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Monetization of Sustainability Indicators Integrating Willingness to Pay into Life Cycle Sustainability Assessment

Ma Sining, Amir Hamzah Sharaai, Nitanan Koshy a/l Matthew and Nazatul Syadia Zainordin

Department of Environment, Faculty of Forestry and Environment, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia

Coressponding Author Email: amirsharaai@upm.edu.my

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Abstract

Sustainability has become a major focus of research, with life cycle sustainability assessment (LCSA) emerging as a widely used method. LCSA evaluates the three pillars of sustainability—social, environmental, and economic—through social life cycle assessment (S-LCA), life cycle assessment (LCA), and life cycle costing (LCC). However, the lack of integration among these methods, which use different units of measurement, makes it challenging for stakeholders to fully grasp the sustainability of products. To bridge this gap, monetization offers a means of translating complex environmental and social impacts into financial terms, enabling stakeholders to make more informed decisions. This review explores the monetization of LCA and S-LCA, focusing on various techniques, with the contingent valuation method (CVM) for estimating willingness to pay (WTP) identified as particularly effective. WTP allows for context-specific results that better reflect individual or organizational preferences. Future research should investigate the integration of WTP into LCSA to guide governments and stakeholders in promoting sustainable products and services.

Keywords: Monetization, Sustainability, Life Cycle Sustainability Assessment, Willingness to Pay, Life Cycle Assessment

Introduction

The modern discourse on environmental conservation often highlights industrial activities as pivotal to both economic prosperity and environmental degradation. As Plat et al., (2019) and Song et al (2018), suggest, the pursuit of economic growth frequently conflicts with environmental preservation. However, the trajectory of rapid economic progress often imposes detrimental effects on the natural environment, as articulated by The degradation of natural resources not only undermines the operational foundations of human society but also precipitates a decline in the health of living organisms, thereby curtailing social well-being and stalling economic development (Ashraf et al.,2021). This nexus of challenges underscores the imperative for sustainable development that harmonizes economic, societal, and environmental objectives, aiming to safeguard the interests of both present and future

generations (Plat et al., 2019). This conflict underscores the necessity for sustainable development that balances economic, environmental, and social goals to safeguard the future. Among the various methodologies employed for sustainability assessment, Life Cycle Sustainability Assessment (LCSA) stands out. LCSA integrates economic (LCC), environmental (E-LCA), and social (S-LCA) perspectives, a pivotal challenge within this paradigm is encapsulated in LCSA methodology, where the integration and effective communication of three sustainability indicators (social, environmental, and economic) to decision-makers pose considerable obstacles (Guinée, 2015). yet its complexity often hinders effective communication with decision-makers. As elucidated by Morel et al., (2018), monetization offers a pragmatic bridge across the disparate realms of environmental, social, and economic evaluation, facilitating a unified monetary framework that enables direct comparison and more nuanced decision-making processes. Historically rooted in policy analysis through cost-benefit assessments since the early 20th century in the United States, monetization has evolved from a research concept to a standardization practice. However, there is currently a gap in the application of monetization to the three indicators of sustainable development and the combined assessment of sustainability. This study aims to leverage monetization as a tool to make sustainability assessments more intuitive and actionable for stakeholders and decision-makers, thereby contributing to the broader quest for sustainable human development. This study leverages monetization to bridge these divides, providing a unified monetary perspective that enhances decision-making and stakeholder engagement.

Literature Review

Monetization in environmental sustainability merges market and non-market values to capture the full economic impact of environmental and social effects. While market values are directly observable, non-market values—such as improvements in human health and environmental quality—are less tangible and often overlooked in policy-making. This review evaluates current methodologies for integrating these values into life cycle assessments, drawing on a range of studies that address both the potential and challenges of these approaches. Special attention is given to methodologies like willingness to pay (WTP), which has been identified as a versatile and widely applicable method for reflecting diverse stakeholder preferences.

Terms of monetization are related to total economic value, which has two components: market value and non-market value. non-market value means that value is not reflected in the market price. However, non-market value denotes an item's worth that is not represented by its market price. However, non-market value is significant since preserving improvements in human health and well-being depends more on the condition of our surroundings. The air we breathe, the water we drink, and the rivers and lakes where we go for pleasure all influence our physical and mental health differently. Markets, however, do not price these valuable services of a clean environment and a natural setting. As a result, they frequently go unnoticed by certain policymakers, who incorrectly think that market revenues or local jobs are the only things that matter. However, because clean and natural settings are helpful, individuals do profit economically from them. Environmental quality is becoming increasingly significant to us due to our rising wages and decreasing availability of natural surroundings (Loomis, 2005).

This paper reviews methods such as total economic value, which encompasses market and non-market values. Non-market values, crucial for reflecting benefits like environmental quality and human well-being, often remain unpriced and undervalued in policy decisions. To convert environmental impact into uniform, standardized financial terms, the idea of monetization emerged (García-Gusano et al., 2018). Numerous environmental categories are compiled by life cycle indicators from hundreds of life cycle inventories. For example, life cycle endpoint indicators are developed using rigorous ecological methodologies to address a range of environmental concerns, including impairment to human health, ecosystem diversity, and resource availability. Unfortunately, it is challenging to combine various endpoint metrics into a single measure. Consequently, the integration of monetized life cycle indicators in the context of environmental and social management, which has never been undertaken, may make it easier to evaluate the results of LCA and offer useful advice for policymakers (Algunaibet et al., 2019). Highlight the challenges and potential of using monetized life cycle indicators for better policy guidance.

From a policy standpoint, there aren't enough trade-offs and sustainability when measuring environmental effects or harm in physical units or even dimensionless fractions. Consequently, monetizing environmental consequences will enhance the conversation, particularly in decision-making (Kaenchan & Gheewala, 2017). Environmental impact monetization refers to efforts to economically quantify the environmental harm produced by a product or process and reflect it in monetary terms (Krieg et al., 2013). Classic examples are contingent valuation, hedonistic pricing, and WTP (Li et al., 2017)

This paper tries to use a critical literature review to understand the current study of sustainability indicator monetization, try to find a gap and intersection between sustainability indicators, and result in getting new methodology farmwork of LCSA to implement the weaknesses and gaps.

Methodology

This paper used a critical literature review to study the current study of life cycle assessment monetization; and social life cycle assessment monetization. A critical literature review, according to (Del Vecchio et al., 2023), is an effective strategy for comprehending objectives that attempt to synthesize prior information on a particular area of interest and offer fresh research options. Using Scopus, separate searches with the following four search terms: “life cycle assessment monetization”; “LCA monetization”; “social life cycle assessment monetization”; and “S-LCA monetization” search was limited to the publication title, abstract, and keywords. Analyze each article and delete irrelevant articles.

Results and Discussions

A comprehensive literature evaluation on the commercialization of social and environmental aspects within life cycle assessments (LCAs) is employed in this work. Current study used keywords like "life cycle assessment monetization" and "S-LCA monetization" search Scopus and filter papers that were relevant based on keywords, abstracts, and titles. Every chosen article was examined to determine the most appropriate monetization strategies and to evaluate their applicability and influence on sustainability evaluations.

The goal of non-market valuation is to estimate the economic value of modifications to the supply or quality of goods and services (health care, education, and the environment) that are not intended for free market trade. The objective is to assess the effects of these changes on people's utility and, consequently, on social welfare in order to manage these goods and services by taking into account their true worth to society (Roussel & Tardieu, 2018). For example, different effects of human activity on the environment exist. Prioritization is required to lessen the total environmental effect since it is challenging to distinguish which consequences are the most severe without distinctive measurements. One method of dealing with this is to monetize environmental effects. The process of monetizing environmental impact involves converting the damage to the environment brought on by the exploitation of natural resources or the release of dangerous chemicals into the environment into monetary units (Arendt et al., 2020). There are many methods to combine with LCA to convert the environmental impact to monetization, One of the most popular methods is willingness to pay, but there are still some hot methods that are not based on willingness to pay, such as the ecotaxes approach, the life-cycle impact assessment method based on endpoint modeling (LIME), the discounting method, the environmental priorities strategies (EPS) method, the Stepwise 2006 method, et al. Economic value cannot be measured using techniques that are not based on willingness to pay (Bockstael et al., 2000).

In addition to the above methods, many other methods are being applied, such as Comello et al (2011), capacity to factor the ecological effects of a project into operational decisions. The link between industry and the environment was then used novelly by monetizing ecosystem services. Krieg et al (2013), created a virtual logistics firm that examined the potential for acidification and global warming using a simplex algorithm and shadow pricing. The External Costs of Energy (ExternE) project was supported by the European Commission in 1995 as a way to quantify the damage that different energy sources do to the environment and society.

Most Frequently Used Monetization Method

The Life-cycle Impact Assessment Method based on Endpoint Modeling (LIME) is a national initiative in Japan that attempts to build a database to provide industry-wide accurate LCA. Eventually, LIME will be a commonly used method for evaluating environmental impacts (Liu et al., 2021). The ultimate goal of LIME is to weigh these four protection themes—primary production, human health, social assets, and biodiversity—and assess harm at the endpoint level (Itsubo et al., 2004). The Life-cycle Impact Assessment Method based on Endpoint Modeling (LIME) is a national initiative in Japan that attempts to build a database to provide industry-wide accurate LCA. Eventually, LIME will be a commonly used method for evaluating environmental impacts (Liu et al., 2021). LIME's ultimate objective is to evaluate damage at the endpoint level and assign weights to these four protection themes: biodiversity, social assets, human health, and primary production (Itsubo et al., 2004). LIME-1 and LIME-2 were

not appropriate for evaluating the environmental effects in other nations or areas since they represented the environmental circumstances and attitudes of the Japanese people (Itsubo et al., 2012). To make LIME-1 and LIME-2's techniques more widely applicable, LIME-3 was created in 2016. Although LIME-3 addresses nine topics, such as air pollution and climate change, it cannot be said that the range of categories is sufficiently broad in comparison to other LCIA techniques. The global scale evaluation requires eutrophication, acidification, and noise to develop damage factors related to ecotoxicity and human toxicity (Inaba & Itsubo, 2018).

Discounting techniques: Using the discounting strategy to lower the monetary value of the environmental effect can aid in decision-making when there are trade-offs between current and future environmental impacts. When converting environmental effects into environmental costs, it's crucial to remember that the money needed to prevent environmental impacts and the policy objectives for reducing environmental impacts fluctuate with time, therefore the cost of pollutant harm shouldn't be stated as a set amount (Zhang, 2017). Hellweg et al (2003), developed a strategy for discounting environmental effects to take temporal aspects into account while analyzing LCA findings. They emphasized that the following elements had to be taken into account while discounting environmental impacts: Changes in the severity of the harm, pure time preferences, capital productivity, and uncertainty are listed in that order. Because of their pure temporal preferences, policymakers frequently utilize advantageous discount rates, either because they could profit from causing environmental harm to others rather than themselves or because they have little immediate concern for people in the future. Only when intermediate differential statistics are available do discounts apply. However, the idea of sustainable growth overrides the need for this time difference when extensive discharge duration are involved. Economics uses discounting to turn future expenses into present value. LCA consequences shouldn't be discounted, according to Hellweg et al (2003), discussion of discounting in connection with LCA. The question of discounting values associated with non-marketed items has long been contentious. acknowledge that reduced outcomes will result from a greater discount rate and vice versa (Arendt et al., 2020).

The Environmental Priorities Strategies (EPS) technique was one of the earliest financial valuation models created to make it easier to compare the environmental implications of various product concepts while they were being developed. The model went through several iterations between 1991 and 1992, with the most recent one being launched in 2000 (Steen, 1999). With this top-down approach, eighteen impact kinds are assigned. The four guarantee areas—biodiversity, ecological productivity, human health, and non-biological population resources—are examined to ascertain it. A variety of protected subjects, such as biodiversity, human health, resources, productivity, and aesthetic elements, are impacted by changes made to the existing global environment, according to the Environmental Accounting Standards (EPS). To minimize detrimental effects on the safeguard subjects, these implications are evaluated compared to one another in Environmental Load Units (ELU) based on willingness to pay (WTP). The WTP assesses raw material resources for alternative renewable processes in order to generate similar services. There is one Euro for every one ELU (Frischknecht et al., 2007). The EPS technique was assessed in the first evaluation by Finnveden, (1999) and contrasted with a methodology created during the External Costs of

Energy project's first financing period. There were many computation flaws discovered in the EPS approach.

Stepwise was recently developed and integrated into SimaPro software with the aim of reducing the uncertainty and incompleteness that were previously encountered in the monetization of a range of environmental consequences (Weidema, 2009). This enhanced the cost-benefit analysis's accuracy in terms of applicability and viability. Stepwise2006 combines the characteristic models of two Life Cycle Impact Assessment (LCIA) approaches, the IMPACT 2002 and the EDIP 2003 methods, to produce the characteristic results at the halfway point. The three categories of harm—human health, ecological quality, and resource productivity—are further subdivided into midway effects (Thi et al., 2016). Productivity Stepwise2006 shifts focus and examines the potential marginal costs of energy extraction from non-conventional sources (ZAMAGNI et al., 2008).

Estimating the economic worth of changes to the availability or caliber of commodities and services (health care, education, and the environment) that are not meant for free market exchange is the aim of non-market valuation. In order to manage these products and services by considering their genuine worth to society, the goal is to evaluate the consequences of these changes on people's utility and, subsequently, on social welfare (Roussel & Tardieu, 2018). For example, different effects of human activity on the environment exist. Prioritization is required to lessen the total environmental effect since it is challenging to distinguish which consequences are the most severe without distinctive measurements. One method of dealing with this is to monetize environmental effects. The process of monetizing environmental impact involves converting the damage to the environment brought on by the exploitation of natural resources or the release of dangerous chemicals into the environment into monetary units (Arendt et al., 2020).

The literature review reveals that the most frequently used monetization method in LCA and S-LCA is the willingness to pay (WTP) approach. This method estimates the economic value of environmental and social impacts by determining what individuals are willing to pay to avoid these impacts. Other methods, such as the Ecotaxes approach and the Environmental Priorities Strategies (EPS) method, provide alternative means of valuation but often lack the versatility and wide applicability of WTP, which is a very subjective indicator because it varies depending on the place, the person or organization, and the circumstance (Reap et al., 2008). Approaches based on individual revealed preferences presume that people show their choices via market activity, whereas willingness to pay is revealed through society's actions. Explicit references often only address use values, and occasionally only address direct use values (Finnveden et al., 2006). Assigning prices to external benefits and costs is a widespread practice in environmental economics (Baracskay, 1998). These virtual costs may be estimated in several ways, including using willingness to pay (WTP) and willingness to accept (WTA) surveys (Fenwick et al., 2004). The WTP approach is used by all techniques that employ contingent valuation to compute damage costs; however, no method makes use of WTA (Arendt et al., 2020).

The Popular Mothered is "Willingness to Pay."

The primary advantage of monetizing sustainability indicators, particularly through methods such as WTP, lies in translating environmental and social impacts into a unified monetary

metric. This allows for a direct and comparable assessment across different domains (environmental, social, and economic), facilitating a holistic view of sustainability impacts. Monetization also enhances stakeholder engagement by providing clear, quantifiable data that can be more readily understood and utilized in decision-making processes.

Cao et al (2012), evaluated the ecological, resource depletion, and health harm caused by Masonry Material using the WTP approach and monetization weighting criteria. Based on green taxes imposed on emissions and natural resources, weighting factors are proposed (Wu et al., 2005). The Life Cycle Assessment (LCA) weighing phase has historically been a contentious topic, in part because it calls for the inclusion of social, political, and ethical considerations. Despite the debates, weighing is frequently employed in practice (Finnveden et al., 2006).

Weighting criteria for ecological harm and resource depletion categories were developed based on the green tax on emissions and natural resources (Wu et al., 2005). Previous research employed actual societal costs assigned to each kilogram of carbon as a proxy due to the flaws in China's green tax system, decreasing the impartiality of the findings (Kong, 2010). Tong et al (2015), developed a health injury evaluation approach with quantitative injury markers. The ability of society to bear the cost of the resulting health harm is then examined using monetization analysis as the foundation for a quantitative evaluation technique. Hofstetter & Müller-Wenk (2005), used data on life expectancy, medical conditions, and allowable treatment costs to estimate the health effects of traffic noise on people.

The WTP value of each grade of ready-mixed concrete unit volume is determined using the revised environmental impact monetization weight factor after the environmental profile of ready-mixed concrete was studied and defined (Li et al., 2011). Yang et al (2017), Based on the concept of environmental efficiency, utilization pathways have undergone extensive analysis from an economic and environmental perspective. Utilizing life-cycle assessment principles, the environmental evaluation was conducted, and societal willingness to pay as a measure of environmental harm was ascertained using the monetization-weighting approach. Damages to significant insured goods that are considered by the Environmental Priorities Strategies (EPS) are assessed financially using WTP in order to avoid changes to the environmental status quo (Thi et al., 2016). The EPS technique takes into account the complete costs of creating renewable fuel alternatives to fossil fuels (i.e., the WTP for effects from emissions, resource consumption, and direct expenses) (ZAMAGNI et al., 2008). Li et al (2017), Apply the WTP and the environmental and health performance (EHP) assessment methodology to quantify the financial cost of a building's negative environmental and health impacts. A social cost of carbon (SCC) can be used to monetize carbon emissions, although it may be appropriate for the United States or a developing nation, and it might not be particularly appropriate for other emerging nations. Therefore, in order to design policies or other forms of sustainability, it is essential to research the cost of carbon or other environmental pollutants in our own nation (United states environmental environmental protection agency, 2017).

However, the accuracy and reliability of monetization methods are significant challenges. Methods like WTP are inherently subjective and can vary widely based on demographic, cultural, and economic contexts. This variability can lead to discrepancies in valuations that

may not truly reflect societal values or the real costs of environmental degradation and social impacts. Moreover, monetizing intricate ecological and social systems can oversimplify them, potentially overlooking non-quantifiable advantages like biodiversity, cultural heritage, and human well-being.

The contingent valuation method (CVM) is a straightforward approach for estimating WTP that is used for non-market valuation or difficult-to-value services, such as the widely used ecosystems method in cost-benefit analysis and environmental impact assessment (Boyer et al., 2017; Venkatachalam, 2004). The CVM avoids the requirement to use market pricing by directly requesting that people assign values to environmental assets. The CVM is a very adaptable and straightforward technique for estimating values for items and services that aren't typically priced in traditional marketplaces (Reddy, 2011). Consequently, the CVM is known as an expressed or proclaimed preference approach at times. The non-use values included in CVM might provide an explanation for this. Something does not automatically equal or add to another measure in the same unit using a different approach just because it is stated in monetary terms (Bockstael et al., 2000). Respondents are asked by CVM how they would feel about hypothetical changes to specific natural resources. CVM uses direct valuation queries concerning people's willingness to pay for environmental changes. The concept of willingness to accept is not as advised since it is often demonstrated to overestimate when compared to willingness to pay predictions, indicating that it does not accurately reflect the situation (Reddy, 2011).

The CVM process's first stage is to define the issue under consideration before moving on to a preliminary survey that involves dialogue with individuals. The actual survey is then conducted, which is a somewhat involved and drawn-out procedure. The implementation comes last, and is followed by an outcomes analysis (Nautiyal & Goel, 2021). A method for reliably ranking effect categories based on determining public choice is provided by monetary valuation (Rabl & Holland, 2008). Therefore, if a monetization weighting approach is employed, it is optimal to determine all economic values included in the weighting method using the same way. Comparing the outcomes of a monetization weighting approach with other kinds of expenses requires caution as well. The units of a monetary approach are intelligible, which facilitates judgments on the appropriateness of the elements. If the weighting components are stated in some dimensionless units, this becomes more challenging (Finnveden et al., 2006).

Suggesting Apply WTP-CVM in the LCA and S-LCA results

Examples of LCSA methods include LCC, S-LCA, and LCA. The LCSA process typically follows these steps: Step 1 involves defining the scope and objectives of the LCSA. Step 2 focuses on conducting an inventory analysis of extractions and emissions. Step 3 entails performing life cycle impact assessments for S-LCA, LCC, and LCA, followed by the monetization of LCA and S-LCA using the WTP-CVM. After monetization, the results from the environmental, economic, and social pillars can be integrated to assess the overall sustainability of the product. The proposed flow for monetizing sustainability life cycle assessment refer to Figure 1.

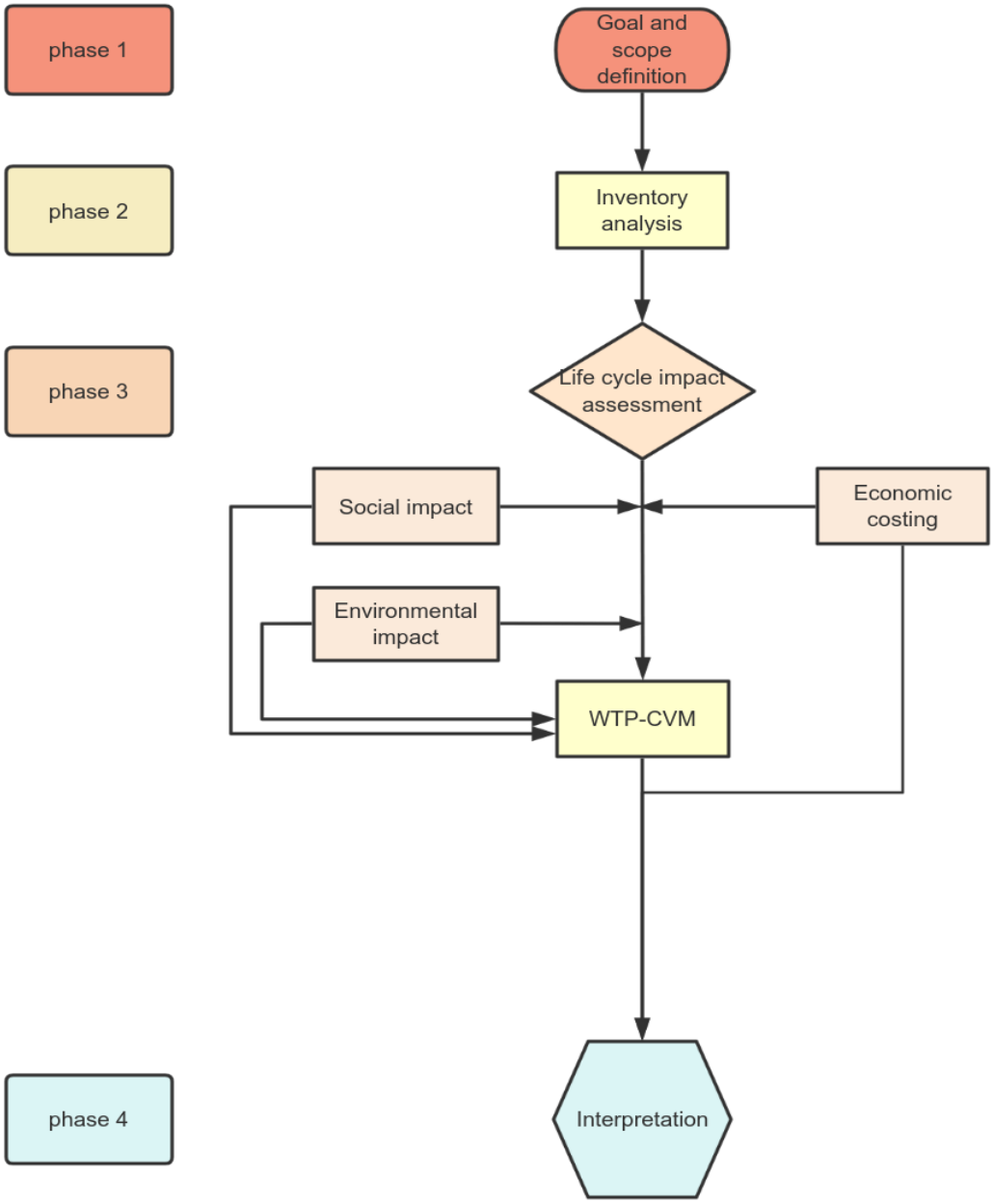

Figure 1: Proposed sustainability life cycle sustainability assessment monetization method flow

The use of WTP-CVM in sustainability assessments offers a crucial advantage by converting environmental and social impacts into a unified monetary metric. This approach enables direct comparison across different domains—environmental, social, and economic—allowing for a comprehensive evaluation of sustainability impacts. As highlighted through various empirical methodologies, monetization serves as a practical tool for assessing trade-offs and synergies between competing objectives. This is essential for aligning with balanced, sustainable development goals. Moreover, monetization enhances stakeholder engagement by presenting clear, quantifiable data that is easier to interpret and apply in decision-making processes. By assigning economic value to environmental and social factors, stakeholders can better understand the full range of costs and benefits associated with their decisions, which might otherwise be underestimated or overlooked.

Conclusion and Recommendation

This analysis confirms the critical role of monetization methods, particularly WTP, in improving the applicability and relevance of LCSA in decision-making processes. Converting environmental and social impacts into monetary terms enables stakeholders to better evaluate the costs and benefits of various actions.

By translating complex environmental and social impacts into monetary terms, stakeholders can more effectively evaluate the trade-offs and benefits of various actions.

This research significantly advances the field of LCSA by integrating monetization methods, specifically the CVM for estimating WTP. Theoretically, it bridges the gap between environmental, social, and economic assessments by converting diverse sustainability impacts into a unified monetary metric. This monetization enables more precise and comparable evaluations across different domains, thus contributing to the broader literature on sustainable product development and environmental economics.

Contextually, this study provides practical tools for policymakers and stakeholders by offering a standardized approach to assess sustainability. The integration of WTP, tailored to geographic and socio-economic factors, ensures that sustainability assessments better reflect localized priorities and conditions. This research is timely and significant given the increasing global focus on sustainable development, and it plays a critical role in enhancing decision-making processes, particularly in regions where environmental and social impacts are often undervalued or overlooked. The findings contribute to both academic knowledge and real-world applications, enabling more sustainable practices across industries.

Future research should focus on incorporating these methods into broader sustainability frameworks to further validate and refine their application. Currently, the social life cycle assessment (S-LCA) monetization approach remains underexplored, with limited research on applying its results to socio-economic cost methodologies and WTP-CVM surveys. In the case of environmental life cycle assessments (LCA), several techniques such as Ecotaxes, WTP-CVM, endpoint modeling, discounting, and environmental priority strategies have been employed to monetize outcomes. However, research on monetizing all three sustainability pillars—social, environmental, and economic—remains limited. Since economic impacts are inherently quantified, only environmental and social dimensions require monetization. WTP-CVM serves as a key intersection between the monetization of environmental and social impacts, considering geographic, social, and contextual factors. It is particularly well-suited

for studies focusing on these variables. Future research should explore WTP-CVM in sustainability assessments, especially for evaluating new products or processes. This approach can provide clearer insights for consumers, business managers, and designers into product sustainability. Additionally, interdisciplinary research combining economics, environmental science, and social science is essential to develop more robust methods that capture the complexities of sustainability without oversimplifying critical impacts.

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References

Algunaibet, I. M., Pozo, C., Galán-Martín, Á., & Guillén-Gosálbez, G. (2019). Quantifying the cost of leaving the Paris Agreement via the integration of life cycle assessment, energy systems modeling and monetization. *Applied Energy*, *242*, 588–601. https://doi.org/10.1016/J.APENERGY.2019.03.081

Arendt, R., Bachmann, T. M., Motoshita, M., Bach, V., & Finkbeiner, M. (2020). Sustainability Comparison of Different Monetization Methods in LCA: A Review. *Sustainability,12* (24),10494 https://doi.org/10.3390/su122410493

Ashraf, S. A., Siddiqui, A. J., Elkhalifa, A. E. O., Khan, M. I., Patel, M., Alreshidi, M., Moin, A., Singh, R., Snoussi, M., & Adnan, M. (2021). Innovations in nanoscience for the sustainable development of food and agriculture with implications on health and environment. *Science of The Total Environment*, *768*, 144990. https://doi.org/10.1016/J.SCITOTENV.2021.144990

Baracskay, D. (1998). *Cost-Benefit Analysis: Concepts and Practice*.

Bockstael, N. E., Freeman, A. M., Kopp, R. J., Portney, P. R., & Smith, V. K. (2000). On Measuring Economic Values for Nature. *Environmental Science and Technology*, *34*(8), 1384–1389. https://doi.org/10.1021/ES990673L

Boyer, T. A., Hopkins, M., & Moss, J. Q. (2017). Willingness to Pay for Reclaimed Water: A Case Study for Oklahoma. *Competition for Water Resources: Experiences and Management Approaches in the US and Europe* (PP. 261–277). https://doi.org/10.1016/B978-0-12-803237-4.00015-X

Cao, X., Li, X., & Hu, Y. (2012). Life cycle assessment of EI of masonry materials. *Advanced Materials Research*, *347–353*, 4055–4061. https://doi.org/10.4028/WWW.SCIENTIFIC.NET/AMR.347-353.4055

Comello, S. D., Lepech, M. D., & Schwegler, B. R. (2011). Project-level assessment of environmental impact: Ecosystem services approach to sustainable management and development. *Journal of Management in Engineering*, *28*(1), 5–12. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000093

Del Vecchio, P., Secundo, G., & Garzoni, A. (2023). Phygital technologies and environments for breakthrough innovation in customers and citizens journey. A critical literature review and future agenda. *Technological Forecasting and Social Change*, *189*, 122342. https://doi.org/10.1016/J.TECHFORE.2023.122342

Fenwick, E., O'Brien, B. J., & Briggs, A. (2004). Cost-effectiveness acceptability curves – facts, fallacies and frequently asked questions. *Health Economics*, *13*(5), 405–415. https://doi.org/10.1002/HEC.903

Finnveden, G. (1999). A critical review of operational valuation/weighting methods for life cycle assessment. *Preparation. På Uppdrag Av AFN Vid Naturvårdsverket*.

Finnveden, G., Eldh, P., & Johansson, J. (2006). Weighting in LCA based on ecotaxes: Development of a mid-point method and experiences from case studies. *International Journal of Life Cycle Assessment*, *11* (Special Issue 1), 81–88. https://doi.org/10.1065/LCA2006.04.015/METRICS

Frischknecht, R., Jungbluth, N., Althaus, H.-J., Bauer, C., Doka, G., Dones, R., Hischier, R., Hellweg, S., Humbert, S., Köllner, T., Loerincik, Y., Margni, M., & Nemecek, T. (2007). *Implementation of life cycle impact assessment methods* (*Ecoinvent Report No. 3, v2.0.*). Swiss Centre for Life Cycle Inventories.

García-Gusano, D., Istrate, I. R., & Iribarren, D. (2018). Life-cycle consequences of internalising socio-environmental externalities of power generation. *Science of The Total Environment*, *612*, 386–391. https://doi.org/10.1016/J.SCITOTENV.2017.08.231

Guinée, J. (2015). Life cycle sustainability assessment: What is it and what are its challenges? *In taking stock of industrial ecology* (pp. 45–68). Springer International Publishing. https://doi.org/10.1007/978-3-319-20571-7_3

Hellweg, S., Hofstetter, T. B., & Hungerbühler, K. (2003). Discounting and the environment: Should current impacts be weighted differently than impacts harming future generations? *International Journal of Life Cycle Assessment*, *8*(1), 8–18. https://doi.org/10.1007/BF02978744/METRICS

Hofstetter, P., & Müller-Wenk, R. (2005). Monetization of health damages from road noise with implications for monetizing health impacts in life cycle assessment. *Journal of Cleaner Production*, *13*(13–14), 1235–1245. https://doi.org/10.1016/J.JCLEPRO.2005.05.011

Inaba, A., & Itsubo, N. (2018). Preface. *The International Journal of Life Cycle Assessment*, *23*(12), 2271–2275. https://doi.org/10.1007/s11367-018-1545-6

Itsubo, N., Sakagami, M., Kuriyama, K., & Inaba, A. (2012). Statistical analysis for the development of national average weighting factors—Visualization of the variability between each individual's environmental thoughts. *The International Journal of Life Cycle Assessment*, *17*(4), 488–498. https://doi.org/10.1007/s11367-012-0379-x

Itsubo, N., Sakagami, M., Washida, T., Kokubu, K., & Inaba, A. (2004). Weighting across safeguard subjects for LCIA through the application of conjoint analysis. *International Journal of Life Cycle Assessment*, *9*(3), 196–205. https://doi.org/10.1007/BF02994194/METRICS

Kaenchan, P., & Gheewala, S. H. (2017). Budget constraint and the valuation of environmental impacts in Thailand. *International Journal of Life Cycle Assessment*, *22*(11), 1678–1691. https://doi.org/10.1007/S11367-016-1210-X/TABLES/5

Kong XQ. (2010).*Research on the health damage assessment model of building during the life cycle.* Master's thesis, Tsinghua University, Beijing, China

Krieg, H., Albrecht, S., & Jäger, M. (2013). Systematic monetisation of environmental impacts. *Transactions on Ecology and The Environment*, *173*, 1743–3541. https://doi.org/10.2495/SDP130431

Li, X., Su, S., & Zhang, Z. (2017). An integrated environmental and health performance quantification model for pre-occupancy phase of buildings in China. *Environmental*

Impact Assessment Review, 63, 1–11. Elsevier. https://doi.org/10.1016/j.eiar.2017.03.005

Liu, C., Dong, H., Cao, Y., Geng, Y., Li, H., Zhang, C., & Xiao, S. (2021). Environmental damage cost assessment from municipal solid waste treatment based on LIME3 model. *Waste Management*, *125*, 249–256. https://doi.org/10.1016/J.WASMAN.2021.02.051

Loomis, J. (2005). Economic Values without Prices: The Importance of Nonmarket Values and Valuation for Informing Public Policy Debates.*Choices: The Magazine of Food, Farm, and Resource Issues, 20*(3), 179–182.

Morel, S., Traverso, M., Preiss, P., Morel, S., Traverso, M., & Preiss, P. (2018). Discussion panel—assessment of externalities: monetisation and social LCA. *Designing Sustainable Technologies, Products and Policies*, (PP. 391–396). https://doi.org/10.1007/978-3-319-66981-6_43

Nautiyal, H., & Goel, V. (2021). Sustainability assessment: Metrics and methods. *Methods in Sustainability Science: Assessment, Prioritization, Improvement, Design and Optimization*, (PP. 27–46). https://doi.org/10.1016/B978-0-12-823987-2.00017-9

Plat, J., Baumgartner, S., Vanmierlo, T., Lütjohann, D., Calkins, K. L., Burrin, D. G., Guthrie, G., Thijs, C., Te Velde, A. A., ACE, V., Sverdlov, R., Garssen, J., Wouters, K., Trautwein, E. A., Wolfs, T. G., van Gorp, C., Mulder, M. T., Riksen, N. P., Groen, A. K., & Mensink, R. P. (2019). Plant-based sterols and stanols in health & disease: "Consequences of human development in a plant-based environment?" *Progress in Lipid Research*, *74*, 87–102. https://doi.org/10.1016/J.PLIPRES.2019.02.003

Rabl, A., & Holland, M. (2008). Environmental assessment framework for policy applications: Life cycle assessment, external costs and multi-criteria analysis. *Journal of Environmental Planning and Management, 51*(1), 81–105. https://doi.org/10.1080/09640560701712275

Reap, J., Roman, F., Duncan, S., & Bras, B. (2008). A survey of unresolved problems in life cycle assessment. *The International Journal of Life Cycle Assessment, 13*(5), 374–388. https://doi.org/10.1007/S11367-008-0009-9

Reddy, V. R. (2011). Economic Analysis of Health Impacts in Developing Countries. *Encyclopedia of Environmental Health* (pp. 197–206). Elsevier. https://doi.org/10.1016/B978-0-444-52272-6.00414-1

Roussel, S., & Tardieu, L. (2018). Non-market Valuation. *Encyclopedia of Law and Economics* (pp. 1–5). Springer. https://doi.org/10.1007/978-1-4614-7883-6_712-1

Song, M., Chen, Y., & An, Q. (2018). Spatial econometric analysis of factors influencing regional energy efficiency in China. *Environmental Science and Pollution Research*, *25*(14), 13745–13759. https://doi.org/10.1007/S11356-018-1574-5/METRICS

Steen, B. (1999). *Centre for Environmental Assessment of Products and Material Systems A systematic approach to environmental priority strategies in product development (EPS). Version 2000-General system characteristics.* Centre for Environmental Assessment of Products and Material Systems.

Thi, T. L. N., Laratte, B., Guillaume, B., & Hua, A. (2016). Quantifying environmental externalities with a view to internalizing them in the price of products, using different monetization models. *Resources, Conservation and Recycling*, *109*, 13–23. https://doi.org/10.1016/J.RESCONREC.2016.01.018

Tong, R., Zhai, Y., Case, X. L.-V. C. P. A., & 2015, U. (2015). An LCA-base**d h**ealth damage evaluation method for coal mine dust. Retrieved from https://books.google.com.

United states environmental environmental protection agency. (2017). The Social Cost of Carbon . Retrieved from https://19january2017snapshot.epa.gov/climatechange/social-cost-carbon_.html

Venkatachalam, L. (2004). The contingent valuation method: A review. *Environmental Impact Assessment Review*, *24*(1), 89–124. https://doi.org/10.1016/S0195-9255(03)00138-0

Weidema, B. P. (2009). Using the budget constraint to monetize impact assessment results. *Ecological Economics*, *68*(6), 1591–1598. https://doi.org/10.1016/J.ECOLECON.2008.01.019

Wu, X., Zhang, Z., Environment, Y. C.-B. and, & 2005, U. (2005). Study of the environmental impacts based on the “green tax”—Applied to several types of building materials. *Elsevier*.

Li, X., Wang, S., Kong, X., & Zhang, Z. (2011). Life cycle assessment of environmental impacts of ready-mixed concrete. Retrieved from https://www.researchgate.net/publication/279574297_Life_cycle_assessment_of_environmental_impacts_of_ready-mixed_concrete

Yang, S., Lin, L., Li, S. P., Li, Q., Wang, X. T., & Sun, L. (2017). Assessment and comparison of three high-aluminum fly ash utilization scenarios in Inner Mongolia, China using an eco-efficiency indicator. *Waste Management & Research,35*(5), 515–524. https://doi.org/10.1177/0734242X16686172

Zamagni, A., Buttol, P., Porta, P. L., Buonamici, R., Masoni, P., Guinée, J., Heijungs, R., Ekvall, T., Bersani, R., Bienkowska, A., & Pretato, U. (2008). Critical Review of the Current Research Needs and Limitations Related to ISO-LCA Practice.

Zhang, Y. (2017). Taking the Time Characteristic into Account of Life Cycle Assessment: Method and Application for Buildings. *Sustainability 9*(6), 922. https://doi.org/10.3390/SU9060922