Future Energy: Opportunities and Challenges

Originally published 2013 by the International Society of Automation (ISA)

Future Energy:
Opportunities and Challenges

Thomas W. Kerlin

FUTURE ENERGY:
OPPORTUNITIES AND CHALLENGES

Thomas W. Kerlin

Everyone is entitled to his own opinion, but not his own facts.

Attributed both to former Senator Patrick D. Moynihan and to former Secretary of Defense James R. Schlesinger

…to live on the earth's energy income rather than its energy capital.

Isaac Asimov

It is quite evident, though, that this squandering cannot go on indefinitely, for geological investigations prove our fuel stores to be limited. So great has been the drain on them of late years that the specter of exhaustion is looming up threateningly in the distance...

Nikolai Tesla (1931)

FUTURE ENERGY:
OPPORTUNITIES AND CHALLENGES

Thomas W. Kerlin

Notice

The information presented in this publication is for the general education of the reader. Because neither the author nor the publisher has any control over the use of the information by the reader, both the author and the publisher disclaim any and all liability of any kind arising out of such use. The reader is expected to exercise sound professional judgment in using any of the information presented in a particular application.

Additionally, neither the author nor the publisher has investigated or considered the effect of any patents on the ability of the reader to use any of the information in a particular application. The reader is responsible for reviewing any possible patents that may affect any particular use of the information presented.

Any references to commercial products in the work are cited as examples only. Neither the author nor the publisher endorses any referenced commercial product. Any trademarks or tradenames referenced belong to the respective owner of the mark or name. Neither the author nor the publisher makes any representation regarding the availability of any referenced commercial product at any time. The manufacturer's instructions on use of any commercial product must be followed at all times, even if in conflict with the information in this publication.

Printed in the United States of America.
10 9 8 7 6 5 4 3 2

ISBN: 978-1-937560-28-7

ISA
67 Alexander Drive
P.O. Box 12277
Research Triangle Park, NC 27709

Library of Congress Cataloging-in-Publication Data in process.

Contents

APPENDICES

Acknowledgment

Thanks to Nancy for gracefully tolerating the time spent studying, learning, and writing.

Randy Gentry and David Brill of The Institute for a Secure and Sustainable Environment at The University of Tennessee provided essential encouragement and support.

Lorna Keathley prepared many of the illustrations. Her expert and professional work enhance the book.

Friends and colleagues reviewed various parts of the book. Special thanks to Gilles Zwingelstein, Ned Rosen, Tom Shannon, Lee Riedinger, Belle Upadhyaya, Larry Miller, Paul Stevens, Rafael Perez, Syd Ball, and Joe Perona.

About the Author

Tom Kerlin retired as head of the Nuclear Engineering Department at the University of Tennessee in 1998, after serving on the faculty for 33 years. His professional interests include instrumentation, nuclear reactor simulation, and dynamic testing for model validation. He has published extensively on these topics.

In addition to his university service, Dr. Kerlin founded a spin-off company, Analysis and Measurement Services Corp., to provide the nuclear industry with the testing capability that he invented for safety system sensors. Dr. Kerlin's method has been used hundreds of times in nuclear power plants in the U.S. and around the world.

Upon retiring, Dr. Kerlin studied the literature on energy production and use and concluded that there was a need for a comprehensive book on our future options that even non-specialists would understand. This book is the result.

2021 PREFACE & COMMENTARY

This is a free download of the book first published by The International Society of Automation in 2013. The content is identical to the original version except for a few corrections, mainly typographical.

Most of the book addresses the science and technology of energy production, transport and use, and that information is still as pertinent and valid as when it was written originally. It also addresses status and trends as they existed when the book was written, but the energy landscape evolves continuously.

The information presented is just a snapshot of conditions at one point in recent history. There have been some major changes in status and trends. Some examples are the increase in the size of oil and gas recoverable reserves and production rates because of hydrofracturing, the scale of renewable energy production, the growth of the electric vehicle market and the wide variations in the U.S. government policy on climate change.

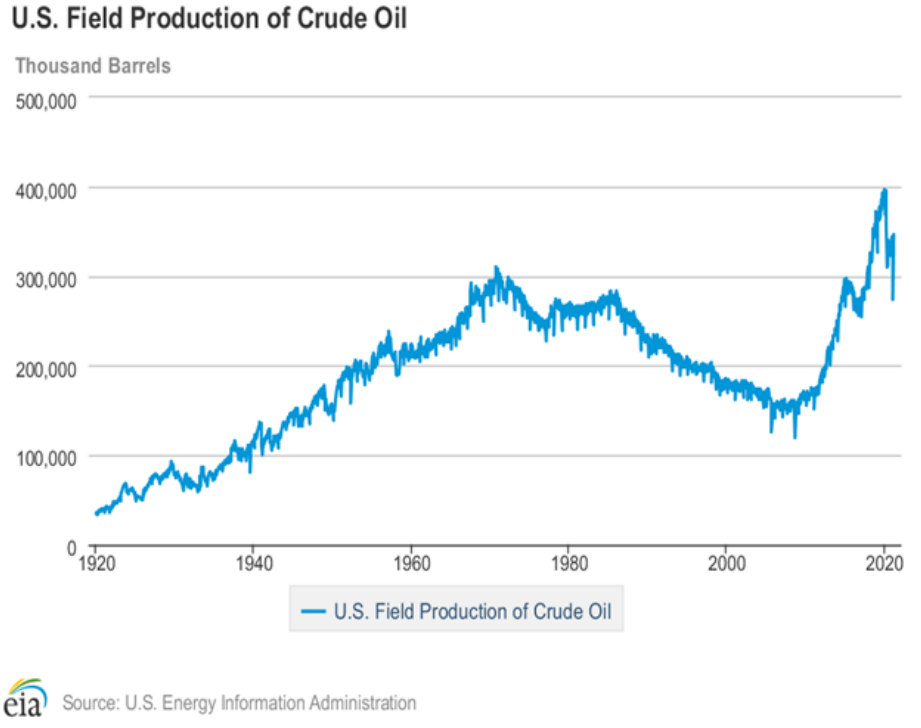
The commentary on the following pages provides brief discussions of these most important changes. Those interested obtaining more information on current status and trends can easily find it on the internet (See Section 2.12 for detailed information on useful web sites.).

The current version is still suitable for anyone interested in learning about our future energy opportunities and challenges. For use as a textbook in an energy-related course, the book can be used "as is" or can be modified by the instructor to better serve the course objectives.

COMMENTARY

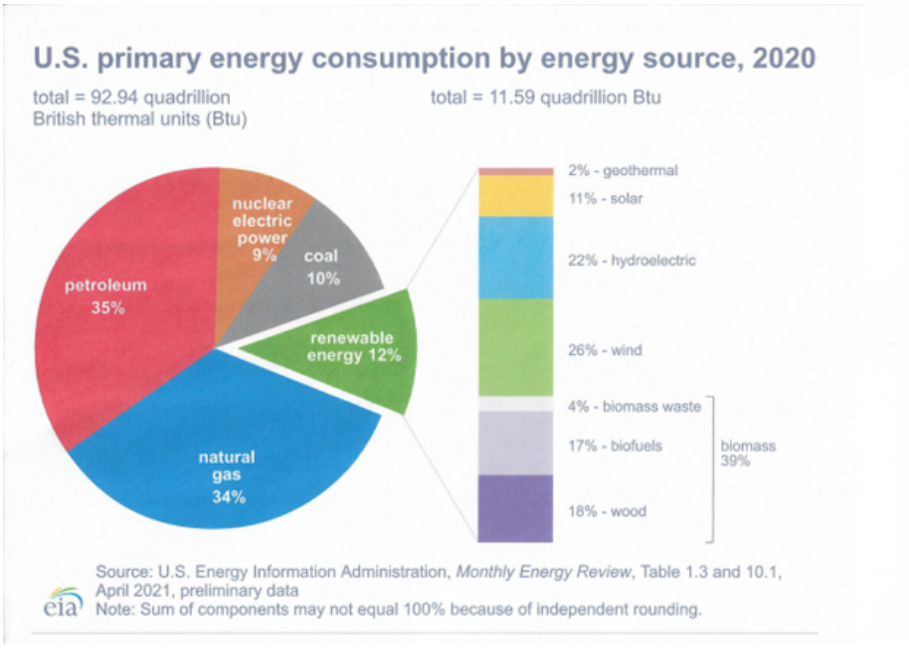
This commentary provides information on some of the most significant changes since the original publication of the book. It updates to June 2021.

Oil Production. U.S. oil production increased dramatically in the second decade of the twenty-first century. The reason was the implementation of hydrofracturing. The figure below is an update of the domestic production curve in Figure 3-5. It shows production through 2021 (in thousand barrels per year). For example, the first peak is around three million barrels per year (300,000*1000=3,000,000) and the second peak is around four million barrels per year.



Clearly, hydrofracturing changed the American oil enterprise tremendously, starting around 2010. But the covid-19 pandemic struck in 2020 and caused a sharp decrease in travel and the need for fuel. The trajectory after 2021 will depend on the two factors: the recovery from the pandemic and a possible major shift to electric vehicles and conservation efforts.

Renewables. Renewable energy production increased significantly in the second decade of the twenty-first century, reaching 12 per cent of total energy consumption (surpassing coal). The contribution of each renewable energy source is shown below.



The growth of renewables, especially wind and solar, is expected to continue.

Electric Vehicles. After entering commercial markets, electric vehicle sales have soared. The glocal on-road number grew from 17,000 in 2010 to 7.2 million in 2019 with China having the greatest number. Many companies are producing or planning to produce electric vehicles. This includes traditional auto manufacturers (like Ford, General Motors and Chrysler) and new companies (like Tesla, the first and largest new U.S. auto company). These companies are working on improvements to increase range, reduce recharge time, reduce cost, increase battery life, reduce battery weight and improve safety. The biggest issue is range, now around 300 miles for most cars. Electric cars could be made more suitable for long trips by increasing battery energy or reducing recharge time (a recharge time of five minutes is a goal. It would make recharge time comparable to time to fuel a gasoline-powered

vehicle).

Climate Change. The Paris Climate Accord was formulated in 2015 by countries (including the U.S.) to limit greenhouse gas emissions in order to limit warming. President Trump (2016-2020) withdrew the U.S. in 2017, citing cost and job losses. President Biden rejoined shortly after his inauguration in 2021. The Biden administration strongly commits to reducing greenhouse emissions.

Reducing emissions costs money and different countries have different abilities to absorb the cost without facing major impacts on their economy. Generally, developed countries are better able to absorb these costs than developing countries. Paris Accord countries negotiate to strive for fair treatment of countries in their efforts to curb greenhouse gas emissions. This involves setting affordable goals and subsidizing poorer counties. Each country must weigh its own immediate priorities versus long-term global priorities. Consequently, negotiations are complex and difficult.

ORIGINAL PREFACE

A revolution in energy production and use is upon us. Huge changes are starting to rumble through our lives. We cannot avoid these changes, but we can manage them if we approach them in an informed way.

Our current dependence on fossil fuels for most of our energy must be reduced or eliminated because of resource depletion and the environmental effects of fossil fuel combustion.

This book offers no prescriptions for achieving a desirable energy future. Instead, it presents the scientific and technical information needed to evaluate our options for intelligent energy production and use.

Everyone uses energy, and many are appropriately concerned about future energy cost, availability, and environmental impact. Some are content to rely on what the "experts" tell them. Others want to know enough about how energy systems work to be able to make their own assessments. Serving this group is the focus of this book.

In order to understand energy production and use, it is necessary to build on a foundation of indisputable facts. This requires some consideration of basic science, but nothing beyond that science which is taught in high schools. Science tells us what is possible and, probably more importantly, what is impossible. Science also provides the framework for obtaining quantitative evaluations of possibilities in energy production and use. Without a basis in science, and without the use of scientific principles to generate numerical assessments, statements about energy production and use must be viewed as uninformed opinion rather than established fact.

It is expected that this book will be used in survey courses about energy in universities and colleges. The book also should serve interested citizens who want to learn about energy and energy professionals who want to learn about energy options outside their specialty. An effort was made to present the science and technology in a simple and intuitive way. When detailed

information was considered necessary for readers who wish to see the basis for assertions in the main text, more detailed discussions appear in appendices.

Exercises are provided for most of the chapters. These are intended primarily for use in college and university courses. Each exercise has one of three purposes: to provide experience in using some of the quantitative assessment methods, to send the reader to current literature to learn about the status of the rapidly changing energy enterprise, and to stimulate the reader to formulate opinions and provide the rationale for those opinions.