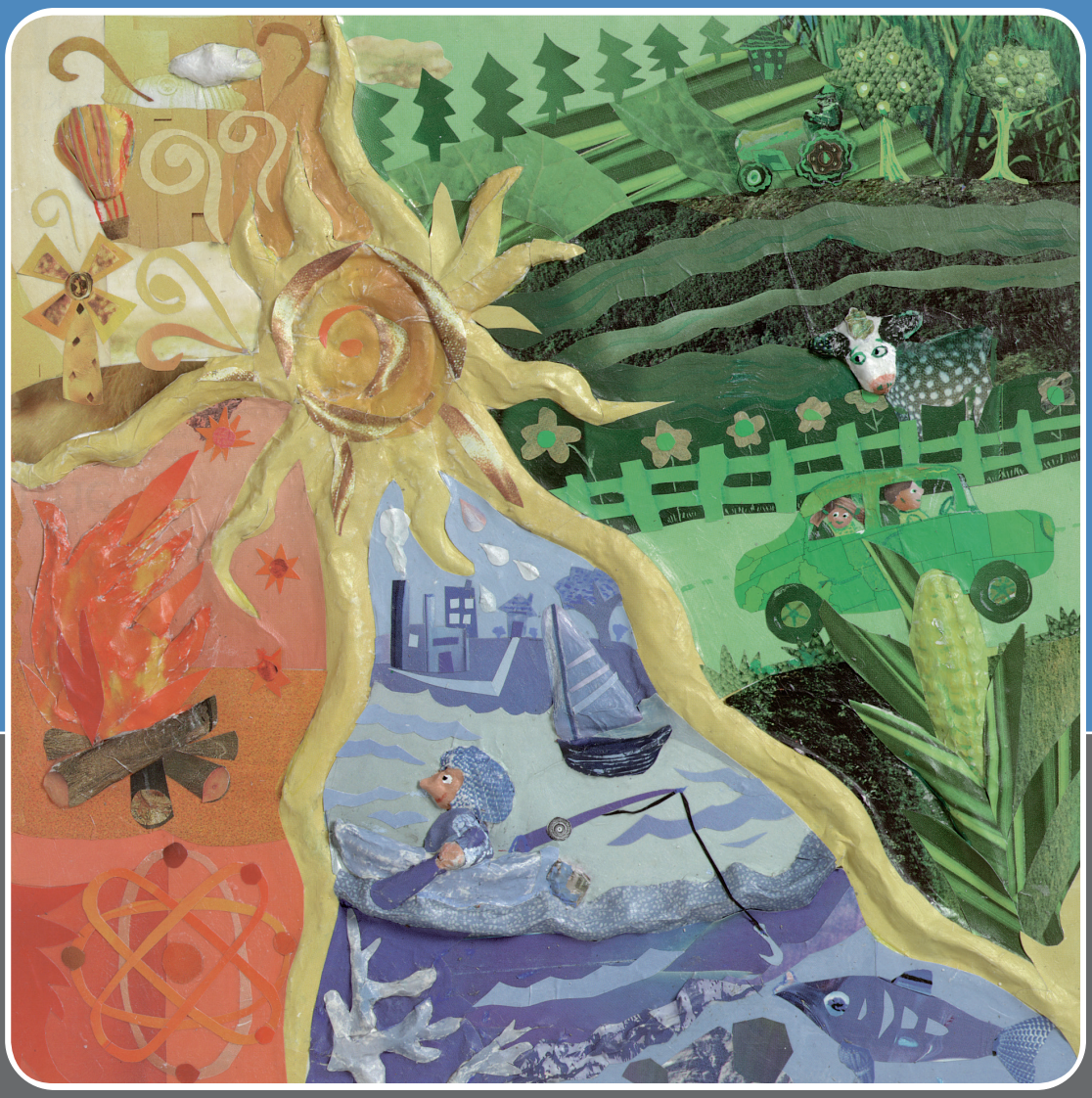

Wisconsin K-12 Energy Education Program

A Conceptual Guide to K-12 Energy Education in Wisconsin

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College of Natural Resources
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Conceptual Framework

Introduction

This energy education conceptual framework is not a curriculum in itself, rather, it is a skeleton that provides the foundation for a curriculum. Just as the bones of a skeleton provide strength and structure to a body, the concepts that make up the framework provide the basis for a strong, organized, and comprehensive curriculum. We have endeavored to provide concepts that address a variety of different issues and viewpoints.

These concepts were derived from energy-related frameworks designed by other educational organizations (National Energy Foundation, 1988; North American Association for Environmental Education, 1990) and from physical and environmental science texts. We developed additional concepts to reflect issues specific to Wisconsin. Throughout this process, the KEEP Steering Committee and two focus groups—consisting of energy resource management specialists, curriculum planners, and educators—reviewed and evaluated the framework. Their assistance helps ensure that the concepts in this framework form the basis of a logically sequenced, comprehensive energy education.

This framework is designed to evolve as energy education evolves. For example, this latest revision of the framework includes renewable energy concepts. These concepts were identified and validated by a Delphi panel comprised of renewable energy resource experts and educators. The renewable energy concepts are noted in the framework with an icon.

We encourage teachers and curriculum developers to assist with this evolution by modifying and adding to this framework as they build a curriculum that best fits the needs of their educational programs.

Framework Organization

The concepts within the framework are organized under four themes. Each theme consists of concepts which are further organized into subthemes.

The themes are arranged so that they build upon each other. The information in the first theme lends understanding to concepts in the second theme, and so forth. The first theme, We Need Energy, defines energy, describes how energy is transferred and converted from one form to another according to the laws of thermodynamics, and explains how energy flows through living and nonliving systems. Developing Energy Resources addresses the sources of energy and how humans, through technology, use energy to meet societal wants and needs. It also shows how humans have come to treat energy as a resource. Effects of Energy Resource Development covers how using energy resources affects human societies and the environment. Finally, Managing Energy Resource Use identifies strategies we can use to help resolve many of the issues presented in the third theme. In addition, this theme discusses how today's energy related decisions and actions influence the future availability of energy resources.

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We Need Energy

The concepts within this theme provide students with a fundamental knowledge about energy and help students appreciate the nature of energy in their everyday lives. This provides students with an awareness of how energy is used to maintain, organize, and change systems that affect their lives. These concepts also provide the foundation upon which the concepts in the following themes are built.

Definition of energy

Understanding these concepts helps students to identify forms of energy.

1. Energy is the ability to organize or change matter or "the ability to do work."
2. Energy exists in two main forms: potential energy (energy stored in matter) and kinetic energy (energy of motion). More specific forms of energy include thermal, elastic, electromagnetic (such as light, electrical, and magnetic energy), gravitational, chemical, and nuclear energy.
3. Energy can be measured and quantified. Different units of measure can be used to quantify energy. One unit can be converted to another. Units of measure for energy include calories and kilowatt-hours.
4. Power is the rate at which energy is used. Units of measure for power include horsepower and watts.

Natural laws that govern energy

Mastering these concepts helps students interpret how energy is transferred and converted. It also helps them recognize that there are natural limitations to the amount of energy that anyone or anything can use.

5. Energy can be transferred from one location to another, as in when the sun's energy travels through space to Earth. The two ways that energy can be transferred are by doing work (such as pushing an object) and by transferring heat (conduction, convection, and radiation).
6. Energy can neither be created nor destroyed, it can only be converted from one form to another. This is the first law of thermodynamics. For example, the chemical energy stored in coal can be converted into thermal energy.
7. With each energy conversion from one form to another, some of the energy becomes unavailable for further use. This is the second law of thermodynamics. For example, the thermal energy released by burning coal is eventually dispersed into the environment and cannot be used again. The measure of this dispersal of energy is called "entropy." For example, the entropy of an unburned piece of coal and its surroundings is lower than the entropy of the ashes, cinders, and the warmed surroundings due to burning that piece of coal.

Energy flow in systems

Comprehending these concepts helps students interpret the natural laws that govern energy flow through living and nonliving systems.

8. All systems obey the natural laws that govern energy.

9. Some of the energy converted by systems flows through them. The rest is stored within them for seconds or even millions of years. Some systems convert energy more efficiently than others.

Energy flow in nonliving systems

Understanding these concepts helps students explain how energy creates weather patterns and shapes Earth's surface.

10. Energy flows through and is stored within a variety of nonliving systems.

- Solar energy absorbed and distributed on Earth's surface gives rise to weather systems and ocean currents.
- The thermal energy stored in Earth's interior shapes and moves Earth's crust as in earthquakes, mountain building, and volcanic activity.

Energy flow in living systems

By mastering these concepts, students should be able to illustrate how humans and other organisms get the energy they need to survive.

11. Living systems use energy to grow, change, maintain health, move, and reproduce. Some of the energy acquired by living systems is stored for later use.

- Plants and other autotrophs convert solar energy to chemical energy via photosynthesis.
- Animals and other heterotrophs covert chemical energy in plants or in other animals to chemical energy they can use via cellular respiration.
- Energy is needed for maintaining the health—nutrition and the quality and quantity of food—of all organisms, including humans.

12. Living systems differ in how fast they use energy. Some living systems—such as birds—use energy quickly for growth and metabolism, and therefore must replace it quickly. Others—such as turtles—use energy more slowly and, therefore, need to replace it less frequently.

Energy flow in ecosystems, including human societies

Fully comprehending these concepts helps students recognize how energy flows through and characterizes ecosystems. It also helps students appreciate that the world around them—including human societies—depends on a continuous supply of energy.

13. Ecosystems use energy to maintain biogeochemical cycles—such as the sedimentary, gaseous, and hydrologic cycles—between living and nonliving systems.

14. Ecosystems are characterized by:

- Types and quantities of available energy sources, such as the chemical energy stored in plants.
- Types and characteristics of energy flows, such as food webs.
- Energy budgets, which are the amount of energy available with respect to the amount of energy used by an ecosystem. The total energy budget of an ecosystem determines its carrying capacity.
- An ability to use energy to maintain a balanced or steady state.

15. Wisconsin has five main biological communities: northern forest, southern forests, prairies, oak savanne and aquatic.

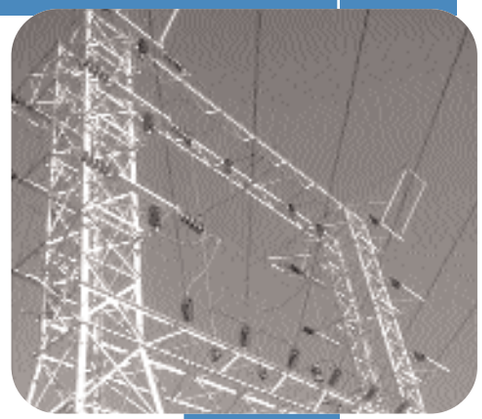
16. Human societies, like natural ecosystems, need energy to organize and maintain themselves. The human use of energy follows the natural laws that govern energy flow in all systems.

17. Human societies range from hunter-gatherer to industrial and can be classified by the amount of energy they use and the rate at which they use it.

- Hunter-gatherer societies are adapted to their natural environments. They depend on energy and materials available directly from nature, and their rates of consumption of the energy and materials they use are often in balance with nature.
- Non-industrial agricultural societies modify their natural environments primarily to domesticate food sources. They depend on modest technologies to provide energy and materials.
- Industrial societies attempt to remake and control their natural environment. They have high rates of energy consumption, depend on sophisticated technologies, and require a substantial energy subsidy to provide energy and materials for residential, commercial, industrial, agricultural, and transportation needs.

18. In general, Wisconsin and the rest of the United States is an industrial, technologically advanced, high-energy-use society.

Developing Energy Resources



This theme helps students realize how they and other humans have become more and more dependent on the development and use of energy resources to satisfy their standard of living. Understanding what energy is and how it flows through systems is necessary to appreciate how humans have come to value and treat energy as a resource.

Development of energy resources

Understanding these concepts helps students explain how humans have used technology to further their ability to use energy. It also helps students identify and compare different energy resources—such as renewable and nonrenewable—and appreciate the importance of energy-related technologies.

19. Primary energy sources are those that are either found or stored in nature.

- See concept 20 for secondary energy resources.
- See concept 25 for renewable and nonrenewable energy resources.

- The sun is a primary energy source and the principal source of Earth's energy. Energy from the sun is stored in other primary energy sources such as coal, oil, natural gas, and biomass (such as wood). Solar energy is also responsible for the energy in the wind and in the water cycle (the hydrologic cycle).

- See concept 13 for the hydrologic and other biogeochemical cycles.

- Other primary energy sources found on Earth include nuclear energy from radioactive substances, thermal energy stored in Earth's interior, and potential energy due to Earth's gravity.

20. Secondary energy resources are produced from primary energy resources using technology. For example, we produce electricity—a secondary resource—by burning coal in a power plant or by using photovoltaic cells to harness solar energy. We can also produce alcohol fuel from crops.

21. Energy sources are considered to be energy resources by individuals and society when they serve societal needs and wants. Examples of using resources are burning wood for warmth as well as extracting and refining oil to produce fuel for transportation or materials such as plastic.

22. Human societies have obtained energy resources in the following ways:

- Hunter-gatherer societies get their energy from decentralized energy systems—as in gathering wood from a forest and burning it to cook food.

- Nonindustrial agricultural societies also get their energy from decentralized energy systems—such as using windmills to grind grain—although these systems are more centralized than those of hunter-gatherer societies.

- Industrial societies get their energy from a mix of centralized energy systems (power plants) and decentralized energy systems (solar panels on rooftops), with centralized energy systems being the dominant energy system. Most of these energy systems are developed by understanding the natural laws that govern energy and applying this knowledge to create sophisticated energy technologies.

23. Some energy sources are concentrated, such as the nuclear energy stored in enriched uranium used in a nuclear power plant, and others are diffuse, such as thermal energy stored in the oceans.

24. Geographically, Earth's energy sources are unevenly distributed.

25. Energy resources are described as nonrenewable and renewable.

- Nonrenewable resources are either replaced very slowly or are not replaced at all by natural processes. Nonrenewable resources include fossil fuels—coal, oil, and natural gas—and nuclear fuels such as uranium.
- Renewable energy resources can be replaced quickly by natural processes. Renewable resources include solar energy, wind, hydropower, and biomass. Even some of these resources can be depleted when their rate of use exceeds their rate of replacement.

• Concepts related to renewable energy resources are provided on page 21.

26. Wisconsin has primary energy sources.

27. Most of the energy resources currently used in Wisconsin are fossil and nuclear fuels, all of which are imported into the state. Other resources used in Wisconsin include biomass, hydropower, solar energy, and wind, all of which are renewable and can be found within the state.

Consumption of energy resources

Mastering these concepts helps students assess modern human societies' dependence on energy and analyze how we have come to value energy as a resource.

28. Supply and demand influence energy resource discovery, development, and use. The supply and demand for an energy resource is determined by resource availability, level of technological development, and societal factors such as lifestyle, health and safety, economics, politics, and culture.

• See the next theme, Effects of Energy Resource Use for concepts that address the economic and sociopolitical effects of energy consumption.

29. Global demands for energy resources are increasing. This is due to human population growth and increasing worldwide consumption. As certain energy resources are depleted and demand increases, competition for these resources also increases. This is especially true of non-renewable resources, such as fossil fuels.

Developing Renewable Energy Resources

These concepts further describe concept 25. They help students realize how they and other humans develop and use renewable energy resources to satisfy their standard of living. Understanding what renewable energy is and how it flows through systems is necessary to appreciate how humans have come to value and treat renewable energy as a resource.

Development of renewable energy resources

Mastering these concepts helps students comprehend renewable energy.

25.1. Renewable energy resources come from sources that can be continuously replenished.

25.2. Renewable resources people commonly use are solar, wind, hydropower, biomass, and geothermal.

25.3. Human societies have used renewable resources to meet their energy needs throughout history.

25.4. Renewable energy is a reliable energy source for many residential and commercial applications, including heat generation, electricity generation, and vehicle fuel.

25.5. Each renewable energy resource has inherent qualities that make it more suitable for some applications than others.

25.6. The efficiency of converting renewable energy sources to useable energy varies according to the source and/or technology used.

25.7. The availability of renewable energy varies; some renewable resources are in constant supply, while others are intermittent. Intermittent energy can be stored for future use.

25.8. Renewable energy systems can be centralized or decentralized. A centralized energy system is one in which large amounts of an energy resource are converted from one form into another form in one location. A decentralized energy system is one in which small amounts of an energy resource are converted from one form into another form in many locations by individuals or small groups of consumers.

Solar Energy

Comprehending these concepts helps students understand solar energy.

25.9. Solar energy is the radiation from the sun that reaches Earth's surface.

25.10. Solar energy is used to generate electricity or to heat air or water. Solar heating can be passive or active. A passive solar heating system captures the sun's energy within a structure and converts it into low-temperature heat, which then naturally circulates. In an active solar heating system, collectors absorb solar energy, and pumps or other devices are used to circulate the heated fluid.

Wind Energy

Comprehending these concepts helps students understand wind energy.

25.11. Wind is air in motion and is produced by the unequal heating of Earth's surface by the sun.

25.12. Wind energy is used to generate electricity, grind grain, and pump water. Wind speed increases above Earth's surface, so wind turbines are mounted on tall towers.

Hydropower

Comprehending these concepts helps students understand hydropower energy.

25.13. Hydropower is the kinetic energy generated by falling water. The water's flow (volume) and fall (height) determine the amount of available energy in moving water.

25.14. Hydropower plants capture the kinetic energy of falling water to generate electricity. People capture the energy by damming a river, creating an artificial reservoir, or channeling a portion of a river through a generating facility.

Biomass

Comprehending these concepts helps students understand biomass energy.

25.15. Biomass energy is the energy released from living or recently living organic matter (as opposed to fossil fuels). People release the energy in organic matter through processes such as burning and fermentation.

25.16. Biomass can be used for a variety of purposes. It can be burned to generate electricity and heat and can be processed to produce fuel.

Geothermal Energy

Comprehending these concepts helps students understand geothermal energy.

25.17. Geothermal energy is heat energy that originates within Earth. Geothermal resources range from shallow ground sources (low temperature) to hot water, steam and rock miles below Earth's surface (high temperature).

25.18. Geothermal resources can be used for a variety of purposes. Low temperature geothermal resources use the relatively constant temperature of the soil or surface water as a heat source and sink for a heat pump, which heats and cools buildings. High temperature geothermal resources are underground reservoirs of hot water or steam that can be tapped for electrical power production.

Effects of Energy Resource Development

Concepts in this theme help students investigate how energy use has affected their lives. Recognizing these effects increases students' awareness of why and how they use energy and promotes an understanding of why it's important to manage energy resource use.

Quality of life

Understanding these concepts helps students analyze current energy-use practices and evaluate how they affect quality of life.

Lifestyles

30. A driving factor in the development of energy-related technology has been people's desire for comfort, convenience, and entertainment.

- See concepts 58-61 for how comfort, convenience, and entertainment relate to cultural aspects of energy development and use.

31. Technologies that support people's lifestyles may lead to the inefficient use of energy resources, depending on how these technologies are designed and used.

32. Individuals can purchase renewable energy from centralized sources such as power utilities. Using renewable energy from these sources requires no modification of lifestyle.

33. Individuals and businesses can create their own renewable energy from decentralized systems such as a wind system. Using renewable energy from a decentralized system may require the following lifestyle modifications:

- Monitoring and maintaining the system
- Employing energy efficient building construction techniques
- Using energy efficient appliances and lights
- Monitoring and managing their energy use

34. The reasons people choose to use renewable energy include the following: environmental concerns, economic concerns, ethical concerns, interest in technology, desire to be self-sufficient, and concerns about electrical reliability.

Health and safety

35. There are personal and community health and safety factors associated with the development and use of energy resources. Energy resource development and use may pose direct risks to personal and community health and safety. By affecting the quality of the environment, energy use may pose indirect risks to personal and community health and safety.

- See concept 65 for environmental risks to the health and well-being of human and nonhuman life.

36. The health and safety of Wisconsin citizens is related to the development and use of energy resources.

37. Using renewable energy will reduce some personal and community health risks since it generally releases fewer pollutants into the environment than fossil fuels.

38. Decentralized renewable energy systems require proper maintenance to be safe.

Economic

39. The availability and use of energy resources influence the economic growth and well-being of society.

40. Many occupations, businesses, and public services—such as utilities—result from the development and use of energy resources.

41. The market price of energy includes the cost of energy resource exploration, recovery, refining, pollution control, distribution, and transportation, as well as taxes and other fees.

42. Other costs that are not part of the market price of energy (called externality costs) are due to factors such as environmental damage, property damage, civil unrest, war, and health care.

43. The rate of energy consumption is influenced by energy prices and externality costs.

44. The cost of energy is a factor in Wisconsin's economic development and affects the household budget of Wisconsin citizens.

45. When consumers consider purchasing renewable energy systems, they are often concerned about payback. Payback refers to recovering the initial cost of purchasing and installing a renewable energy system through its production of energy.

46. With the current prices of energy, some decentralized renewable energy systems will accomplish a full payback within their lifespan. Factors that influence payback include the type of technology, resource used, and location. If demand, production, and technological advances in renewable energy increase, equipment and installation prices will be reduced and the likelihood of payback will increase.

47. When comparing the cost of renewable energy to non-renewable energy, externality costs associated with non-renewable energy should be considered.

48. Many occupations, businesses, and public services (such as utilities) result from the development and use of renewable energy resources.

49. Most renewable energy sources are free. Therefore, development and production investments go toward materials and labor rather than purchasing fuel. This money is often spent within the United States and is frequently spent within the same state or town where the resource is located.

50. Using renewable energy allows the United States to become more energy independent.

Sociopolitical

51. Sociopolitical processes result in laws and regulations that govern energy development, availability, and use. Sociopolitical processes have usually governed centralized energy systems such as public utilities.

52. The demand for energy resources influences relationships—alliances and conflicts—among states, regions, and nations.

53. The positive and negative effects of energy resource development and use are not shared equally among states, regions, nations, and individuals, although sociopolitical processes have made some effort to address this.

54. Wisconsin's sociopolitical processes result in laws and regulations that govern energy development, availability, and use.

55. Support for renewable energy development is influenced by society and politics. In the United States, renewable energy resource development has been governed by the energy policies of political administrations.

56. Sociopolitical processes result in laws and regulations that govern renewable energy development, availability, and use. Access and zoning laws have been developed to guide renewable energy system placement and installation.

57. Renewable energy systems can be owned by individuals, communities, and governments.

Cultural

58. The availability of energy resources has shaped cultures, and each culture has value systems that influence how energy resources are used.

59. Energy use by cultures is expressed through art, architecture, urban planning, music, language and literature, theater, dance, other forms of media, sports, and religion.

60. Because society's understanding of and relationship with energy changes over time, cultural expressions of energy use changes over time as well. For example, ancient Egyptians worshiped the sun, while modern societies associate the sun with a positive mood, recreation, and nature.

61. Wisconsin's culture has been, and will continue to be, shaped in part by available energy resources.

62. Support for renewable energy varies within and among countries, cultures, and governments.

63. Using renewable energy can help mitigate the effects of extracting fossil fuels. Extracting fossil fuels affects the cultures, environments, and health of individuals.

64. Many third world countries are benefiting from the development and deployment of renewable energy equipment from industrialized nations.

Quality of the environment

By comprehending these concepts, students will be able to explain how current energy practices affect the quality of the environment and the health of organisms living in the environment.

65. Energy resource development and use can alter environmental conditions leading to, for example, reduced air and water quality, deforestation, and changes in land use due to road building. These altered environmental conditions may pose risks to the health and well-being of human and other life forms.

66. The faster and more extensively energy resources are developed and used, the more likely it is that environmental conditions will be altered to a greater degree.

67. It takes less energy and less money to preserve the environment than it does to restore the environment after it has been altered.

68. Wisconsin's environment has been, and continues to be, altered by energy resource development and use.

69. Renewable energy technologies use clean sources of energy that have a lower environmental impact than nonrenewable energy sources.

70. There are environmental costs and benefits involved in the development, manufacture, distribution, and installation of renewable energy technologies. Each renewable energy technology and its application (e.g. centralized or decentralized) has unique environmental costs and benefits.

Managing Energy Resource Use

Concepts in this theme help students identify ways to ensure that energy resources will be available for future users. For students to willingly and effectively take action to manage energy resource use, they must have a thorough understanding and appreciation of what energy is, how it flows through systems, its value as a resource, and the effects its use has on human societies and the environment.

Management of energy resource use

By mastering these concepts, students will recognize their ability to make decisions regarding which resources to use and how those decisions influence the future availability of resources. Students will also identify actions they can take based on these decisions.

71. The choice of energy resource and how it is used influences how energy resources are managed.

72. Energy resources may be managed through conservation, which includes reducing wasteful energy use, using energy for a given purpose more efficiently, or reducing energy use altogether. Energy conservation prolongs the availability of energy resources and contributes to the development of a sustainable society.

73. A citizen, acting individually or as part of a group or organization, may make decisions (such as deciding to ride a bicycle instead of driving a car) and take actions (riding the bicycle) that determine how the energy they use will be managed. Citizens may also affect the actions of other individuals, groups, or organizations to determine how the energy they use will be managed. This can be accomplished by ecomanagement (physical action), education, persuasion, consumer action, political action, or legal action.

74. The decisions and actions taken by societies and their citizens depend on the barriers and incentives associated with energy management choices. Examples of barriers include high energy costs, lack of access to new technologies, and laws that discourage the development or use of certain energy resources. Examples of incentives include rebates, building codes that promote energy conservation, and appliance efficiency standards.

75. Energy management products and programs are available to help Wisconsin citizens use energy resources more efficiently, such as through conservation programs, home heating fuel options, and programs that promote certain lifestyles. These products and programs also help maintain the quality of the environment within and beyond Wisconsin.

76. Using renewable energy resources helps prolong the availability of nonrenewable energy resources.

77. Actions supporting renewable energy use can range from simple and inexpensive (e.g., purchasing solar powered calculators) to more advanced and expensive (e.g., installing a home wind system).

78. The use of decentralized renewable energy systems is usually a personal choice rather than a government mandate, although there are government programs that provide incentives for using renewable energy.

Future outlooks for the development and use of energy resources

By understanding these concepts, students can evaluate how their actions affect the quality of life and the environment of their community, nation, and world. Students will also predict how scientific, technological, and social changes will influence future energy resource availability.

79. New energy resources, new ways of managing resources, and new energy technologies will be developed in the future.

80. Choices made today about energy resource management will affect the future quality of life and the environment.

81. New types of societies—such as a sustainable society or a postindustrial society whose economy is based on information and service—may emerge as energy resource development and use changes.

82. Renewable energy use is growing worldwide.

83. Renewable energy technologies continue to improve and become more efficient.

84. New energy resources, new ways of managing energy resources, and new renewable technologies will be developed in the future.