ISSN NO. 2320-5407

*Journal homepage: http://www.journalijar.com*

*INTERNATIONAL JOURNAL OF ADVANCED RESEARCH*

**RESEARCH ARTICLE**

# Approach for Environmental Data: Thai National Life Cycle Inventory Development Framework

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## *Manuscript Info*

***Manuscript History:***

Received: 17 August 2015
Final Accepted: 26 September 2015
Published Online: October 2015

***Key words:***

Life cycle assessment, Life cycle inventory, Environmental data,LCI development framework

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## *Abstract*

Life cycle assessment (LCA) is increasingly being used to evaluate the environmental impacts. However, life cycle inventory (LCI), it talks about inputs and outputs that across whole life cycle of product/process. LCI is the most vital stage for LCA, and also the environmental data in LCI can be used for other environmental assessment tools. This paper proposes the environmental data development framework, extracting from experiences and lessons learned from researchers who involved with Thai national LCI database. Interestingly, modification framework should be adopt to achieve the individual requirements, it would not be suggested that to completely follow the proposed framework. Hence, the structured environmental data is stored in the topology of LCI data architecture; it will be advantageous to apply to many environmental assessment tools. The data have been applied in various applications such as carbon footprint, environmental indicators, national emission inventories, and appliance standards.



## INTRODUCTION

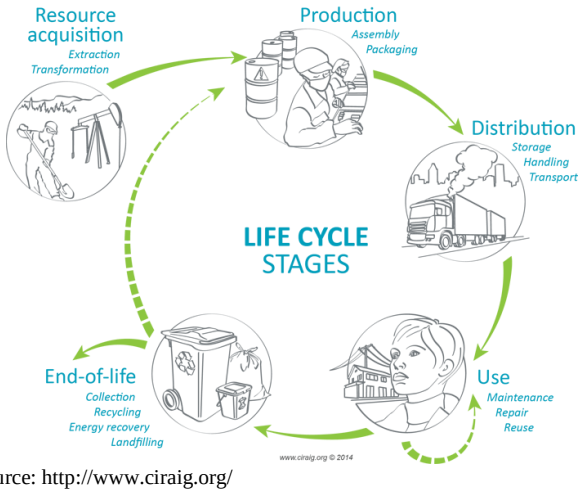
Thailand is one of the developing countries that along with an expansion of economy, the demands for natural resources and energy, have grown dramatically. Furthermore, this development causes a large release of emissions to our society that effecting environmental issues in Thailand such as air pollution, deforestation, water pollution and also climate change. Interestingly, the dramatic economic growth required an increase in demand for commercial energy, in which it leads to a large emit of emissions to the society and environment. The $CO_2$ emissions by GDP (Purchasing Power Parities: PPP) from each country (IEA, 2014), according to the statistics indicated in Table (1) confirms that we have to concern about our environment, not only used it. The result shows that the emissions trend has increased in Thailand. At the opposite side, the developed countries such as the United States, France, Germany, United Kingdom and Japan have been declined. To do so, on utilising the resources, it would be the most worthily and fruitfully directed.

Table (1): $CO_2$ emissions/GDP using PPP (unit= *kilogrammes $CO_2$ / US dollar*) (IEA, 2014)

| Country | 1971 | 1975 | 1980 | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| United States | 0.96 | 0.88 | 0.79 | 0.65 | 0.59 | 0.55 | 0.49 | 0.44 | 0.40 | 0.38 | 0.36 |
| Australia | 0.58 | 0.66 | 0.66 | 0.60 | 0.61 | 0.57 | 0.55 | 0.52 | 0.47 | 0.46 | 0.44 |
| France | 0.53 | 0.45 | 0.41 | 0.30 | 0.25 | 0.24 | 0.22 | 0.21 | 0.19 | 0.17 | 0.17 |
| Germany | 0.77 | 0.70 | 0.65 | 0.58 | 0.46 | 0.38 | 0.33 | 0.31 | 0.28 | 0.26 | 0.26 |
| United Kingdom | 0.75 | 0.64 | 0.58 | 0.50 | 0.43 | 0.36 | 0.30 | 0.27 | 0.23 | 0.21 | 0.22 |
| Japan | 0.54 | 0.51 | 0.42 | 0.34 | 0.32 | 0.32 | 0.32 | 0.31 | 0.29 | 0.30 | 0.31 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| China | 2.09 | 2.19 | 2.08 | 1.55 | 1.38 | 1.07 | 0.79 | 0.81 | 0.65 | 0.65 | 0.62 |
| Malaysia | 0.28 | 0.26 | 0.26 | 0.29 | 0.31 | 0.33 | 0.36 | 0.38 | 0.36 | 0.36 | 0.34 |
| Viet Nam | 0.34 | 0.35 | 0.29 | 0.25 | 0.19 | 0.21 | 0.24 | 0.31 | 0.37 | 0.36 | 0.37 |
| Singapore | 0.30 | 0.29 | 0.29 | 0.28 | 0.33 | 0.28 | 0.24 | 0.18 | 0.15 | 0.15 | 0.15 |
| **Thailand** | **0.20** | **0.21** | **0.22** | **0.21** | **0.25** | **0.29** | **0.31** | **0.33** | **0.31** | **0.32** | **0.32** |

In this paper emphasises one of the excellent tools – Life Cycle Assessment (LCA) to evaluate the emissions from products or processes that will affect the amount of environmental impacts. LCA, which also used "life cycle approach", "cradle to grave analysis" or "Ecobalance" (EEA, 1997), is increasingly being used to support decisions related to environmental technologies and polices, such as environmental footprinting (carbon, water, etc.), sustainable consumption and production (SCP), Green GDP, national emission inventories, and appliance standards. LCA is a powerful quantitative tool to assess environmental information of the products, also to identify and to compare the options to improve the environmental performance of products and it can be used to develop sustainable products. Obviously, LCA is a practical and useful tool that taking into account all stages of product life (whole supply chain), from extraction of raw materials to final disposition as shown in Figure (1). The complete stage of LCA is composed of 1) goal and scope definition, 2) life cycle inventory (LCI), 3) life cycle impact assessment (LCIA) and 4) interpretation (ISO, 2006a). The second stage will be highlighted, life cycle inventory (LCI), it is the skeleton of life cycle assessment because it cannot do anything without data.




Source: http://www.ciraig.org/

Figure (1): the life cycle stages

Environmental data, in this paper refers to the structured environmental data as shown in Figure (2), which illustrates the fundamental of LCI data structure. The figure demonstrates two main entities that composed of flows and process (activity). First, flows are represented inputs and outputs (including product) of the process under study. Inputs, typically, classified into three categories, resources, materials or fuels and electricity or heat, they are put into a process in its operation to produce products. Products flow; it is the representative flow for the appropriate outputs of the process. In addition, there are unwanted outputs called "emissions", which will be released to air, water and soil. These emissions cause many environmental impacts, for example, climate change, acidification, human toxicity and eco-toxicity. Second entity is process or activity such as electricity generation, refinery and agriculture, which will produce the interesting products, consume the inputs and emit emissions to environment.

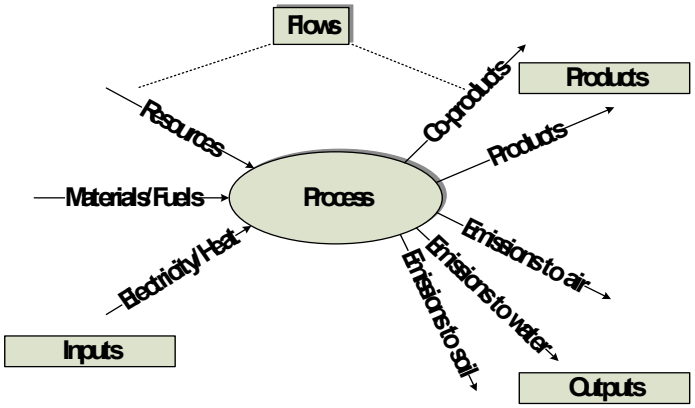



Figure (2): The basic data structure for Life Cycle Inventory (LCI), Flows and Process are two main entities.

## Thai National LCI Database Development Framework

Almost LCAs are developed by using a combination of data sources, covering the product or service may be primary or secondary and averaged datasets. It would be collected from specific suppliers, supply chains, and manufacturer. The requirements for performing and disclosing information and results from an LCA study have been codified in a series of international voluntary standards through the International Organization for Standardization (ISO). The current ISO standards for LCA (part of 14000, environment series) do not provide explicit guidance on creating, maintaining and/or updating LCI databases. As a result, a range of guidelines have been developed over the past two decades on which data should be collected and how data should be modelled and reported to achieve the compatibility and consistency needed by LCA modellers. Thailand has been developed LCI based on the LCA guidance (UNEP/SETAC, 2011) plus ISO standards for LCA (14040 and 14044) (ISO, 2006a, 2006b). The best practice guidelines to assist LCI users in a better understanding the issues of goal and scope of study. Thailand has been started life cycle thinking concept (UNEP, 2004; UNEP/SETAC, 2012) to achieve our goal of sustainability and green growth since 2002, successfully, in 2014 Thailand has been belonged to the steering committee of Global Network of Interoperable LCA Databases (UNEP, 2015). The pathway of Thailand shown in Table (2), it describes that the environmental data in topology of LCI is signification for various environmental assessment tools that have been successfully applied, based on Thai LCI database.

Table (2): Pathway of Thai National LCI Database development

| Starting year | Pathway | Description |
|---|---|---|
| 1990 | Master plan of green growth toward sustainability development | - Clean Technology<br>- Life Cycle Think<br>- Life Cycle Network |
| 2000 | LCA network | Japan, ASEAN and UNEP/SETAC |
| 2002 | Capability Building at MTEC, Partner Organizations & Industries | Supported by Japan government |
| 2003 | Pilot projects of LCI/LCA | Supported by Japan government |
| 2006 | Thai National LCI Database | Infrastructure, energy and basic materials datasets |
| 2008 | Applications and Initiatives | - Carbon footprint<br>- Eco-products<br>- Life Cycle Cost (LCC) for government<br>- Green Procurement<br>- Sustainability Assessment (SD)<br>- Green GPD for industry and agriculture<br>- Water Footprint<br>- Product Environmental Footprint (PEF) pilot project<br>- National Sustainable Consumption and Production (SCP) indicators |
| 2014 | Global Network of Interoperable LCA Databases | Thailand is the member of steering committee |
| 2015 | Environmental data collection for LCI system | Web-based collaboration tools |

Our vision is to propose an efficient and practical framework on the establishment and maintenance of life cycle data (environmental data), as a reliable input for environmental tools and also developed interlinkages of databases worldwide. In addition, it will complement that of other initiatives. Although, it can be explained as variability or real differences between the products, processes, and supply chains, insufficient creation of environmental data is one cause of misinterpretation. The results of a particular LCI are used to compare generalized products; this variability must be incorporated in the consideration of quality for leading to a certain impacts. This paper presents the framework that is extracted the lesson learned from our experiences of real world situation of LCI database development. Proposed framework as described in Figure (3), it is the concreted framework used to develop real national LCI database. The practical procedures and recommendations will be transparent for drivers and researchers who would like to start concerning on environmental data development. The nature and extent of dataset is such that formal methods for generating with all of them are truly challenging to find. However, efficiency and reliability of the results of these assessment methods depends largely on the quality of the inventory data. LCA study, especially

on parameters, will reinforce the confidence in the results and help the decision-making process based on the results and their interpretation in a quantitative and qualitative way.

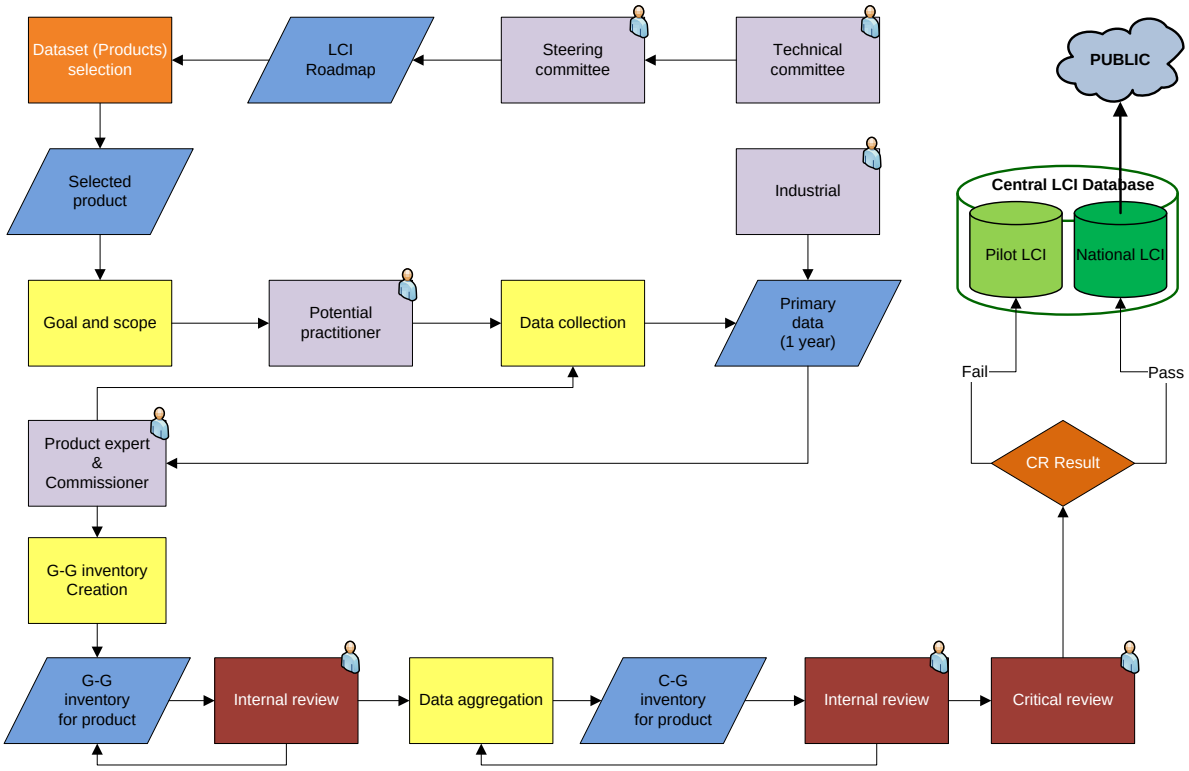



Figure (3): Thai National LCI Database development framework

Methods that consider the life cycle of alternative products are more popular on environmental aspects. Such methods, including life cycle assessment (LCA), net energy analysis, and energetic LCA, rely on life-cycle inventory (LCI) data. These data are usually compiled from various sources, including industrial measurements, government databases, and fundamental knowledge, and include information about resource use and emissions. The reliability of the results of these assessment methods depends largely on the quality of the inventory data. According to proposed framework, the main procedure to develop inventory data will be explained in the following.

1. Environmental roadmap
   Organisation's vision or country's roadmap is the most important factor to develop the national inventory data. In Thailand, we are following our green growth and sustainability strategy, and then we will know which industrial sectors should be concerned in that time. In addition, the database in central LCI database as shown in Figure (3) will consider for updating or improving and will be promoted to be part of national database.
2. Products/processes selection
   As we know, every data is important but we are unable to create many dataset in the same time, product or process prioritisation is essential. The criterion will be divided into two main of products/processes, infrastructure and necessary products/processes.
   - Infrastructure: this group consists of electricity, water, diesel, natural gas, it have to develop because it will be used for basic infrastructure data of other processes.
   - Necessary products/processes: it can be any industrial sectors such as agricultural and livestock products, also high market share products. Normally, these datasets will be extracted from the roadmap that has planned.
3. Data collection

This is time (cost also) consuming step, the actually data that will be collected in annually from manufacturers or industries. The primary data is required to collect, in case the data is not available, simulated data is acceptable. Data collection has to consider the exactly process, every inputs and outputs. Obviously, quality of data, affecting the environmental impacts revealed intrinsically unreliable. Then, data quality requirements should be applied on this step; the following criterion adapted from ISO is used to evaluate the quality will be addressed as below:

- Time-related coverage
- Geographic coverage
- Technology coverage
- Precision
- Completeness
- Representativeness
- Consistency
- Reproducibility
- Source of data
- Uncertainty of the information

4. Data modelling
   After data collection finished, dataset will be created using the computer system. The data can be divided into two kinds of dataset, gate to gate (G-G) and cradle to gate (C-G). Gate to gate data refers to the data collected from the processes of manufacturer; it consists of inputs and outputs that relevant to the production. Cradle to gate data will be a result of gate to gate data modelling. According to this step, it will be revealed the several number of emissions, $CO_2$, $SO_2$, $NO_x$, particular matter (PM), etc. that damage to human health, ecosystem quality and resources.
5. Critical review
   The critical review is the process to decide the quality of dataset developed, 'Pass' or 'Fail' are the binary results of this step (Mungkalasiri *et al*., 2010). The dataset with pass, it will be promoted to be a national LCI data, otherwise, it will be put in the group of pilot LCI. Only national LCI data can make it public, and also their emissions released will be accepted.

## Thai National Life Cycle Inventory Data

In accordance with proposed framework, Figure (4) represents the example of dataset resulted (LCI). This is an example of LCI of 'Tap water' process, the results show that the data is corresponding to the data structure that has been shown in Figure (2). Considering on emissions in this case ($NO_x$, $N_2O$, $CO_2$, $CH_4$, $SO_2$), the tap water production emitted can cause the damages, without doubt, that is why we must pay attention to the data.

| Resource | Amount | Unit |
|---|---|---|
| Ground water | 0.991022 | $m^3$ |
| Surface water | 0.041293 | $m^3$ |

| Raw materials | Amount | Unit |
|---|---|---|
| Alum | 0.024879 | kg |
| Liquid Chlorine | 0.00212 | kg |
| Lime | 0.0009 | kg |
| Polyaluminum Chloride | 0.001613 | kg |
| Calcium Hypochlorite | 0.000255 | kg |
| Polymer | 0.000006 | kg |
| Activated carbon | 0.000053 | kg |
| Sodium Carbonate | 0.000262 | kg |

| Energy | Amount | Unit |
|---|---|---|
| Electricity | 0.327813 | kWh |
| Diesel | 0.00015 | Kg |

Process of Tap water

| Product | Amount | Unit |
|---|---|---|
| Tap water | 1 | $m^3$ |

| Emissions to air | Amount | Unit |
|---|---|---|
| $NO_x$ | 0.000009 | kg |
| $N_2O$ | 3.77E-09 | kg |
| $CO_2$ | 0.000479 | kg |
| $CH_4$ | 1.88E-08 | kg |
| $SO_2$ | 0.000001 | kg |

| Waste | Amount | Unit |
|---|---|---|
| Sludge | 0.02766 | kg |
| Chlorine | 0.001235 | kg |

Figure (4): An example LCI of tap water production

Thailand has been delivered 515 national datasets across different industrial sectors, electricity, water supply, energy, materials, transport, agricultures and waste treatment. In year 2006-2013, numbers of datasets are published as presented in Figure (5). The results shown that in 2008 delivered the highest number of national environmental data is 226 datasets because Thailand worked on diverse projects. Undoubtingly, LCI is the most significant to evaluate the environmental impacts for any environmental assessment tools.

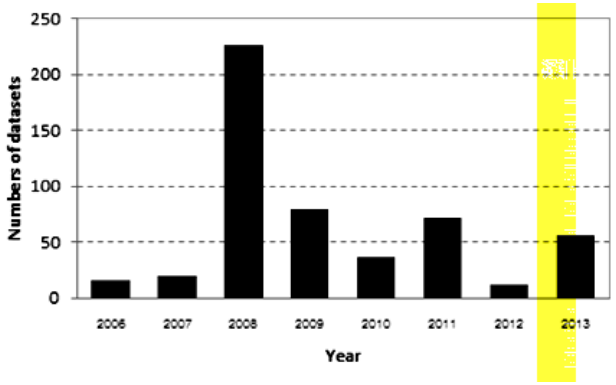



Figure (5): Numbers of Thai LCI datasets in each year

On the other hand, dataset is classified into 18 groups as presented in Figure (6). The results show that the agricultural products and transportation services have a great numbers of datasets because Thailand is predominantly an agricultural country. However, others are also indispensable fuels and energy, electricity and water.

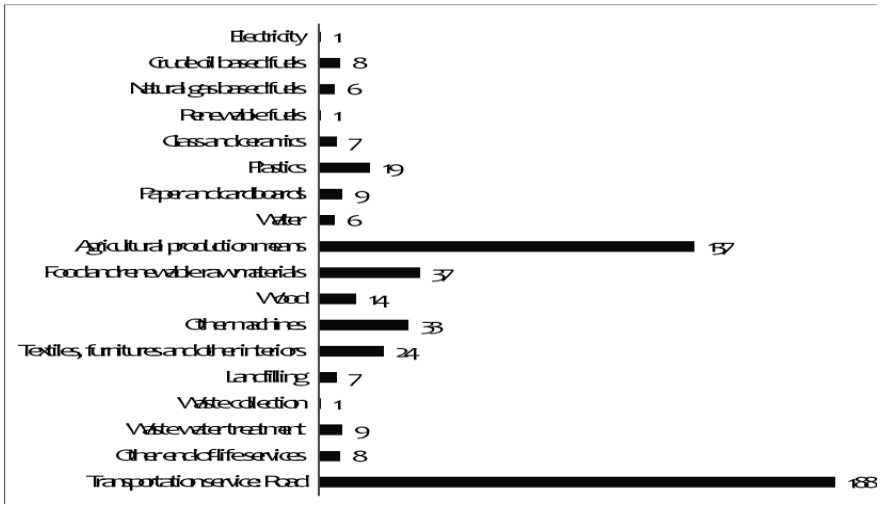



Figure (6): Numbers of datasets within each category

Due to our experiences on LCI database (environmental data) creation, we will not suggest researchers or dataset developers who have not created the LCI data nor have not much experience to completely adopt our proposed framework, it will be better to modify this framework and/or others for your compatible requirements. However, the national data development aims for improvement, national data should be revealed the reality of an activity that will affect to environmental impacts. It can identify the hotspots that may be harmed to our ecosystem and also provide the decision for the sustainability value chain of product/process.

## Conclusions

Internationally acceptable guidance on the establishment of LCI data, the recommendations could also serve as the basis for future compatibility of databases worldwide and the development of national/regional databases in developing countries and emerging economies. To increase the credibility of existing LCI data, as well as the collection of new data, improving data (energy, materials, transport, and waste treatment) and industrial processes,

are areas of high interest. To support a sound scientific basis for product stewardship in industry and life cycle based policies in governments, ultimately, to help the advancement of more sustainable products and processes. Reminding, we have to survive on the earth, where we have to concern about ourenvironment.

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