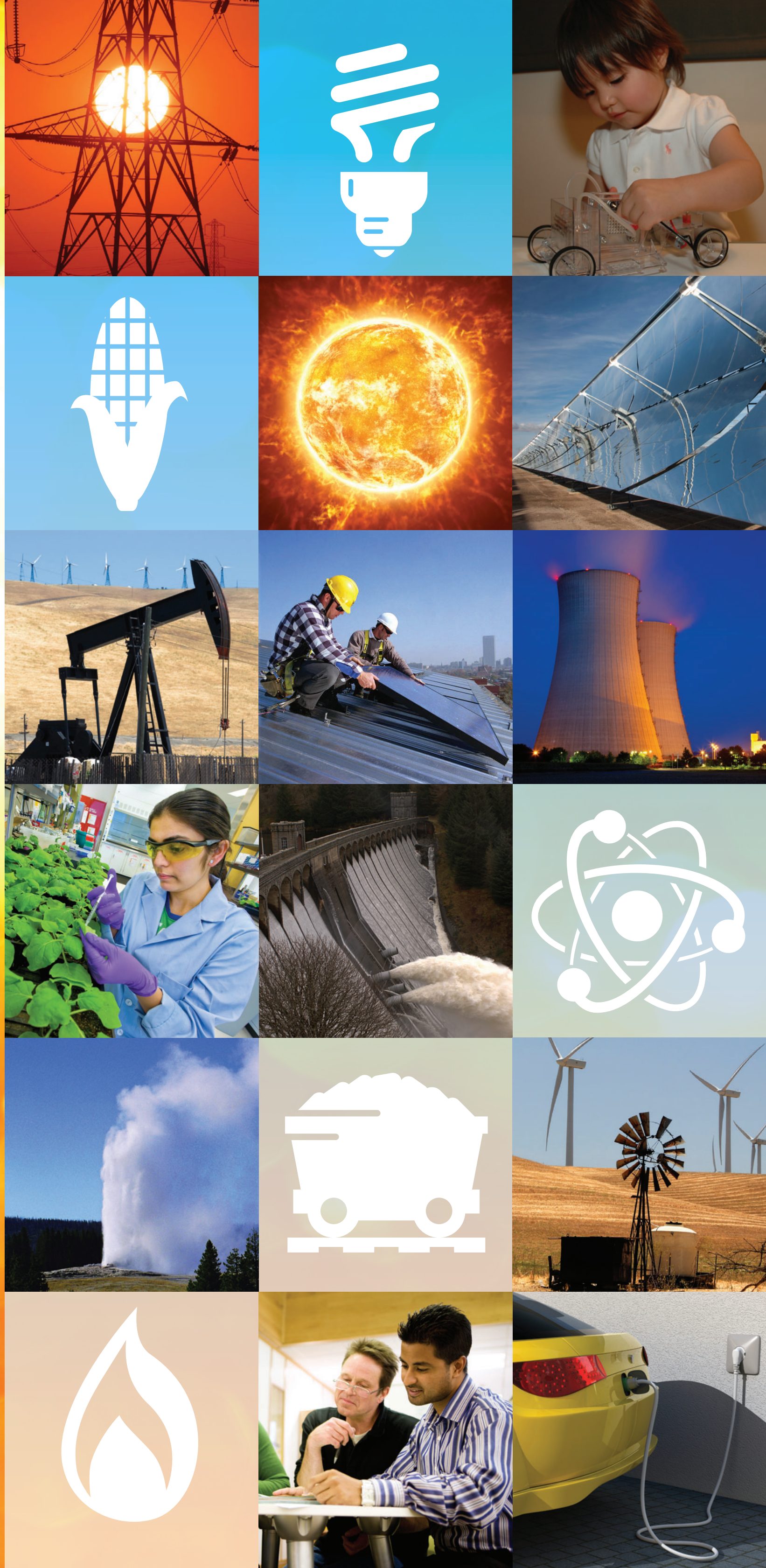


Energy Literacy

Essential Principles and Fundamental Concepts for Energy Education

A Framework for Energy Education for Learners of All Ages

About This Guide

Energy Literacy: Essential Principles and Fundamental Concepts for Energy Education presents energy concepts that, if understood and applied, will help individuals and communities make informed energy decisions.

Energy is an inherently interdisciplinary topic. Concepts fundamental to understanding energy arise in nearly all, if not all, academic disciplines. This guide is intended to be used across disciplines. Both an integrated and systems-based approach to understanding energy are strongly encouraged.

Energy Literacy: Essential Principles and Fundamental Concepts for Energy Education identifies seven Essential Principles and a set of Fundamental Concepts to support each principle. This guide does not seek to identify all areas of energy understanding, but rather to focus on those that are essential for all citizens. The Fundamental Concepts have been drawn, in part, from existing education standards and benchmarks.

The intended audience for this document is anyone involved in energy education. Used in formal educational environments, this guide provides direction without adding new concepts to the educator's curriculum. This guide is not a curriculum. The Essential Principles and Fundamental Concepts offer a framework upon which curricula can be based without prescribing when, where, or how content is to be delivered.

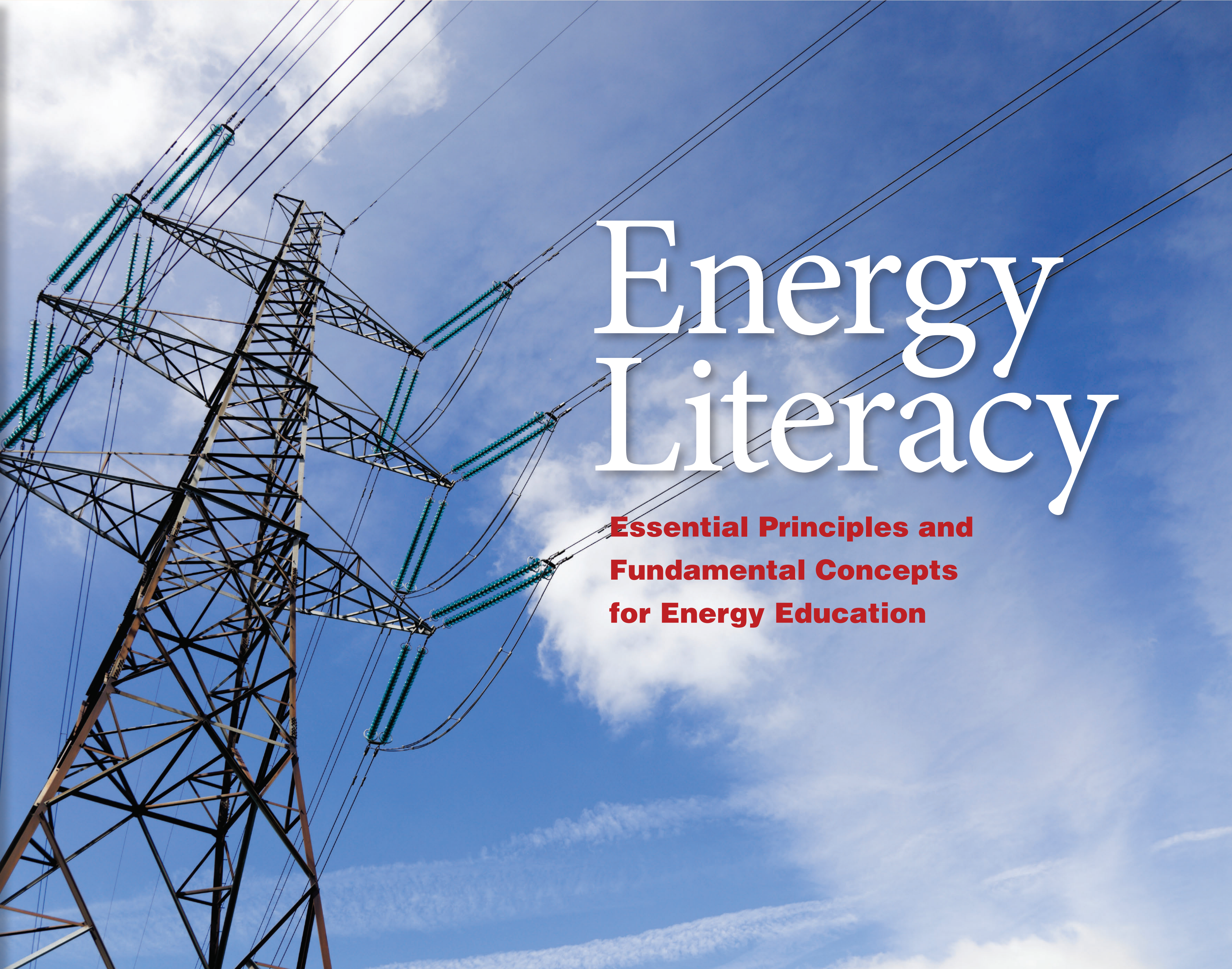
Intended use of this document as a guide includes, but is not limited to, formal and informal energy education, standards development, curriculum design, assessment development, and educator trainings.

Development of this guide began at a workshop sponsored by the Department of Energy (DOE) and the American Association for the Advancement of Science (AAAS) in the fall of 2010. Multiple federal agencies, non-governmental organizations, and numerous individuals contributed to the development through an extensive review and comment process. Discussion and information gathered at AAAS, WestEd, and DOE-sponsored Energy Literacy workshops in the spring of 2011 contributed substantially to the refinement of the guide.

To download this guide and related documents, visit www1.eere.energy.gov/education/energy_literacy.html.

U.S. Department of Energy
1000 Independence Ave SW
Washington, DC 20585
202-586-5000
http://www1.eere.energy.gov/education/energy_literacy.html

Version 1.1: July 2012



Energy Literacy

Essential Principles and Fundamental Concepts for Energy Education

What is Energy Literacy?

Energy literacy is an understanding of the nature and role of energy in the universe and in our lives. Energy literacy is also the ability to apply this understanding to answer questions and solve problems.

An energy-literate person:

- can trace energy flows and think in terms of energy systems
- knows how much energy he or she uses, for what, and where the energy comes from
- can assess the credibility of information about energy
- can communicate about energy and energy use in meaningful ways
- is able to make informed energy and energy use decisions based on an understanding of impacts and consequences
- continues to learn about energy throughout his or her life

Energy Literacy is a Part of Social and Natural Science Literacy

A comprehensive study of energy must be interdisciplinary. Energy issues cannot be understood and problems cannot be solved by using only a natural science or engineering approach. Energy issues often require an understanding of civics, history, economics, sociology, psychology, and politics in addition to science, math, and technology.

Just as both social and natural science are a part of energy literacy, energy literacy is an essential part of being literate in the social and natural sciences. References to energy can be found in National Education Standards in nearly all academic disciplines.

Why Does Energy Literacy Matter?

A better understanding of energy can:

- lead to more informed decisions
- improve the security of a nation
- promote economic development
- lead to sustainable energy use
- reduce environmental risks and negative impacts
- help individuals and organizations save money

Without a basic understanding of energy, energy sources, generation, use, and conservation strategies, individuals and communities cannot make informed decisions on topics ranging from smart energy use at home and consumer choices to national and international energy policy. Current national and global issues such as the fossil fuel supply and climate change highlight the need for energy education.

How Do We Know What We Know About Energy?

Social and natural scientists have systematically developed a body of knowledge about energy through a process much the same as that used by scientific disciplines in general.

Social and natural scientists formulate and test explanations of nature using observation, experiment, and theoretical and mathematical models. Although all scientific ideas are tentative and subject to change and improvement, for most major ideas, there is substantial experimental and observational confirmation. These major ideas are not likely to change greatly in the future. Scientists do adjust and refine their ideas about nature when they encounter new experimental evidence that does not match existing models, rejecting the notion of attaining absolute truth and accepting uncertainty as part of nature. The modification of ideas, rather than their outright rejection, is the norm in science, as powerful constructs tend to survive, grow more precise, and become widely accepted.

In areas where active research is being pursued and in which there is not a great deal of experimental or observational evidence and understanding, it is normal for scientists to differ with one another about the interpretation of evidence being considered. Different scientists might publish conflicting experimental results or might draw different conclusions from the same data. Ideally, scientists acknowledge such conflict and work toward finding evidence that will resolve their disagreement. In this way, communities of social and natural scientists form self-correcting networks, working toward an ever-better understanding of the social and natural universe.

Part of scientific inquiry is to evaluate the results of scientific investigations, experiments, observations, theoretical models, and the explanations proposed by other scientists. Evaluation includes reviewing the experimental procedures, examining the evidence, identifying faulty reasoning, pointing out statements that go beyond the evidence, and suggesting alternative explanations for the same observations. Although scientists may disagree about explanations of phenomena, interpretations of data, or the value of rival theories, they do agree that questioning, response to criticism, and open communication are integral to the process of science. As knowledge evolves, major disagreements are eventually resolved through such interactions.

A Brief History of Human Energy Use

Producers in a food chain–like plants, algae and cyanobacteria–capture energy from the Sun. Nearly all organisms rely on this energy for survival. Energy flow through most food chains begins with this captured solar energy. Some of this energy is used by organisms at each level of the food chain, much is lost as heat, and a small portion is passed down the food chain as one organism eats another.

Over time, humans have developed an understanding of energy that has allowed them to harness it for uses well beyond basic survival.

The first major advance in human understanding of energy was the mastery of fire. The use of fire to cook food and heat dwellings, using wood as the fuel, dates back at least 400,000 years.[1] The burning of wood and other forms of biomass eventually led to ovens for making pottery, and the refining of metals from ore. The first evidence of coal being burned as a fuel dates back approximately 2,400 years.[2]

After the advent of fire, human use of energy per capita remained nearly constant until the Industrial Revolution of the 19th century. This is despite the fact that, shortly after mastering fire, humans learned to use energy from the Sun, wind, water, and animals for endeavors such as transportation, heating, cooling, and agriculture.

The invention of the steam engine was at the center of the Industrial Revolution. The steam engine converted the chemical energy stored in wood or coal into motion energy. The steam engine was widely used to solve the urgent problem of pumping water out of coal mines. As improved by James Watt, Scottish inventor and mechanical engineer, it was soon used to move coal, drive the manufacturing of machinery, and power locomotives, ships and even the first automobiles.[3] It was during this time that coal replaced wood as the major fuel supply for industrialized society. Coal remained the major fuel supply until the middle of the 20th century when it was overtaken by oil.

Humans have been using energy from wind to power human endeavors for centuries. These windmills in the Netherlands were built almost three hundred years ago.

The next major energy revolution was the ability to generate electricity and transmit it over large distances. During the first half of the 19th century, British physicist Michael Faraday demonstrated that electricity would flow in a wire exposed to a changing magnetic field, now known as Faraday's Law. Humans then understood how to generate electricity. In the 1880s, Nikola Tesla, a Serbian-born electrical engineer, designed alternating current (AC) motors and transformers that made long-distance transmission of electricity possible. Humans could now generate electricity on a large scale, at a single location, and then transmit that electricity efficiently to many different locations. Electricity generated at Niagara Falls, for example, could be used by customers all over the region.

During the 20th century, hydroelectric dams such as this one were built on major waterways across the United States. For a time, in the middle of the 20th century, hydropower was the major source of electricity in the United States.

Although hydropower, largely in the form of water wheels, has been in use by human society for centuries, hydroelectricity is a more recent phenomenon. The first hydroelectric power plants were built at the end of the 19th century and by the middle of the 20th century were a major source of electricity. As of 2010, hydropower produced more than 15% of the world's electricity.[4]

Humans have also been using energy from wind to power human endeavors for centuries, but have only recently begun harnessing wind energy to generate electricity. Wind energy propelled boats along the Nile River as early as 5000 B.C. By 200 B.C., simple windmills in China were pumping

---

1 Bowman DM, Balch JK, Artaxo P et al. Fire in the Earth System. Science. 2009, 324 (5926), pp 481–4.

2 Metalworking and Tools, in: Oleson, John Peter (ed.): *The Oxford Handbook of Engineering and Technology in the Classical World*, Oxford University Press, 2009, pp. 418–38 (432).

3 Benchmarks for Science Literacy, American Association for the Advancement of Science, 1993, benchmark 10J/M2.

4 Source of data is the U.S. Energy Information Administration (http://www.eia.gov) unless otherwise noted.

water, while vertical-axis windmills with woven reed sails were grinding grain in Persia and the Middle East. Windmills designed to generate electricity, or wind turbines, appeared in Denmark as early as 1890. Currently, wind provides almost 2% of the world's electricity.[5]

In the 20th century, Einstein's Theories of Relativity and the new science of quantum mechanics brought with them an understanding of the nature of matter and energy that gave rise to countless new technologies. Among these technologies were the nuclear power plant and the solar or photovoltaic cell. Both of these technologies emerged as practical sources of electricity in the 1950s. Nuclear energy quickly caught on as a means of generating electricity. Today, nuclear energy generates almost 15% of the world's electricity. Solar energy provides less than 1% of the world's electricity. Solar is the only primary energy source that can generate electricity without relying on Faraday's Law. Particles of light can provide the energy for the flow of electrons directly.

Humans have also managed to harness the geothermal energy of Earth to produce electricity. The first geothermal power plant was built in 1911 in Larderello, Italy. Geothermal energy is a result of the continuous radioactive decay of unstable elements beneath Earth's surface and gravitational energy associated with Earth's mass. The radioactive decay and gravitational energy produce thermal energy that makes its way to the surface of Earth, often in the form of hot water or steam.

Modern biofuels are another way humans have found to harness energy for use beyond basic survival. Biofuels are plant materials and animal waste used as fuel. For example, ethanol is a plant-based fuel used more and more commonly in vehicles, usually in conjunction with petroleum-based fuels.

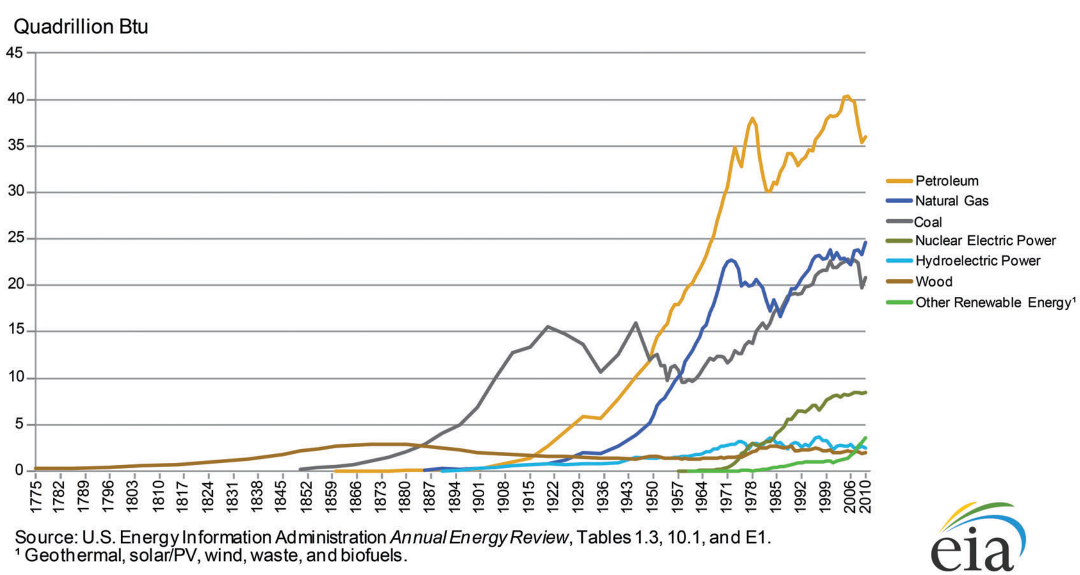
Although humans have found many different sources of energy to power their endeavors, fossil fuels remain the major source by a wide margin. The three fossil fuel sources are coal, oil, and natural gas. Oil has been the major fuel supply for industrialized society since the middle of the 20th century and provides more of the energy used by humans than any other source. Coal is second on this list, followed closely by natural gas. Together they accounted for more than 80% of the world's energy use in 2010.

Industrialization and the rise in access to energy resources have taken place at very disparate rates in different countries around the world. For example, as of 2011, there were 1.3 billion people on Earth with no access to electricity.[6]

As with any human endeavor, the use of energy resources and the production of electricity have had and will continue to have impacts and consequences, both good and bad. Awareness of the energy used to grow, process, package, and transport food, or the energy used to treat water supplies and wastewater, is important if society is to minimize waste and maximize efficiency. These are just a few examples of the many energy issues people can become informed about.

Human society has and will continue to develop rules and regulations to help minimize negative consequences. As new information comes to light and new technologies are developed, energy policies are reevaluated, requiring individuals and communities to make decisions. This guide outlines the understandings necessary for these decisions to be informed.

U.S. Primary Energy Consumption Estimates by Source, 1775-2010



Source: U.S. Energy Information Administration *Annual Energy Review*, Tables 1.3, 10.1, and E1.
¹ Geothermal, solar/PV, wind, waste, and biofuels.

5 World Wind Energy Report, World Wind Energy Association, February 2009.

6 International Energy Agency, World Energy Outlook, 2011.

Energy Literacy

The Essential Principles and Fundamental Concepts

A note on the use of the Essential Principles and Fundamental concepts:

The Essential Principles, 1 through 7, are meant to be broad categories representing big ideas. Each Essential Principle is supported by six to eight Fundamental Concepts: 1.1, 1.2, and so on. The Fundamental Concepts are intended to be unpacked and applied as appropriate for the learning audience and setting. For example, teaching about the various sources of energy (Fundamental Concept 4.1) in a 3rd grade classroom, in a 12th grade classroom, to visitors of a museum, or as part of a community education program will look very different in each case. Further, the concepts are not intended to be addressed in isolation; a given lesson on energy will most often connect to many of the concepts.

1. **Energy is a physical quantity that follows precise natural laws.**
2. **Physical processes on Earth are the result of energy flow through the Earth system.**
3. **Biological processes depend on energy flow through the Earth system.**
4. **Various sources of energy can be used to power human activities, and often this energy must be transferred from source to destination.**
5. **Energy decisions are influenced by economic, political, environmental, and social factors.**
6. **The amount of energy used by human society depends on many factors.**
7. **The quality of life of individuals and societies is affected by energy choices.**

1 Energy is a physical quantity that follows precise natural laws.

1.1 Energy is a quantity that is transferred from system to system. Energy is the ability of a system to do work. A system has done work if it has exerted a force on another system over some distance. When this happens, energy is transferred from one system to another. At least some of the energy is also transformed from one type into another during this process. One can keep track of how much energy transfers into or out of a system.

1.2 The energy of a system or object that results in its temperature is called thermal energy. When there is a net transfer of energy from one system to another, due to a difference in temperature, the energy transferred is called heat. Heat transfer happens in three ways: convection, conduction, and radiation. Like all energy transfer, heat transfer involves forces exerted over a distance at some level as systems interact.

1.3 Energy is neither created nor destroyed. The change in the total amount of energy in a system is always equal to the difference between the amount of energy transferred in and the amount transferred out. The total amount of energy in the universe is finite and constant.

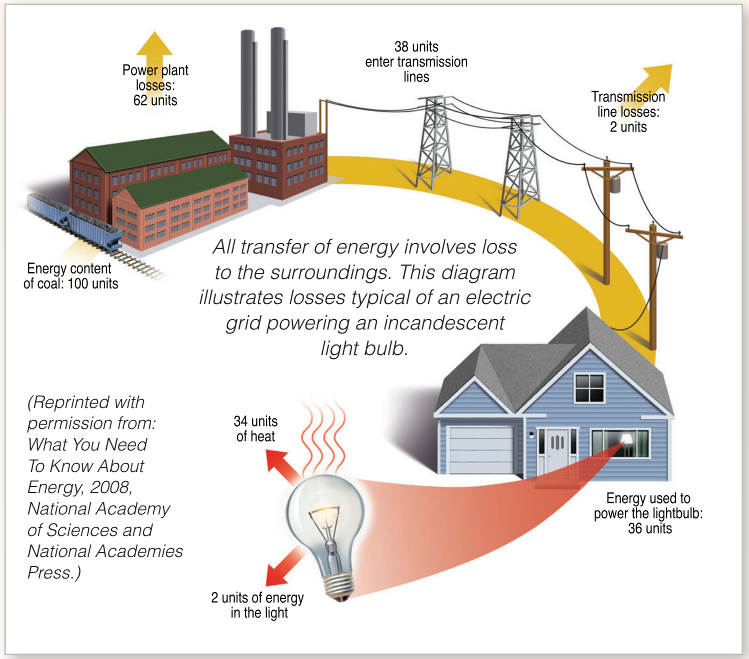
1.4 Energy available to do useful work decreases as it is transferred from system to system. During all transfers of energy between two systems, some energy is lost to the surroundings. In a practical sense, this lost energy has been "used up," even though it is still around somewhere. A more efficient system will lose less energy, up to a theoretical limit.

1.5 Energy comes in different forms and can be divided into categories. Forms of energy include light energy, elastic energy, chemical energy, and more. There are two categories that all energy falls into: kinetic and potential. Kinetic describes types of energy associated with motion. Potential describes energy possessed by an object or system due to its position relative to another object or system and forces between the two. Some forms of energy are part kinetic and part potential energy.

1.6 Chemical and nuclear reactions involve transfer and transformation of energy. The energy associated with nuclear reactions is much larger than that associated with chemical reactions for a given amount of mass. Nuclear reactions take place at the centers of stars, in nuclear bombs, and in both fission- and fusion-based nuclear reactors. Chemical reactions are pervasive in living and non-living Earth systems.

1.7 Many different units are used to quantify energy. As with other physical quantities, many different units are associated with energy. For example, joules, calories, ergs, kilowatt-hours, and BTUs are all units of energy. Given a quantity of energy in one set of units, one can always convert it to another (e.g., 1 calorie = 4.186 joules).

1.8 Power is a measure of energy transfer rate. It is useful to talk about the rate at which energy is transferred from one system to another (energy per time). This rate is called power. One joule of energy transferred in one second is called a Watt (i.e., 1 joule/second = 1 Watt).



All transfer of energy involves loss to the surroundings. This diagram illustrates losses typical of an electric grid powering an incandescent light bulb.

(Reprinted with permission from: What You Need To Know About Energy, 2008, National Academy of Sciences and National Academies Press.)

2 Physical processes on Earth are the result of energy flow through the Earth system.

2.1 Earth is constantly changing as energy flows through the system. Geologic, fossil, and ice records provide evidence of significant changes throughout Earth's history. These changes are always associated with changes in the flow of energy through the Earth system. Both living and non-living processes have contributed to this change.

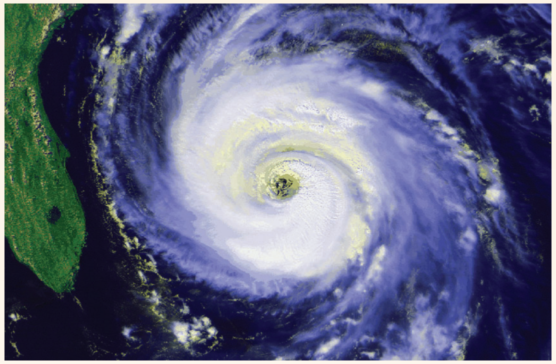
2.2 Sunlight, gravitational potential, decay of radioactive isotopes, and rotation of the Earth are the major sources of energy driving physical processes on Earth. Sunlight is a source external to Earth, while radioactive isotopes and gravitational potential, with the exception of tidal energy, are internal. Radioactive isotopes and gravity work together to produce geothermal energy beneath Earth's surface. Earth's rotation influences global flow of air and water.

2.3 Earth's weather and climate are mostly driven by energy from the Sun. For example, unequal warming of Earth's surface and atmosphere by the Sun drives convection within the atmosphere, producing winds, and influencing ocean currents.

2.4 Water plays a major role in the storage and transfer of energy in the Earth system. The major role water plays is a result of water's prevalence, high heat capacity, and the fact that phase changes of water occur regularly on Earth. The Sun provides the energy that drives the water cycle on Earth.

2.5 Movement of matter between reservoirs is driven by Earth's internal and external sources of energy. These movements are often accompanied by a change in the physical and chemical properties of the matter. Carbon, for example, occurs in carbonate rocks such as limestone, in the atmosphere as carbon dioxide gas, in water as dissolved carbon dioxide, and in all organisms as complex molecules that control the chemistry of life. Energy drives the flow of carbon between these different reservoirs.

2.6 Greenhouse gases affect energy flow through the Earth system. Greenhouse gases in the atmosphere, such as carbon dioxide and water vapor, are transparent to much of the incoming sunlight but not to the infrared light from the warmed surface of Earth. These gases play a major role in determining average global surface temperatures. When Earth emits the same amount of energy as it absorbs, its average temperature remains stable.



Storms like this hurricane are powered by the latent heat energy of water as it changes phase from liquid to gas, and then back to liquid. (Source: National Oceanic and Atmospheric Administration, Environmental Visualization Laboratory)

2.7 The effects of changes in Earth's energy system are often not immediately apparent. Responses to changes in Earth's energy system, input versus output, are often only noticeable over the course of months, years, or even decades.

This geothermal power plant in Iceland makes use of high temperatures beneath Earth's surface to generate electricity. Nearby, people enjoy hot water heated by the same sub-surface energy sources.

3 Biological processes depend on energy flow through the Earth system.

3.1 The Sun is the major source of energy for organisms and the ecosystems of which they are a part. Producers such as plants, algae, and cyanobacteria use the energy from sunlight to make organic matter from carbon dioxide and water. This establishes the beginning of energy flow through almost all food webs.

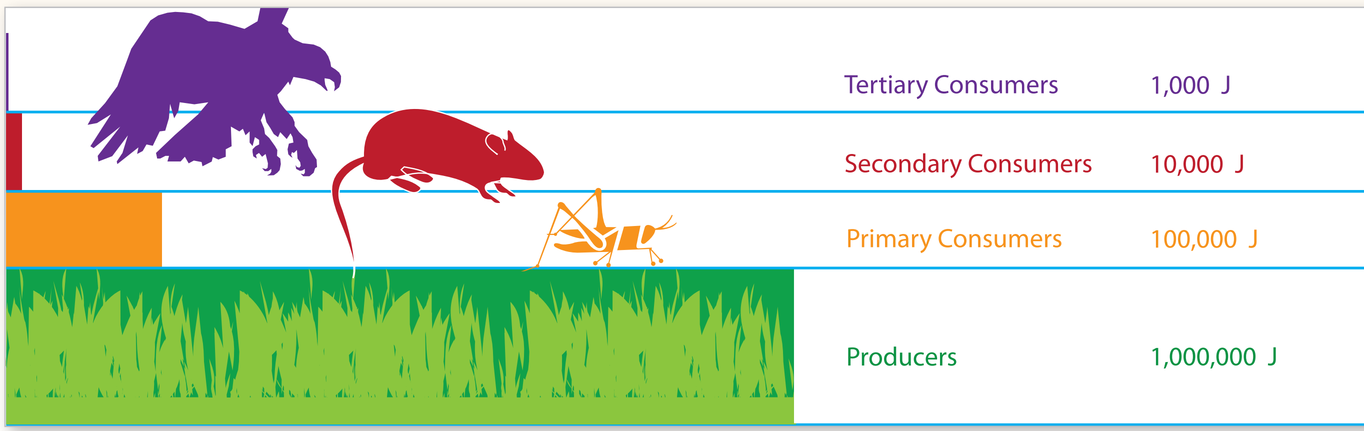
3.2 Food is a biofuel used by organisms to acquire energy for internal living processes. Food is composed of molecules that serve as fuel and building material for all organisms as energy stored in the molecules is released and used. The breakdown of food molecules enables cells to store energy in new molecules that are used to carry out the many functions of the cell and thus the organism.

3.3 Energy available to do useful work decreases as it is transferred from organism to organism. The chemical elements that make up the molecules of living things are passed through food chains and are combined and recombined in different ways. At each level in a food chain, some energy is stored in newly made chemical structures, but most is dissipated into the environment. Continual input of energy, mostly from sunlight, keeps the process going.

3.4 Energy flows through food webs in one direction, from producers to consumers and decomposers. An organism that eats lower on a food chain is more energy efficient than one eating higher on a food chain. Eating producers is the lowest, and thus most energy efficient, level at which an animal can eat.

3.5 Ecosystems are affected by changes in the availability of energy and matter. The amount and kind of energy and matter available constrains the distribution and abundance of organisms in an ecosystem and the ability of the ecosystem to recycle materials.

3.6 Humans are part of Earth's ecosystems and influence energy flow through these systems. Humans are modifying the energy balance of Earth's ecosystems at an increasing rate. The changes happen, for example, as a result of changes in agricultural and food processing technology, consumer habits, and human population size.



Imagine 25,000,000 joules (J) of energy falling on a population of plants. The plants will make use of about 1,000,000 J of this energy. As the plants are eaten by primary consumers, only about 10% of that energy will be passed on. This process of loss continues as primary consumers are eaten by secondary, and secondary by tertiary. Only about 10% of the energy available at one level will be passed on to the next.

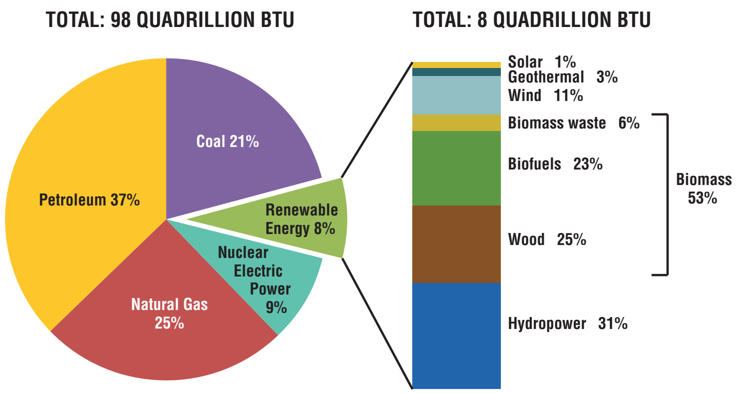
4 Various sources of energy can be used to power human activities, and often this energy must be transferred from source to destination.

4.1 Humans transfer and transform energy from the environment into forms useful for human endeavors. The primary sources of energy in the environment include fuels like coal, oil, natural gas, uranium, and biomass. All primary source fuels except biomass are non-renewable. Primary sources also include renewable sources such as sunlight, wind, moving water, and geothermal energy.

4.2 Human use of energy is subject to limits and constraints. Industry, transportation, urban development, agriculture, and most other human activities are closely tied to the amount and kind of energy available. The availability of energy resources is constrained by the distribution of natural resources, availability of affordable technologies, socioeconomic policies, and socioeconomic status.

4.3 Fossil and biofuels are organic matter that contain energy captured from sunlight. The energy in fossil fuels such as oil, natural gas, and coal comes from energy that producers such as plants, algae, and cyanobacteria captured from sunlight long ago. The energy in biofuels such as food, wood, and ethanol comes from energy that producers captured from sunlight very recently. Energy stored in these fuels is released during chemical reactions, such as combustion and respiration, which also release carbon dioxide into the atmosphere.

U.S. Primary Energy Consumption by Energy Source, 2010



NOTE: Sum of biomass components does not equal 53% due to independent rounding.
Source: U.S. Energy Information Administration, *Annual Energy Review 2010.*

4.4 Humans transport energy from place to place. Fuels are often not used at their source but are transported, sometimes over long distances. Fuels are transported primarily by pipelines, trucks, ships, and trains. Electrical energy can be generated from a variety of energy resources and can be transformed into almost any other form of energy. Electric circuits are used to distribute energy to distant locations. Electricity is not a primary source of energy, but an energy carrier.

4.5 Humans generate electricity in multiple ways. When a magnet moves or magnetic field changes relative to a coil of wire, electrons are induced to flow in the wire. Most human generation of electricity happens in this way. Electrons can also be induced to flow through direct interaction with light particles; this is the basis upon which a solar cell operates. Other means of generating electricity include electrochemical, piezoelectric, and thermoelectric.

4.6 Humans intentionally store energy for later use in a number of different ways. Examples include batteries, water reservoirs, compressed air, hydrogen, and thermal storage. Storage of energy involves many technological, environmental, and social challenges.

4.7 Different sources of energy and the different ways energy can be transformed, transported, and stored each have different benefits and drawbacks. A given energy system, from source to sink, will have an inherent level of energy efficiency, monetary cost, and environmental risk. Each system will also have national security, access, and equity implications.

5 Energy decisions are influenced by economic, political, environmental, and social factors.

5.1 Decisions concerning the use of energy resources are made at many levels. Humans make individual, community, national, and international energy decisions. Each of these levels of decision making has some common and some unique aspects. Decisions made beyond the individual level often involve a formally established process of decision-making.

5.2 Energy infrastructure has inertia. The decisions that governments, corporations, and individuals made in the past have created today's energy infrastructure. The large amount of money, time, and technology invested in these systems makes changing the infrastructure difficult, but not impossible. The decisions of one generation both provide and limit the range of possibilities open to the future generations.

5.3 Energy decisions can be made using a systems-based approach. As individuals and societies make energy decisions, they can consider the costs and benefits of each decision. Some costs and benefits are more obvious than others. Identifying all costs and benefits requires a careful and informed systems-based approach to decision making.

5.4 Energy decisions are influenced by economic factors. Monetary costs of energy affect energy decision making at all levels. Energy exhibits characteristics of both a commodity and a differentiable product. Energy costs are often subject to market fluctuations, and energy choices made by individuals and societies affect these fluctuations. Cost differences also arise as a result of differences between energy sources and as a result of tax-based incentives and rebates.

5.5 Energy decisions are influenced by political factors. Political factors play a role in energy decision making at all levels. These factors include, but are not limited to, governmental structure and power balances, actions taken by politicians, and partisan-based or self-serving actions taken by individuals and groups.

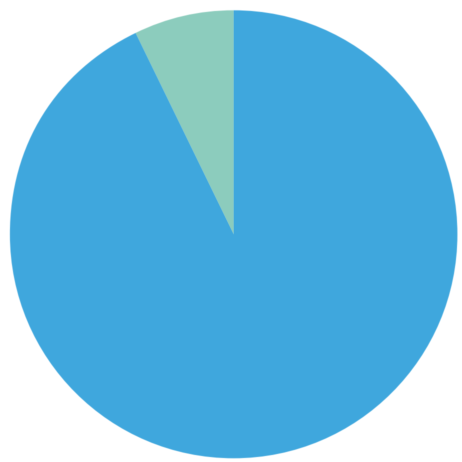
5.6 Energy decisions are influenced by environmental factors. Environmental costs of energy decisions affect energy decision making at all levels. All energy decisions have environmental consequences. These consequences can be positive or negative.

5.7 Energy decisions are influenced by social factors. Questions of ethics, morality, and social norms affect energy decision making at all levels. Social factors often involve economic, political, and environmental factors.

Global Energy Subsidies, 2010

Renewable Energy Subsidies – $66 billion

Fossil Fuel Subsidies – $409 billion



Source – International Energy Agency (IEA), World Energy Outlook, 2011

Decisions regarding energy subsidies have a signifcant effect on energy infrastructure, energy use, and on related impacts and consequences.

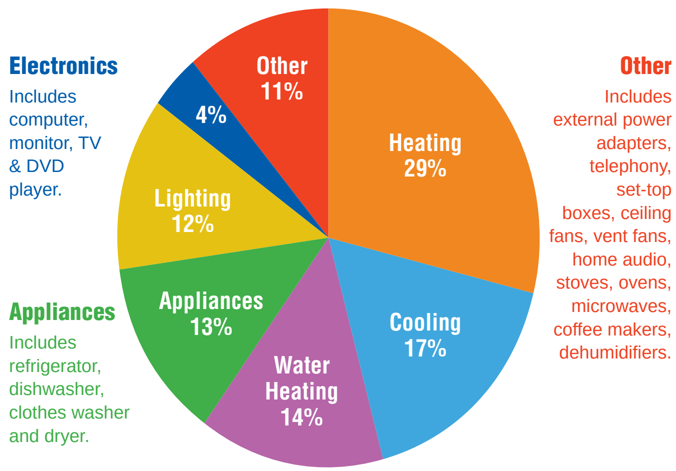
6 The amount of energy used by human society depends on many factors.

6.1 Conservation of energy has two very different meanings. There is the physical law of conservation of energy. This law says that the total amount of energy in the universe is constant. Conserving energy is also commonly used to mean the decreased use of societal energy resources. When speaking of people conserving energy, this second meaning is always intended.

6.2 One way to manage energy resources is through conservation. Conservation includes reducing wasteful energy use, using energy for a given purpose more efficiently, making strategic choices as to sources of energy, and reducing energy use altogether.

Where Does My Money Go?

Annual Energy Bill for a typical U.S. Single Family Home is approximately $2,200.



Source: Typical House memo, Lawrence Berkeley National Laboratory, 2009 and Typical house_2009_Reference.xls spreadsheet.

Average price of electricity is 11.3 cents per kilo-watt hour. Average price of natural gas is $13.29 per million Btu.

6.3 Human demand for energy is increasing. Population growth, industrialization, and socioeconomic development result in increased demand for energy. Societies have choices with regard to how they respond to this increase. Each of these choices has consequences.

6.4 Earth has limited energy resources. Increasing human energy consumption places stress on the natural processes that renew some energy resources and it depletes those that cannot be renewed.

6.5 Social and technological innovation affects the amount of energy used by human society. The amount of energy society uses per capita or in total can be decreased. Decreases can happen as a result of tech nological or social innovation and change. Decreased use of energy does not necessarily equate to decreased quality of life. In many cases it will be associated with increased quality of life in the form of increased economic and national security, reduced environmental risks, and monetary savings.

6.6 Behavior and design affect the amount of energy used by human society. There are actions individuals and society can take to conserve energy. These actions might come in the form of changes in behavior or in changes to the design of technology and infrastructure. Some of these actions have more impact than others.

6.7 Products and services carry with them embedded energy. The energy needed for the entire lifecycle of a product or service is called the "embedded" or "embodied" energy. An accounting of the embedded energy in a product or service, along with knowledge of the source(s) of the energy, is essential when calculating the amount of energy used and in assessing impacts and consequences.

6.8 Amount of energy used can be calculated and monitored. An individual, organization, or government can monitor, measure, and control energy use in many ways. Understanding utility costs, knowing where consumer goods and food come from, and understanding energy efficiency as it relates to home, work, and transportation are essential to this process.

The Energy Star program is run jointly by the U.S. Department of Energy and the Environmental Protection Agency. The Energy Star logo designates products as highly energy efficient.

ENERGY STAR

7 The quality of life of individuals and societies is affected by energy choices.

7.1 Economic security is impacted by energy choices. Individuals and society continually make energy choices that have economic consequences. These consequences come in the form of monetary cost in general and in the form of price fluctuation and instability specifically.

7.2 National security is impacted by energy choices. The security of a nation is dependent, in part, on the sources of that nation's energy supplies. For example, a nation that has diverse sources of energy that come mostly from within its borders is more secure than a nation largely dependent on foreign energy supplies.

7.3 Environmental quality is impacted by energy choices. Energy choices made by humans have environmental consequences. The quality of life of humans and other organisms on Earth can be significantly affected by these consequences.

7.4 Increasing demand for and limited supplies of fossil fuels affects quality of life. Fossil fuels provide the vast majority of the world's energy. Fossil fuel supplies are limited. If society has not transitioned to sources of energy that are renewable before depleting Earth's fossil fuel supplies, it will find itself in a situation where energy demand far exceeds energy supply. This situation will have many social and economic consequences.

7.5 Access to energy resources affects quality of life. Access to energy resources, or lack thereof, affects human health, access to education, socioeconomic status, gender equality, global partnerships, and the environment.

7.6 Some populations are more vulnerable to impacts of energy choices than others. Energy decisions have economic, social, and environmental consequences. Poor, marginalized, or underdeveloped populations can most benefit from positive consequences and are the most susceptible to negative consequences.

At left - Students from a school in Madavunu, Ghana ride a merry-go-round that generates electricity for the school. The school and village are otherwise without electricity.

At right - Students do school work by the light of a rechargeable LED lamp. The battery-powered lamps are recharged by the merry-go-round and can be used in classrooms and at home.

(Photos courtesy of Empower Playgrounds. Chris Owen, photographer.)

Guiding Principle for Teaching and Learning:

Much is understood about how people learn. Effective learning opportunities are designed with these understandings in mind.*

Fundamental Concepts

1. **People are born investigators and learners.** People come to new learning experiences with preconceived ideas and prior knowledge. They have developed their own ideas about how the physical, biological, and social worlds work. Effective learning opportunities acknowledge and access these preconceived ideas and prior knowledge, building on correct understandings and addressing those that are incorrect.

2. **Effective learning focuses on a core set of ideas and practices.** Focus on a core set of ideas and practices—rather than a broad array of what can become disconnected knowledge and isolated facts—allows a learner to make sense of new information and to tackle new problems effectively. This process is aided by explicit instructional support that stresses connections across different topics, disciplines, and learning experiences.

3. **Understanding develops over time.** To develop a thorough understanding of the world and how it works—and to appreciate interconnections—learners need sustained opportunities, over a period of years, to work with and develop underlying ideas. People can continue learning about core ideas their entire lives. Because learning progressions extend over many years, educators must consider how topics are presented at different levels as they build on prior understanding in support of increasingly sophisticated learning.

4. **Literacy requires both knowledge and practice.** The social and natural sciences are not just bodies of knowledge; they are also a set of practices used to establish, extend, and refine that knowledge. Effective teaching infuses these same practices into the learning experience, engaging learners in inquiry-based, authentic experiences that rely on credible information, data, and evidence as the foundation for taking a position, forming conclusions, or making claims.

This young girl is assembling a fuel cell car that is used as part of a lesson on hydrogen and fuel cells.

5. **Connection to interests and experiences enhances learning.** Personal interest and experience is a critical part of an effective learning process. Learners must be helped to see how topics connect to their personal experience and are relevant to them. This not only aids learning in general, but helps to foster lifelong learning.

6. **Educational opportunities must be equitable and accessible to all.** Effective learning requires the right tools and opportunities, and these tools and opportunities must be suited to each individual's needs.

---

* The Fundamental Concepts outlined here are based on a set of six guiding principles laid out in, "A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas," National Research Council, Board on Science Education, 2011. Please see the NRC Framework for more discussion of these concepts and for further references.

Key Definitions

Definitions given here are for the purposes of this document and are not necessarily complete or exhaustive. Words or phrases included here are those for which there may be some confusion as to the meaning intended.

Biofuel – A fuel produced from biomass or biomass used directly as a fuel. Compare Biomass.

Biomass – Organic nonfossil material of biological origin. Compare Biofuel.

Chemical Reaction – A process that involves changes in the structure and energy content of atoms, molecules, or ions but not their nuclei. Compare Nuclear Reaction.

Commodity – A good for which there is demand, but which is supplied without qualitative differentiation across a market. The market treats it as equivalent or nearly so no matter who produces it. Compare Differentiable Product.

Conservation of Energy – See Fundamental Concept 6.1.

Degrade (as in energy) – The transformation of energy into a form in which it is less available for doing work.

Differentiable Product – A product whose price is not universal. A product whose price is based on factors such as brand and perceived quality. Compare Commodity.

Efficient – The use of a relatively small amount of energy for a given task, purpose, or service; achieving a specific output with less energy input.

Embedded or **Embodied Energy** – See Fundamental Concept 6.7.

Energy – See Fundamental Concept 1.1.

Energy Carrier – A source of energy that has been subject to human-induced energy transfers or transformations. Examples include hydrogen fuel and electricity. Compare Primary Energy Source.

Fossil Fuel – Fuel formed from biomass by a process taking millions of years or longer.

Fuel – A material substance that possesses internal energy that can be transferred to the surroundings for specific uses. Included are petroleum, coal, and natural gas (the fossil fuels), and other materials, such as uranium, hydrogen, and biofuels.

Geothermal Energy – See Fundamental Concept 2.2.

Heat – See Fundamental Concept 1.2.

Kinetic Energy – See Fundamental Concept 1.5.

Nuclear Reaction – A reaction, as in fission, fusion, or radioactive decay, that alters the energy, composition, or structure of an atomic nucleus. Compare Chemical Reaction.

Political – Of, relating to, or dealing with the structure or affairs of government, politics, or the state. Or, relating to, involving characteristic of politics or politicians. Or, based on or motivated by partisan or self-serving objectives.

Potential Energy – See Fundamental Concept 1.5.

Power – See Fundamental Concept 1.8.

Primary Energy Source or **Primary Source** – A source of energy found in nature that has not been subject to any human-induced energy transfers or transformations. Examples include fossil fuels, solar, wind and hydropower. Compare Energy Carrier.

Renewable Energy – Energy obtained from sources that are virtually inexhaustible (defined in terms of comparison to the lifetime of the Sun) and replenish naturally over small time scales relative to the human life span.

Reservoir – A place where a supply or store of something is kept or located.

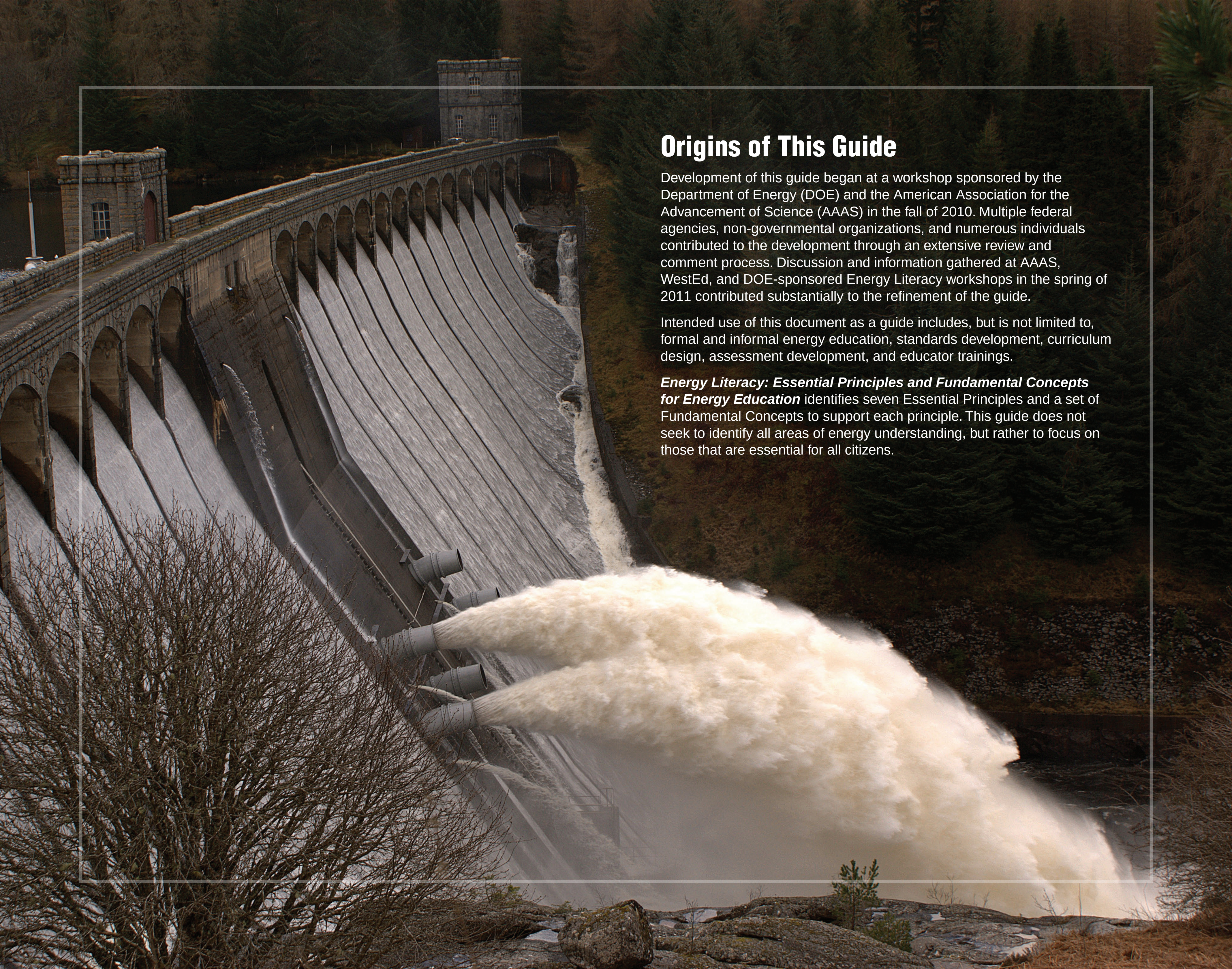
System – A set of connected things or parts forming a complex whole. In particular, a set of things working together as parts of a mechanism or an interconnecting network. The place one system ends and another begins is not an absolute, but instead must be defined based on purpose and situation.

Systems-Based Approach – An approach that emphasizes the interdependence and interactive nature of elements within and external to events, processes, and phenomena. An approach that seeks to identify and understand all cause-and-effect connections related to a given event, process, or phenomenon.

Sustainable – Able to be maintained at a steady level without exhausting natural resources or causing severe ecological damage, as in a behavior or practice.

Thermal Energy – See Fundamental Concept 1.2.

Work – See Fundamental Concept 1.1.



Origins of This Guide

Development of this guide began at a workshop sponsored by the Department of Energy (DOE) and the American Association for the Advancement of Science (AAAS) in the fall of 2010. Multiple federal agencies, non-governmental organizations, and numerous individuals contributed to the development through an extensive review and comment process. Discussion and information gathered at AAAS, WestEd, and DOE-sponsored Energy Literacy workshops in the spring of 2011 contributed substantially to the refinement of the guide.

Intended use of this document as a guide includes, but is not limited to, formal and informal energy education, standards development, curriculum design, assessment development, and educator trainings.

Energy Literacy: Essential Principles and Fundamental Concepts for Energy Education identifies seven Essential Principles and a set of Fundamental Concepts to support each principle. This guide does not seek to identify all areas of energy understanding, but rather to focus on those that are essential for all citizens.

U.S. Global Change Research Program Partner Agencies:

- Department of Agriculture
- Department of Commerce
- Department of Defense
- Department of Energy
- Department of Health and Human Services
- Department of the Interior
- Department of State
- Department of Transportation
- Environmental Protection Agency
- National Aeronautics and Space Administration
- National Science Foundation
- The Smithsonian Institution
- US Agency for International Development

Education Partners:

- Alliance to Save Energy
- American Association for the Advancement of Science, Project 2061
- American Association of Blacks in Energy
- American Nuclear Society
- Association of Public and Land-Grant Universities
- Center of Science and Mathematics in Context, University of Massachusetts, Boston
- Chabot Space & Science Center
- Climate Literacy and Energy Awareness Network
- Cooperative Institute for Research in the Environmental Sciences, University of Colorado, Boulder
- Energy Bridge
- KQED San Francisco, QUEST
- National Center for Science Education
- National Council for Science and the Environment
- National Energy Education Development Project
- National Energy Foundation
- National Science Teachers Association
- North American Association for Environmental Education
- Otherlab
- Science Museum of Minnesota
- TERC
- WestEd
- Wisconsin K-12 Energy Education Program
- Women Impacting Public Policy

U.S. Department of Energy
1000 Independence Ave SW
Washington, DC 20585
202-586-5000
http://www1.eere.energy.gov/education/energy_literacy.html

DOE/EE-0772

Version 1.1: July 2012