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978-0-521-68448-4 - Fueling Our Future: An Introduction to Sustainable Energy

Robert L. Evans

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Fueling Our Future: An Introduction to Sustainable Energy

One of the most important issues facing humanity today is the prospect of global climate change, brought about primarily by our prolific energy use and heavy dependence on fossil fuels.

Fueling Our Future: An Introduction to Sustainable Energy provides a concise overview of current energy demand and supply patterns. It then presents a balanced view of how our reliance on fossil fuels can be changed over time so that we move to a much more sustainable energy system in the near future.

Written in a non-technical and accessible style, the book will appeal to a wide range of readers both with and without scientific backgrounds.

ROBERT EVANS is Methanex Professor of Clean Energy Research and founding Director of the Clean Energy Research Center in the Faculty of Applied Science at the University of British Columbia, Vancouver. He was previously Head of the Department of Mechanical Engineering and Associate Dean of Applied Science at UBC. He is a Fellow of the Canadian Academy of Engineering, the UK Institution of Mechanical Engineers, and the US Society of Automotive Engineers. Prior to spending the last 25 years in academia he worked in the UK Central Electricity Research Laboratory, for the British Columbia Energy Commission, and the British Columbia Ministry of Energy, Mines and Petroleum Resources. He is the author or coauthor of over 140 publications, and holds four US patents.

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ROBERT L. EVANS

Director, Clean Energy

Research Center

The University of British

Columbia



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Preface

Energy use, and its impact on the environment, is one of the most important technical, social, and public-policy issues that face mankind today. There is a great deal of research, and many publications, which address these issues, some of which paint a very pessimistic picture for future generations, while others point to a bright future through the use of new technologies or the implementation of new policies. Although a lot of excellent work is being conducted, much of the research necessarily tends to be quite narrowly discipline-based. Solutions to the problems caused by current patterns of energy use therefore often appear to be somewhat piecemeal in nature, and it is difficult for decision-makers and energy consumers to see the “big picture” which is really needed to understand and design truly sustainable energy processes. This book takes a systems approach to energy use, so that the complete consequences of choosing a particular energy source, or energy conversion system, can be seen. The concept of the complete energy conversion chain, which is a simple but powerful tool for analyzing any energy consuming process, is introduced to link primary energy resources through to the ultimate end-use. Looking at the complete consequences of any proposed energy technology in this way enables the reader to see why some proposed solutions are more sustainable than others, and how the link between energy consumption and greenhouse gas emissions can be broken. This simple systems approach is essential to provide a global understanding of how we can begin the transition to a truly clean and sustainable energy future. The environmental consequences of energy consumption and current energy use patterns are then summarized, providing the necessary background needed to understand the extent and complexity of the problem. Subsequent chapters outline the current state-of-the-art in sustainable energy technology, including non-conventional fossil

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fuels, renewable energy sources, and nuclear power. The challenging problems of developing a more sustainable transportation energy system are addressed in some detail, with a particular focus on road vehicles. Finally, some projections are made about how a sustainable global energy balance might be achieved over the remainder of this century. It is hoped that this book will be a valuable and thought-provoking resource not only for energy practitioners and students, but also for decision-makers and the interested public at large.

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Acknowledgments

Few books such as this can be written without the author drawing freely on the ideas and thoughts resulting from discussions over many years with a wide range of colleagues, friends, and students. This one is no exception, and although there are far too many such individuals to name here, I would particularly like to thank my colleagues in the Department of Mechanical Engineering at the University of British Columbia for many stimulating discussions and debates. I would also like to thank the Master and Fellows of Pembroke College, Cambridge, who graciously granted me the privilege of being a visiting scholar during the 2004–2005 academic year, during which time most of this text was written. The editorial staff at Cambridge University Press were a delight to work with, and I am grateful to Dr. Matt Lloyd, Ms. Lindsay Barnes, Ms. Dawn Preston and Ms. Lesley Bennun for keeping me on track, and on time! My family, June, Kate, Jonathan, and Peter, were constant in their love and encouragement, without which I would never have been able to complete this task. And, finally, I dedicate this work to my granddaughter, May, who is the future.

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Glossary

Barrel:

Crude oil can be measured both in terms of mass (tonnes), or by volume (cubic meters, or barrels). One barrel (Bbl) is equivalent to 35 Imperial gallons, or 42 US gallons. One tonne of oil is equal to approximately 7.35 Bbls.

Efficiency:

The efficiency of any energy conversion system is defined as the ratio of the energy or work output of the system to the energy input to the system. “Thermal efficiency” is usually used to describe the performance of a “heat engine,” in which thermal or chemical energy is used to produce work.

Energy:

Energy can be defined as the “capacity to do work,” and many different units are used. Energy can be found in many different forms, including chemical energy, as contained in fossil fuels, and thermal energy which can be related to the work which can be done as a result of a temperature difference in a substance. Electrical energy is that form of energy in which a flow of electrons can be used to do work with an electric motor, or to provide heat from a resistor network.

The basic energy unit in the SI (Système International) system of units is the Joule (J), where 1 J equals the energy required to do 1 N-m (Newton-meter) of work. In the Imperial system of units, still used in many English-speaking countries (particularly the USA), the basic unit of work is the foot-pound (ft.-lb.), and the basic energy unit is the Btu (British thermal unit). The energy required to heat one pound of water by 1 degree Fahrenheit is 1 Btu. The “mechanical equivalent of heat” states that 778 ft.-lbs. of work is the equivalent of 1 Btu.

Conversion between the two systems of units can be facilitated by noting that 1 Btu is equivalent to 1055 J.

Since the Joule represents a very small quantity of energy, values are often quoted in terms of multiples of one thousand. For example:

1 kilojoule	1 kJ = 10 ³ J
1 Megajoule	1 MJ = 10 ⁶ J
1 Gigajoule	1 GJ = 10 ⁹ J
1 Terajoule	1 TJ = 10 ¹² J
1 Petajoule	1 PJ = 10 ¹⁵ J
1 Exajoule	1 EJ = 10 ¹⁸ J

In Imperial units, it is common to use “millions of Btus,” where:

1 MMBtu = 10⁶ Btu

Because fossil fuels, and in particular crude oil, represents such a large fraction of total energy use in industrialized countries, total energy use is also sometimes quoted in terms of “tonnes of oil equivalent,” or “toe.” In other words, all energy use is converted to the equivalent energy contained in a certain number of tonnes of crude oil. A useful conversion factor is:

1 toe = 41.87 GJ

For large quantities of energy use, multiples of one thousand are again used. For example:

1 Megatonne of oil equivalent	1 Mtoe = 10 ⁶ toe
1 Gigatonne of oil equivalent	1 Gtoe = 10 ⁹ toe

Electrical energy use is usually measured in terms of the electrical power operating for a given amount of time. For example, the basic unit of electrical energy used by electrical utilities is a power of one kW acting for one hour, or 1 kWh. Therefore:

1 kilowatt-hour	1 kWh = 10 ³ W for 1 hour
1 Megawatt-hour	1 MWh = 10 ⁶ W for 1 hour
1 Gigawatt-hour	1 GWh = 10 ⁹ W for 1 hour

Power:

Power is defined as the “rate of doing work,” or equivalently, the “rate of using energy.” The basic unit of power in the SI system of units is the Watt (W), defined as the power produced when 1 Joule is used for 1 second, or $1\text{ W} = 1\text{ J/s}$. Again, multiples of one thousand are used to measure larger power quantities. For example:

1 kilowatt	$1\text{ kW} = 10^3\text{ W}$
1 Megawatt	$1\text{ MW} = 10^6\text{ W}$
1 Gigawatt	$1\text{ GW} = 10^9\text{ W}$

Engineers who design and operate thermal power stations sometimes make the distinction between “electrical power,” using the suffix “e,” and thermal power, using the suffix “t.” For example, a large coal-fired power station may generate 2000 MWe of electrical power, while consuming coal at the rate of 6000 MWt, resulting in a “thermal efficiency” of 33.3%.

A more comprehensive list of energy unit conversions is provided in Appendix 1.