NATIONAL PLATFORM OF LIFE CYCLE INVENTORY DATABASE IN INDONESIA

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Abstract

The national Life Cycle Inventory (LCI) database needs to be built, collaborated and integrated to harmonize LCI data, research and information systems across all stakeholders nationally. The goals of national LCI data harmonization are to: advance national data, research, and information systems by leveraging multi-agency resources and expertise; improve consistency in Life Cycle Assessment (LCA) methods developed by each institution to develop LCA results for decision-making and public disclosure; and enhance public and national institutions to access harmonized data in a standardized searchable format from a common repository. However, the low number of LCI datasets originating from Indonesia results in using other countries' LCI databases that have the potential for high errors and uncertainties and do not represent supply chain data for specific geographical locations in conducting LCA for Indonesian products. The Research Center for Sustainable Production Systems and Life Cycle Assessment (PR SPB PDH) at the National Research and Innovation Agency (BRIN), an institution tasked with establishing a national database for LCI in Indonesia, is currently entering the stage of collecting LCI datasets. This paper proposes recommendations for developing a national platform for the LCI database in Indonesia. The method used is descriptive qualitative analysis from a comparative review of national databases of various countries. The study reveals that the development that has started fulfilled several criteria. However, some requirements must still be met to become a comprehensive LCI national database.

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1. Introduction

A global action plan known as the Sustainable Development Goals (SDGs) was agreed by world leaders, which include Indonesia, agreed to achieve the target in 2030. The SDGs have four pillars consisting of 17 goals. Some of these goals include (SDGs 6) proper sanitation and clean water, (SDGs 7) clean and affordable energy, (SDGs 8) decent work and growth of the economy, (SDGs 9) infrastructure, innovation and industry, (SDGs 11) cities and settlements sustainable development, (SDGs 12) responsible consumption and production, and (SDGs 13) management of climate change (United Nations, 2015). Climate change refers to enduring temperature and weather changes resulting from anthropogenic activities. The primary consequences of climate change manifest in the escalation of the mean global temperature and the occurrence of severe and erratic meteorological phenomena (Shivanna, 2022). For this reason, Indonesia has pledged to reduce greenhouse gas (GHG) emissions by 31.89% (unconditional) and 43.20% (conditional on receiving foreign help), as stated in the Enhanced National Determined Contribution 2030 (Secretariat, 2022). It is consistent with the mandate in the Paris Agreement for a healthy environment and a good life for the global communities (Indonesia, 2021).To achieve the target of net zero emissions in Indonesia, the government has issued policies and set levels of carbon emissions through the imposition of a carbon tax, which is considered one of the progressive steps in supporting efforts to overcome the world's climate crisis. Meanwhile, the Europe (EU) and United State (US) has implemented the most extensive carbon pricing system in the world, the Emissions Trading System (ETS). A new Carbon Border Adjustment Mechanism (CBAM) has been introduced since 2021. The EU has adopted the CBAM regulation to push for the world's first carbon restriction tax on domestic and imported goods. It is planned that the tax will be collected in stages starting in 2026. CBAM would be gradually introduced for certain imports from third countries.

It takes extensive infrastructure planning to impose a carbon tax or prepare for CBAM, from carbon calculations that track carbon to the verification procedure. The requirement for a database to serve as a calculating baseline is essential. The previous efforts call for high-quality and consistent data on carbon footprints at the material/product level, i.e., emissions contained in raw materials, intermediate products, and finished goods, as well as the usage and end-of-life phases.

To improve environmental quality in 2019, the Ministry of Environment and Forestry incorporated the LCA into the Program for Pollution Control, Evaluation, and Rating (PROPER) (Life Cycle Assessment Training Materials for PROPER, 2018). Meanwhile, in a number of international sustainability requirements, such as sustainability reports (environmental, social, government) and The Task Force on Climate Related Financial Disclosures (TCFD) are asked to report scope 1,2,3 in the form of carbon footprints.

Table 1. LCI database for several countries (Institute, n.d.; Lesage & Samson, 2016; Liu et al., 2010; National Cleaner Production Centre, n.d.; Nations, n.d.; Nexus, n.d.; Praveen et al., 2019; Protocol, n Transition, n.d.; Vázquez-Rowe et al., 2019)

Country	LCI Database	Institution	Number of datasets[a]	Format[b]	Year of launch
United States of America	USLCI	Federal LCA Commons, Federal Highway Administration, US Environmental Protection Agency, National Renewable Energy Laboratory (NREL), National Energy Technology Laboratory, US Forest Service Forest Products Laboratory, CORRIM, University of Washington Design for Environment Laboratory, University of Arkansas	660003	ILCD, EcoSpold2, JSON LD, Other	2001
Australia	AusLCI	The Australian Life Cycle Assessment Society (ALCAS)	610	ILCD, EcoSpold 2, Other	2002
China	CLCD (Chinese Life Cycle Database)	Sichuan University, China; IKE Environmental Technology CO., Ltd, China	600	CLCD, Ecospold2, ILCD, Other	2009
German	ProBas (Prozessorientierte Basisdaten für Umweltmanagement-Instrumente)	German Federal Environment Agency (Umweltbundesamt)	3537	ILCD. EcoSpold2, Other	2000
Canada	Quebec LCI Database	The Inter-university Research Centre for the Life Cycle of Products, Processes, and Services (CIRAIG)	372	ILCD, EcoSpold2, Other	2010
Japan	Inventory Database for Environmental Analysis (IDEA)	Advance Industrial Science and Technology (AIST)	5011	ILCD, EcoSpold 2, Other	1998
Korea	Korea LCI Database	Korea Environmental Industry & Technology Institute (KEITI)	349	ILCD, EcoSpold 2, Other	1998
India	Indian LCA Database	National Environmental Engineering Research Institute (SSIR-NEERI)	1321	ILCD, EcoSpold 2, Other	2016
Thailand	Thai National LCI Database	National Science and Technology Development Agency (NSTDA)	542	ILCD, EcoSpold 2, Other	2002
Malaysia	Malaysia Life Cycle Inventory Database (MY-LCID)	Standard and Industrial Research Institute of Malaysia (SIRIM)	181 (public access only)	ILCD	2005
Peru	Peru LCA	Peruvian LCA and Industrial Ecology Network (PELCAN)	50	EcoSpold	2019
Brazil	Sistema de Inventário do Ciclo de Vida (SICV)	Brazilian Institute of Information in Science and Technology (IBICT)	1282	ILCD, EcoSpold 2, Other	2000
Sri Lanka	Sri Lanka LCI Database	National Cleaner Production Centre (NCPC) Srilanka	57	ILCD, EcoSpold 2, Other	2018

[a,b] number of datasets and formats included from independent providers

The LCA is a tool for evaluating sustainability consequences (environmental, social, economic) associated with various life cycle activities, including direct and indirect land use change, production, processes, operations, transportation, utilization, and disposal of products. The LCA processes, which adheres to internationally recognized standards, encompasses four key stages: (1) aim and scope definitions, (2) Analysis of Inventory, (3) Assessment of Impact, and (4) Interpretations (Ciroth & Arvidsson, 2021).

The process of data collection commences with the establishment of the aim and scope, which is subsequently pursued by the act of gathering said data. Direct measurement and secondary data are used to collect the data. The limitation of direct measurements would have cost too much and taken too long to implement. Secondary data from industry, NGOs, Governments, academics, and research reports may be obtained. However, since stakeholder standards and values differ, data collection is delicate. The LCI database also reduces data collection time and cost. Numerous endeavors have been undertaken within the Southeast Asian region to build a comprehensive national LCI database. It is worth mentioning that Thai's LCI database was established in 2002 and the Malaysian LCA project (SIRIM) was in 2006.

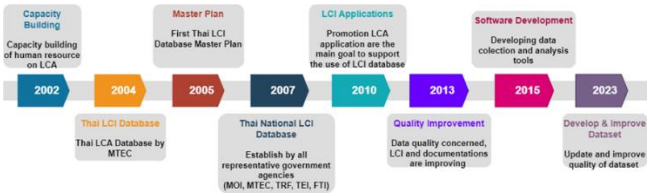

Figure 1. History of the National LCI database in Thailand (Mungkalasiri, 2023)

The structure of LCA includes four steps: identifying objectives and scope, inventory analysis, analyzing life cycle impacts, and interpreting the results (Indonesia, 2016). LCI collects information and data on processes in the researched system parameters. Data collection generally includes difficulties such as product quantity, waste, and basic system processes that enter and exit, as well as additional factors such as data quality and unpredictable distribution (Ciroth et al., 2019). Commercially available LCI is based on methods developed by other countries. Ecoinvent (primarily European data) and US-LCI (data from the United States) are two examples. However, because of differences in practice, using such databases directly for LCA research in Indonesia may yield results with low trustworthiness and high uncertainties. As a result, a nationwide LCI consisting of a collection of production data based on geographic-regional procedures is required (Wiloso et al., 2019).

In recent years, countries worldwide have promoted the advancement of LCI research by creating national LCI databases (Ciroth et al., 2019). Examples of National LCI databases of developed countries include the United States LCI (USLCI), Australian LCI (AusLCI), and Canada (Quebec LCI) databases (Kalverkamp et al., 2020). Developing countries also have national LCI databases, such as Thailand (NSTDA ThaiLCI), Malaysia (SIRIM), Brazil, Chile, Sri Lanka, and India (UNEP, 2020b). Several countries have created LCI databases in partnership with government entities (national initiatives) as well as the commercial sector/industry, non-governmental organizations (NGOs), research institutions, or universities (UNEP, 2020b). International Reference Life Cycle Data System (ILCD), JSONLD, and EcoSpold2 formats are currently the most often utilized for presenting these databases (Fritter et al., 2020). The LCI database for several countries is shown in Table 1.

Establishing a national LCI database can enhance the accessibility of regional data, bolster the capabilities of local LCA stakeholders, and promote the widespread use of LCA methodologies within the nation (UNEP, 2020b). However, Indonesia does not yet have a national LCI database (Dini, 2022). The Research Center for Sustainable Production Systems and Life Cycle Assessment (PR SPB PDH) at the National Research and Innovation Agency (BRIN) has initiated the development of the LCI database in various sectors since 2021. Previously, since 2015 Indonesian Institute of Sciences (LIPI) has built capacity building in the LCA research group, meanwhile Agency for the Assessment and Application of Technology (BPPT) sent 10 staff to Germany to study database systems, methodologies, systems and labeling standards related to LCA in 2019. In the same year the current BPPT changed to BRIN initiating a database prototype called Technology Data Inventory and Analysis (Tech-DIA) through Digital and Smart Government funding (BPPT, n.d.). In 2020, BPPT/BRIN created a 2020 National Artificial Intelligence Strategy Document which also included a roadmap for Life Cycle Assessment in Indonesia (BPPT, 2020). Research Center for Sustainable Production System and Life Cycle Assessment, which was tasked with building a national database for LCI in Indonesia, is currently entering the stage of collecting LCI datasets. This paper aims to provide recommendations for developing a national platform for the LCI database in Indonesia.

2. Methodology

This study used qualitative analysis to analyze the acquired and described data descriptively. This paper tells the current development of national databases in developed and developing countries. The structure and criteria of the LCI database are then investigated. Then, the author conducts a gap analysis by comparing the needs of the national standard LCI database with the development carried out. A table of criteria and standards for developing the national LCI database was created to assist this comparison. The mapping in the table is designed to show the unmet requirements and needs in the information gathered to develop a national LCI database. This study recommends constructing an Indonesian national LCI database platform that meets worldwide LCI database requirements.

3. Results & Discussion

The study conducts a comparative analysis of several countries' national databases in this part. Aspects were compared using elements from UNEP's national LCI

database development (UNEP, 2020a). Among the factors mentioned are database interoperability, data formats, data quality requirements and review, data needs and availability, database hosting, human resources, funding and financing, governance and management, and visions and goals.

A. Comparison of national LCI databases development

The following is a comparison of the development of national LCI (Life Cycle Inventory) databases from three countries that have previously collaborated with Indonesia.

Table 2. Comparison of national LCI database development for several countries (Hussein, 2023; Inaba, 2021; Mungkalasiri, 2023; UNEP, 2020a)

Elements	Japan	Thailand	Malaysia
Visions and goals	Defined	Defined	Defined
Governance and management	Steering committee, advisory committee, impact assessment study committee, inventory study committee, database study committee, planning sub-committee	Steering Committee, Technical Committee, Strategic Partner, Technical Support, Working Group	Project Coordinator, Impact Assessment Sub-committee, Database Sub-committee, Working Group (Sector)
Funds and financing	Government (Ministry of Economic, Trade and Industries/METI, AIST)	Government (NSTDA, Ministry of Science and Technology), External funding (Japan)	Government (through the 9th Malaysian Plan, SIRIM)
Human resources	Research institute, industry association	Research institute, industry association	Research institute, industry association, academician
Database hosting	government agencies	government agencies	government agencies
Data needs and availability	IDEA	Thai National LCI Database	MY-LCID
Data quality requirements and review	Internal review	Internal and external validation	Internal Review
Database interoperability and data format	EcoSpold 2, ILCD, Other	ILCD, EcoSpold 2, Other	ILCD

Japan is the leader in developing the national LCI database in the Asian region. Since 1995, the country has built the database. Then, it becomes a reference for developing a national LCI database in Asian countries, including Southeast Asia. Thai National LCI is the result of cooperation between Japan and Thailand in building a national LCI database. The following compares the development path for Japan's national LCI database with Thailand.

Most of the countries that are developing national LCI databases are coordinated by national research institutions such as Japan by Advance Industrial Science and Technology (AIST), Thailand by the National Science and Technology Development Agency (NSTDA), and Malaysia by Standards and Industrial Research Institute of Malaysia (SIRIM).

B. National LCI Databases Development Mapping

In this section, we map out the need for developing a national LCI database that can be adopted in Indonesia. In some cases, we refer to the criteria used by Japan and Thailand, where we have previously conducted technical cooperation with these two countries in 2022 and 2023. Thailand developed a national LCI database by justifying industries and products that contribute the most to the national gross domestic product (GDP). It is known that Thailand's largest GDP from the non-oil and gas sector comes from the portion of the agro-industry by 48%. It is reflected in the large number of agriculture and agro-product sector datasets of 47.42%. On the other hand, the most immense import value in Japan is agricultural products. It causes Japan to create inventory data for imported agricultural products and inventory data for harvests distributed in the Japanese domestic market.

The current conditions for the development of the national LCI database in Indonesia:

Visions for Indonesian LCI database: develop carbon footprint analysis and databases for major Indonesian products and exports, allowing aggregating and constructing life cycle inventories for LCAs as a national database, which facilitates the One Data Indonesia benchmark for comprehensive data on industrial production process technology and the domestic and the global supply chain network. Human resources: the human resources used in developing the national LCI database in Indonesia are now BRIN employees. Database hosting: for infrastructure, BRIN

has established and advanced the Mahameru High-Performance Computing Laboratory, which serves as a National LCI Database and is managed by Deputy for Research and Innovation Infrastructure (BRIN, n.d.). This endeavor has been accomplished by dedicated research and innovation in the fields of Applied Mathematics and Computing, as well as Artificial Intelligence and Machine Learning. Data needs and availability: data collection gain through some research and industrial projects. Agribalyse 3.0 is used as a benchmark as for the background data for the agriculture and agro-industry sectors. Data quality requirements and review: using the criteria used by the Japanese LCI database and data quality system available in OpenLCA (Ciroth Muller Weidema Lesage, and Ecoinvent Data Quality System), which includes representativeness (technology, geography, and time), which characterizes the extent to which the selected processes and products describe the system being analyzed, and the level of precision which indicates how the data was obtained and the degree of uncertainty associated. In addition, the quality of documentation and data accessibility is an important thing to do. Data formats and database interoperability: the OpenLCA format (JsonLd) is the most likely to be used because it is open source, stable, and has been used by many parties. Besides that, the documentation and guide are complete. For interoperability, it also supports various data formats of other software tools.

The process of implementing the development of the Indonesian national LCA database follows:

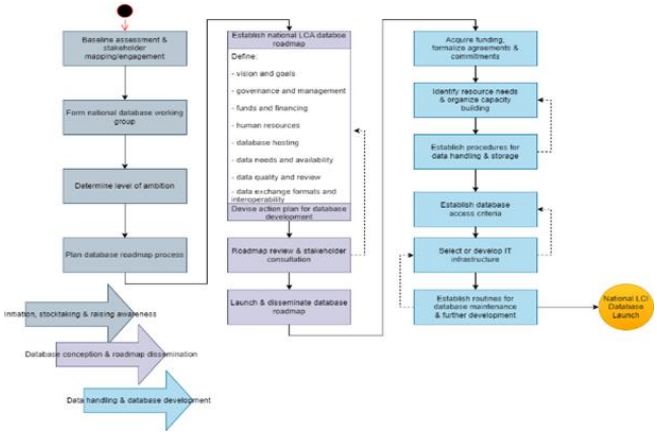

Figure 2. National LCA Database Development Process (modified from UNEP 2020)

UNEP guidelines in developing a national LCA database can be adapted by Indonesia. It provides best practices from UNEP pilot projects in various developing countries. For the development of a national LCI database in Indonesia, especially data development, the following framework can be used as a reference:

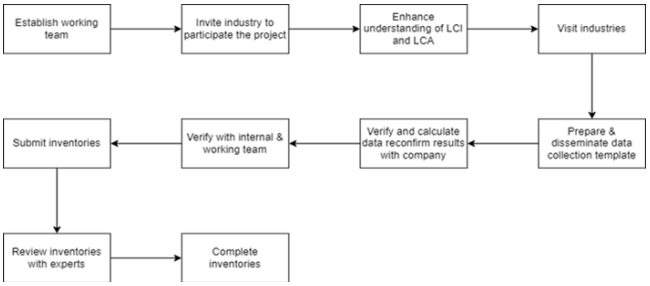

Figure 3. Data development framework (Mungkalasiri, 2023)

As shown in Figure 3 in the form of the data development flow used by Thailand. This flow allows it to be adapted in collecting datasets for LCI in Indonesia.

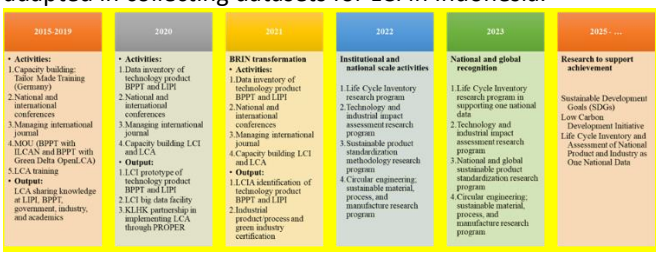

Figure 4. BRIN's Roadmap and Strategic Plan regarding the Development of Life Cycle Inventory & Assessment (LCI/A) 2015 – 2025 (Sasongko, 2022)

Figure 4 shown the road map for LCI and LCA research in Indonesia before the formation of BRIN. This research activity is led by BPPT and LIPI starting from capacity building, creating LCI prototypes to currently supporting One Data Indonesia.

To facilitate extensive participation from many stakeholders in the road mapping process, initiating Indonesia's LCA database construction involved preliminary evaluation of the existing state of LCA inside the country. The establishment of a National Database Working Group (NDWG) is essential. The NDWG membership should represent the LCA stakeholders in Indonesia and include institutions and experts that can provide resources, labor, and/or expertise for the database project. Developing the roadmap and an action plan for database development was undertaken through a series of meetings conducted by NDWG. The following stages involve obtaining stakeholder feedback and approval before finalizing the roadmap. The final steps include disseminating the roadmap and establishing an action plan to develop the database and set data processing methods. To raise awareness, support, and recognize key partners and stakeholders, developing a national LCA database is necessary. The database should be regularly updated for example, with new versions released once or twice a year.

4. Conclusion

To effectively oversee establishing and managing a national Life Cycle Inventory (LCI) database, it is imperative to establish several key entities: strategic partners, steering committee, technical committee, working group, and technical support. To establish the country database, some of the countries relied on domestic public finance and

secured several sources of international research funding, including contributions from partner countries. The current focus of the national LCI database development in Indonesia is primarily on evaluating the life cycle of national export commodities, particularly those subject to implementing the Carbon Border Adjustment Mechanism (CBAM). This endeavor holds significant potential in determining the carbon footprint of Indonesia's primary export goods.

Recommendation:

1. One of the goals is to establish a comprehensive national LCI that can serve as a reliable reference point for conducting LCA.
2. Consider a fair and affordable cost structure for certification, particularly for Micro, Small, and Medium Enterprises (MSMEs).
3. The Government may allow domestic users to access and download data in the JSON-LD, EcoSpold2, or ILCD formats.
4. The national data platform uses the open Collaboration Server application.

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