projects?
4. To what extent are the projected emissions from Breidablikk, Tyrving and Yggdrasil consistent with a per capita allocation of the remaining carbon budget for Norway in 2024?



Approach taken in writing expert report

Conclusions grounded in reports of the IPCC or high-quality peer-reviewed scientific articles

- **Assessments provided in the expert report and this presentation prioritise findings of the Intergovernmental Panel on Climate Change (IPCC).**
- **I supplement these with references to high-quality peer-reviewed studies to provide case study detail or updated figures, since the most recent report of the IPCC was published in 2021-22.**

Quantifying climate change impacts from project-level GHG emissions

Multiple methods to do so, yield substantively the same answer

1. All CO₂ emissions cause climate change impacts.

(a) Every tonne of CO₂ emitted into the atmosphere causes long-term global warming.

- Global average surface temperature increases approximately linearly with the total amount of CO₂ emitted.
- This central concept of climate science is widely accepted and underpins the IPCC's findings that any limit on temperature rise corresponds to a finite carbon budget and that stopping global warming requires net zero CO₂ emissions.
- Consequently: there is no threshold below which emissions do not contribute to warming. All CO₂ emissions result in global temperature rise.

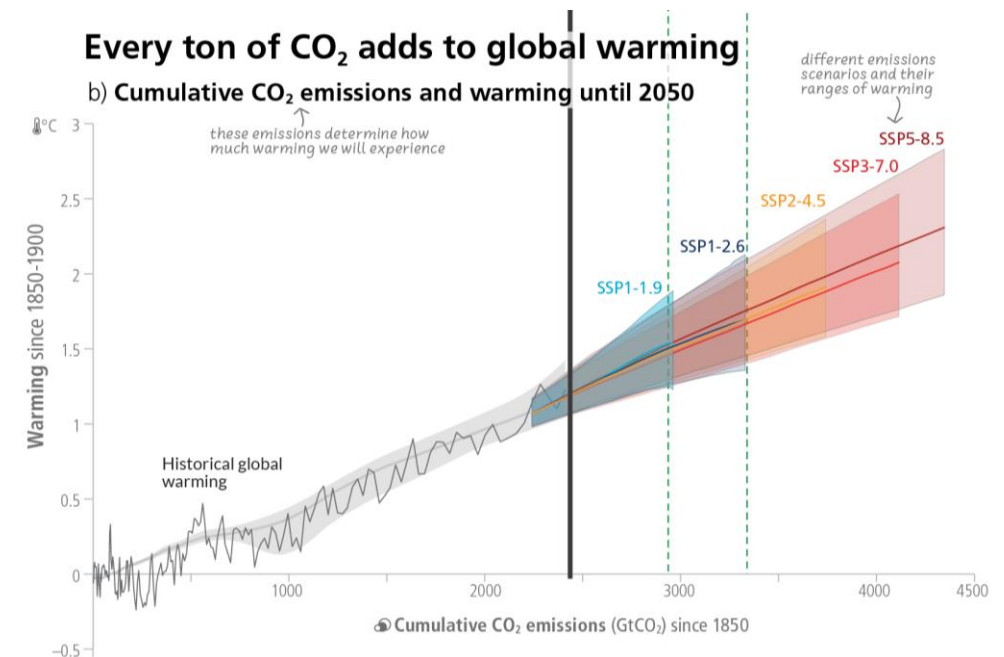


Figure: IPCC Sixth Assessment Report, Synthesis Report Figure 3.5.

Quantifying climate change impacts from project-level GHG emissions

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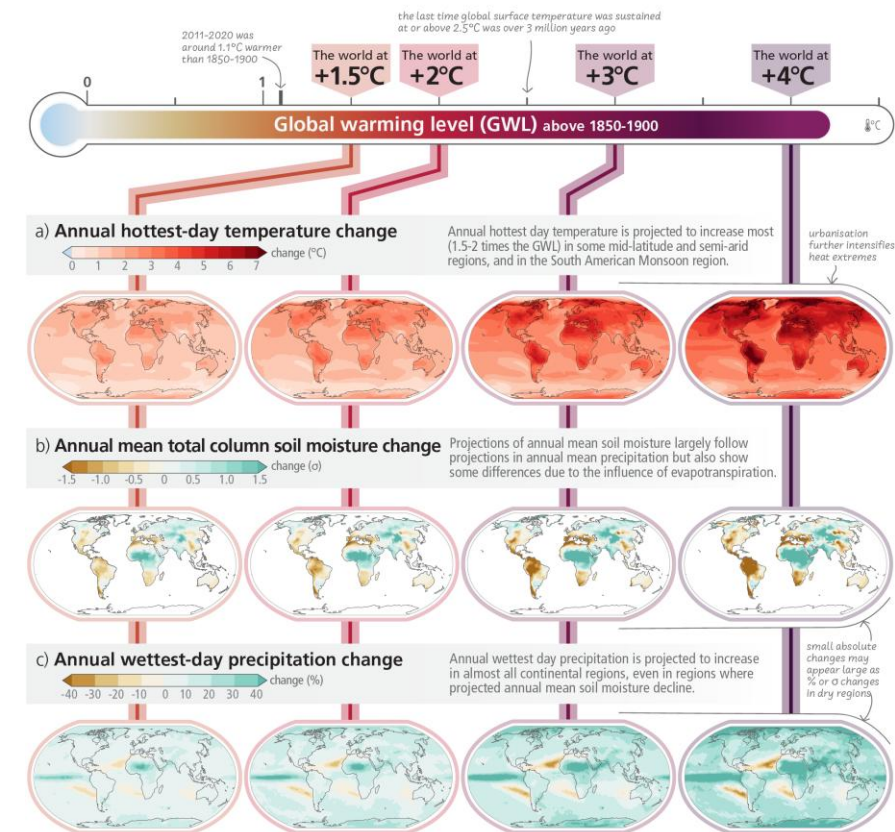
1. All CO₂ emissions cause climate change impacts.

(b) Every rise in global temperatures increases climate change impacts.

- Direct chain of causation from temperature rise to physical impacts of climate change.
- Every increment of temperature rise leads to increasingly intense extreme weather events (including heavy rainfall, heatwaves, and droughts), changes seasonal average weather conditions, and causes the retreat of mountain glaciers and sea-level rise.
- These changes result in economic, health and environmental impacts globally.

Figure: IPCC Sixth Assessment Report, Synthesis Report Figure 3.1.

With every increment of global warming, regional changes in mean climate and extremes become more widespread and pronounced



Understanding the human impacts of climate change

Human impacts of climate change materialise through various causal pathways, mediated by a range of non-climatic factors that determine exposure to hazards, and individuals' vulnerability

- **Extreme weather and climate events – extreme heat, floods, droughts, tropical cyclones, wildfires (excess morbidity, mortality, mental ill-health...)**
- **Exposure to higher ambient temperatures (morbidity and mortality, maternal, neonatal and child health impacts).**
- **Exposure to reduced air quality (including due to wildfires and aeroallergens) – allergic and other respiratory diseases.**
- **Changes in temperature, precipitation and other weather variables, affect spatial distribution, seasonality and incidence of infectious diseases, vectors, etc.**
- **Exposure to climate-driven changes in water and food safety, availability and security can affect disease outcomes.**

An introduction to attribution science

How do we know what the impacts of climate change are?

- **Climate change and extreme weather events are not entirely novel: they happened in the past and would have continued to happen, to some extent without human influence.**
- **But, climate change has made many weather events more intense or more frequent than they would have been had greenhouse gases not been emitted to the atmosphere. It has caused the retreat of glaciers and rising sea levels.**
- **Attribution science is a field of climate science that quantifies the extent to which human influence, typically due to anthropogenic greenhouse gas and aerosol emissions, is responsible for specific changes in the Earth's climate and weather.**

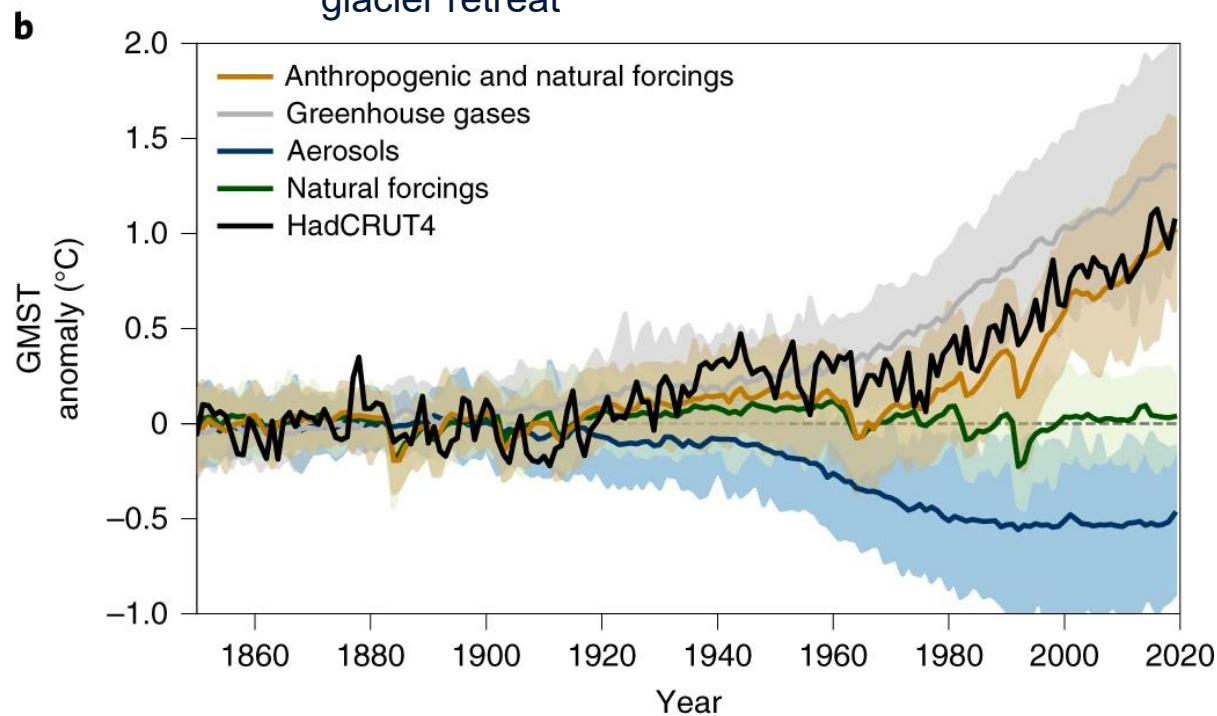
An introduction to attribution science

How do we know what the impacts of climate change are?

Key Methods

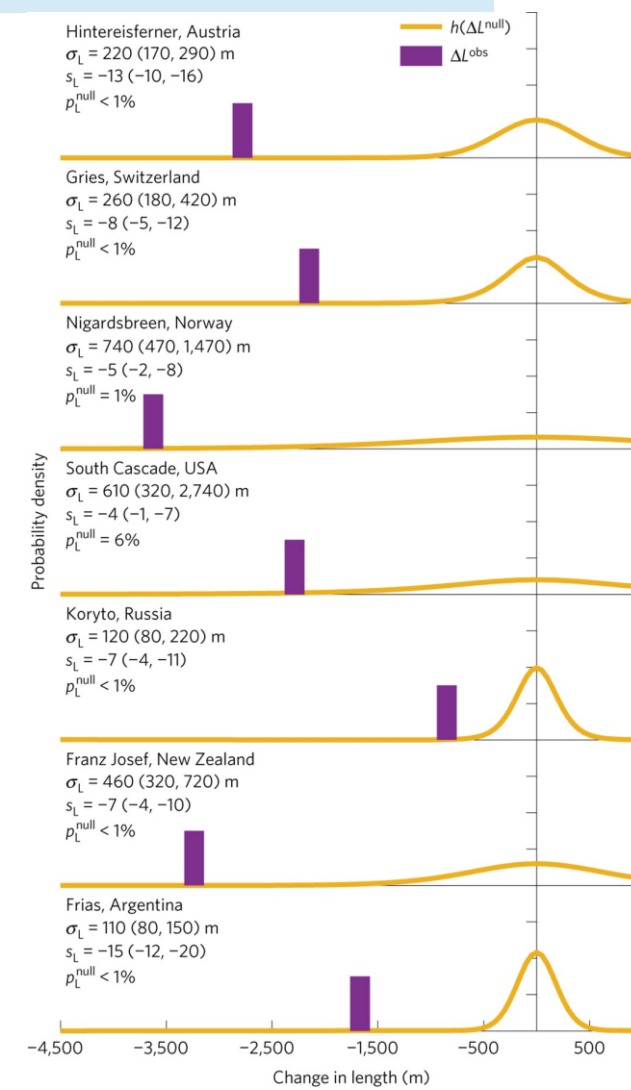
• Detection and Attribution (D&A)

- Detection: extent to which the climate or a system affected by climate has changed
- Attribution: contributions of multiple causal factors to this change
- Typical use: long-term trends – global temperature, regional averages, sea-level rise, glacier retreat



← Gillett, N.P. *et al.* Constraining human contributions to observed warming since the pre-industrial period. *Nat. Clim. Chang.* **11**, 207–212 (2021).

→ Roe, G. *et al.* Centennial glacier retreat as categorical evidence of regional climate change. *Nature Geosci* **10**, 95–99 (2017).



An introduction to attribution science

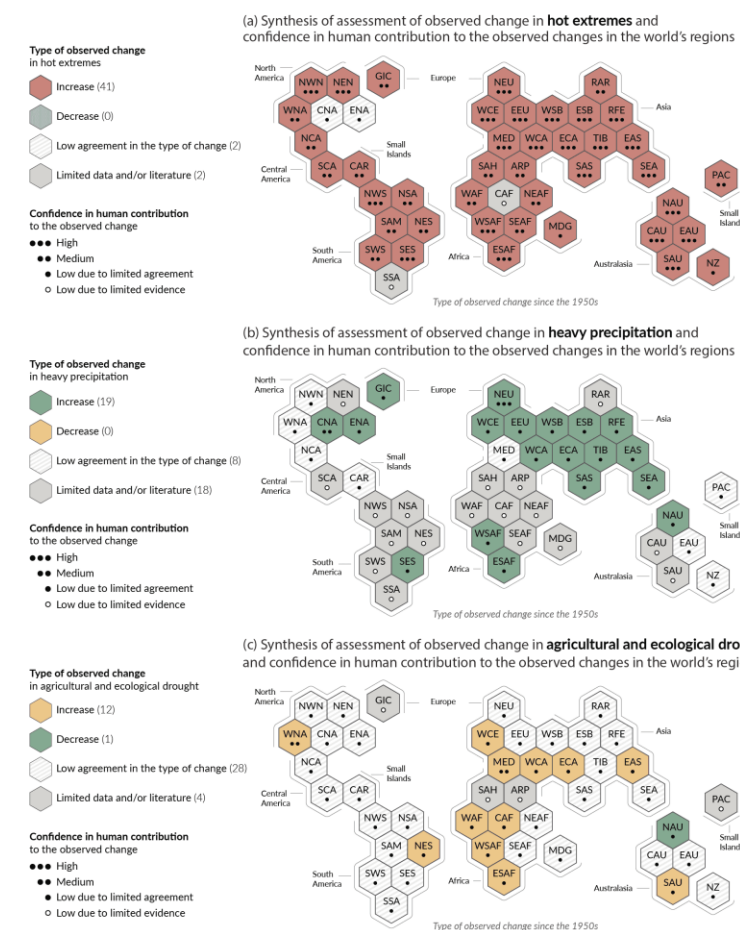
How do we know what the impacts of climate change are?

Key Methods

- **Probabilistic and storyline methods for weather attribution (e.g. of extreme events)**
 - Observations and climate models used to assess how an observed event would have been different in the absence of human-induced climate change.
 - General logic: compare the probability or intensity of the observed event in the current climate with its probability or intensity had the event occurred in a counterfactual climate without human-caused climate change. The difference between the two scenarios is the effect of climate change.

Figure: IPCC Sixth Assessment Report Working Group I, Summary for Policymakers Figure SPM.3 (2021).

Climate change is already affecting every inhabited region across the globe, with human influence contributing to many observed changes in weather and climate extremes



Climate change increasing heat-related deaths worldwide

37% of heat-related deaths attributed to climate change across 43 countries

- Vicedo-Cabrera et al. (2021) estimated heat-related deaths with and without climate change at >700 locations based on epidemiological relationships between temperature and mortality risk.
- Found that for the warm season, an average of 37% of heat-related deaths would not have happened in the absence of climate change (46% in Norway).
- A central concept in epidemiology that lies at the heart of these findings is the ‘exposure-response function’ which states that every small increase in temperature increases the risk of mortality (above the minimum mortality temperature).
 - As the number of hot days increases worldwide with climate change, so does the number of heat-related deaths.



Figure: Vicedo-Cabrera et al., *Nature Climate Change* (2021).

Quantifying climate change impacts from project-level GHG emissions



Proportionately small contributions to global CO₂ emissions cause impacts worldwide

2. Peer-reviewed studies, using a range of methods, have all concluded that the emissions of individual entities (most commonly, states or companies) have resulted in quantifiable climate change impacts.

The linear warming approach

- To date, every tonne of CO₂ emitted to the atmosphere has caused approximately the same amount of warming.
- Research shows that climate change impacts increase with every increment of global warming.
- We know how much warming is caused by every tonne of CO₂ emitted and we can estimate climate change impacts of projects' emissions.

Quantifying climate change impacts from project-level GHG emissions



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**= the 'Transient Climate Response to Cumulative CO₂ emissions',
TCRE.**

**IPCC found TCRE to be 0.45 °C per 1000 billion tonnes of CO₂
emitted ('likely range': 0.27-0.63 °C / 1000 billion tonnes)**

Quantifying climate change impacts from project-level GHG emissions



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For it *not* to be the case that project-level greenhouse gas emissions cause climate change impacts, all climate change impacts would have to increase stepwise such that excluding project-level emissions would result in *no* additional impacts.

However, most climate change impacts increase continuously with global temperatures.

Quantifying climate change impacts from project-level GHG emissions



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The linear warming approach

Case study: contribution of project-level emissions to economic losses from Hurricane Harvey

- Harvey caused \$13 billion in damages attributable to climate change (Wehner & Sampson, 2021).
- Calculate share of cumulative CO₂ emissions that projects would have made up in 2017, had these emissions been produced prior to that date
- Estimate global warming caused by those emissions
- Quantify costs attributable to emissions equal to those of individual projects

Project	Fraction of cumulative CO ₂ emissions to 2017	Portion of anthropogenic warming to 2017	Attributable Losses (\$)
Breidablikk	4.42×10^{-5}	3.49×10^{-5}	\$453,934
Tyrving	4.96×10^{-6}	3.92×10^{-6}	\$50,939
Yggdrasil	1.51×10^{-4}	1.19×10^{-4}	\$1,550,770

Quantifying climate change impacts from project-level GHG emissions



Proportionately small contributions to global CO₂ emissions cause impacts worldwide

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The linear warming approach

Case study: quantifying sea-level rise contributions of project emissions

- Use existing projections of committed sea level rise from different levels of global warming from IPCC Sixth Assessment Report (Working Group I).
- Estimated global warming caused by projects' emissions using the TCRE.
- Quantify sea level rise attributable to emissions from each project based on the proportion of global warming for which they are responsible.

Project	Emissions (MtCO ₂)	Contribution to global mean surface temperature rise (°C)	Contribution to global mean sea level rise at 2°C (cm)	Contribution to global mean sea level rise at 3°C (cm)	Contribution to global mean sea level rise at 4°C (cm)
Breidablikk	107	0.000048	0.0048-0.014	0.0063-0.016	0.014-0.019
Tyrving	12	0.0000054	0.00054-0.0016	0.00072-0.0018	0.0016-0.0027
Yggdrasil	365	0.00016	0.016-0.048	0.021-0.053	0.048-0.064

Quantifying climate change impacts from project-level GHG emissions



Proportionately small contributions to global CO₂ emissions cause impacts worldwide

2. Numerous peer-reviewed studies, using a range of methods have all concluded that the emissions of individual entities (most commonly, states or companies) have resulted in quantifiable climate change impacts.

The 'but for' approach

- Climate models have been shown to accurately reproduce observed climate change in response to observed greenhouse gas emissions. These same models can be used to simulate the climate in the absence of the emissions of individual emitters.
- 42-50% of observed rise in global temperature is attributable to just 90 major industrial emitters (Ekwurzel et al. 2017).
- Hundreds of billions of dollars of climate damages from extreme heat have been attributed to the emissions of individual fossil fuel companies (Callahan & Mankin, 2025).
 - Chevron's emissions caused \$791 billion - \$3.6 trillion in economic losses due to heat over 1991-2020.
 - Just 1% of global emissions is responsible for \$834 billion in economic losses from extreme heat (1991-2020)



The remaining carbon budget for limiting warming to 1.5 °C

How is the remaining carbon budget calculated in the IPCC assessment?

1. The amount of human-induced warming to-date.
2. The amount of warming that would result from a given amount of CO₂ emissions (the transient climate response to cumulative emissions of CO₂).
3. The additional (lagged) warming caused by past CO₂ emissions that has not yet been realised.
4. The amount of warming projected to occur due to emissions of gases other than CO₂ (e.g. methane).
5. The effect of Earth system feedbacks that are not captured by the other factors.

The remaining carbon budget for limiting warming to 1.5 °C

Remaining global carbon budget numbers for 2020 and 2024

- 2020 values are taken from the IPCC’s Sixth Assessment Report
- 2024 values are taken from Forster et al. (2024) applying the same methods as the IPCC’s Sixth Assessment, but with updates including to account for emissions produced in the interim period.
- At the start of 2023, CO₂ emissions that would be produced if existing fossil fuel reserves were exploited: 915 GtCO₂ (Oil Change International, 2023).

Likelihood of limiting global warming to within 1.5°C temperature limit	50%	67%	83%
Estimated remaining carbon budget from the beginning of 2020 (GtCO ₂)	500	400	300
Estimated remaining carbon budget from the beginning of 2024 (GtCO ₂)	200	150	100

Norway's remaining carbon budget from 2024

All projects would produce emissions that are large relative to the remaining carbon budget for Norway

- Norway's remaining carbon budget was calculated by multiplying the global remaining carbon budget by Norway's share of the global population.
- This 'per capita' approach is a highly conservative estimate of Norway's remaining carbon budget relative to internationally equitable approaches. These would reduce Norway's share, e.g. due to its responsibility for historical CO₂ emissions.
- Additionally, States' emissions inventories exclude emissions from international aviation and shipping, further reducing the remaining carbon budget to be allocated between states. This is not accounted for here, rendering Norway's carbon budget a generous estimate.

	2024		
Likelihood of limiting global warming to within 1.5°C temperature limit	50%	67%	83%
Remaining global carbon budget from the beginning of 2024 (GtCO ₂)	200	150	100
Remaining carbon budget for Norway from the beginning of 2024 (GtCO ₂)	0.136	0.102	0.068
Breidablikk % of Norway's remaining carbon budget	78.7%	104.9%	157.4%
Tyrving % of Norway's remaining carbon budget	8.82%	11.8%	17.7%
Yggdrasil % of Norway's remaining carbon budget	268%	358%	537%

Norway's remaining carbon budget from 2025

All projects would produce emissions that are large relative to the remaining carbon budget for Norway

- In 2025, updated carbon budget numbers (based on the same methods as in the 2024 assessment and the IPCC's Sixth Assessment Report) show a further reduced carbon budget.
- The emissions that would be produced through the combustion of products of the Breidablikk and Yggdrasil projects would exceed Norway's remaining carbon budget, even for only a 50% likelihood of remaining within 1.5°C of pre-industrial temperatures.

	2025		
Likelihood of limiting global warming to within 1.5°C temperature limit	50%	67%	83%
Remaining global carbon budget from the beginning of 2024 (GtCO ₂)	130	80	30
Remaining carbon budget for Norway from the beginning of 2024 (GtCO ₂)	0.0884	0.0544	0.0204
Breidablikk % of Norway's remaining carbon budget	121%	197%	525%
Tyrving % of Norway's remaining carbon budget	13.6%	22.1%	58.8%
Yggdrasil % of Norway's remaining carbon budget	413%	671%	1790%

Summary

All project-level emissions cause climate change impacts and new fossil fuel infrastructure is inconsistent with the small size of the remaining carbon budget.

- **It is possible to quantify the climate change impacts of project-level emissions:**
 - All CO₂ emissions result in rising global temperatures and every increase in global temperatures results in climate change impacts that entail economic losses, negative impacts on health, and damage to the natural world.
 - Studies have quantified impacts resulting from the CO₂ emissions of individual companies and countries, there is no technical reason why the same analyses could not be applied to project-level emissions.
 - There are multiple methods that can be used to quantify project-level emissions, each of which show a substantial impact from even proportionately small contributions to global emissions.
- **The small size of the remaining 1.5°C carbon budget and large amount of existing fossil fuel infrastructure means that:**
 - The three projects would result in the production of emissions that are in it of themselves large relative to the remaining 1.5°C carbon budget for Norway.
 - Existing fossil fuel infrastructure globally would already produce enough fossil fuels that, when burned, would produce far more emissions than are consistent with the remaining 1.5°C carbon budget.



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Annex

Supplementary Slides

The remaining carbon budget for limiting warming to 1.5 °C

130 GtCO₂ from Jan 2025 onwards: 3¼ years at the current rate of emissions

- 1.36°C of human-caused warming to date (Jan 2025), temperatures rose by 0.2 °C in the last decade.
- To limit warming to 1.5 °C (>50% probability) cumulative emissions must be limited to ~130 GtCO₂ from Jan 2025 onwards (= the ‘carbon budget’).
 - Data from Forster et al., 2025, using same methods as in the IPCC’s Sixth Assessment Report (2022).
 - Current emissions = 41 GtCO₂ per year.

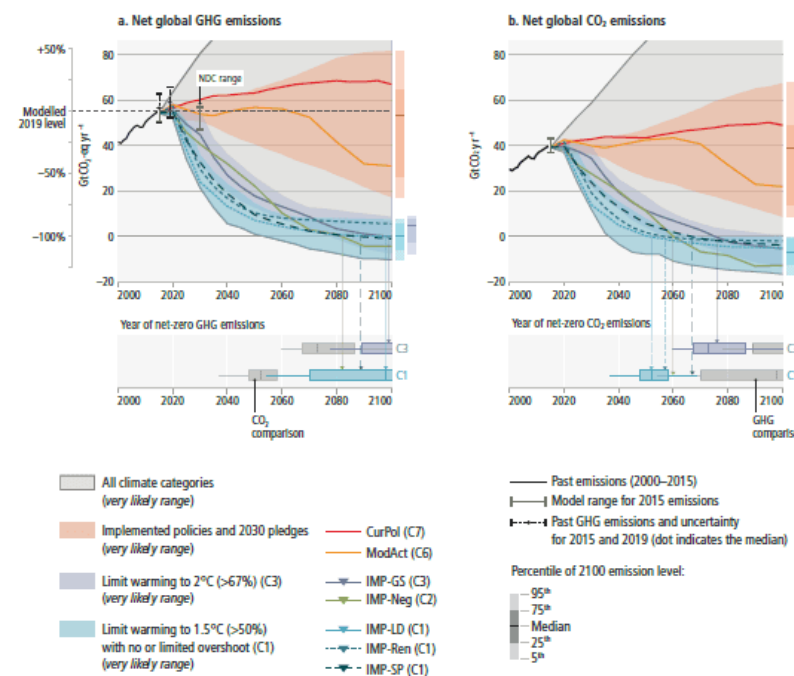


Figure: IPCC Sixth Assessment Report Working Group III, Summary for Policymakers Figure SPM.5.



Difference between remaining carbon budget assessments

The precise size of the remaining carbon budget depends on choices; does not affect assessment of projects' consistency with Norway's share of the remaining carbon budget.

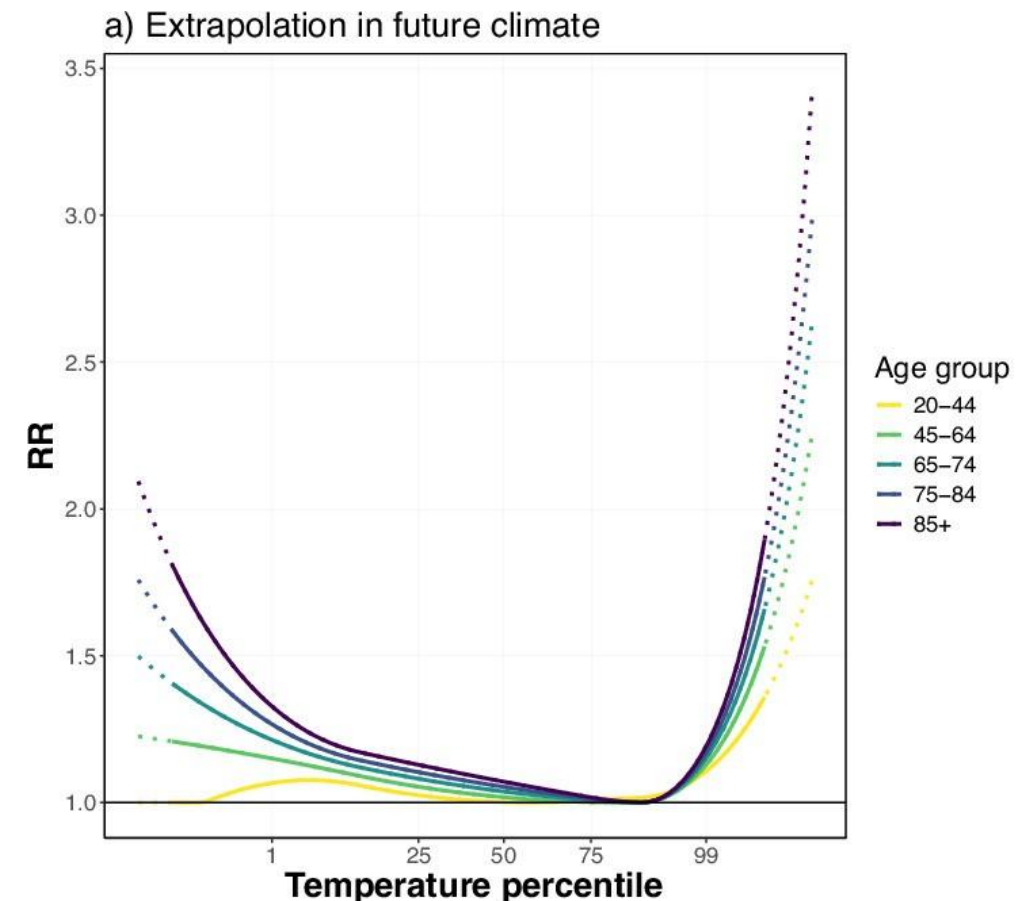
- Especially since the size of the remaining carbon budget is small, changes in assumptions can affect the assessed remaining carbon budget
- The remaining carbon budget is affected by the size of non-CO₂ emissions, but how much non-CO₂ emissions will be produced in coming years depends on mitigation choices.
- Assessments are also affected by uncertainty in the amount of warming that will occur after net zero emissions are reached, and how long it will take to realise this further change in temperature.
- Studies that have taken different assumptions when accounting for these factors (e.g. Lamboll et al., 2023) tend to reduce the remaining carbon budget further. In each case, the remaining carbon budget is very small.

Do reductions in cold-related mortality outweigh increases in heat mortality?

Under a range of mitigation scenarios, the increase in heat-related mortality is projected to far exceed reductions in cold-related mortality.

- Recent studies have found that the net effect of climate change is an increase in temperature-related mortality.
- Absent rapid emission reductions, the net temperature-related deaths due to climate change will increase by 50% this century.
- With less ambitious mitigation, increases in heat mortality still exceed reductions in cold mortality.
- Cold-related deaths do disproportionately contribute to how attributable mortality is calculated, *but* the steeper slope of the relative risk curve at hot temperatures means that heat-related mortality is generally far more sensitive to climate change than is cold-related mortality.
- This is seen clearly in epidemiological studies and is the result of the different mechanisms for cold and heat-related mortality.

Figure: Exposure-response curve for Europe from Masselot et al. (2025) *Nature Medicine*.

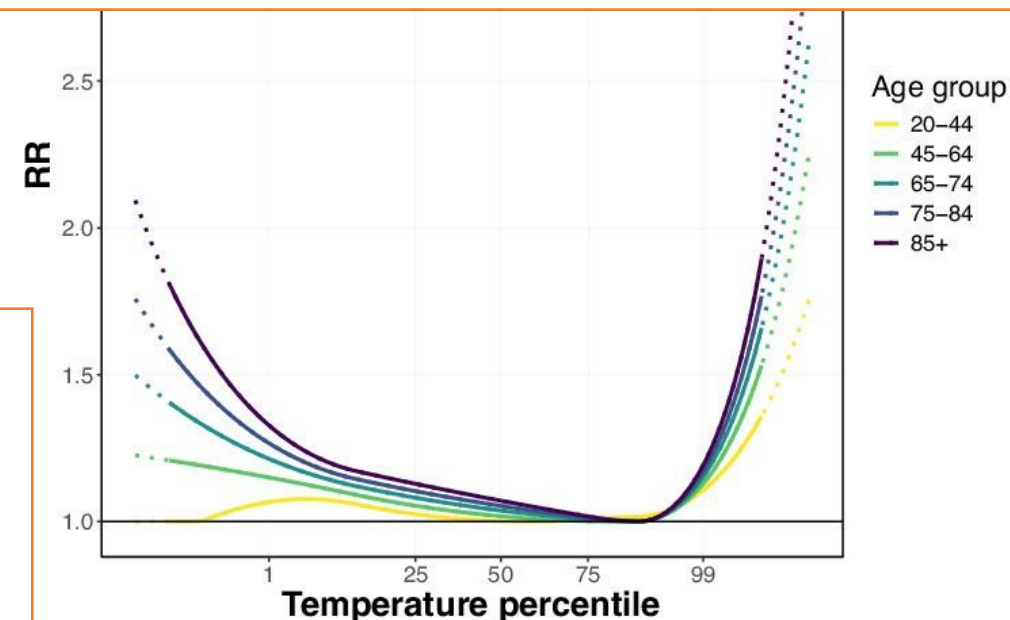


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“given the shape of the exposure–response relationship and the steeper risk on the right-hand side, such shifts can be expected to be associated with a much higher increase in heat-related deaths than for cold”
 - Alahmad et al. (2025) *The Lancet Planetary Health*



The consequence of this, according to Alahmad et al. (2025), is: “given the current climate trends and limited success in climate mitigation, the current epidemiological literature strongly suggests that an urgent focus on heat-related deaths is well justified.”