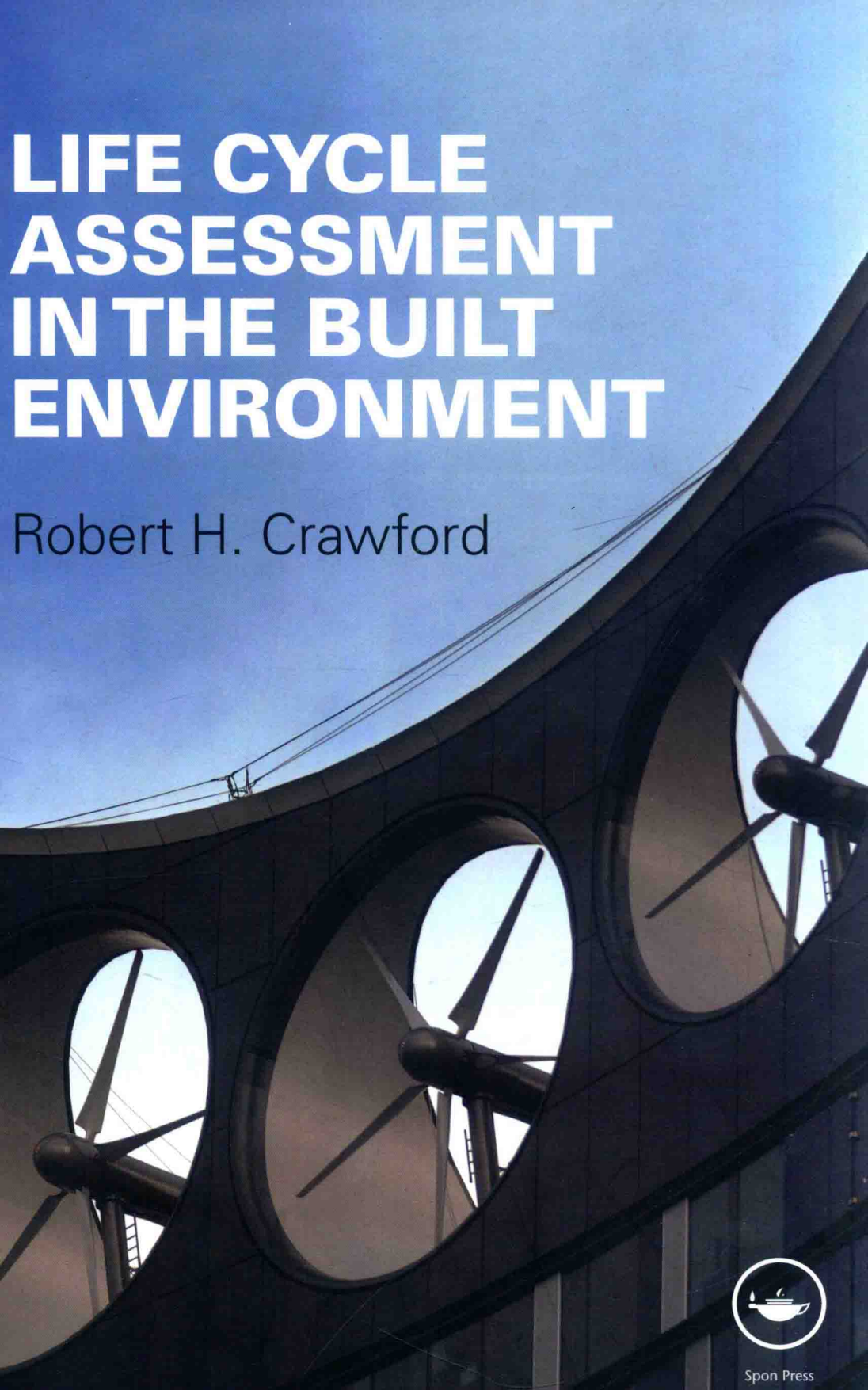
LIFE CYCLE ASSESSMENT IN THE BUILT ENVIRONMENT

Robert H. Crawford



Spon Press

Life Cycle Assessment in the Built Environment

Dr Robert H. Crawford

Spon Press
an imprint of Taylor & Francis
LONDON AND NEW YORK

Published 2011 by Spon Press

2 Park Square, Milton Park, Abingdon, Oxon OX14 4RN

Simultaneously published in the USA and Canada by Spon Press

270 Madison Avenue, New York, NY 10016, USA

Spon Press is an imprint of the Taylor & Francis Group, an informa business

Typeset in Frutiger by Saxon Graphics Ltd, Derby
Printed and bound in Great Britain by CPI Antony Rowe, Chippenham, Wiltshire.

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

Library of Congress Cataloging-in-Publication Data
Crawford, Robert, 1978-

Life cycle assessment in the built environment / Robert Crawford.

p. cm.

1. Building materials--Service life. 2. Buildings--Environmental aspects. 3. Building materials--Recycling. 4. Product life cycle. I. Title.

TA409.2.C73 2011

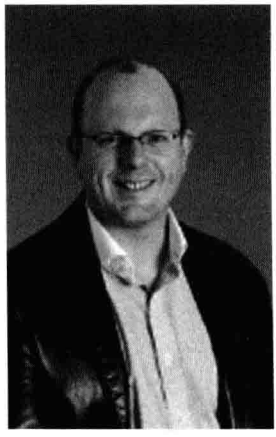
624.1'8--dc22

2010032823

ISBN13: 978-0-415-55795-5 (hbk)
ISBN13: 978-0-203-86817-1 (ebk)

Life Cycle Assessment in the Built Environment

To a friend and an inspiration



1969–2008

Associate Professor Graham Treloar

Figures

Tables

Foreword

The benefits of modern urban settlements are self-evident. Towns and cities provide housing, employment, education, healthcare, public transport and many other services. However, the construction and operation of buildings and infrastructure consume significant resources and produce large quantities of waste. We are now at a stage where we are questioning whether the development path taken in the past is suitable for the future and this is the starting point for this book.

The case for analyzing buildings over their whole life is logically made and this is tied to environmental impacts including the consideration of raw materials, energy, water, emissions, wastes and other indicators as an introduction to life cycle assessment (LCA). The principles, framework and guidelines for LCA, which are now part of international standards, are described in a clear and easily understandable manner.

What follows is the truly innovative part of this book. The combination of embodied energy theory and LCA are integrated into a streamlined environmental assessment approach. Furthermore, input-output-based hybrid analysis is described and used to show how a much more comprehensive assessment of environmental impacts in the built environment is achievable compared with current methods.

This book adds clarity to the uncertainties in life cycle assessment and provides a clear methodology to ensure consistent analyses. Hence, the innovative contribution is to overcome difficulties with system boundary definition and the life cycle inventory data. The text draws upon the work of the late Associate Professor Graham Treloar especially with respect to his innovative pathway extractor tool for input-output analysis. This research has been developed further by the author of this book and the contribution that this body of work has made to LCA is clearly described. *Life Cycle Assessment in the Built Environment* is essential reading for students, researchers and practitioners in the field. Chapter 5 will be especially appreciated as it provides seven case studies which show the exact methods used for conducting streamlined life cycle assessments. Finally, a series of initiatives are proposed for creating more sustainable built environments in the future. This will involve some very challenging choices and this book will play a significant part in that process.

Stephen Pullen
University of South Australia, Adelaide
July 2010

Preface

The need for a detailed understanding of the impact that human activity has on the environment, in order to make more sustainable choices, is becoming more important as an awareness of the broad environmental issues that society is currently facing grows. With the construction and operation of the built environment (our buildings and infrastructure) responsible for a significant proportion of these impacts, those involved across all stages of the built environment life cycle must be armed with the tools and knowledge needed to significantly improve its environmental performance. This is essential if we are to avert potentially catastrophic environmental damage and the threats to our very survival that this may bring.

This book came about by the need to address some of the limitations of existing approaches for assessing the environmental performance of the built environment. It brings together much of my own work in the development and application of hybrid life cycle assessment over the past ten years. More broadly, there has been considerable work done in this area, particularly over the last two decades, with little more significant than that of the late Associate Professor Graham Treloar who, as a passionate advocate for sustainable construction, developed an innovative approach for comprehensively quantifying the environmental impacts caused by, amongst other human activities, the construction of the built environment. This book is an attempt to continue and extend this work as well as make it more accessible to the decision makers in the global construction industry, so that we may collectively work towards a more sustainable approach to building, operating and managing the built environment.

The book begins by describing some of the key environmental issues that we are currently facing and how the built environment is responsible for a significant proportion of the impacts that humans are having on the environment. Chapter 2 addresses some of the approaches and strategies that must be employed in order to slow down and ultimately reverse the environmental damage associated with the design, construction and on-going use and management of the built environment and justifies the importance and need for *environmental assessment* as an integral part of this process. The stages involved in conducting a life cycle assessment are described in detail in Chapter 3. A more specific description of the application of life cycle assessment

within the built environment is provided in Chapter 4, using a single detached residential building as a case study to demonstrate the potential benefits and limitations of using life cycle assessment to inform better environmental outcomes within the design and management of the built environment. Chapter 5 presents some further life cycle assessment studies on a range of built environment case studies, ranging from whole buildings, building components, transport infrastructure and renewable energy technologies. The final chapter discusses the role that some of the key stakeholders in the built environment must play in helping to improve the environmental performance of the built environment. It also highlights some of the current barriers for achieving this, including some of the limitations of current environmental assessment approaches and how, in the future, these may be minimized. Finally, the importance of the integration of environmental assessment into everyday industry practice, and how this may help the professionals involved in the design, construction and on-going management of the built environment realize the full potential of environmental improvement opportunities, is discussed.

Acknowledgements

There are numerous people that have provided advice and expert knowledge that has helped to direct this book and I am truly grateful for their time. No one person has had more of an influence on the development of this book than a long-term friend and colleague in the late Associate Professor Graham Treloar. As an international leader in the methodological development of hybrid life cycle inventory approaches and a passionate advocate for sustainable construction, he has provided the inspiration for this book and my own dedication towards improving the environmental performance of the built environment. I will be forever grateful for the short time we shared and for the opportunity to carry on his legacy.

The following organizations provided information for the case studies presented in Chapters 4 and 5 and I am grateful for their kind support and their permission to use this information: Metricon Pty Ltd for the house plan and a bill of materials for the case study house used in Chapter 4, and the Victorian Department of Infrastructure (Australia), in particular Mr David Hill and Ms Kate Murphy, for permission to reproduce the findings from a study of the environmental performance of alternate railway sleeper types. Thank you also to Professor Manfred Lenzen (University of Sydney, Australia) for permission to use the Australian input-output models developed by him for 1996–7. I am also extremely grateful to Dr Stephen Pullen (University of South Australia) for his friendship and encouragement and also for his invaluable input on earlier versions of the text that has helped to direct this book. And most importantly, thank you to my family for their continuing and unwavering support, before, during and since undertaking this project.

Abbreviations

A$	Australian dollar
ABS	Australian Bureau of Statistics
BiPV	building integrated photovoltaics
CAD	computer-aided design
CFCs	chlorofluorocarbons
CH_4	methane
CO_2	carbon dioxide
DER	direct energy requirement
EE	embodied energy
FC	fibre cement
FG	fibreglass
GDP	gross domestic product
GHG	greenhouse gas
GJ	gigajoule (10^9 joules)
GWP	global warming potential
HFCs	hydrofluorocarbons
HVAC	heating, ventilation and air conditioning
HWS	hot water system
I-O	input-output
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
kL	kilolitre (10^3 litres)
km	kilometre (10^3 metres)
kW	kilowatt (10^3 watts)
LCA	life cycle assessment
LCI	life cycle inventory
LCIA	life cycle impact assessment
MDF	medium density fibreboard
MJ	megajoule (10^6 joules)
MW	megawatt (10^6 watts)
Mt	megatonne (10^9 kilograms)
N_2O	nitrous oxide
PET	polyethylene terephthalate
PFCs	perfluorocarbons

PV	photovoltaic
PVC	polyvinyl chloride
SETAC	Society of Environmental Toxicology and Chemistry
TER	total energy requirement
VOCs	volatile organic compounds
W	watt