Chapter 1
About This Book

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Abstract To reach the UN sustainable development goal, there is a need for comprehensive and robust tools to help decision-making identify the solutions that best support sustainable development. The decisions must have a system perspective, consider the life cycle, and all relevant impacts caused by the solution. Life Cycle Assessment (LCA) is a tool that has these characteristics and the ambition with this book is to offer a comprehensive and up-to-date introduction to the tool and its underlying methodological considerations and potential applications. The book consists of five parts. The first part introduces LCA. The second part is a text book aiming at university students from undergraduate to PhD level, and professionals from industry and within policy making. It follows ISO 14040/14044 structure, draws upon a variety of LCA methods published over the years, especially the ILCD, and offers prescriptions and recommendations for all the most important methodological choices that you meet when performing an LCA. The third part introduces applications of LCA and life cycle thinking by policy- and decision-makers in government and industry. The fourth part is a Cookbook guiding you through the concrete actions to undertake when performing an LCA. The fifth part contains some appendices. The book can be used as a text book, the chapter can be read as stand alone, and you can use the Cookbook as a manual on how to perform an LCA.

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1.1 Introduction

Our generation is facing daunting challenges of a changing climate and an overall increasing pressure on the environment, challenges that are under the influence of human-made activities. Reflecting on these environmental conditions and their relationship to social and economic challenges that we face, a sustainable development was coined in 1987 by UN's World Commission for Environment and Development as a development that "… meets the needs of the present generations without compromising the ability of future generations to meet their own needs" (UN WCED 1987). In 2015 the 193 member states of the United Nations adopted 17 goals to 'end poverty, protect the planet, and ensure prosperity for all as part of a new sustainable development agenda' by 2030, setting targets for the way in which the present generations can meet their needs (UN 2017). To meet the goals and targets, sustainability must gain strong prominence in decision support for professionals who are responsible for creating solutions for the future, but also for everybody else who, in today's global economy, is both a stakeholder and a decision-maker with a role to play concerning sustainability as a consumer, as member of a local community, or as a voter. Each individual needs answers and information based on comprehensive and robust tools to help them decide what best supports a sustainable development, from small- to large-scale decisions. To avoid the often seen problem shifting where solutions to a problem creates several new and often ignored problems, these decisions must take a systems perspective. They must consider what in this book is referred to as the life cycle of the solution, and they need to consider all the relevant impacts caused by the solution. Life Cycle Assessment (LCA) is a tool that has these characteristics, and there is a strong and growing need for professionals who understand or even master this tool and who know how to critically appraise and use the information that it provides. It is our ambition with this book to offer a comprehensive and up-to-date introduction to the tool and its underlying methodological considerations and potential applications.

1.2 Structure of This Book

The book consists of five parts.

The **first part** sets the scene. First, if you are a newcomer to LCA, you get a short introduction to important characteristics of LCA and some of its strengths and weaknesses, illustrated through a collection of questions that LCA can—or cannot be used for answering. This short introduction is followed by a presentation of the history of LCA from its early beginnings half a century ago to today, with a focus on methodological developments, growth in number and variety of applications and international harmonization and consensus building. Finally, LCA is positioned in the context of sustainability and its use as a tool for quantitative sustainability assessment is discussed.

The **second part** is a textbook aiming at university students from undergraduate to PhD level, and professionals from industry and within policy making who need a thorough and pedagogical introduction to LCA methodology. The textbook has been developed based on a cumulated experience from more than three decades with teaching LCA to engineering students at undergraduate and master level courses at Technical University of Denmark and Polytechnique Montréal, Canada, and it is intended to provide a complete curriculum for such courses.

The structure of the introduction to the LCA methodology follows the ISO framework (as presented and elaborated in the ISO 14040 and ISO 14044 standards (ISO 2006a, b)), and we have strived to keep the use of technical terms in accordance with the ISO terminology. When it comes to the methodological details, the ISO standards refrain from prescriptions or recommendations for many of the detailed decisions and choices that must be made by a practitioner who wants to perform an LCA. Here, we have sought inspiration in LCA methods published over the years, including the EDIP method (Wenzel et al. 1997; Hauschild and Wenzel 1998), the Ecoinvent methodologies (Weidema et al. 2013), the Consequential LCA (Ekvall and Weidema 2004), as well as more recent projects within the UNEP/SETAC Life Cycle Initiative and the development of the IMPACT World+ (http://www.impactworldplus.org), the LC-Impact (http://www.lc-impact.eu), or the ILCD life cycle impact assessment methods (Hauschild et al. 2013), and not least in the detailed guidance offered by the General guide for Life Cycle Assessment, the 'ILCD Handbook' that was elaborated by the European Commission to serve as the methodological backbone of its International Reference Life Cycle Data System (EC-JRC 2010). The ILCD Handbook was developed through a broad international consultation process with LCA experts, stakeholders and the public from all over the world with the ambition to minimize ambiguity in LCA studies and provide governments and businesses with a basis for assuring quality and consistency of life cycle data, methods and assessments (EC-JRC 2010; Pennington et al. 2010; Sala et al. 2012). Building on methodological elements from previously published LCA methods, it offers prescriptions and recommendations for all the most important methodological choices that you meet when performing an LCA. We use the ILCD method as a solidly founded, well documented, and detailed reference methodology that is in full accordance with the ISO standards and details methodology descriptions far beyond them.

This part of the textbook offers separate chapters on each phase of the LCA methodology and additional chapters on life cycle costing and social life cycle assessment as well as chapters on central methodological aspects like uncertainty management and sensitivity analysis, and use of input–output analysis in LCA.

The **third part** of the book offers a collection of chapters introducing applications of LCA and life cycle thinking by policy- and decision-makers in government and industry, written by authors who are experts in the field of their chapter. They start out with policy applications around the world and organizational LCA, then move on to industrial applications, life cycle management, ecodesign, environmental labels and declarations, and the Cradle to cradle concept. The focus then moves on to the application of LCA to different technological areas like energy

systems, buildings, food and waste management. Eleven chapters present, within each their technological area, the main types of findings from published LCA studies, identifying methodological considerations that are particularly relevant and highlighting potential pitfalls when performing or using LCA studies within that area.

The **fourth part** consists of a Cookbook which takes you through all the phases of the LCA once more, but this time with concrete actions to undertake when performing an LCA. The ambition with the cookbook is to provide you with the recipes for performing an LCA. Where Part II answers the numerous 'why' questions, the Cookbook answers the 'what' and 'how' questions. It is intended to guide you through the many steps, activities and decisions that are needed to perform an LCA. The Cookbook follows the main structure of the ISO 14044 standard and gives detailed instructions on all the central activities, based on selection of those provisions and actions in the ILCD Handbook that are generally needed in order to perform an LCA.

The **fifth part** of the book is an appendix collection with supporting material for use in LCA teaching like a reporting template offering the student a recommended structure for an LCA report, an example of a complete LCA report on a case study based on student results from an LCA course, and an overview and comparison of existing life cycle impact assessment methods to compliment the methodology chapter on this phase of the LCA.

1.3 How to Use This Book?

As you will see, you may use this book *as a textbook*, focusing on the description of the theory in Part II. All the basic elements of the methodology are presented in chapters with clearly defined learning objectives. An exemplary LCA case study weaves through the methodology chapters and is used, where relevant, to give practical examples of the presented methodological elements. The case study is compiled at the end in a full LCA report in Part V of the book, illustrating the use of the reporting template and serving as an example for students of how a good student LCA report may look. You can select chapters from Part III of the book on the LCA applications that are relevant in your didactic context, and you can use the Cookbook in Part IV and the reporting template and example LCA report in Part V for support to perform a real LCA if this is part of your learning. Each chapter of the book was written in a way that allows it to also function as stand-alone material for studying the respective aspects that it presents. The chapters can thus also be read on their own in order to deepen your knowledge on their specific topics.

Once you have taken the learning from the book, you can use the Cookbook **as a manual on how to perform an LCA**. The cookbook is based on the ILCD guideline and it is thus not a universally endorsed LCA method—in fact, such a method does not exist beyond the ISO standards. We have, however, found that this guideline is useful as a reference because of its very detailed prescriptions. In cases

where you disagree with certain provisions or where a different approach is more relevant for the study that you perform, it will still serve as a reference for transparently and efficiently reporting about the method that you have used by specifying the points where you have chosen a different approach.

Whether you aspire to be a practitioner of LCA or a user of LCA information, the textbook will also serve **as a repository of LCA experience** with the wealth of information on the many application areas presented in Part III of the book.

We wish you a fruitful learning with the book and success with your future LCA activities!

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Author Biographies

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Ralph K. Rosenbaum LCA expert and environmental modeller focusing on LCIA development since early 2000s. Contributed to several UNEP/SETAC working groups towards global harmonisation of LCA methodology. Interested in LCIA modelling of emissions and water/soil resource use, operationalisation of uncertainty management and spatial differentiation.

Stig Irving Olsen LCA expert both as researcher and as consultant. Involved in the development of LCA methodologies since mid 1990s. Contributed to UNEP/SETAC working groups on LCIA methodology. Main LCA interest is human toxicity impacts, emerging technologies, and decision making.