Biomass to Biofuel Supply Chain Design and Planning under Uncertainty

Concepts and Quantitative Methods

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Preface

Growing concerns over climate change, heavy dependence on fossil fuels, increasing demand for energy, and rising oil prices are the main drivers behind the development of renewable energy that would be more cost-effective, less polluting, more efficient, and more sustainable. Among different sources of renewable energy, bioenergy is one of the most prospective sources that could make a substantial contribution to meet global energy demand. Biofuels, as an important source of bioenergy, has attracted considerable attention in recent years for replacing fossil fuels in the transport sector due to numerous merits such as the possibility of production almost anywhere in the world as well as environmentally friendly potential and lower negative impacts on the ecosystem. Investment in the bioenergy industry has been encouraged in many countries around the world by setting national biofuel goals and mandates, with the purpose of replacing specific proportions of non-renewable sources with renewable ones according to a predefined time schedule. For example, the European Council established a binding EU-wide target to source at least 32% of their final energy consumption from renewables by 2030, including a possible upward revision in 2023. However, there are a variety of barriers and uncertainties preventing the large-scale and cost-competitive production of biofuels, and therefore commercialization of the biofuel industry. The main purpose of this book is to produce a complete framework to address the commercialization aspect of biomass to biofuel projects by offering supply chain design and planning models that provide a structure to achieve successful commercialization.

Biomass-to-biofuel supply chains are exposed to a wide range of uncertainties and risks arising from issues such as technology evolution, changing policies and regulations, demand and price variability, unpredictable weather conditions, production cost variations, as well as man-made and natural disasters. Failure to hedge against all such uncertainties may result in suboptimal or even infeasible supply chain decisions. To ensure the large-scale and sustainable production, it is of extreme importance to develop an efficient supply chain that would be reliable enough to function well under dynamic and uncertain business environments for many years. In order to address this problem, this book aims to propose a general framework for biomass-to-biofuel supply chain design and optimization under uncertainty,

which can be successfully used for the commercial-scale implementation of biofuel projects by taking into account the problems and challenges encountered in real supply chains. Thematically, the book focuses on the design and optimization of biomass-to-biofuel supply chains with particular emphasis on quantitative methods developed to solve biofuel supply chain problems under uncertainty.

Therefore, the readers of this book may be classified into at least two groups: (1) researchers and students, who can utilize an extensive overview of emerging research challenges and opportunities which is provided by the book in design and analysis of biomass-to-biofuel supply chains, and (2) practitioners and policymakers, who need a flexible platform for commercial-scale implementation; this group can utilize the general framework for biomass-to-biofuel supply chain optimization proposed in this book that incorporates promising biomass sources, different biofuel options, and major production pathways, which can be readily employed for national-level case studies in a large geographical area. The book can also be used as an excellent textbook for coursework or as a self-study and reference guide on two main topics, involving the design and planning of biomass supply chains, as well as optimization approaches to deal with uncertainty in input data of mathematical models. This book comprises two main parts. The first part (Chapters 1–5) sets out to describe key issues related to biofuel supply chains that is organized as follows:

Chapter 1 provides a comprehensive review of biomass feedstocks currently used in the biofuel industry or being investigated as potential sources under three headlines: first, second, and third-generation biomass. The advantages and disadvantages of three generations of biofuels, along with their challenges and opportunities for commercial-scale biofuel production, are also discussed.

Chapter 2 presents a general structure of the biomass supply chain and describes specific activities and operations of the chain corresponding to biomass production, harvesting, collection, storage, preprocessing, conversion, transportation, and distributions. Moreover, a comprehensive overview of biomass conversion pathways from a variety of biomass sources into biofuels and bioenergy products is provided, along with a description of different technologies of biomass conversion.

Chapter 3 proposes a decision-making framework for biomass-to-biofuel supply chains, which categorizes strategic, tactical, and operational level decisions that are made in different stages of the supply chain, including biomass supply and pre-processing, biofuel production, biofuel blending and

distribution, and biofuel sales. At the end, this chapter reviews the literature of Biofuel supply chain design and planning problems according to the proposed planning framework.

Chapter 4 proposes a novel risk management framework for biomass-to-biofuel supply chains. In order to ensure that the supply chain model is effective and practical for real-world applications, it must provide an adequate safeguard against uncertainty, and therefore, there is a need to develop a comprehensive risk management framework for supply chain optimization models under uncertainty. To achieve this, the developed framework deals with risks and uncertainties threatening the supply chain in three stages: risk identification, risk assessment, and risk treatment.

Chapter 5 focuses on three dimensions of the sustainability paradigm, namely, economic, environmental, and social sustainability in biomass supply chains. First, it reviews different paradigms that have been proposed in the supply chain management literature, and discusses the economic aspect of sustainability in biofuel supply chains. Then, the four-phase life-cycle assessment (LCA) methodology for sustainability analysis of biofuel supply chains, and characteristics of various life cycle impact assessment methods are described in detail. The chapter ends with the description of ISO 26000:2010, as well as a brief review of social impact assessment credible methods and guidelines.

The second part of the book (Chapters 6–9) focuses on the modeling and optimization of the biomass-to-biofuel supply chain under uncertainty using different quantitative methods in order to determine the optimal design and decisions of the supply chain considering the concepts, problems, and issues described in the first part. The second part is organized as follows:

Chapter 6 provides a comprehensive overview of leading optimization approaches for hedging against various types of uncertainty in the biomass supply chain design and planning models, along with a detailed description of mathematical formulations of the uncertainty modeling approaches. Finally, it classifies and reviews the literature of biofuel supply chain studies according to the source of uncertainty, uncertainty modeling approach, the biomass type, and case study region.

Chapter 7 discusses strategic uncertainties that must be considered at the design phase of biofuel supply chains. In view of the fact that the supply chain design and strategic-level decisions are difficult to change in the short term, this chapter introduces optimization approaches to immunize the supply chain design against these risks. To this aim, a two-stage model is

described to show how biofuel supply chains are designed under uncertainty. At the end of the chapter, a case study of the switchgrass-to-bioethanol supply chain is illustrated to exhibit the applicability of the model.

Chapter 8 concentrates on tactical decisions that are made at different stages of biomass-to-biofuel supply chains, and discusses tactical/operational uncertainties in the supply chains. First, to illustrate how to provide an optimal planning model for biofuel supply chains, a multi-period mixed-integer linear programming model (MILP) is presented to address the master planning of Jatropha curcas L. (JCL)-to-biodiesel supply chain under uncertainty. Then, to address the biorefinery process synthesis and design problem, a biorefinery superstructure model for biodiesel production from microalgae is proposed, taking into account uncertainty in technical factors.

This book ends with Chapter 9, which presents the operational decisions that are made at different stages of biomass-to-biofuel supply chains over a short-term, and discusses the most recognized types of uncertainties affecting the operational decisions. Second, in order to address the harvest-scheduling problem, a short-term corn stover harvest-planning model is presented in this chapter, which determines the number of required bailers and assigns the optimal sequence of fields to each baler within its allowable time window. Finally, to cope with the uncertainty in the selling price of stover, a data-driven robust optimization is adopted.

We would appreciate and welcome constructive criticism and feedback from the readers together with suggestions for further improvement of the book for the next edition.

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