POCKET ARCHITECTURE: TECHNICAL DESIGN SERIES

ATHRINA SIMONEN

LIFE CYCLE ASSESSMENT

ROUTLEDGE

Pocket Architecture:
Technical Design Series

Life Cycle Assessment

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PocketArchitecture:
Technical Design Series

Life Cycle Assessment

Life Cycle Assessment addresses the dynamic and dialectic of building and ecology, presenting the key theories and techniques surrounding the use of life cycle assessment data and methods.

Architects and construction professionals must assume greater responsibility in helping building owners to understand the implications of making material, manufacturing, and assemblage decisions and therefore design to accommodate more ecological building. *Life Cycle Assessment* is a guide for architects, engineers, and builders, presenting the principles and art of performing life cycle impact assessments of materials and whole buildings, including the need to define meaningful goals and objectives and critically evaluate analysis assumptions.

As part of the *PocketArchitecture* series, the book includes both fundamentals and advanced topics. The book is primarily focused on arming the design and construction professional with the tools necessary to make design decisions regarding life cycle, reuse, and sustainability. As such, the book is a practical text on the concepts and applications of life cycle techniques and environmental impact evaluation in architecture and is presented in language and depth appropriate for building industry professionals.

Kathrina Simonen is an Assistant Professor in the Department of Architecture at the University of Washington. Licensed as both an Architect and Structural Engineer, her research agenda stems from unresolved questions originated during over 15 years of professional practice. Her research topics include life cycle assessment (LCA) and practice innovations such as prefabrication, digital manufacturing, and alternative project delivery models. She is founding director of the Carbon Leadership Forum, an industry/academic research collaborative focused on linking the science of life cycle assessment to industry best practices in order to help enable quantifiable reduction of the environmental impact of the built environment.

PocketArchitecture:
Technical Design Series

Series Editor: Ryan E. Smith

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"Assistant Professor of Architecture Kathrina Simonen writes on the practice of life cycle assessment, authoring the handbook that she herself sought while wrestling with pressing questions of building, environment and quantification. Simonen positions LCA as an 'emerging discipline,' contextualizes LCA within its strengths, weaknesses and limitations, and dispels for the architect any attempt to idealize the practice. She translates what oft appears as a confounding method with concise and accessible language, case studies, didactic diagrams, and the aplomb to continuously remind us where methods require refinement, debate and consensus. An architect who has intuitively uttered the phrase 'embodied environmental impacts' in relation to a building, component or material – one who has desired a way of knowing environmental impacts more fully – will find herein a thorough discussion of the topic and description of the method. Simonen's handbook is timely and necessary as the building industry self-organizes to adopt environmental assessment methods pervasively and proactively for design decision making."

– Billie Faircloth, *KieranTimberlake*

"Professor Simonen expertly bridges the gap between the practices of building design and life cycle assessment, and her book is another testament to that. It gives comprehensive guidance to understanding and implementing LCA from a uniquely US architect's perspective."

– Frances Yang, Structures and Sustainability Specialist, Arup

Series Editor's Preface

Although architects and building professionals come into contact with, specify, design, and build technical practices every day, they actually know relatively little about them. They are "abstract systems" construed and constructed upon industry norms passed down through generations of professionals. Most of them are correct, but many when disassociated from their cultural underpinnings of building vernacular and, more importantly, their scientific basis and practice contexts, present challenges that cause buildings not to perform as intended or, worse, lead to physical, economic, or social catastrophe.

PocketArchitecture: Technical Design Series fills this void. The series comprises succinct, easy-to-use, topic-based volumes that collate in one place unbiased, need-to-know technical information about specific subject areas by expert authors. This series demystifies technical design criteria and solutions. It presents information without overladen theory or anecdotal information. *PocketArchitecture* is on point.

As the name would suggest, the volumes in this series are pocket-sized and collectively serve as a knowledge base on technical subjects in architecture, creating a value-added information base for building novices and masters alike. In addition to architects, engineers, and contractors that deliver building projects, the series is appropriate for students and academics interested in accessible information on technical information as it relates to building design and construction.

Despite their size, the series volumes are highly illustrated. Furthermore, the volumes use easily accessible language to succinctly explain the fundamental concepts and then apply these basic ideas to cases of common issues encountered in the built environment. *PocketArchitecture* is essential, accessible, and authoritative. This makes it important reading for architectural technologists, architects, building surveyors, building commissioners, building engineers, other construction professionals, even owners and clients.

This volume, *Life Cycle Assessment*, addresses the dynamic and dialectic of building and ecology, presenting the key theories and techniques surrounding the use of life cycle assessment data and methods. As part of the *PocketArchitecture Series*, the book includes both fundamentals and advanced topics. The book is primarily focused on arming the design and construction professional with the tools necessary to make design decisions regarding life cycle, re-use, and sustainability. As such, the book is a practical text on the concepts and applications of life cycle techniques and environmental impact evaluation in architecture.

Ryan E. Smith
Series Editor

Preface

As a practising architect, I struggled to understand the environmental impact of building materials and strove to find ways to integrate this knowledge into design and construction practice. What began as a search for the "carbon footprint" of specific materials and transportation methods expanded to a study of the broad range of environmental impacts related to building materials, products and buildings using a life cycle perspective.

As an architecture researcher, I have been exploring life cycle assessment (LCA) methods, data and tools to understand the opportunities and challenges that these resources provide to architects (and others in the building industry) looking to understand and reduce the environmental impact of buildings.

This book is designed to be the resource that I searched for when I began attempting to use LCA data in practice: an introduction to the fundamentals of LCA, graphic representation of abstract concepts, developed examples of application to the building industry, and identification of relevant LCA resources.

Acknowledgments

My understanding of LCA has been greatly enhanced by the support from fellow faculty members including, most significantly, Joyce Cooper, Associate Professor of Mechanical Engineering at the University of Washington, who graciously included me (and my student researchers) in her LCA graduate seminar and has provided sound advice and mentorship. Additionally, Liv Haselbach, Associate Professor of Civil and Environmental Engineering at Washington State University, and Elaine Oneil, Research Scientist in the College of the Environment at the University of Washington, along with Joyce Cooper, collaborated effectively to develop research exploring the integration of LCA into the Washington State Building code. The research we developed together for that report provided a solid foundation from which to develop the content of this book. Thank you, Joyce, Liv and Elaine.

Thank you also to graduate student researchers: Kyle Boyd, Yasaman Esmaili, David Fish, Dahra Goradia, Lissa Gotz, Monica Huang, Jocelyn Reutebuch, Kristen Strobel and Mazohra Thami. Their LCA research contributed both directly and indirectly to this book. Mazohra deserves special recognition for her help in establishing the graphic quality of the illustrations.

Generous permission to use or adapt images, text and/or data was provided by the following: Armstrong World Industries, Arup, the Carnegie Mellon University Green Design Institute (CMU GDI), CEDA, the Consortium for Research on Renewable Industrial Materials (CORRIM), the European Commission Joint Research Centre Institute for Environment and Sustainability, the European Environment Agency (EEA), the European Committee for Standardization (CEN), the International Organization for Standardization (ISO), John Basbagil, the *Journal of Environmental Science and Technology*, the *Journal of Industrial Ecology*, the Forestry Commission (UK), the National Oceanic and Atmospheric Administration (NOAA),

the Institute of Construction and Environment (IBU), National Renewable Energy Laboratory (NREL), UL Environment and the World Resource Institute (WRI).

I would also like to thank the following LCA practitioners and industry experts who took the time to read sections of this book including: Claire Broadbent, Lindita Bushi, Chris Erickson, Erin Moore, Elaine Oneil, Tien Peng, Edie Sonne Hall, Cassie Theil and Frances Yang. Their comments greatly improved the clarity and accuracy of the text and images.

I am pleased to be included in this new series of handbooks for architects and appreciate the editorial advice of Ryan Smith and the enthusiasm of the staff at Routledge.

Support for the research and development for the book was provided by the Mithun/Russell Family Foundation Endowed Professorship in Sustainability, the University of Washington's College of Built Environments and the Carbon Leadership Forum (www.carbonleadershipforum.org) industry sponsors who include: Arup, Central Concrete, the National Ready Mixed Concrete Association, Webcor Builder as well as Climate Earth, Ceratech, Degenkolb and Magnusson Klemencic Associates.

And most significantly, I would like to thank my mother, Candace, for reading, editing and improving my writing from the beginning; my father, Tom, for encouraging me to pursue engineering; Oliver, Max and Gus for nighttime NERF battles; and Rolland for his love and support.

Abbreviations

ANSI	American National Standards Institute
ASTM	ASTM Standards
BOF	Basic oxygen furnace
CEN	European Committee for Standardization
EAF	Electric arc furnace
EEA	European Environmental Agency
EIO	Economic input–output
EPA	Environmental Protection Agency (US)
EPD	Environmental Product Declaration
EU	European Union
GCV	Gross calorific value
GGBFS	Ground granulated blast furnace slag
GHG	Greenhouse gas
GLB	Glue laminated beam (or timber)
HPD	Health product declaration
ISO	International Standards Organization
LCA	Life cycle assessment
LCCA	Life cycle cost analysis
LCI	Life cycle inventory
LCIA	Life cycle impact assessment
MEP	Mechanical Electrical and Plumbing
NCV	Net calorific value
NO_x	Nitrogen oxides
PAS	Publicly Available Specification from British Standards Institution
PCR	Product category rules
PM	Particulate matter

SETAC	Society for Environmental Toxicology and Chemistry
SO_x	Sulfur oxides
TRACI	Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (US EPA)
UN	United Nations
UNEP	United Nations Environment Program
US	United States

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