Independent Expert Report
End-to-End Attribution of the ‘Browse to North West Shelf’ Project and Impacts on Coral Loss in the Great Barrier Reef

Compiled in accordance with the Federal Court of Australia Expert Evidence Practice Note (GPN-EXPT) and Expert Witness Code of Conduct

Prepared by:
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Date: 12 February 2026

1. INTRODUCTION AND INSTRUCTIONS

[1] I have been instructed to provide an independent expert opinion in relation to end-to-end attribution science in the context of the Browse to North West Shelf Development (Browse Project), namely the attribution of project-level greenhouse gas (GHG) emissions to thermal stress and coral loss in the Great Barrier Reef (GBR).

[2] The specific questions I have been asked to address are set out in Sections 6 – 10 and concern:

- The quantification of additional global warming attributable to the Browse Project;
- Whether, and to what extent, that additional warming will have or is likely to have impacts on coral loss in the GBR; and
- Specifications concerning the underlying methodology of the respective analysis.

[3] I understand that my duty is to the Court and not to any party, in accordance with the Federal Court of Australia's Expert Evidence Practice Note and the Expert Witness Code of Conduct.

[4] I confirm that I have complied with, and will continue to comply with, that duty.

[5] I confirm that the opinions expressed in this report are wholly or substantially based on my specialised knowledge derived from my training, study and experience.

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2. GENERAL SCOPE OF REPORT

[6] This report addresses:

- The translation of cumulative CO_2 emissions from the Browse Project into additional global mean surface temperature (GMST) change;
- The attribution of that additional global warming to changes in thermal stress in the Great Barrier Reef Marine Park (GBRMP);
- The relationship between thermal stress and coral loss on the GBR;
- The assumptions, data, models, uncertainty ranges, and confidence levels used; and
- The relationship between the methods applied and prior attribution science.

[7] This report does not assess legal causation, liability, or policy considerations.

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3. QUALIFICATIONS, EXPERTISE AND APPOINTMENTS

3.1 Academic Qualifications

[8] I am a Professor of Climate Science in the Fenner School of Environment and Society at the Australian National University (ANU) with expertise in climate change, extreme heat, detection and attribution, extreme event attribution, impact attribution, climate observations and physical climate models.

[9] I hold the following qualifications:

- Bachelor of Science from Macquarie University (2005)
- Postgraduate Certificate in Research Preparation from Macquarie University (2005)
- PhD in Climate Science from UNSW (2010)

3.2 Professional Experience and Appointments

[10] My professional experience includes:

- 2024-present, Professor in climate science, Fenner School of Environment & Society, The Australian National University
- 2021-2024, Senior Lecturer/Associate Professor & Australian Research Council Future Fellow, School of Science, UNSW Canberra
- 2018– 2021, Senior Lecturer & Australian Research Council Future Fellow, Climate Change Research Centre, UNSW Sydney
- 2014-2017, Australian Research Council Discovery Early Career Researcher Award Fellow, Climate Change Research Centre, UNSW Sydney
- 2011-14, ARC Centre of Excellence for Climate System Science, Post-doctoral Researcher, UNSW Sydney
- 2009-11 CSIRO, Postdoctoral researcher (Pacific Climate Change Science Program)

[11] I currently hold the following appointment:

Professor of Climate Science, Fenner School of Environment and Society, Australian National University.

President, Australian Meteorological and Oceanographic Organisation

Deputy Director and lead of Engagement & Impact Portfolio, ARC Centre of Excellence for the Weather of the 21st Century

Co-ordinating Lead Author, Working Group I, Intergovernmental Panel of Climate Change 7th Assessment Report

3.3 Relevant Publications

[12] My relevant peer-reviewed publications include:

1. Perkins-Kirkpatrick, S., Gregory, C., Vanos, J., Baldwin, J., Staudmeyer, H., Guzman-Echavarria, G. and Jay, O., 2025. non-survivable heat stress conditions are already occurring. Nature Communications, accepted.

2. Undorf, S., Dimitrova, A., Harrington, L.J., Hegerl, G.C., Jézéquel, A., Kimutai, J., Lo, E., Mengel, M., Perkins-Kirkpatrick, S., Pietroiusti, R. and Pinto, I., 2026. Approaches and challenges in attributing climate change impacts. Nature Reviews Earth & Environment, accepted.

3. Wehner, M., Perkins-Kirkpatrick, S., Simpson, I. and Singh, D., 2025. Detection and attribution of the human influence on extreme weather and climate events. Environmental Research: Climate, 4(4), p.040203.

4. Mora, C.J., Malik, A., Alexander, L.V., Stuart-Smith, R.F., King, A.D., Perkins-Kirkpatrick, S. and Schinko, T., 2025. Attributing global impacts of local extremes to climate change for improving loss and damage estimates. Environmental Research Letters, 20(3), p.e031009.

5. **Abram, N.J., Maher, N., Perkins-Kirkpatrick, S., Falster, G.M., Hughes, T.P., Meissner, K.J., Slater, L.J., King, A.D., Pitman, A.J., Moon, G. and Morgan, W., 2025. Quantifying the regional to global climate impacts of individual fossil fuel projects to inform decision-making. npj Climate Action, 4(1), p.92.**

6. Perkins-Kirkpatrick, S., Palmer, L., King, A. and Ziehn, T., 2025. Heatwaves in a net zero World. Environmental Research: Climate, 4(4), p.045015.

7. Grose, M., Hope, P., Risbey, J., Mora, C.J., Perkins-Kirkpatrick, S., King, A., Harrington, L.J., Rosier, S., Matear, R., Black, M. and Stone, D., 2024. Processes and principles for producing credible climate change attribution messages: lessons from Australia and New Zealand. Environmental Research: Climate, 3(3), p.035009.

8. Perkins-Kirkpatrick, S.E., Selvey, L., Aglas-Leitner, P., Lansbury, N., Hundessa, S., Stone, D., Ebi, K.L. and Osborne, N.J., 2025. Attributing heatwave-related mortality to climate change: a case study of the 2009 Victorian heatwave in Australia. Environmental Research: Climate, 4(1), p.015004.

9. Perkins-Kirkpatrick, S. E., Alexander, L. V., King, A. D., Kew, S. F., Philip, S. Y., Barnes, C., ... & Zscheischler, J. (2024). Frontiers in attributing climate extremes and associated impacts. Frontiers in Climate, 6, 1455023.

10. Perkins-Kirkpatrick, S., Barriopedro, D., Jha, R., Wang, L., Mondal, A., Libonati, R., & Kornhuber, K. (2024). Extreme terrestrial heat in 2023. Nature Reviews Earth & Environment, 5(4), 244-246.

11. Perkins-Kirkpatrick, S. E., Stone, D. A., Mitchell, D. M., Rosier, S., King, A. D., Lo, Y. T. E., ... & Wehner, M. (2022). On the attribution of the impacts of extreme weather events to anthropogenic climate change. Environmental Research Letters, 17(2), 024009.

12. Perkins-Kirkpatrick, S. E., & Lewis, S. C. (2020). Increasing trends in regional heatwaves. Nature communications, 11(1), 3357.

13. Lewis, S.C., Perkins-Kirkpatrick, S.E., Althor, G., King, A.D. and Kemp, L., 2019. Assessing contributions of major emitters' Paris-era decisions to future temperature extremes. Geophysical Research Letters, 46(7), pp.3936-3943.

14. Harrington, L.J., Lewis, S., Perkins-Kirkpatrick, S.E., King, A.D. and Otto, F.E., 2019. Embracing the complexity of extreme weather events when quantifying their likelihood of recurrence in a warming world. Environmental Research Letters, 14(2), p.024018.

15. Lewis, S.C., Blake, S.A., Trewin, B., Black, M.T., Dowdy, A.J., Perkins-Kirkpatrick, S.E., King, A.D. and Sharples, J.J., 2020. Deconstructing factors contributing to the 2018 fire weather in Queensland, Australia. Bulletin of the American Meteorological Society, 101(1), pp.S115-S122.

16. Lewis, S.C., King, A.D., Perkins-Kirkpatrick, S.E. and Wehner, M.F., 2019. Toward calibrated language for effectively communicating the results of extreme event attribution studies. Earth's Future, 7(9), pp.1020-1026.

17. Perkins-Kirkpatrick, S.E. and Gibson, P.B., 2017. Changes in regional heatwave characteristics as a function of increasing global temperature. Scientific Reports, 7(1), p.12256.

18. Oliver, E.C., Benthuysen, J.A., Bindoff, N.L., Hobday, A.J., Holbrook, N.J., Mundy, C.N. and Perkins-Kirkpatrick, S.E., 2017. The unprecedented 2015/16 Tasman Sea marine heatwave. Nature communications, 8(1), p.16101.

19. Perkins, S.E. and Gibson, P.B., 2015. 31. INCREASED RISK OF THE 2014 AUSTRALIAN MAY HEATWAVE DUE TO ANTHROPOGENIC ACTIVITY. Bulletin of the American Meteorological Society, 96(12), pp.S154-S157.

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4. MATERIALS AND SOURCES OF INFORMATION

[13] In preparing this report, I have relied upon the following sources of information:

- The letter of instruction dated 22 January 2026 (Environmental Justice Australia, EJA)
- Lifetime GHG emissions estimates for the Browse Project (scope 1 and scope 3) extracted from the document titled *PROPOSED BROWSE TO NWS PROJECT - DRAFT EIS/ERD* (Woodside Energy Ltd., 2019);
- The 'Department of Climate Change, Energy, the Environment and Water' document titled *Australian National Greenhouse Accounts Factors – For individuals and organisations estimating greenhouse gas emissions* (DCCEEW, 2025);
- Peer-reviewed attribution and climate impact literature, specifically *Global warming transforms coral reef assemblages* (Hughes et al., 2018), *Reef-scale thermal stress monitoring of coral ecosystems: New 5-km global products from NOAA Coral Reef Watch* (Liu et al., 2014) and *Warming Trends and Bleaching Stress of the World's Coral Reefs 1985–2012* (Heron et al., 2016);
- The publication *Quantifying the regional to global climate impacts of individual fossil fuel projects to inform decision-making* (Abram et al., 2025a);
- The code used for analysis, which is publicly available on Zenodo in Matlab (Abram et al., 2025b) and Python (Stepin & Abram, 2025);

- The Sixth Assessment Report of the United Nations (UN) Intergovernmental Panel on Climate Change (IPCC AR6, 2021);
- The Berkeley Earth global temperature record (monthly resolution) (Rohde & Hausfather, 2020);
- The NOAA Coral Reef Watch (CRW) Degree Heating Week (DHW)* product (daily resolution) – specifically the 5km-resolved DHW dataset (Heron et al., 2016; Liu et al., 2014)

  * DHW / °C-weeks: a measure of thermal exposure. In reef environments this leads to thermal stress and bleaching of corals (Liu et al., 2014).

[14] A full bibliography is provided in Section 13

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5. OVERVIEW OF END-TO-END ATTRIBUTION SCIENCE

[15] The end-to-end attribution framework applied in this report is based on the peer-reviewed methodological approach set out in the recent publication by Abram et al. (2025a) ***"Quantifying the regional to global climate impacts of individual fossil fuel projects to inform decision-making"***. The study develops a detailed risk-assessment and attribution framework linking project-level GHG emissions to changes in GMST and various downstream global and regional consequences based on established climate-impact relationships.

[16] For the Browse Project, the framework has been adapted only where necessary to reflect project-specific characteristics. Application to the GBR follows the Abram et al. (2025a) publication without alteration to the underlying scientific assumptions or uncertainty treatment.

[17] Specifically for the quantification of GBR coral loss, the framework is applied through four linked steps as follows:

a) Estimation of cumulative project-level CO_2 emissions and translation of those emissions into additional GMST change (addressed in Part A);
b) Scaling of the additional warming to regional thermal stress in the GBRMP and application of empirically observed relationships between thermal stress and coral loss in the GBR (addressed in Part B).

The implementation of this framework, including data sources, assumptions, spatial treatment, timescale, and uncertainty, is described in Part C.

PART A – GLOBAL WARMING ATTRIBUTABLE TO THE BROWSE PROJECT

[18] The IPCC AR6 (2021, Summary for Policymakers D.1.1) states that global warming increases in direct proportion to cumulative CO_2 emissions, as described by the Transient

Climate Response to CO_2 Emissions (TCRE) with a best estimate of 0.45°C per 1,000 $GtCO_2$ and a 66–100% likelihood that warming lies between 0.27°C and 0.63°C. This well-established, approximately linear relationship underpins estimates of remaining carbon budgets and climate targets such as limiting warming to 1.5°C or well below 2°C. No assessed minimum CO_2 threshold exists below which the TCRE relationship fails (Canadell et al., 2021).

6. Question 1: Additional Global Warming Attributable to the Project

[19] Following the framework laid out in Section 5, paragraph [17 a], cumulative scope 1 and scope 3 CO_2-equivalent (CO_2-e) emissions were extracted from the *Proposed Browse to NWS Project, Draft Environmental Impact Statement* (Woodside Energy Ltd., 2019) (Table 7-5 (Scope 1) and Table 7-9 (Scope 3)), adopting the extended field life scenario (44 years), which reports **total project emissions of 1,602 Mt CO_2-e**.

[20] Conversion from CO_2-e to CO_2-only mass was undertaken using category-specific assumptions regarding gas composition, ensuring compatibility with the TCRE framework ([18]). For combustion-related sources (including installation activities using heavy-duty diesel), CO_2 fractions were derived from emissions factors reported in Table 7-3 (Woodside Energy Ltd., 2019) and the *Australian Government National Greenhouse Accounts Factors* (DCCEEW, 2025), while reservoir emissions were treated as CO_2-only in accordance with the project methodology. Applying these gas-specific conversion assumptions yields a **total of 1,597.41 Mt CO_2** over the extended field life, indicating that CO_2 accounts for virtually all reported project GHG emissions.

Emissions source (Scopes 1 & 3)	*CO_2-equivalent emissions [Mt]*	*CO_2 fraction [%]*	*CO_2 [Mt]*
Installation	1.0	99.3	0.99
Fuel combustion	53.0	99.7	52.84
Flaring	3.0	95.4	2.86
Upstream reservoir	93	100	93
Processing	98	99.7	97.71
Downstream reservoir	24	100	24
Third-party consumption	1,330	99.7	1326.01
Total	**1,602**		**1,597.41**

[21] To **quantify the additional global warming attributable to these emissions**, this report applies the TCRE best estimate of 0.45°C per 1000 Gt CO_2 (IPCC AR6, 2021), which yields an estimate of additional global mean surface warming attributable to the CO_2-only emissions from the Browse Project of:

- **Best estimate: 0.00072°C**;
- Likely range: 0.0005 – 0.0010°C, reflecting combined uncertainty in climate sensitivity and carbon-cycle response.

[22] These values represent the incremental contribution of the Browse Project's emissions to global warming and were calculated using the following equation from Abram et al. (2025a, p.3):

$$Additional\ warming\ (°C) = Emissions\ (Mt\ CO_2) \times \frac{0.45\ (°C)}{1{,}000{,}000\ (Mt\ CO_2)}$$

PART B – CORAL LOSS ON THE GREAT BARRIER REEF

7. Question 2: Impact of Additional Global Warming on GBR Coral Loss

[23] Building on the results from Part A, this assessment further applies the framework described in Section 5, paragraph [17 b] to quantify impacts on coral loss in the GBR. This is done by linking the additional global warming attributable to the Browse Project to changes in thermal stress in the GBRMP, measured using degree heating weeks (DHW*), and ultimately to observed empirical relationships between DHW and coral mortality on the GBR.

*DHW (°C-weeks) is a metric of cumulative thermal exposure, combining the intensity and duration of marine heatwaves (positive sea temperature anomalies relative to the local bleaching threshold), and is strongly associated with the severity of coral bleaching** and mortality (Liu et al., 2014).

**Bleaching is a heat-stress response in which corals expel their symbiotic algae and become physiologically weakened; if thermal stress is severe or prolonged, bleaching can lead to high coral mortality (Hughes et al., 2018).

[24] Applying this analytical approach, the additional warming attributable to the Browse Project is estimated to produce:

- **An incremental increase in accumulated thermal exposure in the GBRMP of 0.003165 °C-weeks** (likely range 5–95%: 0.0012–0.0067 °C-weeks) during marine heatwave events; and
- A corresponding incremental **coral cover loss of 0.0111%** (likely range 0.0034–0.0252%) during each future mass bleaching event*, equivalent to the **loss of approximately 29.35 million individual coral colonies** (likely range 9.04–66.78 million colonies), across the 1.06 million hectares of shallow (0-20 m) coral habitat in the GBRMP.**

  *A mass bleaching event occurs when elevated sea temperatures cause most corals in a region to lose their symbiotic algae, leading to widespread paling and elevated mortality risk (Henley et al., 2024).

  **The mortality relationship is derived from observed bleaching events, which quantify how elevated heat stress (DHW) increases event-specific coral mortality (Hughes et al., 2018). The Browse Project's additional warming (ΔGMST) represents an incremental and persistent increase in GMST that would intensify DHW during future mass bleaching events. The resulting estimate therefore represents the additional coral mortality attributable to the Project per event, rather than total mortality or a cumulative one-off loss.

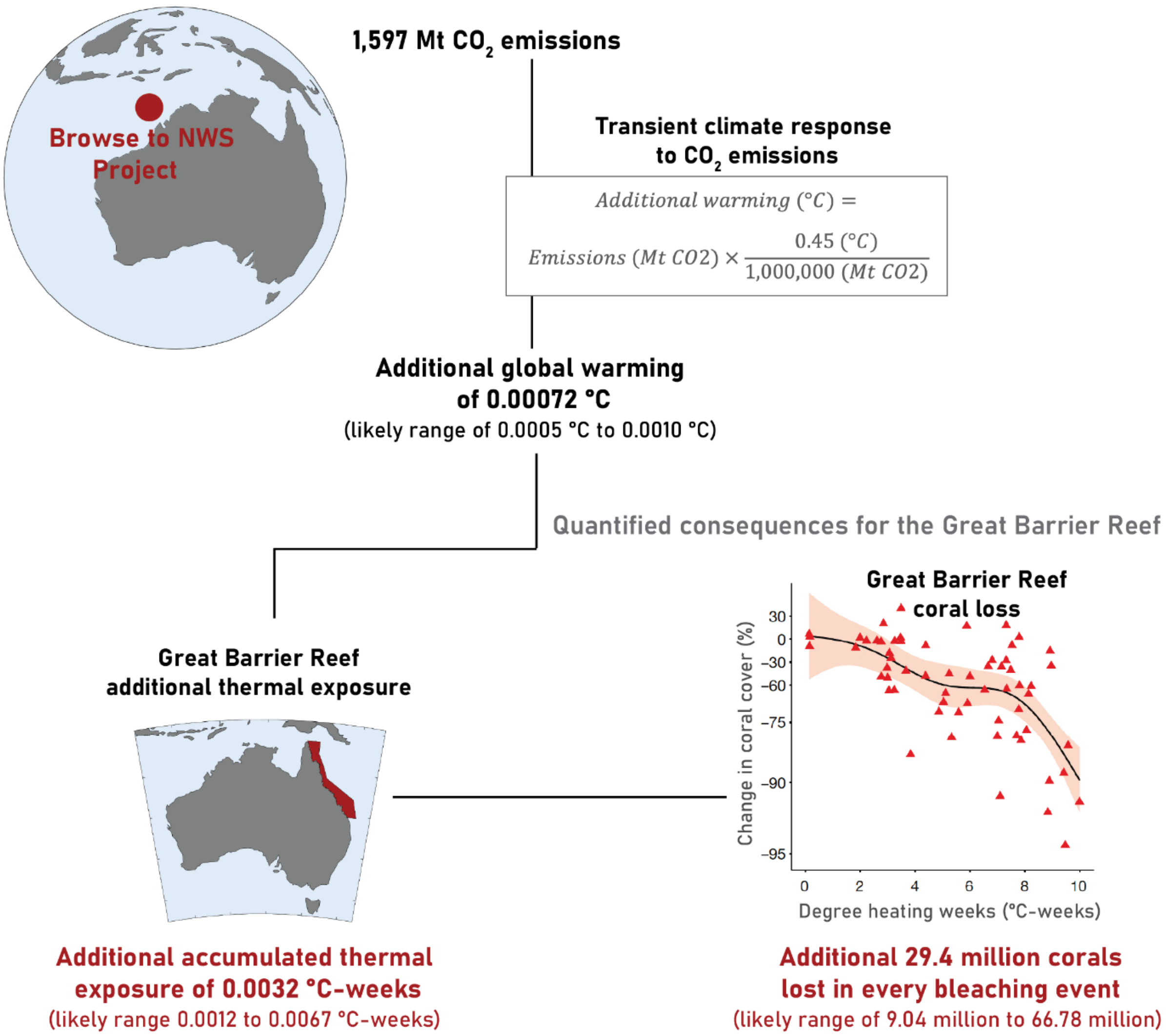
[25] These estimates are probabilistic, reflecting uncertainty in:

- Spatial variability of DHW responses across the GBRMP; and
- The empirical relationship between DHW and coral cover loss.

The total area of coral reef habitat is treated as a fixed, conservative estimate (1.06 million hectares of shallow reef), and coral density is similarly fixed (0.25 million colonies per hectare). Neither reef area nor coral density is included as a source of probabilistic uncertainty in the analysis. Consequently, total coral losses may be underestimated if additional reef habitats are affected or if coral density varies spatially across different reef regions.

[26] The quantified impacts assume that:

- The relationship between DHW and coral mortality remains consistent in the future; and
- Other stressors such as ocean acidification, extreme weather events, and ecological shifts are not included in this calculation. Consequently, the **estimates represent the incremental impact of the Browse Project's emissions alone** on coral loss during marine heatwave events.



PART C – MODEL, DATA, AND ASSUMPTIONS

8. Question 3: Methodology and Assumptions

8.1 Overview of Model Implementation

[27] This section addresses Question 3 by explaining how the attribution framework described in Section 5 was implemented to quantify the impacts of additional global warming on coral loss in the GBR. It describes the model structure, data sources, and key assumptions used to translate GMST change into regional thermal stress and coral mortality.

[28] The subsections below respond directly to the subquestions in Question 3 by setting out:
(a) how impacts on the GBR are treated spatially;
(b) how additional atmospheric warming is related to ocean thermal stress;
(c) the appropriateness of the model for the project's operational lifetime; and
(d) the treatment of uncertainty, confidence levels, and likelihood statements.

8.2 Question 3(a): Spatial Treatment of Impacts on the Great Barrier Reef

[29] Thermal stress impacts on the GBR are quantified using DHW averaged across the entire GBRMP.

[30] The relationship between GMST and DHW is derived from:

a) Monthly GMST anomalies* from Berkeley Earth global temperature record (Rohde & Hausfather, 2020); and

b) Daily, 5-km resolution DHW data covering 12,222 individual grid cells across the GBRMP from NOAA Coral Reef Watch over 39 years (1986-2024) (Heron et al., 2016; Liu et al., 2014).

*GMST anomaly refers to the deviation of annual global mean temperature from the long-term austral summer average; the Browse Project's additional warming (ΔGMST) represents a projected temperature anomaly due to its estimated CO_2 emissions.

[31] For each grid cell, a linear model was fit relating summer-centred annual maximum DHW values to summer-centred annual GMST anomalies (summer-centred = July-June). The resulting cell-level slopes capture spatial heterogeneity across the reef and follow a lognormal distribution, which is used to characterise spatial uncertainty in the DHW–GMST relationship within the attribution analysis. The primary attribution analysis fits a linear regression between annual maximum GBR-wide DHW and summer-centred annual GMST anomalies and uses the resulting reef-wide slope (°C-weeks per °C) to estimate changes in DHW from small increments of additional warming. This linear approximation is appropriate for the tiny magnitudes of warming attributable to the Browse Project. For larger magnitudes of additional warming, the GMST–DHW relationship is expected to become non-linear, consistent with the observed heterogeneity in cell-level responses. All downstream calculations of DHW change, coral cover loss, and coral colony mortality are based on this single reef-wide relationship.

[32] Spatial heterogeneity in the DHW–GMST relationship is propagated probabilistically through Monte Carlo sampling (Cox et al., 2003, provides background on Monte Carlo uncertainty propagation). The lognormal distribution of cell-level DHW–GMST slopes described in [31] is sampled 100,000 times to produce 5–95% confidence bounds for projected DHW increases. This approach ensures that the reef-wide mean projection is used for impact calculations while fully accounting for uncertainty arising from variation in cell-level relationships.

8.3 Question 3(b): Translation from Atmospheric Warming to Ocean Thermal Stress

[33] The model does not simulate ocean temperatures using a physical ocean model. Instead, it estimates ocean thermal stress empirically by relating GMST anomalies to accumulated thermal stress in reef waters, expressed as DHW.

[34] This relationship is quantified using linear regression, in which annual, summer-centred GMST anomalies [30 a] are regressed against summer-centred annual maximum DHW values across the GBRMP [30 b], based on historical observations. Summer-centring (July-June) avoids splitting the GBR coral bleaching season across annual boundaries.

The resulting relationship takes the form: *DHW = intercept + slope × GMST.*

[35] Daily DHW values across the GBRMP are first averaged to produce a daily reef-wide mean. For each of the data set's 39 summer-centred years, the annual maximum is calculated from these daily means. This approach provides a representative measure of reef-wide thermal exposure during the bleaching season, aligns with empirical coral mortality relationships (Hughes et al., 2018), and avoids bias from isolated thermal hotspots. Linear regression of these summer-centred annual maxima against corresponding summer-centred annual GMST anomalies yields an aggregate scaling relationship of 4.4 °C-weeks per 1 °C warming, which is used to estimate changes in thermal stress for small increments of additional warming such as that attributable to the Browse Project.

[36] A linear approximation is appropriate for the small additional warming attributable to an individual project. Based on 39 years of historical data, the GMST–DHW relationship is approximately linear over such marginal increases.

[37] Empirical observations from mass bleaching events on the Great Barrier Reef indicate that each additional 1 °C-week of accumulated thermal stress is associated with an average loss of approximately 2–5% of coral cover. This relationship provides the empirical basis for translating projected increases in DHW into estimates of coral cover loss and coral colony mortality.

8.4 Question 3(c): Appropriateness for a 40-Year Project Lifetime

[38] The Browse Project is expected to operate over a period of approximately 40 years (expected field life: 31 years, extended field life: 44 years) (Woodside Energy Ltd., 2019).

[39] The attribution framework is appropriate for this timescale because:

- CO_2 is a long-lived greenhouse gas, with atmospheric residence times extending over decades to centuries;
- Global warming depends primarily on cumulative CO_2 emissions rather than the precise timing of emissions, such that emissions in earlier years contribute alongside later emissions;
- The climate system responds over decadal to centennial timescales, as heat is absorbed and redistributed by the oceans and the atmosphere; and
- Coral bleaching impacts depend on incremental increases in background warming, which intensify the frequency and severity of marine heatwave events over time.

[40] The quantified coral losses represent the incremental mortality attributable to the Browse Project's emissions during each future mass bleaching event, added to the background warming trajectory represented by the Berkeley Earth GMST data, rather than as a one-off impact.

8.5 Question 3(d): Confidence Levels and Likelihood Statements

[41] Uncertainty in the attribution of Browse Project emissions to coral loss on the Great Barrier Reef is quantified at each stage of the attribution chain:

- Climate sensitivity (TCRE);
- DHW-GMST relationship (including spatial heterogeneity across the reef); and
- Empirical relationship between thermal stress and coral mortality.

Reef area and coral density are treated as fixed parameters and do not contribute to uncertainty in the reported ranges.

[42] Probabilistic uncertainty is propagated through the attribution chain using 100,000 Monte Carlo draws, capturing both parameter uncertainty and spatial variability across GBRMP grid cells (characterised by a lognormal distribution as described in Section 8.2). Potential non-linearity at higher levels of warming is acknowledged as a limitation of the linear approximation, consistent with observed spatial variability in cell-level responses.

[43] Likelihood statements are expressed using calibrated probabilistic language consistent with established climate science practice:

- Best estimates correspond to the mean of each parameter distribution; and
- Likely ranges represent the central 90% of the distribution, approximated as the 5–95% confidence interval of the Monte Carlo distribution.

[44] The framework propagates the uncertainties listed in [41] throughout the attribution chain, distinguishing between physical climate uncertainties (TCRE and the DHW-GMST relationship) and empirical uncertainties (DHW-coral mortality), while holding other environmental and ecological factors constant. The reported range therefore reflects climate-driven coral loss specifically.

[45] Using this framework, the projected additional coral loss from the Browse Project during future mass bleaching events can be reported as probabilistic estimates without relying on single deterministic values, enabling transparent communication of the range of possible outcomes.

PART D — OVERALL IMPACTS ON THE GREAT BARRIER REEF

9. Question 4: Impacts of the Browse Project

[46] Based on the attribution framework analysis above, the Browse Project will have the following impacts on the GBR (respective quantification is provided in Section 6):

- A quantifiable, though very small, increase in GMST (0.00072°C*);
- A corresponding incremental increase in thermal stress (DHW) across the GBRMP during marine heatwaves (0.0032 °C-weeks*); and
- Additional coral mortality during each future mass bleaching event (29.4 million individual coral colonies*).

  *best estimate

[47] These probabilistic projections form the basis for assessing the Browse Project's impacts on the GBR. While the absolute contribution to global warming is small, the Monte Carlo analysis demonstrates that even marginal additional warming translates into quantifiable increases in DHW across the GBRMP and, in turn, additional coral mortality.

[48] The analysis conservatively excludes compounding and interacting effects, including:

- Reduced recovery time between successive bleaching events (Hughes et al., 2017);
- Ocean acidification; and
- Other climate-driven stressors affecting reef ecosystems.

PART E — NOVELTY OF THE ABRAM et. al (2025) ARTICLE

10. Question 5: Relationship to Existing Attribution Science

[49] The methods applied in Abram et al. (2025a) draw on established attribution science but extend it in a significant and novel direction.

[50] Earlier attribution studies have generally been retrospective in nature and have typically either:

- Attributed observed climate change or impacts to historic aggregate emissions at global, national, or sectoral scales; or
- Focused on attributing observed extreme events to anthropogenic climate change, without tracing responsibility back to discrete sources such as individual projects.

[51] By contrast, the analysis in Abram et al. (2025a) is prospective and decision-focused. The novelty does not lie in new physical climate science, but in the integration of established emissions–warming–impact relationships into a project-level framework designed to inform decision-making. It is distinct in that it:

- Enables attribution of additional warming expected to result from the emissions of individual fossil fuel projects, rather than to aggregated emitters;
- Establishes a transparent and scientifically grounded causal chain linking project-level emissions to global temperature change and onward to projected ecological and human impacts at global and regional scales; and
- Quantifies those impacts in probabilistic and policy-relevant terms that are directly applicable to project approval and risk assessment processes.

[52] In my opinion, this constitutes a material extension of prior attribution science. Rather than restating existing methods, the article repurposes and integrates them into a new framework designed explicitly to inform real-world decision-making at the point of project approval.

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11. Statement of Independence and Duty to the Court

[53] I confirm that:

- I have made all inquiries that I consider necessary and appropriate;
- No matters of significance have been withheld; and
- The opinions expressed are honestly held and based on my specialised knowledge.

[54] I reacknowledge that my paramount duty is to the Court, not to any party.

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12. Limitations and Assumptions

[55] The assessment treats the total area of coral reef habitat as a fixed estimate of 1.06 million hectares, which may underestimate total reef extent, particularly at greater depths. Estimates of coral colony loss further rely on a fixed average density of 250,000 coral colonies per hectare, consistent with published field counts of colonies above minimum size thresholds. Coral abundance is poorly constrained at reef-wide scales because it is typically measured as percent cover rather than colony counts, and because juvenile corals are too small to be feasibly counted. The adopted density excludes many billions of juvenile corals and therefore represents a conservative assumption.

[56] This assessment assumes that the empirical relationships between thermal stress (DHW) and coral loss observed historically will remain broadly applicable in the future.

[57] This assessment is limited to quantifying incremental coral loss and does not evaluate impacts on other climate-sensitive species in the GBRMP or the potential secondary consequences for species and ecosystems that depend on corals. Coral mortality rates may also increase if reef composition shifts toward more heat-susceptible species.

[58] Consequently, the quantified impacts reported should be regarded as conservative estimates of the Browse Project's incremental contribution to coral loss on the GBR.

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13. References

Abram, N. J., Maher, N., Perkins-Kirkpatrick, S., Falster, G. M., Hughes, T. P., Meissner, K. J., Slater, L. J., King, A. D., Pitman, A. J., Moon, G., & Morgan, W. (2025a). *Quantifying the regional to global climate impacts of individual fossil fuel projects to inform decision-making*. npj Climate Action, *4*(1), Article 92. https://doi.org/10.1038/s44168-025-00296-5

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