

# Life Cycle Assessment (LCA) Method As Environmental Law Enforcement In Green Economic Development

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## ABSTRACT

Apart from having the impact of rapid economic growth, rapid economic growth will optimize production factor inputs and generate abundant national income, but it also leaves negative effects on the environment due to residues in the economic process which have an impact on environmental degradation and damage. To find out the existence of Life Cycle Assessment in environmental preservation and Life Cycle Assessment to encourage environmentally sound development. The method used is descriptive qualitative by collecting literature studies and basing it on data analysis literature using systematic literature review techniques. Life Cycle Assessment (LCA) is a methodology used to assess the environmental impact of all stages in the life cycle of a product, from raw material extraction, production, distribution, use, to final processing or recycling. This method provides a comprehensive picture of the total environmental footprint of a product or service. Environmentally sound development is a conscious and planned effort to use and manage resources wisely in planned and sustainable development to improve the quality of human life. This perspective on sustainable development must be understood as an ethic in development politics, namely a moral commitment to organizers in development, carried out to achieve goals without sacrificing other aspects.

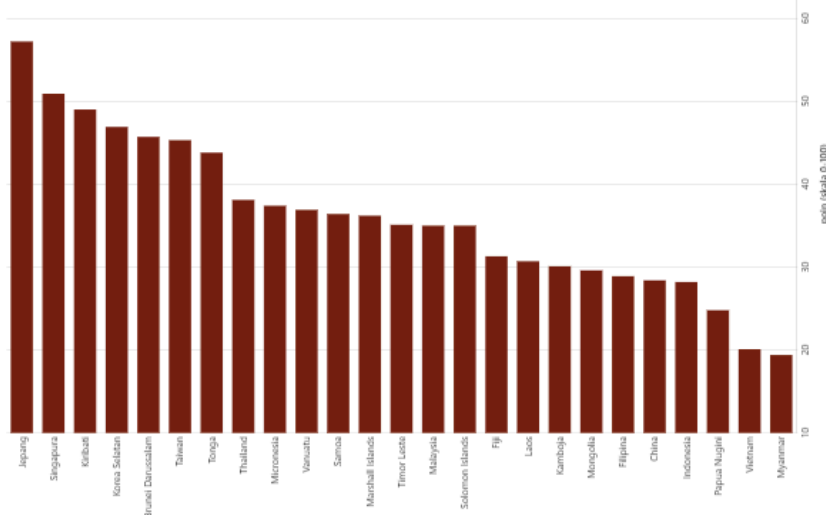
## KEYWORDS

Life Cycle Assessment, Economic Development, Sustainable Environment

## 1. INTRODUCTION

The economic growth of a country is characterized by an increase in total output in national income as a result of increased economic activity in that country. The higher the level of economic growth indicates that economic tools are working effectively (Ayu, P, et al, 2021). Rapid economic growth has two different sides, on the one hand fast economic growth will optimize production factor inputs and generate abundant national income. On the other hand, it will leave negative effects on the environment due to residues in economic processes which have an impact on environmental degradation and damage. Negative impacts or damage done to the environment hinder the enjoyment of these and other human rights (Tang, Ke and Otto Spijkers, 2022).

According to the Environmental Performance Index (EPI) 2022, Indonesia's environmental sustainability is classified as poor on a global scale, even on the Asia Pacific regional scale. If seen on a regional scale Indonesia is ranked 22nd out of 25 Asia Pacific countries (Ahdiat, Adi, 2022). Indonesia got a score of 28.2 out of 100 and ranked 164th out of 180 countries. In this report, Indonesia received low scores for all indicators, with details of an ecosystem vitality score of 34.1, an environmental health score of 25.3, and a climate change mitigation policy score of 23.2 out of 100. EPI states that low scores are received by countries that prioritize economic growth over environmental sustainability.



**Figure 1.** Environmental Sustainability Rankings in Asia Pacific Countries 2022 (Source: databoks.katadata.co.id)

The declining quality of the environment has threatened the continuity of human life and other living creatures, so it is necessary to protect and manage the environment. Republic Act Indonesia Number 32/2009 concerning Environmental Protection and Management states that a good and healthy environment is a human right of every Indonesian citizen as mandated in Article 28H of the 1945 Constitution of the Republic of Indonesia. In addition, national economic development must be carried out based on the principles of sustainable and environmentally sound development.

With the very poor state of environmental conservation in Indonesia, it is necessary to guarantee legal certainty and provide protection for everyone's right to a good and healthy living environment. The abundance of natural resources significantly increases

environmental deterioration in the long and short run (Awosusi, Abraham A, et al. 2022).

Therefore, a Life Cycle Assessment is needed (LCA). LCA is a systematic and comprehensive methodology for assessing the environmental impact of a product or service throughout its life cycle, from raw material extraction, production, distribution, use, to final processing or disposal. LCA aims to provide a complete picture of the environmental impacts of various stages in the life cycle of a product or service, thereby enabling more sustainable decision making.

## **2. METHODOLOGY**

The method used in this research is a descriptive qualitative method by collecting literature studies or literature studies. Literature study is aimed at by searching for data and information through documents. In this research, the author bases it on data analysis literature using a systematic literature review technique, where the researcher carries out the process of identifying, assessing and interpreting a number of data related to a predetermined research theme in order to fulfill the research objectives. Thus, the data sources that researchers used in developing this research include a number of textbooks, journals, articles and proceedings on a national and international scale as well as website pages, government documents, electronic news, statutory regulations and encyclopedias.

## **3. RESULTS AND DISCUSSION**

### **3.1 The Existence of Life Cycle Assessment in Environmental Conservation**

Economic development activities in Indonesia are mostly based on natural resources. Considering that Indonesia has relatively more natural resources compared to other countries. This is why aspects of environmental protection and preservation are often neglected, giving rise to various environmental problems, such as pollution, damage to soil quality, forest damage, conversion of agricultural land and so on. Such conditions lead to a further decline in the productivity of natural resources and the environment, thereby encouraging the emergence of pockets of poverty in communities whose lives depend on these natural resources and the environment. Specifically, for an organization to be sustainable, it must be financially secure to create long-term value, it must be able to reduce the impact on the environment through its product innovations and activities, and it must adopt a strategy to generate a competitive advantage that is in line with societal expectations (Alsayegh, Maha Faisal, Rashidah Abdul Rahman, and Saeid Homyoun, 2020)

Life Cycle Assessment (LCA) is a methodology used to assess the environmental impact of all stages in the life cycle of a product, from raw material extraction, production, distribution, use, to final processing or recycling. Life cycle assessment (LCA) has been identified as a comprehensive evaluation approach (Osman, Ahmed I, et al. 2021). This method provides a comprehensive picture of the total environmental footprint of a product or service. The main objectives and benefits of implementing LCA are as follows:

**Table 1.** Benefits and Objectives of Life Cycle Assessment

No	Category	Objectives and benefits
1	Identifying and Reducing Environmental Impacts	Goal: understand and reduce the environmental impact of each stage of a product or service's life cycle. Benefits: identifying the stages with the greatest environmental impact and developing strategies to reduce them, such as reducing greenhouse gas emissions, saving energy and reducing waste.
2	Increase the Efficiency of Resource Use	Goal: optimization of use of raw materials and energy Benefits: reduces consumption of natural resources, increases production process efficiency, and reduces operational costs through more efficient use
3	Supports Environmentally Friendly Product Design	Goal: drive innovation in more sustainable product design Benefits: developing products that are easier to recycle, using more environmentally friendly raw materials, and extending product life
4	Improving Sustainable Decision Making	Goal: provide a scientific basis for more sustainable decision making Benefits: helps companies and policy makers make decisions based on accurate and comprehensive data about environmental impacts
5	Increasing Company Transparency and Accountability	Goal: increase transparency in environmental reporting Benefits: build trust with stakeholders and consumers through accurate and transparent reporting on the environmental impact of products or services.

By understanding the environmental impact of each stage of production, distribution, use and disposal, companies can identify opportunities to reduce resource consumption, emissions and waste, and develop more efficient and sustainable products. Moreover, in this case the application of LCA can be applied to various fields such as (a) Manufacturing Industry, assessing the environmental impact of the production, use and recycling of manufactured products such as electronics, automotive and textiles. Example: using LCA to identify ways to reduce CO2 emissions in a car production supply chain. (b) Energy Sector, evaluating the environmental impacts of various energy sources, including fossil fuels and renewable energy. Example: Using LCA to compare the environmental impact of a wind power plant with a coal-based power plant. (c) Construction Industry, assessing the environmental impact of building materials, construction processes and building life cycles. Examples: using LCA to select more sustainable building materials and design more energy efficient buildings. (d) Agriculture and Food, evaluating the environmental impacts of production, processing, distribution and consumption of food products. Example: using LCA to assess and

reduce the environmental impact of meat production compared to plant-based food production. (e) Transport and Logistics, assessing the environmental impact of various transport modes and supply chain optimization. Example: using LCA to design a more environmentally friendly public transportation system and reduce emissions from private vehicles.

The importance of LCA is not only limited to individual companies, but also covers entire industries and sectors. Several mechanisms help to explain the relationship between economic development and entrepreneurship (Amoros, Jose Ernesto, et al. 2019). Environmental sustainability has become the need of the hour and has been greatly emphasized because of the increased environmental awareness and resulting problems caused by negligence (Weina, An and Yang Yanling. 2022). By implementing LCA, industries can work together to reduce their overall environmental impact, leading to more sustainable and environmentally friendly production and consumption systems. With great attention to sustainable environmental preservation, LCA has the following basic principles:

**Table 2.** Basic Principles of LCA

No	Principle
1	LCA Coverage (Goal and Scope Definition)
Goal Setting	Establish the goals of the LCA, such as reducing environmental impacts or meeting sustainability standards.
System Limitations	Determine the boundaries of the system to be analyzed, namely the scope of the stages in the product or service life cycle that will be considered. This covers everything from raw material extraction to final processing or recycling
Functional Units	Establish a functional unit that is the basis for comparison, such as one kilogram of product, one liter of fuel, or one year of product use
2	Data Inventory Analysis (Life Cycle Inventory – LCI)
Data collection	Collect quantitative data on materials, energy and emissions related to all stages in the product or service life cycle
Data source	Data can come from various sources, including primary data from the production process itself, secondary data from literature or LCA databases, and tertiary data from reports or publications
3	Environmental Impact Assessment (Life Cycle Impact Assessment – LCIA)
Impact Category	Identify relevant environmental impact categories, such as global warming, ozone depletion, eutrophication, and human toxicity
Modeling Impacts	Assess environmental impacts by modeling relationships between inventory data and impact categories. This involves using scientific models to quantify the impact of emissions and resource use

4 Normalization and Scoring Assessment

Normalization	Transforming impact results into a comparable scale. This allows comparisons between different impact categories or different products.
Scoring	Assign scores or weights to different impact categories based on their importance. This helps in simplifying the results and making decision making easier

5 Interpretation of Results

Analysis of Results	Interpret LCA results taking into account the uncertainties and assumptions made during the analysis
Identify Opportunities for Improvement	Determine areas where environmental impacts can be reduced, and provide specific recommendations for process, product, or design improvements
Consistency and Traceability	Ensure that all steps in an LCA are consistent with the stated objectives and scope, and that data and assumptions can be traced back to their source

Based on the basic principles of LCA, integration between economic development and environmental development is very important to be implemented immediately. Therefore, the green economic paradigm needs to be put forward by the government in implementing natural resource management and utilization policies, to prevent environmental damage and realize fair and sustainable management and utilization of natural resources. Even though the green economy has become the mainstream of economic thinking, so far the development of the green economy in Indonesia, especially in the regions, is still at a normative level, or at least does not yet have a significant proportion in the regional economic system. The concept of a green economy has not yet fully become a reference in the regional development process. Currently, development implementation is still based on the assumption of business as usual (BUA). The industrialization and polluted logistics operations lifted environmental problems (Khan, Syed Abdul Rehman, et al. 2020).

LCA can be applied in various fields to support sustainable decision making, such as in product and process design, comparison of product or process alternatives, supply chain management, environmental labeling, and environmental policy development. By utilizing LCA appropriately, organizations and companies can move towards more sustainable and environmentally friendly practices, and help in achieving overall global sustainability goals. LCA implementation must be carried out wisely and precisely by carrying out the following stages:

**Table 3.** Stages of LCA

Stage 1	Definition of Goals and Scope		
1.a	Determining the Goals and Scope of the LCA Study	Objective	Establish the primary objectives of the LCA study, such as identifying opportunities for environmental improvement, meeting regulatory requirements, or providing information for strategic decision making

		Scope	Determine the scope of the study, including the type of product or service to be analyzed, the life cycle stages to be covered, and the geographic or temporal boundaries of the study
1.b	Identify the Product System to be Analyzed	Product System	Defines the product system in detail, including components, production processes, distribution, use, and end-of-life of the product.
		Product Function	Determine the functional unit that will be used as a basis for comparison in the LCA study, for example one kilogram of product, one unit of product, or product usage for one year
1.c	Setting System Boundaries and What to Count in LCA	System Limitations	Determining system boundaries, namely determining which processes will be included and excluded in the analysis, such as cradle-to-gate (from raw materials to the product leaving the factory) or cradle-to-grave (from raw materials to the end of product life) boundaries.
		Scope of Analysis	Determine the types of environmental impacts that will be calculated, such as greenhouse gas emissions, energy use, water use, and waste
Stage 2	Data Inventory		
2.a	Collect Data on Input and Output from Each Stage of	Inventory Data	Collect quantitative data on raw materials, energy, and emissions associated with each stage of the product

	the Product Life Cycle		life cycle, including production, distribution, use, and disposal
		Data source	Identify relevant data sources, such as LCA databases, data from suppliers, surveys, and scientific literature
2.b	Determine data sources and data collection methods	Data source	Using primary data sources (data directly from the process or product) and secondary (data from literature, databases or previous reports)
		Collection Method	Use appropriate methods to collect data, such as direct measurements, surveys, interviews, or literature analysis

2.c	Processing and Validating Collected Data	Data processing	Organize collected data into a format suitable for LCA analysis, including normalization and data aggregation
		Data validation	Ensure data validity and accuracy by verifying and validating data sources and collection methods
Stage 3	Impact Assessment		
3.a	Categorizing and Classifying the Environmental Impact of Products	Classification	Group inventory data into environmental impact categories, such as climate change, ozone depletion, human toxicity, eutrophication, and acidification
		Impact Category	Identify impact categories relevant to the aim and scope of the study
3.b	Calculating Environmental Impacts Using Appropriate Methods	Characterization	Calculate the magnitude of the environmental impact in each impact category based on inventory data and relevant impact models
		Impact Model	Using appropriate impact assessment methods, such as ReCiPe, TRACI, or CML, to quantify environmental impacts
3.c	Interpreting Impact Assessment Results	Interpretation	Interpret the results of impact assessments by identifying the life cycle stages that make the greatest contribution to environmental impacts
		Sensitivity Analysis	Conduct sensitivity analysis to understand the influence of data uncertainty and assumptions on impact assessment results
Stage 4	Interpretation and Conclusion		
4.a	Interpreting LCA Results Comprehensively	Comprehensive Analysis	Interpret the overall results of the LCA study by considering all impact categories and life cycle stages
		Linkages	Assess the relationship between LCA results and the aim and scope of the study



4. b	Drawing Conclusions about the Environmental Impact of Products	Main Conclusion	Draw conclusions about the environmental impact of the analyzed product or service, including the most impactful stages and areas requiring improvement
		Recommendation	Identify recommendations to reduce environmental impacts, such as changes in product design, use of alternative materials, or increased energy efficiency
4.c	Providing Recommendations for Product Improvement and Development	Improvement Strategy	Develop strategies for environmental improvement based on LCA results, including the development of new, more environmentally friendly products and improving production processes
		Implementation	Prepare implementation plans to adopt recommendations for improvement and ensure sustainable actions in managing environmental impacts

Example of Application of Life Cycle Assessment (LCA) for Green Buildings, the aim is to assess the environmental impact of a green building during its life cycle. The process is carried out in several stages, (1) Stage 1: Definition of Objectives and Scope - Determine the objectives of the study, such as evaluating the effectiveness of green building design in reducing energy consumption and waste, and determine the scope, including design, construction, use and maintenance building. (2) Stage 2: Data Inventory – Collect data on building materials, construction processes, energy used, and waste management, (3) Stage 3: Impact Assessment – Calculate the environmental impacts of green buildings, such as CO2 emissions, water use, and construction waste, and (4) Stage 4: Interpretation and Conclusion – Analyze LCA results to understand the relative contribution of each stage of the green building life cycle to environmental impacts, and provide recommendations for design improvements and more sustainable construction practices.

By considering the environmental impact of a product or service from the beginning to the end of its life cycle, LCA provides deep insights to support wiser and more sustainable decisions. Therefore, the application of Life Cycle Assessment must be encouraged in various industries and sectors. In this way, we can create a more sustainable world, where products and services not only meet today's needs, but also protect the environment for future generations.

### 3.2 Life Cycle Assessment Encourage Environmentally Conscious Development

Development is a process of processing natural resources and utilizing human resources by utilizing technology. It requires very thorough and integrated planning by taking into account all points of view and perceptions that influence each other in implementing this development. Apart from that, development also needs to pay

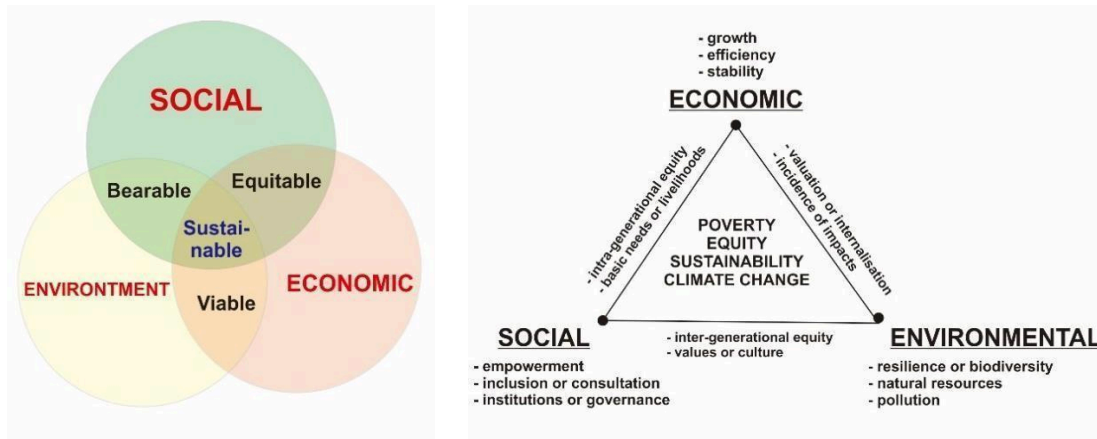
attention to existing environmental conditions, in terms of physical (land, water, air), biotic (flora, fauna), and cultural (culture, interactions between people). Environmental quality conditions will tend to continue to decline if it is not balanced with the concept of sustainable development planning in an effort to preserve existing environmental functions. It is fully realized that development activities, especially those of a physical nature and related to the use of natural resources, clearly contain risks of changes in the ecosystem. The economic policy uncertainty affects the economic agents' behavior such as consumption and investment decisions (Ayad, Hicham, et al. 2023). Furthermore, these changes will result in impacts, both negative and positive. Therefore, the development activities carried out should not only have a social and economic perspective but also an environmental perspective.

Environmentally sound development is a conscious and planned effort to use and manage resources wisely in planned and sustainable development to improve the quality of human life. Implementing environmentally sound development and controlling the wise use of natural resources is the main objective of environmental management. Sustainable development is closely related to environmental management programs and policies. Environmental problems are treated as sectoral problems that seem to have a world of their own. As a sector, it is often contrasted with development, so that people seem to be faced with a choice between "environment" and "development". The term of "sustainability" and the concept of "sustainable architecture" are currently trending in the architecture's frame and design for at least two specific purposes: formal and functional (Bungau, Constantin C., et al. 2022). In fact, the environment is a problem that is interrelated with development. The nature of the interdependence found in the environment cannot make the environment a separate sector, so it is felt necessary to look for a range of problems that link the environment and development.

Life Cycle Assessment (LCA) is a methodology used to assess the environmental impact of all stages in the life cycle of a product, from raw material extraction, production, distribution, use, to final processing or recycling. The common measurement tool in the field of environmental sustainability is life cycle assessment (LCA) (Lueddecens, Stefan. 2020). With methods that pay attention to environmental sustainability, this can be used as a basis for carrying out sustainable development. The concept of sustainable development or better known as sustainable development is a development process (land, cities, business, society, etc.) which has the principle of "meeting current needs without sacrificing meeting the needs of future generations". LCA has been applied in policy development and implementation in several countries, including the USA (Sala, Serenella. 2021).

Environmentally sound development can be measured for its sustainability based on 3 (three) criteria, namely: a. no wasteful use of natural resources or; b. no pollution and other environmental impacts; and c. Activities must be able to increase useable resources or replaceable resources. Sustainable development with an environmental perspective requires solid integration and coordination between the use of natural resources, human resources and artificial resources over a period of time, spatial dimensions and in a coordinated manner so that they are appropriate, effective and efficient. An overview of a sustainable development scheme that is interconnected between the three pillars, namely the economic, social and environmental pillars (Figure A). At the meeting point of these three pillars, we further explore the concept of sustainable development by stating that "...cultural diversity is as important for humans as biodiversity is for nature". Thus "development is not only understood as economic development, but also as a tool to achieve intellectual, emotional, moral and spiritual

satisfaction". In this view, cultural diversity is the fourth policy in the scope of sustainable development policy. The relationship between the 3 (three) pillars is based on the 3 (three) pillars/dimensions of Sustainable Development (Figure B).



**Figure 2.** Interrelationship of Economic, Social and Environmental Pillars in Sustainable Development and Sustainable Development Triangle (Source: www.textiletoday.com.bd)

Sustainable development is referred to as the relationship between environmental, social and economic aspects known as the "three pillars" of sustainability. In sustainable development there is a balance between natural resources and improving human standards of living and preserving them for the future. Sustainable development is directly or indirectly related to factors that influence our daily lives, natural problems and environmental aspects. The sustainable development process is oriented towards the global economy, natural problems and human life. Therefore, everyone must participate in the sustainable development process.

Integrated environmental conservation efforts related to environmental management include planning, utilization, control, maintenance, supervision and law enforcement. If everything is not implemented properly, then the law will act. Criminal law enforcement in this Law introduces the threat of a minimum sentence in addition to the maximum, expansion of evidence, punishment for violations of quality standards, integrated criminal law enforcement, and regulation of corporate crimes. Enforcement of environmental criminal law continues to comply with the ultimum remedium principle which requires criminal law enforcement to be implemented as a last resort after the implementation of administrative law enforcement is deemed unsuccessful. The application of the ultimum remedium principle only applies to certain formal criminal acts, namely punishment for violations of waste water quality standards, emissions and disturbances. Because according to Article 2 of Law of the Republic of Indonesia Number 32 of 2009 concerning Environmental Protection and Management, it is explained that "Environmental protection and management is carried out based on the principles of: state responsibility; sustainability and sustainability; harmony and balance; cohesiveness; benefit; caution; justice; ecoregion; biodiversity; polluters pay; participative; local wisdom; good governance; and regional autonomy.

This perspective on sustainable development must be understood as an ethic in development politics, namely a moral commitment to organizers in development, carried out to achieve goals without sacrificing other aspects. LCA is increasingly being

applied to evaluate the environmental mental impacts of buildings during the design phase. (Fnais, Abdulrahman, et al. 2022). Sustainable development is not only about maintaining the quality of the environment, or how economic development can run properly. Sustainable development covers overall development and how development is carried out, without sacrificing other aspects.

#### 4. CONCLUSION

Life Cycle Assessment (*LCA*) is a methodology used to assess the environmental impact of all stages in the life cycle of a product, from raw material extraction, production, distribution, use, to final processing or recycling. This method provides a comprehensive picture of the total environmental footprint of a product or service. Environmentally sound development is a conscious and planned effort to use and manage resources wisely in planned and sustainable development to improve the quality of human life. This perspective on sustainable development must be understood as an ethic in development politics, namely a moral commitment to organizers in development, carried out to achieve goals without sacrificing other aspects.

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