Cost Benefit Analysis of Climate Change Impacts and Adaptation Measures for Canadian Mines

A Literature Review

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Ontario Centre for Climate Impacts and Adaptation Resources

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COST BENEFIT ANALYSIS OF CLIMATE CHANGE IMPACTS AND ADAPTATION MEASURES FOR CANADIAN MINES

A LITERATURE REVIEW

1.0 Introduction

The impacts of a changing climate are currently observable, affecting many Canadian businesses and industries including the mining sector (Ford et al., 2010; Pearce et al., 2011). Addressing these impacts in a way that simultaneously minimizes damage and protects human and environmental health, while maximizing competitiveness and ensuring business continuity, is a complex undertaking (NRTEE, 2011; Sussman and Freed, 2008). Emerging literature reveals that comprehensive economic analysis that provides an understanding of the costs and benefits associated with climate change impacts and adaptation options can encourage timely and efficient adaptive action (NRTEE, 2011; WHO, 2013; Metroeconomica, 2004; Moore, 2012).

Economic analysis is widely used throughout Canadian government decision-making (Trebilcock et al, 2007) and helps to identify optimal cost-effective investment options. In the context of preparing businesses or industry for climate change impacts, this process enables stakeholders to efficiently coordinate and allocate resources between different adaptation measures and between adaptation action and climate change mitigation measures (Zhu and van Ierland, 2010). Despite its widespread use in other business and government decision-making processes, economic analysis is not yet commonly used to assess anticipated climate change risks or adaptation options.

Although studies and tools are available to assist Canadian businesses in the economic analysis of climate change impacts and adaptation, there is little evidence that this work is being broadly undertaken (NRTEE, 2011). In the mining sector for example, despite general acceptance of the potential financial implications of climate change (ICMM, 2013; Pearce et al., 2011), there has been little reported effort by companies to systematically quantify costs associated with climate change impacts, or evaluate the cost effectiveness of adaptation options. This literature review explores existing resources, guides and tools to develop an understanding of the available literature for stakeholders. The results of the review will also inform the development of a conceptual framework, which will evaluate the costs and benefits of climate change impacts and adaptation in two case studies from the Canadian mining sector.

2.0 Methodology

This review considered 46 international resources from both academic and grey literature. To facilitate a robust understanding of the available research on the costs and benefits of climate change impacts and adaptation actions, the review focused on three main themes: climate change and economic analysis, climate change cost quantification, and available tools and resources. Resources that focused on climate change and economic analysis outlined the analytical approaches, including their strengths and weaknesses. Resources related to climate change cost quantification provided extensive information on estimated future costs for individual industries and countries. Finally, the review considered several quantification tools and resources that were used in climate change economic analysis.

The selected resources provide a snapshot of methods currently used by businesses and industry to evaluate the costs and benefits of climate impacts and adaptation measures. Although the results of this literature review are not specific to the Canadian mining sector, they provide relevant examples and lessons learned that may be applied.

3.0 Climate change and Economic Analysis

Climate change has the potential to impact business/ industry development and operation in a number of ways. First order impacts such as damage directly caused by a flood or other climate event, can limit required resources, damage infrastructure or increase health and safety risks for the labour force (Pearce et al. 2011; NRTEE, 2011; ICMM, 2013; Damigos, 2011). Second order impacts pose more indirect, but still significant, risks to business and industry. Examples of second order climate change impacts include disruption of supply chains, loss of revenue due to changing consumer demand, regulatory changes, higher insurance costs, reduced productivity due to climate health related issues, or risks related to climate impacts on related or required industries (i.e. business disruption due to power outage or food processors facing risks when the agricultural sector is threatened) (ICMM, 2013; Sussman and Freed, 2008; Damigos, 2011).

3.1 Economic Analysis Approaches

A thorough understanding and prioritization of climate risks, quantification of costs and benefits, and investment in appropriate and cost-effective climate change adaptation will enable companies to safeguard people and property and maintain business continuity through adaptation (GIZ, 2013; Moore; 2012; Metroeconomica, 2004). There are several different types of economics analysis that may contribute to the achievement of these goals, including:

- **Cost Benefit Analysis (CBA)**: A CBA is an ideal vehicle for this type of analysis. Most widely adopted across industries, this approach is preferred if the costs and benefits of alternative adaptation options can be expressed in monetary terms (GIZ, 2013; UNFCCC, 2011). Under

these circumstances, a CBA allows users to compare the costs and benefits of an intervention (or investment) over time (GSF, 2011).

- **Cost Effectiveness Analysis (CEA)**: A CEA determines how an objective can be achieved in the most cost-efficient way (GIZ, 2013; UNFCCC, 2011). It is often used when it is difficult (or impossible) to assign monetary value to benefits (for example: life).
- **Multi-Criteria Analysis (MCA)**: An MCA offers users the ability to rank and prioritize among multiple adaptation options. Unlike a CBA, the prioritization is based not only on economic factors but also "on a qualitative assessment of criteria such as feasibility, cost-effectiveness, co-benefits, ease of implementation and resources required" (GIZ, 2013; UNFCCC, 2011). MCAs are most commonly used when benefits cannot be measured quantitatively or when multiple benefits cannot be aggregated.
- **Partial Equilibrium and General Equilibrium Models**: Both partial equilibrium and general equilibrium provide a framework through which a user may look at potential interactions between climate change impacts and adaptation options and the economic system. They achieve this by forecasting future market changes based on driving forces observed in the past and assumptions of market mechanisms (GIZ, 2013).
- **Ricardian/Physical Models**: Using patterns of observed behavior, Ricardian or Physical models, predict the impact of industry behaviour (E.g. significant design change) on a selected region under certain conditions. This type of approach is primarily used to provide insight on a 'what-if' scenario (as opposed to being used to establish baseline costs), as it does not account for unique regional climate patterns, assuming instead that climate change impacts and adaptation outcomes will be similar regardless of location (GIZ, 2013).

3.2 Challenges in using Economic Analysis to Evaluate Climate Change Impacts and Adaptation Options

The review identified several challenges associated with using each of the economic analysis approaches to assess climate change impacts and adaptation options, as each is best suited to a certain type of assessment (noted above). However, the review also highlighted several common challenges. For example, uncertainty in climate models and ensuing challenges in accurately quantifying expected losses and costs was cited as one of the primary challenges (UNFCCC, 2011; GIZ, 2013; Nassopoulos et al., 2012; Moore, 2012; Parry et al., 2009; Metroeconomica, 2004). Uncertainty can cause errors in calculations of relevant thresholds or dimensions, which subsequently results in erroneous cost and benefit calculations throughout the analysis (Nassopoulos et al., 2012). As a result, additional scenario analysis may be required to reduce uncertainty by identifying the dimensions along which structures (social, economic and environmental) evolve over time (GIZ, 2013; Nassopoulos et al., 2012).

A second challenge associated with economic analysis of climate change impacts and adaptation (and particularly with CBA), is the tendency to focus on 'hard' adaptation measures[1], as they are relatively easy to quantify (Agrawala and Fankhauser, 2008). Costs of 'softer' adaptation measures such as land use planning or behavioural incentives are comparatively more difficult to quantify (Agrawala and Fankhauser, 2008; Zhu and van Ierland, 2010). A continued bias towards the assessment of 'hard' adaptation measures may lead to the neglect of potentially critical adaptation measures, which can result in inappropriate and costly adaptation measures (Agrawala and Fankhauser, 2008; Zhu and van Ierland, 2010).

Underestimation of costs and benefits is another common challenge associated with economic analysis of climate change impacts and adaptation. This challenge has been noted throughout the review and in critiques of several economic analyses conducted by international organizations such as the World Bank, UN Framework Convention on Climate Change and the Stern Report (Parry et al., 2009; ECA, 2009). Although there are numerous contributing factors responsible for the underestimation of costs and benefits, one of the most common is the tendency to consider the additional costs of climate change adaptation as 'climate mark-ups'[2] assuming low levels of investment (Parry et al., 2009; ECA, 2009). The use of climate mark-ups can result in inaccurate costing in two ways. First, the climate 'mark-up' factor is not always an accurate estimate of the costs involved in implementing adaptation measures. This is particularly true in cases where adaptation benefits will be achieved over the long-term (Parry et al., 2009). In some sectors, particularly those that are heavily reliant on the built environment, investment flows are significant enough that even a small change in the mark-up value can radically change cost and benefit estimates (Parry et al., 2009). A second related issue is the question of whether to establish climate mark-up values to reflect current levels of investment or higher levels that are needed to achieve resilience (Parry et al., 2009). This issue is particularly relevant in areas or sectors that have notable infrastructure deficits. In these cases, full funding would need to be dedicated to repair the deficit before a climate mark-up will accurately reflect the cost of climate-proofing.

Similarly, inaccurate estimation in an economic analysis can occur when addressing long-term investments through discounting[3]. Similar to the 'mark-up' factor, setting the discounting rate requires

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[1] Refers to adaptation measures and investment related to infrastructure or equipment.

[2] Refers to a risk transfer technique developed by the World Bank whereby a fraction of a climate-sensitive investment is multiplied by a 'mark-up' factor to reflect the cost of climate proofing those investments (Parry et al., 2009).

[3] " In economic assessments, future costs and benefits are usually discounted. This is because an alternative to making the investment would be to put the money into the capital market and earn interest. By converting all future costs and benefits that occur at different points in time into their *present value*, discounting makes them comparable" (GIZ, 2013).

consideration of a number of external factors (such as interest rates and market trends) and can have significant impacts on the analysis if incorrect (Zhu and van Ierland, 2010).

4.0 Climate Change Cost Quantification

4.1 International level analysis

In recent years cost benefit analysis of climate change impacts and adaptation has received significant international attention. Assessments have been conducted at the International, national and sector levels, providing policymakers with useful information on costing trends and critical investments (E.g. Damigos, 2011). Reports like the Stern Review (2006), the UNFCCC assessment of the Costs and Benefits of Adaptation Options (2011), and the World Bank's report *The Economics of Adaptation to Climate Change* (2010) assessed the likely costs and benefits related to climate change impacts and adaptation, with particular focus on costs for developing nations (Parry et al., 2009).

At the international level, the emphasis has primarily been on calculating costs related to climate change adaptation rather than the potential costs associated with climate change impacts. At this level, calculating costs associated with climate change impacts would not be feasible, as it would require input from too many sources and involve too many factors[4] (Moore, 2012; Hourcade et al., 2009). The calculations of adaptation costs in these reports range from $4bn/yr to $100bn/yr representing a poor state of knowledge as well as a scarcity of independent studies that use a variety of analysis approaches (Parry et al., 2009; Hourcade et al., 2009). The estimates provided are based on calculations in key sectors including agriculture, coastal zones, water, energy, infrastructure, health and tourism (Parry et al, 2009).

Partially in response to the emerging critiques of international CBAs, new techniques have been developed for conducting accurate economic analyses at the international level. In May 2010, the Pew Centre on Global Climate Change hosted a workshop titled *Assessing the Benefits of Avoided Climate Change: Cost-Benefit Analysis and Beyond: The Need for a Fresh Approach to Climate Change Economics.* To improve upon existing economic analysis approaches, the workshop participants opted to examine the assumptions used within the economic models and found that CBAs are limited in their ability to consider climate change impacts and adaptation costs and benefit due to two main factors: a heavy

[4] For example, a single storm event would require costing relating to infrastructural damage, health impacts, business disruption, service disruption, supply chain disruption and many other factors in terms of the impact they had at the household, community, business, industry and government (local to international) levels.

reliance on assumptions[5] and an inability to account for costs or benefits without a strict monetary value (i.e. reputation or level of community engagement). The participants identified several alternative approaches that would provide a more flexible technique for conducting international economic analysis. The alternative approaches included: 'tolerable windows' approach (TWA), 'safe landing' approaches (SLA), 'robust decision-making' approaches (e.g. Nassopoulos et al., 2012) and CEAs among others[6] (Ackerman et al., 2010).

4.2 Use of Economic Analysis to Assess Climate Change Impacts and Adaptation in Canada

In Canada, economic analysis to assess climate change impacts and adaptation (particularly CBAs) has been conducted at the national level (E.g. NRTEE, 2011; Cheng et al., 2012*)*, the provincial/territorial level (Yao et al., 2012) and the sector level (Ochuodho et al., 2012; NRTEE, 2011). Collaborative studies on the costs and benefits of climate change impacts and adaptation between the provincial/federal government and academia have begun to address shortcomings in socioeconomic aspects of the analyses in Ontario. (E.g. York University's 'Work in a Warming World', University of Western Ontario's work with the Institute for Catastrophic Loss Reduction, University of Waterloo's School Environment, Enterprise and Development).

At the national level, the NRTEE report *Paying the Price: The Economic Impacts of Climate Change for Canada* used an impacts cost assessment to assess the potential costs of climate change, as well as a Cost Benefit Analysis to evaluate adaptation options. The techniques used in the analysis recognized uncertainty in the climate model output and addressed it by using a probabilistic approach when required. The report found that climate change impacts costs in Canada are expected to accelerate, increasing from an average of $5bn/yr in 2020 to an average of between $21bn and $43bn/yr by 2050[7] (NRTEE, 2011). In addition to broad regional estimates of costs and benefits, more specific impact cost

[5] All economic analyses of climate change impacts and adaptation rely on assumptions made about the rate of climate change as compared to the rate of technological change, and the cost of damage caused by future climate events. However, many CBAs also make assumptions about future discount rate, the worth of human lives and ecosystems, among other aspects.

[6] The Tolerable Windows Approach and the Safe Landing Approach are based on 'pre-defined constraints that exclude intolerable climate change on the one hand and unacceptable mitigation measures on the other. The admissible scope for action is sought by investigating the dynamic cause-effect relationships between society and environment' (Bruckner et al., 1999). Robust decision-making approaches focus on implementing robust adaptation strategies to reduce vulnerability across the broadest possible range of climate changes (Nassopoulos et al., 2012).

[7] Based on the A2 emissions scenario.

estimates[8] are being conducted with a focus on one climate parameter. Results of a recent impacts cost estimate for Ontario demonstrated that both the monthly total number of rainfall-related water damage claims and incurred losses could increase by 13%, 20% and 30% for the periods 2016-2035, 2046-2065 and 2081-2100 respectively (Cheng et al., 2012).

At the sector level, impact cost assessments are most commonly used to estimate the financial risk associated with climate change for key Canadian sectors. Several cost impact assessments have been completed focusing on forestry, hydro-electricity, health, transportation and fisheries (NRTEE, 2011, ICLR, 2012; Ochuodho et al., 2012; Mills et al., 2008). The studies are focused on first-order estimates of damage or risk assessment and are often driven in part by extreme event experiences at the sector or municipal levels (Ochuodho et al., 2012). Comprehensive CBAs that estimate the benefits of climate change impacts (in addition to their costs) remain uncommon.

4.3 Use of Economic Analysis to Assess Climate Change Impacts and Adaptation at the Business/Industry Level

The review revealed few resources pertaining to economic analysis of climate change impacts and adaptation occurring at the business or industry level. Where economic analysis was undertaken, it was isolated and focused on climate change impact costing (Investec Asset Management, 2013; Pearce et al., 2011). There was no evidence for example that impact cost assessments had been conducted systematically across an industry or sector. There was no evidence that benefits related to climate change impacts were assessed. Finally, there was no indication that either costs or benefits had been considered with respect to available adaptation options. This suggests two things: first, businesses and industry stakeholders are typically reticent to publish a report that may contain sensitive or proprietary information while governments and academic stakeholders are more likely to develop and distribute such materials and second, the concept of conducting economic analysis with regard to climate change impacts and adaptation measures is relatively new. Case studies showcasing early adopters in business and industry have not yet emerged.

As business and industry stakeholders are on the front line of experiencing climate change impacts and making decisions about adaptation measures, literature (case studies, reports, papers etc.) pertaining to their use of economic analysis is of particular interest. Moreover, given the scope of work, level of detail available (about specific hard and soft costs) and institutional structure at the industry level, a better understanding of the techniques and challenges related to the use of CBAs in this context would be valuable.

[8] Impact costs assessments do not consider the benefits related climate change impacts

5.0 Available Tools and Resources for Economic Analysis of Climate Change Impacts and Adaptation Resources

The literature revealed a robust collection of resources and tools that could benefit industry (particularly mining) decision-makers.

5.1. Economic Analysis Resources

Several different types of resources were identified that could be used to guide CBAs and inform the development of the framework. In particular, there were guidance documents that pertained specifically to using a CBA to evaluate climate change impacts and adaptation measures. Other resources provided:

- Important information on economic analysis types and challenges,
- Concrete case studies of economic analysis used as a tool to prevent climate change impacts,
- Anticipated sector wide costs and expected adaptation measures based on cost benefit analysis.

Below is a brief description of a few of the resources that used economic analyses to estimate climate change impacts and adaptation.

Metroeconomica Limited. 2004. Costing the Impacts of Climate Change in the UK. (UKCIP)

Despite being one of the oldest resources reviewed, this document provided clear, comprehensive guidelines for the use of CBA, CEA and MCA in assessing the costs of climate change impacts and adaptation options. In addition, the document explored decision-making strategies, use of impact matrices and common mistakes. The guide is unique in that it noted and addressed uncertainty in economic analysis, and advised on valuating both hard and soft costs in order to obtain both direct and indirect climate impact costs. Finally the guidelines also contained a set of case studies, providing examples of the methodology and information required to perform each of the economic analysis exercises. Benefit analysis was only emphasized with regard to climate change adaptation measures. Climate change impacts were assessed for cost but not benefit. This emphasis may bias the analysis.

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). 2013. Economic Approaches for Assessing Climate Change Adaptation Options Under Uncertainty: Excel Tools for Cost Benefit Analysis.

One of the most comprehensive resources reviewed, this report reviewed each of the three primary economic analysis approaches (CBA, CEA and MCA) as well as several alternative methods (Partial Equilibrium and General Equilibrium Models, Ricardian or Physical models). Designed for decision-makers, the report explained the purpose of each approach and its appropriate application, detailed specific challenges related to each approach and provided a brief description on how to use each technique to assess adaptation measures for ability to reduce costs, cost effectiveness and suitability.

The guidelines did not discuss the use of economic analysis tools to assess climate change impacts, which could conceivably limit its applicability. The report was paired with a set of excel-based tools, which will be explored in greater detail in Section 5.2 (Tools).

UNFCCC. 2011. Assessing the Costs and Benefits of Climate Change Adaptation Options.

This report provided an overview of the three main economic analysis approaches, discussed key methodological issues, explained each of the approaches in detail and provided lessons learned and good practices through several case studies. The report did not discuss how to treat uncertainty within economic analysis and did not address the costs associated with climate change impacts. As with other internationally focused resources, its emphasis remained on the assessment of the costs of adaptation measures. Unfortunately, this oversight will mean that stakeholders will find this resource most valuable when used in conjunction with other guidelines.

NRTEE. 2011. Climate Prosperity: Paying the Price: The Economic Impacts of Climate Change for Canada.

This report conducted an assessment of the costs of climate change impacts, and the costs and benefits of climate change adaptation option across Canada, with a focus on several key sectors including timber supply, coastal areas, human health and ecosystems. For each sector the report reviewed the costs related to expected climate change impacts and identified adaptation strategies that could be employed to reduce the risks related to each impact. The costs and benefits associated with each adaptation strategy were also assessed to allow for comparison and prioritization. Similar to other resources, this report did not assess climate change impacts for possible benefits to the selected sectors. In addition, the report limited its impacts assessment to a select group based on several factors including: connection between impact and climate change; vulnerability of Canadians to impact; and available climate data.

Nassopoulos et al., 2012. Adaptation to an Uncertain Climate Change: Cost Benefit Analysis and Robust Decision Making for Dam Dimensioning.

This article compared two approaches to economic analysis with regard to their ability to design resilient dams in the face of climate data uncertainty: 'robust decision-making' and cost-benefit-analysis. Robust decision-making determines the size or cost of infrastructure based on a target in water delivery while cost-benefit-analysis calculates the optimal infrastructure design based on the costs associated with construction, operation and benefit from water demand satisfaction. Based on this understanding, the report determined that climate model uncertainty represents a greater challenge for decision-makers employing cost-benefit-analysis as it can cause errors regarding optimal dam dimensioning. Under an uncertain climate, there is a significant 'potential for sunk costs if the realized climate is not consistent with the climate that the dam was designed for'. Instead the report suggests that scenario analysis combined with a robust decision-making approach will be better suited for designing dams under a changing and uncertain climate as it will promote flexible and resilient dam designs and avoid the design limitations imposed by cost assessment. In cases where CBA will be employed, the use of multiple models and scenario analysis will reduce the chance of design error. By providing the reader

with a comparison of two decision-making approaches, the report highlighted the benefits and limitations associated with using economic analysis (CBA in this case) to identify and implement adaptation actions.

Damigos, D. 2011. Monetizing the Impacts of Climate Change on the Greek Mining Sector. Mitigation and Adaptation Strategies for Global Change.

This article described the top-down approach used by the Greek government to assess the costs of climate change impacts on the country's mining sector. Using available climate data under the A1B emissions scenario[9], relevant climate change impacts were identified and quantified in physical terms. This list included destruction of mining infrastructure, forest fires, a decrease in water resources availability and an increase in dust emissions among others. Using primary and secondary sources including costing reports of damage, the government then developed costing estimates for each of the identified impacts. The article provides very high-level estimates of costs that have a heavy focus on infrastructure damage. A more detailed analysis that includes 'softer' costs and region-specific context for expected climate change impacts would provide a more accurate estimate of the costs expected for the Greek mining sector. The article also focuses solely on costs associated with climate change impacts and does not consider the costs or benefits associated with adaptation options.

ECA. 2009. Shaping Climate-Resilient Development: A Framework for Decision-Makers.

Designed for national and local decision-makers, this decision-making framework was built around two sets of tools: one set to quantify a location's total climate risk, the other to promote the use of cost-benefit techniques to evaluate potential adaptation measures. Not a true cost-benefit analysis, the framework used risk management techniques to identify and prioritize climate risks without attempting to quantify them in monetary terms. The methodology employed does not seem to consider the potential benefits or opportunities associated with climate change impacts. Cost-benefit analysis was only used to assess possible adaptation measures. The framework is notable for exploring the role of risk transfer techniques and for promoting flexible, resilient measures over less effective adaptation measures. The report also addresses issues of value to decision-makers including the ability to unlock funding and the integration of cost-benefit analysis with climate risk assessment, vulnerability assessment and other decision-making tools.

[9] As defined by the Intergovernmental Panel on Climate Change (IPCC) referring to fast global economic growth, global population peaking in mid-century and then declining, rapid introduction of new and more efficient technologies and a balanced energy source

5.2 Economic Analysis Tools

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). 2013. Economic Approaches for Assessing Climate Change Adaptation Options Under Uncertainty: Excel Tools for Cost Benefit Analysis.

The tools packaged with the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) report were designed for decision-makers. A CBA prototype spreadsheet and an MCA prototype spreadsheet are provided and can be downloaded from AdaptationCommunity.net. The Cost-Benefit Analysis spreadsheet allows users to compare the undiscounted costs and benefits related to several adaptation options over a 30-year period. Each adaptation option can be broken down into separate cost elements, or represented as a one-time investment to accurately characterize costs over time. The multi-criteria analysis template allows users to define and apply a list of up to ten criteria to up to ten adaptation options. Each criterion can be weighted to present a nuanced analysis of each option. The manual at the end of the report provides a detailed explanation of how to use and read the spreadsheet tools.

The tools allow users to calculate *only* the costs and benefits related to future adaptation options. Costs and benefits related to climate change impacts cannot be entered within the tools. This design may lead users to ignore the costs and benefits related to climate change impacts in their economic analysis, or it may require users to supplement the tool with a separate impact cost assessment in order to uncover the true economic impact of climate change on their business. The manual warned users that the prototypes should not be considered substitutes for well-structured data generation.

Climate-Adapt. Cost Benefit Database. European Climate Adaptation Platform.

The Cost Benefit Database was developed by Climate-Adapt and lists tools and resources related to cost benefit assessment of climate change impacts and adaptations. The online database is part of the European Climate Adaptation Platform and is designed to allow users to search by adaptation sector and impact type to further refine the findings.

World Health Organization (WHO). 2013. Climate Change and Health: A Tool to Estimate Health and Adaptation Costs.

This tool was prepared by the WHO to inform a strategic approach for health based adaptation measures. The health sector notes that adaptation responses will require a sound understanding of the full economic and financial impacts of climate change. By inputting numerical information along with the appropriate mathematical relationships into the spreadsheet tool, users can generate a range of impact cost, adaptation cost and efficiency ratios. The tool is accompanied by a comprehensive manual containing information on potential damage; formulas for required calculations; additional resources and support; and instructions on how to use the tool. Moreover, it is one of the only tools that emphasize cost analysis on both climate impacts and adaptation. However, the emphasis is solely on cost assessment and the tool does not require or permit the assessment of benefits related to the climate impacts or adaptation measures, which means that decision-makers cannot use the tool to complete a full cost-benefit analysis on climate impacts and adaptation.

Integrated Assessment Models

Two documents explored the use of Integrated Assessment Models (IAMs) in conducting climate change impact and adaptation cost benefit assessments (Sova, 2013; Ackerman et al., 2010). These tools differ from traditional cost-benefit-analysis tools because "IAMs are computerized tools that use complex algorithms to predict the impact that climate data will have on selected socioeconomic models" (Sova, 2013). More specifically, IAMs are used to estimate the yearly economic costs of climate change. Though neither resource provided access to an IAM prototype tool for use by stakeholders, the detailed description of their potential use by the authors provide value for those who seek methods for assessment of climate change impacts and adaptation

6.0 Conclusions

The literature review uncovered a range of different resources and tools for cost benefit analysis (or more generally economic analysis) of climate change impacts and adaptation. Many resources provided information on different types of economic analysis or the future costs of climate change on business and industry, while fewer identified comprehensive guidance that could be used to undertake a complete cost-benefit analysis of both climate impacts and adaptation. Some of the documents focused on establishing *costs* of climate change impacts and adaptation while others showed methods to determine *costs and benefits* related to either climate impacts, OR adaptation measures. Very few of the resources detailed economic or financial benefits associated with either impacts or adaptation measures, and none of the guidance documents detailed costs and benefits of both impacts and adaptation. This sort of comprehensive analysis tool/technique would be most valuable for various sectors or levels of government.

A full cost-benefit tool for climate change impacts and adaptation geared for industry, accompanied by a guidance document and case studies of implementation, would allow the business community to fully appreciate financial risks stemming from climate change, as well as potential cost savings stemming from a variety (or combination) of adaptation actions. To increase its value, the proposed guidance document should also address common challenges that apply to decision-makers including direction on the application of climate models, dealing with uncertainty in the economic analysis, as well as clear guidelines on the establishment and use of both discount and climate 'mark-up' rates. Furthermore, a

discussion on how to blend economic analysis approaches to best fit the parameters or scope of specific industries and scenarios, may be appropriate given the limitations[10] of cost benefit analysis.

In addition, none of the tools selected for review were appropriate for use in a cost-benefit analysis of climate impacts and adaptation resources in their current format. The protocol spreadsheets developed by GIZ, although simple, well organized and straightforward, fail to allow for inclusion of sector- or situation-specific information required to assess costs and benefits of climate change impacts. Similarly, the WHO toolkit is well rounded in that it allows users to calculate costs relating to both climate change impacts *and* adaptation options; provides formulas and guidance for users who must develop mathematical relationships between climate changes and operational costs; and allows users to generate efficiency ratios relating to adaptation options. In its current format however, the tool limits the user's ability to evaluate the potential benefits associated with climate impacts and adaptation measures, which reduces its utility. A comprehensive tool designed specifically for CBA of climate impacts and adaptation measures would be very valuable.

Finally, the literature review noted the absence of guidance pertaining to the integration between CBAs (or other economic analysis approaches) and other planning or decision-making tools and processes such as risk management, environmental assessments or vulnerability analysis. The current independent nature of adaptation planning tools and cost-benefit analysis tools reveals that users should seek to bridge that gap in order to strengthen the assessment of the impacts of climate change to include the economic or financial costs.

[10] For a cost-benefit analysis to be successful, costs and benefits must be able to be measured in monetary terms. This can lead to a focus on 'hard' costs and benefits relating to climate change (those that are easily measurable in monetary terms). In addition, a CBA requires the user to determine the relationship between climate changes and resultant costs or benefits. Completing a scenario analysis to account for climate data uncertainty within the CBA may strengthen the accuracy of the analysis.

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