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Hassan Qudrat-Ullah

The Physics of Stocks and Flows of Energy Systems

Applications in Energy Policy

Springer

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To my wife, Tahira Qudrat, who patiently listens to my ramblings about complex systems and bears with the associated, often logical but long discussions, and my wonderful children, Anam, Ali, Umer, and Umael, who, on an ongoing basis, represent a beautiful and adorable kind of a complex dynamic system.

Preface

People from all walks of life regardless of their origin, creed, sect, social strata, and value systems desire a better life. Energy plays a fundamental role in the well-being, prosperity, and improved lives of all of us. Planners and decision makers of any region, state, or country therefore, have or at least aspire to have a common goal: an adequate, reliable, cleaner, and affordable supply of energy. In order to achieve this goal, the responsible governments and authorities, often at the time of the promulgation of their national development plans and economic agendas, enact, implement, assess, and adjust various energy policies.

To realize energy policy objectives, the common challenge for the decision makers is how to design an effective and efficient energy policy subject to sociotechnical constraints. To begin with, the design of an effective and efficient energy policy is a complex task. Energy systems are essentially sociotechnical systems. Although the complexities of physical energy generation systems (e.g., run-of-river and reservoir-based hydro power plants, nuclear power plants, wind, solar, biomass, and tidal power generation technologies, transmission and distribution systems) are highly technical, the nature of issues related to the affordability (e.g., ability of the consumers to pay) and adoption of technologies (e.g., due to the consumers' sensitivity to environmental emissions) is predominantly social. The limited resources and conflicting objectives of various stakeholders (e.g., local community, business community, regulatory agencies, and governments) further complicate the energy policy decisions. Therefore, an appreciation and understanding of the dynamics of these sociotechnical systems is an essential prerequisite of the design of an energy policy. Hence, the objective of this book is to enhance systematically our understanding of and gain insights into the general process by which the physics of stocks and flows of an energy system explains the making of an efficient and effective energy policy.

Approach of This Book

To realize the objective of this book, we identify some fundamental accumulation processes (stocks and flows) spanning across the demand and supply sectors of energy systems that are common to the majority of energy policy related issues across the globe. To understand the physics of these identified stocks and flows of energy systems, we apply the system dynamics approach (i.e., stocks and flows based modeling). By presenting examples of some "validated and in use" system dynamics simulation models wherein these accumulation processes are drivers of the behavior of the represented energy system, we demonstrate the importance and utility of the fundamental and foundational structures (i.e., stocks and flows based feedback loops) of energy systems. Based on these modeling efforts, three cases, (i) the dynamics of green power in Ontario, Canada, (ii) socioeconomic and environmental implications of the energy policy of Pakistan, and (iii) the dynamic of the electricity generation capacity of Canada, are analyzed and discussed. Finally, for dealing with complex, dynamic energy policy issues, a step-by-step model based on the stock and flow perspective is presented.

Outline of Book

This book has seven chapters dealing with three distinct but related themes of energy policy:

1. The introduction to the subject of "modeling for energy policy," its importance and complexity, and stock and flow perspective (i.e., system dynamics approach) as a "solution" modeling approach (Chaps. 1 and 2).
2. The physics of stocks and flows and how it deals with the complexity of energy systems (Chaps. 3 through 5).
3. The physics of stocks and flows in action; the applications of system dynamics models developed for dealing with various energy policy issues, thereby, helps to drive critical lessons to be learned (Chaps. 6 and 7).

Use and Users of Book

This book provides the reader with a comprehensive understanding of the physics of stocks and flows encountered in the design of an efficient and effective energy policy for a region or country. By studying the dynamics of the fundamental structures of an energy system, she or he will not only appreciate the existence and utility of key stocks and flows of energy systems but also contribute to the policy-making projects across various domains. This book is intended for managers and practitioners, teachers, researchers, and students of design and assessment of energy policy making for complex, dynamic energy systems.

For managers (utility managers, professionals working in energy, environment, and resource industries) and practitioners (energy policy consultants, climate change writers and journalists, and IPPs consortiums), this book provides insights into the complex dynamic systems that they often encounter. For these readers, Chaps. 4 and 5, which provide methodological details on the physics of stocks and flows, may be skipped initially so that they can go directly to the applications of stocks and flows based simulation models to various energy policy related issues and the important lessons learned (Chaps. 6 and 7).

Teachers and instructors in the post-secondary education sector can adopt this book as a textbook for a half course on Policy Modeling or Energy Policy Modeling.

For researchers and students, this book provides probably the most systematic study of the physics of stocks and flows in energy systems. The background material in Chaps. 3 through 5 provides a solid base to understand and organize the existing system dynamics models for energy policy design.

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Contentwise, this brief book draws heavily on my own research in and practice of "energy policy modeling" that I started in 1996–1997 at the University of Bergen, Norway, during my masters' program; I am grateful to Prof. Paal Davidsen for introducing me to this research area, specifically for teaching system dynamics methodology.

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