M. Pehnt, M. Cames, C. Fischer, B. Praetorius,
L. Schneider, K. Schumacher, J.-P. Voß

Micro Cogeneration

Towards Decentralized Energy Systems

Martin Pehnt, Martin Cames,
Corinna Fischer, Barbara Praetorius,
Lambert Schneider, Katja Schumacher,
Jan-Peter Voß

Micro Cogeneration

Towards Decentralized Energy Systems

With Contributions by Michael Colijn, Jeremy Harrison,
Yasushi Santo, Jon Slowe, and Sylvia Westermann

With 59 Figures

SÖF Sozial-ökologische Forschung

Springer

Dr. Martin Pehnt
IFEU Institut für Energie-
und Umweltforschung GmbH
Wilckensstr. 3

69120 Heidelberg

Dr. Corinna Fischer
Freie Universität Berlin
Environmental Policy
research Centre (FFU)
Ihnestr. 22

14195 Berlin

Dr. Barbara Praetorius
Katja Schumacher
Deutsches Institut für
Wirtschaftsforschung
Königin-Luise-Str. 5

14195 Berlin

Lambert Schneider
Martin Cames
Jan-Peter Voß
Öko-Institut e.V.
Novalisstr. 10

10115 Berlin

ISBN 10 3-540-25582-6 **Springer Berlin Heidelberg New York**
ISBN 13 978-3-540-25582-6 **Springer Berlin Heidelberg New York**

Library of Congress Control Number: 2005931799

Springer is a part of Springer Science+Business Media
springeronline.com

Printed in The Netherlands

Cover design: E. Kirchner, Heidelberg
Production: A. Oelschläger
Typesetting: Camera-ready by the Authors

Printed on acid-free paper 30/2132/AO 543210

Contents

Introduction

The electricity systems of many countries are currently undergoing a process of transformation. Market liberalization has induced major mergers and acquisitions in the electricity sector, but has also forced companies to seek out new business areas. Environmental regulations, like the Kyoto process and the European Emissions Trading Scheme, are exposing the sector to external pressure. New technologies – such as renewable energy, combined heat and power (CHP), or "clean coal" technologies – are emerging. Recent worldwide experiences with blackouts have once more put security of supply on the agenda. In Germany, the nuclear phase-out and decommissioning of outdated coal plants will lead to a need for replacement of more than one third of the current generation capacity by 2020.

The need for replacement is an extremely important driving force for the current transformation, forcing conventional and new technologies to compete for a role in the future energy supply. The overall transformation of electricity systems is neither driven nor shaped by technical or societal modifications alone, but rather by a rich diversity of processes in the realms of technology, politics, society and economy.

Achieving sustainable development in the energy sector entails specific qualities characterizing the changes which need to be undertaken. Climate change and limited fossil resources call for a reduction of non-renewable primary energy input and greenhouse gas (GHG) emissions by 50 to 80 % by 2050 (Enquête 2002). The resulting structural transformation will require innovation in many different realms, including the development of new technologies, new forms of corporate organization, new user routines, new institutional arrangements for governance, new conceptions regarding how problems should be understood, and new means of measuring electricity system performance.

One possible developmental path is decentralization of the electricity system. Distributed power generation in small, decentralized units is expected to help in reducing emissions and saving grid capacity, while also providing opportunities for renewable energy. It could thus form a constituent part of a more sustainable future. Broad implementation of distributed generation, however, would imply thoroughgoing structural change as well as a surge in innovation.

Recently, decentralization and developing means for autonomous or individual energy supply also appear to be *en vogue*. A trend towards smaller technical systems has, since the 1970s, been advocated by many writers as a return to life on a human scale. The economist and writer E. F. Schumacher, for instance, wrote that technological development should be given “a direction that shall lead it back to the real needs of man, and that also means: *to the actual size of man*. Man is small, and, therefore, small is beautiful. To go for giantism is to go for self-destruction” (Schumacher 1973). This vision of decentralized, and often autonomous, technological systems has been often replicated and has also been applied to energy systems. For instance, in its 2002 memorandum the Club of Rome demanded that, whenever possible, a decentralized energy supply should be established (Club of Rome 2002). Visionary thinkers like Jeremy Rifkin have stated that, in the new age of decentralized energy production, everybody could, in principle, generate and consume his own energy (Rifkin 2002).

The present book focuses on one such element of distributed generation options which could play a role within the development of sustainable energy systems for the future, actually a micro-aspect within the overall transformations that are already going on and will be going on over the coming years. This is the combined production of electricity and heat in small units that are directly embedded in the buildings where the heat and electricity are to be used. This configuration is referred to as *micro cogeneration*.

Compared to the currently dominant pattern which combines electricity production in central plants, supplying 100,000 buildings at once, with separate on-site heating systems, micro cogeneration would make a fundamental difference in electricity systems if it actually became widely implemented. It not only integrates technological as well as cultural and institutional components, but also entails the potential for reducing the ecological impacts of electricity production. However, as many chapters in this book will seek to illustrate, the current context for micro cogeneration in many countries is not a very bright one.

Micro cogeneration thus offers a rewarding opportunity for studying the conditions facing radical innovations in potentially unfavorable regime contexts. At the same time, when market and economic factors become favorable, micro cogeneration may have the potential for reaching a considerable market size, thereby helping to advance other downstream or system innovations, such as the “virtual power plant” or new household energy-management systems, combined with altered consumer awareness.

More recently, the interest in micro cogeneration has also been fuelled by an enthusiastic interest in fuel cells, which could, amongst other applications, also be used in individual buildings as CHP devices. But micro cogeneration goes beyond fuel cell technology and involves various other conversion technologies.

This book aims at assessing the potential contribution of micro cogeneration towards a sustainable transformation of electricity systems. We examine the role it should or may play within a sustainable energy strategy, assess related implementation conditions and discuss possibilities to improve the context for introducing micro cogeneration on a larger scale. The issue demands a multifaceted answer that considers the various factors involved in real world applications of micro cogeneration. This book, therefore, combines the perspectives of engineering and life cycle studies, economics, sociology, applied psychology, and political science. Not only various academic disciplines, but also different national perspectives need to be taken into account, because the success chances of micro cogeneration largely depend on both the “hardware” and “software” of a country: on the one hand, the existing infrastructural context which micro cogeneration has to fit into (e.g., building stock, dominant fuels, district heating infrastructure) and, on the other hand, the political and economic framework, including support schemes, innovation policy, energy prices, and micro cogeneration legislation. Therefore, authors from several countries where significant micro cogeneration-related developments are now taking place were invited to contribute to this book.

Structure of the book. The core of this book is based on research carried out within a project called “Transformation and Innovation in Power Systems” (www.tips-project.de), funded by the German Ministry for Education and Research (*Bundesministerium für Bildung und Forschung, BMBF*), under the auspices of the Socio-Ecological Research Framework (*Sozial-ökologische Forschung*), launched in 2001.

Chap. 1 defines the book’s terrain: what is micro cogeneration? What are adequate conversion technologies? Which further technological components are required for establishing a functioning micro cogeneration system?

Micro cogeneration is part of a larger transformation process. In **Chap. 2**, we investigate the relevance of this process for the future performance of micro cogeneration and, vice versa, the role different kinds of energy scenarios attribute to micro cogeneration. In **Chap. 3**, we discuss important parameters which determine market perspectives for micro cogeneration, and try to assess the potential for it in the German market under different conditions.

How far this market potential is actually exploited depends primarily on the economic performance of micro cogeneration (**Chap. 4**). Here, we calculate its economic viability from different perspectives. Another prerequisite for successful market development is the environmental superiority of this innovation. Therefore, an environmental life cycle perspective on micro cogeneration is presented in **Chap. 5**.

Because micro cogeneration can be considered to be one of the most extreme examples of decentralization, the consumer gains in importance. Under certain circumstances, the boundary between consumer and producer is even blurred or eliminated. In **Chap. 6**, the users, particularly early pioneers who are necessary for spreading information about and realizing the systems, are the object of detailed description. Not only the consumers, but also energy companies are major actors involved in developing, or retarding, micro cogeneration development. **Chap. 7** looks at the setting of energy markets and entrepreneurial actors relevant to implementing micro cogeneration in Germany; it inquires about their interests, motivations, and strategies to foster, or to hold back, this innovative technology. The institutional framework of micro cogeneration in Germany involves not only directly CHP-related legislation, but also general energy legislation, innovation policy, and funding for research and development. **Chap. 8** tries to precisely locate the field on which micro cogeneration has to prove itself.

Successful development of micro cogeneration requires compatibility with existing and future energy systems. This concerns not only security of supply and availability of fuels, but also technical compatibility with electricity networks. This embedding of micro cogeneration is investigated in **Chap. 9**.

Whereas the TIPS study funded by the German ministry focused on micro cogeneration from an analytic point of view, the experiences of a micro cogeneration practitioner are described in **Chap. 10**, dealing with the various types of micro cogeneration operators and the range of the unforeseen problems occurring in the everyday operation of micro cogeneration.

Micro cogeneration is being developed, and in fact has been more successfully implemented, in other regions worldwide. We therefore invited micro cogeneration experts from the four most important micro cogeneration countries outside Germany – Great Britain, the Netherlands, Japan, and the United States of America – to report on micro cogeneration hard- and software, and the respective peculiarities in these countries (**Chap. 11 to 14**). Following our conclusions in **Chap. 15**, the reader is referred to a substantial body of literature and World Wide Web resources (**Chap. 16**).

The authors would like to thank the guest authors, namely, Sylvia Westermann, Michael Colijn, Jeremy Harrison, Yasushi Santo, and Jon Slowe, for their contributions. We also acknowledge valuable contributions from Raphael Sauter (FU Berlin); Katherina Grashof, Sabine Poetzsch, and Jens Gröger (Öko-Institut); Regina Schmidt and Bernd Franke (IFEU); as well as Lars Winkelmann (Berliner Energieagentur GmbH).

The authors gratefully acknowledge the funding of the TIPS research project by the German Ministry for Education and Research.

Martin Pehnt, Martin Cames, Corinna Fischer, Barbara Praetorius, Lambert Schneider, Katja Schumacher, Jan-Peter Voß

Heidelberg, Berlin, July 2005

Supported by the German
Ministry for Education and Research,

SÖF Sozial-
ökologische
Forschung