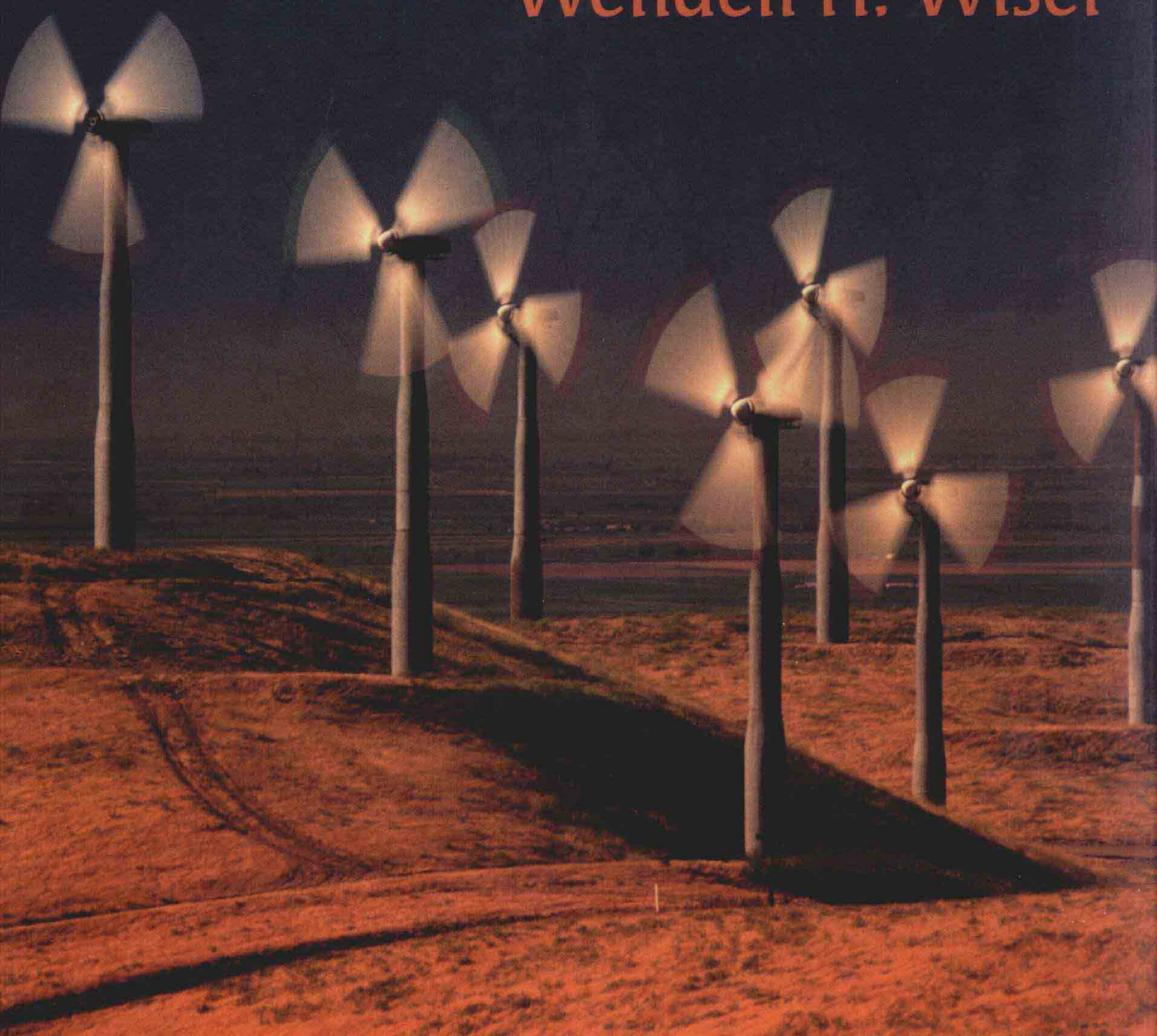


Energy Resources

Occurrence,
Production,
Conversion,
Use

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Energy Resources

*To my wife Barbara and our family:
Jerry and Susan, David, Greg, Diane, Sharon and Spencer,
and our grandchildren,
for all their help and encouragement.*

Preface

This book is directed primarily toward two types of readers. First, it is intended for use as a textbook for students in a liberal education course in science for non-science and non-engineering majors in college or university. The technical level of presentation assumes no background in chemistry or physics on the part of the reader, and no science prerequisites or prior preparation are of concern. At the same time, elementary equations of chemistry and physics are included, particularly in relation to interconversion of energy resources and utilization, for the benefit of the student with a more than passing interest in science who can learn much about these aspects of chemistry from equations presented in the book.

Second, and considered to be of major concern and importance, it is intended for use as a reference book for teachers of science in the high schools and junior high schools. Because of the importance of energy in the daily life of the average citizen, a need is usually felt by the teacher at those levels to discuss various aspects of energy in daily life. However, often a source containing valid information is not available to the teacher. In the absence of a valid text, the teacher often resorts to information found in the press—information that is rarely accurate. The information presented in this book is soundly based in science, and in most cases the data presented are up-to-date as of the date of this writing.

However, the book will also provide answers to questions in the mind of the casual reader with an interest in the subject of energy availability for the future. In addition, the more serious student of the subject of energy will find the data on worldwide reserves of petroleum and natural gas contained

in Chapters 2 and 3, information on the chemistry of conversion of coal to gaseous and liquid fuels contained in Chapter 5, and other technical presentations contained in the book, to be of value. Both groups of readers, with or without a background in science, will find the projections of the application of all energy resources to future energy needs, as contained in Chapter 17, to be of interest.

The technical level of the book has been established in relation to a liberal education course taught for more than ten years by the author at the University of Utah. The class is a science core course for non-science and non-engineering majors. Based upon the observation that there are many things that a student can learn and appreciate concerning the impact of energy in one's daily life, without the need to perform calculations concerning the same, the class evolved into a course which students can take and understand with no background in chemistry or physics, and with only a limited background in mathematics. Although certain amounts of elementary chemistry and physics are introduced for the student possessing both the interest and background to understand them, understanding those elements of science is not required to comprehend the balance of the book.

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Energy Concepts, Forms, Laws

INTRODUCTION

In a developed country, such as the United States, energy is a vital component in almost every phase of life. Consider the fuel consumed in modern transportation systems; in lighting and heating and air conditioning, at home and in the work place; the many appliances in the home which provide for the comforts of modern living; the operation of machinery and other equipment in the work place; and numerous other purposes. In the United States, more than 99 percent of work defined as mechanical work, which term includes essentially all physical labor, is performed by machines, all of which require energy for operation. Almost everything one does during the waking hours has energy involved in it somewhere.

The principal objectives of this text are:

- to introduce the reader to energy in a way that will lead to appreciation for what energy is, what it does for us, and how truly indispensable it is in our lives
- to identify for the reader the nature and magnitude of resources available for supplying energy for our needs
- to examine how we now obtain energy from those resources

- to identify the extent to which each resource is now utilized in providing for our energy needs
- to explore what we may need to do in the future to adapt a resource such that it can serve some of our needs.

Some energy resources do not fit very well into the type of society in which we live. For example, coal is present in very large quantities, but is dirty and inconvenient to use, compared with petroleum and natural gas. Solar energy is an inexhaustible resource, but presents engineering and economic challenges to making it available for extensive use. It may be desirable, even necessary, to convert a resource to a different form, such as solid coal to a liquid fuel, to make it more useful, such as for transportation fuels, and more environmentally acceptable.

We will discuss the various uses we now make of the different resources and consider possible adaptations of resources which are most plentiful, to uses now served primarily by resources that may soon be in short supply, such as petroleum. Finally, consideration will be given to probable consumption of energy from the various resources in the short term (up to 25 years) and in the long term (beyond 25 years).

BASIC ENERGY CONCEPTS

In order to achieve the objectives outlined above, we first must become acquainted with the language of energy. Some of these energy terms will be readily identified in the experience of the reader. Others will be new to the reader. Attention will be focused on those terms that either have application in the reader's experience today or are destined to have application at some time in the lifetime of the reader.

A logical place to begin is to define energy. A rather commonly accepted definition for energy in the fields of science and engineering is:

Energy: The capacity for doing work

We next need to define the term "work." In this setting we are discussing mechanical work, as used in the fields of physics and engineering. A force may be produced by the expending of energy. Indeed, the expending of energy in some form is required to produce a force. However, just the application of a force upon a body may not necessarily result in performance of work.

Work: The product of a force acting upon a body times the distance through which the force acts, or the distance through which the body moves

Now I will illustrate that definition. Some years ago when I was trying to landscape my yard I found a large rock, whose visible dimensions became larger as I dug down around it. I finally estimated that this rock would weigh about one and one-half tons. I set about to try to use my knowledge of physics to raise the rock to a level where I could then pull it with a pickup truck. I estimate that I labored on that rock for some four or five hours and was very tired at the end of that experience, but I had not moved the rock even a fraction of an inch. Notwithstanding all of the energy I had expended, I had not done any work. Work in our context is mechanical work, as defined above.

When we talk about energy, we must be able to talk about quantities, so we need to define a certain number of terms that enable us to express quantities of energy. Unfortunately, in the United States we have two systems of units, namely the British system (now also sometimes called the American system) and the metric system. Most of us have grown up on what we call the British system. That system is characterized by feet for distance, pounds for weight or mass, and so on. Most of the countries of the world use the metric system, which is characterized by centimeters or meters for distance, grams or kilograms for weight or mass, etc. In more recent years, in an attempt to standardize a system of units throughout the world, an adaptation of the metric system has arisen which is called the International System of Units, referred to by the term SI units. We will define energy terms first in the British system, then in the metric system. The SI system will not be discussed here.

In the British system, the unit for energy is the British Thermal Unit, abbreviated Btu. That is a very important term that will be used many, many times throughout this text. The Btu is defined as the quantity of energy required to raise the temperature of one pound of water by one degree Fahrenheit. If one wants to be very precise in defining that amount of energy, one must specify a particular temperature, because that quantity decreases as the temperature increases. However, for usual purposes, for water in a liquid state, it is sufficient simply to use the above definition without specifying a temperature.

In the metric system the standard unit is the calorie, which is defined as the quantity of energy required to raise the temperature of one gram of water by one degree Centigrade, or one degree Celsius. The Centigrade and Celsius scales are one and the same.

With the introduction of quantity labels in the food industry, it is useful to relate a couple of these terms: 454 grams = 1 pound and 252 calories = 1 Btu.

Because of the small size of the gram, it is common practice to use the term kilogram—the word kilo meaning a thousand—a kilogram being a thousand grams. Likewise, a kilocalorie is one thousand calories. We don't do that with the Btu or with the pound because they represent much larger quantities.

In talking about work we need to be able to calculate and express quantities of work done. As defined above, work (meaning mechanical work) is the product of a force acting upon a body times the distance through which the force acts or the distance the body actually moves. Therefore:

$$\text{work} = \text{force} \times \text{distance}$$

In the British system, the force unit is pounds of force, and the distance unit is the foot. Therefore:

$$\text{pounds of force} \times \text{feet} = \text{ft-lbs of work}$$

In the metric system, there are two force units commonly used: the dyne, when using centimeters as the distance variable, and the Newton when the distance unit is the meter. When these terms are multiplied together, the result is the dyne-centimeter or the newton-meter. In the British system the foot-pound is retained as the work unit, but in the metric system another name has been given to the more commonly used newton-meter, after a famous physicist, namely the joule:

$$\text{force in newtons} \times \text{distance in meters} = \text{work in joules}$$

Most countries of the world use the metric system of units. Use of the British system is found only in the United States and a few other English-speaking countries. It would appear to be convenient if all countries of the world used the same system. However, it has proven to be very difficult to make the transition in the United States from the British system to the metric system. The first step in such a transition is to educate people so that they can use metric units. This task is not too difficult, and today in the elementary and high schools in the United States, metric units are taught to varying degrees. A much more difficult task will be to convert the industrial and manufacturing industries to the metric system. Such a conversion will involve changing all of the instrumentation—meters, thermometers, everything that measures lengths, volumes, weights or temperatures—to the new system. Such a changeover would be extremely expensive. Consequently, today in the domestic, industrial or commercial sectors, one virtu-