Roadmap for national LCA database development

Guidance and recommendations from around the world

Life Cycle Initiative

UN environment programme

Acknowledgements

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European Commission

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UN environment
United Nations Environment Programme

FOREWORD

LIGIA NORONHA

DIRECTOR, ECONOMY DIVISION
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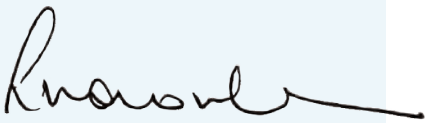
The "Roadmap for national LCA database development — Guidance and recommendations from around the world" brings together the most recent efforts in supporting countries to develop and implement roadmaps and action plans, as an approach to establishing national LCA databases. Such roadmaps are a practical tool to raise and align the support and multi-stakeholder efforts required to generate, structure, and disseminate LCA data while pursuing interoperability with other data sources.

Life Cycle Assessment (LCA) thoroughly accounts for the environmental impacts associated to the way production and consumption systems ('the economy') deliver functions to humans (e.g. a plastic bottle to deliver safe drinking water). LCA points at the key drivers of impact as well as potential trade-offs caused by alternative ways of delivering the same function (e.g. a filtering system to deliver safe drinking water). As such, LCA sets the foundation for measuring resource efficiency, environmental impacts and ultimately circularity in our products and economies. LCA has been increasingly acknowledged as the way to ensure our decisions and policies on products and technologies lead to sustainable development faster and more efficiently. In recent years, the Fourth Session of the UN Environment Assembly (2019) or ongoing meetings of the G7 and G20 request the use of LCA to appraise the impacts of products and their alternatives in the areas of sustainable mobility, textiles, buildings and construction, as well as plastics, to name a few. Regions like Europe or North America have LCA deeply embedded in their policy frameworks, as is evident for instance in the 'Single Market for Green Products' initiative by the European Commission, which established the Product and the Organisation Environmental Footprint (PEF/OEF) to measure environmental performance throughout the life cycle.

Even though it is widely recognized that adopting a life cycle approach is key, the access to locally relevant LCA datasets (the building blocks of LCA studies), and the lack of capacity to generate them, is often a constraint in developing countries and emerging economies. The demand for environmental information on products is increasing, and thus the ability to generate, provide access to and apply such knowledge becomes a matter of competitiveness for exporting economies. For this reason, UNEP strives to provide technical support to Member States that request assistance in the development of national LCA databases.

The "Roadmap for national LCA database development: Guidance and recommendations from around the world" brings together the most recent efforts in supporting countries to develop and implement roadmaps and action plans, as an approach to establishing national LCA databases. Such roadmaps are a practical tool to raise and align the support and multi-stakeholder efforts required to generate, structure and disseminate LCA data while pursuing interoperability with other data sources. The publication builds on the solid foundation that UNEP, with the Life Cycle Initiative, has laid over the past two decades, especially with the Shonan Global Guidance Principles for LCA databases (2011) and, more recently, the Global LCA Data Access Network and the Technical Helpdesk for LCA Databases.

The UN Environment Programme deeply appreciates the continued collaboration and financing from the European Commission in developing the enabling conditions for global use of Life Cycle Assessment as a public good to inform decisions and policies towards sustainable development.



Ligia Noronha
Director, Economy Division
UN Environment Programme

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF BOXES

LIST OF TABLES

ACRONYMS

ADEME	the French Environment and Energy Management Agency (France)
ALCAS	Australian Life Cycle Assessment Society (Australia)
API	application program interface
BONSAI	Big Open Network for Sustainability Assessment Information
CDLCI	Community-Driven Life Cycle Information
CILCA	Conferencia International Análisis de Ciclo de Vida, the Latin American LCA Conference
CO2PE!	Cooperative effort on Process Emissions in manufacturing Initiative
CPC	Cooperative Patent Classification
CSIR-NEERI	National Environmental Engineering Research Institute (India)
EAC	East African Community
EC-JRC	Joint Research Centre of the European Commission
ELCD	European Reference Life Cycle Database
EPD	environmental product declaration
EULA	end-user license agreement
FAQ	frequently asked questions
FICCI	Federation of Indian Chambers of Commerce and Industry (India)
GLAD	Global LCA Data Access Network
ILCD	International Reference Life Cycle Data Systems
ISIC	International Standard Industrial Classification
IT	information technology
IWG	international working group
ISO	International Organization for Standardization
JSON-LD	JavaScript Object Notation for Linked Data
LCA	life cycle assessment
LCI	life cycle inventory
LCIA	life cycle impact assessment
LCDN	Life Cycle Data Network
LCM-CMM	life cycle management capability maturity model
MINAM	Ministry of Environment in Peru
MTEC	National Metal and Materials Technology Center (Thailand)
MYLCID	Malaysian Life Cycle Inventory Database (Malaysia)
NCPC-SA	National Cleaner Production Centre in South Africa
NCPCSL	National Cleaner Production Centre in Sri Lanka
NDWG	national database working group
NGO	non-governmental organisation
NREL	National Renewable Energy Laboraty (U.S.)
OEF	Organisation Environmental Footprint
PDCA	plan-do-check-act
PEF	Product Environmental Footprint
PELCAN	Peruvian Life Cycle Assessment and Industrial Ecology Network (Peru)
REAL	Resource Efficiency through Application of Life cycle thinking' project
R&D	research and development
RICV	Red Iberoamericana de Ciclo de Vida, the Ibero-American Life Cycle Network
SICV	Sistema de Inventário do Ciclo de Vida, Brasil
SIDA	Swedish International Development Agencyl
SIS	Swedish Standards Institute
SRI	Sustainable Recycling Industries programme
TAC	technical advisory committee/council
TOT	training-of-trainers
UNEP	United Nations Environmental Programme
UNESCAP	United Nations Economic and Social Commssion for Asia and the Pacific
UNSPSC	United Nations Standard Products and Services Code
WWF-SA	World Wide Fund for Nature (formerly World Wildfire Fund), South Africa
XML	Extensible Markup Language

EXECUTIVE SUMMARY

LCA sets the foundation for measuring resource efficiency, environmental impacts and ultimately circularity in our products and economies. The development of a national LCA database can help increase the availability of regionalized data, build local capacity in LCA, and increase the practical application of LCA in the country.

A key factor hampering the use of life cycle thinking in policy-making and environmental decisions, in countries around the world, is the lack of regionally representative data for Life Cycle Assessments (LCA). LCA is a standardized method to quantify the environmental footprint of products and services throughout their life from extraction of raw materials to the product's end of life. As such, LCA sets the foundation for measuring resource efficiency, environmental impacts and ultimately circularity in our products and economies. The development of a national LCA database can help increase the availability of regionalized data, build local capacity in LCA, and increase the practical application of LCA in the country. A way to guide the development process of a national LCA database is through the establishment of a roadmap with an action plan that specifies the tasks to be executed by specific individuals/institutions within a certain timeframe1. This document focuses on the process to develop such a roadmap, and maps the key elements to be considered, including guidance on how to identify and involve key stakeholders to gain support for the national LCA database. To this end, it incorporates insights from previous national LCA databases developed around the world, as well as from literature. This guidance document is primarily informed by the experiences of six countries (Brazil, Ecuador, India, South Africa, Sri Lanka, and Uganda) that developed national LCA database roadmaps under the project *Resource Efficiency through Application of Life cycle thinking (REAL)*[2]. This document is intended to support national LCA communities that want to drive database development in their respective countries.

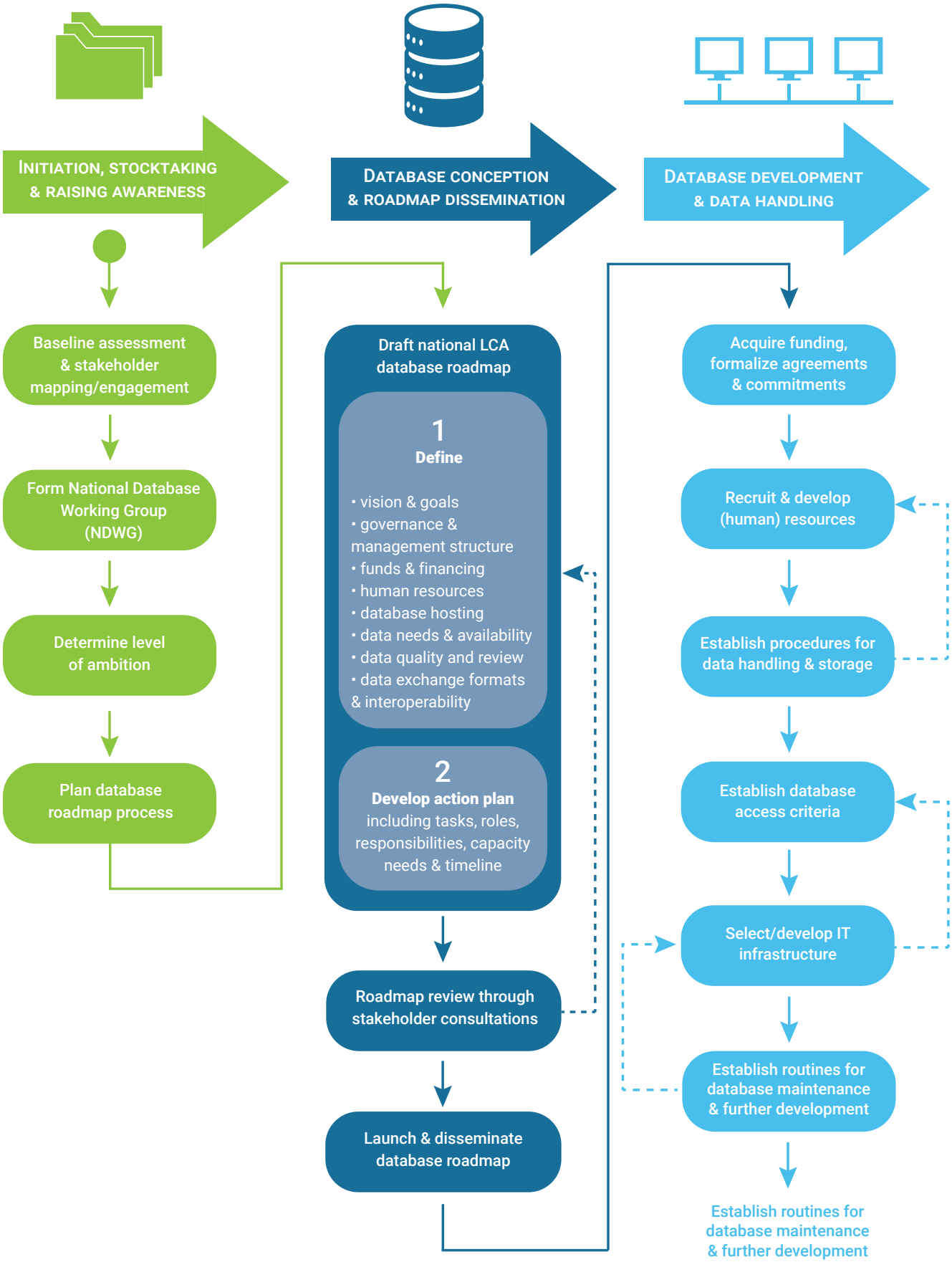
National LCA Database Development process

The development of a national LCA database should begin with a baseline assessment of the state of LCA in the country and stakeholder mapping, with a view towards building broad stakeholder engagement in the roadmapping process. The next recommended step is to establish a national database working group (NDWG). The NDWG membership should reflect the LCA stakeholder groups in the country and include individuals/entities that could contribute funds, effort and/or expertise to the database initiative. An important task of the NDWG is to determine the level of ambition for the national LCA database (i.e. ranging from a fully functional LCA database to a repository of consistent datasets), which will determine many of the subsequent database development and management requirements. The next steps, conducted through a series of NDWG meetings, include drafting a national LCA database roadmap with an action plan for database development (i.e. defining pathways to achieve the defined goals, including a prioritized list of tasks and deliverables, a timeline, well-defined roles and responsibilities, and review and quality control mechanisms). Care should be taken to ensure inclusiveness and broad stakeholder acceptance

1 While we have followed the roadmap approach in this report, there are national LCA databases that have been successfully established without a roadmap.

2 Funded by the European Commission and implemented by United Nations Environmental Programme (UNEP) under the Life Cycle Initiative.

NATIONAL LCA DATABASE DEVELOPMENT PROCESS



throughout the process. Subsequent steps include obtaining stakeholder review of, and support for, the draft roadmap, before finalizing the roadmap. The final steps of the process are to disseminate the roadmap and begin implementation of the action plan to actually develop the database and establish procedures for data handling. The national LCA database should be launched to raise awareness and support while acknowledging relevant partners and stakeholders and then maintained continuously and updated regularly, with a new version of the database being released periodically, e.g. each or every second year.

Main elements of a roadmap for national LCA Databases

- **Define vision and goals:** The first step when drafting an LCA database roadmap is to formulate a vision statement. This requires understanding the context and rationale for developing a national database, as well as the needs of the potential users. The vision statement should encapsulate the ideal future outcome and it is thus critical for guiding the overall strategic planning. Next, clear goals should be set to help achieve the vision. The goals should be based on a realistic assessment of the national context and be specific and actionable. The key requirements for the national database development will emerge, once vision and goals are set.
- **Agree on the governance and management structure** that will guide the database development and how it will be managed and maintained. A typical governance structure is formed by a board or steering committee, often advised by a technical advisory committee/council (TAC) which allows for expert and/or stakeholder inputs. The board or steering committee will typically appoint the management team (or individual), with database management skills, tasked with aspects such as data handling and review, fundraising/financial management and information technology. The roadmap should clearly define roles, relationships, mandates and responsibilities of individuals and organizations in the proposed governance structure.
- **Securing a source of funding** is of paramount importance for the database project to progress and succeed, from its initial development to its long-term management and maintenance. Funds are required to remunerate the people involved in the operation and management of the database; to generate, update and review datasets; as well as for capacity building. The roadmap should include an estimate of the funding needs, and identify potential sources of funds for each phase (along with a plan to obtain them), and/or propose a funding model for the database in the long term, e.g. considering whether datasets will be available free of charge (and to whom).
- **Define the human resources needed** (in terms of skills and capacity). This includes IT skills for developing/running the database IT infrastructure; scientific/LCA skills for developing data quality guidelines, generating and reviewing datasets; database management skills; financial and fundraising skills, etc. Working collaboratively and capitalizing on regional and/or international expertise and experiences can help build skills while keeping the number of full-time personnel required to a minimum (at least during the initial stages). Building LCA capacity in the country is essential as it helps to build a strong user-base, as well as a source of data for the database. It should therefore be included in the action plan and rolled-out as part of the actual database implementation.
- **Database hosting considerations** refer to both finding an organizational 'home' for the database, as well as defining the IT system that will need to be set up to manage, store and share the datasets. The level of IT service required is determined by the vision and goals for the database, and the amount of resources available for database hosting.
- **The intended uses and scope of the database** will inform the data needs. Given that there might be thousands of unit processes needed for an LCA database, it is recommended that an iterative approach based on dataset prioritization is followed. The roadmap should define data content goals for the national database, considering, for instance, the most relevant industries or sectors in the national economy, industries of high environmental significance or unique to the national context. Data availability is also an important consideration when defining the data content goals, since obtaining a critical mass of datasets is important for demonstrating viability and maintaining support for the database project.
- **The data quality requirements and review procedure** should be carefully defined when developing the roadmap to set up a national LCA database. The data quality requirements should reflect the scope and intended uses of the LCA data, to ensure that data included is fit for purpose. The criteria, against which data submissions can

A key factor hampering the use of life cycle thinking in policy-making and environmental decisions, in countries around the world, is the lack of regionally representative data for Life Cycle Assessments (LCA). LCA is a standardized method to quantify the environmental footprint of products and services throughout their life from extraction of raw materials to the product's end of life.

be evaluated for inclusion in the database, are commonly provided in the form of data quality guidelines. These guidelines cover the main technical and methodological aspects requiring definition in dataset development. Developing data quality guidelines is a very technical undertaking and thus beyond the scope of most database roadmap projects. However, the roadmap should consider how the issue of data quality and the development of guidelines will be handled, as well as propose how the review procedure will be structured and incorporated into database management.

- **The roadmap should consider which data exchange formats** will be used or supported. Several LCI/LCA databases (with global scope, or specific for some industries or sectors) can provide supplementary data for parts of supply chains not covered or that are beyond the national boundaries. Orientation or alignment with specific sources of background data can influence several of the aspects related to the database set up or of the elements of the roadmap listed above. This should hence be considered carefully from an early stage. While a database might start out with one specific format, it is recommended that databases should strive for interoperability with other data sources, and ideally support several formats. In particular, databases are encouraged to connect to (i.e. to become a 'node' of) the Global LCA Data Access network (GLAD) network, provided by UNEP and the Life Cycle Initiative. GLAD enables users around the world to browse for and access LCI datasets from all nodes connected via its interface. National databases should therefore consider GLAD's requirements for data interoperability while defining native data format(s) and own quality guidelines.

Structure of the report

This guidance document is structured into six main sections: the first summarizes the main motivations for developing a national LCA database and clarifies what constitutes an 'LCA database' in terms of its main characteristics. The second section presents an outline of the roadmap process conceptualized and applied in the Development of National LCA Database Roadmaps project. The third chapter describes the key elements (eight core areas) requiring consideration in the database roadmap development process, namely: (i) vision and goals; (ii) governance and management; (iii) funds and financing; (iv) human resources; (v)

database hosting; (vi) data needs and availability; (vii) data quality requirements and review; and (viii) data exchange formats and interoperability. The fourth section focuses on the importance of obtaining the support from key stakeholders and securing the needed resources for developing the national LCA database. The fifth section addresses the crucial next steps to pass from roadmap development to its implementation and establishment of the national LCA database, including advice on how to manage common risks. Insights from experiences of countries from around the world with national databases development are interspaced in textboxes throughout the report. The practical examples, references, and resources provided throughout this document are intended for orientation and illustration but should not be considered exhaustive. A collection of further resources to explore, as relevant, is provided at the end of the report in section six.

Target audience

The intended audience of this document are individuals and entities aspiring to drive national LCA database development in their respective countries or regions. It is assumed that readers and users of this document possess a good knowledge of LCA methodology and are generally familiar with the LCA database concept.

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The capabilities required for establishing and maintaining a national LCA database are inherently multidisciplinary: ranging from mobilizing support to acquire endorsements and funding, defining governance structures and mechanisms and database management, to subject matter expertise (e.g. on LCA methodology, data collection and quality requirements, data exchange formats), informatics and IT project implementation. This document is aimed at LCA technical leads, which are technical users with solid LCA knowledge, who are guiding or supporting a national LCA database development process, through the roadmap approach. It is expected that it is the responsibility of the LCA technical lead to interpret and explain the salient information in these guidelines to other stakeholder groups in a familiar language. The detailed IT requirements for hosting a database online are beyond the scope of this report. It is expected that the database technical lead, teams up with or hires experts with the requisite knowledge of such aspects.

CHAPTER 1

INTRODUCTION

Background

The availability of, or access to, reliable and regionally representative data for Life Cycle Assessment (LCA) is poor or even non-existent in many countries around the world. This limits the utility of LCA, making it difficult for governments, businesses and individuals to assess the environmental impact of, for instance, policies, product or design choices, or consumption patterns. Initiatives to establish national or regional LCA databases represent an important development towards mainstreaming life cycle thinking as well as the uptake and practical application of LCA globally. National LCA databases may, for example, focus on products, activities or industries of particular relevance to the local economy or reflect the priorities of key stakeholder groups. These database initiatives are also free to decide whether to define own data quality requirements or to adhere to established guidelines and standards from other sources. Compared to life cycle inventory (LCI) databases of global scope, national LCA databases have more flexibility to respond to the local demands for, and availability of, regionalized LCA data. Such initiatives are, therefore, complementary to global LCA databases. Adherence to the principles of consistency, flexibility and data interoperability is imperative to maximizing utility for local users, as well as the wider international LCA and sustainability communities.

The Development of National LCA Database Roadmaps project

The project 'Resource Efficiency through Application of Life cycle thinking' (REAL) was established to integrate resource efficiency in global value chains by using life cycle data on potential environmental impacts. Funded by the European Commission, the project ran from 2016 to 2020 and was implemented by the United Nations Environmental Programme (UNEP) in collaboration with the Life Cycle Initiative. One component of the REAL project aimed to support the development of national life cycle database initiatives, enhance access to LCA databases and further their interoperability. This constituted the goal for the sub-project 'Development of National LCA Database Roadmaps'. Running from October 2018 until August 2019, this sub-project was led by the ecoinvent Association in Switzerland and included national project coordinators and partners from Brazil, Ecuador, India, South Africa, Sri Lanka, and Uganda (the full project consortium is listed in Annex 1 - Project consortium at the end of this report).

The objective of the Development of National LCA Database Roadmaps project was to establish database roadmaps in a number of countries with emerging economies, as well as to advance data availability in those participating countries considered more mature in terms of LCA capacity. The database roadmaps represent detailed plans to guide collective efforts and actions toward a common goal – in this case, the successful launch and sustained operation of national LCA database initiatives. In addition, the project contributed to the development of the Technical Helpdesk for National LCA Database, a forum hosted by UNEP within the One Planet Network, which aims to support database development globally and to help national LCA databases ensure interoperability with other data sources.

In the first phase of the project, the national project partners carried out baseline assessments of the current status of LCA in six countries (Brazil, Ecuador, India, South Africa, Sri Lanka, and Uganda), considering data availability and the insights from any previous LCA database initiatives, as well as stakeholder mapping and engagement. In parallel, the consortium members in an International Working Group (IWG) – comprised of representatives from each participating country, the European Commission, and UNEP – prepared a first version of these guidelines and recommendations for establishing roadmaps aimed at national LCA database development. The guidelines supported the National Database Working Groups (NDWGs) – composed of key actors and stakeholders of the local LCA community – in their task to establish national database roadmaps during the second project phase. The guidance was subsequently revised and expanded by adding the experiences and insights gained from the database roadmap processes towards the end of the project.

The main outputs of the project were the finalization and dissemination of the database roadmap reports as well as the planning and initiation of first roadmap implementation activities. Where feasible, the project encompassed data-related activities for harmonization and connection of available data to the Global LCA Data Access (GLAD) network. The reports and other information material that resulted from the project have been published as shared resources on the Technical Helpdesk for LCA Databases.

The present publication is prepared for UNEP by members of the original consortium following the completion of the Development of National LCA Database Roadmaps project in 2019. This publication

expands on the guidance and recommendations compiled during the Development of National LCA Database Roadmaps project, supplementing the main text with concrete examples and lessons learned from the project partners, as well as broadening the perspective with experiences from other countries following a similar path.

Why a national LCA database?

Once fully embraced, national LCA databases support a wide variety of actors and audiences, including government at all levels, the private sector,[3] NGOs, education, academia and other research institutions. Users may include policymakers and analysts, researchers, LCA practitioners and environmental sustainability experts in commercial services, industry and industry associations, as well as organizations and individuals engaged in product assessments, the development of standards, certification and environmental labelling, and product, process, and system development.

One of the main challenges for national LCA database initiatives is the compilation of essential background data for products, processes or industries of high importance to the economy and the environment, while ensuring appropriate regional representativeness (or regionalization). It is therefore crucial to understand the degree and relevance of geographical representativeness required by users and key stakeholders. Efforts to compile regionalized LCA data also serve to develop local expertise on life cycle thinking and its approaches. The importance of such expertise extends far beyond the application of LCA (in its narrow sense) by supporting science-based targets and initiatives for sustainable development more broadly. It is therefore advisable to raise awareness of these benefits at all levels of government and among other stakeholder groups.

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Before proceeding with the guidance for establishing a roadmap for the development of a national LCA database, it is necessary to first delineate what is meant by an LCA or life cycle inventory (LCI) database.[4] The Shonan Global Guidance Principles (UNEP 2011; p.86)[5] describes the difference between a LCI database and a dataset library as follows:

3 For a compilation success stories from diverse businesses around the world please refer to: UNEP (2019) The business case for life-cycle thinking. United Nations Environmental Programme (UNEP)and the Life Cycle Initiative. Paris, France.

4 For this guidance, the two terms 'LCI database' and 'LCA database' are used interchangeably.

5 UNEP (2011) Global guidance principles for life cycle assessment databases - A basis for greener processes and products. United Nations Environment Programme, UNEP. Paris, France. ISBN: 978-92-807-3174-3.

'An LCI database is a system intended to organize, store, and retrieve large amounts of digital LCI datasets easily. It consists of an organized collection of LCI datasets that completely or partially conform to a common set of criteria including methodology, format, review, and nomenclature. The database will allow for interconnection of individual datasets to create LCI models. The computed results can be used with identified life cycle impact assessment (LCIA) methods for cycle assessment (LCA). Databases are managed using database management systems, which store database contents, allowing data creation and maintenance, search, and other access. In contrast, a dataset library is a collection of datasets that may not conform to common criteria and do not allow for interconnections and common applications for LCA or LCIA purposes.'

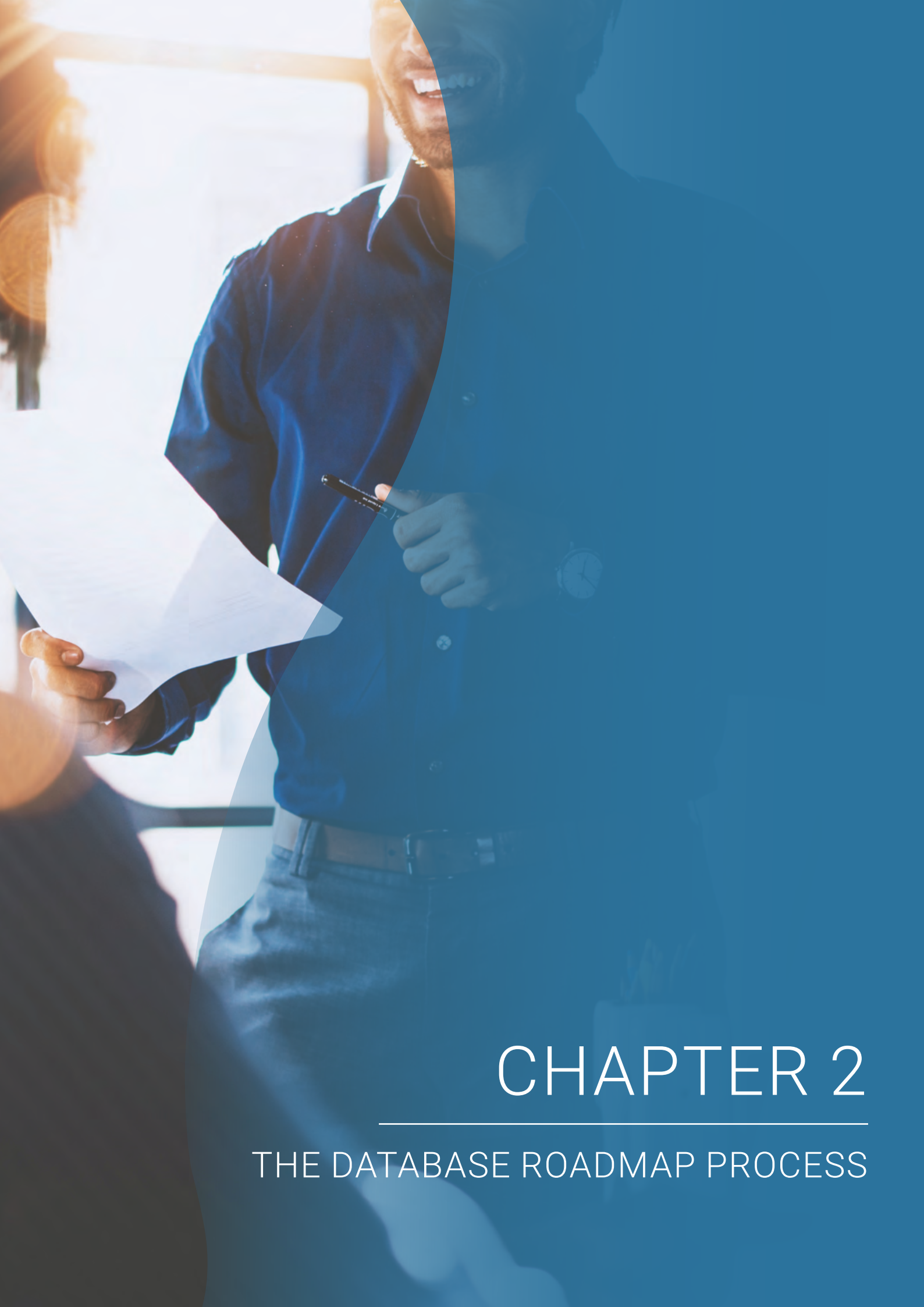
— The Shonan Global Guidance Principles (UNEP 2011;

In this context, a dataset should be understood as: 'a document or file with the life cycle information of a specified quantitative reference (reference flow, functional unit, or other references, e.g. product, site, process) including descriptive metadata and quantit*ative LCI or LCIA data (various sources).*' (UNEP 2011, p. 86) The quantitative information (data) found in a dataset is the result of the inventory modelling, with its inputs typically derived from a variety of data sources, such as operational data from one or more plants, sites, or companies, industry or national statistics, or the grey or academic literature. Furthermore, the linking of process inventories into product systems is determined by a system model, representing a set of linking rules contained in an algorithm. That is, the general term 'LCA data' is broad and somewhat ambiguous, as it also encompasses the output of models of economic activities.

UNEP (2016, p. 57)[6] noted that recent developments have led to the creation of data hubs and networks of databases, e.g. the openLCA nexus and the nodes available through the Life Cycle Data Network (LCDN) of the European Commission. Meanwhile, the GLAD network can also be added to this list. Whereas a data network consists of two or more interlinked initiatives for improved management and exchange of data, a data hub is an access point for data from different providers (such as LCA databases). In these guidelines, the aforementioned definition of an LCI/LCA database is followed. It is, however, acknowledged that the path to developing a national LCA database may include an initial phase as a dataset library. For example, it might first serve as a common repository for existing LCA data during the conception of a consistent database. This is reflected in the roadmaps established within the Development of National LCA Database Roadmaps project, i.e., the goal of these database roadmaps extends beyond the creation and sharing of a collection of unmanaged or inconsistent LCA data.

On a general level, the Shonan Global Guidance Principles provides a list of overall principles for LCA databases to adhere to (UNEP 2011; section 1.2), with the following keywords: accessibility, accountability, accuracy, completeness, consistency, exchangeability, materiality, practicality, quality assurance, relevance, reproducibility and transparency. These aspects offer orientation when setting out on the process of establishing a national LCA database initiative. They also provide guidance for the transition from precursor states, e.g. as data libraries or repositories, to a functional LCA database.

6 UNEP (2016) *Opportunities for National Life Cycle Network Creation and Expansion Around the World*. United Nations Environment Programme, UNEP. Paris, France.



CHAPTER 2

THE DATABASE ROADMAP PROCESS

A roadmap is a strategic plan that defines a vision and the goals of a project or other undertaking. It includes the major steps or milestones needed to reach the desired outcome. As a high-level strategic document, it is also a communication tool that establishes common vision and goals, the underlying motivation and the action plan developed for reaching them.

It is important to distinguish between the process for establishing a database roadmap (as outlined below), and the development of a national LCA database. The latter should be guided and informed by the outputs of the former, with the content of the database roadmap addressing various aspects relevant for a successful national LCA database initiative. And while the database roadmap process might be considered an activity separate from (and typically preceding) the database development, funds for roadmap implementation should ideally be raised already during the database roadmap process. This is necessary to build on the support and momentum gained in the roadmap activities, thereby preventing the process from stalling.

The following list outlines the steps conceptualized and undertaken in the *Development of National LCA Database Roadmaps project*. A schematic illustration of the process is provided in the executive summary. The database roadmap process set out in the following steps strives to ensure a high degree of inclusiveness of perspectives through extensive stakeholder consultation and representation. The actual sequence of the steps described below can be adapted (at least to some extent) to suit the needs and preferences of the actors involved. It is also left open whether dedicated funding is required for the database roadmap process, or whether it is performed completely based on in-kind contributions from the core team and participants.

1. Baseline assessment and stakeholder mapping and engagement[7]

Understanding the status, needs and main users of LCA in the country is an essential starting point. This includes eliciting the interests and degree of influence of the main actors, as well as considering the experience of previous or related initiatives. Broad stakeholder engagement in the roadmap process is instrumental to ensuring the wide participation that is needed further down the line in the database development process. Stakeholder engagement should include all stakeholder groups that can be expected to fulfil different roles or carry any stake in the national LCA database project, such as government agencies for governance, hosting and/or funding; researchers and consultants as experts in LCI modelling and technical aspects; public and private sector companies and industry associations as data providers and project funders; and NGOs or representatives of civil society as facilitators and advocates of public interests (e.g. for the uptake of, and harmonization with, impact assessment developments). Note that all these groups are also potential users of the final LCA database.

2. Establish a national database working group

Following from stakeholder engagement, a National Database Working Group (NDWG) should be established. The NDWG should have a broad stakeholder representation but not be so large as to become unmanageable or ineffective. A small working group alongside a wider advisory group (e.g. with stakeholders acting in an advisory and/or a reviewer capacity) is recommended. It is also advisable to invite to the NDWG the people and organizations that are expected to fund and/or put in the effort to implement initial activities envisaged for the development of national LCA data and the database.

3. Determine the level of ambition

The NDWG should determine early on whether the ambition is to set up a fully functional national LCA database or a repository of consistent datasets. The level of ambition should align with estimated costs and the ability of the main implementing agency to raise funds in the foreseeable future to cover those costs. The experience of successful global LCA database providers indicates that it may take several years for databases to become financially viable. Until that point, dataset development may need to depend on grants, donations and/or public funding, but also substantial in-kind contributions.

4.Plan the roadmapping process

NDWG members should be committed to a pre-defined number of meetings/ engagements and an overall project plan should be developed (comprising, among other things, a meeting schedule and timeline for a first draft, review, final draft and launch of the database roadmap). For this step, the general structure of the roadmap process must be defined, including the method or approach to be used for the consultations and database roadmap formulation. The most suitable set up depends on the national context and, hence, may vary from one case to another. Different

7 The baseline assessments and stakeholder mapping reports for the six countries in the Development of National LCA Database Roadmaps project are available from the Technical Helpdesk for LCA Databases

approaches, such as surveys/questionnaires, brainstorming sessions, facilitated workshops or the Delphi method,[8] or a combination thereof, may be used to ensure inclusiveness and establish broad consensus and stakeholder acceptance for the finalized database roadmap.

5. Roadmap development – vision and goals of the database initiative

A first step to establish a roadmap for database development is to formulate a vision and clear understanding of the purpose of the national LCA database. The formulation of a vision should take place in an inclusive setting within the NDWG, and be informed by consultations with the wider stakeholder community. A set of concrete goals should then be developed. The purpose of the goals being to ensure the achievement of the vision as defined. Through this, the requirements on the national database should become clear. If not already identified and approached, then potential funding partners for roadmap implementation should be considered and first contacts established at this stage.

6. Roadmap development – action plan for database development

Once clear goals have been established, pathways to achieving these goals can be developed. The action plans for database development should include the following: a clearly defined and prioritized list of deliverables and tasks, as well as a timeline for their completion; descriptions of the roles and responsibilities of the project team; and an overview of review and quality control mechanisms. The aim should be a manageable process in which progress can be easily tracked and stakeholders can be kept engaged.

7. Draft the database roadmap document

The vision, goals, tasks and action plan, dependencies between tasks and activities, roles and responsibilities and timelines should be compiled into a single, comprehensive reference document for the roadmap (i.e. a draft version of the LCA database roadmap). All available resources, such as these guidelines, experiences from other national database initiatives, and the *Technical Helpdesk for LCA Databases*, should be used to ensure all relevant aspects are covered in the database roadmap.

8. Review the roadmap and obtain stakeholder support

Representatives of local stakeholder groups and international experts should be invited to review the draft database roadmap. This review process may encompass a review of the document and/or workshops or webinars with stakeholders. Written and verbal feedback should be compiled in a single document alongside recommendations. As wide a dissemination of the draft roadmap into the local LCA user community as possible is encouraged to increase a sense of ownership of the national database process, which will potentially lead to greater collaboration and use of the database going forwards. The funding strategy and connection to potential donors for roadmap implementation should ideally be well established at this point, with good prospects for securing the funding in time for the completion of the database roadmap.

A first step to establish a roadmap for database development is to formulate a vision and clear understanding of the purpose of the national LCA database. The formulation of a vision should take place in an inclusive setting within the NDWG, and be informed by consultations with the wider stakeholder community.

8 For more information on the Delphi method, please refer to the RAND Cooperation and Linstone and Turoff (1975) The Delphi Method: Techniques and Applications, Reading, Mass. US: Addison-Wesley, ISBN 978-0-201-04294-8.

9. Revise and finalize the roadmap

Based on the stakeholder and expert inputs received, the roadmap should be revised and finalized. As part of this step, a dissemination plan for the roadmap should be developed. Clear summaries, possibly aimed at different stakeholder groups, may help with dissemination. Immediate next steps should be made explicit in the summaries.

10. Disseminate the roadmap and execute first steps

Finally, the national LCA database roadmap should be published and launched, e.g. through a workshop event at which interested stakeholders can volunteer to participate. A dissemination platform is recommended, through which interested stakeholders can receive updates, get involved and eventually also access the infant database. If possible, first implementation steps should be communicated at the event or on the platform (e.g. first collection of core datasets or pilot studies) so as to demonstrate actual momentum on the project and spur further actions.

Although every country initiative must devise this process according to its specific context, the experiences from Ecuador within the Development of National LCA Database Roadmaps project highlights the value of learning from others. As outlined in "Text box 1. South-South cooperation in Ecuador to inspire and guide the national LCA database roadmap process." on page 25, the team behind the national database roadmap process in Ecuador reached out to their colleagues in Peru to gain insights and guidance, but also for inspiration, from a neighbour country to which the national stakeholders can relate.

Text box 1. South-South cooperation in Ecuador to inspire and guide the national LCA database roadmap process.

The *Ecuadorian Life Cycle Network* was created in 2014 with decisive international support. From the beginning, there was an active research community in LCA. The activities organized initially, mainly workshops and seminars, were well-attended and positively received, demonstrating interest and appetite for life cycle approaches in the country. However, the step from uptake in academia to government and industry was not achieved: governmental LCA-related initiatives were not consolidated, and there was a serious lack of Ecuadorian business case studies for raising awareness about the potential value of a life cycle perspective with local relevance.

When the REAL project provided the opportunity to discuss the implementation of a roadmap for the national LCA database in Ecuador, South-South cooperation was at the heart of the strategy to achieve stakeholder engagement from the start. At the time, the neighbour country Peru was launching the Peruvian LCA database. Besides the exchange of knowledge, experience, and expertise, and the potential for engagement in mutual learning and solution sharing, the case of Peru illustrated that the development of a national LCA database was not only meaningful but also already possible for a developing country such as Ecuador.

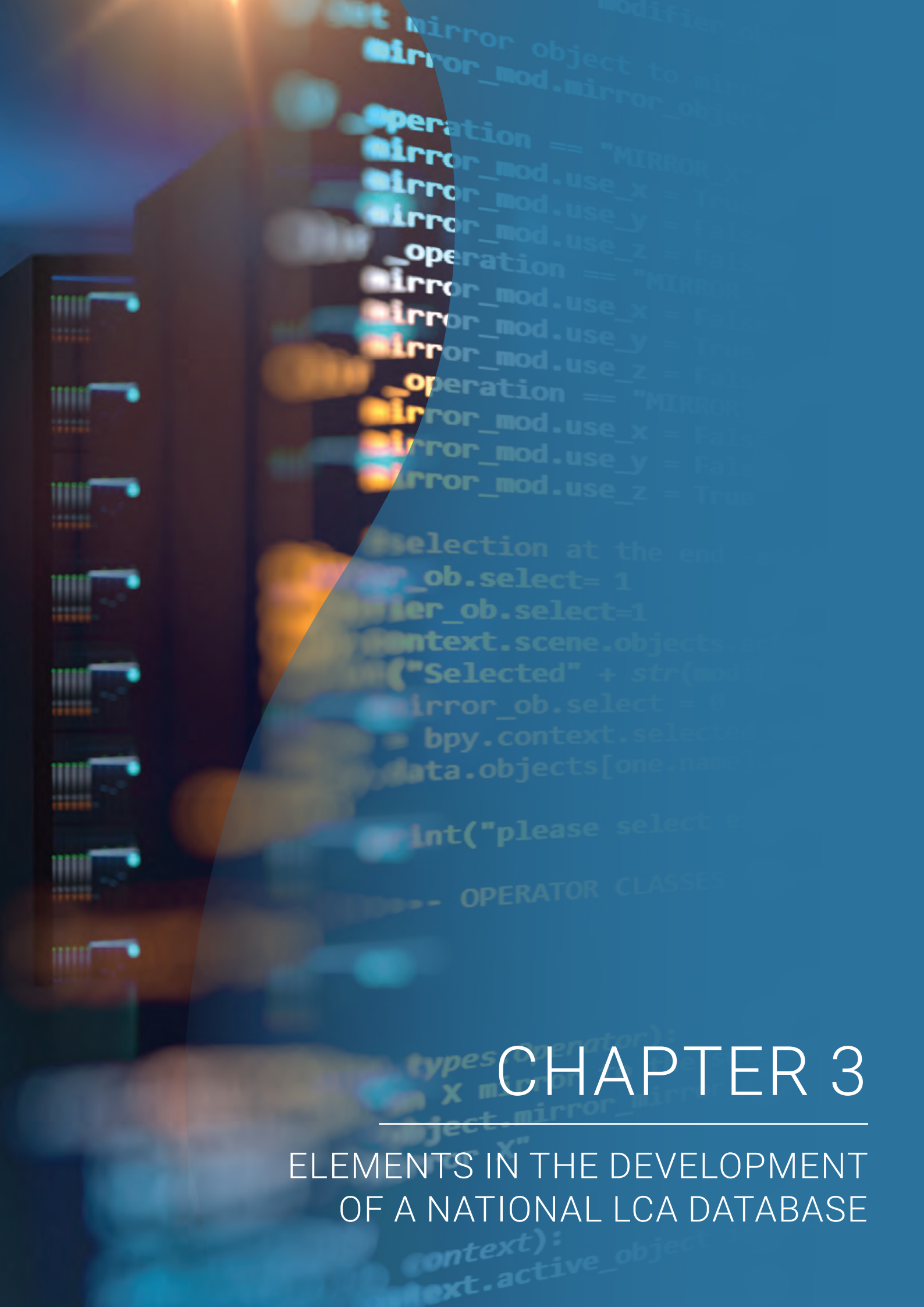
Two workshops were organized in Quito and Guayaquil at the outset of the national roadmap process, with representatives of the Peruvian LCA Network participating. While the event in Quito targeted the public sector and academia, the workshop in Guayaquil focused on the private sector (supported by the Entrepreneurial Council for Sustainable Development of Ecuador). Combining awareness-raising and stakeholder consultations, the workshops covered three main sections:

1. Providing a proper understanding of the life cycle perspective and approaches.
2. Challenges and opportunities for national LCA database development in Ecuador.
3. Making it real: lessons learnt from the Peruvian experience.

Figure 1. Impressions from stakeholder workshops in Quito (left) and Guayaquil (right) in February 2019.

The discussions about lessons learnt from the process in the neighbour country, from database governance and management to data prioritization, were crucial for raising the interest and maximizing stakeholder involvement. The Peruvian experience was also relevant for the definition of key aspects related to the aspired service level (technical requirements, budget, time, etc.), which were then further discussed throughout the national database roadmap activities.

This successful exchange demonstrates the potential success of South-South cooperation, which must be seen as an accelerator and multiplier of sustainable development. There is a great opportunity for international and regional actors to play the role of effective interlocutors, leveraging their networks and programmes at the global level to foster Triangular and South-South Cooperation.



CHAPTER 3

ELEMENTS IN THE DEVELOPMENT OF A NATIONAL LCA DATABASE

The following elements are expected to be of high relevance in the development of a national LCA database, hence constituting important areas to be addressed in an LCA database roadmap: [9]

- Vision and goals
- Governance and management
- Funds and financing
- Human resources
- Database hosting
- Data needs and availability
- Data quality requirements and review
- Data formats and database interoperability

This chapter is structured according to the elements listed above. The information and guidance provided in the sections below is intentionally kept rather broad and generalized. This is because there is rarely a 'one-size-fits-all' solution, and many trade-offs are inevitable when developing a national LCA database. In addition, the guidance and recommendations remain as neutral as possible, e.g. with respect to data (exchange) formats or database systems. The topic of promoting LCA uptake in public policy (and beyond) is addressed in a separate section, titled 'Making the case for LCA, placed directly after the present section.

Vision and goals

To create an effective roadmap for the development of a national LCA database, it is necessary to understand the context and motivation for having the database and the needs of its potential users. The vision and strategy established in the roadmap might have to bridge or balance the perspectives of different stakeholder groups. The final vision for the national LCA database should build on a common purpose and the problem or challenges at hand, and it depicts what it would mean to fulfil that purpose and to solve those problems. An example of a vision statement from the roadmap for the United States LCI Database Project is provided in "Text box 2. Vision statement and goals of the U.S. LCI Database Project; from NREL (2009)." on page 28.

Text box 2. Vision statement and goals of the U.S. LCI Database Project; from NREL (2009).

The US LCI Database was first launched to the public in 2003. An expansion of the project became relevant already in subsequent years as the demands for the database increased rapidly. The roadmap for the U.S. LCI Database Project was derived from the inputs and feedback received during a meeting with interested parties in 2009. An online survey was conducted prior to the stakeholder meeting, including on the underlying drivers creating a need for a national LCA database in the U.S. From the responses and the stakeholder consultations, the following vision was formulated for the database roadmap document:

Vision Statement

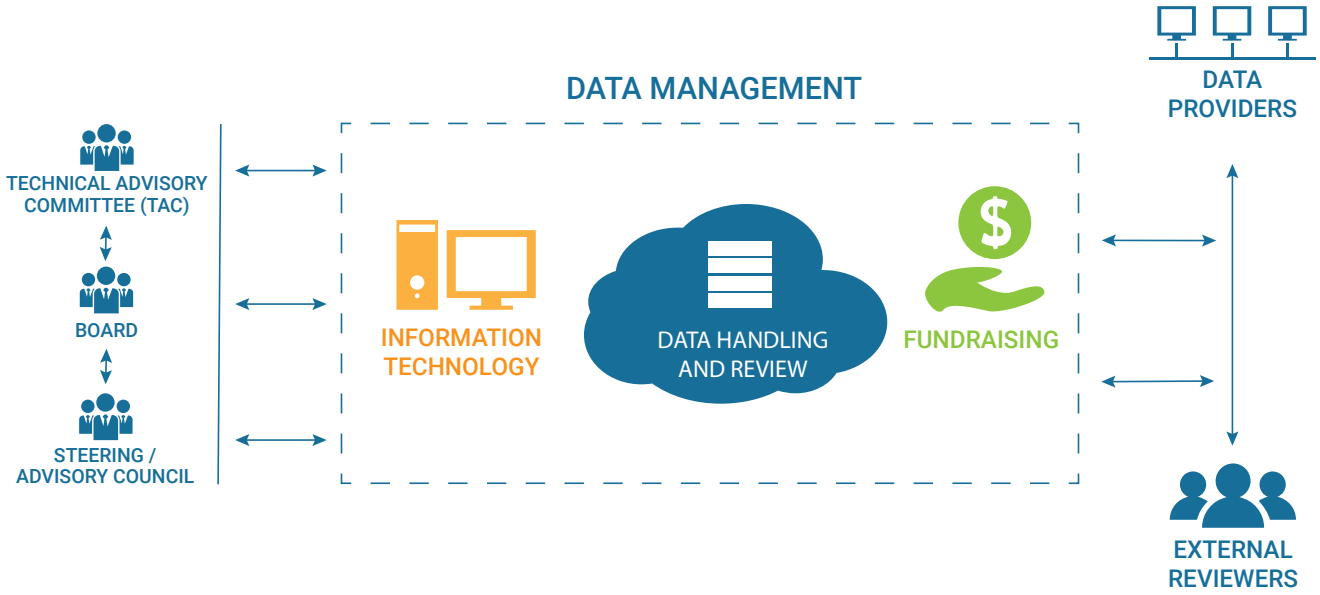
'The U.S. Life Cycle Inventory Database will be the recognized source of U.S.-based, quality, transparent life cycle inventory data and will become an integral part of the rapidly expanding use of life cycle assessment as an essential environmental analysis and decision-making tool.'

Seven goals were stated for the U.S. LCI Database Project following the aforementioned vision statement. Besides addressing aspects such as data quality, transparency, coverage, accessibility, and interoperability (with other LCI databases), these goals also include supporting the increased use of LCA and the competitiveness of the U.S. industry. Finally, there is also a goal related to the need for broad and sustainable support.

Four 'critical paths' for realizing the vision for the U.S. LCI database were conceived for the roadmap, related to project management, data management, LCI data (content/coverage), and communications. Each of these paths encompassed a number of more specific tasks ('action items'), which were subsequently put into a two-year action plan. Additionally, more long-range objectives were established for each of the critical paths beyond that period.

9 Examples of database roadmaps following this structure are available as deliverables D4.1-4.5 of the Development of National LCA Database Roadmaps project on the Technical Helpdesk for LCA Databases platform.

Figure 2. Example of a governance and management structure for an LCA database.



The vision is critical for guiding the strategy definition and execution. A vision statement encapsulates the ideal future outcome of the undertaking. By providing a target state, it guides and informs the subsequent strategic and operational planning. Following on from a clear, carefully considered vision, a set of concrete goals should be developed so as to be able to achieve the vision. Strategic goals should ideally be specific, measurable, achievable, relevant, and time-bound (SMART), and should be based on a realistic assessment of the current situation and a projected scenario. They should be objective statements – usually two to three sentences each – that clarify the goal's intent and meaning. Through the combination of vision and goals, a clear picture of the requirements of the national database should emerge.

It is advisable to take special care to ensure that the vision and goals capture the particular context and needs of the country, and are understood and agreed upon by stakeholders. The vision is the 'selling-point' of the LCA database, and if it does not resonate with the stakeholders, the roadmap is unlikely to gain support and progress (especially if funding is to be sought on the back of the roadmap). For example, it was clear that policymakers in South Africa would find no resonance with the vision and goals if they did not explicitly address South Africa's need for social development alongside environmental protection (see Text box 8 in the next chapter). To that end, it is also useful to precede the vision with a 'preamble' or statement that positions the need for a national LCA database.

Governance and management

The governance and management of the database need to be clearly defined.[10] The database governance structure should entail the roles, relationships, authorities or mandates and responsibilities of the individuals and organizations involved. As such, it establishes the various parts or entities within the database initiative, such as a board, steering committee, technical advisory committee (TAC), scientific expert group(s) or advisory/stakeholder council(s). A national LCA database may have one or more of these structures, e.g. a steering committee and an advisory council, to oversee the overall direction and management structures of the database. It is recommended that the board and advisory council include members from the different stakeholder groups active in LCA in the country, e.g. government, industry, academia and civil society, as a way to ensure that the interests and needs of different stakeholders and user groups are well represented. An example of a possible database governance and management structure is illustrated in Figure 2.

10 According to the Business Dictionary, the term 'governance' entails '[the] establishment of policies, and continuous monitoring of their proper implementation, by the members of the governing body of an organization. It includes the mechanisms required to balance the powers of the members (with the associated accountability), and their primary duty of enhancing the prosperity and viability of the organization.

The board of the database, as informed by one (or more) advisory committees, will generally be responsible for appointing the database management team. The database management team is typically responsible for database development, content handling, maintenance, updates (or at least the coordination thereof, in the case of external data/dataset providers and reviewers), and dissemination or publication. The tasks and activities related to this can roughly be grouped into three main functional areas: information technology (IT), data handling and review/quality control (again, assuming that data collection is an activity mainly performed externally or by member institutions), and fundraising.[11] As an option, one or more councils (e.g. a strategic advisory committee/board, a scientific expert committee/group, or a stakeholder/member council) can be added to oversee and give advice on the execution of these three activities.

While the management structure in Figure 2 might seem extensive, it is possible to start small and still ensure good governance and representation. For example, it might be possible to start with a single database manager, where experts on advisory councils give of their time for free, and using service providers (e.g. part-time contracts) for IT and data-related tasks, including for data collection (data providers) or inventory generation and dataset creation (dataset providers).

Once the responsibilities are defined, an action plan covering goals and targets, schedule, responsibilities, resources needed, monitoring indicators and funding sources can be established. A systematic approach using the plan-do-check-act (PDCA) management method can support achieving an effective LCA database and ensure improvements along the way.

Database management duties

A set of nine criteria for responsible database management practices, elaborated by Vigon and Ciroth (2017),[12] provides an indication of the wide range of duties and expectations faced by LCA database developers and providers. The first four criteria relate to the interactions with the database users, and encompass providing a clear point of contact (ensuring responsibility and accountability), offering adequate technical and methodological support, supplying guidance to ensure that updates are installed correctly, and publishing documentation as a basis of providing consistent datasets and making any limitations clear.

The remaining criteria include striking a balance between database continuity and innovation, as well as potential trade-offs related to the level of transparency granted to the end users versus the need to respect the confidentiality of any sensitive information. The database management is also responsible for ensuring secure storage of the information to prevent unintended loss or accidental distribution of data. The integration of new or updated data content must be carefully managed to ensure harmonization with the existing content and to maintain overall database consistency. Finally, the database provider should strive to support common data exchange formats to enable use in different LCA software applications and systems.

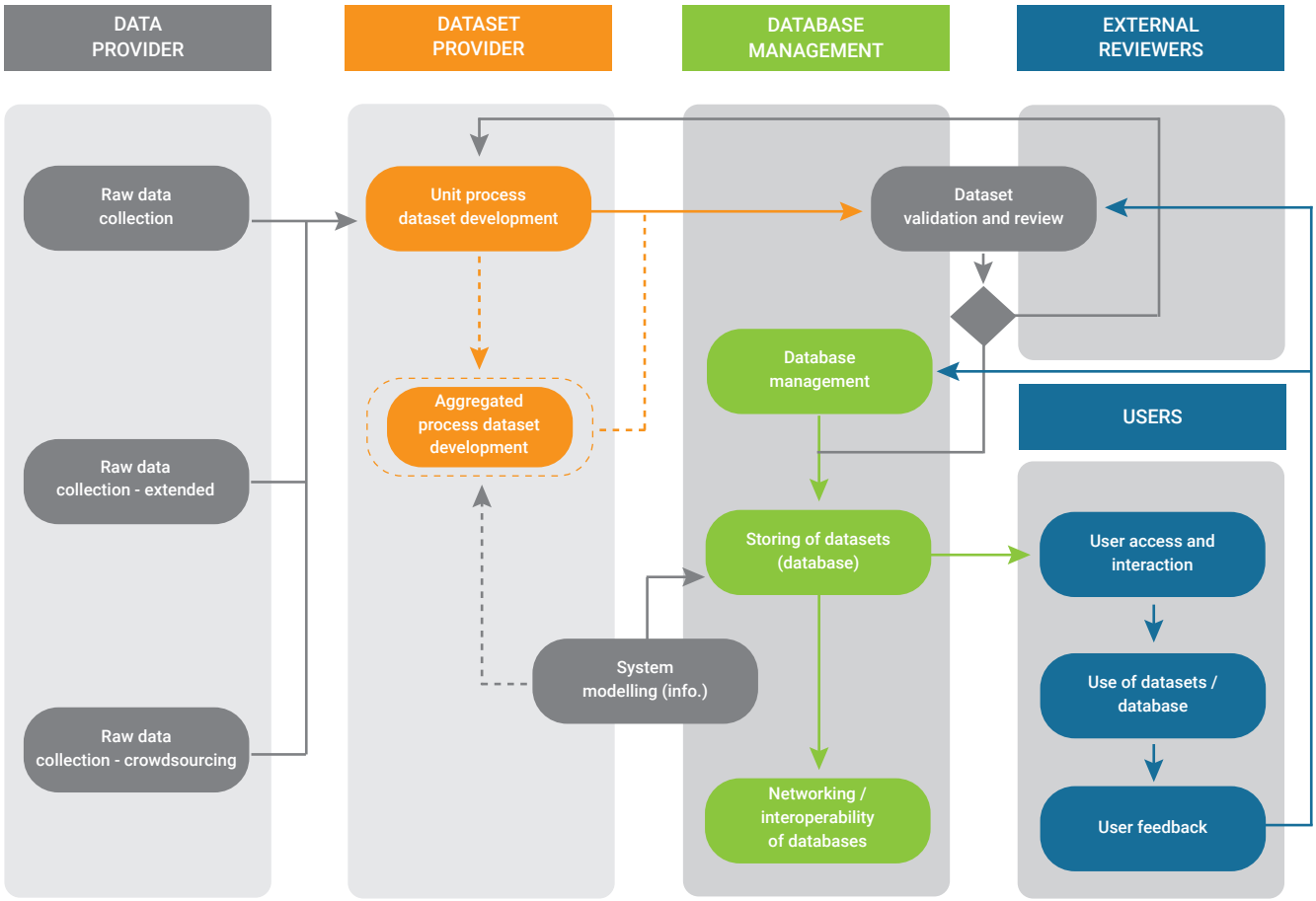
Several of the aforementioned criteria have implications not only for the database management arrangements and will also be addressed in the dedicated sections below. These aspects can be bridged by going further into detail about the roles of the three functional areas of database management. A schematic overview of the roles, activities, and information flows for data submissions and database provision is provided in Figure 3. The IT team or working group is responsible for the infrastructure of the database, guaranteeing its availability, usability, integrity and security (see also sections on 'Human resources' and 'Database hosting'). It is recommended that the IT team also be responsible for facilitating the interoperability of the database with other databases and data networks (see 'Data needs and availability').

Regarding the data content and review procedure, a number of high-level technical or methodological definitions are needed during the conception of an LCA database (discussed in more detail under 'Data quality requirements and review' below). It should be stressed that the strategic management of the database initiative should be clearly separated from data collection and handling, the latter of which should be science-driven and adhere to best-practices. The process for establishing these aspects may differ between different LCA database initiatives. It may, for example, be led by an expert, a group of expertse or internally by the database management team, and reviewed by a technical advisory committee/council.

11 The term 'fundraising' is used here in a broad sense, i.e. including sales, licensing and acquisition of projects, donations or crowdfunding.

12 Vigon, B. and A. Ciroth (2017). Responsible Management Practices in LCA Databases – Concepts and Criteria. UNEP. Presentation available from the Technical Helpdesk for LCA Databases

Figure 3. Roles of actors in the data supply chain (adapted and modified from figure 1.3 in UNEP 2011).



Once approved and operational, the database management is responsible for the application of the data quality requirements for datasets to be included in the database and for coordinating the review process by which datasets are approved for inclusion.

The service level to be offered (and whether it will be offered free of charge or for a fee), in terms of access and support to users/customers, resellers, LCA software providers, LCIA method developers, etc. needs to be decided upon for all of the aforementioned stakeholders. The demand and, hence, also the capacity required for user support, is difficult to predict but it should not be underestimated. It is therefore crucial to clearly define and communicate the service level that users and other stakeholders can expect from the database management. Databases may decide to offer a basic service level for free but charge a fee for further support or services.

Lastly, but no less importantly, to actively manage and maintain an LCA database entails the establishment of a strategy, procedures, and the capacity for fundraising, e.g. for acquiring or developing new datasets and updating existing ones. The budgets established and approved by the board must therefore be such that they guarantee the availability of funds necessary to make the database viable (see next section on Funds and Financing

Funds and financing

Potential costs related to the establishment and running of an LCA database include, but are not limited to, the remuneration of people involved in its operation and management, as well as for capacity building, awareness-raising, database development and updating and reviewing of datasets. There are several avenues through which funding and financing for a database can be acquired, from both public and private sources. Several LCA databases were initially established using predominantly public funding from domestic or foreign sources, e.g. AusLCI in Australia, SICV in Brazil, the ecoinvent database in Switzerland, and the national database initiatives in Malaysia, Peru and Thailand. There are also LCA databases that are privately funded, e.g. through data sales, licence or membership fees, often provided by corporations or consultants with a background in commercial sustainability services. In developing and emerging countries, seed money for capacity building has been provided by the European Commission and other donor countries/organizations for various projects implemented by, for example, UNEP, the Life Cycle Initiative, national standardization institutes, LCA consultants and international experts, LCA databases and software providers etc. The creation of the Malaysian Life Cycle Inventory Database (MYLCID) is summarized in "Text box 3. The Malaysian Life Cycle Inventory Database (MYLCID), an LCA database entailing a national initiative towards cleaner production." on page 33.

It is recommended for the initial development phase of a national LCA database initiative to focus on identifying the specific needs of one or a few key user or stakeholder groups, and that the available resources are deployed to respond to their specific needs. With the main objective being to 'set the wheels in motion', this requires that a certain degree of flexibility be maintained in terms of who will be the initial or primary users of the database. National self-sufficiency in terms of data coverage should not be a core objective, especially in the early phase. Connectivity to other databases is generally much appreciated by users. There are a number of LCI/LCA databases of a global scope that can serve to provide supplementary data for sectors not covered or on parts of supply chains outside the national boundaries. For this to work satisfactorily, though, data interoperability is imperative.

The need of certain user groups to have free access to the database can be an argument for public funding. However, that does not contradict pursuing a commercial model (e.g. based on licensing) for other user groups in parallel. It is important to keep in mind that if there is value created by the database, then someone should be motivated to raise the funds for its provision. That key user group or industry/sector should be the focus in the beginning to create value where it is most (urgently) needed. This will, in turn, create further opportunities as life cycle thinking is adopted in other sectors. Subsequent efforts should strive to increase the base of LCA users nationally (e.g. through the promotion and application of LCA in policy formulation and decision making). Demonstrating the value created by the LCA database through monitoring both tangible results (e.g. usage of the database, number of licences, members or contributors, etc.; see section 'Monitoring progress') and more general signs of LCA becoming mainstream (e.g. uptake of LCA in education, research, and public policy, sustainability initiatives or innovations in the region built on life cycle thinking and the potential impact thereof, etc.) will also help build support for it. It is usually easier to find funding for projects aimed at developing new data/datasets, tools or features than for maintenance and updates. To secure the long-term provision and maintenance of the database necessitates timely and careful attention to the funding opportunities for developing a sustainable business model, ideally already during the database roadmap process. This helps to avoid the initiative stalling once the initial seed funding or start-up grants are exhausted.

Text box 3. The Malaysian Life Cycle Inventory Database (MYLCID), an LCA database entailing a national initiative towards cleaner production.

The need to establish a national LCA database in Malaysia was inscribed in the 9th Malaysian Plan (2005-2010). By facilitating the application of LCA to evaluate production and manufacturing in the country, the goal was to promote environmentally sound technologies and the adoption of self-regulatory measures in the Malaysian industry. SIRIM Berhad, a publicly owned industrial research and technology organization, has been mandated by the Government to undertake this task.

At that point of time, the low awareness of LCA among stakeholders in general posed a major challenge for SIRIM to initiate engagements with the relevant industries, academics and the public sector. With SIRIM's LCA practitioners just being introduced to the concept of LCA coupled with the lack of software support and available data, SIRIM partnered with an international LCA software developer to realize the mandate. The main criteria relied on was that the LCA database system must be developed in line with the ISO/TS 14048:2002 requirements. The LCA database known as Malaysia Life Cycle Inventory Database (MYLCID) was successfully rolled out by the end of the 9th Malaysian Plan.

Malaysia has benefitted from international support and collaborations for building human resource capacity: through the assistance of Japan (JETRO), SIRIM implemented a capacity-building programme 'Establishment of LCA Methodology and Application in Malaysia' from 2004 to 2008. Following that, SIRIM continued with further initiatives under the EU's SWITCH-Asia project on 'Environmental Declaration for Sustainable Construction & Building Materials' from 2012 to 2015. Within the same period (from 2014 to 2015), SIRIM received external expert support from UNEP and the Life Cycle Initiative's programme on 'Relating to the Technical Support of National & Regional Initiatives and Networks on LCA Databases and Related Capacity Building, Communication and Research Elements' which also benefited the counterparts from Thailand and Philippines. This initiative resulted in a batch of LCA datasets published in the MYLCID.

Ten years on since the inception of MYLCID, the development of the LCA database has stagnated due to lack of support in terms of users and continuing funding. The users of the system are mostly confined to academics, e.g. master's and doctoral degree candidates conducting LCA studies. Minimal requests for LCI datasets come from the industrial sector, research institutions, or the public sector. Other sources of information and data are considered sufficient to meet the requirements related to environmental performance metrics at present.

Despite increasing numbers of LCA studies carried out by academics and public sector-based research arms, none are yet contributing to the MYLCID database. A stakeholders' engagement initiative to continuously spur interests was held in April 2019 in tandem with a public awareness workshop on 'Enhancing LCI Database to Support Environmental Product Declaration' supported by the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP). The workshop solicited support from regional counterparts (Republic of Korea, Chinese Taipei, and Thailand).

Figure 4. Impression from Malaysia Life Cycle Inventory Database system.

Human resources

Human resources, that is, the skills and capacity of the people at the heart of a national LCA database initiative, are needed both for providing the necessary IT infrastructure, as well as for developing and reviewing datasets and managing the database as a whole. The establishment and implementation of standards and data quality guidelines also requires expertise and effort. In general, countries looking to develop national LCA databases should not underestimate the skills and efforts required. At the same time, many existing databases began with very few, and often no, full-time personnel. Working collaboratively, with several organizations providing resources and capacities in-kind at a moderate level, can be successful. In this way, efforts can be distributed and existing skillsets can be combined effectively. Generally, full-time personnel should only be added once needs and funding are clear and likely to remain in the long term.

The IT team or working group needs to understand the goal of the database to identify and develop solutions to support it. Having capable people in this team is essential to fulfil the principles and common goals of LCA databases (see section "Why a national LCA database?" on page 17). Furthermore, it is necessary for the IT team to work closely with the dataset developers and reviewers, as well as different user groups, to ensure that these principles are fulfilled. Ideally, three general competence areas need to be represented within the IT team, related to management, domain and technical execution. Management ideally encompasses an IT project manager (or Scrum master) and a product owner (preferably a domain expert, who understands both the database provider and user perspectives). Domain knowledge (or subject-matter expertise) entails incorporating the relevant requirements, terminology and functionality from the LCA field into the software development. The technical execution requires capacity for front and backend development and system deployment.

For successful implementation of IT projects, it is important to allocate sufficient resources for 'requirements engineering'[13] upfront and to adopt an iterative development approach (such as agile, prototyping or similar) allowing feedback from focus groups/beta-testers. Careful identification and specification of system requirements (e.g. through 'use cases') is an investment that can save significant time and resources over the life span of the system/software, or even prevent project failure. For this, hiring or acquiring the support of an experienced IT project manager throughout the IT project should be considered. Expertise in the development of LCA databases has been built up internationally, and involving an international expert might be a better solution than trying to build such expertise from scratch at the outset. However, where such partnerships are established, the transfer of skills should be an integral and explicit part of the agreement, with the goal that the national LCA database is able to function independently.

The number of people involved in the provision of data to an LCA database depends on its goal and scope. Data collection, inventory generation and dataset submissions can be performed internally by the database management team, through external data providers (e.g. LCA researchers or commercial service providers, industries or industry associations, etc.) or in a combination thereof. In terms of dataset development, it might also be possible to capitalize on human resources not directly related to the database, e.g. academic or research and development (R&D) projects or national statistics, generating data that can be transformed into compatible datasets with reasonable effort.

An LCA study typically requires data on processes spanning a wide range of different industries (e.g. energy, transportation, manufacturing, agriculture and waste management). Processes in each industry might have distinct characteristics and terminologies, but will still need to be linked to other processes (datasets) from other industries to build consistent product systems. Researchers or industry experts from different backgrounds are therefore necessary to establish a common terminology and requirements to guarantee the consistency demanded for an LCA database.

An LCA database is only as good as the utility it offers its users, for example, in terms of the policies or decisions it can support. In this regard, 'human resources' are also needed to form a stable user base for the database in the country. To this end, broad and inclusive capacity building is necessary. Research projects, including those of undergraduate and graduate students, can facilitate dataset creation and explore new ways of analysing and applying the data. The application of LCA has been supported and promoted in many countries by the Life Cycle Initiative since 2002,

13 See for example the international standard ISO/IEC/IEEE 29148:2018 for Systems and software engineering – Life cycle processes – Requirements engineering.

Text box 4. The steps towards establishing a 'critical mass' of national capacity for LCA in Uganda.

Formal LCA capacity building in Uganda started in 2013 under the international development and cooperation programme 'Trade Promotion through Standardization in the East African Community (EAC) Region'. This was a joint programme between the EAC countries and Swedish Standards Institute (SIS), funded by the Swedish International Development Cooperation Agency (Sida). SIS was the contracting party with Sida. The medium-term outcome of the programme enhanced the capacity of stakeholders in EAC in the ISO standard-setting processes and implementation of the LCA-related ISO standards. This included capacity building in database development in 2013 and 2014. The project also provided training for a pool of LCA practitioners and a 'training of trainers' (LCA-ToT) in 2015 and 2016. These training sessions were aimed at building the capacity in the use of the ISO LCA-related standards by utilizing blended learning approaches. This model complemented and scaled up current practices and activities related to environmental management systems in Uganda, thus improving national awareness in the relevant ISO standards.

Figure 5. Participants of the Training-of-Trainers on LCA in 2015-2016.

With the aim of developing a national LCA database, seventeen people were trained in data acquisition and documentation (including LCI modelling and analysis), data quality review, and strategic continuous improvement in quality and quantity. On the other hand, the LCA-ToT included three training sessions of 40 hours each, first pilot projects, and an examination. This training course addressed the fundamental concepts of LCA, for the trainees to develop their understanding and skills in the application to start conducting their own LCA studies and undertake further capacity building in Uganda. Overall, 35 people were trained in the application of LCA standards between 2013 and 2017, with six people qualifying as LCA trainers. The pilot projects were conducted in partnership with Kyambogo University and Makerere University, in which 25 trainees participated in case studies on pineapple, hot pepper, coffee, sugar, papaya, and wood briquettes. Two of these studies are currently undergoing critical review for publication in scientific journals.

Going forward, the LCA practitioners who benefited from earlier training activities participated in the implementation of the UNEP-funded pilot case study on 'Life Cycle Management Capability Maturity Model' (LCM-CMM) in 2014. The national community formed the LCA Network Uganda, which in turn engaged in the development of LCA database roadmap for Uganda. One member received the Life Cycle Initiative's LCA award 2017 (with the project earning a Certificate of Excellence in 2019).

resulting in the creation of regional LCA networks (e.g. the Ibero-American Life Cycle Network, RICV). Online training is also available free of charge through the Life Cycle Initiative as e-learning modules, to raise awareness and support knowledge building. The first phase of the Sustainable Recycling Industries (SRI) programme in 2014-2018 also supported LCA capacity-building efforts in various countries, including Brazil, India and South Africa. In the Brazilian case, several workshops were performed, with their purposes ranging from awareness-raising to training on more advanced topics in LCI and LCIA modelling. For example, over 600 people have been trained in Brazil through the LCA-related activities of the SRI programme alone. "Text box 4. The steps towards establishing a 'critical mass' of national capacity for LCA in Uganda." on page 35 provides a summary of the activities under other initiatives that formed the LCA community in Uganda.

Database hosting

Database hosting is here understood to refer both to the organization assigned the responsibility to provide a 'home' for the database initiative as well as the IT system set up to this end. There is a wide range of expectations and responsibilities that come with the hosting of an LCA database. One important aspect, raised in the stakeholder consultations undertaken within the Development of National LCA Database Roadmaps project, was the relationship and trust between regulated industries for providing data to a database hosted by the regulator (such as the national environmental protection agency). Having an organization perceived as being 'neutral' by both sides to serve as database host might help bridge this gap and could also prove less vulnerable in the long run. At the same time, being embedded in a larger organization, such as a government agency or research institute, might offer several operational advantages, e.g. access to existing infrastructure and administrative support). It might also prove beneficial for promoting uptake of LCA in public policy by shortening the 'distance' to policy-makers. Looking around the world, there are examples of existing databases hosted by government agencies (e.g. in Brazil, the European Union, Malaysia, Switzerland, Thailand and the U.S.), universities or other research institutes (e.g. in China, New Zealand, Sweden), national LCA networks (e.g., Peru) and similar organizations (e.g., Australia). An example of the process for designating a host institution for a prospective national LCA database in Sri Lanka is outlined in "Text box 5. Finding a 'home' for a national LCA database initiative, the experience from Sri Lanka." on page 37.

An LCA database can be made available to its users by sharing or distributing datasets or result files directly or online through a web-based system, e.g. with a browser, or over an application program interface (API). Regardless of the solution chosen, the database hosting system must be reliable, secure and guarantee the integrity of the data content, while at the same time easy for users to access and use. The requirements for database hosting IT infrastructure depend mostly on the level of service offered (or intended to be offered). At the simplest end of the spectrum, a zipped archive with all the datasets in a given format and a few explanatory files can be distributed directly or placed on a file-sharing platform. At the other end of the spectrum, a database system, such as a Product/Organisation Environmental Footprint (PEF/OEF) node or the ecoQuery system, offers various features, such as user management (login, password reset, etc.), a search engine, data visualization, selective download, user support like interactive forums or FAQs, etc. Some tools for database hosting are available for free, e.g. the European Commission provides Soda4LCA for setting up and customizing online nodes that allows sharing databases in the ILCD format, and the direct connection with GLAD and the LCDN.

It is up to the database manager to establish the level of service that is required in accordance with the vision and goals that have been defined for the database, and the degree to which that is attainable under the resources available (insufficient resources might require the vision and goals to be revisited). As soon as the selected option is more complex than a simple archive download, web design and server management knowledge (human resources) are necessary. The time and resource investment to host a database should not be underestimated, and the description of the user experience should therefore be carefully defined in detail. Working with established solutions can save resources. Setting up nodes, for example, on GLAD is feasible with free, open-source software that can serve both hosting and interoperability needs.

Text box 5. Finding a 'home' for a national LCA database initiative, the experience from Sri Lanka.

Within the Development of National LCA Database Roadmaps project, the primary goal for the national LCA database development for Sri Lanka was to provide country-specific, high-quality LCA data for supporting LCA activities in the country. The vision of the LCI database roadmap for Sri Lanka is therefore to create an authoritative, transparent, consistent, and reliable platform that provides easily accessible, up-to-date, quality LCA data on the country's major products, services, and industries. In addition, it should promote the best-practice in LCA.

The identification of an appropriate host institution is key to secure the viability of the national LCA database initiative. In Sri Lanka, a suitable layout of the governance structure for the LCA database development was first mapped out in the discussions within the NDWG. From these discussions, the National Cleaner Production Centre in Sri Lanka (NCPCSL), the implementation partner of the database roadmap project, was nominated to also assume responsibility for the roadmap implementation and database management. This decision was further approved by representatives of the national stakeholder communities during the first national LCA conference on 30 May 2019, where the final database roadmap report was disseminated to a wide stakeholder audience.

Figure 6. Impressions from the first national conference on LCA in Sri Lanka, organized by NCPCSL.

As the lead organization, the NCPCSL will oversee the overall coordination of the national activities for the database creation, content, maintenance, and updating with the help of working committees, such as a steering committee, advisory board, and other working groups for the different database development tasks. In earlier LCA-related activities, the NCPCSL has developed LCIs for the agri-food sector (tea, rice and dairy) in Sri Lanka under UNEP's 'Consumer Information Project'.

With almost two decades in the sustainability field, NCPCSL has the experience in working with stakeholders from industries, academia, public institutions, UN organizations, international donors and funding organizations, NGOs, etc. NCPCSL works closely with government ministries in national activities such as policy formulation, representing major international environmental conventions in various steering committees and advisory boards. The NCPCSL is therefore ideally positioned to develop a national LCA database with broad stakeholder acceptance and support. As a member of RECPnet, a global network for organizations promoting resource efficiency and cleaner production present in about 60 countries, the experiences from Sri Lanka serve as an inspiration for how NCPCs can play a central role in national LCA database initiatives.

Data needs and availability

There can be hundreds or thousands of datasets covering distinct (unit) processes needed for a LCA database in order to adequately represent important product systems and supply chains. Defining which datasets are needed as a priority is crucial but challenging. Maintaining interoperability between different data sources might allow for focusing resources on addressing the most pressing needs for local data. The scope of the database content should be planned, and more ambitious data coverage should be approached iteratively. The intended uses of, and potential value created by, the national LCA database should be kept in mind during this process as they will help define both the data needs as well as the data quality requirements.

Defining data content goals for a national LCA database can be performed in different ways:

1) Covering the most relevant processes or industries based on their contribution to the (national) economy as a whole;

2) Covering the most relevant processes or industries in an economy based on widespread use, e.g. transport activities and electricity generation and distribution;

3) Covering processes of high environmental significance or concern, e.g. mining, production of construction materials, and transport activities (e.g. the case of Quebec, described in Lesage and Sampson 2016); [14]

4) Covering processes unique or of particular relevance to the country (e.g. coal-based chemicals and liquid fuels, as in the case of South Africa, Russo and von Blottnitz 2018);[15]

5) Considering data availability;

6) Other regional criteria, e.g. industries under pressure to adopt (international) standards or labelling schemes, such as environmental product declarations (EPDs).

Once the prioritized list of products, processes or industries has been defined, the next step is to determine a strategy for data collection, inventory generation and dataset creation. Whereas primary data are usually preferable in LCA, this often necessitates a strong commitment and openness from the affected industries. Publicly owned or controlled enterprises (e.g. in generation/distribution of basic utilities, petroleum extraction/refineries, etc.) might in some cases be in a better position to support this kind of initiative and share primary data directly. Industry associations can act as trusted intermediaries for taking the lead on systematic data collection and preparation of representative industry averages, while ensuring the privacy of the individual members. For some industries or economic activities, such as agricultural crop production and forestry, clinker and cement, petroleum refineries, water supply, or waste and wastewater treatment, one might have to resort to secondary data sources such as national statistics and emission inventories or to dedicated models/tools for LCI generation.

In recent years, community-driven approaches to generate sustainability information have started to emerge. For example, the Community-Driven Life Cycle Information (CDLCI) initiative aims to make it easier to develop and access sector- and region-specific databases. These will be able to build on core data on widely used activities, e.g. related to energy, transport services or waste management, sourced with a common methodology from relevant experts in the LCA community and beyond. Other novel initiatives explore innovative data approaches: the objective of the Big Open Network for Sustainability Assessment Information (BONSAI) is to maintain open data and open source software to produce transparent and reproducible product footprints. The strategy of BONSAI includes the application of innovative methods and tools for automated data harvesting and processing into reliable sustainability information. Further examples of new approaches, from the agricultural sector, include trase and Hestia.

Recontextualization

Another approach consists of the 'recontextualization' of inventories, where data on activities in one region are used to represent those activities in another region. This might entail the creation of copies of datasets for another region and linking these to represent local supply chains (e.g. in the presence of regional markets). A higher degree of recontextualization, on the other hand, includes adjusting key inputs or the inventory model parameters driving the results, such as fuel types and other sources of energy, irrigation systems or tillage operations, process efficiencies or yields, climatic factors and

14 Lesage, P. and Samson, R. (2013) The Quebec Life Cycle Inventory Database Project. *The International Journal of Life Cycle Assessment*, 21:1282–1289. DOI: 10.1007/s11367-013-0593-1.

15 Russo V., and von Blottnitz H. (2018) *Life Cycle Inventories of Synthetic Fuel Production from Coal and Domestic Fuel Markets - South Africa.* ecoinvent association, Zürich, Switzerland.

precipitation, infrastructure requirements, etc. Working with established background databases of global scope, and adjusting or updating to the specific country context where most needed, can hence be an effective way to expand a national LCA database, especially during the initial phase. Recontextualized datasets should, regardless of the original source, be validated and reviewed according to the same data quality requirements as other data submissions prior to acceptance to the national LCA database. It is also important to note that recontextualization constitutes a form of derivative use of the original datasets, which might be subjected to copyright restrictions stipulated by the end-user license agreement (or similar).

Missing data

Representative or appropriate data may not always be readily available. Rather, it is not uncommon to find oneself in a situation where data is missing or inaccessible, or that the available data (including metadata and accompanying documentation) do not meet the data quality requirements of the database. In the case of missing data, one may decide to assign a value of 'zero', or assign a non-zero value derived from, for example, expert estimation or derived from an approximate activity. A 'zero' value that is entered due to the absence of better information should be clearly distinguished from informed zero values in an inventory. ISO 14044:2006 states that the treatment of missing values shall be documented and explained. In addition, the completeness criteria set by the data quality guidelines should be heeded. It is advisable to resort to 'best-guesses' (based on qualified estimates or extrapolations) rather than zero values where possible, as LCI data gaps might result in (deceivingly) favourable LCIA results compared to more complete inventories. The data quality for estimates or approximations should be indicated transparently and assessed (see also next sub-section on "Data quality requirements and review" on page 40).

Incomplete datasets

In some situations, region-specific data may be available but they do not fulfil the established data quality requirements of the database. In Brazil, for instance, a number of academic LCA studies have been published since the turn of the century. However, data collected in these studies are not yet available in SICV because the value of contributing to a database is not widely recognized by the academic community. Furthermore, during the LCI component within the SRI programme, hundreds of datasets were developed that are available freely to SICV but that do not fulfil the data format requirements. As a result, it is necessary to find strategies and funding for further work that enables the integration of these readily available datasets into the database. At the same time, the efforts necessary to 'upgrade' older da**tasets,** e.g. conceived for a specific study setting, are easily underestimated. It is therefore advisable to also consider the option of new data collection/inventory modelling alongside revisions of existing data.

Maintaining the database content

While a database may sometimes be perceived as a static deliverable, it is important to realize that LCA data will need to be maintained and updated to stay relevant over time. For example, materials, technologies, practices and processes represented may change, or shifts in the market positions of competing production routes or producing regions can occur. The long-term management, including both maintenance and development, of the database should be planned from the outset. As mentioned in the preface, there is also the possibility of data libraries – decentralized collections of datasets – without any directly controlling entity. In this document, we deal primarily with the development of databases that are intended to be actively managed and that impose specific requirements on datasets to be included to ensure consistency.

> In recent years, community-driven approaches to generate sustainability information have started to emerge [...] Another approach consists of the 'recontextualization' of inventories, where data on activities in one region are used to represent those activities in another region.

The quality of a national LCA database does not only depend on aspects like scope of coverage or (geographic) representativeness. It is also closely linked to the consistency of the data content across the database. An important principle is therefore that the data content follows predefined data quality guidelines. These include several high-level technical or methodological definitions that are needed during the conception and development of an LCA database.

The responsibility for evaluating the need for data content updates typically rests with the database management. Alternatively, a technical expert group/council might instead provide the analysis with recommendations as an input to the database management. Periodic reviews based on the available information (e.g. dataset age and reference period, data quality indicators, user feedback, etc.), ideally involving the relevant topic expert(s), can serve to identify and prioritize among the needs for updates. Data content maintenance can be resource-intensive, especially when extensive data collection or modelling efforts are needed to keep information up to date. Any modifications to the information in the datasets or as supplementary material must respect the copyright agreement established between the LCA database organization and the original data source or the dataset providers. Version control and regular (e.g. yearly or biannual), well-documented updates help users to follow how the database content evolves over time, while also enabling unambiguous referencing to the database version used.

Data quality requirements and review

The quality of a national LCA database (i.e. the degree to which it fulfils the users' requirements and meets their needs) does not only depend on aspects like scope of coverage or (geographic) representativeness. It is also closely linked to the consistency of the data content across the database. An important principle is therefore that the data content follows predefined data quality guidelines. These include several high-level technical or methodological definitions that are needed during the conception and development of an LCA database:

- inventory and system modelling support (e.g. for dealing with multifunctionality)
- LCIA methods supported or results to be offered
- data quality requirements, including best practice for inventory modelling and dataset documentation
- nomenclature, data exchange formats and interoperability features
- validation and review procedures for new data submissions, as well as of the integrity of the database as a whole (see UNEP 2011 for principles of databases, ISO standards 14040/44/48, and the section on data quality requirements and review, below).

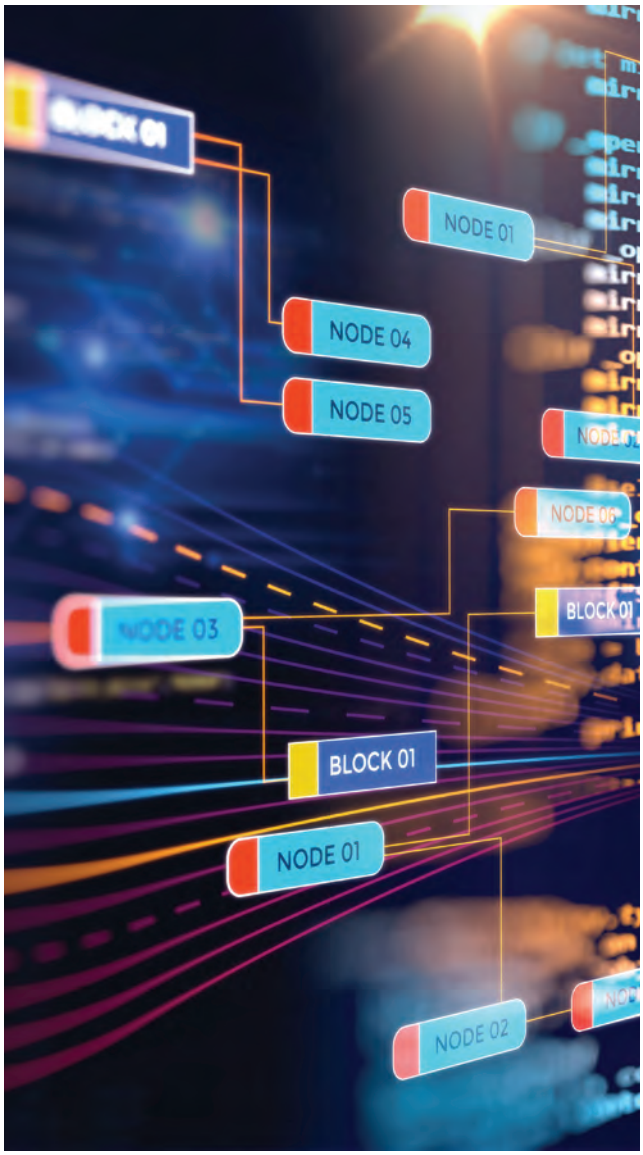
A formal review procedure is a common approach to

address and enforce the requirements stipulated in the data quality guidelines for new or updated data submissions. The review procedure ideally includes a (technical) validation, typically performed internally by the database management team, a review of data content involving appropriate subject experts and, if relevant, a review of the underlying model(s) used for inventory generation. The continuity (stability) of the database results, e.g. the calculated LCIA scores, can then be evaluated through a combination of semi- or fully automated analysis and expert reviews.

In any data submission, some data may be missing, unrepresentative or otherwise inappropriate or from an unreliable data source. Furthermore, some data may be derived from modelling rather than direct measurements or statistics. As a result, it is important to transparently document the extent to which data fulfil the data quality requirements of the database. The data quality guidelines should clearly distinguish between mandatory requirements and optional aspects. Not all datasets will reach the same level of detail and quality, and the database system should allow for assessing the fitness-of-purpose, e.g. through transparent documentation, systematic meta-information, uncertainty information and/or data quality indicators. The scope and intended uses of the database will have significant influence on the data quality requirements, which is why the database quality requirements should be carefully defined when designing and setting up the national LCA database. To maximize the utility of the data content for domestic and international users alike, as well as to avoid compatibility issues and facilitate interoperability with other data sources, it is recommended to consider using English alongside national languages for the dataset creation and documentation.

Examples of data quality guidelines or requirements can be found for the *Life Cycle Data Network (LCDN)* in EC-JRC (2016) and EC-JRC (2019), ecoinvent version 3 (ecoinvent 2013), and QualiData (IBICT, 2016; see also "Text box 6. Establishing data quality guidance and requirements: the example of 'QualiData' for SICV in Brazil." on page 42). Once the requirements are established, the process for reviewing needs to be defined, including the steps, responsibilities, inputs and outputs. "Figure 7. An example of a review procedure for a dataset submission to an LCA database." on page 43 illustrates an example of a review process consisting of two main steps: (1) verification that the dataset conforms to the **format requirements** (i.e., technical validation) and (2) verification of the **content level** by subject experts. If all requirements are met, the dataset is deemed ready to be stored and integrated into the database and published.

It is also important to reflect on the needs and requirements for data on an **individual (unit) process level** versus **higher levels** of aggregation. The *Shonan Guidance Principles* for LCA databases recognizes that **'there may be valid technical, business, or practical reasons for having aggregated datasets in an LCI database.**' (UNEP 2011, p. 127) Nevertheless, it is also recommended that unallocated unit process data are provided as far as possible. A unit process (UPR) is the smallest element of a product system considered in LCI analysis for which data are collected and inputs and outputs are quantified. (ISO 14044:2006).



Text box 6. Establishing data quality guidance and requirements: the example of '*QualiData*' for SICV in Brazil.

The 'QualiData' guidance was established as a part of the consolidation of SICV Brazil, the national LCA database initiative in Brazil. The underlying principle of the SICV Brazil is that all data submissions to the database should meet clear expectations for quality and transparency. The preparation of the data quality requirements was structured into three main steps. First, a selection of existing reference documents and supporting material was reviewed and analysed to inform the formulation of the 'QualiData' guidance. This included the data quality requirements or guidelines for the Product Environmental Footprint (PEF) by the European Commission (EC, 2012), version 3 of the ecoinvent LCI database (Weidema et al., 2013), and for the AusLCI database in Australia (ALCAS, 2014). These documents were chosen mainly due to their timeliness, perceived relevance, and recognition among LCA practitioners globally. The review revealed that while each of these documents defines a series of minimum requirements that must be met by data submissions to the respective systems, some requirements were not found across the set. In addition, common items or aspects were not always classified consistently (i.e., as being considered either mandatory, recommended or optional).

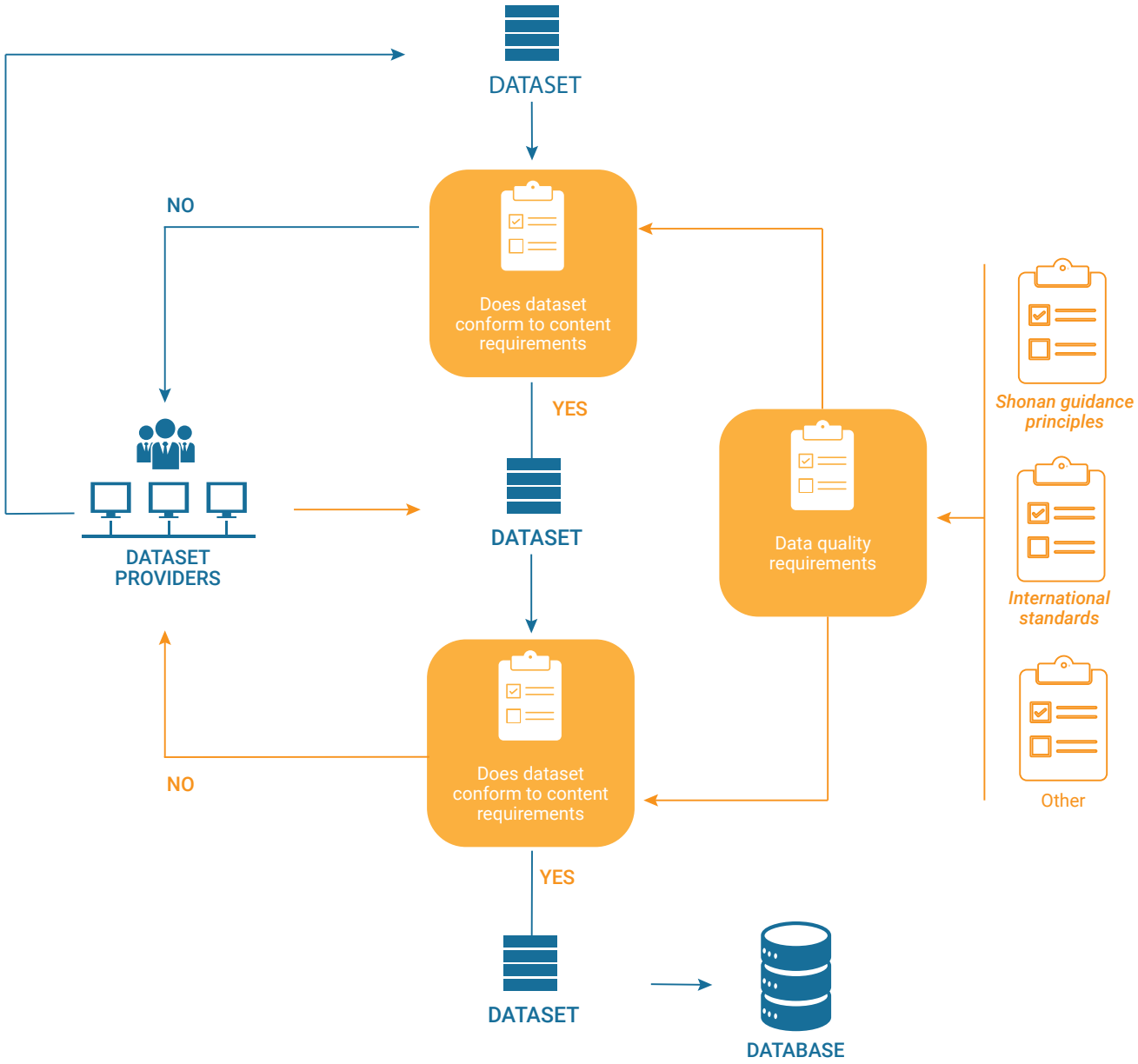
As the next step, the team responsible for the preparation of the QualiData Guide defined the minimum requirements by selecting 42 items, organized into four groups: General; Methods and Processes; Flows, and; Review. These items served as the starting point for drafting the actual data quality guidelines document. To summarize and simplify the information required to approve a dataset, a practical checklist was provided in the appendix. Each requirement was associated with an objective question, and supplemented by descriptive questions (e.g. 'which?', 'how?', 'how much?'), for those requirements that require further clarification. The 42 selected requirements were classified as either mandatory, recommended, or optional. For a dataset to be accepted into SICV Brazil, it must meet all requirements classified as mandatory.

As QualiData is a document to be used by the Brazilian LCA community, the guidance it provides was consolidated after a public review process. To this end, a set of LCA experts were invited to suggest improvements for its content prior to the release of the final version. This third-party review was aimed to make the process of establishing the QualiData guidance more robust and transparent. Three years after its first release, Gerhardt et al. (2019) evaluated the use of QualiData, concluding that it needs to be updated or complemented with new requirements, especially regarding data quality and a dataset quality score. To this end, it is foreseen to expand the discussions, e.g. regarding the minimum requirements and directions provided for dataset creation, beyond the authors of the original document to include further stakeholders.

Unallocated unit processes offer the highest degree of transparency and flexibility in terms of supporting future updates and different system modelling choices, e.g. for attributional or consequential studies and different allocation methods. Furthermore, the added resolution in the supply chains allows for performing in-depth contribution and sensitivity analyses that aid in the interpretation of results and lead to better product system understanding. More aggregated datasets can be obtained by averaging data from several assembly lines or production sites/suppliers/regions/technologies/etc. (i.e., horizontal averaging) and/or by covering multiple interlinked sequential processes within the supply chain or over different life cycle phases (i.e., vertical aggregation). Aggregated datasets can be more convenient to work with due to reduced complexity and calculation effort. They may also help ensure confidentiality of the underlying data and of individual data sources/providers while still offering the benefits of unit processes, provided that the degree of aggregation is not too extensive, and that the datasets are sufficiently documented.

Chapter 3 of the Shonan Guidance Principles (UNEP 2011) provides guidance on several critical aspects that need to be addressed when considering whether to aggregate process data for LCA dataset development. To ensure credibility, the Shonan Guidance also recommends that unit process datasets be reviewed and verified independently prior to the generation of aggregated process datasets, and that data providers

Figure 7. An example of a review procedure for a dataset submission to an LCA database.



clearly specify and document the motivation and modelling approaches used for the aggregation, as well as the intended use of the datasets.

Data formats and database interoperability

A number of life cycle data exchange formats have emerged to manage the large amount of information (including metadata) needed in datasets for LCA purposes. An ISO standard (ISO/TS 14048:2002)[16] was also developed to provide guidance to life cycle data developers. The most widely used data exchange formats are covered here. Emerging LCA databases might start out with only one but should ideally strive to support several of these formats.

As processes are linked to others along the life cycle of a product, collecting data on all the processes is resource-intensive. In general, a database operator can expect that users will resort to multiple databases and other data sources for their work. While some applications, such as PEF, require the use of specific data, it is generally more common to see practitioners use a variety of data sources. In this regard, it is strongly recommended that national databases be prepared to be interoperable with others. Relying on multiple data sources, enabled by data interoperability, can improve the completeness of the product systems or supply chains under study. But it is recommended that the users take care during the interpretation phase due to the possible differences in data quality requirements and system models in different databases.[17]

To exchange data, a standardized format must be selected. The ILCD and ecoSpold (v1 and v2) formats represent the two most well-established data exchange formats currently available. Both ILCD and ecoSpold are compliant with ISO/TS 14048 and are based on Extensible Markup Language (XML). Conversion between these most common data exchange formats is supported by available converters, e.g. in LCA software, the openLCA format converter provided by GreenDelta or the converter function in the GLAD network. This overview of formats also encompasses the relatively new JSON-LD data exchange format.

16 ISO/TS 14048:2002 Environmental management – Life cycle assessment – - Data documentation format. International Organization for Standardization.

17 See, for example, Saade et al. (2019) for a review of system model choices in scientific publications using the ecoinvent database: Saade, M.R.M., Gomes, V., da Silva, M.G. et al. (2019) Investigating transparency regarding ecoinvent users' system model choices. The International Journal of Life Cycle Assessment 24(1). DOI: 10.1007/s11367-018-1509-x.

ILCD

The development of the International Reference Life Cycle Data System (ILCD), started in 2005 (originally under the name ELCD data format), was driven by the need for:[18] (i) a data format for the European Reference Life Cycle Database (ELCD), (ii) a common format to support data exchange (import and export) of the ELCD reference datasets with other databases and software tools, (iii) a common format to be used to exchange LCA datasets among all relevant LCA tools and databases (e.g. for LCA information transfer along supply chains) and for data networks, and (more recently) and (iv) the development of data under the Environmental Footprint scheme (PEF/OEF). The ILCD format was developed with these aspects in mind and has evolved since then based on existing practice and through broad consultation between several partners under the coordination of the Joint Research Centre of the European Commission (EC-JRC).

The ELCD's function has been superseded by the Life Cycle Data Network (LCDN), which is based on the ILCD format. The format is used in the Product and Organisation Environmental Footprint (PEF/OEF) pilot projects of the European Commission. The specifications of the ILCD format and guidance for the creation of ILCD entry level and PEF/OEF-compliant data are provided on the website of the EC-JRC. A series of tools for data analysis, validation and sharing through LCND is also available. The ILCD format is supported by most major LCA software applications and it is used, besides in the LCDN, by national LCA databases, such as SICV in Brazil, MYLCID in Malaysia and the Thai National LCI database. The PEF/OEF was developed in ILCD format with significant changes to the elementary flow nomenclature system. These changes must be considered during the development of national databases due to the need for homogeneity in nomenclature among the datasets to be created using the ILCD system. This is also fundamental for ensuring data interoperability, as addressed below.

ecoSpold

The ecoSpold format is the result of several iterative evolutions of XML-based data formats for LCA data, beginning in the 1990s. While sometimes associated

18 Wolf, M.A., C. Düpmeier, O. Kusche (2011) The International Reference Life Cycle Data System (ILCD) Format – Basic concepts and implementation of life cycle impact assessment (LCIA) method data sets; in EnviroInfo 2011: Innovations in Sharing Environmental Observations and Information. Shaker Verlag Aachen, ISBN: 978-3-8440-0451-9.

primarily with the ecoinvent LCI database, it is an open-source format, and its most recent version is the ecoSpold v2 format (Meinshausen et al. 2016).[19] The ecoSpold format is supported by most major LCA software applications, and it is used, besides for the ecoinvent database, by the AusLCI in Australia, PeruLCA in Peru and the Quebec LCI database in Canada.

JSON-LD

A format based on JavaScript Object Notation for Linked Data (JSON-LD) was developed and implemented by GreenDelta as an alternative to the established formats in XML. Besides the aim to reduce the effort for implementation and remove inconsistencies between the ILCD and ecoSpold formats, other advantages, such as being human-readable and the ease of integration into web-applications, were also put forward as motivation for a new format. JSON-LD was implemented as one of the formats used by openLCA in 2015, but support for this format in other LCA software is still limited. The JSON-LD data exchange format is directly created in openLCA over the LCA Collaboration Server and is, thus, straightforward to use with GLAD (interoperability is described in the next subsection below).

Interoperability over the Global LCA Data Access (GLAD) network

UNEP serves as the secretariat for the Global LCA Data Access (GLAD) network, which is maintained by the Life Cycle Initiative and strives for better data accessibility and interoperability among different sources of data. The network provides users with an interface to find and access LCI datasets from different independently operated LCA databases (nodes). The interoperability of data from different nodes and in different formats is achieved through a set of metadata descriptors required for all datasets linked to GLAD. Furthermore, nodes joining the GLAD network commit to fulfilling a minimum set of requirements, including: use of one of the main data exchange formats, a common flow nomenclature, that all meta-information of datasets is provided in the English language (as a minimum), and that this information is freely available (see also GLAD node requirements and Further resources at the end of this document).[20]

Guidance on how to establish a node and how to link datasets to GLAD, by completing the metadata descriptors for data in either the ILCD or ecoSpold v2 format, is available to datasets providers on the GLAD website. It should be noted that the guidance document concludes from two test cases that the implementation efforts go beyond what has so far been required for the most common LCA data exchange formats, including the mapping of process datasets to the United Nations Standard Products and Services Code (UNSPSC) categories. Additional classification systems are listed under 'Further resources' at the end of this report. Correspondence tables are available to map between some of the common classification systems, e.g. from the United Nations Statistical Division. It is recommended that these partly diverging requirements between different data exchange formats be kept in mind when determining which format(s) to be used (or supported) and the quality standards to be followed for national LCA databases.

New database initiatives should not underestimate the value of being interoperable with other data sources and the visibility that a platform such as the GLAD network can offer. Users will appreciate any efforts that database providers can make to help them find, import and use LCA data, and the GLAD network is intended to support and facilitate these processes. The experience from AGRIBALYSE, an LCI database from France for agricultural products, on addressing data interoperability challenges is presented in "Text box 7. AGRIBALYSE, the French agricultural and food LCI database – addressing data interoperability challenges." on page 46.

19 Meinshausen, I., P. Müller-Beilschmidt, T Viere (2016) The EcoSpold 2 format - why a new format? *The International Journal of Life Cycle Assessment*, 21(9),1231–1235. DOI: 10.1007/s11367-014-0789-z.

20 The full list of requirements is available under the section *Further resources* at the end of this document or on the GLAD website.

Text box 7. AGRIBALYSE, the French agricultural and food LCI database – addressing data interoperability challenges.

The AGRIBALYSE database was first developed in 2009 by ADEME (the French Environment and Energy Management Agency) in partnership with a number of research organizations, technical institutes and ministries. It aims at supporting eco-design and environmental information in the agricultural and food sector; supporting private initiatives as well as public policies; from both production and consumption perspectives. Aligned with governmental policies promoting Open Data for all public work, the database is available for free to anyone.

It was clear from the beginning that it would be impossible for French partners to develop LCI datasets for all food products relevant from a French consumption perspective. Also, the aim was that users outside of France would be able to use AGRIBALYSE datasets for benchmarking, rather than them having to develop LCI datasets for French production activities themselves. Data interoperability was, therefore, a clear priority for the developers from the outset. Key steps taken to ensuring interoperability included: (a) providing data at the unit process level to support transparency; (b) using the ecoinvent database for background processes; (c) providing extensive documentation and methodological reports; (d) always striving for alignment with international standards (e.g. ISO, PEF, LEAP, as well as the Data Quality Guidelines from the ecoinvent Association); (e) using English as the default working language for all deliverables (most of which are also translated into French for local users); (f) using common data exchange formats and ensuring ease of access for users by directly distributing the database through LCA software applications and platforms that are most commonly used by the French food-LCA community. It is also intended that this data interoperability strategy will be maintained in the future.

Figure 8. Impression from a gathering of AGRIBALYSE partner organizations (left) and the logotype (right).

AGRIBALYSE version 3.0 will be published in April 2020. It combines many French datasets developed internally with data on imported products taken from the ecoinvent database and the World Food LCA Database. These connections were possible thanks to interoperability choices, both from a methodological and technical perspective. Being active in the LCA community (e.g. LCAfood, long-term cooperation with Agroscope and the ecoinvent Association, the PEF initiative, OLCAPest projects, etc.) also greatly helped in fostering and maintaining fruitful collaborations. Already widely used in its earlier versions, the AGRIBALYSE v3.0 database, with its broad scope and ability to connect with nutritional data, is expected to reach an even broader audience in the whole food sector.

CHAPTER 4

MAKING THE CASE FOR LCA

Alongside setting up a plan for database development, the database roadmap process can also be used to align within the local LCA community and key stakeholder groups on how to mainstream life cycle thinking and LCA-based approaches and metrics in the country. Important areas to address include promoting uptake in public policies, in the private sector and in research and education. Broad recognition and implementation through public policies or by industry may prove pivotal in acquiring the resources necessary to sustain a financially viable national LCA database. In addition, with the underlying data as the vehicle, these actors and institutions can become main drivers for a more sustainable development. Ultimately, these efforts all contribute to the positive impact of the national LCA database initiative. Practical application examples and success stories with tangible positive outcomes from other countries, industries or fields of research are powerful for transmitting the potential of adopting life cycle thinking and practices. This awareness-raising should ideally start already during the stakeholder consultations and then accompany the various database roadmap stages. Resources and tools are available to support such efforts, including a suite of e-learning modules provided by the Life Cycle Initiative. Available free of charge and in at least two different languages, the modules currently cover an introduction to life cycle thinking, as well as its application in business decision-making and policy-making.

LCA can support public policies aimed at promoting sustainable development, not only on the product level, but also for organizations, consumers, and regions (Hellweg and Milà i Canals, 2014).[21] LCA may, for example, provide information for sustainability reporting, identify processes or industries that demand improvement and drive innovation, support public procurement regulations and strengthen the competitiveness of organizations in restricted markets. Examples include the establishment of sustainability requirements for biofuels to receive government support in Europe under the Renewable Energy Directive[22] (based on quantified life cycle emissions of greenhouse gases), to provide incentives for fuel producers with better environmental performance (RenovaBio in Brazil), for environmental labelling or market access (Single Market for Green Products in Europe), and the Buy Clean California[23] Act to determine the eligibility of supplier of selected construction materials for public procurement in California through facility-specific EPDs or similar (as defined by the ISO 14025:2006 standard).

The development and expansion of national LCA databases ideally goes hand-in-hand with increased use of LCA to support public policy-making and regulation. It is therefore strongly recommended to engage and actively involve representatives of the relevant governmental bodies throughout the database roadmap process and implementation. An example from South Africa of the formation of a national database working group with special emphasis on public sector involvement is presented in in Text box 8. The representatives of these stakeholder groups can aid formulation of strategies for increased policy uptake through their insights into the policy-making process and their understanding of the political landscape and agenda. This may serve to set the priorities and requirements for data and also to obtain the funds and official support needed to address crucial data gaps.

From a business perspective, a recent publication by UNEP and the Life Cycle Initiative highlighted, from a diverse set of success stories from around the world, both the opportunities as well as the challenges in adopting life cycle thinking in business practices.[24] The potential benefits include reduced environmental (and social) footprint and risks, and improved resource efficiency. On the other hand, resistance within the company or from actors along the supply chains might block the process. And while 'early adopters' and 'champions' are important to lead the way and to spark interest, the full potential of LCA-based approaches is only realized through broad uptake and collective effort. Central pillars to this end include establishing trust and collaborations within and across industries and sectors, as well as building up the necessary human resource capacity and basis for LCA data in the country. As the understanding and acceptance of LCA as a tool for system analysis and decision support improves in industry, the willingness to share data on their processes should also increase. As the pool of regionally representative data grows,

21Hellweg, S., L. Milà i Canals (2016) Emerging approaches, challenges and opportunities in life cycle assessment. Science, 344(6188):1109-13. DOI: 10.1126/science.1248361.

22 Directive 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources

23 *The Buy Clean California Act* (Public Contract Code § 3500-3505).

24 UNEP (2019) *The Business Case for Life Cycle Thinking*. United Nations Environmental Programme (UNEP), the Life Cycle Initiative. Paris, France.

Table 1. Stages and main characteristics of LCA database maturity.

	STAGE OF MATURITY		
ASPECT	INFANCY	TEENAGE	ADULT
Governance	Not formalized (trial or spontaneous organization structure)	Increased formalization	Clear structure with roles and responsibilities formally defined
Capacity building and awareness-raising in LCA	First knowledge transfer among researchers and to PhD and Master's students	Training (typically standalone) of practitioners and increased awareness among directly affected stakeholder groups	Trainings widespread and well-integrated in the academic curriculum and some professional courses
Use of LCA	Mainly for academic studies	Some cases implemented in organizations[25]	Widespread, both in public (including for policies) and private sectors
Funding of LCA database	Voluntary (in-kind) contributions; seed money from national agencies or international donors	Mixed funding, often project-based; support from government agencies pivotal to expansion	Financial stability with established business model
Infrastructure	Datasets developed independently by single person/team	Datasets developed by several groups with some level of coordination	Implementation of standardized data formats and IT tools.
Datasets	Datasets developed ad-hoc for specific studies	Non- or only partly harmonized datasets, available without updates	Consistent datasets, regular updates
Interoperability	Poor to no data interoperability, e.g. single system set up	Datasets can be used in different platforms, but with some work	LCA database interoperable, connected to GLAD

the relevance of LCA to identifying hotspots and support setting priorities is further enhanced. This, in turn, benefits those industries willing to learn and adopt a life cycle perspective in improving resource efficiency and environmental performance, as well as by enabling better risk management, marketing and communication.

But all journeys must start from somewhere, by making the most of the resources at hand. Table 1 provides a generalized high-level summary of key aspects of LCA database development over three stages of maturity. National LCA database initiatives may initially need to focus on covering core industries or sectors and on creating real value for key user groups in specific applications. To reach full 'functionality' for LCA purposes, this means that complementary data sources will be required to cover inputs from other sectors or to model international supply chains. Ensuring data interoperability is therefore crucial. Initial seed funding, e.g. from national or international donor agencies, might be required to get the LCA database development started. Ideally, the LCA database development gets embedded in larger sustainability initiatives, which might offer both more context but also more stable funding. Regardless of which, once the national LCA database generates real value for its users, the motivation to contribute to its funding should increase. A potential key user group or industry/sector should therefore be the focus in the beginning to create value where it is most (urgently) needed. This will, in turn, create further opportunities as life cycle thinking is adopted by other actors.

25 See UNEP (2019) and the Life Cycle Initiative website for a compilation of success stories from diverse businesses around the world.

Text box 8. NDWG formation in South Africa for the Development of National LCA Database Roadmaps. project.

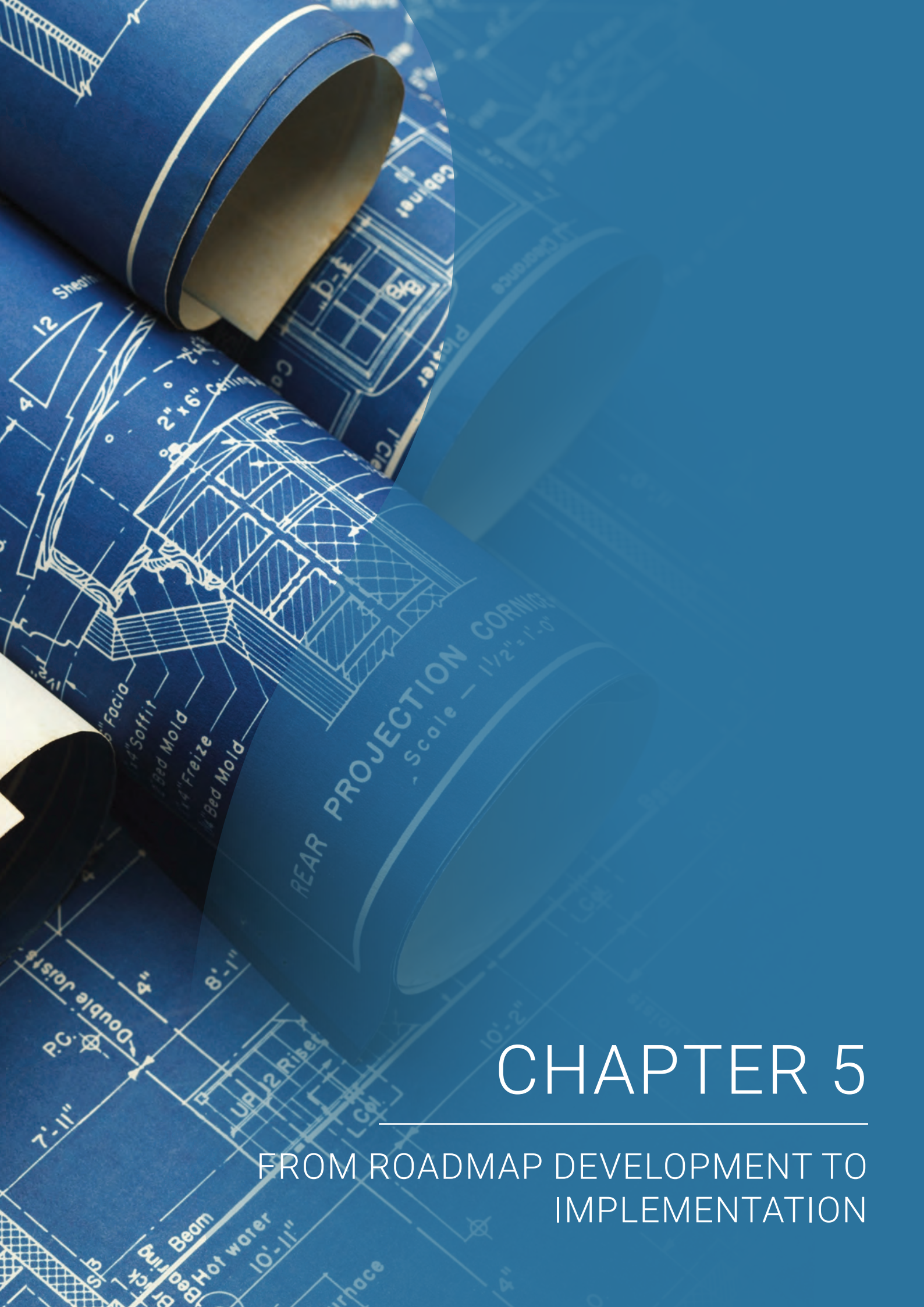
In South Africa, LCA has a well-established base, and academics and consultants have been generating LCA studies in a range of industry sectors since the mid-1990s. However, little data sharing between projects occurs, despite the need for this being recognized for a number of years. Previous efforts include a workshop to harmonise life cycle data on electricity in 2011, a UNEP workshop on Mainstreaming Life Cycle Thinking in 2014, and a UNEP/Life Cycle Initiative workshop 'Preparing elements for a roadmap of the South African LCA Database' in 2015. Appreciation of the need for a national LCA database was evident at these workshops and other LCA forums held since then. However, a common theme that emerged in discussions is the lack of any party having a clear mandate to drive LCA database efforts.

When it came to convening an NDWG for the Development of National LCA Database Roadmaps project, it was thus decided not to repeat the large workshop format but instead move the findings of the previous workshops forward and convene a small, targeted working group. The aim was to cover the range of LCA stakeholders in South Africa, while particularly targeting entities that could take on or be part of a national database project. Government representation was particularly sought, as the stakeholder least represented at previous workshops, despite having high potential for hosting a national database. The resultant NDWG consisted of eight members, with representation across academia/research (Universities of Witwatersrand and of Cape Town, and the Council for Scientific and Industrial Research), government (National Departments of Science and Innovation and Environment, Forestry and Fisheries) public sector (NCPC-SA, The Innovation Hub and Green-Cape) and civil society (WWF-SA).

Having NDWG members outside of the 'traditional' LCA community in South Africa with little knowledge on LCA but instead an understanding of the need for data to support policy development created a different dynamic to the discussions in the NDWG. In particular, much time/effort went into defining the vision and goals for a national LCA database that would meet the need for credible data to support South Africa's transition to a sustainable society. For government to support — and/or host — a national LCA database it became clear that it is essential that the LCA database resonates with the policy context in South Africa, most notably, that it is able to support the top priorities of the National Development Plan on eliminating poverty and reducing inequality.

Figure 9. Database roadmap dissemination at the NCPC-SA's 4th Industrial Efficiency Conference.

The roadmap process provided a valuable step on the road to a South African LCA database, moving beyond discussions to providing a tangible pathway towards developing a national database that will provide value to its users.



CHAPTER 5

FROM ROADMAP DEVELOPMENT TO IMPLEMENTATION

Executing the action plan: activities and timeline

Once the roadmap has been established, the next step is to progress with the development of the national LCA database by following the action plan agreed upon. By this point, each country will have its own unique database roadmap; it follows, therefore, that the process for implementing the roadmap will also vary among countries. However, the general steps will be relatively consistent. This section provides an overview of the work that can be expected to be done for taking the roadmap off the drawing board and into implementation. It is here assumed that funding for the initial phase of database development has been acquired. Thus, preceding the activities listed below are likely to be fundraising efforts and/or efforts towards finding a sponsor for the database. An account of previous efforts and the different approach taken in India within the Development of National LCA Database Roadmaps project is provided in "Text box 9. Find a strategy for turning a national database roadmap into actions: the case of India." on page 57. Furthermore, the experiences leading up to the launch of a national LCA database in Peru is summarized in "Text box 10. An inspiring milestone: from roadmap to implementation of Perú LCA, the Peruvian life cycle database." on page 58.

Typically, the following activities must be undertaken to initiate and progress roadmap implementation.

1. Approval of roadmap and organizational structure/collaborations to be established

In general, to ensure implementation of any roadmap or strategic plan, the most critical aspect is about clarity on who has the responsibility for ensuring progress with its implementation. Since the development of a database requires concerted action by multiple stakeholders, it is critical to identify an empowered agency, organization or a group, such as a task force or working group, that takes responsibility for coordinating the multiple agencies involved and in maintaining momentum. The roadmap development exercise should include the nomination of, and ideally the acceptance by, an agency of this responsibility. Ownership or responsibility does not mean that all the activities for implementation have to be carried out by the agency taking ownership/responsibility itself. Rather, the agency will be responsible for identifying, coordinating and establishing communication mechanisms among the various actors that will contribute to the development of the database, similar to the role of a project manager. It is expected that an initial set of data providers and database users will be identified during the roadmap development. Any loose ends in bringing the initial data providers and key user groups on board should also be tied up at this point.

2. Capacity building

Members that constitute the empowered agency, as well as other collaborating agencies or individuals, need to be capable and have the capacity to fulfil their roles and responsibilities on time. While initiating implementation, briefing and capacity building of the main stakeholder groups should be organized to facilitate smooth implementation. In general, capacity building includes an assessment of learning needs (content), selection of learning methods (e.g. seminar discussions, hands-on exercises), selection of delivery channels (e.g. face-to-face or virtual), procurement of expert services for content preparation and delivery, and finally, delivery of capacity-building programmes. The main stakeholder groups, whose capacity should be developed, consist of (at least):

- A responsible agency or the members of the implementing group
- A database management team
- The data/dataset providers and reviewers
- The data(base) users

3. Establishment of data collection and dataset creation, review and storage procedures

The database roadmap will contain, at a minimum, an indication of prioritized data needs and how they might be obtained, e.g. through direct measurement campaigns (primary data collection), from some existing database or data sources (secondary data) or models/tools for inventory generation. Actions can be prioritized based on the data availability and the needs of the database users, as identified in the initial baseline assessment and stakeholder analysis. Broad tasks for this activity are identified below:

- Study of user needs and further prioritization of sectors, industries or products
- Definition of work and information flow for data collection and dataset submissions
- Design and delivery of guidance and tools for:
  - data/dataset providers and reviewers
  - database management team for internal data handling, including database integration of accepted dataset submissions
  - database users

Text box 9. Find a strategy for turning a national database roadmap into actions: the case of India.

In India, it is not yet clear whether it is preferable to develop a standalone national database or a repository of Indian datasets that may be readily available for use in LCA studies through integration with other LCA databases. In order to make an informed decision on this issue, the national database development work is divided into two phases: First, the National Environmental Engineering Research Institute (CSIR-NEERI) will develop a prototype in association with a user organization by going through the end-to-end process of collecting new data, accessing existing data, using LCA software, generating additional data, and developing a prototype IT solution to host the data. Second, experience and learning gained through the development of the prototype will be considered to take key decisions on whether or not to establish a national database.

In general, the Indian national LCA database will follow global best practice and procedures adapted in an 'action research' mode to suit the local context. This means that initially when new datasets are developed, the ambition will be to match global best practice. However, the specifics of data collection, data representativeness, data quality and review, data format and interoperability, etc. will be decided in accordance with immediate requirements and licensed tools already available from existing work in LCA.

Figure 10. Impressions from a NDWG meeting held at CSIR-NEERI on April 2019.

The national database working group (NDWG), set up to guide the roadmap development process in India, is formed as an empowered group open to members who actively contribute not only to roadmap development but also to implementation activities. The emphasis on NDWG members' contribution to roadmap implementation activities is a consequence of an earlier roadmap development activity conducted by the Federation of Indian Chambers of Commerce and Industry (FICCI). Through this, initial activities in the roadmap were identified but those entities that supported the development of the roadmap did not have access to the resources required for its implementation.

This time around, NDWG members recommend not only on what others should do, but also how they themselves may contribute towards roadmap implementation. Each NDWG member taking up a joint project with CSIR-NEERI will shape the process for developing the Indian LCA data collection and hosting solution individually through the joint project, as well as collectively through periodic meetings and updates on projects by other NDWG members. This has been possible because the organization driving the roadmap, CSIR-NEERI, is part of a network of national government research institutes and has best access to resources and authorizations needed for developing nationally representative LCA datasets.

Text box 10. An inspiring milestone: from roadmap to implementation of Perú LCA, the Peruvian life cycle database.

Peruvian LCA practitioners have gone through a long and winding road in the past decade that culminated with the creation of Perú LCA, the Peruvian national life cycle database, which is now a node connected to GLAD since March 2020. The launch of Perú LCA in May 2019 implies that practitioners now have different levels of life cycle know-how, datasets and computation modules freely available in a single place. The website, currently powered by the Peruvian Life Cycle Assessment and Industrial Ecology Network (PELCAN), was built with the support of the Ministry of Environment (MINAM) and UNEP, and involved a series of meetings, seminars and workshops in which multiple actors in the private, public and academic sectors got together to unite efforts in database building.

Informal meetings were first held in 2012-2015. During this period, the idea of creating a national database was strengthened through efforts by PELCAN providing capacity-building workshops on life cycle thinking to actors in governmental agencies and in relevant productive sectors in the country. In 2013, a white paper with preliminary recommendations for a Peruvian LCA database was submitted by PELCAN to MINAM (Quispe & Kahhat, 2013). This allowed transmitting essential knowledge on life cycle methodologies, including their applications, to support environmentally-informed decisions in policy-making (Hellweg & Millà i Canals, 2014), enhancing green public procurement or improving the environmental profile of products and consumer choices.

Hosting the Latin American LCA Conference (CILCA) in 2015 marked an important next step. This allowed some of the most important actors in the LCA community, including representatives from the UNEP's Life Cycle Initiative or from the main worldwide databases, to visit Lima and engage directly with local actors from PELCAN, public and private agencies. Moreover, at CILCA a regional Latin American roadmap was developed, with certain milestones for different countries based on their previous level of advancement in database creation. In fact, at that specific moment, only Mexico, Chile and Brazil had modest advancements in database implementation.

A third and final step occurred with the implementation of the International Climate Initiative (IKI) Project in Peru, funded by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMUB) in Germany. The main objectives of this project were to build a database containing process LCA datasets of critical productive sectors in Peru (e.g. hydropower plants, refinery products or landfills) and to develop the environmental matrices for the Peruvian economic input-output LCA (EIOLCA) (Vázquez-Rowe et al., 2019). The current implementation and use phase is expected to be complemented in coming years with outputs from future research projects on other sectors in the Peruvian economy. This cumulative process should continuously lead to the incorporation of new datasets in the database after a due and thorough peer-review process.

Figure 11. Impressions from workshops during the development of a national LCA database in Peru.

4. Establishment of customer and user conditions

Some of the decisions regarding data access, e.g. which user group has access to what data and what data can be accessed (not) free of charge, would have been touched upon in the roadmap. These decisions will now be formalized so that they can be incorporated into the requirements for the IT platform that will host those data. The key tasks here will be:

- Define access criteria
- Define **e**nd-user license agreement (EULA) and financial terms, as relevant
- Marketing and communication to data providers and database users

5. Selection and development of IT platform

Based on the above requirements, the IT platform for data handling, storage and access can be conceptualized and specified. It is not necessary to build the platform from scratch, there are many possibilities for collaborating with established providers of databases, services or software to select a configuration that fits in with the strategy and budget of the national database in question. Illustrative tasks for this activity include:

- Define criteria for selection of IT platform
- Identify/evaluate alternatives, decide on platform and procure technical services
- Develop work schedule for platform development
- Design of the pilot platform
- Test launch of pilot platform
- Improvement and feedback from the test
- Launch of platform
- Hand over database operations to responsible agency, organization or team

6. Establishment of routines for continuous maintenance and development of database

The launch of the IT platform needs to be accompanied by an activity aimed at structuring the ongoing maintenance and evaluation. The goals of this step are to ensure maximum return on investment while striving for increased utility of the national database to stakeholders through stable operations and continuous improvements. Broadly, this activity will comprise the following tasks:

- Set up of monitoring mechanism to assess roadmap implementation success
- Define routines to identify, prioritize, execute and review the results of maintenance tasks
- Create a process to identify needs for, prioritize among, execute and review the results of database development
- Periodically review routines for maintenance and development of the database, drafting corrections, and providing actions to drive continuous improvement

Risk management

The activities outlined in the preceding section should comprise the roadmap implementation process and build sufficient momentum for it to proceed. Experience of database development in many countries indicates, however, that there will likely be several difficulties encountered along the way. Risks to projects can generally be considered to be of technical, managerial, commercial, or external nature and may result in either positive or negative outcomes.

Strategies to cope with negative risks include escalating, avoiding, transferring, mitigating or simply accepting the risk. To escalate a risk entails passing it up in an organization. Some risks may be avoided, e.g. through the implementation of suitable measures to ensure that it does not occur in the first place. Transferring means to share the risk with a third party, e.g. by purchasing an insurance. Mitigation measures reduce the probability or impact of a risk to an acceptable level. Finally, in some cases, the best strategy might be to accept the risk and instead focus on creating contingency and/or fall-back plans, accordingly.

"Table 2. Common risks expected to be encountered when developing a national LCA database" on page 60 summarizes some typical risks associated with initiatives for LCA database development, along with examples of possible ways to manage these risks to avoid situations that might stall the database development process. At the highest level, common risks can generally be grouped into three types: resource constraints, data availability and quality problems, and issues related to stakeholder commitment or engagement.

Two main types of resource constraint can be relevant: funding and expertise. Like most initiatives that benefit multiple stakeholders with diverse interests, it may initially be difficult to get financial commitments to start the work. However, once a 'critical mass' of data is available and the benefits of having the database have been demonstrated to key

Table 2. Common risks expected to be encountered when developing a national LCA database

RISK TYPE	RISK	SUGGESTED ACTIONS TO MANAGE RISK
Resource constraints	Financial constraints in developing and maintaining the national LCA database	Establish business model at the outset and engage agencies that will fund the database development and those that will benefit from it. If the beneficiaries themselves are funding the development, financial commitments are more likely to be forthcoming
	Insufficient expertise among national stakeholders	Establish linkages by inviting external experts to support and build local capacity. Attend or organize international conferences or workshops. Consult regional and international networks, including the Technical Helpdesk for LCA Databases
	Limited experience with database management, especially related to (commissioning) IT projects	Inexperience can easily result in unrealistic expectations and under-specification of needs and requirements. Ensure adequate resources allocated to 'requirement engineering' upfront, as well as to adopt an iterative development approach (like agile, prototyping or similar) and to collect feedback from focus groups/beta-testers before arriving at the final IT solution. For this, consider hiring or acquiring the support of an experienced IT project manager.
Data availability and quality	Inadequate data quality (incorrect, inconsistent, outdated, etc.)	Defining data quality goals and setting benchmarks to check whether the data meets the data quality requirements. Define methods for data quality assessment and improvement into the data collection strategy, and establish an appropriate review procedure.
	Geographical coverage limitations	Start with the most representative data available and gradually improve datasets by increasing the degree of regionalization based on priority and/or stakeholder consensus. Consider recontextualization of datasets from other data sources (as relevant and permissible
	Difficulties in the collection of, or access to, primary data	Include secondary data sources, (e.g. governmental and industrial documents and statistics, trade reports and databases, national databases and emission inventories, consultancies, academic studies, patents, engineering models and expert judgments)
Stakeholder commitment and engagement	Lack of stakeholder involvement in database development	Involve empowered stakeholders right from the beginning of the roadmap process. Secure formal commitments of support/funds
	Insufficient support and participation from particular stakeholder groups (e.g. government, industry or academia)	Undertake a promotional campaign at the outset to raise awareness, educate and motivate key stakeholders with clear messages on the benefits to each group. Consider whether the different stakeholder groups can support the process by applying pressure on each other or by championing
	Loss of stakeholder interest over time	Regular progress reports, content updates, and continuing engagement with stakeholders through periodic interactions/events or collaborative application examples (e.g. case studies)
	Apprehensions on misuse of data	Address apprehensions at the outset and resolve open questions about who can access the data and for what purpose. Establish and validate protocols and technical solutions to ensure the integrity and security of the database, its content and any user information
	Lack of active database users	Establish linkages with existing problems that are of concern to stakeholders and remove any bottlenecks in accessing the data (e.g. unduly high cost or cumbersome process). Consider engaging with stakeholder groups in collaborative application examples (e.g. case studies) or consider prioritizing data content additions or updates of particular relevance to key stakeholder groups

user groups, financial contributions may be easier to secure. Also, in the initial stages when the concept of LCA is novel, local experts may not be available to support technical development activities. Such expertise needs to be built in order to avoid relying on expensive expertise from other countries that, in any case, will need to be supplemented with local contextualization. A certain proportion of the database development budget should be allocated to developing local capacity. Some of the experts developed in this way could also engage with, and contribute to, the global community of database experts and representatives of similar initiatives, gathered through the Technical Helpdesk for LCA Databases forum.

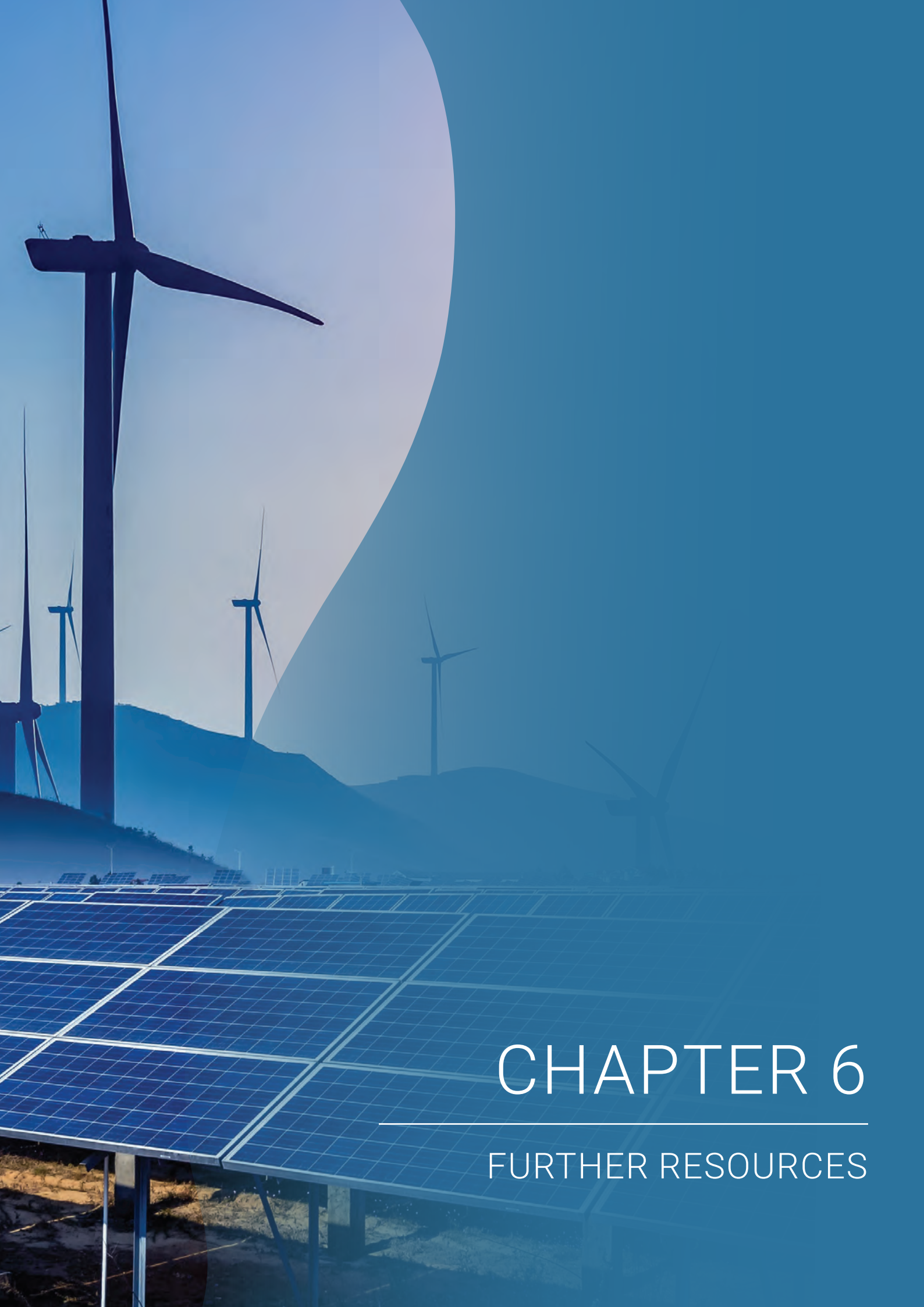
There is a multitude of risks related to the availability and quality of data. Among the most important aspects are data availability, geographical representation (i.e., degree of regionalization), consistency, and usefulness (fitness for purpose). Issues related to any of these aspects can cause serious loss of credibility and stakeholder confidence in the database. Problems related to stakeholder commitment might slow down or even stall database development. Once in operation, a lack of stakeholder engagement might result in the 'critical mass' of database users not being reached or in an insufficient extent of data applications. Guidance on how to stimulate the commitment and activity of key stakeholders is provided among the suggestions in "Table 2. Common risks expected to be encountered when developing a national LCA database" on page 60.

Monitoring progress

Monitoring activities are intended to assess the success of the roadmap implementation and to make corrections wherever implementation did not progress as anticipated. At the time of roadmap development, criteria for assessing its success should be discussed and defined. For monitoring, these criteria can be articulated in the form of indicators. The indicators should be periodically assessed and adjusted as necessary as the LCA database matures.

The following indicators may be useful to track and then determine further actions required for improving outcomes from roadmap implementation:

- Number of participants at meetings and events where the database development work is presented or discussed
- Number of data providers, and database users associated with the project
- Number of datasets submitted, reviewed, accepted and/or published.
- Number and/or share of datasets becoming available or connected to the GLAD network
- Number of stakeholders engaged or the degree of stakeholder representation within the database initiative
- Trends in number of requests for data coming in
- User satisfaction level assessment (e.g. through surveys)



CHAPTER 6

FURTHER RESOURCES

The Technical Helpdesk for LCA Databases

The Technical Helpdesk for LCA Databases is a forum hosted under The One Planet Network, the network of the 10-Year Framework of Programmes on Sustainable Consumption and Production. Gathering LCA data experts, initiators and developers of new national databases, managers of existing databases and other interested individuals, the Technical Helpdesk provides stakeholders wishing to establish and operate LCA databases with both training and support by international experts. The Technical Helpdesk has been established to facilitate communication among experts and stakeholders and to provide key informational resources and guidance on responsible management practices and technical requirements for database set up and operation.

The consortium of the Development of National LCA Database Roadmaps project committed to contribute to the development of the Technical Helpdesk, e.g. by uploading and sharing relevant project outputs upon completion. Going forward, the experiences from the actual implementation of these national database roadmaps should be shared periodically in the months and years to come. This in order to exchange on promising solutions, unforeseen pitfalls and lessons learned with the wider stakeholder community and with the Technical Helpdesk community. As the number of national LCA database initiatives grows, it might also be relevant to revisit the guidance and recommendations for establishing database roadmaps, as presented here, to revise advice and technical information provided and to add further concrete examples.

Guidelines for LCA data, databases and networks

- ALCAS (2014) AusLCI – The Australian Life Cycle Inventory Database Initiative, AusLCI – Requirements for the development of AusLCI Data sets. Australian Life Cycle Assessment Society, ALCAS.
- GLAD (2018) – Supporting document for nodes interested to join GLAD. UN Environment/Global LCA Data Access Network, GLAD.
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- Wolf, M.A. (2014) – White paper: National LCA databases - Status and ways towards interoperability. maki Consulting. Berlin, Germany.

LCA database roadmaps from other countries

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GLAD node requirements

Nodes joining the GLAD network commit to:

- Minimum requirements for dataset documentation: the Node commits to working towards enhanced data access and interoperability by providing the minimum metadata descriptors to enable search by users, as well as by using the agreed nomenclature mapping made available by the Network. The use of a common data exchange format and flow nomenclature is encouraged.
- The Node commits to using the Network API [application programming interface] to enabling the search of its dataset metadata descriptors, but the Node is free to develop its own solutions to participate in the Network, within the given network principles.
- In order to establish interoperability between datasets within the Network, the Node commits to using a common data exchange format and flow nomenclature (refer to Table 1 on the Web).
- Freely accessible metadata: all metadata for each dataset that is searchable in the Network must be available for free (no charge to consult dataset's metadata).
- Dataset providers are responsible for the operation of their own node and maintain full control over their node as well as the data hosted on the node. For paid databases, actual transaction should occur between the users and the individual nodes.
- License policies: each node can have its own license policy establishing what users can do with the datasets provided through their node. However, use of datasets accessed from other nodes may have their own license policies. Thus, license conditions need to be clear and transparent.
- Registered Nodes need to be available online, or at least post the metadata values of their datasets online and offer access to metadata descriptors for free.
- Dataset providers must demonstrate willingness and effort to present datasets with GLAD metadata and nomenclature conventions to the extent possible. GLAD reserves the right to restrict access to providers not participating in good faith according to the principles of the Network.
- Language: the Node commits to making metadata available in English as a minimum, in addition to another language if desired.
- Due Diligence: the Nodes provide access to datasets that are in line with GLAD principles to the best of their knowledge and fully documented.

Common classification systems

- United Nations Standard Products and Services Code (UNSPSC)
- CO2PE! Initiative (Cooperative effort on Process Emissions in manufacturing)
- International Standard Industrial Classification (ISIC)
- Cooperative Patent Classification (CPC; for products)
- Harmonized Commodity Description and Coding Systems (HS)
- The classification scheme required for the ILCD data exchange format is available in the .xml-file "ILCDClassification.xml"

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Annex 1 - Project consortium

The consortium of the '*Development of National LCA Database Roadmaps*' sub-project was composed of the following people and organizations, with the national project coordinators underscored:

- **Project lead:** ecoinvent Association, Switzerland [Dr. Gregor Wernet, Dr. Carl Vadenbo]
- **Brazil:** Universidade Tecnológica Federal do Paraná [Prof. Cássia Ugaya, Mr. José Paulo Savioli]
- **Ecuador:** Escuela Superior Politécnica del Litoral [Prof. Ángel Ramírez]; Escuela Politécnica Nacional [Dr. Beatriz Rivela]; Ministry of Environment; Conservación Internacional Ecuador
- **India:** National Environmental Engineering Research Institute [Dr. Rajesh Biniwale, Mr. Praveen Siluvai Antony, Mr. Asheesh Sharma]; Confederation of Indian Industry [Ms. Nisha Jayaram]; Dr. Sanjeevan Bajaj, independent consultant
- **South Africa:** University of Cape Town [Prof. Harro von Blottniz, A-Prof. Pippa Notten]
- **Sri Lanka:** National Cleaner Production Centre Sri Lanka [Mr. Samantha Kumarasena, Ms. Upendra Arjeevani, Ms. Ayomi Pabasara]
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