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Energy Systems: From Design to Management **Series**

Analysis of Energy Systems

Management, Planning, and Policy

Edited by Vincenzo Bianco

Engineering - Electrical

Analysis of Energy Systems

The analysis of energy systems is of utmost importance in modern era, since it is the basis to guarantee future energy sustainability and sustainable economic development. The book covers major advanced topics related to the analysis of energy by considering different aspects, namely management, planning and policies. The most recent trends, such as smart grids, transition from fossil fuels to renewables based energy systems and distributed generation, are also discussed in this book.

Intended to be a collection of various contributions from experts all around the world, it includes latest research results, innovations and methodologies in order to support discussions and enhance knowledge about the analysis of energy systems. The author has also included *"lessons learnt"* in different countries in order to support readers to understand what is happening in other parts of the world.

The book also focuses to contribute to the current debate related to the evolution of energy systems, by discussing in an open way the pro's and con's without any pre-constitute point of view. Title is aimed to be a reference for the academic community, students and professionals with a wider interdisciplinary background.

- Presents integration of renewable sources with conventional energy systems.
- Topic is addressed from a multidisciplinary point of view, i.e. economy, technical, modelling, and planning.
- Investigates management and planning aspects of future energy supplies.
- Multidimensional nature of energy systems is highlighted and discussed.
- Contributes towards implementing policy measures to reduce primary energy consumptions and carbon footprint.

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6000 Broken Sound Parkway, NW
Suite 300, Boca Raton, FL 33487
711 Third Avenue
New York, NY 10017
2 Park Square, Milton Park
Abingdon, Oxon OX14 4RN, UK

K29768

ISBN: 978-1-4987-7739-1

www.crcpress.com

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CRC Press
Taylor & Francis Group
Boca Raton London New York

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

CRC Press
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742

Printed on acid-free paper
Version Date: 20161229

International Standard Book Number-13: 978-1-4987-7739-1 (Hardback)

Library of Congress Cataloging-in-Publication Data

Names: Bianco, Vincenzo, editor.
Title: Analysis of energy systems : management, planning and policy / [edited by] Vincenzo Bianco.
Description: Boca Raton, FL : CRC Press, 2017. | Series: Energy systems from design to management | Includes bibliographical references and index.
Identifiers: LCCN 2016050541 | ISBN 9781498777391 (hardback : alk. paper) | ISBN 9781498777469 (ebook : alk. paper)
Subjects: LCSH: Power resources. | Power resources--Management | Energy policy. | Energy industries.
Classification: LCC HD9502.A2 A55 2017 | DDC 333.79068--dc23
LC record available at https://lccn.loc.gov/2016050541

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http://www.taylorandfrancis.com

and the CRC Press Web site at
http://www.crcpress.com

Analysis of Energy Systems: Management, Planning, and Policy

Series on
ENERGY SYSTEMS: FROM DESIGN TO MANAGEMENT

SERIES EDITOR

Vincenzo Bianco
Università di Genova, Italy

RECENT TITLES

Analysis of Energy Systems: Management, Planning and Policy
Vincenzo Bianco

Preface

The analysis of energy systems is of paramount importance in modern societies, since it is fundamental to guarantee a sustainable economic development. It combines technical and economic research with a specific focus on quantitative modeling, in order to optimize the modalities of energy demand and supply globally.

Management, planning, and policy are three key aspects in the study of complex energy systems, which have to be considered at the same time, because of the "multidimensional" nature of energy-related interactions.

Through effective energy management, it is possible to reduce consumption, thus enhancing energy efficiency, and to optimize supply and demand in the medium/short term.

Energy planning, instead, is a fundamental step in pursuing winning long-term strategies in terms of energy supply and demand optimization. Sophisticated instruments and methodologies, ranging from energy demand forecast up to the computation of the optimal supply–demand balance or minimization of pollutant emissions, are available to support complex energy planning.

Similarly, energy policy has a relevant role, because it helps reshape the energy sector and improve its effectiveness by designing and implementing appropriate supporting schemes for the diffusion of the best technologies.

The aim of the present book is to bring together a number of selected contributions regarding the analysis of energy systems from several experts of different countries. The latest research results, innovations, and methodologies are reported in the book in order to support discussion, to circulate ideas and knowledge about the analysis of energy systems.

The most recent trends, such as smart grids and transition from fossil fuels to renewables-based energy systems and distributed generation, are discussed in depth, as briefed here:

- Chapter 1 discusses the nexus between energy transition and sustainability by analyzing possible benefits for the society, the economy, and policy framework necessary to sustain this evolution.
- Chapter 2 proposes an analysis on the role of analytical tools in the context of energy and climate planning. A significant range of tools and methodologies are presented, compared, and discussed in detail.
- Chapter 3 analyzes the role of Energy Service Companies (ESCO) in the energy system and the related policies necessary to stimulate this business. An analysis of the Russian context is proposed, including two case studies on Eurasia Drilling Company and TGT Oilfield Services.

- Chapter 4 discusses the competitiveness of distributed trigeneration, namely, the contemporary generation of heat, power, and cool. An overview of the topic is presented by introducing the main technologies and sectors of application. Furthermore, a methodology to evaluate the competitiveness of the different solutions is presented.
- Chapter 5 focuses on the role of smart grids. In particular, the Northwestern European context is analyzed in terms of economic, environmental, and regulatory issues
- Chapter 6 investigates the problem of renewables optimization on "energy only" power markets. The scope is to analyze the "missing money" problem provoked by the tremendous development of RES in EU, with a focus on the Iberian market.
- Chapter 7 proposes an analysis on the optimal scheduling of a microgrid under uncertainty conditions. An introduction and classification of microgrids is presented and then a methodology to perform the optimization, namely, minimizing the generation cost, is presented and discussed.
- Chapter 8 presents a methodology to perform cost–benefit analysis (CBA) for energy policies. In particular, the chapter focuses on the methodological aspects of the CBA, by illustrating its framework and possible application in the field of energy policy.
- Chapter 9 examines the effect of the implementation of energy efficiency policies in the Middle East and North Africa (MENA) by introducing a benchmarking methodology. The methodology allows comparing the different countries and analyzing their successful policy measures.
- Chapter 10 analyzes the European natural gas market by highlighting the most recent trends, which led to complete reshaping of the sector. The regulatory framework, supply and demand balance, market context, and infrastructure development are discussed in depth.
- Chapter 11 offers a deep insight into the Spanish energy policy with particular emphasis on renewables. A snapshot at the EU level is also given, and the differences between the Spanish and EU context are also highlighted.

The present book aims to be a reference for the academic community, students, and professionals with a wider interdisciplinary background. It provides readers with up-to-date knowledge and innovative ideas for the analysis of energy systems.

Contributors

Vincenzo Bianco
Department of Mechanical, Energy, Management and Transportation Engineering
University of Genoa
Genoa, Italy

Carmelina Cosmi
Institute of Methodologies for Environmental Analysis
National Research Council of Italy
Potenza, Italy

Senatro Di Leo
Institute of Methodologies for Environmental Analysis
National Research Council of Italy
Potenza, Italy

Oana M. Driha
Department of Applied Economic Analysis
University of Alicante
Alicante, Spain

Tareq Emtairah
International Institute for Industrial Environmental Economics
Lund University
Lund, Sweden

Gabriella Ferruzzi
Department of Industrial Engineering
University of Naples Federico II
Naples, Italy

Nuno Carvalho Figueiredo
Energy for Sustainability
Faculty of Economics
University of Coimbra
Sustainable Energy Systems
MIT-Portugal
INESCC
Coimbra, Portugal

Giorgio Graditi
Energy Technologies Department
Italian National Agency for New Technologies, Energy and Sustainable Economic Development
Portici Research Center
Naples, Italy

Konstantinos C. Kavvadias
European Commission, Joint Research Centre (JRC)
Directorate for Energy, Transport and Climate
Petten, the Netherlands

Andrey Kovalev
Institute for Statistical Studies and Economics of Knowledge
National Research University Higher School of Economics
Russian Federation

Julián López-Milla
Department of Applied Economic Analysis
University of Alicante
Alicante, Spain

Michele Moretti
Faculty of Business Economics
Center for Environmental Sciences
Hasselt University
Diepenbeek, Belgium
and
Gembloux Agro-Bio Tech
University of Liege
Gembloux, Belgium

Nurzat Myrsalieva
Energy Consultant
United Nations Development Programme
Bahrain

Sylvestre Njakou Djomo
Department of Agroecology
Aarhus University
Tjele, Denmark

Filomena Pietrapertosa
Institute of Methodologies for Environmental Analysis
National Research Council of Italy
Potenza, Italy

Liliana Proskuryakova
Institute for Statistical Studies and Economics of Knowledge
National Research University Higher School of Economics
Russian Federation

Monica Salvia
Institute of Methodologies for Environmental Analysis
National Research Council of Italy
Potenza, Italy

Martín Sevilla-Jiménez
Department of Applied Economics
University of Alicante
Alicante, Spain

Patrícia Pereira da Silva
INESCC and CeBER
Energy for Sustainability and MIT- Portugal
Faculty of Economics, University of Coimbra
Coimbra, Portugal

Jacopo Torriti
School of the Built Environment
University of Reading
Reading, United Kingdom

Steven Van Passel
Faculty of Business Economics
Center for Environmental Sciences
Hasselt University
Diepenbeek, Belgium
and
Department of Engineering Management
University of Antwerp
Antwerp, Belgium

Nele Witters
Faculty of Business Economics
Center for Environmental Sciences
Hasselt University
Diepenbeek, Belgium

Georgeta Vidican Auktor
Institute of Economics
Friedrich Alexander University Erlangen-Nürnberg
Erlangen, Germany
and
German Development Institute
Bonn, Germany

Contents

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Systemic Interventions to Achieve a Long-Term Energy Transition toward Sustainability

Georgeta Vidican Auktor

CONTENTS

1.1 Multi-Dimensions of Energy System Transition

The main message of this edited volume is that energy systems are multidimensional and require simultaneous interventions at management, planning, and policy level. Given the complex nature of energy-related interactions, a one-dimensional approach to the analysis of energy systems is likely to miss opportunities for achieving long-term sustainable development objectives. With a focus on the link between energy and economic development and on the importance of transforming energy systems toward sustainability, this chapter discusses the need for integrating the analysis of energy systems (simplified here as the system for generation, transmission, and consumption of energy) with other economic and social policies and strategies for enabling a long-term energy transition. The imperative for integration emerges from four main reasons.

First, energy and development are intrinsically related. Economic growth is powered by energy production for fueling industrial development and for sustaining technological innovation; access to energy is essential for improving livelihoods and welfare and for enabling access to markets and entrepreneurship. Thus, an integration of energy policy with industrial and social policy is essential to enabling energy system transformation.

Second, in light of concerns with global climate change, clean energy technologies (in particular renewable energy technologies) need to become more prominent in energy production and consumption. Economic growth based on conventional fuels has historically been associated with increasing levels of environmental degradation. While early industrializing countries have managed to gradually reduce their environmental footprint, developing and emerging economies face massive challenges to decouple economic growth from environmental degradation, especially as related to the scale of investments and know-how. However, opportunities also exist; developing countries could leapfrog industrial development based on fossil fuels by expanding their capabilities in renewables, thus paving the way to a sustainable growth pathway. Such a development process would require, however, a change in the way we produce and consume energy, in the industrial process itself, and the infrastructure for energy generation and distribution.

Third, as conventional energy systems are locked-in into existing infrastructure and power structures (Unruh 2000), institutional path dependencies (e.g., subsidization of fossil fuels) need to be disrupted. The role of the state in this process, in correcting market and coordination failures (Lütkenhorst et al. 2014), is critical. By creating incentives for renewable energy deployment and energy efficiency adoption, a market for low-carbon energy can be enabled, opening up opportunities for local value creation (through job creation, knowledge, and research capabilities). A shift to low-carbon technologies can be, of course, costly in the face of other development requirements (especially for developing and emerging economies), but the co-benefits that can be captured in this process could compensate these costs in the medium and long term.

Fourth, the main question, of course, is how to capture such benefits, how to lock-out the energy system (and the development trajectory) from a fossil fuel-based system and achieve a lock-in into a system based on low-carbon energy technologies. The answer, I argue, lies within an integrated policy approach and long-term planning, based on systemic learning and experimentation. Policy integration across sectors leads to cooperation between stakeholders with different interests and fosters consensus with regard to the direction and sequencing of reforms. Integration can also contribute to opening up new markets for renewable energy technologies with applications in different sectors (e.g., water generation, agriculture, or housing). Long-term planning needs to be based on a national vision for sustainable development, which gives direction and purpose for various initiatives. The narrative framing such a vision should be elaborated by an alliance of diverse stakeholders, representing the civil society, business sector, and policy makers. Systematic learning and experimentation is an essential part of this transition process. Such a systemic and deliberate transformation has almost no precedent in economic development history. Moreover, policy solutions implemented in one context might not be suitable to another. The example of the feed-in tariff (FIT) is a case in point; while this policy

instrument has been successfully used in Germany, many developing countries (for instance, India) have found that competitive bidding is more appropriate to their market and institutional context (Altenburg and Engelmaier 2013). Thus, experimentation, reflection, and reassessment of initial objective of strategies are essential for effectively implementing such a transition process, when uncertainties prevail.

This chapter aims to shed light of these issues. As some of these aspects will be discussed in more detail in the subsequent chapters, with reference to different parts of the energy sector, in this chapter I emphasize the systemic nature of the transition process, instead of offering an exhaustive discussion on the subject. The chapter is structured as follows. Section 1.2 discusses the complex link between energy and economic development. The role of the state in developing and guiding the national vision toward sustainability is also discussed. Section 1.3 highlights the co-benefits that can be captured by diversifying the energy system to integrate a larger share of low-carbon energy technologies. Last, Section 1.4 has in focus the need for integrated policy interventions given the complex nature of the process of transformation toward sustainability, emphasizing the importance of learning and systematic implementation of policies. In effect, multidisciplinary and cross-sectoral approaches are critical for capturing value creation in terms of job creation, competitiveness, and poverty reduction.

1.2 Complex Link between Energy and Development

Historically, energy sources have been critical for the development of civilization (Cottrell 1955) and for long-term economic growth and development (Smil 2003). The first industrial revolution is the prime example of how the availability and transformation of energy sources have put into motion the engine of economic growth in our contemporary society (Fouquet 2008, Ayres 2009). Inventions such as the internal combustion engine, creating new ways of moving goods and people and accelerating transportation in our modern world, as well as the steam locomotive (powered by coal or wood) became symbols of modernity and progress by the end of the nineteenth century (Moe 2010, Carbonnier and Grinevald 2011). Later, the railway and air travel accelerated the growth process.

Yet, as Moe (2010) emphasizes, it is the symbiosis between energy and industry contributing to structural change and thus to economic progress. Specifically, without new sources of energy growth in new industries would not have been possible, and, at the same time, without technological change and industrial progress incentives for exploiting and developing new sources would have been minimal. Correlations between human

development indicators and electricity consumption per capita show the positive effect that the availability and consumption of energy have on socio-economic development (GEA 2012).

Energy plays a critical role for poverty reduction. Access to reliable and clean energy has been increasingly recognized to be critical for economic development. Universal access to electricity and modern forms of energy for cooking, as well as switching from traditional solid fuels to cleaner liquid fuels and combustion technologies, is important for developing countries to be able to overcome poverty and support economic growth (GEA 2012).

Access to energy is essential for the delivery of key services, such as education, health, and other social services, for consumption of goods, increasing productivity, and for expanding employment opportunities through industrial development. Currently, there are almost one and a half billion people worldwide without access to electricity (IEA 2010). When considering those who have access only to intermittent sources of energy, this number is much larger.

The relationship between energy and poverty can be characterized by a vicious cycle: poor people lacking access to (cleaner and) affordable energy are often trapped in a cycle of deprivation and limited incomes; at the same time, a large share of their income is used for expensive and unhealthy forms of energy (GEA 2012: 164).

For the preceding reasons, improving access to energy is essential for development. Ensuring access to affordable, reliable, sustainable, and modern energy for all has also been designated by the United Nations as one of the Sustainable Development Goals (SDGs) to achieve the 2030 Agenda. In spite of the difficulty of operationalizing this goal in clear and measurable targets (Loewe 2015), it has a high degree of importance as it emphasizes the need to not only improve access to energy but to also rely increasingly on renewable energy and energy efficiency. As such, it places strong emphasis on transitioning to sustainable energy systems for both developed and developing countries.

However, as it has been widely emphasized, this symbiosis between energy and development owes much to politics, which can either constrain or enable the ability of new energy technologies to transform economies and lay the foundation for long-term economic growth (Moe 2010). The role of politics becomes even more evident in the case of transitions toward a clear energy system.

Specifically, disrupting old pathways (i.e., energy systems based on conventional energy sources) requires overcoming various market failures by creating "policy rents" to unlock the potential for renewable energy and energy efficiency. Market failures, especially emerging from coordination failures, externalities, and the public good nature of environmental quality (see Table 1.1), distort the incentives for investing in clean energy technologies, leading to lock-in in conventional energy systems. Breaking out of this