Edited by
Michael Grubb, Tooraj Jamasb and Michael G. Pollitt

Delivering a Low-Carbon Electricity System

Technologies, Economics and Policy

CAMBRIDGE

Delivering a Low-Carbon Electricity System

Technologies, Economics and Policy

Michael Grubb
Tooraj Jamasb
Michael G. Pollitt

CAMBRIDGE
UNIVERSITY PRESS

CAMBRIDGE UNIVERSITY PRESS
Cambridge, New York, Melbourne, Madrid, Cape Town, Singapore, São Paulo, Delhi

Cambridge University Press
The Edinburgh Building, Cambridge CB2 8RU, UK

Published in the United States of America by Cambridge University Press, New York

www.cambridge.org
Information on this title: www.cambridge.org/9780521888844

First published 2008

Printed in the United Kingdom at the University Press, Cambridge

A catalogue record for this publication is available from the British Library

Library of Congress Cataloguing in Publication Data
Grubb, Michael.
Delivering a low carbon electricity system : technologies, economics, and policy / Michael Grubb, Tooraj Jamasb, Michael G. Pollitt.
p. cm.
Includes bibliographical references and index.
ISBN 978-0-521-88884-4 (hardback)
1. Electric power production–Environmental aspects. 2. Air–Pollution–Prevention. 3. Carbon dioxide mitigation. 4. Atmospheric carbon dioxide–Environmental aspects. 5. Energy conservation. 6. Energy policy. 7. Electric utilities. I. Jamasb, Tooraj. II. Pollitt, Michael G. III. Title.
TD195.E4G79 2008
333.793′2–dc22 2008013456

ISBN 978-0-521-88884-4 hardback

Delivering a Low-Carbon Electricity System

Meeting targets aimed at tackling the climate change challenge requires moving towards a low-carbon economy. These targets can only be met with major reductions in carbon emissions from the electricity sector.

Written by a team of leading academics and industry experts, *Delivering a Low-Carbon Electricity System* analyses the social, technological, economic and political issues that affect the attempt to create a low-carbon electricity sector and assesses the main instruments for achieving this aim. The book begins by looking at how low-carbon generation technologies might be added in sufficient quantity to the electricity system. Next, it examines how networks and the demand side can help to decarbonise the sector. It then highlights the role of innovation and discusses instruments for promoting technological progress. Finally, given the economic framework and technological possibilities, it presents a number of general and specific policy instruments and options for the future.

MICHAEL GRUBB is Chief Economist at the UK Carbon Trust and Senior Research Associate in the Faculty of Economics and the ESRC Electricity Policy Research Group (EPRG), University of Cambridge. He is also Visiting Professor of Climate Change and Energy Policy at Imperial College London.

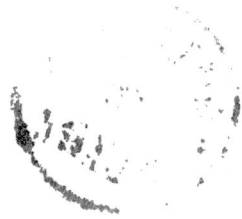
TOORAJ JAMASB is Senior Research Associate in the Faculty of Economics and at the ESRC Electricity Policy Research Group (EPRG) at the University of Cambridge.

MICHAEL G. POLLITT is Reader in Business Economics at the Judge Business School and Assistant Director of the ESRC Electricity Policy Research Group (EPRG), University of Cambridge. He is also Fellow and Director of Studies in Economics and Management at Sidney Sussex College, Cambridge.

University of Cambridge
Department of Applied Economics
Occasional Papers 68
Delivering a Low-carbon Electricity System

Recent books in this series

58 Structural Change in the the UK Economy edited by *Ciaran Driver and Paul Durme*
59 The Stock Market by *Cliff Pratten*
60 Industrial Restructuring and Trade Reorientation in Eastern Europe edited by *Michael A. Landesmann and István P. Székely*
61 Full Employment Regained? *James Meade*
62 The Youth Labour Market in Britain: The Role of Intervention by *B. M. Deakin*
63 Applied Economics and Public Policy edited by *Iain Begg and S. G. B. Henry*
64 The Arithmetic of Tax and Social Security Reform: A User's Guide to Microsimulation Methods and Analysis by *Gerry Redmond, Holly Sutherland and Moira Wilson*
65 Microsimulation Modelling for Policy Analysis: Challenges and Innovations edited by *Lavinia Mitton, Holly Sutherland and Melvyn Weeks*
66 The Internet Revolution: A Global Perspective edited by *E. Giovanetti, M. Kagami and M. Tsuji*
67 Future Electricity Technologies and Systems edited by *Tooraj Jamasb, William Jo Nuttall and Michael G. Pollitt*



Contributors

JONATHAN P. ATKINS is Senior Lecturer in Economics at the Business School, University of Hull.

GRAHAM AULT is Senior Lecturer in Electronic and Electrical Engineering in the Institute for Energy and Environment at Strathclyde University.

KESHAB BHATTARAI is Lecturer in Economics at the Business School, University of Hull.

JANUSZ BIALEK is Bert Whittington Chair of Electrical Engineering at the University of Edinburgh.

MARK BILTON is Doctoral Researcher at the Imperial Centre for Energy Policy and Technology, Imperial College London.

GRAEME BURT is Reader in Electrical Power Engineering in the Institute of Energy and Environment at Strathclyde University.

JIM CUST is Research Assistant in the Faculty of Economics at the University of Cambridge.

HANNAH DEVINE-WRIGHT is Research Associate in the School of Environment and Development at the University of Manchester.

PATRICK DEVINE-WRIGHT is Senior Lecturer in the Manchester Architecture Research Centre in the School of Environment and Development, University of Manchester.

IAN ELDERS is Senior Research Fellow in Electronic and Electrical Engineering in the Institute for Energy and Environment at Strathclyde University.

JON GIBBINS is Senior Lecturer in the Energy Technology for Sustainable Development Group, Mechanical Engineering Department, Imperial

College London, and Principal Investigator for the UK Carbon Capture and Storage Consortium.

RICHARD GREEN is Professor of Energy Economics and Director of the Institute for Energy Research and Policy, University of Birmingham.

MICHAEL GRUBB is Chief Economist at the UK Carbon Trust, Senior Research Associate at the Faculty of Economics, Cambridge University, and Visiting Professor (formerly Professor of Climate Change and Energy Policy) at Imperial College London.

NADINE HAJ-HASAN is Strategy Manager at the Carbon Trust.

SAM HOLLOWAY is Senior Geologist in the Sustainable and Renewable Energy Group at the British Geological Survey.

CHRIS HOPE is Reader in Modelling Policy at the Judge Business School at the University of Cambridge and was Advisor on the PAGE model to the Stern Review on the Economics of Climate Change.

TOORAJ JAMASB is Senior Research Associate in the Faculty of Economics and at the ESRC Electricity Policy Research Group at the University of Cambridge.

KIM KEATS-MARTINEZ is Associate Director of International Infrastructure Analysis at IPA Energy + Water Consulting.

DANIEL KIRSCHEN is Professor and Head of the Electrical Energy and Power Systems Research Group at the University of Manchester.

JONATHAN KÖHLER is Senior Research Associate at the Tyndall Centre and 4CMR (Cambridge Centre for Climate Change Mitigation Research) Department of Land Economy, University of Cambridge.

MATTHEW LEACH is Professor of Energy & Environmental Systems in the Centre for Environmental Strategy at the University of Surrey.

ALEXANDRA MARATOU is Research Assistant in the Faculty of Economics at the University of Cambridge.

JIM MCDONALD is Professor and Head of Department of Electronic and Electrical Engineering in the Institute of Energy and Environment at Strathclyde University.

KARSTEN NEUHOFF is Senior Research Associate at the Faculty of Economics, University of Cambridge.

DAVID NEWBERY is Professor of Applied Economics in the Faculty of Economics and Research Director of the ESRC Electricity Policy Research Group at the University of Cambridge.

WILLIAM J. NUTTALL is University Senior Lecturer in Technology Policy, a shared post of the Judge Business School and Cambridge University Engineering Department.

MICHAEL G. POLLITT is Reader in Business Economics at the Judge Business School, University of Cambridge and Fellow and Director of Studies in Economics and Management at Sidney Sussex College, Cambridge. He is also Assistant Director of the ESRC Electricity Policy Research Group.

CHARLOTTE RAMSAY is Research Associate in the Control and Power Group, Department of Electrical and Electronic Engineering, Imperial College London.

DAVID M. REINER is Lecturer in Technology Policy and Course Director of the MPhil in Technology Policy at Judge Business School, University of Cambridge.

FABIEN A. ROQUES is an economist in the Economic Analysis Division of the International Energy Agency.

GRAHAM SINDEN holds a public position with the Department for Business, Enterprise and Regulatory Reform's Renewables Advisory Board, and is Technical Manager at the UK Carbon Trust.

STEVEN SORRELL is Senior Fellow in the Sussex Energy Group at SPRU, University of Sussex.

STEPHEN TROTTER is Lecturer in Economics at the University of Hull.

RYAN TUMILTY is Research Assistant in Electronic and Electrical Engineering in the Institute for Energy and Environment at Strathclyde University.

PAUL TWOMEY is Jean Monnet Fellow at the Florence School of Regulation, European University Institute, Florence.

JAMES WILDE is Director of Insights at the Carbon Trust.

MILTON YAGO is Senior Lecturer in Economics and International Business at Leeds Metropolitan University.

Foreword

With its radical regulatory changes starting in the late 1980s, in many eyes the UK electricity system became a 'laboratory' for the world in new ways of running a power system. One consequence of being at the forefront of electricity liberalisation is that the UK needs to find innovative ways of meeting new challenges in ways that are consistent with its competitive electricity and gas markets. Twenty years after its initial market reforms, the UK system is facing a challenge which again may make it a focus of global attention: to decarbonise a largely fossil-fuel-based power system without compromising the sector's operational integrity and long-term sustainability, while improving security of supply and economic competitiveness.

At the beginning of this decade, the Engineering and Physics Research Council (EPSRC) formulated the Supergen research programme to prepare the analytic base for addressing this challenge. In addition to technology-specific research, Supergen FutureNet was established to investigate the system-wide issues associated with a low-carbon power system. The resulting programme emerged as a consortium of seven university groups around the UK, combining engineering, economic and social research expertise.

An important part of the consortium's work was to study how the transition to a new electricity system may come about. The work on 'System Evolution and Incentives', coordinated by the team at the University of Cambridge, drew on expertise across the consortium, and in particular the work on scenarios, and was linked to other Supergen consortia. This strand of research sought to combine the engineering insights into a view of the economic and policy implications of moving towards a low-carbon electricity system. In 2006, we published the first product of this work, *Future Electricity Technologies and Systems* (also from Cambridge University Press), assessing from a systems and economic perspective the technology options that can shape the future of the electricity sector towards 2050.

This second book represents the culmination of the research effort, by integrating the associated economic and social underpinnings, and assessing the policy dimensions of a low-carbon power system.

The first book concluded that there are many possible technological combinations that could deliver a low-carbon electricity system by mid-century. This book finds that important steps on the path can be made by 2020 at modest costs, and lays out the policy and societal choices that will have to be made to get us on such a path – and to sustain it. The first book found that, after a century of fossil-fuel-based power system development, a low-carbon system is technically possible: this book shows how it can be done.

Professor Sir John O'Reilly FREng
Vice-Chancellor, Cranfield University
Formerly Chief Executive, EPSRC

Professor Jim Skea OBE
Research Director
UK Energy Research Centre

Professor Tim Green
Professor of Electrical Power Engineering
Department of Electrical and Electronic Engineering
Imperial College London

Acknowledgements

The editors are very grateful to a large number of individuals without whom this book would not have been possible. We acknowledge the help and support of the UK Research Councils, the UK Carbon Trust and the Supergen community and especially the FutureNet consortium of universities researching Future Network Technologies for a sustainable energy policy for the UK. Together they have facilitated the collaboration of a wide range of individuals coming from different disciplines to communicate their expertise and views on the future of the electricity system and its place in meeting carbon emissions reduction targets.

We particularly wish to thank Shimon Awerbuch, Mark Barrett, Erik Britton, Paul Ekins, Tim Foxon, Rob Gross, Jason Hayman, Ben Jones, Alex Kemp, Gordon McKerron and Nils Røkke who, as external referees, have ensured the quality of the substance of this book. A special mention must be made of Jim Cust and Misato Sato, Research Assistants at the Cambridge Faculty of Economics and, above all, Alexandra Maratou and and Aoife Brophy, who successfully managed the entire process from inception to completion.

We are also grateful to David Newbery, Research Director of ESRC Electricity Policy Research Group, for his always useful insights and assistance throughout; Sean Holly, Research Director of the Faculty, as well as Chris Harrison and Philip Good at Cambridge University Press, for their support and work in preparing the book for publication. And last but not least we extend our sincere thanks to all the authors.

MICHAEL GRUBB
TOORAJ JAMASB
MICHAEL G. POLLITT

Contents

Figures