BEFORE THE FAST TRACK PANEL
AT WELLINGTON

I MUA I TE KŌTI TAIAO O AOTEAROA
TE WHANGANUI-A-TARA ROHE

UNDER	the Fast Track Approvals Act 2024 (the "**Act**")
IN THE MATTER	of an application by Trans-Tasman Resources Ltd for marine and discharge consents to undertake iron sand extraction in the South Taranaki Bight The 'Taranaki VTM Project' [**FTAA-2504-1048**]
BETWEEN	**TRANS-TASMAN RESOURCES LIMITED (TTRL)** *Applicant*
AND	**THE ENVIRONMENTAL PROTECTION AUTHORITY** *The EPA*

JOINT STATEMENT OF EVIDENCE OF PROFESSOR CHRISTOPHER FLEMING AND ANDREW BUCKWELL (Economics)

FILED ON BEHALF OF KIWIS AGAINST SEABED MINING, GREENPEACE AOTEAROA INCPORATED

Dated 6 October 2025

[redacted]
Barrister
Globelaw
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[redacted]
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INTRODUCTION

1. We are Professor Christopher Fleming, Dean of Research and Professor of Economics at Griffith Business School, Griffith University, Queensland, Australia and Andrew Buckwell, Research Fellow and Griffith Business School, Griffith University, Queensland, Australia.

2. We have been asked to prepare the **attached** report **APPENDIX A** which is the peer review of the *Economic impact assessment of TTRL's Taranaki VTM Iron Sands Project (*the "**NZIER report"**.)

3. In preparing this statement and report we have reviewed:

    a. Various application documents, including the TTR Siecap pre-feasibility study report.
    b. Binney, J. (2017). Statement of Evidence by James Binney on Behalf of Kiwis Against Seabed Mining Incorporated.
    c. We have had direct discussions with Jim Binney on his evidence.
    d. The Sanofex Report, attached to the evidence of Whanganui District Council;
    e. Statement of evidence of Jill Cooper, 06 October 2025;
    f. Draft statement of evience of Ganesh Nana, Oct 2025.

4. In this statement of evidence, we have included:
    a. a summary of the key findings of our peer review:
    b. made comments on the conclusions in the above statements of evidence, identifying where we agree and where we disagree.
    c. Made comment on other matters that have arisen since the date of our peer review report.

CODE OF CONDUCT

5. We confirm that we have read the Code of Conduct for Expert Witnesses as contained in the Environment Court Practice Note dated 1 January 2023. We agree to comply with

this Code. This evidence is within our areas of expertise, except where we state that we are relying upon the specified evidence of another person. We have not omitted to consider material facts known to us that might alter or detract from the opinions that we express.

SUMMARY OF KEY FINDINGS

Modelling approach:

6. The economic assessment method used in the NZIER Report measures the gross economic benefit of the proposal but does not assess the net benefit.

7. The current economic impact assessment of TTRL's Taranaki VTM Iron Sands Project to TTRL provides insufficient evidence on which to base a decision to proceed and, therefore, does not support approval of TTRL's submission.

8. The economic assessment method used does not provide (and is not capable of providing) any information pertaining to costs of the project going ahead, only quantum of the economic activity generated (good, bad, or indifferent).

9. The assessment lacks potentially critical information on the non-market (environmental and social) costs associated with the project, nor does it adequately consider opportunity costs associated with interference with the wind energy and fishing sectors, and a diminishment of the 100% Pure New Zealand brand.

10. To ensure all environmental, economic, and social costs (including opportunity costs) are considered in any economic assessment, we recommend that a detailed social benefit cost analysis be undertaken. There is now a wealth of readily available evidence to support such an analysis. Such an analysis would ensure the benefits and costs of the project are fully reflected in a transparent way.

11. In the absence of a detailed social benefit cost analysis, it is not possible to determine whether the project provides a net benefit to the people of New Zealand-Aotearoa at the local, regional or national level.

TTRL'S economic assessment

12. The NZIER report claims that 67% of TTRL's annual operating expenditure will be in New Zealand. Of this, one third is reported to be expenditure on Intermediate Fuel Oil. New Zealand has no fuel refining capacity, 100% of the refined product will, therefore, be imported, suggesting that closer to one third of the annual operating expenditures will be from within New Zealand.

13. It is claimed that 303 employees will be directly employed. The average unemployment rate for the Taranaki Region is lower than the national average and has been predominantly lower for 20 years. Notwithstanding domestic migration, this suggests there will be considerable employment substitution out of other industries. This is not accounted for in the NZIER report.

Missing costs

14. The modelling approach taken by NZIER inevitably deems all economic activity generated by the project to be of benefit and does not consider the overall welfare impacts of a new activity, which inevitably must consider the costs, particularly the social and environmental costs.

15. A social benefit cost analysis considers these costs (and benefits) from a 'whole of society' perspective using the Total Economic Value (TEV) framework. This is the appropriate approach for assessing the societal welfare impacts of a proposal such as this.

16. Estimating the TEV value of ecosystem services and the gamut of values that may be lost or diminished is the domain of the discipline of environmental economics. The discipline has developed a range of valuation methods to suit different value sets and a significant and robust corpus of data.

17. This is recognised by the New Zealand Government, who have produced a Guide to Social Cost Benefit Analysis that is accompanied by the CBAx Tool, which incorporates a database of values to monetise impacts in a range of employment, health, social, economic and environmental domains.

18. There remains uncertainty on the social and environmental costs associated with the project. This reflects a lack of local studies undertaken by the proponent to fully understand the true (net) economic benefits of the project. We are very confident, however, that the social and environmental costs are not zero and maybe substantial.

Opportunity costs

19. A major opportunity cost of seabed mining is the value that may be generated by alternative industries, particularly the wind energy sector, fisheries and tourism that cannot operate, or be maximised, in parallel with seabed mining.

20. PWC report that the wind energy sector claims offshore wind cannot be built within an operational seabed mining project, nor perhaps in an area where seabed mining has been.

21. A further opportunity cost that should be considered is the loss of brand value associated with 100% Pure New Zealand, which positions the country with messages indicating clean and green, sustainability, environmental awareness and an association with the strength of New Zealand's indigenous Māori culture and their spiritual connection with the land.

COMMENTS ON OTHER STATEMENTS OF EVIDENCE

22. We have reviewed the statement of evidence of Ganesh Nana and make the following remarks:
    a. We agree that multiplier model analysis presented in the NZIER report is substantially appropriate for its purpose.
    b. However, we also agree that economic effects presented by the multiplier model analysis should be viewed with caution, given the considerable limitations of such models.
    c. We would like to place emphasis on Nana's statement (para 17) that the '…model is inherently restricted to a *produce and spend* perspective on economic activity. That is, producing and spending result in economic effects that are inferred as positive benefits.' As Nana notes, this inference is misleading. Economic activity cannot be

equated with economic benefit, let alone equated with having a causal link to improved societal welfare.

d. We also strongly agree with Nana's statement (para 21) that '…economic effects should properly go beyond the produce and spend foundation. At the very least, the use and non-use value of resources should be addressed – ideally within a Total Economic Value (TEV) framing.' This is the crux of our argument. The type of model employed by NZIER is incapable of properly reflecting the potential benefits or costs to society of the proposed mining activity. Yet, that is precisely the information upon which a decision should be made.

e. We note Nana's comment (para 63) about the limitations of using a social benefit-cost analysis due to the requirement for all values to be monetised. We do not believe that this limitation is insurmountable (and there are ever-improving techniques and a growing corpus of economic studies that demonstrate this) and maintain that undertaking such an analysis is the only appropriate means of determining whether the proposal is likely to increase societal welfare.

23. We have reviewed the statement of evidence of Jill Cooper and make the following remarks:

    a. We agree with Cooper's assessment (para 9) that there is currently a glut in iron reserves and that current suppliers show no signs of reserve depletion.

    b. We also note Cooper's comments (para 19-22) on the feasibility of employing desalination plants to remove the salt from the extracted iron sand. We would add that desalination plants have large environmental impacts in terms of energy use, brine discharge and the use of chemicals for cleaning. These impacts are not adequately considered in the proposal nor included in the NZIER report.

COMMENTS ON OTHER MATTERS

24. We have reviewed the SANOFEX report and make the following remarks:

a. The report critiques a number of assumptions on the prices the proponent's commodity outputs. This critique presents further challenges to demonstrating the merit of the project from both an input-output model and a social benefit cost perspective. In the first instances it suggests that GDP estimates in the proponent's model are over-estimated. In the second instance, in any project *net* benefits would be over-estimated.
b. Whilst business investment decisions are always made in an environment of uncertainty (e.g., risk and reward are opposite sides of the same coin) and investors will likely be aware of fluctuations in the commodity prices and will make their own decisions on solidness of their conclusions, in resource sectors, such as sea-bed mining, social costs will be incurred. If these costs are incurred and the business fails, society is left with the costs and no apparent benefit. Therefore, such critique of business decisions is in the interests of society.

25. We have reviewed the Manuka Resources Limited's Annual Report for the year ended June 2025 and would like to bring attention to the following:
    a. The report (para 3.2) reveals that the group incurred a loss of $16,876,465 and had net cash outflows from operating activities of $5,203,385 for the year ended 30 June 2025. Further, as of 30 June 2025, the company's net current liabilities were $47,880,425. This raises concerns about the ongoing viability of the company. If the company was to become insolvent while operating in New Zealand, payments to creditors may be in jeopardy. This could include, but is not limited to, staff, suppliers and the Crown and any rehabilitation works that maybe required to rectify social costs already incurred on a failed project.
    b. An alternative scenario is that the company's financial position, and the consequences of insolvency, is used as a bargaining chip to avoid paying royalties.
    c. Concerns about the financial position of Manuka Resources Limited were also noted in the SANOFEX report discussed above.

26. We have reviewed a recent (September 2025) research report presenting the results of a comprehensive benefit cost analysis of deep-sea mining and make the following remarks:
    a. The report's lead author is Dr. Ussif Rashid Sumaila, Professor and Canada Research Chair in Interdisciplinary Ocean and Fisheries Economics at the Institute for the Oceans and Fisheries, and the School of Public Policy and Global Affairs, University of British Columbia. Dr Sumaila is a pre-eminent scholar, the world's most highly cited scholar in fisheries economics and ocean policy.
    b. We note the report has not yet been accepted for publication in a peer reviewed journal and is in 'pre-print' format. Whilst this in no way infers any error by the authors, full peer review and acceptance will further improve its status.
    c. The authors take an approach (social benefit cost analysis) to understand the potential for economic *benefits* from sea-bed mining, rather than the economic *impacts* of associated economic activity (which will always be positive). This is the economic assessment approach supported by Binney, SANOFEX, Nana, and by Fleming and Buckwell.
    d. According to the authors, the report's findings highlight the economic flimsiness of deep-sea mining, reinforcing ecological and social concerns.
    e. Further, the authors conclude that there is a possibility of generating a meagre direct financial gain from deep-sea mining, which can easily be reduced to zero by plausible changes in prices of extracted material, operational costs or a combination thereof.
    f. In our view, this study, and others like it, increase the need to ensure a transparent and robust full economic, environmental and social evaluation of TTRL's proposed project.

Dated 6 October 2025

APPENDIX A

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1 THE AUTHORS

1. Our names and associations are as follows:

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2. Professor Fleming is Dean (Research) at the Griffith Business School and formerly the Director of the Griffith Institute for Tourism (2020-2021) and Director of Griffith University's MBA program (2015-2020). Prof. Fleming teaches, consults, undertakes research, and provides public policy advice on a range of economic issues, including the economic determinants of well-being, climate change economics, tourism economics, and the sustainable management of natural resources. Prof. Fleming holds a Bachelor of Arts (Economics) from the University of Otago, a Master of Applied Economics with first-class honours from Massey University, and a Ph.D. (Economics) from the University of Queensland. Prof. Fleming was previously employed as a Senior Consultant for MainStream Economics and Policy, and Marsden Jacob Associates, and was a Senior Advisor within the Sustainable Development Policy Group of the New Zealand Ministry for the Environment.

3. Andrew Buckwell is a Research Fellow at Griffith Business School and Griffith University's Climate Action Beacon. Mr. Buckwell is an applied environmental and resource economist and social scientist with significant experience in consulting, field research, and policy and economic analysis, specialising in non-market economic valuation, resource economics, and social benefit cost analysis. Mr. Buckwell's broader research agenda is to define the conditions and the measures that enable communities and resource users to understand the impacts and dependencies of their resource use to encourage capital to flow naturally towards socially equitable and ecologically regenerative investments and endeavours.

4. Professor Christopher Fleming and Andrew Buckwell (the authors) have been commissioned by Kiwis Against Seabed Mining (KASM), Greenpeace Aotearoa Inc., and Concerned Communities of Taranaki and Manawatu Against Seabed Mining to provide independent analysis of the economic impacts of a proposed seabed iron ore mining operation by Trans-Tasman Resources Limited (TTRL) – the Taranaki VTM Iron Sands Project (the 'project').

5. We confirm we have read the Code of Conduct for Expert Witnesses as contained in the Environment Court Practice Note dated 1 December 2014. We agree to comply with this Code.

This evidence is within our area of expertise, accepting that we also draw on evidence of another person. We have not omitted evidence deliberately that would knowingly challenge facts known to us, which might alter or detract from the opinions that we express.

2 SUMMARY OF FINDINGS

6. The current submission *Economic impact assessment of TTRL's Taranaki VTM Iron Sands Project* to TTRL provides insufficient evidence on which to base a decision to proceed and, therefore, does not support approval of TTRL's submission.

7. The economic assessment method used does not provide (and is not capable of providing) any information pertaining to costs of the project going ahead, only quantum of the economic activity generated (good, bad, or indifferent).

8. The assessment lacks potentially critical information on the non-market (environmental and social) costs associated with the project, nor does it adequately consider opportunity costs associated with interference with the wind energy and fishing sectors, and a diminishment of the *100% Pure New Zealand* brand.

9. To ensure all environmental, economic, and social costs (including opportunity costs) are considered in any economic assessment, we recommend that a detailed social benefit cost analysis be undertaken. There is now a wealth of readily available evidence to support such an analysis. Such an analysis would ensure the benefits and costs of the project are fully reflected in a transparent way.

10. In the absence of a detailed social benefit cost analysis, it is not possible to determine whether the project provides a net benefit to the people of New Zealand-Aotearoa at the local, regional or national level.

3 LIMITATIONS OF MODELLING APPROACH

11. The economic assessment approach used by NZIER is an input-output analysis used to estimate the economic impact of the project, were it to proceed. It estimates economic and employment outcomes at a local (South Taranaki/Whanganui), regional (Taranaki Region/Whanganui), and national (New Zealand) level. The analysis estimates output and GDP measures of economic activity (see Box 1 for an explanation of the difference between the two).

12. In assessing the economic impact of TTRL's proposed project, NZIER employ input-output modelling (I-O modelling), utilising inputs from TTRL along with NZIER's input-output multipliers model. As clearly articulated in responses to the 2017 application, I-O modelling is not considered an appropriate method for determining the net economic impact of an activity to a community, whether that be measured at a local, regional or national scale. For example, in his submission, Jim Binney states "…a comprehensive benefit-costs analysis (BCA) is the only appropriate economic assessment methodology to inform the regulatory approvals process. This

should include all relevant environmental and social values that could be adversely impacted by the project"[1] We wholeheartedly agree with that assessment.

13. The use of Benefit Cost Analysis (BCA)[2] for decision making is also supported by the New Zealand-Aotearoa Treasury, who in their 2015 *Guide to Social Cost Benefit Analysis*, note "A rough CBA is better than no CBA".[3]

14. The key shortcomings of relying on I-O modelling for decision-making is the lack of any assessment of costs (or disbenefits) associated with the project. That is, I-O modelling focuses on economic activity generated by an investment (deployment of credit, or funds) but does not evaluate benefits, nor measure costs, including environmental and social costs. In so doing, I-O modelling is incapable of measuring the *net* benefit or any measure of welfare of a discreet project or event at the local, regional or national level. In Section 6 of the report (Concluding comments) NZIER makes the claim that "TTRL's VTM Iron Sands Project will bring *benefits* to the New Zealand economy" (our emphasis).[4] This claim needs to be qualified, as I-O modelling by itself cannot support this conclusion. Appendix A sets out a theoretical explanation of the difference between what I-O modelling measures (total additional exchange value) and what BCA measures (net benefit (or cost) to society).

15. A further shortcoming of the I-O modelling is a lack of transparency. The assessment resembles a 'black box' where the assumptions and parameters are not made clear to any inquiry. Clark (2018, p.1) states that for "…modelling to be useful, it must provide credible evidence to inform debate. Too often, practitioners have attempted to win favour with decision-makers by skewing modelling results to match a preferred, pre-determined outcome. This misuse undermines the credibility of modelling and means that decision-makers (and the public) do not have access to a valuable tool to inform policy debate".[5]

16. Estimates generated from I-O modelling employing Keynesian closed versions of such models are commonly biased upwards, as they ignore the price and financial feedback that tend to reduce multipliers in macroeconomic models. I-O modelling should, therefore, be confined to providing estimates of the industrial or regional breakdown of the direct impact of a project, or of the employment impacts of program spending. It should not be used to generate Keynesian multipliers.[6] This is recognised in NZIER's report.[7]

[1] Binney, J. (2017). Statement of Evidence by James Binney on Behalf of Kiwis Against Seabed Mining Incorporated. para.9.
[2] Also referred to as cost-benefit analysis or CBA.
[3] New Zealand Government (2015). Guide to Social Cost Benefit Analysis, p.6. Available: https://www.treasury.govt.nz/sites/default/files/2015-07/cba-guide-jul15.pdf. The forward to the same document, written by Gabriel Makhlouf, then Secretary to the New Zealand Treasury, concludes with the statement "For myself, I will always expect to see a cost benefit analysis (CBA) when the Government is being asked to make a significant decision".
[4] NZIER (2025). Economic Impact Assessment of TTRL's Taranaki VTM Iron Sands Project: A Report for Trans-Tasman Resources Limited, p.21.
[5] Clark, M. (2018). Whole-of-Economy Modelling: Beyond the Black Box, Queensland Productivity Commission Staff Research Paper. Available: https://apo.org.au/sites/default/files/resource-files/2018-04/apo-nid140041.pdf.
[6] Grady, P., & Muller, R. A. (1988). On the use and misuse of input-output based impact analysis in evaluation. Canadian Journal of Program Evaluation, 3(2), 49-61. https://doi.org/10.3138/cjpe.3.004.
[7] See Section 2.2.

17. Specifically, limitations of assumptions underpinning I-O modelling include:

    (i) a linear relationship between different industry's inputs and outputs; firms may require different quantities or mixes of inputs and outputs to achieve the same level of output.

    (ii) no price effects due to changes in demand (e.g., of labour).

    (iii) no supply constraints (e.g., labour and capital will be available as and when required).

18. Ironically, I-O analysis does not include any estimate of consumer surplus (a benefit) that a project may generate. Consumer surplus is an economic measure of the benefit that consumers receive when they can secure a good or service at a price lower than the maximum price they are willing to pay (or accept, in relationship to considering wages from a worker's perspective). It represents the difference between what consumers are willing to pay (their marginal benefit) and what they pay (the market/wage price).

Box 1: Difference between measures of GDP and output

Measures of output and measures of GDP presented in the input-output model are related, but distinct concepts. The key differences are as follows.

Output Measure (Total Output):

This represents the total value of all transactions in the economy, from the project going ahead, including intermediate and final goods and services. It captures the gross sales of all industries, meaning it includes not only final goods and services, but also intermediate inputs used in production.

Total output, as the sum of all sectoral outputs in an input-output model can be much larger than GDP because of double counting (as intermediate goods are included).

GDP Measure (Gross Domestic Product):

GDP measures capture only the final value of goods and services produced in the economy, excluding intermediate goods to avoid double counting. It focuses on the value-added at each stage of production.

GDP = Total Output – Intermediate inputs.

In I-O analysis, GDP is typically measured using the sum of value-added (compensation of employees, gross operating surplus, and taxes minus subsidies).

19. BCA is a more appropriate economic assessment tool to estimate and compare the net benefits of a project. To be comparable, benefits and costs are homogenised into economic (monetary) values. BCA also considers the timing of benefits and costs and converts these into today's prices so that they can be meaningfully compared, regardless of the time at which they occur. In this way, a BCA can enable a comparison of options that deliver different streams of benefits and costs over time. It does this through the concept of 'discounting' – the application of an annual rate by which future values are discounted back to present day values. The BCA measure of welfare (or the net social benefit) associated with a proposal is the extent to which a community is better off.

20. A *social* BCA can consider the costs and benefits from a 'whole of society' perspective. Specifically, a social BCA is the most appropriate economic analysis tool for assessing the net benefits of a project. Social BCA can account for both market and non-market costs and benefits. Thus, it can account for environmental and social impacts, so long as the economic values can be homogenised into monetary values.

21. To pursue this objective, a diverse, robust, and now systematic corpus of data has been assembled by environmental economists.[8] Economic valuation methods can assess the range of values that are inherent to the Total Economic Value (TEV) framework (Figure 1). Note that economic valuation methods have been developed to assess so-called 'non-market values' – the benefit obtained, often from nature and ecosystem services, that are not traded through markets and thus do not fetch a price.

22. Therefore, social BCA can consider flows of social and environmental costs and benefits beyond the direct financial costs and economic benefits of a project. Social and environmental benefits and costs can include changes to environmental quality, quantity and amenity, changes to recreational values and impacts on ecosystem services — the direct use, indirect use and non-use benefits human society receives free from their experiences and relationships with nature.

23. Whose costs and benefits count in a BCA is the issue of standing[9]. To reflect Pareto efficiency—where at least one person benefits and nobody is made worse-off—the Kaldor-Hicks principle of compensating losers from the net gains needs to be maintained[10,11]. Standing should be defined by whom would be willing to pay (WTP) or be willing to accept (WTA) compensation for the loss of a benefit. A social BCA analysis should note that one party's WTP/WTA should not be constrained by a lack of institutions that enable this (such as functioning markets and property rights) or a lack of information (moral hazard).

24. On issues of standing, there are few comprehensive reviews of guidelines for different jurisdictions. However, a recent review of BCA by Boardman et al. (2022)[12] (a leading voice in cost benefit analysis) suggests that many guidelines recommend at least reporting on the global consequences of a project or policy change. For example, HM Treasury, in the United Kingdom, recommends a *global* estimate of costs when assessing greenhouse gas emissions.[13] Supranational agencies (World Bank, Asian Development Bank, for example) also suggest a global perspective should be provided but that GHG emissions should also be considered separately as their impacts are crucially dependent upon the valuation of carbon used.[14] Boardman et al. (2022) conclude that though the national (or sub-national, where resources belong to states / provinces) should be the default, **where international treaties cover a topic (as for GHG emissions) a global view of standing should be taken**. In this instance, any

[8] See for example the System of Environmental Economic Accounting Ecosystem Accounting (SEEA EA) framework and the Common International Classification of Ecosystem Services (CICES). Available: https://seea.un.org/ecosystem-accounting AND https://cices.eu/content/uploads/sites/8/2012/09/CICES-V4_Final_26092012.pdf.

[9] Boardman, A. E., Greenberg, D. H., Vining, A. R., & Weimer, D. L. (2022). Standing in Cost-Benefit Analysis: Where, Who, What (Counts)? Journal of Policy Analysis and Management, 41(4), 1157-1176. https://doi.org/10.1002/pam.22397.

[10] Boardman, A. E., Greenberg, D. H., Vining, A. R. & Weimer, D. L. (2017). Cost-Benefit Analysis: Concepts and Practice. Cambridge University Press, UK.

[11] Cayford, J. (2023). The Costly Betrayal of Cost-Benefit's Promise. Washington DC: United States Government. Available: https://www.regulations.gov/comment/OMB-2022-0014-0023.

[12] Boardman, A. E., Greenberg, D. H., Vining, A. R., & Weimer, D. L. (2022). Standing in Cost-Benefit Analysis: Where, Who, What (Counts)? Journal of Policy Analysis and Management, 41(4), 1157-1176. https://doi.org/10.1002/pam.22397.

[13] As reported in Boardman et al. (2022) p.1161.

[14] Crucially, this is because many of the World Bank's low- and middle-income client Governments disagree that this should influence their investment decisions.

consideration of carbon emissions from the project should consider the costs of Scopes 1 and 2 emissions from a global perspective, using the value of the social cost carbon.[15]

25. In addition, in not applying a social BCA, conceptual incorporation of the 'precautionary principle' is missing. For example, Sunstein concludes that "cost-benefit can and should incorporate concerns about precaution. For example, a problem characterised by irreversibilities […] can be modelled using standard techniques in cost-benefit analysis. Uncertainties about both benefits and costs can also be incorporated".[16]

26. It is fair to say that BCA is values-based – that is, the components that comprise the costs and benefits are open to the judgement of the analyst, as is the discount rate applied. However, undertaken properly, and with integrity, social BCA, more fully accounts for direct project benefits and costs when compared to a business-as-usual scenario.

27. In conclusion, our view is that social BCA is a superior method to I-O modelling. This is shared by Binney[17] and Joseph et al. (2017)[18] among many others.

4 ASSESSMENT OF CLAIMS IN TTRL'S ECONOMIC ASSESSMENT

28. Section 2.3.2 of the report (Direct expenditure) claims that 67% of TTRL's annual operating expenditure will be in New Zealand (totalling NZ$ 220.7m). Of this, one third is reported to be expenditure on Intermediate Fuel Oil (IFO) sourced through "its supplier located in New Plymouth".[19] New Zealand now has zero fuel refining capacity, therefore 100% of the refined product will be imported. This suggests that nearer two thirds of TTRL's annual operating expenditure will not be from within New Zealand and/or have very minimal supply chain impact from within New Zealand.

29. Section 2.3.1 of the report (Direct employment) claims that 303 employees will be directly employed in the operations, support, monitoring, and administration of the project. Section 2.2 accepts key limitations of I-O modelling is its inability to model supply constraints – assuming that there is no "displacement that may occur when output in one industry increases and requires additional resources" and "resources (including labour and capital) are available in unlimited quantities and extra output can be produced in one industry without taking resources away from other industries".[20] This runs contrary to the commonly espoused economic concept of the 'production possibilities frontier' – theoretical threshold of all the combinations of two goods an economy can produce using its resources fully and efficiently, which highlights the trade-offs and opportunity costs of shifting production between them.[21] The average

[15] US EPA, "Supplementary Material for the Regulatory Impact Analysis for the Final Rulemaking, 'Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review.'"
[16] Sunstein, C. R. (2005). The precautionary principle as a basis for decision making. The Economists' Voice, 2(2). p.6. Available: https://www.degruyterbrill.com/document/doi/10.2202/1553-3832.1079/html.
[17] Binney, J. (2017). Statement of Evidence by James Binney on Behalf of Kiwis Against Seabed Mining Incorporated.
[18] Joseph, C., Gunton, T., Knowler, D., & Broadbent, S. (2020). The role of cost-benefit analysis and economic impact analysis in environmental assessment: the case for reform. Impact Assessment and Project Appraisal, 38(6), 491-501. https://doi.org/10.1080/14615517.2020.1767954.
[19] NZIER, "Economic Impact Assessment of TTRL's Taranaki VTM Iron Sands Project: A Report for Trans-Tasman Resources Limited," 9.
[20] NZIER, 7.
[21] Lovell, CA (1993). Production Frontiers and Productive Efficiency. The Measurement of Productive Efficiency: Techniques and Applications 3, 67.

unemployment rate for Taranaki Region (3.6%) is currently lower than the national average (4.0%) and has been predominantly lower for 20 years. Notwithstanding domestic migration, this suggests there *will* be considerable employment substitution out of other industries into seabed mining. (Note: if this was assessed using BCA the likely increase in wages as a result could be assessed as a project benefit.)

5 MISSING ENVIRONMENTAL COSTS

30. As argued above, I-O modelling inevitably deems all economic activity generated by the project to be of benefit and does not consider the overall welfare impacts of a new activity, which inevitably must consider the costs, particularly the social and environmental costs. This lies behind the recommendation from Binney, and more general recommendations by the New Zealand Government, that a benefit cost analysis is an appropriate method to use to assess projects such as the proposal by TTRL to undertake sea floor mining activities.

31. Under the **Fast-track Approvals Act 2024** (Schedule 10, Clause 6), proponents are required to consider (amongst other matters):

    a. The effects of the proposed activity on the environment; [22]

    b. The importance of protecting the biological diversity and integrity of marine species, ecosystems, and processes; [23]

    c. The importance of safeguarding rare and vulnerable ecosystems and the habitats of threatened species; [24] and

    d. Whether the project is likely to result in significant regional or national benefit. [25]

    While the term 'benefit' is not explicitly defined, other provisions in the Fast-track Approvals Act reference the need to consider the environmental impacts of competing activities[26] (cost comparison and opportunity cost considerations) and the associated costs of the proposed activity as relevant factors [27] (social and environmental costs).

32. Several costs are identified in the literature. These costs are founded TEV framework. TEV is a conceptual approach used to estimate the overall value of goods, services, or resources, or in this case, the full gamut of benefits that may lost if project activities have an impact on their delivery. It provides a structured way to account for the various benefits provided by ecosystems, including those that are not captured in market prices. Undertaking social BCA through the lens of TEV enables analysts to provide the most complete picture of the net value of a project — particularly those that significantly and permanently change the seascape or a landscape.

33. TEV is comprised of:

[22] S59 EZZ Act 1991.
[23] S59 EEZ Act 1991.
[24] S59 EEZ Act 1991.
[25] S3 Fast-Track Approvals Act 2024.
[26] See s22(6) Fast-Track Approvals Act 2024.
[27] S22(2)(a) Fast-Track Approvals Act 202

a) direct use values (tangible goods and services directly enjoyed; often provisioning ecosystem services and recreation);

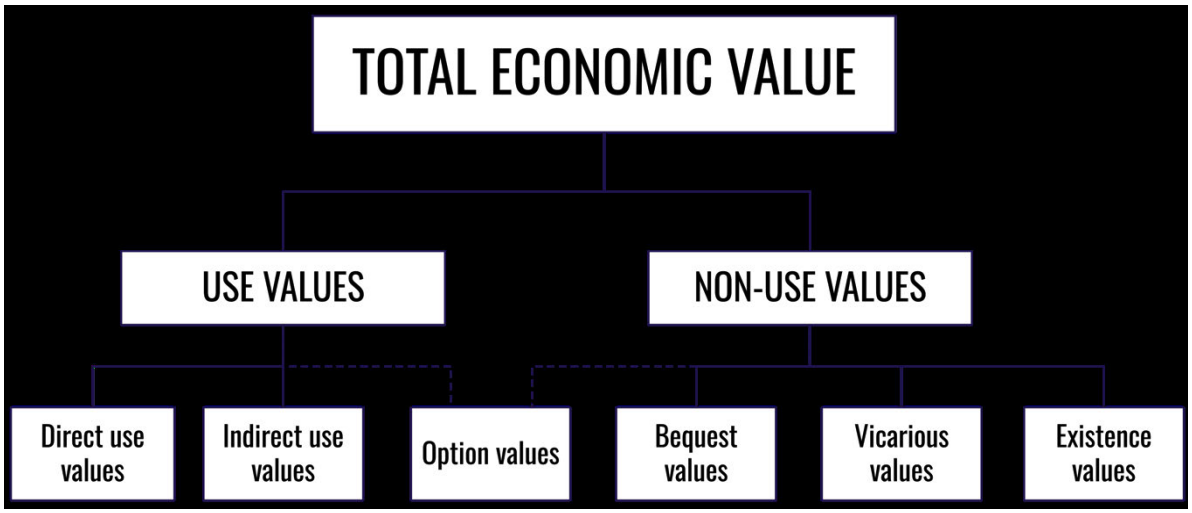
b) indirect use values (intangible benefits received indirectly from ecological functions and regulating ecosystem services, such as climate stability and soil stability);

c) non-use values (non-marketed, non-consumptive or non-extractive benefits, often experienced through a cultural, or spiritual connection with the landscape); and

d) option values (the opportunity cost of maintaining landscapes or habitats for future generations' enjoyment and benefit).

Costs associated with the TEV framework are often non-market goods and services (often ecosystem services) not bought and sold in traditional markets but may nevertheless be highly valued by society. Despite there being no market-based institutions to reveal a price, there are established ways, based in environmental economics, that enable analysts to estimate a monetary value and thus include their value in BCA.

Figure 1: The total economic value framework



34. A social BCA considers these costs (and benefits) from a 'whole of society' perspective, therefore it can additionally consider flows of social and environmental costs and benefits beyond the direct financial costs and economic benefits of a project. Social and environmental benefits and costs can include changes to environmental quality, quantity and amenity, changes to recreational values and impacts on ecosystem services — the direct use, indirect use and non-use benefits human society receives free from their experiences and relationships with nature.

35. Estimating the TEV value of ecosystem services and the gamut of values that may be lost or diminished is the domain of the discipline of environmental economics. The discipline has developed a range of valuation methods to suit different value sets and a significant and robust corpus of data.[28] *Monetary* valuation of ecosystem services allows for ready comparison with

[28] Costanza, R., De Groot, R., Braat, L., Kubiszewski, I., Fioramonti, L., Sutton, P., ... & Grasso, M. (2017). Twenty years of ecosystem services: How far have we come and how far do we still need to go? Ecosystem Services, 28, 1-16. https://doi.org/10.1016/j.ecoser.2017.09.008.

services commonly exchanged in markets, or economic valuation of natural capital can enable comparison with other forms of capital stocks. Expressing value in monetary terms, therefore, has proven useful in helping to consistently frame trade-offs between options that have to address multiple assessment criteria. Monetary valuation is a key component in social BCA.

36. Of course, data, and particularly locally relevant data that can be monetised, is a limitation in analysis, however, advances in economic valuation techniques, which can include the more esoteric non-use values, has enabled broader application of TEV, where there is a willingness of the analyst to include them. Analysts need to be cognisant of not totalising incompatible aspects of TEV and of not double counting.[29] Judicious and objective application of TEV in social BCA can surmount this challenge.

37. Whilst hundreds of primary studies of various ecological domains and ecosystems are published each year, the very bespoke and localised nature of the values being estimated mean that studies specific to the context of this project are rare. Thus, many practitioners employ 'benefit transfer' – estimating the economic value of ecosystem services at a target site by employing data from an existing study (or studies) conducted at an alternative source site or sites. Often this means using means, medians, and ranges from numerous appropriate studies. Despite some critics, it is generally accepted in the economics profession and is argued to be a "…feasible means to provide information on economic values to support decision-making when time, funding and other practical constraints impede the use of original valuation studies".[30]

38. The New Zealand Government's *Guide to Social Cost Benefit Analysis* is accompanied by the CBAx Tool, which incorporates a database of values to monetise impacts in a range of employment, health, social, economic and environmental domains. In addition to this database, there are a plethora of global reports, individual studies, meta-analyses, review papers, and ecosystem service valuation databases that analysts can draw upon.

39. Mineral extraction from the seabed, as proposed by TTRL, will remove 11 metres of the sediment, resident seafloor organisms, and ultimately the habitat in the areas of operation. Such activities will inevitably entail local destruction and/or changes in species composition. In addition to altering seabed morphology, mineral extraction results in degradation of water quality through sediment plumes that increase water turbidity and smother organisms. There is also potential release of harmful substances from the sediment and disturbance to marine organisms via noise, light, and vibration from the operations.[31] Some attempts have been made to fully catalogue the likely range of ecosystem goods and services generated by the ocean floor. For example, Armstrong et al. (2012)[32] identify a range of provisioning, regulating, cultural, and supporting ecosystem services, which is reproduced in Appendix B.

[29] Boyd, J., & Banzhaf, S. (2007). What are ecosystem services? The need for standardized environmental accounting units. Ecological Economics, 63(2-3), 616-626. https://www.sciencedirect.com/science/article/pii/S0921800907000341.
[30] Johnston, R. J., Boyle, K. J., Loureiro, M. L., Navrud, S., & Rolfe, J. (2021). Guidance to enhance the validity and credibility of environmental benefit transfers. Environmental and Resource Economics, 79(3), 575-624. https://doi.org/10.1007/s10640-021-00574-w.
[31] Folkersen, M. V., Fleming, C. M., & Hasan, S. (2018). The economic value of the deep sea: A systematic review and meta-analysis. Marine Policy, 94, 71-80. https://doi.org/10.1016/j.marpol.2018.05.003.
[32] Armstrong, C. W., Foley, N. S., Tinch, R., & van den Hove, S. (2012). Services from the deep: Steps towards valuation of deep sea goods and services. Ecosystem Services, 2, 2-13. https://doi.org/10.1016/j.ecoser.2012.07.001.

40. Seabed mining will likely generate social and environmental externalities.[33,34,35,36] Externalities can be either negative or positive and can arise between producers, between consumers, or between producers and consumers. From an economics perspective, *negative* externalities arise at the point where marginal social cost exceed marginal social benefit. Externalities lead to economic inefficiencies, or a lack of consideration of externalities can lead to an allocation of property rights that is not optimal from an economic welfare perspective.[37]

41. Kaikkonen and Virtanen (2022), for example, state that shallow-water mining exerts additional pressures on vulnerable coastal ecosystems which are already burdened with cumulative impacts from human activities and the effects of climate change, making them less resilient to new human activities. Despite faster recovery times of shallow-water ecosystems compared with vulnerable and slow-growing deep-sea communities, the overall environmental footprint of mining will be significant also in shallow area.[38] The authors conclude "…shallow-water mining contradicts international conservation and sustainability goals, and its regulative legislation is still being developed. In the absence of thorough comparisons of different mining practices, there are no justifications in favour of shallow-water mining".[39]

42. Binney[40] identifies several sources and studies of potential monetary values associated with seabed ecosystems, including the TEEB Valuation Database (a global database of valuations from studies from all biomes, including the seabed; now subsumed into the Ecosystem Services Valuation Database)[41], Jobstovgt et al. (2014)[42] (estimating the value of increased conservation measures in the UK), Costanza et al. (2014)[43] (estimating the value of the change in ecosystem services). It is the latter, using a benefit transfer approach, that Binney draws the following estimates of the value of lost ecosystem services that may occur because of TTRL's project (adjusted to 2023 NZ$ values):

    (a) Lower estimate: NZ$ 172/hectare/annum

    (b) Upper estimate: NZ$ 3,383/hectare/annum

    (c) Median estimate: NZ$ 274/hectare/annum

43. Whilst there remains a fair degree of uncertainty associated with ecosystem service valuations, and the subsequent social and environmental costs associated with the project, this is more a

[33] Amon, D. J., Gollner, S., Morato, T., Smith, C. R., Chen, C., Christiansen, S., ... & Pickens, C. (2022). Assessment of scientific gaps related to the effective environmental management of deep-seabed mining. Marine Policy, 138, 105006. https://doi.org/10.1016/j.marpol.2022.105006.
[34] Leduc, D., Clark, M. R., Rowden, A. A., Hyman, J., Dambacher, J. M., Dunstan, P. K., ... & Woolley, S. N. C. (2024). Moving towards an operational framework for defining serious harm for management of seabed mining. Ocean & Coastal Management, 255, 107252. https://doi.org/10.1016/j.ocecoaman.2024.107252.
[35] Levin, L. A., Amon, D. J., & Lily, H. (2020). Challenges to the sustainability of deep-seabed mining. Nature Sustainability, 3(10), 784-794. https://doi.org/10.1038/s41893-020-0558-x.
[36] Miller, K. A., Brigden, K., Santillo, D., Currie, D., Johnston, P., & Thompson, K. F. (2021). Challenging the need for deep seabed mining from the perspective of metal demand, biodiversity, ecosystems services, and benefit sharing. Frontiers in Marine Science, 8, 706161. https://doi.org/10.3389/fmars.2021.706161.
[37] Pigou, A. C. (1920). The Economics of Welfare. MacMillan, UK.
[38] Kaikkonen, L., & Virtanen, E. A. (2022). Shallow-water mining undermines global sustainability goals. Trends in Ecology & Evolution, 37(11), 931-934.
[39] Kaikkonen & Virtanen, (2022) p. 931.
[40] Binney, "Statement of Evidence by James Binney on Behalf of Kiwis Against Seabed Mining Incorporated" pages 9 and 10.
[41] Ecosystem Services Valuation Database (ESVD). Available: https://www.esvd.net/.
[42] Jobstvogt, N., Hanley, N., Hynes, S., Kenter, J., & Witte, U. (2014). Twenty thousand sterling under the sea: estimating the value of protecting deep-sea biodiversity. Ecological Economics, 97, 10-19. https://doi.org/10.1016/j.ecolecon.2013.10.019.
[43] Costanza, R., De Groot, R., Sutton, P., Van der Ploeg, S., Anderson, S. J., Kubiszewski, I., ... & Turner, R. K. (2014). Changes in the global value of ecosystem services. Global Environmental Change, 26, 152-158. https://doi.org/10.1016/j.gloenvcha.2014.04.002.

reflection of a lack of local studies undertaken by the proponent to fully understand the economic implications of the project, rather than any flaws in the approach. We are very confident that the social and environmental costs are not zero and maybe substantial.

6 OPPORTUNITY COSTS

44. The opportunity cost of anything of value is typically understood as the value of the next best alternative that must be forgone when making a choice.[44] In this instance, a major opportunity cost of seabed mining is the value that may be generated by alternative industries, such as the wind energy sector and tourism that cannot operate, or be maximised, in parallel with seabed mining. Social BCA must always consider the opportunity cost of feasible alternatives. This is consistently argued by Boardman et al. (2017) who argue that opportunity cost is the correct measure of cost in a CBA. [45] Since the goal of social BCA is to assess whether a project increases economic efficiency, it must compare the project's net benefits to those of alternative uses of the resources. When evaluating the cost of using a resource, what matters in social BCA is not the historical price or accounting cost, but rather what is given up by using that resource in the project instead of in its best alternative use. Feasibility is key, only feasible alternatives (those that could reasonably be chosen instead) should be considered.

45. In a recent report by PWC, the wind energy sector claims that "…[o]ffshore wind assets cannot be built withing an operational seabed mining project" and furthermore that it "…may not be able to be built in an area which was previously subject to seabed mining, or may be delayed decades after mining activities are completed". [46]

46. Whilst this claim can be interpreted as a gambit for less encumbered access to the area by another industrial sector, the wind energy industry nevertheless makes considerable economic claims on the quantity (not the benefit) of the economic activity that will be generated. For example, the industry claims it will:

> *"generate between $12b and $94b GDP (real) over the life of the projects and between 5,300 and 30,000 domestic jobs during the construction phase. About half of the economic benefit is concentrated during the construction period, with the other half sustained over a 25-35 year operational period."* [47]

47. This economic activity is nation-wide, however the industry claims that that a significant proportion of its planned development interests exist in the South Taranaki Bight, conflicting with TTRL's seabed mining proposals. PWC estimates that 3.9 GW of the nearly 12 GW of planned wind turbines will be located in Taranaki. [48] Thus it can be assumed that loss of this area will have a material impact on the measures of economic activity. This economic activity

[44] Quiggin, J. (2019). Economics in Two Lessons: Why Markets Work So Well, and Why They Can Fail So Badly. Princeton University Press, US. Available: https://www.torrossa.com/en/resources/an/5560098.
[45] Boardman, A. E., Greenberg, D. H., Vining, A. R. & Weimer, D. L. (2017). Cost-Benefit Analysis: Concepts and Practice. Cambridge University Press, UK.
[46] PWC (2024). National Impact Study: New Zealand Offshore Wind Industry. Available: https://www.pwc.co.nz/pdfs/2024/national-impacts-report-new-zealand-offshore-wind-industry-mar-2024.pdf.
[47] PWC (2024). National Impact Study: New Zealand Offshore Wind Industry. p. 13.
[48] PWC, "National Impact Study: New Zealand Offshore Wind Industry," 26.

compares favourably, at a national level, with the GDP generated by economic activity and jobs benefits put forward by TTRL (NZ$ 246 million per annum).

48. As a result, wind energy is a preferred economic development strategy of Venture Taranaki, Taranaki's Regional Development Agency. [49] (Venture Taranaki is a charitable trust controlled and owned by New Plymouth District Council and also partners with South Taranaki District Council and Stratford District Council.)

49. We recognise that the PWC report commissioned by the wind energy sector also makes claims based on I-O modelling, thus not presenting a picture of the both the costs and the benefits of the wind energy sector as a discreet proposal. It is beyond the scope of this report to evaluate the wind energy claims, noting that the wind energy sector suffers its own negative externalities, in particular, amenity values and potential impacts on wildlife, which are often articulated by community and interest groups' claims of the industry yet to gain a social licence to operate.[50]

50. Nonetheless, the wind energy sector claims that offshore wind assets cannot be built within an operational seabed mining project and furthermore that it may not be able to be built in an area which was previously subject to seabed mining, or may be delayed decades after mining activities are completed. Therefore, New Zealand-Aotearoa must consider the strategic choices available to it, in terms of supporting the energy transition to renewable energy and committing to the relatively short to medium term economic activity (and potential benefits) from seabed mining.

51. A further opportunity cost that should be fully explored is that of the loss of brand value associated with ***100% Pure New Zealand***, mainly targeted at backpackers and tourism, but also on building primary industry exports to increase foreign currency exchange. *100% Pure New Zealand* brand values include positioning the country with messages indicating clean and green, sustainability, and environmental awareness and an association with the strength of New Zealand's indigenous Māori culture and their spiritual connection with the land.[51] It is understood that local iwi stand in opposition to TTRL's proposal.

52. Several academic studies have assessed the potential for loss of brand value when countries are associated with potential damaging extractive activities.[52] Other studies have looked at the direct impacts on recreation (surfing) of incompatible coastal activities[53] and another specifically looking at the impacts of seabed mining on tourism in Fiji that concluded divers would be likely to reduce their trips with the presence of seabed mining.[54]

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[49] Venture Taranaki, "Offshore Wind: A New Energy Opportunity for Taranaki - Discussion Paper."

[50] See: Brownlee, M. T., Hallo, J. C., Jodice, L. W., Moore, D. D., Powell, R. B., & Wright, B. A. (2015). Place attachment and marine recreationists' attitudes toward offshore wind energy development. Journal of Leisure Research, 47(2), 263-284. https://doi.org/10.1080/00222216.2015.11950360.

[51] Morgan, N., Pritchard, A., & Piggott, R. (2002). New Zealand, 100% pure. The creation of a powerful niche destination brand. Journal of Brand Management, 9, 335-354. https://doi.org/10.1057/palgrave.bm.2540082.

[52] Craig-Smith, S. J., Tapper, R., & Font, X. (2006). The coastal and marine environment. In Tourism and global environmental change (pp. 107-127). Routledge.

[53] Reineman, D. R., & Ardoin, N. M. (2018). Sustainable tourism and the management of nearshore coastal places: place attachment and disruption to surf-spots. Journal of Sustainable Tourism, 26(2), 325-340. https://doi.org/10.1080/09669582.2017.1352590.

[54] Folkersen, M. V., Fleming, C. M., & Hasan, S. (2018). Deep sea mining's future effects on Fiji's tourism industry: A contingent behaviour study. Marine Policy, 96, 81-89. https://doi.org/10.1016/j.marpol.2018.08.001.

53. The mining area is located near productive fishing grounds. Disruption to these areas will more than likely affect the abundance and distribution of commercially important fish species. In prior applications (notably that of 2016 [55]) evidence has been submitted that the development of seabed mining in the Taranaki region will have a material impact on existing and the development of further commercial fishing interests (shellfish and pelagic species), notably from turbidity from the plume (including toxic heavy metals), noise and possible light pollution generated by mining operations, and by the effect of the mining operations attracting pelagic fish into the mining area. [56]

54. Evidence is provided Talley's Group Ltd. (TGL), which estimates that the value of their interest in the Fisheries Management Area (FMA 8; overlapping with TTRL's seabed mining operation) area was NZ$ 12 million [57] (NZ$ 15.38 million in today's prices). TGL has fishing rights to around NZ$ 9.19 million worth of wild catch fish annually in FMA 8 (at today's prices, not accounting for any changes in quota prices). [58] Whilst the impact of TTRL's seabed mining proposal will not completely dimmish the value of the commercial fishery, losses could still be economically significant. For example, one tonne of snapper unable to be caught (out of a quota of 50 tonnes) results in a loss to TGL of NZ$ 60,000 (NZ$ 76,000 in today's prices, not accounting for any change in the marginal value of the quota).

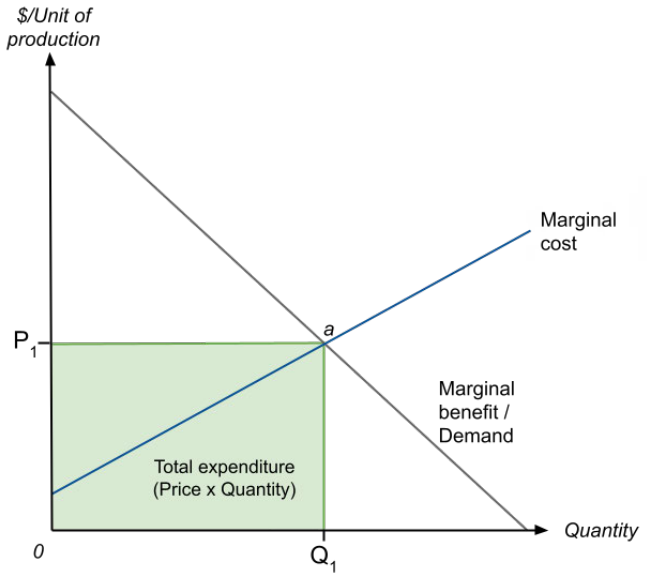
55. There is limited formal economic analysis, however, in further evidence provided by Piper, with regards to the potential future output of just the Surf Clam sector, it is claimed that the potential value of the harvest in FMA 8 could be NZ$ 128m/year (in today's prices; based on a total allowable catch of 10,000 tonnes) and provide jobs 50 full-time employees. [59] Whilst this is unverified, it nevertheless demonstrates that significant output and jobs can be generated through even a single fishery, which could be put in jeopardy.

[55] Evidence available at https://www.epa.govt.nz/database-search/eez-applications/view/EEZ000011
[56] For example, see evidence from A P Smith Fishing Consultancy Ltd. at https://www.epa.govt.nz/assets/FileAPI/proposal/EEZ000011/Submissions-and-or-comments-Submissions/f8bb48eec9/APS-Fishing-Consultancy-Ltd-121976.pdf
[57] By Mr Saunders-Loder; see p.182 of https://www.epa.govt.nz/assets/FileAPI/proposal/EEZ000011/Boards-Decision/TTRL_Marine_Consent_Decision_EEZ000011_FINAL_version.pdf
[58] See p.7 of https://www.epa.govt.nz/assets/FileAPI/proposal/EEZ000011/Evidence/abe94799a0/Fisheries-Submitters-Doug-Saunders-Loder.pdf
[59] Submission at https://www.epa.govt.nz/assets/FileAPI/proposal/EEZ000011/Evidence/7f2c0dc9cc/Fisheries-Submitters-Anthony-Piper.pdf

APPENDIX A: COMPARING MEASURES OF OUTPUT WITH COSTS AND BENEFITS

One way of envisioning the contrast between output values and externality costs is to abstract to the micro-economic level and look at one set of transactions. Figure A1 shows a single micro-economic equilibrium abstraction of one market from the totality of the output value, which would comprise of multiple markets in the value chain of the seabed mining proposal (labour, materials, fuel, etc.). For each transaction, the output generated is the product of the price (per unit) and the quantity transacted, represented in Figure A1 by the rectangle $aQ_1 0P_1$ at the equilibrium price. Whilst there are numerous assumptions made in such abstractions, Figure A1 represents how output is calculated: price multiplied by quantity.

Figure A1: Supply, demand, and output



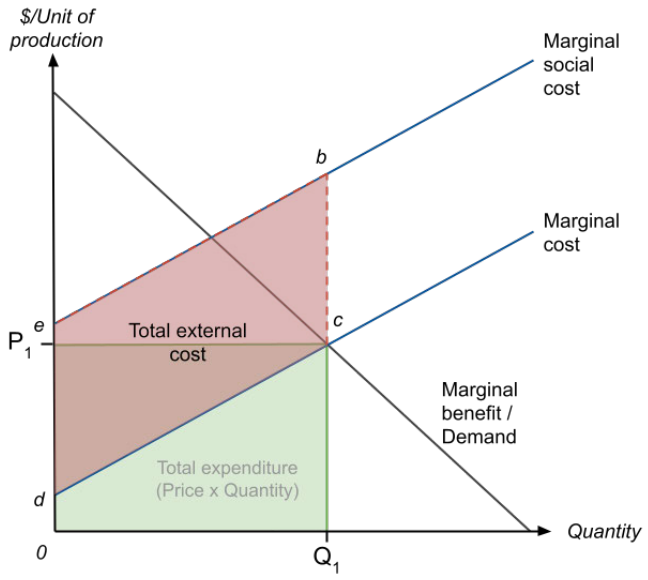
Depending on which particular transaction in we are looking at, it is highly likely that there are externalities associated with it – particularly where we are considering extractive industry sectors, which mine non-renewable resources. An externality is (specifically a *negative* externality) refers to the unintended and uncompensated costs imposed on society or third parties due to economic activities. These costs are not reflected in the market price of goods or services and are typically borne by individuals, communities, or the environment rather than the producer or consumer responsible for the activity. Furthermore, this needs to consider the marginal user cost (MUC) associated with non-renewable resources. The MUC can be thought of as the opportunity cost of extracting and using one more unit of the resource today instead of leaving it for the future. Every year a unit extract now leaves fewer resources available for future use. The marginal user cost reflects the value of keeping the resource in the ground and extracting it in the future when prices are higher.[60]

In this instance, for example, negative externalities can be associated with damage to the ocean floor environment or greenhouse gas emissions from energy demands of the operations and through the value chain (known as Scope 1, 2 and 3 emissions). The negative externality can be represented as an

[60] Daly, H. E., & Farley, J. (2011). Ecological Economics: Principles and Applications. Island Press, US, p. 187.

additional marginal cost on each unit of economic activity, which is now termed the marginal *social* cost – marginal private cost plus marginal external cost. This represents a theoretical real cost of that activity to the economy. The total external cost is dependent on the volume transacted and is represented by the polygon *bcde* added to polygon cQ_10d in Figure A2.

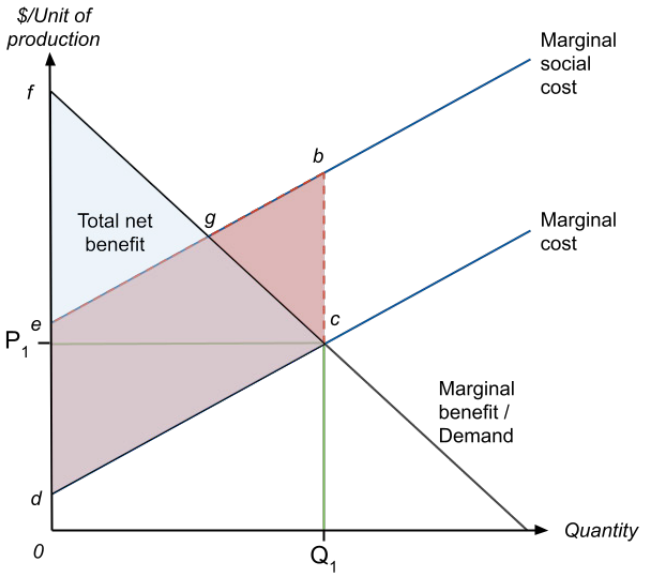
Figure A2: Representation of total external cost.



This external cost is not considered when using output as a measure of benefit to a project. Note that the total external cost cannot be simply subtracted from the output value to derive a net benefit, as output and benefit are measuring different aspects of the economy.

Finally, Figure A3 relates to how a project's total net benefit is derived. Total benefit is the sum of profit (P_1cd) and consumer surplus (fcP_1). Accounting for social costs total net benefit – the recommended measure of the benefit of a project is represented by the deduction of total external cost (*bcde*) from the total benefit (*fcd*), which is area (*fge*) – (gbc). This does not include opportunity cost – where investments generate greater returns on investments.

Figure A3: Relationship between project total benefit and project total net benefit (without opportunity cost).



APPENDIX B: ECOSYSTEM GOODS AND SERVICES GENERATED BY THE SEA FLOOR

Table B1: Example ecosystem goods and services from Armstrong et al. (2012)[61]

Services/Ecosystems and habitats		Cold water corals	Open slopes and basins	Canyons	Sea-mounts	Chemo-synthetic	Water column	Sub-seabed
Supporting	Nutrient cycling	?	+	?	?	+	+	0
services	Habitat	+	+	+	+	+	+	0
	Resilience	?	?	?	?	?	?	0
	Primary production	?	?	?	?	+	+	0
	Biodiversity	+	+	+	+	+	+	?
	Water circulation and exchange	0	+	+	?	0	+	0
Provisioning	Carbon capture and storage (artificial)	0	0	0	0	0	+	€
services	Finfish, shellfish, marine mammals	+	+	+	+	+	€	0
	Energy: Oil, gas, minerals	?	?	0	?	?	0	€
	Chemicals compounds—industrial/ pharmaceutical	+	?	?	?	+	?	?
	Waste disposal sites	0	+	+	0	0	0	+
Regulat-ing	Gas and climate regulation	0	?	+	0	+	+	+
Service	Waste absorption and detoxification	0	+	+	0	0	+	0
	Biological regulation	?	+	?	?	+	+	0
Cultural services	Educational	+	+	+	+	+	+	+
	Scientific	+	+	+	+	+	+	+
	Aesthetic	+	?	?	?	+	+	0
	Existence/Bequest	+	?	?	?	?	+	?

[61] Armstrong, C. W., Foley, N. S., Tinch, R., & van den Hove, S. (2012). Services from the deep: Steps towards valuation of deep sea goods and services. Ecosystem Services, 2, 2-13. https://doi.org/10.1016/j.ecoser.2012.07.001.

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