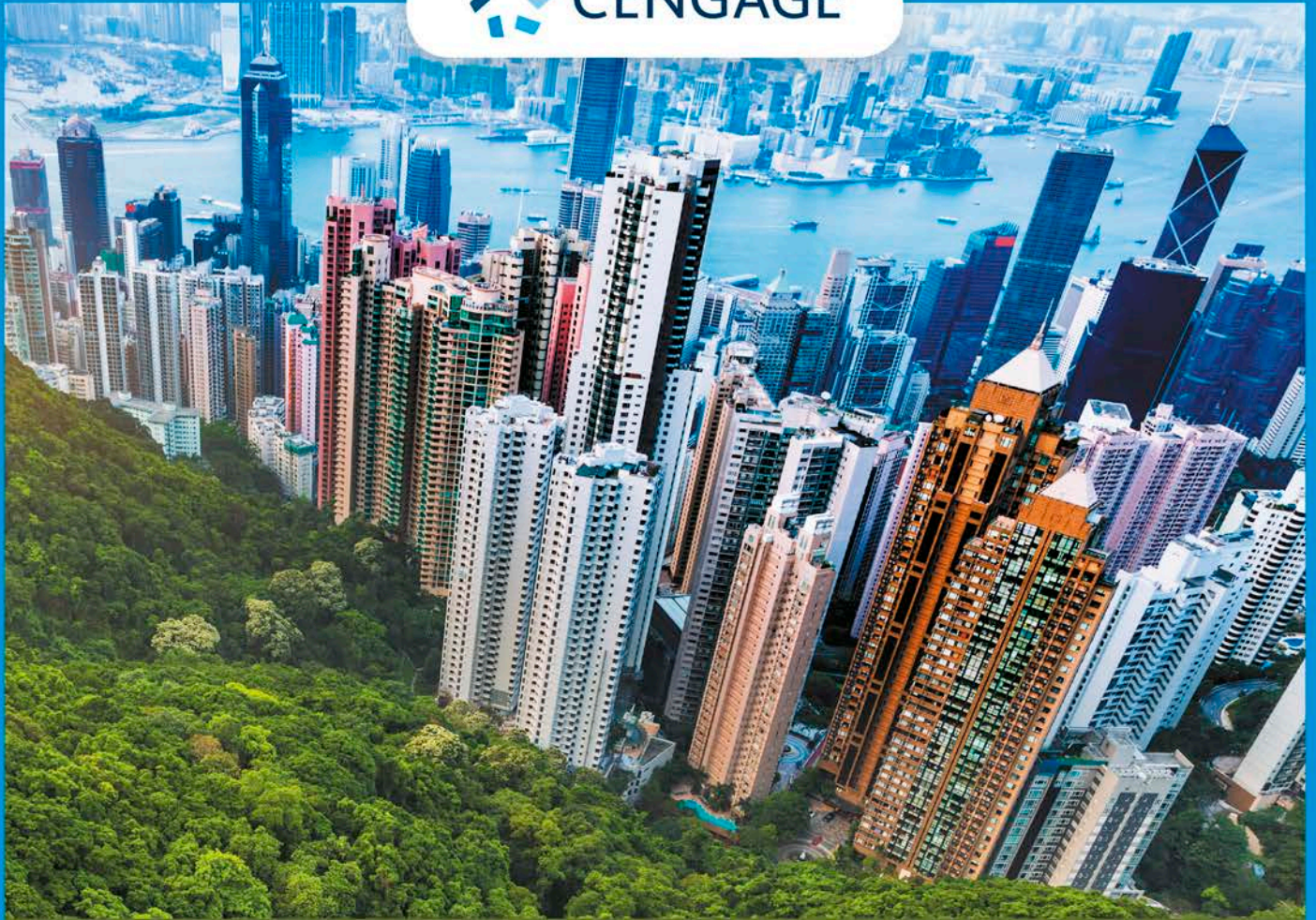




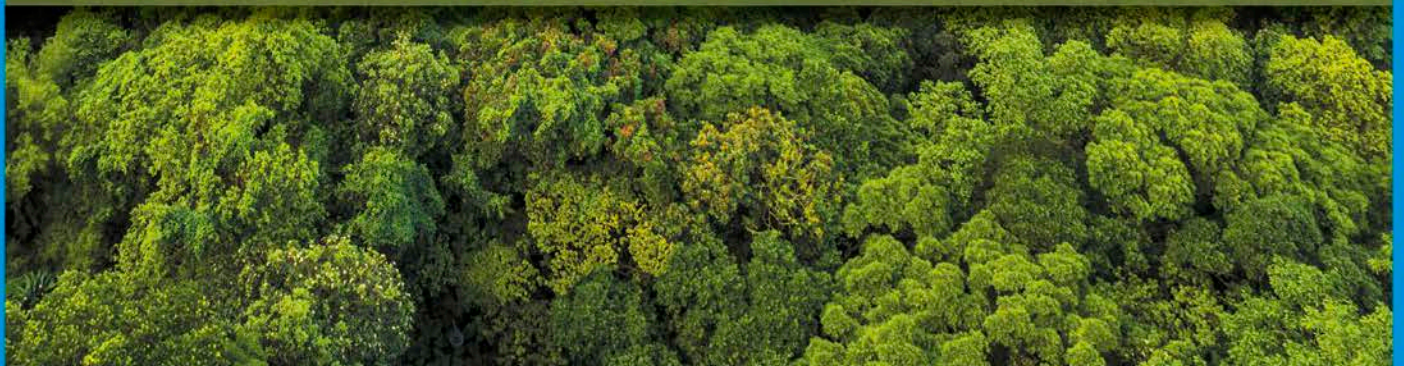
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# Energy, Environment, and Sustainability

**SAEED MOAVENI**

Second Edition



# ENERGY, ENVIRONMENT, AND SUSTAINABILITY

SECOND EDITION

**Saeed Moaveni**

MINNESOTA STATE UNIVERSITY, MANKATO



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**Second Edition**  
**Saeed Moaveni**

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We all realize the importance of understanding fundamental concepts dealing with energy, environment, sustainability, and their relationships, as they affect the quality of our lives. We also agree that a functioning democracy requires well-educated responsible citizens. Unfortunately, the vast majority of students today graduate from high school and college without developing any understanding of the role energy plays in their daily lives and how energy consumption and waste impact the environment and future generations.

This book is an attempt to lay down the foundation for the development of responsible citizens with a clear understanding of contemporary issues dealing with energy, environment, and sustainability. Great care has been exercised to use real-world examples to get important points across, foster critical thinking, and use evidence-based analyses. The content is designed not only to develop the ability of students to go beyond mere understanding of the concepts but to also quantify their energy and environment footprints in order to determine whether their actions are sustainable. The content is also presented with a simple conversational tone with many visual aids to keep today's students engaged. The level of mathematical requirements is kept low so that the topics can be taught to all students. If students can add, subtract, and multiply, then they will be able to follow the examples presented in this textbook, solve the homework problems, and determine their environmental footprints. Moreover, in order to reach out to as many students as possible, the content is prepared as a general education course that can be taught at a community college or a university by instructors with various backgrounds, including physics, science, or engineering. When it comes to energy, environment, and sustainability, we must realize that *we are all in this together!*

## Changes in the Second Edition

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The Second Edition, consisting of fourteen chapters, includes several new additions, changes, and features that were incorporated in response to adopters' comments, as well as pedagogical and sustainability advances. The major changes include:

- A new chapter on evidence-based data analysis introducing students to an approach that is based on basic scientific principles and easy-to-understand mathematical and statistical models
- A new chapter on electronic spreadsheets which are commonly used to record, organize, and analyze data using formulas, as well as to present the results of an analysis in graph form
- Over 50 new problems

- Greater focus on global interdependency and global data, critical thinking, complex problem-solving, and application of knowledge in real-world settings
- Greater emphasis on a blended model where collaborative problem-solving and community engagements are encouraged

## Organization

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This book is organized into four parts and 14 chapters; each chapter begins by stating the **learning objectives (LO)** and concludes by summarizing what the student should have gained from studying the chapter. Relevant, everyday examples, with which students can associate easily, are provided throughout the book. Many **hands-on problems** conclude each chapter, asking the student to gather and analyze information. Moreover, these problems require students to make brief reports and presentations so that they learn the importance of good written and oral communication skills. To emphasize the significance of teamwork and to encourage group participation, many of the problems also require group work; some require the participation of the entire class. The main parts of the book are described below.

### Part One: Basic Concepts

In Part One, consisting of Chapters 1 through 4, we introduce the students to the importance of understanding basic concepts such as human needs, energy, environment, sustainability, and the fundamental dimensions and units that we use every day in our lives. As good global citizens, it is also important to follow a systematic approach to sort carefully through information that is presented to us when we are confronted with a complex problem. We need to make decisions that are based on sound scientific principles, scientific research, scientific data, and mathematical and statistical models.

**Chapter 1** provides an introduction to the current state of our world. It introduces the students to world population and its trends, basic human needs, and why it is important to understand concepts of energy, environment, and sustainability. We explain the traits of good global citizens and the importance of developing good communication skills—all essential for a well-educated democratic society. We also emphasize that responsible citizens must have a good grasp of issues related to energy and environment and take active roles in their communities. We point out that although the activities of good citizens can be quite varied, there are some personality traits and involvement practices that typify them:

- Good citizens are well informed and have a firm grasp of current issues, particularly issues related to energy, environment, and sustainability.
- Good citizens have a desire to be life-long learners. For example, they are well read; they attend community meetings and presentations to stay abreast of new events and innovations in technologies and understand how new developments may affect their lives.
- Good citizens have good written and oral communication skills.
- Good citizens have time management skills that enable them to work productively, take good care of their families, and be active in their communities.
- Good citizens generally work in a team environment where they consult each other to solve complex problems that affect all of us.

**Chapter 2** explains the role and importance of fundamental dimensions (e.g., length, time, mass, temperature) and systems of units (e.g., foot, meter, second, pound, kilogram, degree Fahrenheit, degree Celsius) in our daily lives. We emphasize to the students that they have been using these concepts all their lives; we now define them in a formal way, so that students can understand and quantify more intelligently their own environmental impact, water and energy consumption rates, and waste.

In **Chapter 3**, we introduce students to evidence-based analysis, an approach that is based on scientific principles, scientific research, scientific data, and mathematical and statistical models. In recent years, the use of this systematic approach in a wide range of topics, including sustainability, has resulted in more reliable decisions. We also discuss linear models, as they are the simplest form of equations used to describe a range of situations. Basic concepts dealing with probability and statistics are also discussed. Probability deals with the branch of science that attempts to predict the likelihood of an event to occur, and statistics is the area of science that deals with the collection, organization, analysis, and interpretation of data.

Spreadsheets are used to record, organize, and analyze data using formulas. They are also used to present the results of an analysis in chart forms. **Chapter 4** covers Microsoft Excel, which offers a large selection of built-in functions that students can use to analyze data. Excel also offers many choices when it comes to creating charts. We also show how to use Excel to find an equation that best fits a set of data and forecasts future trends.

## Part Two: Energy

In Part Two, consisting of Chapters 5 through 9, we introduce students to the importance of understanding the basics of conventional and renewable energy; its sources and production; and consumption rates in homes, buildings, transportation, food production and manufacturing. **Chapter 5** explains the basic concepts related to energy and efficiency. These are concepts that every college graduate, regardless of their area of interest, should know. We need energy to build shelter, to cultivate and process food, to make goods, and to maintain our living places at comfortable settings. To quantify the requirements to build things, move or lift objects, or to heat or cool buildings, energy is defined and classified into different categories. We discuss what we mean by mechanical energy and thermal energy. The units of energy and power, including kilowatt-hour, Btu, kilowatt, and horsepower, are also discussed in this chapter. **Chapter 6** covers the basic concepts of electricity and electric power production. We also cover residential power consumption, particularly lighting systems, because lighting accounts for a major portion of electricity use in buildings; lighting systems have received much attention recently due to the energy and sustainability concerns. **Chapter 7** covers the fundamentals of heat transfer, and heat loss and gain in buildings. Space heating and air conditioning account for nearly fifty percent of energy use in homes in the United States. **Chapter 8** provides a comprehensive coverage of energy sources including gasoline, natural gas, coal, and wood, as well as their consumption rates. We detail how much energy we consume in our homes, buildings, and in the transportation and manufacturing sectors. **Chapter 9** explains renewable energy and its sources as well as the basic concepts related to solar energy, wind energy, and hydro-energy.

## Part Three: Environment

In Part Three, consisting of Chapters 10 through 13, we focus on the environment and introduce students to air and water and the anatomy of earth, its natural resources, and rates of consumption and waste. We emphasize that our earth has finite resources. **Chapter 10** provides general information about the atmosphere, weather and climate, along with outdoor and indoor air quality standards. **Chapter 11** covers water resources, quality standards, and consumption rates in our homes, in agriculture, and in the industrial and manufacturing sectors of our society. **Chapter 12** provides a detailed understanding of common materials that are used to make products and structures. **Chapter 13** discusses waste and recycling.

## Part Four: Sustainability

In Part Four, consisting of **Chapter 14**, we introduce key sustainability concepts, methods, and tools. Every college graduate must develop a keen understanding of the Earth's finite resources, environmental and socioeconomic issues related to sustainability, ethical aspects of sustainability, and the necessity for sustainable development. Students should also know about life-cycle based analysis, resource and waste management, and environmental impact analysis, and be familiar with sustainable-development indicators such as the U.S. Green Building Council (USGBC) and Leadership in Energy and Environmental Design (LEED) rating systems. Finally, in Chapter 14, we have included several personal and community-based projects to promote responsible citizenship and sustainability.

## Active Learning Features

---

This book includes numerous features intended to promote active learning. These features include: (1) Learning Objectives (LO), (2) Discussion Starters, (3) Before You Go On, (4) Highlighted Key Concepts, (5) Summary, (6) Key Terms, (7) Apply What You Have Learned, and (8) Life-long Learning.

### Learning Objectives (LO)

Each chapter begins by stating the learning objectives (**LO**), enabling students to identify the most important concepts to take away from that chapter. These objectives are revisited throughout the chapter and are also highlighted within the chapter summary.

### Discussion Starters

Pertinent facts and articles serve as chapter openers to promote meaningful discussion and engage students. They provide a means to understanding the importance of what students are about to learn. A good way for the instructor to use a Discussion Starter is by giving students a few minutes to read it at the beginning of a class and then ask the students about their thoughts.

## Before You Go On

This feature encourages students to test their comprehension and understanding of the material discussed in a section by answering questions before they continue to the next section.

## Vocabulary

It is essential for students to understand the importance of developing a complete vocabulary to converse correctly about today's pressing issues. This feature promotes understanding of basic terminology by asking students to state the meaning of new terms that are covered in a section.

## Key Concepts

Key Concepts are highlighted and defined in special boxes throughout the book.

## Summary


Each chapter concludes by summarizing what the student should have gained from the chapter. These summaries are designed to help students comprehend and become proficient with the materials.

## Key Terms

At the end of each chapter, key terms are indexed so that students can use them for review or check back in the chapter for their meaning.

## Apply What You Have Learned

This feature, designed to highlight practical applications of course concepts, encourages students to apply what they have learned to an interesting problem or a situation. To emphasize the importance of teamwork and to encourage group participation, many of these problems require group work.

**Life-Long Learning Problems** that depict and apply concepts that are critical for life-long learning are clearly denoted by  to draw attention to their importance.

## Supplements

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Additional instructor resources for this product are available online. Instructor assets include a Solution Answer Guide, Image Library, and PowerPoint® slides. Sign up or sign in at [www.cengage.com](http://www.cengage.com) to search for and access this product and its online resources.

## Acknowledgments

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Thank you for considering this book, and I hope you enjoy it.

—*Saeed Moaveni*



# About the Author

Saeed Moaveni is a successful engineer, author, and educator. Dr. Moaveni is a licensed professional engineer in the State of New York and has over 35 years of experience in practice, teaching, and research. He has held faculty appointments at several universities, including University of South Carolina, Syracuse University, and Minnesota State University, and has served as a graduate program coordinator, department chair, and dean. He is the former Dean of the David Crawford School of Engineering at Norwich University—one of the oldest engineering schools in the country (founded in 1819).

As a well-known educator and researcher, Professor Moaveni has received numerous awards throughout his career, including the Jack Cermak Distinguished Professor Fellowship, the American Society for Engineering Education Outstanding Young Faculty Award, the International Network for Engineering Education & Research Recognition Award, and the Global Citizen Award from Minnesota State University.

Professor Moaveni's various textbooks have been translated into many languages, including traditional Chinese, simplified Chinese, Portuguese, Farsi, and Korean. He has been invited abroad as a visiting scholar at numerous universities, including Kyushu University (Japan), National Chiao Tung University (Taiwan), National Cheng Kung University (Taiwan), the Institute of Theoretical and Applied Mechanics at National Taiwan University, Shanghai University of Engineering Science, and Kwame Nkrumah University of Science and Technology (Ghana).



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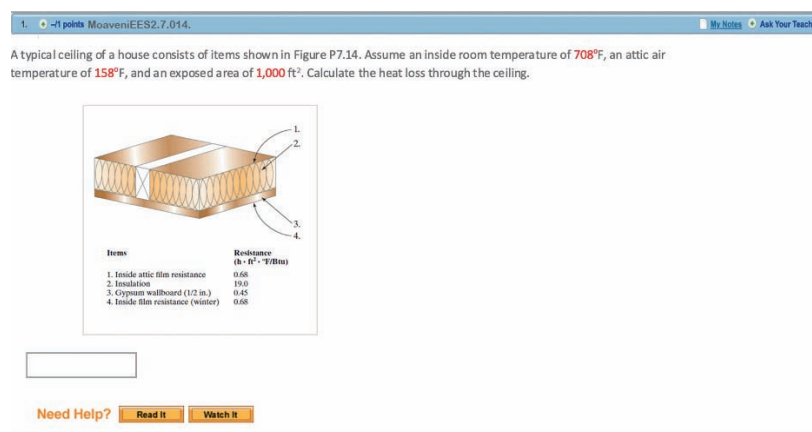
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1. -1 points MoaveniEES2.7.014. My Notes Ask Your Teacher

A typical ceiling of a house consists of items shown in Figure P7.14. Assume an inside room temperature of  $708^{\circ}\text{F}$ , an attic air temperature of  $158^{\circ}\text{F}$ , and an exposed area of  $1,000\text{ ft}^2$ . Calculate the heat loss through the ceiling.

Items	Resistance ( $\text{h} \cdot \text{ft}^2 \cdot ^{\circ}\text{F}/\text{Btu}$ )
1. Inside attic film resistance	0.68
2. Insulation	19.0
3. Gypsum wallboard (1/2 in.)	0.45
4. Inside film resistance (winter)	0.68

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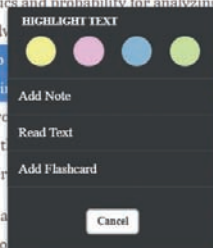
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### 3.6 Mean, Median, and Standard Deviation

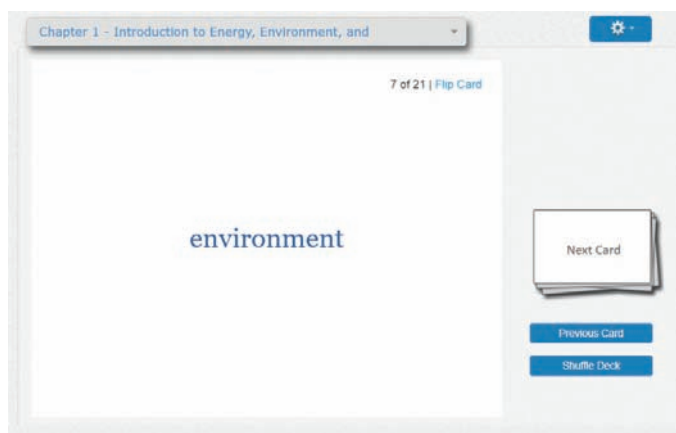
In this section, we will discuss some simple ways to examine the central tendency and variations within a given data set. Every college graduate should have some understanding of the basic fundamentals of statistics and probability for analyzing important data that affects their daily lives. There are always uncertainties associated with all experimental observations. If several variables are measured to determine the accuracy of the results, the inaccuracies associated with these individual measurements will influence the accuracy of the final result. For example, suppose you measure the temperature of pure water at sea level and standard pressure with a thermometer. However, you know from your physics background that the temperature of pure water at sea level and standard conditions is 100°C. Suppose two groups of students in a laboratory measured the temperature of water at 20°C. Each group consisted of ten students. They reported their results as shown in Table 3.7. We would like to know if any of the reported data is in error.

LO6



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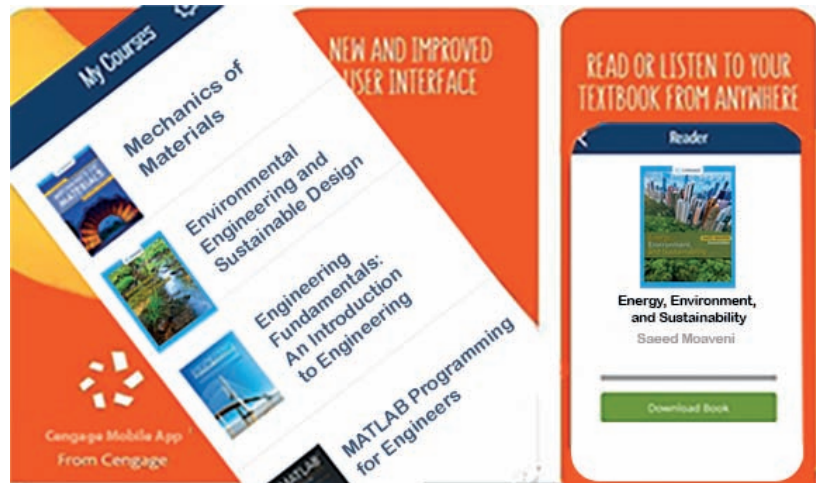
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ENERGY,  
ENVIRONMENT,  
AND SUSTAINABILITY

SECOND EDITION

# Basic Concepts



## PART

# 1

**I**n Part One of this book, we introduce you to the importance of understanding basic concepts such as human needs, energy, environment, and sustainability. Good citizens are well informed and have a firm grasp of current issues, particularly those related to population trends, energy, environment, and sustainability; these are all essential for a well-educated democratic society. Responsible citizens also take active roles in their communities; have a desire to be life-long learners; stay abreast of innovations in technologies and understand how new developments affect their lives; have time management skills that enable them to work productively, take good care of their families, and be active in their communities; and work in a team environment where they consult each other to solve problems that affect all of us.

In Part One, we also explain the role of fundamental dimensions such as length, time, mass, and temperature and systems of units such as the foot (or meter), second, pound (kilogram), and degree Fahrenheit (Celsius) in our daily lives. You have been using these concepts all your lives; however, here we define them in a formal way so that you can use them to quantify your own environmental impact, water and energy consumption rates, and waste.

As a good global citizen, it is also important to follow a systematic approach to sort carefully through information presented to you when you are confronted with a complex problem. In Part One, you will also be introduced to concepts related to evidence-based analysis: an approach that is based on scientific principles, scientific research, scientific data, and mathematical and statistical models. In recent years, the use of this systematic approach in a wide range of topics including sustainability has resulted in more reliable decisions.

Spreadsheets are commonly used to record, organize, and analyze data using formulas, and to present the results of an analysis in graph form. In this part of the book, we will also discuss the use of spreadsheets in solving problems.

<b>CHAPTER 1</b>	<b>Introduction to Energy, Environment, and Sustainability</b>
<b>CHAPTER 2</b>	<b>Fundamental Dimensions and Systems of Units</b>
<b>CHAPTER 3</b>	<b>Evidence-Based Data Analysis</b>
<b>CHAPTER 4</b>	<b>Electronic Spreadsheets</b>



# Introduction to Energy, Environment, and Sustainability



## LEARNING OBJECTIVES

- LO<sup>1</sup>** Basic Human Needs: understand the basic human needs, including clean air, clean water, food, and shelter
- LO<sup>2</sup>** Energy: understand that it takes energy to address basic human needs and be familiar with energy consumption rates and sources in your daily life
- LO<sup>3</sup>** Environment: explain what we mean by environment and be familiar with its main components
- LO<sup>4</sup>** Sustainability: define sustainability and its role in your daily life

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# Discussion Starter

**W**e all want to make the world a better place, but how do we do it, and where do we start? Leo Tolstoy, a Russian novelist and philosopher, once said:

*“Everyone thinks of changing the world, but no one thinks of changing oneself.”*

Increasingly, because of worldwide socio-economic trends, environmental concerns, and the Earth’s finite resources, more is expected of all of us. As responsible global citizens, we are expected to consider the link among the Earth’s finite resources and environmental, social, ethical, technical, and economical factors as we make decisions regarding the services that we use and the products we consume. This book is designed to introduce you—a college student—regardless of your area of study, personal interests, and future career path, to important issues such as energy, environment, and sustainability that affect all of us. A quote often attributed to Chief Seattle of the Dkhw’Duw’Absh (1786–1866) says it best:



*“What befalls the Earth befalls all the sons (and daughters) of the Earth. This we know: the Earth does not belong to man, man belongs to the Earth. All things are connected like the blood that unites us all. Man does not weave this web of life. He is merely a strand of it. Whatever he does to the web, he does to himself.”*



**To the Students:** What does all this mean to you? Have you thought about changing the world (or yourself)? Where do you start?

## LO<sup>1</sup> 1.1 Basic Human Needs

During the past decades, much has been said about vital issues related to *energy, the environment, and sustainability*. What are these issues, and why is it important for you to understand them? Increasingly, because of worldwide socioeconomic trends, environmental concerns, and the Earth’s finite resources, more is expected of all of us. As responsible global citizens, we are expected to consider the link among the Earth’s finite resources and environmental, social, ethical, technical, and economical factors as we make decisions in our daily lives. In our decision-making process, we are expected to consider our energy and environment footprints and take into account factors such as the natural resources that were consumed to make a product. We also need to consider how much energy it takes to manufacture, transport, use, and finally dispose of the product.

This book is an attempt to introduce you to these important issues that affect all of us. Currently, there is great international competition for Earth's finite resources as each nation works to address their own energy, water, and food security needs. However, it is important to develop a global view of our needs. A human body is made of many interacting parts that work well together and share resources effectively. Furthermore, when a part of our body—even as small as a tooth—is in pain, the body as a whole is uncomfortable until the pain is gone. We should develop a similar, holistic view of our societies: one that increases commonality of human purpose, and one that gives a greater meaning to life beyond the walls of our homes, beyond the boundaries of our cities, and beyond our own countries. It is imperative that we all understand that *we are all in this together*, and in order to address our energy, clean air and water, and food security needs intelligently, we must work together and be well educated in topics such as energy, environment, and sustainability. *It is only then that we can consume resources in such a way that meets our present needs without compromising the ability of future generations to meet their needs.*

We as people, regardless of where we live, need the following things: clean air, clean water, food, and shelter. In our modern society, we also need various modes of transportation to get to different places. We also like to have some sense of security, to be able to relax, and to be entertained. We desire to be liked and appreciated by our friends and family as well. Some people have a good

standard of living, while many (especially those who live in developing countries) do not. You will probably agree that our world would be a better place if every one of us had clean air and water; enough food to eat; a comfortable and safe place to live; meaningful work to do; and some time for relaxation, family, and friends.

At the turn of the 21st century, there were approximately six billion of us inhabiting the Earth; as a means of comparison, the world population about 100 years ago, at the turn of the 20th century, was one billion. Think about this! It took us since the beginning of human existence to year 1900 CE to reach a population of one billion. Then it only took 100 years to increase the population fivefold.

According to the latest estimates and projections of the United Nations, the world population will reach 9.7 billion people by the year 2050. Not only will the number of people inhabiting the Earth continue to rise,

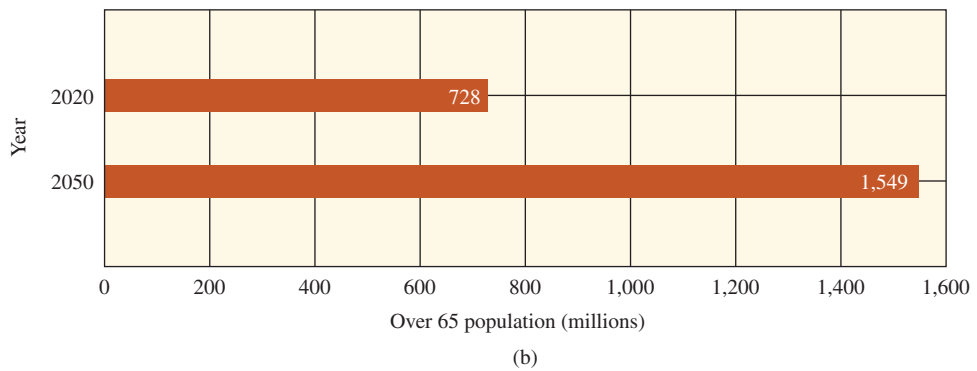
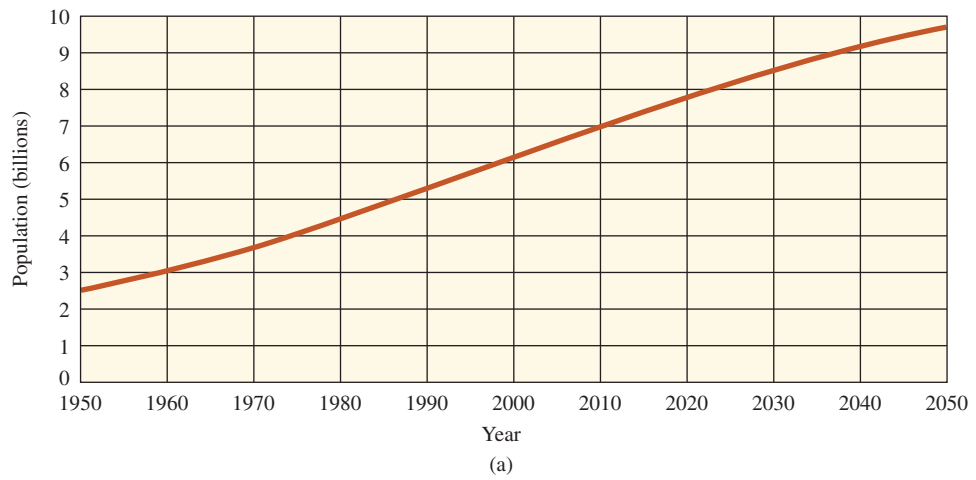
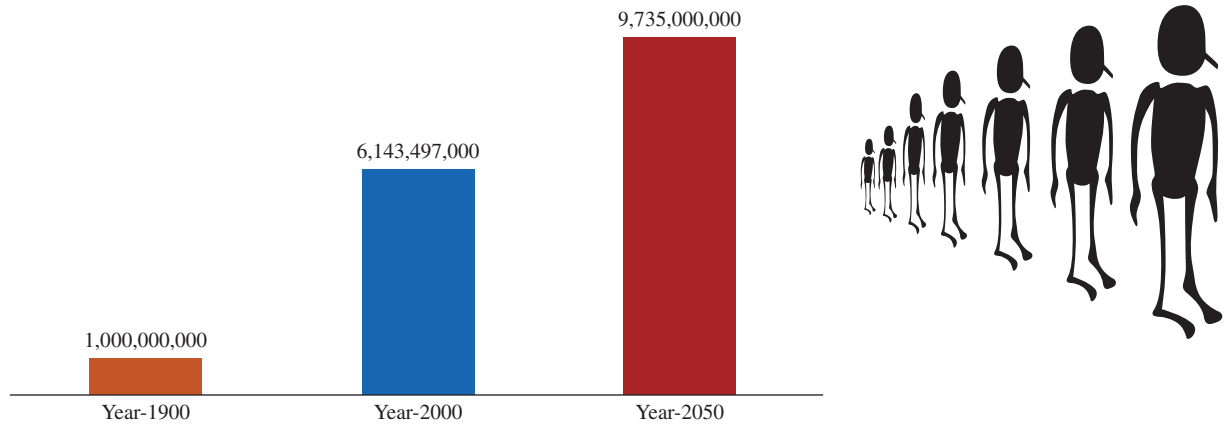
but the age structure of the world population will also change. The world's senior population—people at least 65 years of age—will more than double in the next 30 years (see Figure 1.1).

How is this information relevant? Well, let's start with our most essential need, clean air; without it, we cannot live.



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It is expected that the world population will reach 9.7 billion people by the year 2050.



**FIGURE 1.1** (a) The latest projection of world population growth. (b) The latest estimate of U.S. senior population growth.  
 Source: United Nations, Department of Economic and Social Affairs, Population Division (2019)

**We Need Clean Air** Every day, human activities through *stationary* and *mobile* sources contribute to the pollution of outdoor air. Power plants, factories, and dry cleaners are examples of stationary sources that create outdoor air pollution. Mobile sources of air pollution, such as cars, buses, trucks, planes, and trains, also add to the level of outdoor air pollution. In addition to these human-made sources, *natural* air pollution also occurs due to forest fires, windblown dust, and volcanic eruptions. Moreover, because most of us spend approximately 90 percent of our time indoors, indoor air quality is also very important to our short-term and long-term health. In recent years, we have used more synthetic materials in newly built homes that can give off harmful vapors. We also use more chemical pollutants, such as pesticides and household cleaners.



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**We Need Clean Water** Our next essential need is water. Droughts are good reminders of how significant water is to our daily lives. In addition to quantity, quality is also a concern. As you would expect, human activities and naturally occurring microorganisms contribute to the contaminant level in our water supply. In agriculture, for example, pollutants such as fertilizers, pesticides, and animal waste from large cattle, pig, or poultry farms contribute to water pollution. Other human activities such as mining, construction, manufacturing goods, landfills, and waste water treatment plants are also major contributors to water pollution.

**We Need Food** To lead a normal active life, we need to consume a certain number of calories that come from eating meat, fish, eggs, dairy products, fruits, bread, vegetables, and the like. In the American diet, carbohydrates, protein, and fat are the main sources of calories.

The total number of food calories a person needs each day to lead an active and healthy life depends on factors such as gender, age, height, weight, and level of physical activity. Moreover, in order to maintain a healthy body weight, calories consumed from food and drinks must equal calories expended through daily activities. Therefore, if you



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To maintain a healthy body weight, calories consumed from food and drinks must equal calories expended through daily activities.

consume more calories than you expend, you will gain weight. As we later explain in Chapter 2, the energy content of food is typically expressed in Calories (with an uppercase C). For example, a banana has about 100 Calories, whereas a medium serving of French fries has around 400 Calories. One Calorie is equal to 1,000 calories (with a lowercase c), and one calorie is formally defined as the amount of energy required to raise the temperature of one gram (1 g) of water by one degree Celsius (1°C). For now, don't worry if you don't fully understand

what one calorie represents; this and other important concepts will be explained in greater detail in Chapters 2 and 5.

In the United States, by law, dietary guidelines for Americans are reviewed and published every five years by the U.S. Department of Agriculture (USDA) and the U.S. Department of Health and Human Services (HHS).



ODPHP, 2020–2025 Dietary Guidelines for Americans, [www.dietaryguidelines.gov/resources/2020-2025-dietary-guidelines-online-materials](http://www.dietaryguidelines.gov/resources/2020-2025-dietary-guidelines-online-materials)

Table 1.1 shows the estimated total Calorie needs for weight maintenance based on age, gender, and physical activity level. This data is from the *Dietary Guidelines for Americans 2015* USDA and HHS report. As shown in Table 1.1, adult women