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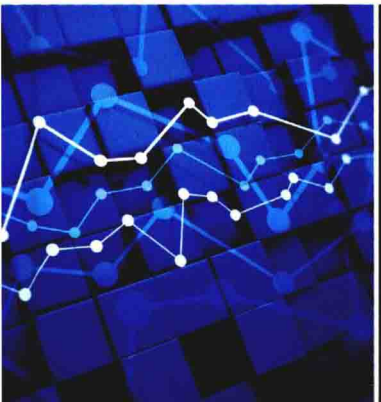
ENVIRONMENTAL ASSESSMENT ON ENERGY AND SUSTAINABILITY BY DATA ENVELOPMENT ANALYSIS



Toshiyuki Sueyoshi
Mika Goto

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Introduces a bold, new model for energy industry pollution prevention and sustainable growth

Balancing industrial pollution prevention with economic growth is one of the knottiest problems faced by industry today. *Environmental Assessment on Energy and Sustainability by Data Envelopment Analysis* introduces a novel approach to using data envelopment analysis (DEA) as a powerful tool for achieving that balance in the energy industries—the world's largest producers of greenhouse gases. It describes a rigorous framework that integrates elements of the social sciences, corporate strategy, regional economics, energy economics, and environmental policy, and delivers a methodology and a set of strategies for promoting green innovation while solving key managerial challenges to greenhouse gas reduction and business growth.

In writing this book the authors have drawn upon their pioneering work and considerable experience in the field to develop an unconventional, holistic approach to using DEA to assess key aspects of sustainability development. The book is divided into two sections, the first of which lays out a conventional framework of DEA as the basis for new research directions. In the second section, the authors delve into conceptual and methodological extensions of conventional DEA for solving problems of environmental assessment in all contemporary energy industry sectors.

- Introduces a powerful new approach to using DEA to achieve pollution prevention, sustainability, and business growth
- Covers the fundamentals of DEA, including theory, statistical models, and practical issues of conventional applications of DEA
- Explores new statistical modeling strategies and explores their economic and business implications
- Examines applications of DEA to environmental analysis across the complete range of energy industries, including coal, petroleum, shale gas, nuclear energy, renewables, and more
- Summarizes important studies and nearly 800 peer reviewed articles on energy, the environment, and sustainability

Environmental Assessment on Energy and Sustainability by Data Envelopment Analysis is a must-read for researchers, academics, graduate students, and practitioners in the energy industries, as well as government officials and policymakers tasked with regulating the environmental impacts of industrial pollution.

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Sueyoshi Goto

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Operations Research and Management Science (ORMS) is a broad, interdisciplinary branch of applied mathematics concerned with improving the quality of decisions and processes and is a major component of the global modern movement towards the use of advanced analytics in industry and scientific research. The Wiley Series in Operations Research and Management Science features a broad collection of books that meet the varied needs of researchers, practitioners, policy makers, and students who use or need to improve their use of analytics. Reflecting the wide range of current research within the ORMS community, the Series encompasses application, methodology, and theory and provides coverage of both classical and cutting edge ORMS concepts and developments. Written by recognized international experts in the field, this collection is appropriate for students as well as professionals from private and public sectors including industry, government, and nonprofit organizations who are interested in ORMS at a technical level.

PREFACE

Global warming and climate change are now a very serious issue around the world. The climate change problem, due to global warming, implies an increase in average global temperature regarding air, sea and land. Natural events and economic activities, including industrial developments and business activities, contribute to the increase in average global temperature. Such a climate change is primarily caused by an increase in greenhouse gases such as carbon dioxide. In addition, we are now facing various environmental difficulties, such as how to handle nuclear and industrial wastes, all of which are byproducts of our economic and industrial developments.

To combat the environmental issues, this book discusses the importance of both economic success and environmental protection for sustainability enhancement. The underlying philosophy of this book is that we need to develop eco-technology innovation and managerial challenges to support a progress for reducing an amount of greenhouse gas emissions. In challenging toward such a research direction, this book proposes a new use of "data envelopment analysis (DEA)," as a holistic approach, to assess various aspects concerning sustainability development. In the sense, the new methodology proposed in this book is referred to as "DEA environmental assessment."

An important feature of this book is that it focuses upon "energy sectors" because they are closely associated with environmental problems. Therefore, this book is not interested in a conventional use of DEA for performance assessment, rather discussing the new approaches for energy-related sustainability development. In discussing these new approaches for energy and environmental

assessment, it is necessary for us to clearly specify important concerns to be discussed in this book. Some of these concerns are summarized as follows:

(a) *History*: Many DEA researchers have long believed that the first DEA publication was the article prepared by Professor W. W. Cooper and coworkers in 1978. Viewing DEA as an extension of goal programing, along with fractional programming and a historical linkage between L1 regression and goal programming, this book considers that DEA has an analytical linkage with L1 regression. In this view, the history of DEA was connected in a roundabout fashion with the development of science in the eighteenth century, as manifested in the work of Laplace and Gauss, because they attempted to develop algorithms for the L1 regression.

(b) *Methodological Bias*: DEA is not a perfect methodology for performance assessment. Many different models have been proposed since the initial publication. DEA researchers and users need to understand the existence of methodological bias in their applications. Said simply, different methodologies produce different results. Therefore, it is necessary for us to examine several different DEA models to examine the methodical validity to prepare business and policy implications.

(c) *Measures*: It is usually believed among researchers and users that DEA is a methodology for efficiency assessment. Acknowledging the importance of DEA-based efficiency assessment, this book is different from the conventional belief because DEA can provide us with not only the efficiency assessment but also other different measures such as scale measures (e.g., returns to scale and damages to scale), substitution measures (e.g., marginal rate of transformation and rate of substitution) and other various managerial measures (e.g., future prediction). Thus, it is not sufficient to examine only the level of efficiency regarding various organizations.

(d) *Undesirable Outputs*: Conventional DEA incorporates multiple components of the input vector and the desirable output vector. The previous approach had only two production factors. Meanwhile, DEA environmental assessment additionally incorporates multiple components of the undesirable output vector, thus having three production factors.

(e) *Disposability Concepts*: The proposed environmental assessment utilizes two disposability concepts. One of the two concepts is "natural disposability" in which operational performance is measured as the first priority and environmental performance is measured as the second priority. The other disposability concept is "managerial disposability" which has an opposite priority on operational and environmental performance measures. Here, the concept of disposability indicates the elimination of inefficiency sources.

(f) *Congestion*: This book discusses a possible occurrence of congestion that is classified into two categories: (f-1) undesirable congestion under natural

disposability and (f-2) desirable congestion under managerial disposability. The proposed DEA approach incorporates a possible occurrence of undesirable congestion and that of desirable congestion into the environmental assessment. We discuss how to measure an occurrence of desirable congestion, or eco-technology innovation, in a comparison with that of undesirable congestion. The identification of undesirable congestion is important, for example, in avoiding a cost increase due to a shortage of transmission or a limit of transportation capacity in a whole production system. However, the identification of desirable congestion is more important than that of undesirable congestion because we are interested in reducing an amount of various pollutions, so developing a sustainable society.

(g) *Input Direction*: The proposed environmental assessment incorporates an analytical capability to increase or decrease the components of an input vector. The input increase implies an "economic or corporate growth" under managerial disposability, while the input decrease implies these "stabilities" under natural disposability. The input increase has an upper limit on an efficiency frontier related to undesirable outputs, while the input decrease has a lower limit in an efficiency frontier related to desirable outputs. The analytical feature is very different from a conventional use of DEA that incorporates only the direction of an input decrease along with an increase in some components of the desirable output vector. The direction of an input vector becomes an important component in examining and developing social or corporate sustainability. This book will explore the methodological issue from the perspective of DEA-based sustainability development.

This book consists of two sections. Section I describes a conventional framework of DEA which provides us with a mathematical basis for understanding the proposed research direction toward environmental assessment and sustainability development. Section II, which is the gist of this book, is related to its conceptual and methodological extensions toward environmental assessment in energy and other industrial sectors.

In preparing this book, the authors have reused figures, tables and related descriptions from their original publications. They have obtained copyright permissions concerning the reuses from publishers (e.g., Elsevier, IEEE and John Wiley & Sons) via the Copyright Clearance Center (Danvers, Mass.). The authors realize that their original works no longer belong to them, rather belonging to the publishers after publishing their articles in journals.

The authors acknowledge that this book has been financially supported by Japan Society for the Promotion of Science (JSPS) Grant-in-Aid for Scientific Research (KAKENHI) 26285050 and 16K01236.

At the end of this preface, it is important to note that comments and constructive criticisms should be directed to the first author of this book. After spending four years, he can finally escape from the painful effort of producing this book.

Now, the first author will be able to reply to positive inquiries, not negative ones, about the book. All errors and mistakes related to this book are his responsibility alone.

Finally, it is hoped that this book will make a contribution for developing new DEA models and applications in energy and other industrial sectors. We look forward to seeing many research extensions of the approaches discussed in this book.

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SECTION I

DATA ENVELOPMENT ANALYSIS (DEA)

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