WEATHER AND CLIMATE (4B)

The earth has a variety of climatic patterns, which consist of different conditions of temperature, precipitation, humidity, wind, air pressure, and other atmospheric phenomena. These result from a variety of factors. Climate and changes in climate have influenced in the past and will continue to influence what kinds of life forms are able to exist. Understanding the basic principles that contribute to maintaining and causing changes in weather and climate increases our ability to forecast and moderate the effects of weather and to make informed decisions about human activities that may contribute to climate change.

The map is organized around four strands—*temperature and winds, water cycle, atmosphere,* and *climate change*. The progression of understanding begins in the elementary grades with observations about heat transfer, changes in water from one state to another, and changes in weather over the course of a day and over the course of seasons. By middle school, the focus is on the water cycle, patterns of change in temperature, and the notion of climate change. In high school, seasons and winds and the water cycle are related to gravity and the earth's rotation, and climate change is related to natural causes and human activities.

Benchmarks in this map about temperature and winds draw on ideas about heat transfer and transformation in the **ENERGY TRANSFORMATIONS** map. Benchmarks in the *climate change* strand are also related to the **SCIENCE AND SOCIETY** map. The widespread use of climate models to improve our understanding of the earth's climate system and climate change suggests a connection to benchmarks in the **MODELS** map as well.

NOTES

The left-hand side of the *temperature and winds* strand presents a progression of understanding of seasons. The explanation of the seasons in terms of the tilt of the earth requires students to engage in fairly complex spatial reasoning. For this reason, although the idea is introduced at the 6-8 grade level in *Benchmarks*, the map places it (4B/H3) at the 9-12 level.

Benchmarks related to the heating of materials and the transfer of thermal energy lay the conceptual groundwork for understanding solar heating, global circulation, seasonal weather patterns and climate, and the effect of greenhouse gases. To understand how thermal energy moves in both oceanic and atmospheric systems, students need to know that convective currents are an essential mechanism that aids in that movement. In middle school, understanding of convection currents is linked to experiences with relevant phenomena. Understanding convection in terms of gravity, buoyant forces, and pressure is not expected until high school. It is not necessary for students to have a molecular comprehension of thermal energy to be able to understand atmospheric and oceanic circulation patterns and their role in climate.

Several lines of conceptual development converge in the new 9-12 benchmark that begins "Climatic conditions result from…." These include an understanding of temperature patterns over the earth, atmospheric and oceanic circulation patterns, and the water cycle. A double-headed arrow between this benchmark and another new benchmark (4B/H6) on climate change indicates that they are closely related but that neither is conceptually dependent on the other.

RESEARCH IN *BENCHMARKS*

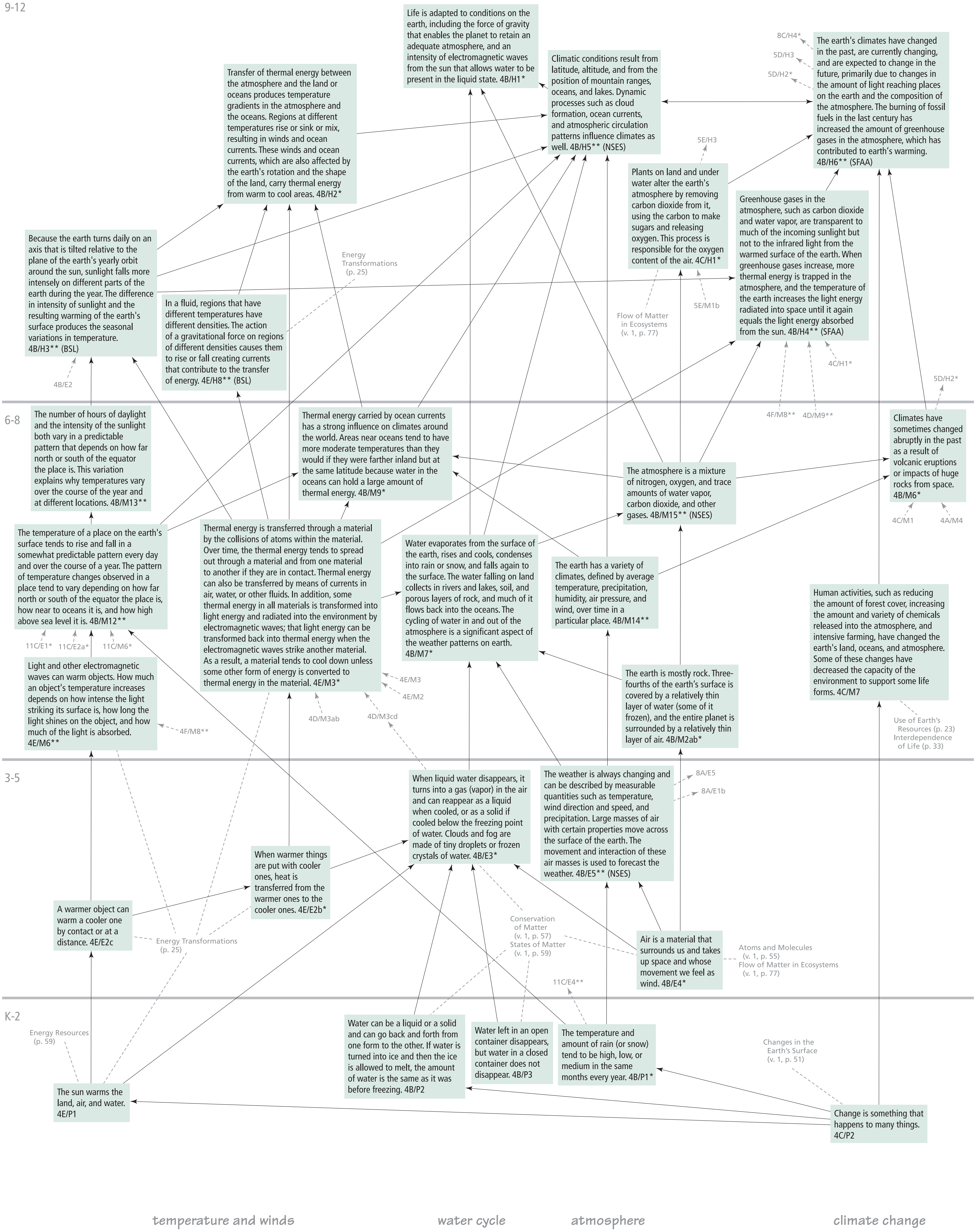
Students of all ages (including college students and adults) have difficulty understanding what causes the seasons. Students may not be able to understand explanations of the seasons before they reasonably understand the relative size, motion, and distance of the sun and the earth (Sadler, 1987; Vosniadou, 1991). Many students before and after instruction in earth science think that winter is colder than summer because the earth is farther from the sun in winter (Atwood & Atwood, 1996; Dove, 1998; Philips, 1991; Sadler, 1998). This idea is often related to the belief that the earth orbits the sun in an elongated elliptical path (Galili & Lavrik, 1998; Sadler, 1998). Other students, especially after instruction, think that the distance between the northern hemisphere and the sun changes because the earth leans toward the sun in the summer and away from the sun in winter (Galili & Lavrik, 1998; Sadler, 1998). Students' ideas about how light travels and about the earth-sun relationship, including the shape of the earth's orbit, the period of the earth's revolution around the sun, and the period of the earth's rotation around its axis, may interfere with students' understanding of the seasons (Galili & Lavrik, 1998; Salierno, Edelson, & Sherin, 2005). For example, some students believe that the side of the sun not facing the earth experiences winter, indicating a confusion between the daily rotation of the earth and its yearly revolution around the sun (Salierno, Edelson, & Sherin, 2005).

Although upper elementary students may identify air as existing even in static situations and recognize that it takes space, recognizing that air has weight may be challenging even for high-school students (Sere, 1985; Driver et al., 1994a; Krnel, Watson, & Glazar, 1998). Students of all ages (including college students) may believe that air exerts force or pressure only when it is moving and only downwards (Driver et al., 1994a; Sere, 1985; Henriques, 2002; Nelson, Aron, & Francek, 1992). Only a few middle-school students use the idea of pressure differences between regions of the atmosphere to account for wind; instead, they may account for winds in terms of visible moving objects or the movement of the earth (Driver et al., 1994a).

Before students understand that water is converted to an invisible form, they may initially believe that when water evaporates it ceases to exist, or that it changes location but remains a liquid, or that it is transformed into some other perceptible form (fog, steam, droplets, etc.) (Bar, 1989; Russell, Harlen, & Watt, 1989; Russell & Watt, 1990; Krnel, Watson, & Glazar, 1998). With special instruction, some students in 5th grade may be able to identify the air as the final location of evaporating water (Russell & Watt, 1990), but they must first accept air as a permanent substance (Bar, 1989). For many students, difficulty understanding the existence of water vapor in the atmosphere persists in middle school years (Lee et al., 1993; Johnson, 1998). Students can understand rainfall in terms of gravity once they attribute weight to little drops of water (typically in upper elementary grades), but the mechanism through which condensation occurs may not be understood until high school (Bar, 1989).

Students of all ages may confuse the ozone layer with the greenhouse effect, and may have a tendency to imagine that all environmentally friendly actions help to solve all environmental problems (for example, that the use of unleaded petrol reduces the risk of global warming) (Andersson & Wallin, 2000; Koulaidis & Christidou, 1998; Meadows & Wiesenmayer, 1999; Rye, Rubba, & Wiesenmayer, 1997). Students have difficulty linking relevant elements of knowledge when explaining the greenhouse effect and may confuse the natural greenhouse effect with the enhancement of that effect (Andersson & Wallin, 2000).

See **ENERGY RESOURCES** and **ENERGY TRANSFORMATIONS** for additional research.


9-12
6-8
3-5
K-2
Life is adapted to conditions on the earth, including the force of gravity that enables the planet to retain an adequate atmosphere, and an intensity of electromagnetic waves from the sun that allows water to be present in the liquid state. 4B/H1*
Transfer of thermal energy between the atmosphere and the land or oceans produces temperature gradients in the atmosphere and the oceans. Regions at different temperatures rise or sink or mix, resulting in winds and ocean currents. These winds and ocean currents, which are also affected by the earth's rotation and the shape of the land, carry thermal energy from warm to cool areas. 4B/H2*
Climatic conditions result from latitude, altitude, and from the position of mountain ranges, oceans, and lakes. Dynamic processes such as cloud formation, ocean currents, and atmospheric circulation patterns influence climates as well. 4B/H5** (NSES)
8C/H4*
5D/H3
5D/H2*
The earth's climates have changed in the past, are currently changing, and are expected to change in the future, primarily due to changes in the amount of light reaching places on the earth and the composition of the atmosphere. The burning of fossil fuels in the last century has increased the amount of greenhouse gases in the atmosphere, which has contributed to earth's warming. 4B/H6** (SFAA)
5E/H3
Plants on land and under water alter the earth's atmosphere by removing carbon dioxide from it, using the carbon to make sugars and releasing oxygen. This process is responsible for the oxygen content of the air. 4C/H1*
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 the earth. When greenhouse gases increase, more thermal energy is trapped in the atmosphere, and the temperature of the earth increases the light energy radiated into space until it again equals the light energy absorbed from the sun. 4B/H4** (SFAA)
Because the earth turns daily on an axis that is tilted relative to the plane of the earth's yearly orbit around the sun, sunlight falls more intensely on different parts of the earth during the year. The difference in intensity of sunlight and the resulting warming of the earth's surface produces the seasonal variations in temperature. 4B/H3** (BSL)
Energy Transformations (p. 25)
In a fluid, regions that have different temperatures have different densities. The action of a gravitational force on regions of different densities causes them to rise or fall creating currents that contribute to the transfer of energy. 4E/H8** (BSL)
Flow of Matter in Ecosystems (v. 1, p. 77)
5E/M1b
4C/H1*
4B/E2
5D/H2*
4F/M8**
4D/M9**
The number of hours of daylight and the intensity of the sunlight both vary in a predictable pattern that depends on how far north or south of the equator the place is. This variation explains why temperatures vary over the course of the year and at different locations. 4B/M13**
Thermal energy carried by ocean currents has a strong influence on climates around the world. Areas near oceans tend to have more moderate temperatures than they would if they were farther inland but at the same latitude because water in the oceans can hold a large amount of thermal energy. 4B/M9*
The atmosphere is a mixture of nitrogen, oxygen, and trace amounts of water vapor, carbon dioxide, and other gases. 4B/M15** (NSES)
Climates have sometimes changed abruptly in the past as a result of volcanic eruptions or impacts of huge rocks from space. 4B/M6*
4C/M1
4A/M4
The temperature of a place on the earth's surface tends to rise and fall in a somewhat predictable pattern every day and over the course of a year. The pattern of temperature changes observed in a place tend to vary depending on how far north or south of the equator the place is, how near to oceans it is, and how high above sea level it is. 4B/M12**
Thermal energy is transferred through a material by the collisions of atoms within the material. Over time, the thermal energy tends to spread out through a material and from one material to another if they are in contact. Thermal energy can also be transferred by means of currents in air, water, or other fluids. In addition, some thermal energy in all materials is transformed into light energy and radiated into the environment by electromagnetic waves; that light energy can be transformed back into thermal energy when the electromagnetic waves strike another material. As a result, a material tends to cool down unless some other form of energy is converted to thermal energy in the material. 4E/M3*
Water evaporates from the surface of the earth, rises and cools, condenses into rain or snow, and falls again to the surface. The water falling on land collects in rivers and lakes, soil, and porous layers of rock, and much of it flows back into the oceans. The cycling of water in and out of the atmosphere is a significant aspect of the weather patterns on earth. 4B/M7*
The earth has a variety of climates, defined by average temperature, precipitation, humidity, air pressure, and wind, over time in a particular place. 4B/M14**
Human activities, such as reducing the amount of forest cover, increasing the amount and variety of chemicals released into the atmosphere, and intensive farming, have changed the earth's land, oceans, and atmosphere. Some of these changes have decreased the capacity of the environment to support some life forms. 4C/M7
11C/E1*
11C/E2a*
11C/M6*
Light and other electromagnetic waves can warm objects. How much an object's temperature increases depends on how intense the light striking its surface is, how long the light shines on the object, and how much of the light is absorbed. 4E/M6**
4F/M8**
4E/M3
4E/M2
4D/M3ab
4D/M3cd
The earth is mostly rock. Three-fourths of the earth's surface is covered by a relatively thin layer of water (some of it frozen), and the entire planet is surrounded by a relatively thin layer of air. 4B/M2ab*
Use of Earth's Resources (p. 23)
Interdependence of Life (p. 33)
When liquid water disappears, it turns into a gas (vapor) in the air and can reappear as a liquid when cooled, or as a solid if cooled below the freezing point of water. Clouds and fog are made of tiny droplets or frozen crystals of water. 4B/E3*
The weather is always changing and can be described by measurable quantities such as temperature, wind direction and speed, and precipitation. Large masses of air with certain properties move across the surface of the earth. The movement and interaction of these air masses is used to forecast the weather. 4B/E5** (NSES)
8A/E5
8A/E1b
When warmer things are put with cooler ones, heat is transferred from the warmer ones to the cooler ones. 4E/E2b*
A warmer object can warm a cooler one by contact or at a distance. 4E/E2c
Energy Transformations (p. 25)
Conservation of Matter (v. 1, p. 57)
States of Matter (v. 1, p. 59)
Air is a material that surrounds us and takes up space and whose movement we feel as wind. 4B/E4*
Atoms and Molecules (v. 1, p. 55)
Flow of Matter in Ecosystems (v. 1, p. 77)
11C/E4**
Energy Resources (p. 59)
Water can be a liquid or a solid and can go back and forth from one form to the other. If water is turned into ice and then the ice is allowed to melt, the amount of water is the same as it was before freezing. 4B/P2
Water left in an open container disappears, but water in a closed container does not disappear. 4B/P3
The temperature and amount of rain (or snow) tend to be high, low, or medium in the same months every year. 4B/P1*
Changes in the Earth's Surface (v. 1, p. 51)
The sun warms the land, air, and water. 4E/P1
Change is something that happens to many things. 4C/P2
temperature and winds
water cycle
atmosphere
climate change

USE OF EARTH'S RESOURCES (4B)

Of all the diverse planets and moons in our solar system, only the earth appears to be capable of supporting life as we know it. Water and air are essential resources; altering the quality of the water or the composition of the earth's atmosphere can have serious consequences for living systems. Informed citizens need to understand the implications of decisions about the use of Earth's resources.

The map is organized around four strands—*use of energy resources, needs of organisms for Earth's resources, human impact on the environment,* and *use of material resources*. In the elementary grades, the focus is on the survival needs of organisms and people's use of fuels. In middle school, the focus is on the use and trade-offs of different energy and material resources and on the dependence and impact of organisms (particularly humans) on their environment. In high school, the focus is on factors affecting the equilibrium of the synthesis and depletion of resources and the recycling of waste products resulting from resource use.

This map is closely related to both the **ENERGY RESOURCES** and **MATERIALS SCIENCE** maps.

NOTES

The *use of energy resources* strand focuses on the increased use and depletion of energy resources. Benchmarks in this strand also appear in the **ENERGY RESOURCES** map. Most of the benchmarks in the *use of material resources* strand also appear in the **MATERIALS SCIENCE** map, which addresses in more depth the problem of waste disposal and recycling.

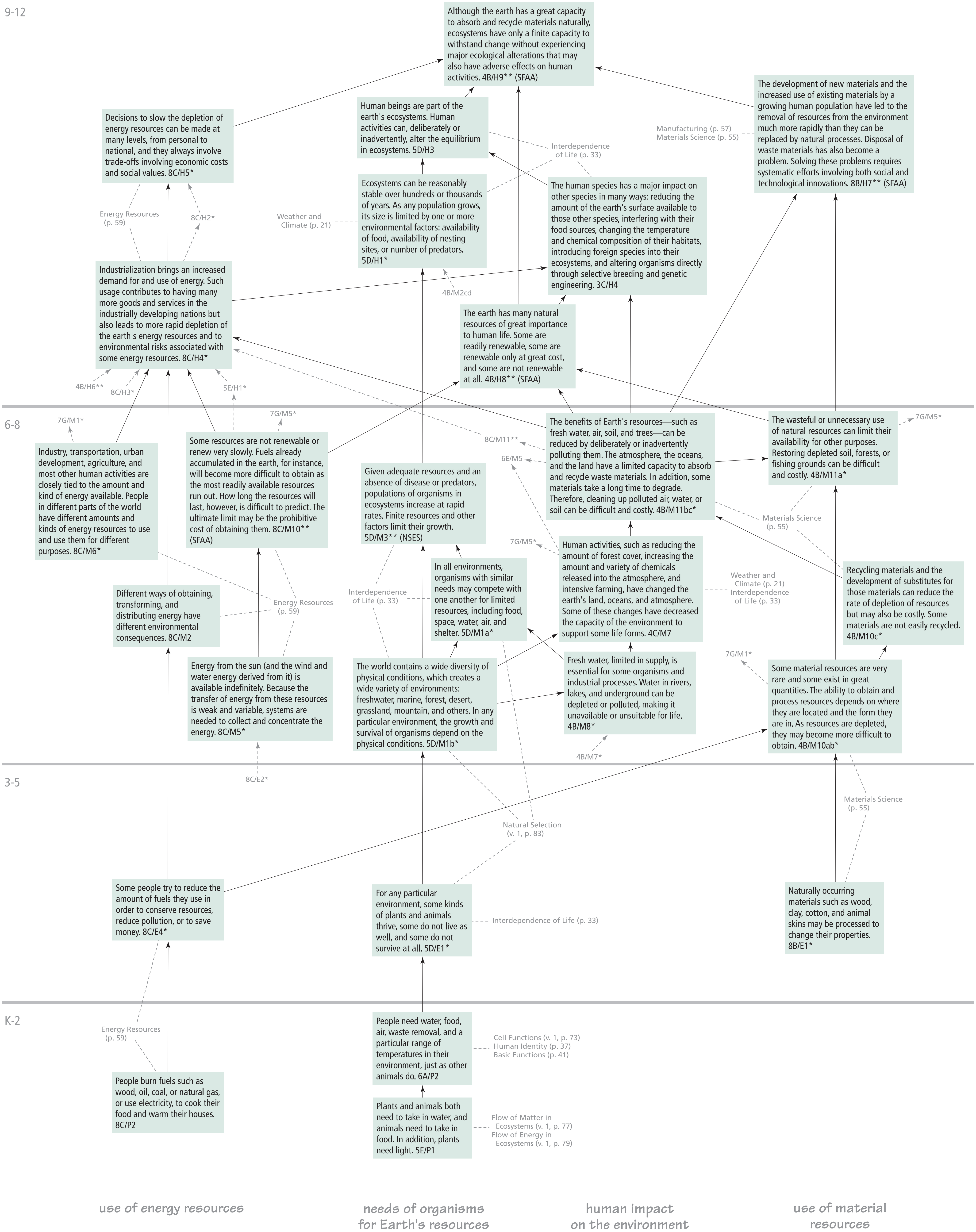
The *use of energy resources* and *use of material resources* strands include many similar key ideas: Some resources are renewable, some are not, and some are renewable at great cost; some resources take a very long time to accumulate; the growth of technology has led to increased use of resources; as resources are depleted, they may be more difficult and costly to obtain; and use of resources is associated with environmental risks.

The *needs of organisms for Earth's resources* strand addresses how organisms depend on their environment for resources, and shares several benchmarks with the **INTERDEPENDENCE OF LIFE** map. The *human impact on the environment* strand considers how humans affect the environment. The two strands converge on the 9-12 benchmark "Human beings are part of the earth's ecosystems...."

Students' understanding of the use of Earth's resources should be integrated with their growing knowledge of the processes that shape the earth (see the *Atlas 1* map **CHANGES IN THE EARTH'S SURFACE**). For example, knowing about the slow nature of the rock cycle would enable students to understand that mineral resources cannot be renewed for human use within a time span that is determined by the rate at which humans deplete them.

RESEARCH IN *BENCHMARKS*

No relevant research available in *Benchmarks*.


9-12
Although the earth has a great capacity to absorb and recycle materials naturally, ecosystems have only a finite capacity to withstand change without experiencing major ecological alterations that may also have adverse effects on human activities. 4B/H9** (SFAA)
Human beings are part of the earth's ecosystems. Human activities can, deliberately or inadvertently, alter the equilibrium in ecosystems. 5D/H3
Decisions to slow the depletion of energy resources can be made at many levels, from personal to national, and they always involve trade-offs involving economic costs and social values. 8C/H5*
The development of new materials and the increased use of existing materials by a growing human population have led to the removal of resources from the environment much more rapidly than they can be replaced by natural processes. Disposal of waste materials has also become a problem. Solving these problems requires systematic efforts involving both social and technological innovations. 8B/H7** (SFAA)
Manufacturing (p. 57)
Materials Science (p. 55)
Interdependence of Life (p. 33)
Ecosystems can be reasonably stable over hundreds or thousands of years. As any population grows, its size is limited by one or more environmental factors: availability of food, availability of nesting sites, or number of predators. 5D/H1*
Weather and Climate (p. 21)
Energy Resources (p. 59)
8C/H2*
The human species has a major impact on other species in many ways: reducing the amount of the earth's surface available to those other species, interfering with their food sources, changing the temperature and chemical composition of their habitats, introducing foreign species into their ecosystems, and altering organisms directly through selective breeding and genetic engineering. 3C/H4
Industrialization brings an increased demand for and use of energy. Such usage contributes to having many more goods and services in the industrially developing nations but also leads to more rapid depletion of the earth's energy resources and to environmental risks associated with some energy resources. 8C/H4*
4B/M2cd
The earth has many natural resources of great importance to human life. Some are readily renewable, some are renewable only at great cost, and some are not renewable at all. 4B/H8** (SFAA)
4B/H6**
8C/H3*
5E/H1*
6-8
7G/M1*
7G/M5*
Industry, transportation, urban development, agriculture, and most other human activities are closely tied to the amount and kind of energy available. People in different parts of the world have different amounts and kinds of energy resources to use and use them for different purposes. 8C/M6*
Some resources are not renewable or renew very slowly. Fuels already accumulated in the earth, for instance, will become more difficult to obtain as the most readily available resources run out. How long the resources will last, however, is difficult to predict. The ultimate limit may be the prohibitive cost of obtaining them. 8C/M10** (SFAA)
8C/M11**
6E/M5
The benefits of Earth's resources—such as fresh water, air, soil, and trees—can be reduced by deliberately or inadvertently polluting them. The atmosphere, the oceans, and the land have a limited capacity to absorb and recycle waste materials. In addition, some materials take a long time to degrade. Therefore, cleaning up polluted air, water, or soil can be difficult and costly. 4B/M11bc*
The wasteful or unnecessary use of natural resources can limit their availability for other purposes. Restoring depleted soil, forests, or fishing grounds can be difficult and costly. 4B/M11a*
7G/M5*
Given adequate resources and an absence of disease or predators, populations of organisms in ecosystems increase at rapid rates. Finite resources and other factors limit their growth. 5D/M3** (NSES)
Materials Science (p. 55)
7G/M5*
Human activities, such as reducing the amount of forest cover, increasing the amount and variety of chemicals released into the atmosphere, and intensive farming, have changed the earth's land, oceans, and atmosphere. Some of these changes have decreased the capacity of the environment to support some life forms. 4C/M7
In all environments, organisms with similar needs may compete with one another for limited resources, including food, space, water, air, and shelter. 5D/M1a*
Weather and Climate (p. 21)
Interdependence of Life (p. 33)
Recycling materials and the development of substitutes for those materials can reduce the rate of depletion of resources but may also be costly. Some materials are not easily recycled. 4B/M10c*
Different ways of obtaining, transforming, and distributing energy have different environmental consequences. 8C/M2
Energy Resources (p. 59)
Interdependence of Life (p. 33)
7G/M1*
Energy from the sun (and the wind and water energy derived from it) is available indefinitely. Because the transfer of energy from these resources is weak and variable, systems are needed to collect and concentrate the energy. 8C/M5*
The world contains a wide diversity of physical conditions, which creates a wide variety of environments: freshwater, marine, forest, desert, grassland, mountain, and others. In any particular environment, the growth and survival of organisms depend on the physical conditions. 5D/M1b*
Fresh water, limited in supply, is essential for some organisms and industrial processes. Water in rivers, lakes, and underground can be depleted or polluted, making it unavailable or unsuitable for life. 4B/M8*
Some material resources are very rare and some exist in great quantities. The ability to obtain and process resources depends on where they are located and the form they are in. As resources are depleted, they may become more difficult to obtain. 4B/M10ab*
4B/M7*
3-5
8C/E2*
Materials Science (p. 55)
Natural Selection (v. 1, p. 83)
Some people try to reduce the amount of fuels they use in order to conserve resources, reduce pollution, or to save money. 8C/E4*
For any particular environment, some kinds of plants and animals thrive, some do not live as well, and some do not survive at all. 5D/E1*
Interdependence of Life (p. 33)
Naturally occurring materials such as wood, clay, cotton, and animal skins may be processed to change their properties. 8B/E1*
K-2
Energy Resources (p. 59)
People need water, food, air, waste removal, and a particular range of temperatures in their environment, just as other animals do. 6A/P2
Cell Functions (v. 1, p. 73)
Human Identity (p. 37)
Basic Functions (p. 41)
People burn fuels such as wood, oil, coal, or natural gas, or use electricity, to cook their food and warm their houses. 8C/P2
Plants and animals both need to take in water, and animals need to take in food. In addition, plants need light. 5E/P1
Flow of Matter in Ecosystems (v. 1, p. 77)
Flow of Energy in Ecosystems (v. 1, p. 79)
use of energy resources
needs of organisms for Earth's resources
human impact on the environment
use of material resources

THE LIVING ENVIRONMENT

INTERDEPENDENCE OF LIFE (5D)

Every species is linked, directly or indirectly, with a multitude of others in an ecosystem. Ecosystems are shaped by both the nonliving environment and by its inhabitants, including humans. Hence, benchmarks on this map are closely related to benchmarks on the **FLOW OF MATTER IN ECOSYSTEMS** map in *Atlas 1* and to benchmarks on the **USE OF EARTH'S RESOURCES** map.

The map is organized around four strands—*interactions among organisms, dynamic nature of ecosystems, dependence of organisms on their environment,* and *human impact*. The learning progression begins in the elementary grades with an emphasis on the needs of organisms and how they are met in different environments. In middle school, the emphasis is on understanding how organisms (including humans) interact with one another and with the environment in a wide variety of ecosystems. In high school, students' knowledge about the interdependence of organisms in ecosystems and the environment is linked to more abstract ideas about stability and change in systems.

NOTES

Students may not regard food as a scarce resource for animals and, hence, may not consider competition among species for food resources. Therefore, the grades 6-8 benchmark "In all environments, organisms with similar needs…" was modified to include the idea that resources for which animals compete are limited. A new benchmark (5D/M3) was added to the map to extend students' understanding of the implications of finite resources for populations of organisms.

Students' knowledge of the variety of environments and changes in environmental conditions on Earth needs to be integrated with their growing understanding of earth science, in particular with benchmarks related to climate in the **WEATHER AND CLIMATE** map. As students become more familiar with the characteristics of systems in general, they can begin to recognize some of those characteristics—such as interdependence of parts, stability, and change—as they appear in ecosystems.

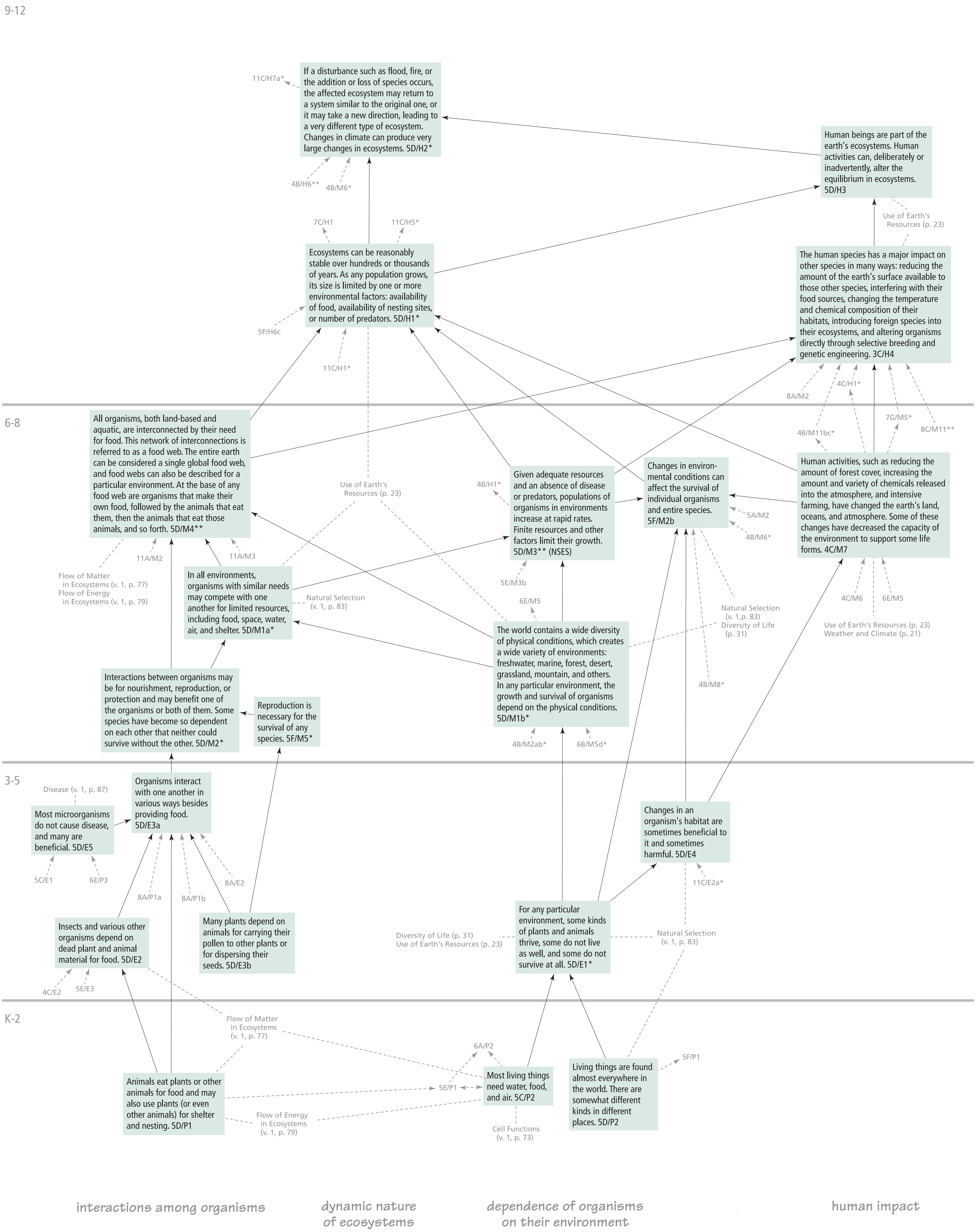
Ethical choices and the implications of various uses of the environment are not explicitly addressed in this map. However, the map can provide contexts for learning about the effects of science on society, ethics in research, and the incompleteness of scientific answers as presented on the **SCIENCE AND SOCIETY** map and the **SCIENTIFIC WORLD VIEW** map.

RESEARCH IN *BENCHMARKS*

Lower elementary-school students can understand simple food links involving two organisms. Yet they often think of organisms as independent of each other but dependent on people to supply them with food and shelter. Upper elementary-school students may not believe food is a scarce resource in ecosystems, thinking that organisms can change their food at will according to the availability of particular sources (Leach et al., 1992). Students of all ages think that some populations of organisms are numerous in order to fulfill a demand for food by another population (Leach et al., 1992).

Middle-school and high-school students may believe that organisms are able to effect changes in bodily structure to exploit particular habitats or that they respond to a changed environment by seeking a more favorable environment (Jungwirth, 1975; Clough & Wood-Robinson, 1985a). It has been suggested that the language about adaptation used by teachers or textbooks to make biology more accessible to students may cause or reinforce these beliefs (Jungwirth, 1975).

Some middle-school students think dead organisms simply rot away. They do not realize that the matter from the dead organism is converted into other materials in the environment. Some middle-school students see decay as a gradual, inevitable consequence of time without need of decomposing agents (Smith & Anderson, 1986). Some high-school students believe that matter is conserved during decay, but do not know where it goes (Leach et al., 1992).


9-12
11C/H7a*
If a disturbance such as flood, fire, or the addition or loss of species occurs, the affected ecosystem may return to a system similar to the original one, or it may take a new direction, leading to a very different type of ecosystem. Changes in climate can produce very large changes in ecosystems. 5D/H2*
4B/H6**
4B/M6*
Human beings are part of the earth's ecosystems. Human activities can, deliberately or inadvertently, alter the equilibrium in ecosystems. 5D/H3
Use of Earth's Resources (p. 23)
7C/H1
11C/H5*
Ecosystems can be reasonably stable over hundreds or thousands of years. As any population grows, its size is limited by one or more environmental factors: availability of food, availability of nesting sites, or number of predators. 5D/H1*
5F/H6c
11C/H1*
The human species has a major impact on other species in many ways: reducing the amount of the earth's surface available to those other species, interfering with their food sources, changing the temperature and chemical composition of their habitats, introducing foreign species into their ecosystems, and altering organisms directly through selective breeding and genetic engineering. 3C/H4
8A/M2
4C/H1*
7G/M5*
4B/M11bc*
8C/M11**
6-8
All organisms, both land-based and aquatic, are interconnected by their need for food. This network of interconnections is referred to as a food web. The entire earth can be considered a single global food web, and food webs can also be described for a particular environment. At the base of any food web are organisms that make their own food, followed by the animals that eat them, then the animals that eat those animals, and so forth. 5D/M4**
Use of Earth's Resources (p. 23)
4B/H1*
Given adequate resources and an absence of disease or predators, populations of organisms in environments increase at rapid rates. Finite resources and other factors limit their growth. 5D/M3** (NSES)
Changes in environmental conditions can affect the survival of individual organisms and entire species. 5F/M2b
5A/M2
4B/M6*
Human activities, such as reducing the amount of forest cover, increasing the amount and variety of chemicals released into the atmosphere, and intensive farming, have changed the earth's land, oceans, and atmosphere. Some of these changes have decreased the capacity of the environment to support some life forms. 4C/M7
11A/M2
11A/M3
Flow of Matter in Ecosystems (v. 1, p. 77)
Flow of Energy in Ecosystems (v. 1, p. 79)
In all environments, organisms with similar needs may compete with one another for limited resources, including food, space, water, air, and shelter. 5D/M1a*
Natural Selection (v. 1, p. 83)
5E/M3b
6E/M5
The world contains a wide diversity of physical conditions, which creates a wide variety of environments: freshwater, marine, forest, desert, grassland, mountain, and others. In any particular environment, the growth and survival of organisms depend on the physical conditions. 5D/M1b*
Natural Selection (v. 1, p. 83)
Diversity of Life (p. 31)
4C/M6
6E/M5
Use of Earth's Resources (p. 23)
Weather and Climate (p. 21)
Interactions between organisms may be for nourishment, reproduction, or protection and may benefit one of the organisms or both of them. Some species have become so dependent on each other that neither could survive without the other. 5D/M2*
Reproduction is necessary for the survival of any species. 5F/M5*
4B/M8*
4B/M2ab*
6B/M5d*
3-5
Disease (v. 1, p. 87)
Most microorganisms do not cause disease, and many are beneficial. 5D/E5
Organisms interact with one another in various ways besides providing food. 5D/E3a
Changes in an organism's habitat are sometimes beneficial to it and sometimes harmful. 5D/E4
5C/E1
6E/P3
8A/P1a
8A/P1b
8A/E2
11C/E2a*
Insects and various other organisms depend on dead plant and animal material for food. 5D/E2
Many plants depend on animals for carrying their pollen to other plants or for dispersing their seeds. 5D/E3b
Diversity of Life (p. 31)
Use of Earth's Resources (p. 23)
For any particular environment, some kinds of plants and animals thrive, some do not live as well, and some do not survive at all. 5D/E1*
Natural Selection (v. 1, p. 83)
4C/E2
5E/E3
K-2
Flow of Matter in Ecosystems (v. 1, p. 77)
6A/P2
5F/P1
Animals eat plants or other animals for food and may also use plants (or even other animals) for shelter and nesting. 5D/P1
5E/P1
Most living things need water, food, and air. 5C/P2
Living things are found almost everywhere in the world. There are somewhat different kinds in different places. 5D/P2
Flow of Energy in Ecosystems (v. 1, p. 79)
Cell Functions (v. 1, p. 73)
interactions among organisms
dynamic nature of ecosystems
dependence of organisms on their environment
human impact

ENERGY RESOURCES (8C)

Industry, transportation, urban development, agriculture, and most other human activities are closely tied to the amount and kind of energy available. Energy is required for technological processes and needs to be distributed from its source to where it is to be used. Energy sources and ways of using them have different costs, implications and risks. Moreover, the increasing world demand for energy raises national and global issues and the need for an informed public to address them.

The map is organized around three strands—*resources, efficient use,* and *societal and environmental implications*. In the elementary grades the focus is on energy resources and basic ideas about heat transfer. In middle school the emphasis shifts to the transformation and distribution of various energy resources and their environmental consequences. In high school the focus is on trade-offs of various energy resources, the efficiency of energy transformations, and the inevitable dissipation of thermal energy into the environment. At each level, benchmarks about energy are connected to benchmarks about technology and societal implications of energy use.

This map is closely related to the **ENERGY TRANSFORMATIONS** and **INDUSTRIAL REVOLUTION** maps. It also illustrates general principles about the nature of technology in **THE INTERACTION OF TECHNOLOGY AND SOCIETY** and **DECISIONS ABOUT USING TECHNOLOGY** maps in *Atlas 1* and the **SCIENCE AND SOCIETY** and **TECHNOLOGY AND SCIENCE** maps in this volume and can serve as a context for learning benchmarks on these maps.

NOTES

The *resources* strand moves from ideas about the variety of energy resources available to ideas about whether different resources are renewable or not and why. The benchmark "Sunlight is the ultimate source…" is positioned at the 3-5 grade level in *Benchmarks* but has been delayed until the 9-12 level in the map. This change in grade level placement recognizes that understanding how the energy in fossil fuels comes from energy captured by plants long ago requires students to have a more sophisticated knowledge of matter and energy transformations in ecosystems and of processes that shape the earth.

In the *efficient use* strand, the new grades 9-12 benchmark "The useful energy output of a device…" is to be interpreted broadly and intends for students to understand the concept of designing devices to maximize the efficiency of transformation. A prerequisite to understanding the concept of "useful energy" is the idea expressed in benchmark 4E/H3 that less can be done with energy that is spread out.

Two new middle-school benchmarks in the *efficient use* strand come from *Science for All Americans*. The benchmark "Energy is required for technological processes…" describes a variety of processes that use energy and provides the background for appreciating the increased demand and use of energy in industrialized societies. Another new benchmark 8C/M8 expects students to become familiar with a variety of energy-transforming devices and consider what their inputs and outputs are in preparation for discussing the devices' efficiency.

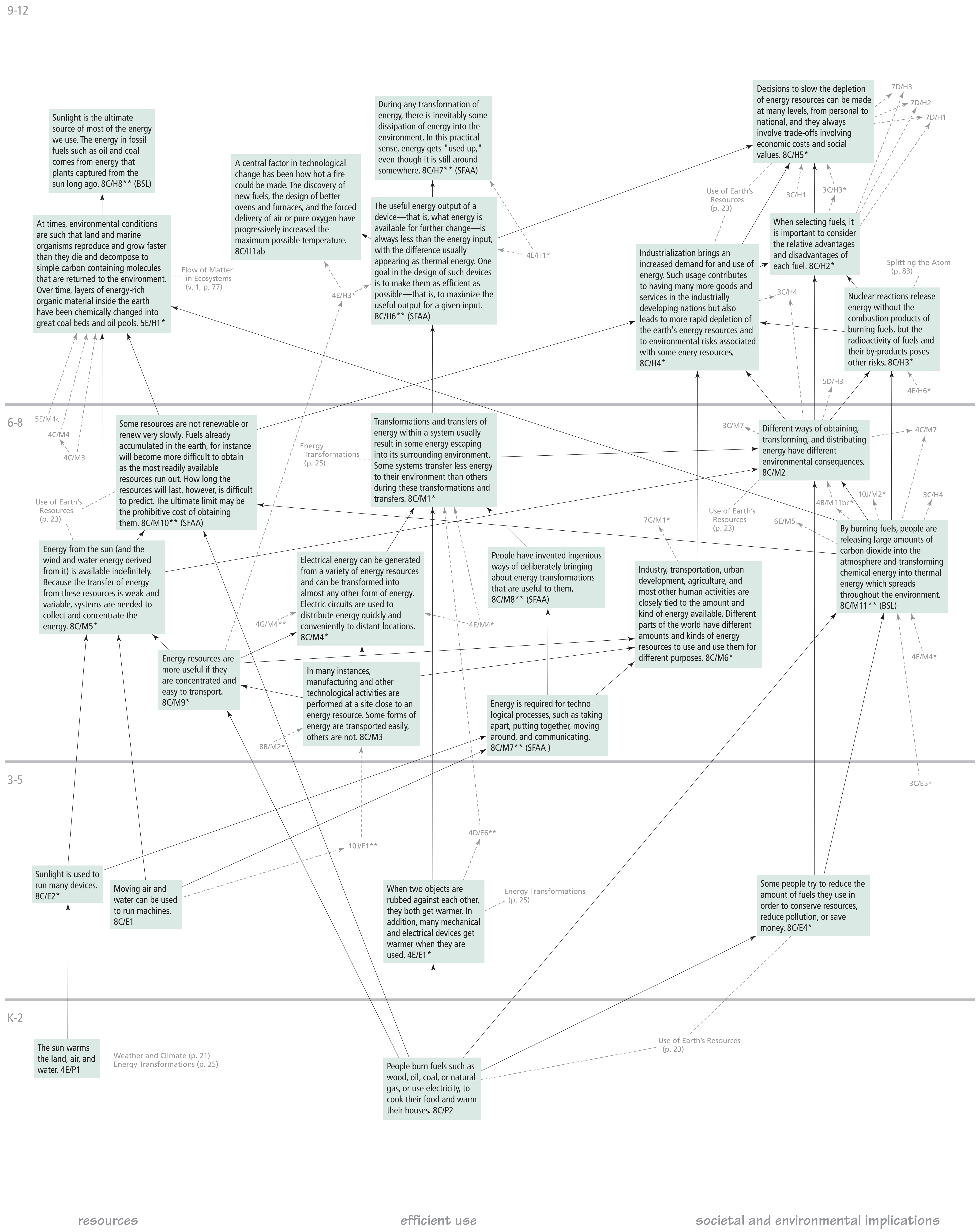
Energy use is always associated with costs and benefits. Hence, the high-school benchmark "Decisions to slow the depletion of energy resources…" is linked to a number of benchmarks related to considering costs and benefits of using technologies, the complexities of decision making, and social trade-offs.

RESEARCH IN *BENCHMARKS*

Students may identify the transfer of energy to the environment with pollution or waste materials being thrown to the environment (Ametller & Pinto, 2002). Students are not likely to be aware of the heating of the environment which accounts for the energy dissipated (Driver et al., 1994b). Students who have developed an awareness of heat transfer to the environment as a component of most energy transformations may assume that such a transfer results in energy "being lost." They do not think that energy has become spread out and is not as useful as energy which is "concentrated" in one place (Driver et al., 1994b).

Middle-school students do not always explain the process of heating and cooling in terms of heat transfer (Tiberghien, 1983; Tomasini & Balandi, 1987). Some students think that "cold" is being transferred from a colder to a warmer object, others that both "heat" and "cold" are transferred at the same time. Middle- and high-school students often do not explain heat conduction phenomena as interactions (Kesidou, Duit, & Glynn, 1995; Tiberghien, 1985). For example, students sometimes think that, depending on its properties, an object which is at the same temperature with its surroundings can cool down spontaneously. Even after instruction, students don't always give up their naive notion that some substances (for example, flour, sugar, or air) cannot heat up (Tiberghien, 1985) or that metals get hot quickly because "they attract heat," "suck heat in," or "hold heat well" (Erickson, 1985; Lewis & Linn, 1994). Middle-school students believe different materials in the same surroundings have different temperatures because they feel different (for example, metal feels colder than wood). As a result, they may not recognize the universal tendency to temperature equalization (Tomasini & Balandi, 1987; Lewis & Linn, 1994). Helping most students develop scientific ideas in this domain appears to be possible only with long-term interventions that focus on connecting scientific ideas about rate of heat transfer, insulation/conduction, and thermal equilibrium with each other and with ideas students hold based on everyday experiences (Clark & Linn, 2003; Clark & Jorde, 2004; Clark, 2006).

See **ENERGY TRANSFORMATIONS** for additional research.


9-12
6-8
3-5
K-2
Sunlight is the ultimate source of most of the energy we use. The energy in fossil fuels such as oil and coal comes from energy that plants captured from the sun long ago. 8C/H8** (BSL)
At times, environmental conditions are such that land and marine organisms reproduce and grow faster than they die and decompose to simple carbon containing molecules that are returned to the environment. Over time, layers of energy-rich organic material inside the earth have been chemically changed into great coal beds and oil pools. 5E/H1*
Flow of Matter in Ecosystems (v. 1, p. 77)
A central factor in technological change has been how hot a fire could be made. The discovery of new fuels, the design of better ovens and furnaces, and the forced delivery of air or pure oxygen have progressively increased the maximum possible temperature. 8C/H1ab
During any transformation of energy, there is inevitably some dissipation of energy into the environment. In this practical sense, energy gets "used up," even though it is still around somewhere. 8C/H7** (SFAA)
The useful energy output of a device—that is, what energy is available for further change—is always less than the energy input, with the difference usually appearing as thermal energy. One goal in the design of such devices is to make them as efficient as possible—that is, to maximize the useful output for a given input. 8C/H6** (SFAA)
4E/H1*
4E/H3*
Decisions to slow the depletion of energy resources can be made at many levels, from personal to national, and they always involve trade-offs involving economic costs and social values. 8C/H5*
7D/H3
7D/H2
7D/H1
Use of Earth's Resources (p. 23)
3C/H1
3C/H3*
When selecting fuels, it is important to consider the relative advantages and disadvantages of each fuel. 8C/H2*
Industrialization brings an increased demand for and use of energy. Such usage contributes to having many more goods and services in the industrially developing nations but also leads to more rapid depletion of the earth's energy resources and to environmental risks associated with some enery resources. 8C/H4*
3C/H4
Splitting the Atom (p. 83)
Nuclear reactions release energy without the combustion products of burning fuels, but the radioactivity of fuels and their by-products poses other risks. 8C/H3*
5D/H3
4E/H6*
5E/M1c
4C/M4
4C/M3
Some resources are not renewable or renew very slowly. Fuels already accumulated in the earth, for instance will become more difficult to obtain as the most readily available resources run out. How long the resources will last, however, is difficult to predict. The ultimate limit may be the prohibitive cost of obtaining them. 8C/M10** (SFAA)
Energy Transformations (p. 25)
Transformations and transfers of energy within a system usually result in some energy escaping into its surrounding environment. Some systems transfer less energy to their environment than others during these transformations and transfers. 8C/M1*
3C/M7
Different ways of obtaining, transforming, and distributing energy have different environmental consequences. 8C/M2
4C/M7
10J/M2*
3C/H4
4B/M11bc*
Use of Earth's Resources (p. 23)
7G/M1*
6E/M5
Use of Earth's Resources (p. 23)
Energy from the sun (and the wind and water energy derived from it) is available indefinitely. Because the transfer of energy from these resources is weak and variable, systems are needed to collect and concentrate the energy. 8C/M5*
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 quickly and conveniently to distant locations. 8C/M4*
4G/M4**
4E/M4*
People have invented ingenious ways of deliberately bringing about energy transformations that are useful to them. 8C/M8** (SFAA)
Industry, transportation, urban development, agriculture, and most other human activities are closely tied to the amount and kind of energy available. Different parts of the world have different amounts and kinds of energy resources to use and use them for different purposes. 8C/M6*
By burning fuels, people are releasing large amounts of carbon dioxide into the atmosphere and transforming chemical energy into thermal energy which spreads throughout the environment. 8C/M11** (BSL)
4E/M4*
Energy resources are more useful if they are concentrated and easy to transport. 8C/M9*
In many instances, manufacturing and other technological activities are performed at a site close to an energy resource. Some forms of energy are transported easily, others are not. 8C/M3
8B/M2*
Energy is required for technological processes, such as taking apart, putting together, moving around, and communicating. 8C/M7** (SFAA)
3C/E5*
4D/E6**
10J/E1**
Sunlight is used to run many devices. 8C/E2*
Moving air and water can be used to run machines. 8C/E1
When two objects are rubbed against each other, they both get warmer. In addition, many mechanical and electrical devices get warmer when they are used. 4E/E1*
Energy Transformations (p. 25)
Some people try to reduce the amount of fuels they use in order to conserve resources, reduce pollution, or save money. 8C/E4*
The sun warms the land, air, and water. 4E/P1
Weather and Climate (p. 21)
Energy Transformations (p. 25)
Use of Earth's Resources (p. 23)
People burn fuels such as wood, oil, coal, or natural gas, or use electricity, to cook their food and warm their houses. 8C/P2
resources
efficient use
societal and environmental implications