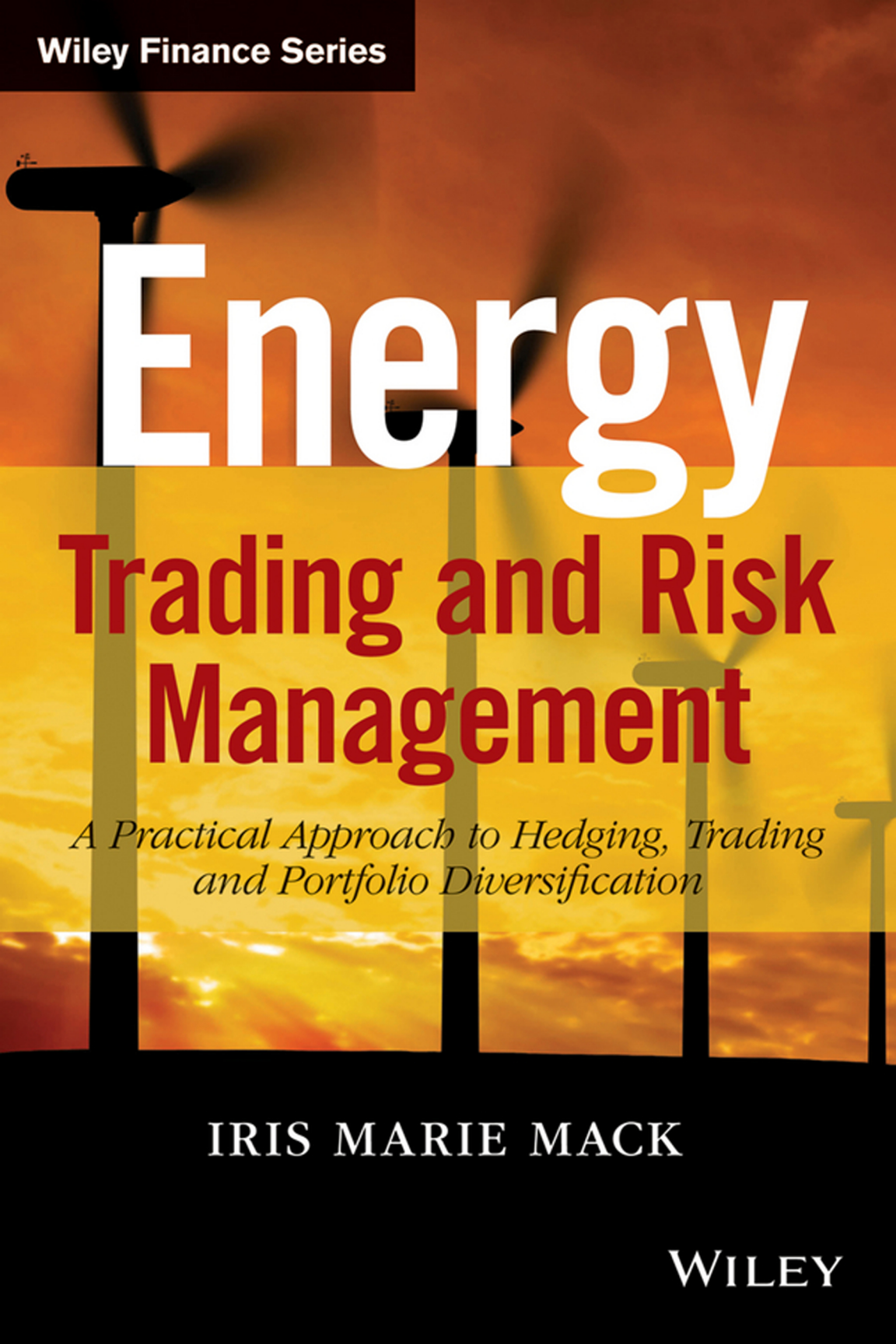

Wiley Finance Series
Energy
Trading and Risk Management
A Practical Approach to Hedging, Trading and Portfolio Diversification
IRIS MARIE MACK
WILEY

Energy Trading and Risk Management

Founded in 1807, John Wiley & Sons is the oldest independent publishing company in the United States. With offices in North America, Europe, Australia and Asia, Wiley is globally committed to developing and marketing print and electronic products and services for our customers' professional and personal knowledge and understanding.

The Wiley Finance series contains books written specifically for finance and investment professionals as well as sophisticated individual investors and their financial advisors. Book topics range from portfolio management to e-commerce, risk management, financial engineering, valuation and financial instrument analysis, as well as much more.

For a list of available titles, visit our Web site at www.WileyFinance.com.

Energy Trading and Risk Management

A Practical Approach to Hedging, Trading, and Portfolio Diversification

IRIS MACK

WILEY

Cover Design: Wiley
Cover Image: ©iStockphoto.com/Estate of Stephen Laurence Strathdee

Published by John Wiley & Sons Singapore Pte. Ltd.
1 Fusionopolis Walk, #07-01, Solaris South Tower, Singapore 138628

Other Wiley Editorial Offices
John Wiley & Sons, 111 River Street, Hoboken, NJ 07030, USA
John Wiley & Sons, The Atrium, Southern Gate, Chichester, West Sussex, P019 8SQ, United Kingdom
John Wiley & Sons (Canada) Ltd., 5353 Dundas Street West, Suite 400, Toronto, Ontario, M9B 6HB, Canada
John Wiley & Sons Australia Ltd., 42 McDougall Street, Milton, Queensland 4064, Australia
Wiley-VCH, Boschstrasse 12, D-69469 Weinheim, Germany

ISBN 978-1-118-33933-6 (Hardcover)
ISBN 978-1-118-33936-7 (ePDF)
ISBN 978-1-118-33934-3 (ePub)

Typeset in 10/12 pt, Sabon LT Std by Aptara

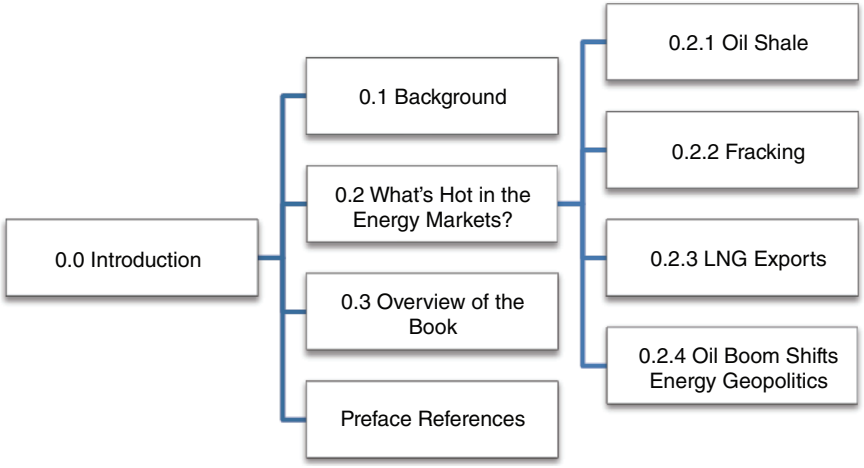
Printed in Singapore by C.O.S. Printers Pte Ltd

10 9 8 7 6 5 4 3 2 1

In loving memory of my parents:
Dorothy Mack Watson (mom)
U.S. Army Veteran Willie Mack, Jr. (dad)
Fred Watson Sr. (stepdad)

Contents

Preface



The Preface presents a preview of what the reader will find if he or she keeps turning the pages of this book. More specifically, I discuss why the book was written and some of the current hot topics in the energy markets. I also give an overview of how this book is organized.

0.1 BACKGROUND

I grew up in New Orleans, which is in a state with a fairly sizable energy industry. Although Louisiana's energy industry suffered because of Hurricane Katrina and the BP oil spill, it is still thriving. For example, the existence of oil shale in the Gulf of Mexico and advances in fracking technology have opened new possibilities for Louisiana's energy industry. Hopefully this book will be useful to energy market participants in my home state as they still attempt to recover from the devastation of Hurricane Katrina and the BP oil spill (EIA 2012; Good 2011).

For a substantial part of my academic studies and professional life, I have been involved in energy-related work.

- The mathematics and computer models developed in my Harvard doctoral thesis are utilized to study the transient stability analysis of electrical power systems (Mack 1986).
- I conducted some of my Harvard doctoral thesis research at Sandia National Laboratories. Lockheed Martin manages Sandia for the U.S. Department of Energy's National Nuclear Security Administration.
- My London Business School MBA thesis included applications to electricity and weather derivatives (Mack 1999).
- As a university faculty member, I worked on a consulting/research contract for Lockheed Martin Energy Systems.
- For a couple of years, I worked on real options applications to valuation of aircraft investments and fuel cost hedging when I was a faculty member of the MIT Sloan School, a Boeing Welliver Fellow, and a Boeing faculty researcher (Mack 2011a), (Mack 2011b).
- Some of my work at financial institutions in the United States, London, and Asia involved the structuring and trading of energy and commodities derivatives. This included a stint as a power options trader at Enron.
- I currently consult, advise, and/or lecture on energy and commodities derivatives in the United States, United Kingdom, and Asia for
  - Fitch 7City Certificate in Quantitative Finance Programme (http://cqf.com/lecturers?page=2)
  - Fitch 7City Corporate and Finance Consulting Division (www.fitchlearning.com/uk/corporate-and-finance-division)
  - AlgoAnalytics Trading and Financial Analytics (http://algoanalytics.com)
  - Market Express Financial News and Research (http://www.marketexpress.in)
  - Terrapinn Group Singapore (www.terrapinntraining.com/our-faculty/dr.%20iris%20mack)

0.2 WHAT'S HOT IN THE ENERGY MARKETS?

Energy producers are confronted with a host of challenges in trying to provide safe and affordable energy sources to consumers. Technological breakthroughs coupled with a thirst for the next major energy find are unlocking the door to potentially "hot" energy sources all across the globe. In this section we discuss the following hot topics in the energy markets:

- Discovery of new oil shale sources
- Advances in fracking technology

- Liquefied natural gas (LNG) exports
- Oil boom shifting global energy geopolitics

0.2.1 Shale

Natural gas and crude oil are important primary fossil fuels. The common use of petroleum is often restricted to the liquid oil form, that is, crude oil. Crude oil is a complex mixture of hydrocarbons derived from the geologic transformation and decomposition of plants and animals that lived hundreds of millions of years ago.

Shale oil is an alternative to conventional crude oil. Shale (shown in Figure P.1) is a dark fine-grained laminated sedimentary rock formed by compression of successive layers of clay-rich sediment. Oil shale is a fine-grained shale containing oil. When heated, oil shale yields petroleum or natural gas. Figure P.2 shows a schematic overview of why shale may be an interesting source of energy in the U.S. market.

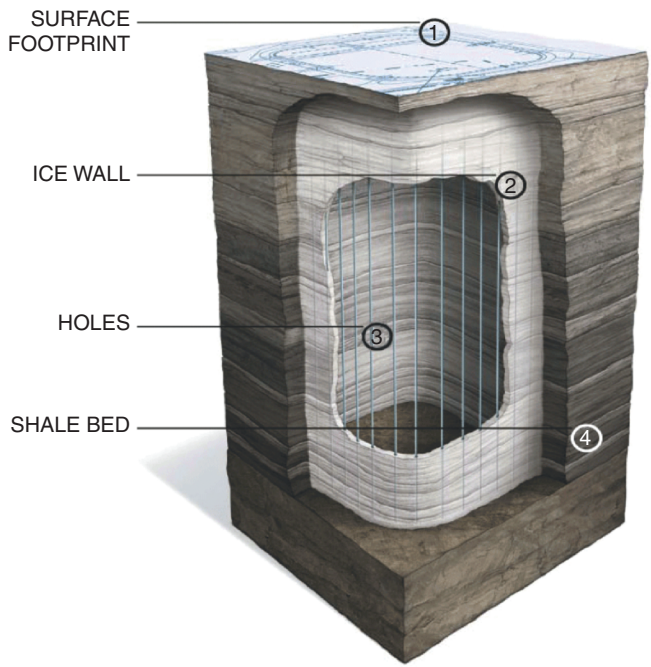


FIGURE P.1 Shale
Source: U.S. Bureau of Land Management.

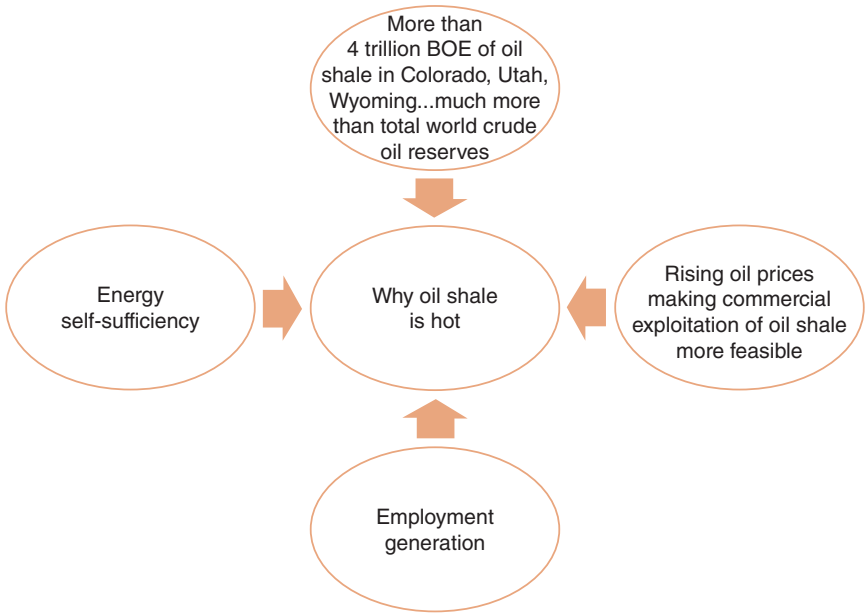


FIGURE P.2 U.S. Shale Oil Resources
Note: Barrel of oil equivalent (BOE) is a unit of energy based on the approximate energy released by burning one barrel (42 U.S. gallons) of crude oil.

SHALE OIL

Shale oil is an alternative to conventional crude oil. Shale is a dark fine-grained laminated sedimentary rock formed by compression of successive layers of clay-rich sediment.

0.2.2 Fracking

Hydraulic fracturing ("fracking"), illustrated in Figure P.3, involves the use of a high-pressure blend of chemicals, water, and sand injected into gas-bearing rock formations deep underground to free trapped gas and bring it to the surface. Critics of fracking argue that this extraction process can pollute the air and ground water. Conversely, proponents of fracking maintain that it is safe when performed properly (Drajem 2013; Edwards 2013; Fox 2010; McElroy and Lu 2013; Nearing 2012).

HYDRAULIC FRACTURING (FRACKING)

Hydraulic fracturing (“fracking”) involves the use of a high-pressure blend of chemicals, water, and sand injected into gas-bearing rock formations deep underground to free trapped gas and bring it to the surface.

Some of the forecasted benefits of shale exploration are as follows (MarketWatch 2013):

- The United States is projected to become the largest producer of oil by 2020.
- By 2030 the United States is projected to become a net exporter of oil.
- It is projected that by 2035, the United States should be fairly self-sufficient in energy.
- The prospects of many U.S. energy companies should greatly improve.

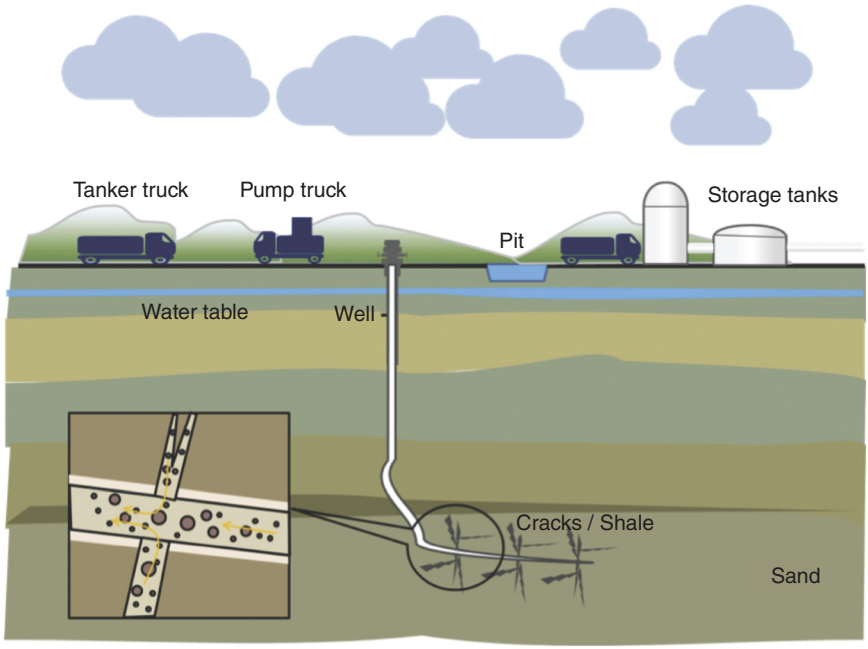


FIGURE P.3 Fracking

0.2.3 Liquefied Natural Gas Exports

Liquefied natural gas (LNG) is natural gas that has been cooled to approximately –256 degrees Fahrenheit so that it can be transported from regions with a surplus of natural gas to those with a deficit. In its liquefied state, natural gas takes up 1/600th of the space of uncooled gas. Figure P.4 shows the complete LNG production process. LNG is much easier to ship and store when pipeline transport is not feasible. As world energy consumption increases, experts anticipate that the LNG trade will grow in importance.

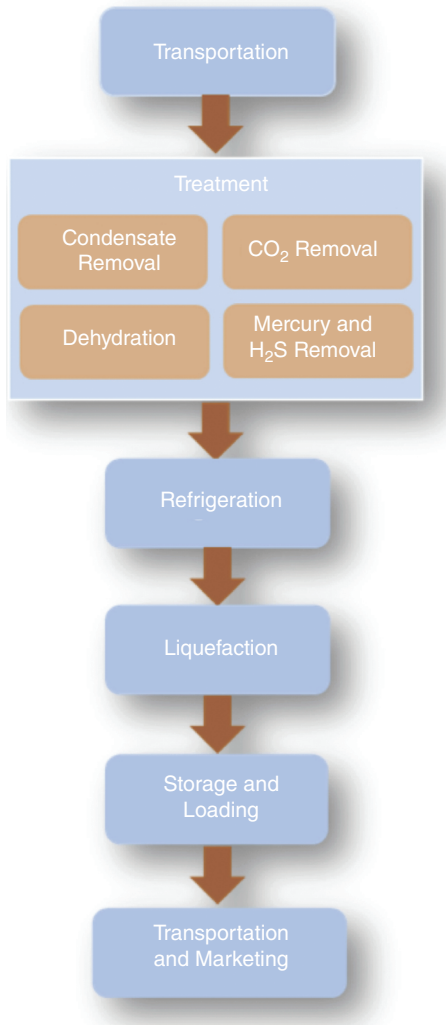


FIGURE P.4 Liquefied Natural Gas (LNG) Production Process

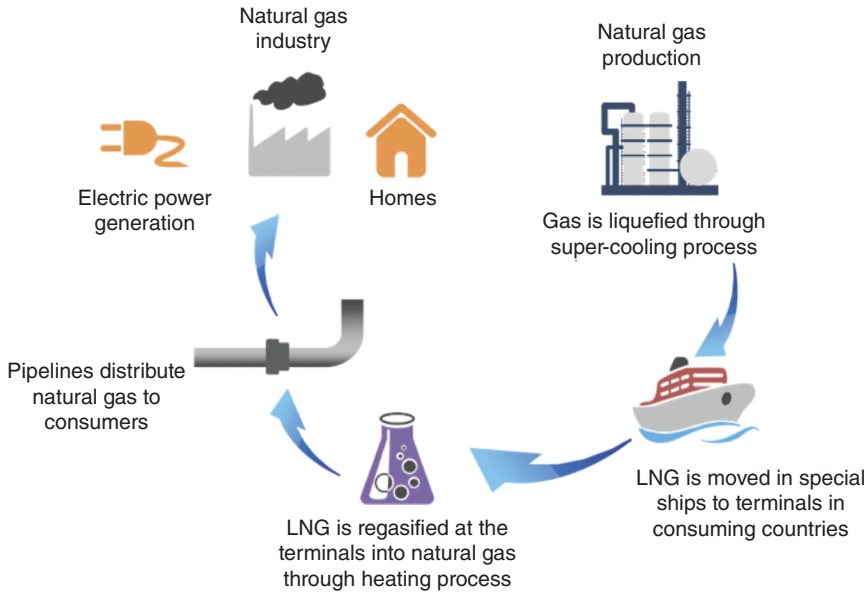


FIGURE P.5 How Liquefied Natural Gas (LNG) Reaches Gas Customers

Shale development has led to an increase in the U.S. domestic natural gas production. There are more than 110 LNG facilities operating in the United States. Depending on location and use, an LNG facility may be regulated by various federal and state agencies. U.S. producers are making moves to export LNG due to an oversupply in the U.S. natural gas markets and because the global demand for LNG is increasing. In Figure P.5 we illustrate how LNG reaches gas customers (FERC 2013).

LIQUEFIED NATURAL GAS (LNG)

Liquefied natural gas (LNG) is natural gas that has been cooled to approximately –256 degrees Fahrenheit so that it can be transported from regions with a surplus of natural gas to those with a deficit.

LNG facilities may provide one or more of the following services:

- Export natural gas.
- Provide natural gas supply to the interstate pipeline system.
- Provide natural gas to local distribution companies.

- Store natural gas for periods of peak demand.
- Produce LNG for vehicle fuel or for industrial use.

0.2.4 Oil Boom Shifts Energy Geopolitics

> *We have a revolution here. This is the equivalent of a Category 5 hurricane.*
>
> Larry Goldstein, Director of the
> Energy Policy Research Foundation

Large quantities of oil and gas have been discovered in the Americas—from Canada, to the United States, to Colombia, to Brazil. Most of these newly discovered energy resources are embedded in shale rock. This energy boom is shifting global energy geopolitics, potentially resulting in energy independence for various countries in the Americas (Forero 2012).

In 2005 the United States imported 60 percent of its liquid fuels. Later in 2011, the U.S. liquid fuels imports declined to 45 percent. This downward trend was due in part to:

- The economic downturn in the United States
- Improvements in automobile efficiency
- Reliance on biofuels
- Fracking

0.3 OVERVIEW OF THE BOOK

An ***energy derivative*** is a derivatives contract based on (derived from) an underlying asset such as crude oil, natural gas, electricity, and so forth. Some energy derivatives are traded on an exchange. There are also over-the-counter (privately negotiated) energy derivatives such as forwards or swap agreements. The value of an energy derivative will vary based on the changes in the price of the underlying energy product. In this book I present three ways energy derivatives are utilized by energy market participants (see Figure P.6).

ENERGY DERIVATIVE

An ***energy derivative*** is a derivatives contract based on (derived from) an underlying asset such as crude oil, natural gas, electricity, and so forth.

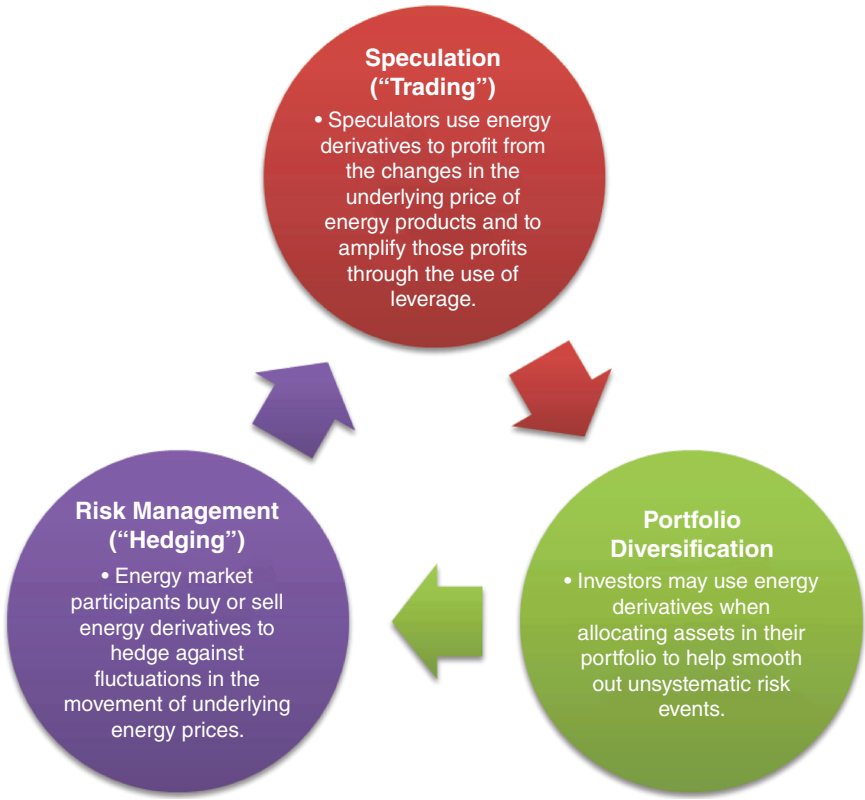


FIGURE P.6 Applications of Energy Derivatives

Some of the key features of this book are the numerous examples, industrial case studies, and illustrations of various theoretical concepts from the energy markets. This book should make for a handy resource manual for energy market participants, Wall Street and hedge fund traders, consultants, academic researchers, regulators, and students interested in careers in energy trading and risk management.

The structure of the chapters of this book is as follows:

Chapter 1: Energy Markets Fundamentals—physical forward, futures, spot, intraday, balancing and reserve markets; congestion and transmission rights

Chapter 2: Quant Models in the Energy Markets—stochastic models for estimating electricity spot and forward prices

Chapter 3: Plain Vanilla Energy Derivatives—global commodity exchanges, stochastic pricing models for vanilla derivatives, their roles and limitations in the energy markets

Chapter 4: Exotic Energy Derivatives—stochastic pricing models for exotic derivatives, their roles and limitations in the energy markets

Chapter 5: Risk Management and Hedging Strategies—hedging strategies for the energy markets, risk management, the "Greeks," quant models utilized to manage energy risk

Chapter 6: Illustrations of Hedging with Energy Derivatives—examples and case studies of how energy market participants can use energy derivatives to protect against large price fluctuations

Chapter 7: Speculation—key trading terminology, fundamental and technical analysis; speculation in the oil, natural gas, and electricity markets

Chapter 8: Energy Portfolios—modern portfolio theory (MPT), energy portfolio management (EPM), portfolio optimization, economic load dispatch case study

Chapter 9: Hedging Non-Linear Pay-Offs Using Options—a wind energy case study designed and coauthored by Dario Raffaele

Chapter 10: Case Study: Hydropower Generation and Behavioral Finance in the U.S. Pacific Northwest—a hydroelectric case study designed and coauthored by Bill Dickens

Back-of-book content—a compilation of all the references listed at the end of each chapter

It is our hope that our readers utilize this book as a resource to help grapple with the very interesting and oftentimes complex issues that arise in energy trading and risk management. Please note that it was my goal to include a chapter on energy regulations in this edition of my book. However, due to the current political gridlock in Washington, D.C., over the implementation of the Dodd-Frank Wall Street Reform and Consumer Protection Act, many regulatory issues are currently in flux. As a result, most of the research I conducted on the regulations chapter was basically obsolete by the time this book went to press (CFTC 2010).

REFERENCES

Drajem, Mark. 2013. "Methane in Water Seen Sixfold Higher Near Fracking Sites." Bloomberg. www.bloomberg.com/news/2013-06-24/methane-in-water-seen-sixfold-higher-near-fracking-sites.html.

Edwards, Lin. 2013. "Fracking Risks to Ground Water Assessed." PHYS.org. http://phys.org/news/2013-05-fracking-ground.html.

Federal Energy Regulatory Commission (FERC). 2013 (June). "Industries: LNG." http://ferc.gov/industries/gas/indus-act/lng.asp.

Forero, Juan. 2012. "Oil Boom in the Americas Shifts Energy Geopolitics." Global Association of Risk Professionals. www.garp.org/risk-news-and-resources/risk-headlines/story.aspx?newsid=47220.

GasLand. Directed by Josh Fox. http://www.amazon.com/GasLand-Josh-Fox/dp/B005C0DHEY/ref=sr_1_1?ie=UTF8&qid=1393640152&sr=8-1&keywords=gasland.

Good, Allison. 2011."New Possibilities Are Opening for Louisiana's Energy Industry." *The Times Picayune* www.nola.com/business/index.ssf/2011/08/new_possibilities_are_opening.html.

Mack, Iris, and Harrison Rowe. 1981. "Coupled Modes with Random Propagation Constants." Radio *Science Journal*, 16(4), 485-493, July-August 1981.

Mack, Iris. 1986. "Block Implicit One-Step Methods for Solving Smooth and Discontinuous Systems of Differential/Algebraic Equations: Applications to Transient Stability of Electrical Power Systems." PhD diss., Harvard University Press.

———. 1999. "Day-Ahead Lunch-Time Electricity Demand Forecasting: Applications to Electricity and Weather Derivatives." Master's Thesis, London Business School.

Mack, Iris, and Sloan School of Management. 2011a. "Generalized Picard-Lindelf theory." (White paper). Available at http://amzn.to/1fbHxEX.

Mack, Iris, and Sloan School of Management. 2011b. "Convergence analysis of block implicit one-step methods for solving differential/algebraic equation." (White paper). Available at http://amzn.to/1igEnaF.

MarketWatch. 2013. "Potential Hidden Opportunities in the Fracking Industry." *Wall Street Journal*. www.marketwatch.com/story/potential-hidden-opportunities-in-the-fracking-industry-2013-02-05.

McElroy, Michael, and Xi Lu. 2013. "Fracking's Future." *Harvard Magazine*. http://harvardmagazine.com/2013/01/frackings-future#article-images.

Nearing, Brian. 2012. "Report Finds Little Drilling Damage." *GARP*. www.garp.org/risk-news-and-resources/risk-headlines/story.aspx?newsid=46723.

U.S. Commodity Futures Trading Commission (CFTC). 2010. "Dodd-Frank Wall Street Reform and Consumer Protection Act." U.S. Congress, H.R. 4172. www.cftc.gov/ucm/groups/public/@swaps/documents/file/hr4173_enrolledbill.pdf.

U.S. Energy Information Administration (EIA). 2012. "Louisiana: Profile Overview." www.eia.gov/state/?sid=la.

Acknowledgments

I wish to thank John Wiley Global Finance Publishers in Singapore for giving me the wonderful opportunity to write this book. Thank you to my publisher Nick Wallwork and to my editors Emilie Herman and Gemma Diaz.

Mr. Dario Raffaele and Mr. Bill Dickens helped to make this book attractive to practitioners by collaborating to design and develop wind and hydropower case studies, respectively. These case studies can be found in the last two chapters of this book.

I wish to thank Suresh Pabbisetty—a former student in the *Certificate in Quantitative Finance* program and an *ERCOT* energy regulator—for his keen proofreading and industry feedback. In addition, I wish to thank the following individuals for their contributions to this book project: Vynogradov Dmytro V. of the *National Academy of Sciences of Ukraine*; Ezilarsan PKP, Founder of *Market Express Financial News and Research*; and Mohammad Asif of *JaZaa Financial Services*.

About the Author

Iris Mack, PhD, EMBA earned a Harvard doctorate in Applied Mathematics and a London Business School Sloan Fellow MBA. She is a former MIT professor. Dr. Mack is also a former Derivatives Quant/Trader who has worked in financial institutions in the U.S., London, and Asia. In addition, Dr. Mack has also spent some of her professional career at NASA, Boeing, and AT&T Bell Laboratories—where she obtained a patent for research on optical fibers (Mack, 1981).

Dr. Mack lectures and consults on Energy Derivatives, Quantitative Finance and High Frequency Trading for

1. *Fitch 7City Certificate of Quantitative Finance Program* in NYC
2. *Fitch 7City Corporate Finance Consulting Group* in Singapore
3. *The Terrapinn Group* in Singapore, Hong Kong, Indonesia, and London

In addition, Dr. Mack serves on various boards:

- *National Academy of Sciences Transportation Research Board*
- *The Edwin Moses Global Institute*
- *AlgoAnalytics Trading and Financial Analytics* (India)
- *MarketExpress Financial News and Research* (India)

Dr. Mack founded Phat Math Inc. and The Global Energy Post in Miami, Florida. In 2007 she and her colleagues at Phat Math launched their prototype mathematics edutainment social network PhatMath.com. Students in grades K-12 and college have access to free 24/7 online math homework help on PhatMath.com—named one of the Top 50 Social Sites for Educators and Academics and 25 Useful Networking Sites for Grad Students.

Dr. Mack has been an astronaut semifinalist, one of *Glamour* magazine's "Top 10" college students, one of *Glamour's* "Top 10" working women, an investment banker, an Enron Energy Trader, and an MIT professor. In addition, she was the second African-American female to earn a doctorate in Applied Mathematics from Harvard. Later she became a mathematics and business school professor, while simultaneously running a consulting firm.