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Big World, Small Planet – Module 3: Meeting Human Needs Sustainably, Teacher Edition

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BIG WORLD, SMALL PLANET

Module 3: Meeting Human Needs Sustainably

Teacher Edition



A comprehensive guide to global issues and sustainable solutions

Facing the Future

BIG WORLD,

SMALL PLANET

A Comprehensive Guide to Global Issues

and Sustainable Solutions

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Module 3: Meeting Human Needs Sustainably
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About Facing the Future

Facing the Future is a program of Western Washington University. Facing the Future's mission is to create tools for educators that equip and motivate students to develop critical thinking skills, build global awareness, and engage in positive solutions for a sustainable future.

Facing the Future develops and delivers standards-based hands-on lessons, student texts, curriculum units, and professional development opportunities for educators. Facing the Future curriculum is in use in all 50 U.S. states and over 140 countries by teachers and students in grades K-12, in post-secondary education, and across multiple subject areas. Facing the Future reaches over 1.5 million students through its programming.

For more information, visit **www.facingthefuture.org**.

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To the Teacher

Here are a few comments about getting started with the Activity Guide.

1. **Teacher Edition Contents:** Some material is provided only in the Teacher Edition. In addition, the Teacher's Edition also includes work papers to be copied and handed out to students when needed.

2. **Reading Assignments:** Activities note which pages should be read to prepare for that particular assignment. The unit schedule notes the pages that are required pre-reading for the activity to be done each day. It also lists recommended reading for each day of a 20-day unit. This recommended reading schedule spreads the reading over the 20-day unit and will have students prepared for each day's activities.

3. **Field Books:** Students will prepare Field Books at home after Day 1 of the unit. In the Field Books, students will record their work during the unit; write reflections on class activities; and describe daily observations of wild nature, using both sketches and text.

   The Field Books can be created using binders, 8-1/2" by 11" composition books, spiral-bound notebooks, or stacks of paper held together with brads or binder clips. Students will need to add pages from time to time; if you use bound or spiral notebooks, students will need tape or glue pages into their Field Book occasionally.

4. **Field Book Reflections and Discussion Questions:** Daily activities have Discussion Question and Field Book sections at the end. Discussion questions relate to the classwork. Field Book instructions include prompts for nature journaling, references to Think About It boxes in the day's reading assignment, and sometimes other reflection questions or activities.

   You may also choose to ask students to answer some of the Discussion Questions in their Field Book reflection pages instead of discussing them in class. You can also choose – or let students choose – which Think About It boxes you would like students to respond to in writing; there are probably more than you will want to assign on some days.

5. **Unit Schedule:** A proposed unit schedule is included. The schedule includes daily activities, reading needed for the assignment, text reading assignments, and a summary of Field Book activities and reflections.

6. **Academic Standards:** U.S. Next Generation Science, Common Core, and National Council for the Social Studies high school standards are provided. Middle school standards are available on the Facing the Future website.

Suggested Unit Schedule

Day	Recommended Reading	Required Pre-Reading for Activity	Activities	Field Book Reflections and Observations
Pre-Unit				
1	Pages 2-7		Introductory Activity ***Mind Map*** of food webs you are in Activity One ***Set Up Field Book*** Activity Two Preparation ***My Food Impacts***	Activity One ***Think About It*** boxes, Pages 2 and 5
2	Pages 7-12	***Activity Two*** Pages 2-7	Activity Two ***Food Choices and Impacts*** Day 1 Activity Three ***Nature Journal***	Activity Two ***Think About It*** boxes, Pages 6 and 10 Activity Three ***Nature Journal***
3	Pages 13-18	Pages 7-12	Activity Two ***Food Choices and Impacts*** Day 2	***Think About It*** boxes, Pages 12 and 14 ***Nature Journal***
4	Pages 19-21	Pages 13-18	Activity Two ***Food Choices and Impacts*** Day 3	***Think About It*** boxes, Pages 16 and 17 ***Nature Journal***
5	Pages 22-25	Pages 11-14	Activity Four ***Casual Loop Diagrams and Sustainable Agriculture***	***Think About It*** boxes, Pages 18 and 20 ***Nature Journal***
6	Pages 26-30	Pages 22-25	Activity Five ***Nested Systems and My Watershed***	***Think About It*** boxes, Page 23 (two boxes) ***Nature Journal***
7	Pages 31-36	***Big Ideas of Sustainability*** Page 4 ***Contamination and Pollution*** Page 26 ***Think About It*** Page 27 ***Wastewater*** Page 34-35	Activity Six ***Pollution, Economics, and Society, Part 1*** Day 1 ***Cleaning Up a Polluted River***	***Think About It*** boxes, Pages 25 and 27 ***Nature Journal***
8	Pages 37-40	Pages 34-35	Activity Six ***Pollution, Economics, and Society, Part 1*** Day 2 ***Cleaning Up a Polluted River***	***Think About It*** boxes, Pages 28 and 29 ***Nature Journal***
9	Pages 42-46	Pages 37-39	Activity Seven ***Making Sustainable Desicions***	***Think About It*** boxes, Pages 34 ***Nature Journal***
10	Pages 47-51	***Review*** Pages 1-40 and ***Field Book*** work	Activity Eight ***Food and Water Unit Reflections, Self-Assessment, and Commitments***	***Nature Journal***
11	Pages 52-54	Pages 42-51	Activity Nine ***Air Pollution Infographic*** Day 1	Set up pages for new unit ***Think About It*** boxes, Pages 42 and 47 ***Nature Journal***
12	Pages 55-58	Pages 42-51	Activity Nine ***Air Pollution Infographic*** Day 2	***Think About It*** boxes, Pages 50 and 52 ***Nature Journal***

Day	Recommended Reading	Required Pre-Reading for Activity	Activities	Field Book Reflections and Observations
13	Pages 59-62	Pages 50-54	Activity Ten ***Pollution, Economics, and Society, Part 2*** Day 1 Case Study ***Air Quality in a Developing Country***	***Think About It*** boxes, Pages 54 and 55 ***Nature Journal***
14	Pages 63-65	Pages 50-54	Activity Ten ***Pollution, Economics, and Society, Part 2*** Day 2 Case Study ***Air Quality in a Developing Country***	***Think About It*** boxes, Pages 57 and 58 ***Nature Journal***
15	Pages 66-67	Pages 55-56	Activity Eleven ***Using the Iceberg Model***	***Nature Journal***
16	Pages 68-71	Pages 57-67	Activity Twelve ***Air, Water, and Energy Interconnections***	***Think About It*** boxes, Page 60 ***Nature Journal***
17		Pages 48-49 ***Climate Change*** Pages 59-61 ***Fossil Fuels*** Pages 63-67 ***Renewables and Conservation/Efficiency***	Activity Thirteen ***Making Societal Decisions: Fossil Fuels and Climate Change***	***Think About It*** boxes, Page 63 ***Nature Journal***
18		Pages 57-71	Activity Fourteen ***Renewable Energy, Fossil Fuels, or Both?*** Day 1	***Think About It*** boxes, Page 68 ***Nature Journal***
19		Pages 57-71	Activity Fourteen ***Renewable Energy, Fossil Fuels, or Both?*** Day 2	***Think About It*** boxes, Page 71 ***Nature Journal***
20		***Review*** Pages 41-71 and ***Field book*** work	Activity Fifteen ***Air and Energy Unit Reflections, Self-Assessment, and Commitments***	

Academic Standards

The following standards are addressed in this module.

Standard	Description
Next Generation Science Standards - High Schoool[i]	
Disciplinary Core Ideas	
HS-PS3.D	Energy in Chemical Processes: The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis.
HS-LS1.C	The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen.
HS-LS2.B	Cycles of Matter and Energy Transfer in Ecosystems: Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. Plants or algae form the lowest level of the food web.
HS-LS2.C	Ecosystem Dynamics, Functioning and Resilience: Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations. Anthropogenic changes (induced by human activity) in the environment — including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change — can disrupt an ecosystem and threaten the survival of some species.
HS-LS4.D	Biodiversity and Humans: Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus, sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value.
HS-ESS2.A	Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.
HS-ESS2.C	Role of Water: The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks.
HS-ESS2.D	Weather and Climate: Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere.
	Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen.

Standard	Description
HS-ESS2.D	Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.
HS-ESS3.A	All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors.
HS-ESS3.C	Human Impacts on Earth Systems: The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.
	Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation
HS-ESS3.D	Global Climate Change: Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts.
	Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities.
HS-EST1.A	Defining and Delimiting Engineering Problems: Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.
	Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.
HS-EST1.B	Developing Possible Solutions: When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.
Science and Engineering Practices	
Constructing Explanations and Designing Solutions	Design or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.
Engaging in Argument from Evidence	Construct an oral and written argument or counter-argument based on data and evidence. Evaluate the evidence behind currently accepted explanations or solutions to determine the merits of arguments.
Developing and Using Models	Use a model based on evidence to illustrate the relationships between systems or between components of a system.
Obtaining, Evaluating, and Communicating Information	Communicate scientific information (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).

Standard	Description
Crosscutting Concepts	
Systems and System Models	Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions – including energy, matter, and information flows – within and between systems at different scales.
	When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.
	Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.
Cause and Effect	Cause and effect relationships can be suggested and predicted for complex natural- and human-designed systems by examining what is known about smaller scale mechanisms within the system.
Energy and Matter	Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.
Patterns	Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.
Connections to Engineering, Technology, and Applications of Science	
Influence of Science, Engineering, and Technology on Society and the Natural World	New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.
Crosscutting Concepts	
Science Addresses Questions about the Natural and Material Worlds	Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions.
	Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge.
	Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues.
National Council for the Social Studies Thematic Strands[ii]	
People, Places, and Environments	The study of people, places, and environments allows us to understand the relationship between human populations and the physical world.
	Learners develop an understanding of spatial perspectives and examine changes in the relationship between people, places and environments.

Standard	Description
People, Places, and Environments	Apply knowledge, skills and understandings to today's social, cultural, economic and civic issues: How do people interact with the environment and what are the consequences of those interactions?
Individual Development and Identity	Questions related to identity and development are central to understanding who we are. Who do individuals grow and change physically, emotionally and intellectually? Why do individuals behave as they do? What influences how people learn, perceive, and grow? How do people meet their basic needs in a variety of contexts? How do social, political, and cultural interactions support the development of identity?
Power, Authority, and Governance	Students study dynamic relationships between individual rights and responsibilities, the needs of social groups, and concepts of a just society. Become more effective problem-solvers and decision-makers.
Production, Distribution, and Consumption	People have wants that often exceed limited resources. Unequal distribution of resources leads to systems of exchange. Economic decisions are increasingly global. Students need to study interdependent world economy and role of technology in economic growth.
Science, Technology, and Society	Science, and its practical application, technology, influence social and cultural change and ways people interact with the world. Modern life, as we know it, would be impossible without technology and the science that supports it.
	Students think analytically about the consequences of change and how we can manage science and technology to increase benefits to all.
Global Connections	Analyses of the costs and benefits of increased global connections, and evaluations of the tensions between national interests and global priorities contribute to the development of possible solutions to persistent and emerging global issues. By interpreting the patterns and relationships of increased global interdependence, and its implications for different societies, cultures and institutions, students learn to examine policy alternatives that have both national and global implications.
Civic Ideals and Practices	High school students increasingly recognize the rights and responsibilities of citizens in identifying societal needs, setting directions for public policies, and working to support both individual dignity and the common good. They become familiar with methods of analyzing important public issues and evaluating different recommendations for dealing with these issues.
Common Core Language Arts[iii]	
CCSS.ELA-LITERACY. RH.9-10.4	Determine the meaning of words and phrases as they are used in a text, including vocabulary describing political, social, or economic aspects of history/social science.
CCSS.ELA-LITERACY. RH.9-10.7	Integrate quantitative or technical analysis (e.g., charts, research data) with qualitative analysis in print or digital text.
CCSS.ELA-LITERACY. RST.9-10.4	Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9-10 texts and topics.

Standard	Description
CCSS.ELA-LITERACY. W.9-10.1.A	Introduce precise claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that establishes clear relationships among claim(s), counterclaims, reasons, and evidence.
CCSS.ELA-LITERACY. W.9-10.1.D	Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.
CCSS.ELA-LITERACY. W.9-10.2	Write informative/explanatory texts to examine and convey complex ideas, concepts, and information clearly and accurately through the effective selection, organization, and analysis of content.
CCSS.ELA-LITERACY. W.9-10.4	Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
CCSS.ELA-LITERACY. W.9-10.9	Draw evidence from literary or informational texts to support analysis, reflection, and research.
CCSS.ELA-LITERACY. W.9-10.10	Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.
CCSS.ELA-LITERACY. SL.9-10.1	Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9-10 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.
CCSS.ELA-LITERACY. SL.9-10.1.A	Come to discussions prepared, having read and researched material under study; explicitly draw on that preparation by referring to evidence from texts and other research on the topic or issue to stimulate a thoughtful, well-reasoned exchange of ideas.
CCSS.ELA-LITERACY. SL.9-10.1.B	Work with peers to set rules for collegial discussions and decision-making (e.g., informal consensus, taking votes on key issues, presentation of alternate views), clear goals and deadlines, and individual roles as needed.
CCSS.ELA-LITERACY. SL.9-10.1.C	Propel conversations by posing and responding to questions that relate the current discussion to broader themes or larger ideas; actively incorporate others into the discussion; and clarify, verify, or challenge ideas and conclusions.
CCSS.ELA-LITERACY. SL.9-10.1.D	Respond thoughtfully to diverse perspectives, summarize points of agreement and disagreement, and, when warranted, qualify or justify their own views and understanding and make new connections in light of the evidence and reasoning presented.
CCSS.ELA-LITERACY. SL.9-10.4	Present information, findings, and supporting evidence clearly, concisely, and logically such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task.
CCSS.ELA-LITERACY. SL.9-10.6	Adapt speech to a variety of contexts and tasks, demonstrating command of formal English when indicated or appropriate.

Unit 1

Meeting Human Needs Sustainably

Essential Questions For This Unit

1. *How is my body connected to nature through food and water?*
2. *How are food and water issues related to each other?*
3. *How can food and water be produced and shared sustainably, now and into the future?*
4. *Where do my food and water come from?*

Food and Water: Necessities of Life

Food, Water, and the Web of Life

Food: one of the basic needs of all living things on Earth. All animals are driven by a need to eat regularly. Food provides the energy that animals – including humans – need to grow, function, move, and reproduce. Food connects us with the web of life because all living things share the need to bring in energy.

Ultimately, all energy used by living things comes from the sun. Plants form the base of the food web, using photosynthesis to convert the sun's energy into sugars that help the plants function. In aquatic ecosystems, phytoplankton also fill this role; phytoplankton are microscopic plants. An **ecosystem** is a community of organisms – plant, animal, and other living organisms – together with their environment that function as a unit. The sun's energy spreads through the food web as herbivores – plant-eating animals – eat the plants. Omnivores – animals that eat both plants and animals – and carnivores – animals that eat other animals – are next in line. Finally, decomposers break down the remains of other living things. At each stage, some energy is used within the organism and some is released as heat.

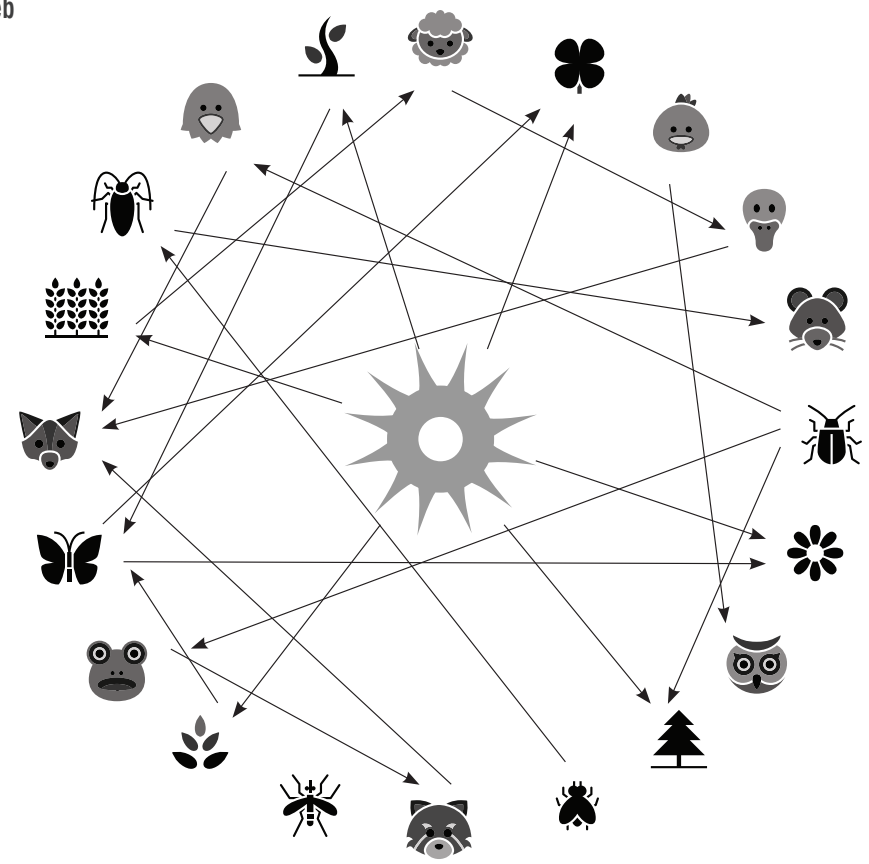
Important nutrients also cycle through the food web. Plants absorb nutrients like nitrogen, phosphorus, and iron from the soil. They are distributed throughout the food chain and are eventually returned to the soil by decomposers. In nature, all materials are reused and recycled. What might be waste for one organism or system becomes food for another.

The food web also provides a way for organisms to share water. Water serves several important functions in living organisms, making it just as essential as food for maintaining life. Many biological processes rely on molecules dissolving and materials mixing. Water is an excellent liquid for the job because almost all materials can at least partially dissolve in water. Also, the flow of a liquid easily moves materials like nutrients or wastes to different parts of plants or animals.

Think About It!

What functions does water serve in your body? Are these functions the same in all animals? Can you think of ways in which water supports plant life? How are these functions similar or different?

Food Web



Food, Water, and Sustainability

What will it take to meet a growing human population's need for food and water? Understanding food and water from a sustainability perspective can help us recognize where existing food and water systems are successful, make effective predictions about systems that may not work well, and develop solutions that better serve people, our economy, our society, and other living things.

Sustainability can be defined as meeting the needs of those living today without limiting the ability of future generations to meet their needs. We can also think of sustainability as describing a safe and just world for all species, forever. We can work towards creating a sustainable world by developing a **sustainability worldview**, which is a set of knowledge, values, capabilities, and behaviors that bring about a sustainable world.

Sustainability can be framed by eight big ideas:

Nature Connection

We are part of nature; it is our home, rather than a storehouse of resources, a place for recreation, or a wild space to be conquered. Nature has sustained life for billions of years throughout widely changing conditions. People can learn from and adopt nature's patterns.

Respect For Limits

Earth has a limited capacity to supply all of its inhabitants with clean air, fresh water, food, and the ability to recycle waste. Accepting these limits helps us take responsibility for our choices.

Universal Responsibility

Just as we each have universal human rights, we also have universal responsibilities. We can learn to take responsibility for our personal choices and actions. We can also take on the deeper responsibility of creating a safe and just world for all, forever.

Equity and Justice

Each person should have equal access to opportunities and resources. The impacts and consequences of societal and global choices should also be shared equally. Equity and justice also need to be extended to future generations and other species.

Health and Resiliency

Sustainability focuses on the well-being of living things and the natural and social systems on which we depend. Resiliency refers to the ability to function and develop even under changing conditions. Because human actions are changing the planet in many ways, it is important for people and human systems to be resilient.

Interconnectedness

Interconnectedness points to the many relationships that allow a group of objects or organisms to form a complex whole that works as a unified system.

Local to Global

Our local actions are linked with global social, economic, and environmental systems. This idea also reflects the understanding that people are citizens of the world with shared values that cross cultures, nations, and religions.

Peace and Collaboration

Peace is a fundamental human need. We can learn to live together peacefully, respecting the needs of others – today and in the future – as equally important as our own. This idea also reflects the need to recognize the power that human societies have over other species and to recognize the value of all living things.

For more detailed descriptions of these big ideas, please see the Facing the Future website at https://www.facingthefuture.org.

Food

Think About It!

Read the partial list of Earth Charter values below. As you read this unit, keep these values in mind.

EC5. Protect and restore the integrity of Earth's ecological systems, with special concern for biological diversity and the natural processes that sustain life.

EC7. Adopt patterns of production, consumption, and reproduction and safeguard the Earth's regenerative capacities, human rights, and community well being.

EC15. Treat all living beings with respect and consideration.

For more detailed information on these values, please see http://earthcharter.org/discover/.

Background on Food Production and Agriculture

For thousands of years, people lived as hunter-gatherers, following animal migrations and the seasonal growth of plants. World population remained low and grew slowly. Over time, people began to grow their own food to make food supplies more certain and productive. Agriculture required early farmers to collect and replant the seeds of desired plants. Farmers domesticated animal species by controlling their reproduction and isolating them from wild populations. With more plentiful and secure food supplies, populations grew rapidly.

Agriculture began independently in many places around the globe. Humans began to alter the environment as never before. They dammed rivers and streams to irrigate crops, eliminated unwanted species in an area, and deliberately planted particular species of interest to humans. These changes have had varying effects on ecosystems. In some cases, humans have learned to farm in ways that are cooperative with nature. In other cases, clearing native plants to make space for farming has led to soil erosion and expansion of deserts.

In the 1950s agriculture went through a transformation called the Green Revolution. Industrial products began to be used in agriculture, including fertilizers, pesticides, new machinery, irrigation systems, and hybrid seeds – those developed by scientists to develop specific traits. New agricultural practices and technologies dramatically increased crop yields, helping to feed a growing world population. By the 1960s, **monocultures** – fields where only one crop is grown – and dependence on chemical fertilizers, pesticides, and herbicides had become widespread throughout the world. More farmland was created by clearing forests, filling wetlands, and converting prairies. These agricultural processes reduced plant and animal habitats.

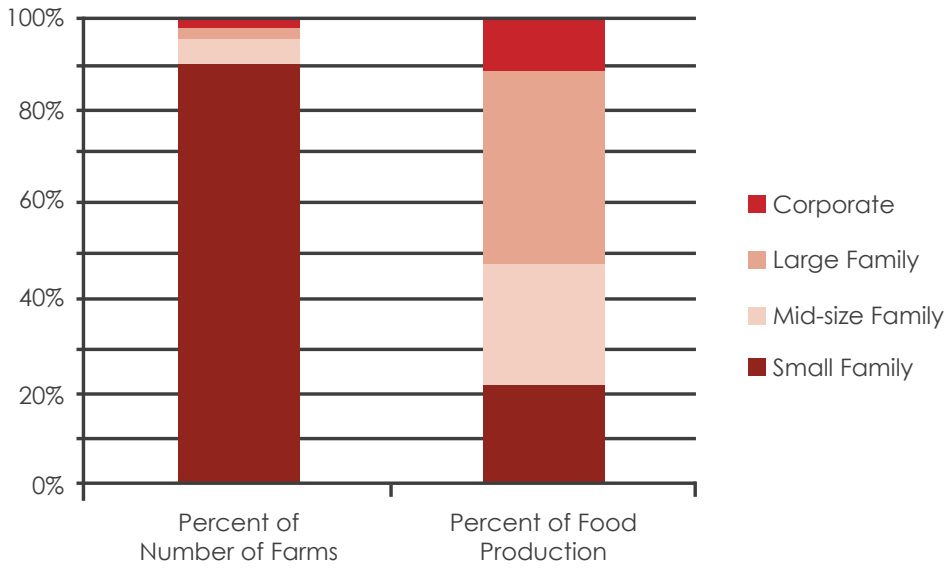
Think About It!

Based on the figure below, what conclusions can you draw about farming and food production in the U.S.?

Agriculture Today: Production

There are an estimated 570 million farms in the world; almost all of them – about 500 million – are believed to be smaller than 2 hectares (5 acres or 0.01 square miles). Over 60% of the world's farms are located in India and China. In the U.S., about 90% of all farms are considered small family farms. Only 2% are owned by corporations rather than by families. The figure below shows the kinds of farms found in the U.S. and their contribution to food production.[1]

U.S. Farms and Food Production



In developing countries, small farms produce four-fifths of food consumed. In many of these countries, women – and children – are responsible for much of the farming work. For example, in Nepal, women collect food for buffaloes; one buffalo alone can eat as much as 40 tons of grass and leaves per year. Few women own the land or the animals with which they work.[2] For the most part, these farms focus on supplying food for local needs. Cash crops – those sold to earn money – account for only a small portion of farm produce in developing countries. Latin America and the Caribbean are exceptions: they grow coffee, cocoa, and sugar for export to other countries. Southeast Asian countries like Malaysia grow palm oil as a cash crop; it takes up 65% of their farmland.[3] In the U.S., most food is produced on large farms that sell the food they produce. The largest crops in the U.S. are corn, hay, soy, and wheat.[4]

Conventional Agriculture

Conventional agriculture seeks to maximize the yield – or food production – of crops. To maximize efficiency, conventional agriculture separates crops into monocultures. Monoculture crops require simplified, though constant, maintenance because a large field planted with a single crop can be treated uniformly. Heavy-duty farm equipment like tractors can till – or prepare by digging and turning – large fields and harvest crops. However, monoculture crops are more vulnerable to pests, which can spread rapidly in a field full of hospitable host plants. Once the crop is harvested, plant waste is generally removed.

To produce high-yield single crops, conventional agriculture relies on chemical inputs. **Synthetic fertilizers, herbicides,** and **pesticides** – those made by people – are used to enrich the soil, kill weeds, and keep away pests. Bare soil allows water to evaporate, requiring intensive irrigation, or watering, by people or equipment.

Though many critics of conventional agriculture may agree that these techniques produce a lot of food, they raise several concerns about such farming practices. One concern is the exposure of humans and wildlife to hazardous chemicals. These chemicals can affect farm workers, food consumers, and wildlife, including pollinators like bees. Pesticides, herbicides, and chemical fertilizers can also run into and pollute water bodies and groundwater. Also, conventional farming requires fossil fuels to run heavy-duty farming equipment. In fact, it takes ten calories of fossil fuel energy to produce one calorie of food.[5] A calorie is a unit of energy measurement. Another concern about conventional agriculture is the possibility of depleting water sources and eroding soil. Critics say that creating high yields alone will not alleviate hunger; underlying problems like poverty and challenges in getting food to the locations that need it most must also be addressed.

Some other issues associated with conventional agriculture are discussed below.

***Genetically Modified Foods*:** For centuries, scientists tinkered with seed production, selecting seeds from higher-yielding crops or tastier fruits in an attempt to ensure those traits persisted in their next harvest. Today, some plant breeders are going beyond this practice to create **genetically modified organisms (GMOs)**. Genetic modification involves inserting genes from one organism into the genes of another to produce desired characteristics. Examples include plants that have resistance to certain pests, diseases, or environmental conditions; reduction of spoilage; or resistance to chemicals, such as herbicides. This means a field can be sprayed with chemical herbicides to kill the weeds but the food crop plants will not die. Some people see the increasing use of GMOs as the only way to feed the world's rapidly growing population.

genetically modified organism:

An organism whose genetic material has been changed by genetic engineering.

Others oppose GMOs and question their safety for humans, citing possible toxicity, allergens, and adverse nutritional effects, as well as the potential for GMOs to accidentally introduce engineered genes into wild populations. Many people favor labeling GMO foods to allow consumers to decide if they want to purchase them. There is no labeling law in the U.S. In 2014, Vermont passed a law that requires foods containing GM foods to be labeled. Because of this law, in 2016 food companies started to label products containing GMOs for distribution throughout the United States. For these companies, it is not worthwhile to produce special labels for only one state.[6] GM foods already constitute a substantial part of food intake in the U.S. because corn and soy crops are often genetically modified. These crops are used in products like corn syrup sweeteners or soy and vegetable oil products, all of which are used in many common packaged foods. Globally, sixty-four countries require GM foods to be labeled, including Australia, Bolivia, Ethiopia, Sri Lanka, and New Zealand.[7]

***Livestock*:** Raising livestock for large-scale meat and dairy production requires a significant amount of water and land. Globally, half of all grains are grown to feed livestock for meat production. The United Nations estimates that shifting that grain harvest to people would feed 3.5 billion people.[8]

In some tropical locations, ranchers are clearing rainforests in order to create pasture for cows. This approach to beef production reduces the biodiversity found in the rainforest by reducing habitat for many species. Brazil is addressing this issue by improving protection of its rainforests and reducing illegal logging; at the same time, the beef industry has come under pressure to improve farming practices rather than clear more land.

Grazing animals eat a lot of plants, and their hooves compact soils, making it difficult for plants to grow again. A technique that minimizes grazing impacts is **rotational grazing**. Instead of allowing animals to graze an entire pasture, farming using rotational grazing leaves animals in a smaller area for a short time. Then the animals are moved to a new area, giving the recently grazed area time to recover. This practice helps to prevent overgrazing and erosion and leaves livestock supplied with new plants to eat.

Current practices for raising livestock – which are similar to traditional farming and ranching practices – include efforts to minimize crowding of livestock animals and bring animals closer to their natural ways of living. Chickens can be raised with access to the outdoors with at least some opportunity to forage on insects and grass. Cows can be pastured on grasslands and fed hay. Grasses are cows' natural diet, but many cattle farms rely on less costly corn for feed. The traditional practices result in healthier animals and lower environmental impacts but typically increase food costs for consumers.

***Irrigation*:** Water is an essential resource for agriculture. While fields are sometimes watered by rainfall, most farmers rely on wells in aquifers to provide irrigation water. **Aquifers** are areas of porous rock below ground where water collects. Agricultural water use currently accounts for 80 percent of the ground and surface water used in the United States and about 70% of global water use.[9] In many places, aquifers are now being depleted faster than they can recharge, or fill.

***Climate Change*:** Food production contributes to **climate change** through the burning of fossil fuels in farm equipment; methane produced by rice paddies and livestock; the release of nitrogen from fertilizers, soil, and animal waste; and methane production from food waste in landfills. Greenhouse gas emissions – air contaminants that cause the planet to warm – from the entire food supply chain account for 22% of total emissions.[10]

climate change:

Disruption of longstanding climate patterns such as temperatures and rainfall due to increasing emissions of greenhouse gases like carbon dioxide and methane.

Think About It!

How does this table demonstrate the sustainability big idea of interconnectedness? Does it demonstrate other big ideas?

Food production and climate change are deeply interconnected: climate change can affect food production as well. Changing temperatures can affect farmers' plant selections, and droughts or floods could affect crop health. In some areas, warmer temperatures may allow more food to be grown.

The table below compares water use and greenhouse gas emissions from the growing of some common foods.

Environmental Impacts of Common Foods[11]

Food Item Serving Size: about 0.1 kg (4 oz)	Water Used in Production liters (gallons)	Greenhouse Gas Emissions kg CO2
Beef	1609 (425)	27
Chicken	250 (66)	7
Egg	178 (47)	5
Rice	246 (65)	3
Broccoli	76 (20)	2

Sustainability Big Idea: Equity and Justice

Fair treatment of farm workers is a global concern. They often receive low wages and work long hours. In many developing countries, farm workers may own small, independent farms but may not be able to negotiate good prices with buyers. Almost all agriculture workers in these countries – 83% – live below the poverty level of $5.00 per day.[12] In the United States, 61% of farm workers live in poverty.[13]

Systems Thinking and Conventional Agriculture

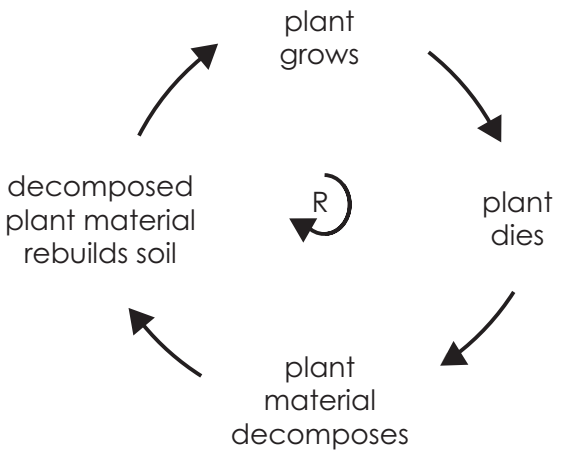
Systems are groups of components in which the parts work together as a unified whole to accomplish some purpose. In systems thinking, we look for relationships between components and try to understand how they work together. **Systems Thinking** is an approach that helps us recognize systems and understand their behavior. Some of the components in conventional agriculture include:

- soil
- water
- plants
- fertilizers
- pesticides
- herbicides
- farm equipment
- soil organisms.

Well-functioning systems contain **feedback loops**, in which a change in the behavior of one component "feeds back" into the system to affect overall system behavior. A feedback loop is a cycle in which a system uses information from its components to change its behavior. These feedback loops allow systems to be **resilient**, meaning that the systems can respond to changing conditions by changing their behavior. In this way, they can continue to function within change.

Causal loop diagrams are a systems thinking tool that helps us map out interconnections and cause-and-effect relationships. A plant's natural cycle of growth and decay, which includes cycling nutrients through the plant and soil, is one example of a cause-and-effect relationship. This cycle can be represented by the causal loop diagram shown in the figure above.

Casual Loop Diagram for Plant Lifecycles



Each step in the cycle leads to the next in a cause-and-effect pattern. The "R" in the center tells us that this is a **reinforcing loop**. A reinforcing loop is a feedback loop in which change gets reinforced, or strengthened, with each step around the cycle.

resiliency:

The ability of a system to adapt to change while continuing to function and develop. Individuals, communities, and ecosystems can all be resilient.

Conventional agriculture does contain some cause-and-effect relationships. But overall, it is a linear, one-way process, so it cannot be mapped as a cause-and-effect loop. The figure below shows where conventional agriculture has cause-and-effect relationships in the cycle of plant growth, decay, and nutrient cycling – and where it does not.

Cause and Effect Relationships in Conventional Agriculture

fertilizers, pesticides, herbicides added to soil → plant grows → plant dies → plant waste removed

Think About It!

If the natural plant cycle is a reinforcing loop – meaning that an increase in one step leads to an increase in the next – what stops plants from unlimited growth?

Sustainable Agriculture

Sustainable agriculture is an alternative to conventional agriculture. It is a way to produce food that works with and takes its cues from natural systems. The goals include sustaining the health of soils, ecosystems, and people to produce social, economic, and environmental benefits. This approach is also sometimes called **agroecology**.

Healthy soil is an important element of sustainable agriculture. There are a variety of techniques for improving soil. Cover crops – often a grain or grass – are grown during non-growing seasons to protect against soil erosion and to suppress weeds. At the end of the season, the grass is cut and left as mulch – a plant-based ground cover – or incorporated into the soil to decompose and provide nutrients. Either of these approaches helps retain soil moisture, so less water is required for irrigation. Sustainable agriculture emphasizes reduced or no tillage to prevent soil damage and compaction; reducing tillage also reduces fossil fuel use, as less machinery is used. Farm waste and animal manure can be recycled

into **compost**, which serves as a mulch and returns nutrients to the soil. Composting allows sustainable farmers to improve their soil while making use of valuable materials that would otherwise be thrown away.

> compost:
> *A mixture of decayed plant material used to improve soil.*

Sustainable agriculture systems rely on **ecosystem services** and **biodiversity** to help protect against pests; often native plants and flowers are grown near food crops to attract beneficial organisms that can help fend off pest species. This approach is less harmful to the land, bodies of water, and wildlife. Food is typically grown closer to consumers, who also benefit from the lack of chemicals in their food. Reducing food transportation also minimizes fossil fuel use in trucks.

Sustainable farms grow food that is suited to the region's climate and season. These choices mean that crop plants are stronger and healthier, making the use of chemical additives easier to avoid.

Some sustainable agriculture farms are certified **organic**. This certification means that a certifying organization or government agency, like the Department of Agriculture in the U.S., has inspected the farm. Inspections guarantee to the consumer that the farm meets specific standards for avoiding use of toxic substances or genetically modified organisms.

Advocates for sustainable agriculture feel that sustainable farms benefit the environment and consumers by using fewer toxic materials and less water. Sustainable farms also produce less water runoff, since the improved soil can absorb irrigation water better. Often the food from small farms can be purchased right at the farm at roadside stands or at neighborhood farmers markets.

Skeptics have raised concerns that sustainable agriculture cannot produce enough food for the planet, predicting that much more land would be needed for sustainable farms than for conventional farms. In developed countries that rely heavily on chemical inputs, scientific studies to answer this question give mixed results. Some long-term studies show that organic farms can produce as much as conventional farms; other, shorter-term studies have shown that organic farming may produce about 20% less food than conventional farming, especially in the first few years when a farm is transitioning to sustainable operations.[14] However, in the world's poorest regions – where people are more likely to be hungry – sustainable farms are likely to deliver 20 to 90% higher yields. At these farms, the increased soil productivity and increased ability to hold water make all the difference. Sustainable farming also brings economic benefits to these farmers, since expensive chemical fertilizers and pesticides are not needed.[15]

Learning from Nature: Permaculture

Permaculture uses careful design to bring nature's cycles to farms and gardens. The word "permaculture" combines "permanent" and "culture", reflecting the central idea of an ongoing, self-sustaining way of providing food. This approach shares many ideas with sustainability. It is based on a set of ethics: "Earth care, people care, fair share." These principles remind practitioners to care for the soil, which should be full of living organisms; care for ourselves, our families, and our communities; and to share what we have while taking no more than our fair share of the Earth's bounty. Permaculture practice includes observing and designing thoughtfully, using energy and water efficiently, using all outputs to avoid production of waste, using nature's patterns, and valuing diversity.[16]

Permaculture began in Australia in the 1970s. It is now practiced across the world. One of the largest installations is in the Zimbabwe community of Chikukwa. Deforestation led to soil loss through erosion; the remaining soil was of poor quality. Permaculture methods helped the community's 8,000 small farms stabilize eroded soil, improve soil water retention, and plant crops to produce abundant food. The farms in the region benefit from saving seeds for the next year's planting, using plant waste to mulch the soil to retain water and support soil microbes, using agriculture byproducts to feed livestock, cycling animal manure into the soil, and focusing on diverse food crops rather than cash crops. The permaculture program produces food for families along with some surplus to generate cash – without the need to purchase seeds, fertilizers, or pesticides.[17]

permaculture:
A food production system based on ecology, ethics, and valuing diversity.

Think About It!

What would a causal loop diagram for permaculture's cycle of plant growth, decay, and nutrient cycling look like? Is it more like nature's cause-and-effect relationships or conventional agriculture's relationships? Draw a causal loop diagram for plant growth and another one for the cycle of animal feeding and waste recycling.

Food Distribution

A **foodshed** is the geographic area from which a population center derives its food supply. It includes the area where the food is grown and produced and the route the food travels to get to the consumer. Foodsheds may be large or small depending on where one lives, how many people live there, climate, seasons, soils, water availability, individual desires, and financial wealth. Large foodsheds require more fossil fuels to transport food. If each human could shrink their foodshed and eat food grown and produced as close as possible to where they live, the amount of resources needed to feed everyone would be reduced.

Getting all of a community's food needs met from where it is located is desirable but not always possible to implement. For instance, people that live in deserts may not have local produce available. Or if someone lives in a northern climate but desires tropical foods such as bananas or chocolate, those food items will travel a long distance to get to the consumer.

Sustainability Big Idea: Local to Global

Recall that the big idea of Local to Global refers to global impacts of local choices and local impacts of global trends. **Food miles** tie in to this idea; they are a measure of the distance between the farm and the consumer. High food miles imply high use of fossil fuels for transportation, resulting in air pollution and global warming. Many meals in the U.S. now contain ingredients from as many as five other countries.[18]

Food Security

Everyone needs to eat. Today, farmers are able to grow enough food for all people on Earth to have the nourishment to lead healthy, productive lives.[19] The number of people who go hungry has decreased by 25% since 1990.[20] Even so, almost 10% of people on Earth do not have enough to eat.[21] In the U.S., 13% of people experience hunger on a regular basis.[22] Experts are concerned that rising global population can further strain food supply.

The 1996 World Food Summit explained **food security** this way: "when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life."[23] Commonly, food security is defined as including both physical and economic access to food that meets people's dietary needs as well as their food preferences.

Globally, there are many different reasons why people do not have enough to eat. Sometimes people go hungry when there is enough food to go around but it is not distributed equally. This situation can occur for reasons such as poverty, discrimination, corrupt governments, or civil war. In some cases, even if food is available, poor people do not have the money to buy it. In other cases, a specific ethnic group may be prohibited from accessing food. Sometimes governments in poor countries export the food they grow in order to pay debts to other countries instead of using

it to feed their own people. In other instances, unsustainable farming may have reduced soil fertility so that a farm can no longer produce enough food.

Water and land issues can also cause hunger. Regions of eastern Africa and the Middle East include much land area considered arid, or very dry. These areas receive little rainfall and are vulnerable to prolonged droughts. Other geographic constraints might be related to loss of farmland due to urban growth, industry, or the land being used for other uses.

In rural and lower income urban areas in both developing and developed nations, people's access to food can be limited because of poverty or lack of transportation to a grocery store. A **food desert** is a place lacking in fresh fruit, vegetables, and other healthful **whole foods**. Food deserts occur largely due to a lack of grocery stores or other providers of fresh food such as farmers markets. Instead, food may only be found in convenience stores that primarily sell highly processed foods and foods loaded with sugar and fats. These foods are known contributors to obesity.

food desert:

A place where residents have limited access to affordable, healthy food because of a lack of nearby grocery stores.

United Nations Sustainable Development Goals

In 2015, the United Nations created a framework of sustainable development goals to reduce poverty, bring about peace, and heal the planet. Here is the goal for food:

Goal 2 - Zero Hunger: End hunger, achieve food security and improved nutrition and promote sustainable agriculture.

Achieving this goal requires action steps such as increasing agricultural productivity, improving incomes of small food producers – especially women, and expanding sustainable agriculture.[24]

Think About It!

Take a look at a food insecurity index map at http://foodsecurityindex.eiu.com. Find a global map online that shows poverty levels by country. How are these two maps similar or different? What conclusions can you draw about food insecurity from this exercise? What sustainability big ideas are reflected in food insecurity and food deserts? What Earth Charter values apply?

Food Consumption

When we are surrounded by fast food, sweets, and super-sized portions, it can be hard to remember that the basic purpose of food is to nourish our bodies. Food is a primary way in which we connect with the world around us: we literally bring it into our bodies and make it our own. Experiencing this exchange by eating healthy, natural food can be very enjoyable.

A healthy diet is one of the foundations of well-being. People with healthy diets get sick less, have more energy, and have a better chance of avoiding long-term health problems like heart attacks, diabetes, some types of cancer, and obesity.[25] The U.S. Department of Agriculture recommends filling half of your plate with vegetables, eating whole fruits, choosing whole grains half the time, consuming low- or non-fat dairy products, eating a variety of proteins, and minimizing salt, saturated fats – those that are solid at room temperature – and added sugars. For the first time, the 2015 guidelines were developed with consideration of environmental impacts of food production.[26]

People in industrialized societies often eat food prepared in a factory. Some of these **processed foods** are perfectly healthy, but many contain a lot of salt and sugar. Processed foods have been refined, treated, or cooked and are usually packaged in boxes, cans, jars, or bags. In the U.S., packaged foods are required to be labeled with information about ingredients, calories, added sugars, and salt. These labels are designed to help consumers make healthy food choices. Food processors also add terms to their product labels like "natural," "healthy," or "organic." Of these labels, only foods labeled "organic" must meet legal standards. Other terms like "healthy" or "natural" have no standard meaning: it is up to each food manufacturer to decide what they mean by those terms.

Portion size is another challenge to healthy eating. Restaurant meals are four times larger today than they were in the 1950s. Typical servings of French fries have grown from 57 grams (2 ounces) to 198 grams (7 ounces). Hamburgers are now 340 grams (12 ounces), compared to 113 grams (4 ounces) in the 1950s. Sodas have seen the biggest growth, from 198 grams (7 ounces) to as much as 1,191 grams (42 ounces).[27] Our waistlines have grown along with our meal sizes. In 2016, for the first time global obesity rates were higher than underweight rates. Between 1975 and 2014, global obesity among men tripled and among women it more than doubled.[28] **Obesity** is an excessive amount of body fat. Obesity has been linked to increased risk for medical conditions including diabetes, heart disease, high blood pressure and stroke.

Think About It!

Consider the following processed foods. Try to trace them back to whole, natural foods and the original plants that converted the sun's energy into food. How do you think the nourishment in the processed food items compares to the nourishment available in the whole foods? What additional energy and materials went into preparing the processed food?

- *potato chips*
- *an energy drink*
- *a coffee beverage*
- *a granola bar*
- *a fast food hamburger*

Try this exercise with other processed foods you eat or see.

whole food:

A food that is unprocessed or unrefined and does not contain artificial ingredients.

processed food:

A food that has changed in any way before it is available for eating.

Food Waste

Food waste has enormous impacts on food supply. Globally, an astonishing 33% of all food produced is wasted or discarded before it is used.[29] Food waste rates are even higher in the U.S., where 40% of food goes uneaten – six times more food waste than in countries in Southeast Asia. That wasted food makes expensive garbage, with the U.S. portion valued at $165 billion each year.[30] More than the food itself goes in the trash: by throwing that food away, the land use, water, energy, chemicals, and time spent growing the food are also wasted. And once the food is disposed of in a landfill, it contributes to climate change by creating methane, a greenhouse gas. Most important of all, hungry people could have eaten that food.

Many kinds of losses contribute to food waste; these losses occur all along the food production cycle. The biggest losses come from spoilage of fruits and vegetables at farms – 20% – and from consumers tossing out unused produce – 12 to 33%, depending on the food item.[31]

Improvements are possible. The European Union resolved to reduce food waste by half by 2020. As part of that effort, the United Kingdom's food waste has already declined by 18%.[32] Consumers can help by shopping carefully, planning meals that use food on hand, and avoiding over-ordering at restaurants. Vancouver, Canada, no longer allows food waste to be thrown into the regular trash collected by the city. Instead, food waste is collected separately so it can be made into compost.[33]

Think About It!

Recall that in nature, there is no waste. Materials that are unused by one organism become food or shelter for another. How could this principle apply to food waste?

Pathways to Progress

There are many examples of positive work to increase the availability of sustainably-grown food.

Efficient Food Production

Food productivity improvements include reducing the demand for resource-intensive food such as meat and dairy, developing crops that have higher yield, and halting urban sprawl so farmland is preserved.

Consumer Demand

- ***Be Informed and Make Wise Choices:*** Become aware of where your food is grown, how it is grown, and who grows it. As a consumer you have a voice in how your food is produced. You can buy seasonally appropriate food grown by a farmer that lives within 100 miles from you. You can also choose to buy food that was grown according to environmental standards that are important to you.
- ***Read Labels:*** One way to learn about how your food is raised is to read the label. There are many food-related terms on food labels: organic, natural, wild-caught, locally-grown, hormone-free, grass-fed, cage-free, etc. Do research and learn what these words mean.
- ***Meet Your Farmer:*** The best way to learn about where your food comes from is to meet the people who grow it. Shopping at a farmer's market, buying a share in a Community Supported Agriculture program – in which you receive a weekly box of farm produce – or visiting a local farm are great opportunities to ask farmers questions.
- ***Eliminate Food Deserts:*** Do you live in a neighborhood without a grocery store or farmer's market? If you want your neighborhood store to carry more fresh fruits and vegetables, ask your grocer. Get others in your neighborhood involved and show a local food retailer that many people will buy fresh foods if they're available.

Government Support

Federal programs can support food security. The U.S. Farm Bill encourages sustainable agricultural practices such as soil and water conservation and offers financial support to farmers transitioning to organic methods. The Farm Bill also encourages school lunch programs to purchase locally grown farm produce when possible. [34] In 2016, Congress passed the Global Food Security Act that authorizes the federal government to create a comprehensive strategy for U.S. foreign assistance to promote global food security, resilience, and nutrition[35]

Support Projects that Reduce Hunger

Individuals can help reduce hunger by volunteering at local food banks or contributing to food drives. Backing local, national, and international organizations in reducing hunger and malnutrition, supporting sustainable agriculture, and eliminating food deserts also helps.

Urban Agriculture, Community Gardens, and Home Gardens

Growing your own food is a good idea in so many ways: it helps provide healthy, local food; helps many people reduce stress; offers physical exercise; and helps us connect with nature. Some research even suggests that getting our hands in the dirt can lift our moods and reduce anxiety. It may be that a species of bacteria found in the soil causes the release of brain chemicals that help us feel better and even improve our thinking ability.[36] Here is another interconnection between sustainability big ideas: nature connection and well-being.

Think About It!

Just for fun, watch this short video about the Vegetable Orchestra, which creates their own musical instruments from – yes, vegetables. The Viennese group has been performing all over the world since 1998. Please see http://www.vegetableorchestra.org/videos.php.

Local gardens can begin in many ways. Some cities work with community groups and local businesses to build urban agricultural projects. Vacant lots, public land, school grounds, and flat roofs on buildings are all perfectly fine places to create gardens. The town of Todmorden, England, uses their public space to grow vegetables and herbs.[37] Food can even be grown on pavement using raised beds filled with garden soil. Other cities set aside public space community gardens where individuals come to grow food. People with yards can grow fruits and vegetables. Many schools now have gardens; some schools even use their own produce to make school lunches.

Career Profile

Will Allen, Growing Power

Will Allen is transforming the planning, cultivation, production, and delivery of healthy, local food to urban and rural populations. He is an urban farmer and the founder and CEO of Growing Power, Inc.

Will Allen

Will grew up on a small farm in Maryland. He was one of six children of a sharecropper – a small farmer who rents their farm plot. After playing professional basketball in the U.S. and Belgium, he eventually took over operation of his wife's family farm located near Milwaukee, Wisconsin.

Looking for a place to sell his produce, he found a vacant 3-acre garden center in the city. The property was the last tract in Milwaukee that was still zoned for agriculture. Will realized he could sell food from his own nearby farm and also grow food at the 3-acre site. It was located in an urban neighborhood where there was little fresh food to be found.

Before long, young people from the neighborhood, including kids who lived in the largest low-income public housing project in Milwaukee, began to ask him for advice and assistance with growing their own vegetables. Will took up the mantle of teacher and trainer, and the impromptu gathering of neighborhood children became the Youth Corps, a program that continues today. In 1995, Growing Power was born: a non-profit center for urban agriculture training and the building of community food security systems.

Will developed an innovative gardening system that combines composting, vermicomposting – using worms to make and refine compost – and aquaponics – growing fish. The system collects irrigation run-off into a fish pond. Fish waste and pond water are cycled back to irrigate and feed plants. Plant waste is composted and applied to planting beds. The system recycles nutrients and water in a closed system, creating no waste. These and other intensive practices result in remarkable yields of food in a very small area.

Today, Growing Power, Inc., is involved in more than 70 projects in Milwaukee, across the U.S., and throughout the world. Will has taught in Ukraine, Macedonia, and Kenya. Will has received many awards for his innovative work.

Water

Water is a sacred symbol in cultures around the world. For many indigenous peoples, water is considered the element of creation. Rituals born out of a belief in water's healing powers are present in various cultures and religions. Even today, many people feel more relaxed, peaceful, and connected when they spend time around water.

Water is one of the planet's most precious natural resources – all life on Earth depends on it for survival. Water serves several functions in living organisms. First, many biological processes require molecules to mix and dissolve, which can only occur within a liquid. Water does the job well, because almost all materials can at least partially dissolve in water. Also, the flow of a liquid easily moves materials like nutrients to different parts of plants or animals. Humans can survive for quite a while without food but only for a short time without drinking fresh water.

Water as Commons

A **commons** is a public good shared by all. Traditionally, the social or political group would decide how to manage use of the commons so that the needs of individuals were balanced with the needs of the community. Without strong agreements within the community, an individual could try to increase their personal gain from using the commons; this situation could harm the community as a whole. This emphasis on personal gain from the commons over community well-being is known as "the tragedy of the commons." Water is the ultimate commons: we share it with all other species. And because no new water is being made, the water we use today is the same water that will be used by future generations. Water flow – rain, rivers, groundwater – follows natural boundaries rather than national boundaries. Sharing water fairly can build peace between nations.

Water Supply

In its various forms – solid, liquid, or gas – water moves on the Earth and in the atmosphere through the water cycle. The cycle consists of four main phases: evaporation, condensation, precipitation, and runoff. Water is considered a **renewable resource** – a natural substance with economic value that can be replaced in roughly the same time frame in which it is used. However, the total amount of water on the Earth is limited. The majority of water on Earth – 97.5% – is salt water. Of the 2.5% that is fresh water, most is frozen in ice caps or glaciers and is unavailable to use. Less than 1% of the fresh water on Earth is available for use by humans and other living beings outside of the oceans.[38] This water is found in freshwater lakes and rivers and in **groundwater** – water that collects underground in spaces in sand, soil, and rock.

Watersheds

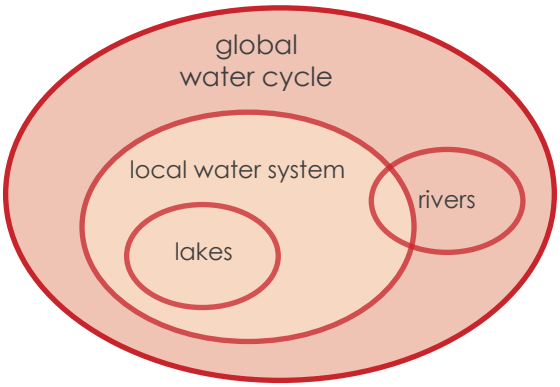
Watersheds are one of the ways nature moves water around. A watershed is a geographic area between ridgelines or higher ground that "sheds" or drains rainwater and snowmelt into a stream, river, or lake. A watershed catches water that falls to the earth and channels it to an outlet such as the mouth of a stream or river. One way to think about meeting human needs for water would be for communities to try to get all of their fresh water from within the watershed they live in or from one nearby.

Think About It!

Where does your water come from? How can you find out? What natural features define your watershed?

Watersheds are systems nested within the larger global water cycle. **Nested systems** are complete systems that function on their own and at the same time are part of larger systems. The figure below shows the watershed nested within the water cycle and lakes – also systems on their own – nested within the watershed. Rivers are also nested systems within the global water cycle. But they are considered overlapping systems with the local watershed, since only part of a river flows through the watershed.

Nested and Overlapping Water Systems



Think About It!

How would groundwater fit into the figure above? What other parts of the water cycle nest within or overlap a local watershed?

Sources of Freshwater

Most people living in industrialized countries, especially in cities, are provided water by their local government. This might mean a city, county, or state government is in charge of managing, conserving, and protecting a watershed to keep the water clean. Water agencies test water regularly, treat the water as needed to make sure it is clean, and deliver it through pipes to homes and businesses.

In more rural areas where piped-in water supplies may not be available, many people dig water wells to access groundwater. Underground formations filled with groundwater are called **aquifers**. Many aquifers provide water in large enough quantities to be used for irrigation and drinking. Aquifers are recharged – or refilled – as precipitation trickles down through layers of soil and rock.

Think About It!

From a sustainability perspective, what are the pros and cons of public or private water supplies?

In developing countries, water is often collected by physically carrying it from rivers or lakes. The task of fetching drinking water often falls to women and girls, who collect two-thirds of families' water. In several African countries, about a quarter of the population have to walk 30 minutes to bring water to their families. This tiring and time-consuming task makes it less likely that girls will attend – or succeed in –school. [39]

Hippo Water Roller: Improving Water Access, Food Security and Income Generation

Designed in Africa for use in Africa, the 90-litre Hippo Water Roller enables women, children, and the elderly to collect five times more water than they could with a single bucket by rolling the water container instead of carrying it. It was specifically designed for use in tough rural conditions. The roller is especially useful in communities where water infrastructure is either unreliable or not available.

Hippo Water Roller

© www.hipporoller.org

Using the Hippo Roller results in many social benefits, most of which are immediate. It improves health and hygiene by helping families obtain more water to use for drinking, cooking, washing, and growing food. It also frees up time for education, household tasks, and food production. Increasing food production can improve families' economic conditions and help them break free of poverty. The Roller reduces the suffering and long-term injuries caused by carrying heavy loads. Men are more likely to use this technology to help with water. The wide rolling surface also helps reduce erosion of footpaths caused by narrow wheels of wheelbarrows, which are common alternatives. [40]

Hippo Rollers are used in at least twenty countries, benefitting over 300,000 people.

Rainwater collection is becoming more common in the southwestern United States and Australia, both of which often experience droughts. This water can be used to irrigate landscaping, helping reduce the demand on local water supplies. Some cities even supply rainwater collection barrels at low or no cost to encourage this practice. In Australia, 26% of homes collect rainwater.[41] However, some locations restrict rainwater harvesting as the water is needed to replenish aquifers and streams.

In water-strapped areas near coastlines, **desalination** plants are sometimes built. These large factory-like structures remove salt from ocean water to make it suitable for drinking. To reduce the enormous energy needs of these facilities, Saudi Arabia is developing the world's first solar-powered desalination plant.[42] Israel obtains 40% of its water from this technology and has developed a new process to bring down the typical high cost of desalination.[43] Globally, 150 countries operate over 18,000 desalination plants.[44]

Public or Private Resource?

Since water is a shared resource, it is usually managed by the government, which is charged with representing the public good. Governments typically secure water supplies, distribute water, oversee use of groundwater, and manage wastewater. People do not always have a say in how the water they depend on is managed, as they may not have the authority, time, or resources to impact decisions. The coordination of all the government agencies that deal with water rights is also a challenge. In some countries, a river used for shipping, fishing, and irrigation could be managed by three different agencies, each governed by different laws that must coordinate with each other.

In some cases, private companies provide water for people. **Privatizing** water involves selling publicly owned water to private companies. People then receive their water from the private company that manages the watershed. Some people see privatization as a "market solution" because it relies on the economic theory that competition will lead to better service at a lower price. Unfortunately, there are many cases in which privatization has made water more expensive. Also, private companies are structured to make a profit, which may conflict with the public good.[45]

Availability of Fresh Water

Today, most people have access to an improved source of drinking water – one that is protected from contamination. In fact, an important success of sustainable development has been increasing the number of people with improved water; this number increased from 76% in 1990 to 91% in 2015. Even so, the number of people without this type of access – 663 million – is still too high.[46] More troubling, 40% of the global population experiences some degree of water scarcity.[47] Most of these people are from developing countries.

The following are possible reasons for water scarcity.

***Water Is Not Evenly Distributed*:** Rain and snow fall in some places on Earth and not others. Mountain locations form watersheds, which determine where rainwater and snowmelt run. As a result, many arid regions in the world – meaning areas of low rainfall – frequently face drought conditions.

Humans Use Water Faster Than It Can Be Replenished By The Water Cycle: Overuse of water can be caused by many factors, including too large a population for the existing water supply or unsustainable water-use decisions by people. One example of overuse is the shrinking of the Aral Sea, located between Kazakhstan and Northern Uzbekistan. In the 1950s, so much water was diverted to support agriculture that the amount of water evaporating from the sea soon exceeded the amount of water flowing into it. The Aral Sea lost two-thirds of its water over a 40-year period.[48]

***Contamination And Pollution*:** Human-made pollution can contaminate fresh water. Contamination can come from sewage, industrial waste, agriculture, lead from aging pipes, or an accident such as an oil spill; whatever the source, human pollution can make water unusable for people and other species.

One early – and rather astonishing – example of water pollution involved the Cuyahoga River in Cleveland, Ohio. In 1969, oil floating on the surface of the river caught fire. The Cuyahoga River had been heavily polluted for decades, having been used by local industries for wastewater discharge. Sadly, the 1969 fire was not the first, only, or even worst time the river had burned. By the 1969 fire, city residents had already approved funds to clean up the river. However, the fire did prompt the Cleveland mayor and local college students to pressure the U.S. government to begin work on clean water laws. The United States' first environmental law, the Clean Water Act of 1972, was approved partly in response to the Cuyahoga River fire. And as time went on, the river was cleaned up; the riverfront now includes restaurants and other entertainment.[49]

***Climate Change*:** Another threat to water supplies is climate change, which is expected to change rainfall, snowfall, and weather temperature patterns. The intensity of droughts and floods is predicted to increase. Scientific models used by the Intergovernmental Panel on Climate Change suggest that the number of people affected by water scarcity will increase by two to four times over the next three to four decades.[51]

***Population Growth*:** The growing global population is one of the biggest threats to an adequate freshwater supply. If global population grows as much as predicted, there could be two to three billion more people on the planet by 2050. This growth is likely to occur mostly in the poorest countries, with half of the expected increase to take place in countries in Africa.[52] Because these countries are already experience water stress, experts are concerned that water supplies will be stretched too thin. Measures to improve water security include reducing the number of people living in poverty by building sustainable economies, building water supply systems, improving management of water supplies, and using water more efficiently.[53]

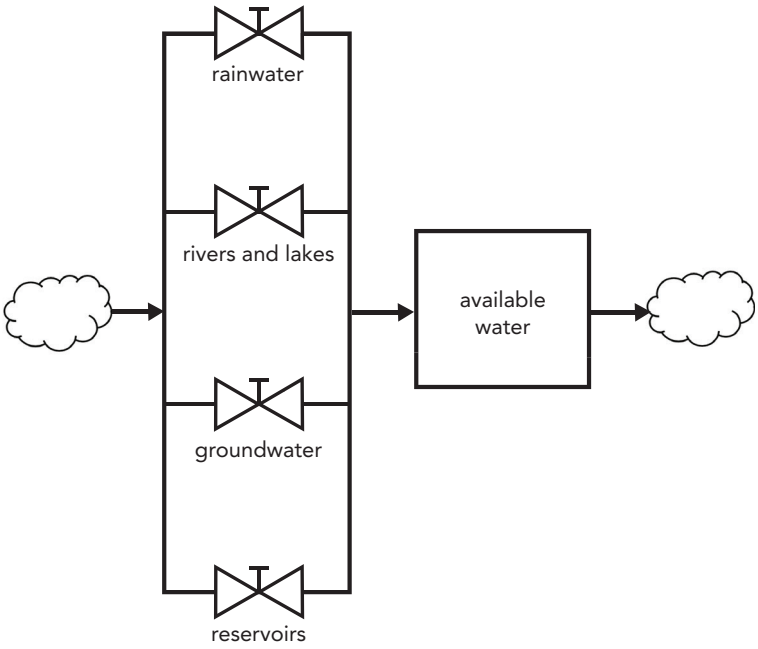
Sustainability Big Idea: Respect for Limits

The Colorado River flows through the U.S. and Mexico. But in recent years, its flow has dried up about 60 miles from the Gulf of California in Mexico, where it historically met the ocean. Mexico and the U.S. have recently updated their agreement on sharing water from the river. Under the new agreement, both countries take less water during drought years, and Mexico can store some of its surplus water in the U.S. during rainy years. This agreement works much better for Mexico, which previously received a steady flow regardless of rainfall. The environment wins with the new agreement, too: both countries and a collection of environmental organizations will release some of their water rights to make sure the river flows to the ocean again. The new flow will help restore native plants and wildlife to the river delta. This deal worked because both countries recognized that increasing droughts were limiting the amount of water they had to share – and that ecosystem needs were also important.[54]

Think About It!

Historians tell us that Cleveland citizens accepted the river's pollution for many years. They viewed it as a necessary part of the overall economic prosperity that factories brought to the city. Later, the industrial economy declined. Over time, citizens decided the pollution was a problem and approved $100 million – equivalent to $645 million today – to clean up the river. What can we infer about the worldview of Cleveland citizens? What conditions or factors contributed to it? What situations or conditions could give rise to a similar worldview today? How might this situation have been addressed from a sustainability worldview?[50]

Stock and Flow Diagram of Water Supply



Systems Thinking and Water Supply

Systems thinking uses **stock and flow diagrams** to help map out the structure of systems. Stocks are components of the system; they can increase or decrease over time. Flows are actions or changes that affect the amount of the stock. A flow represents how a stock interconnects with other components or the environment.

The figure below shows a stock and flow diagram for water supply. The amount of available water is a stock; it can be thought of as a sink that can be filled with water or drained. Stocks are represented by rectangles in the diagrams. The flows – inputs into the stock – are the various sources of water. These are represented by the triangle-shaped figures; they can be thought of as faucets that can be opened or closed to increase or decrease the rate of flow. This diagram does not show any drains on water use. The clouds represent elements outside the part of the system that we are looking at.

Think About It!

How does the diagram represent changes that could happen in a drought year or a rainy year? What flows might reduce the stock – or amount – of available water?

Water Distribution

Sharing Water Fairly

Water is a finite resource which must be shared among people of all countries and with other living things. Deciding who gets water – and how much – has been a source of struggle and conflict through the ages. Because water crosses international borders, nations must work together to be sure water – an essential need – is shared fairly. Today, water disputes are found in many places in the world. India is downstream of a dam being built in Tibet that could limit water flow. A similar situation took place in Ethiopia, where dam construction prompted new water negotiations with Egypt and Sudan, both downstream countries.[55]

Water Crisis in Flint, Michigan

In 2014, the city of Flint, Michigan, decided to change the source of its water supply to the Flint River in order to save money. Most of Flint's residents are black; 40% live in poverty. The corrosive river water caused lead from aging pipes to leach into the water supply. Drinking water in Flint, MI, became contaminated, causing many people – especially children – to become ill. Lead exposure can cause permanent learning disabilities, delayed mental development, and problems with behavior, especially in young children. Residents complained to the government about the foul and discolored water that was making them sick. However, no action was taken.

Later, an independent panel concluded that disregard for the concerns of minority groups and people living in poverty contributed to the government's slow response to complaints. The panel concluded that the government failed to protect its citizens, and its lack of action was an environmental injustice. A state action plan has been developed that calls for replacing the city's water lines and providing extra support to schools and young children with raised lead levels in their blood, along with other measures.[57]

Think About It!

How are decisions affecting community well-being made? Who makes these decisions? How should they be made? How could sustainability big ideas and Earth Charter values influence these decisions?

Scientists are developing new approaches to find balance between the needs of people today and people in future generations and between people and wildlife. Water projects in Australia, the U.S., and South Africa have established adequate water flow for ecosystems as key objectives.[56]

Delivering Water

For centuries, people have figured out ways to even out nature's uneven water distribution. Systems of pipes have been built since Roman times more than 2,000 years ago. Dams and reservoirs – artificial lakes – collect and store river flows and rain and snowmelt runoff. While these systems help the people who receive water, dams and reservoirs flood areas where people or wildlife lived previously.

Water Consumption

Water Use by Sector

About 70% of global freshwater consumption is used for agricultural irrigation, 22% for industry, and 8% for individual and home us.[58] Let's take a closer look at the direct and indirect ways that humans around the world are using water.

***Agriculture*:** Water availability impacts the amount of food farmers can produce and sell. Different irrigation techniques vary greatly in how efficiently they use water. Overhead watering – like most home sprinklers – can lose a large amount of water to evaporation; also, some of the water spray stays in the fruit or vegetable and does not reach the roots. Drip irrigation is more efficient at delivering water directly to the soil. Growing crops suited to the natural rainfall in a region can help decrease the water needed for agriculture. Avoiding overwatering also helps. Soil can only absorb a certain amount of water at a time; excess water runs off to water bodies or evaporates.

Some foods require more water than others. Growing one kilogram of corn – enough for about 12 corn tortillas – requires an average of 1,220 liters (322 gallons) of water.[59] An apple requires about 68 liters (18 gallons) of water. A half kilogram (1.1 pounds) of beef requires about 7,300 liters (1,900 gallons) of water, most of which is used to irrigate the grain that is fed to the cow.[60] Raising vegetables uses less water than raising livestock, so eating lower on the food chain decreases water footprints.

Micro-Irrigation Brings Life-Changing Alternatives to Hondurans

In Honduras, International Development Enterprises (iDE), a non-profit organization, is helping introduce affordable drip irrigation to 300 small farmers whose lack of irrigation keeps them from growing more than a single crop during the year. Access to drip irrigation represents not just a way for farmers to grow more productive crops but also a way to diversify their crops, escaping the poverty prevalent throughout the country.

Coffee is the country's largest cash crop, but it only generates income for farmers during the harvest from November through March. Lacking affordable irrigation during the remainder of the year, farmers depend on rain to grow other crops or have to take out expensive loans.

iDE Honduras helps farmers grow other crops on the coffee farms by providing affordable drip irrigation. The coffee farmers are now able to diversify and grow corn, beans, cocoa, bananas, plantains, fruit trees, and vegetables for commercial purposes. Some farmers have even been able to introduce livestock thanks to affordable micro sprinkler systems that irrigate pastures throughout the year.[61]

Industry And Electricity Generation: Historically, water started powering machines in the first English factories 200 years ago. Today, most manufactured products still require at least some water. Paper mills, food-processing plants, and chemical factories all depend on freshwater supplies in their production processes.

Water is also used heavily in electricity production. Many power plants operate by heating water to produce steam that turns a generator; water may also be used to cool process equipment. Water is essential to the production of fossil fuels – coal, oil, and natural gas. Older factories tend to use more water than newer, more efficient facilities, but it is expensive to replace the old factories.

Hydroelectric power relies on large water flows to spin turbines that generate electricity. The flow is created by dams that hold back the river water in reservoirs. Water evaporates much faster from reservoirs than from rivers, so dams cause huge water losses downstream.

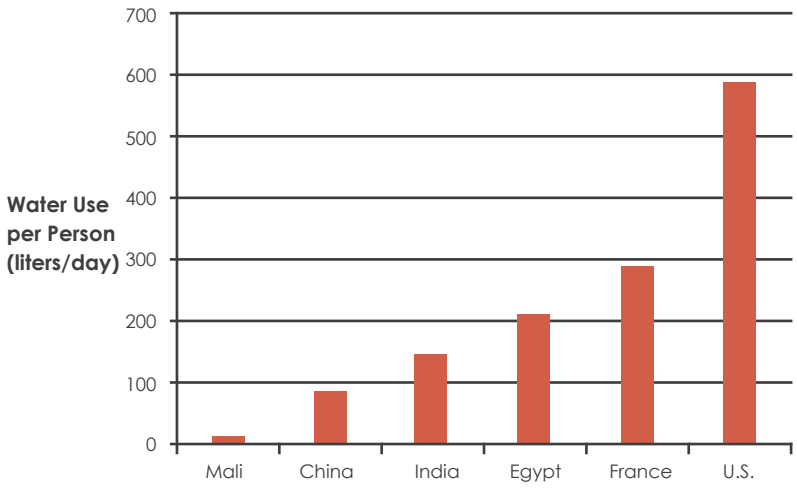
Energy is also a vital resource for developing water supplies. Water from wells – especially large ones – is usually pumped using electric motors. Regions like California move water long distances, pushing it along with electric pumps and gravity. In this system, water is collected from mountains and other sources in the northern part of the state and transferred to arid urban areas like Los Angeles in the south. Large amounts of energy are also used to operate desalination plants.

Home, Business, And Personal Use: Domestic – or home – water use refers to the water consumed by people in their homes and at commercial businesses. People use water directly for drinking,

United Nations Sustainable Goal 6: Ensure access to water and sanitation for all.

This goal seeks to achieve universal access to safe and affordable drinking water and sanitation, reduce pollution, increase water-use efficiency, and protect and restore water ecosystems by 2030.[65]

Daily Domestic Water Use per Day [64]



cooking, and cleaning. We use water to flush our toilets, wash our dishes and clothes, bathe, and brush our teeth. Good **sanitation** is essential for health – poor sanitation causes 10% of diseases worldwide.[62] The number of people with some form of improved sanitation increased from 39% to 64% from 1990 to 2012.[63]

Each person needs about 50-100 liters (13 to 26 gallons) of water each day to meet their basic needs. People living in developed countries use more water each day than people living in developing countries. The figure above shows daily water use/person for several countries around the world.

Those who use more water than is required to meet basic needs have a different challenge – water conservation. Water faucets suggest an infinite amount of water, but the supply of fresh water is finite.

sanitation:

The safe disposal of human waste. In industrialized societies, plumbing systems and toilets typically are used to manage waste. Biological systems like composting toilets, which use microorganisms, can also provide sanitation.

Is Bottled Water Sustainable?

Concerns about the quality of tap water led many people to begin buying bottled water. While these concerns in general have turned out to be false, the habit of drinking bottled water has held on. But bottled water is not such a good idea from a sustainability perspective.

- More than half of bottled water is tap water.
- Bottled water privatizes a portion of shared water supply.
- Bottled water is expensive compared to tap water. In the U.S., bottled water can cost $1 to $8 per gallon, while a gallon of tap water costs an average of $0.002 per gallon.
- Plastic water bottles use 2.7 million tons of plastic per year worldwide.
- About 86% of plastic water bottles wind up in the trash rather than being recycled.[66]

A number of colleges now ban single-use water bottles. Filling a reusable water bottle with tap water is a good alternative.

What do you think – is bottled water sustainable?

Water Footprint

As the world's population grows, so does our water consumption. The world's rate of freshwater consumption is growing even faster than the rate of population growth due to increasing personal and national water footprints. **Water footprint** is a term used to describe the total volume of freshwater used and polluted directly and indirectly by a person, community, business, or nation. It can also be used to describe how much water is used to produce a food item or create a product. Everything we use or consume has a water footprint. A personal water footprint is the amount of water one consumes in their daily life, including the water used to grow the food they eat, to produce the energy they use, and for all of the products in their daily life – their books, music, house, car, furniture, and the clothes they wear. Water footprints help individuals, businesses, and countries reveal water use patterns, from the individual level all the way to the national level.

water footprint:

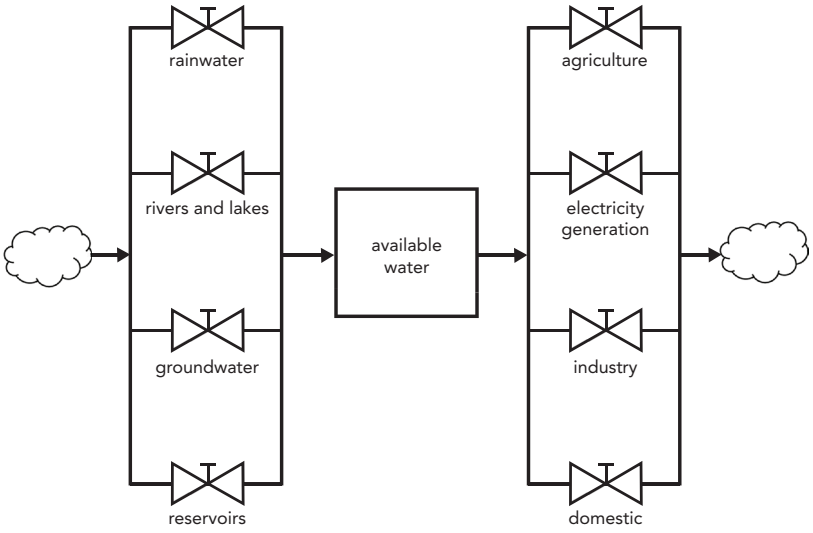
A measurement of the amount of freshwater used and affected by a person or group of people.

Water footprints are becoming increasingly global. For instance, about 20% of the water footprint of someone living in the United States lies outside of the United States because many of the water-intensive goods purchased are grown, extracted, or produced in other countries.[67] Each ingredient in a product may come from a different place. A cookie might contain wheat from Canada, sugar from Brazil, vanilla from Madagascar, and eggs from a local farmer. The making of one cookie uses water from a number of river basins in countries around the world.

Systems Thinking and Water Use

Making good decisions about reducing water footprints relies on a solid understanding of water supplies and uses. Stock and flow diagrams can support this effort by helping us visualize the factors affecting a water footprint. We can now modify our earlier stock and flow diagram, which included only water sources, to factor in water uses. The available water – the stock – can be imagined as filling an enormous sink. This is the amount of water that will be available for all desired uses. As we discussed above, more or less water may enter the system, depending on rainfall, available groundwater, and so on. The amount of available water will be drawn down by the various uses. In order to figure out how to reduce individual or community water footprints, we can evaluate how much water we have coming in. We can investigate ways we could "turn the faucet" to increase or decrease these flows. We can also look at the details of our water use to identify ways the flows from those faucets could be turned down. We can also predict ways in which the faucets might be turned up.

Stock and Flow Diagram



Think About It!

Can you think of other flows that could be added to water supplies or water uses to make the diagram more complete?

Wastewater

Much of the water we use winds up as wastewater. Washing, industrial processes, and even agriculture can create wastewater flows. Nature cleans water through a multi-layered process of filtering and absorption. Soils in wetlands, streamside forests, and sandy riverbanks filter out larger waste items like sediment, fallen leaves, or other waste products, and then absorb water into the ground. Healthy soil contains billions of microorganisms, which can break down or use nutrients and even some chemicals. The clean water may filter down to aquifers or find its way to rivers.

In larger cities in industrialized countries, domestic wastewater is collected in sewer systems and taken to central treatment plants. These plants use filtering and biological processes that mimic natural water treatment along with mechanical processes. Sometimes the cleaned water can be reused. Israel – located in a very dry region of the world – uses recycled water for 25% of its freshwater needs.[68] Singapore, which faced water rationing in the 1960s, meets 30% of its water needs with recycled water.[69] This recycled water is first treated to meet international clean water standards. The city of Arcata, California, uses a series of constructed ponds, wetlands, and marshes that mimic a natural wetland to treat its wastewater. The system has become a haven for migratory birds and other wildlife.

Some regions now allow a form of wastewater reuse known as **greywater recycling**. Greywater is water that has been lightly used

greywater recycling:
A method of reusing previously used water that contains minimal amounts of soaps or other harmless materials.

in sinks, showers, or washing machines. City governments, universities, businesses, and even homeowners may be able to install systems to reuse this relatively clean, used water away from sewer systems. Greywater is fine for flushing toilets or watering landscaping, especially if the soap it contains is biodegradable and care is taken with its reuse.

Industrial and agricultural pollution is more difficult to treat, as it can contain a wide variety of contaminants. Agricultural runoff can contain excess fertilizers, pesticides and herbicides, which can harm natural ecosystems downstream of the runoff. Most industrialized countries have strict laws limiting the amount and type of contaminants that can be released into waterways. As manufacturing plants move to developing countries, it is taking time for regulations to catch up with new sources of pollution.

In many developing countries, domestic wastewater is also a significant challenge. Untreated wastewater can impact fresh drinking water supplies and downstream ecosystems. However, progress is being made. For example, in Kigali, Rwanda, a new program collects wastewater and composts it into fertilizer for local farmers.[70]

Pathways to Progress: Water

There are many people working toward sustainable solutions to water challenges. Some of these solutions involve changes at the personal level, while others involve changes at the structural level.

Personal Solutions

Because a large amount of water is embodied in food and products, consumption choices are a way to shrink water footprints. For instance, using tap water rather than bottled water saves both water and money; a filter on the tap can help if the taste of city water is unpleasant. Our choices of what to eat can also impact water use. Eating smaller portions of meat and dairy is a good way to limit the water needed to bring food to our plates. Information on different foods and how much water they contain is available through online water footprint calculators. We can also reduce our water footprint by installing water-efficient appliances. Toilets are one of the biggest consumers of water. Replacing older, less water-efficient toilets could save huge amounts of water per day. We can also reduce water use by reusing it. For example, some commercial car washes collect water, clean it, and reuse it, so this is a better choice than washing a car in a driveway where the water runs into storm drains. Also, greywater recycling is an option in some areas.

Community Solutions

Water issues often require collective action. At times, cultural ideas about water use create waste. For example, lawns are the norm for many homes, but they can be replaced with

plants that are native to the local climate and can rely primarily on rainfall. Working to develop communities where water conservation is commonplace and aesthetically pleasing is a way that we can collectively address water issues.

Structural Solutions

To achieve sustainable global water systems, the development of water infrastructure in places where it is lacking is needed. Nonprofit organizations can help communities complete water and sanitation projects by offering resources and expertise.

Because most major river basins lie in more than one country, comprehensive and effective water management plans must involve the governments of all those who depend on a river. Water and the services it provides can be delivered more easily if the needs of everyone in the basin are considered. An example is the Danube River Basin that flows through 19 countries. Together these countries have agreed to manage their waterway collectively and composed the Danube River Protection Convention. The main objective of the Convention is to ensure that surface waters and groundwater within the Danube River Basin are managed and used sustainably and equitably.[71]

What You Can Do: Water

Wondering how you can get involved in water issues? Small actions made by many individuals can make a big difference.

Here are some ideas for you to consider:

- Change the way you use your tap. Turn off the faucet while you are brushing your teeth and plug the drain when you are washing dishes.
- Talk to your family and school administrators about installing water-efficient technology in your home and schools. Installing low-flow toilets or placing an aerator on your shower head can be a great place to start saving water – and the amount of money spent on water bills.
- When your family is in the market for a new appliance such as a dishwasher, look for products that are highly water efficient.
- Fix leaks on faucets, toilets, and appliances. The average home wastes 10,000 gallons of water per year from leaks – enough water to fill a swimming pool. Common leaks like leaky toilet flaps, dripping faucets, and leaky valves are easy to fix.
- Remember water when you shop. By reducing the number of products you buy – especially products made using water-intensive methods – you can reduce the amount of water used to produce these goods.
- Educate members of your community about how to bring safe, accessible drinking water to those who don't have it.
- Keep your water clean. Organize a river or beach cleanup in your neighborhood. Educate your neighbors about how natural waterways and marine species can be harmed by storm water runoff.

Sustainability Skill Building: Creating a Safe and Just Space For All

As you now know, one of the definitions of sustainability is meeting our own needs without limiting the needs of future generations to meet their own needs. This module covers sustainability as it pertains to basic human needs: food, water, air, and energy. As we have discussed food and water from a sustainability point of view, we have seen that better – more sustainable – ways to provide people with food and water are becoming available. At the same time, we are living in a time of transition. It takes time for new ways to take hold and become available to everyone. It takes time for old ways to fade into the past. And in any change, people who benefitted from old ways need to be encouraged and supported so they can have a just transition to the new ways.

Many sustainability leaders believe that change starts at the **grassroots** level. This means that individual people, including single leaders and communities of people working together, are the real change agents. Leaders – government officials, business leaders, and other people working in key institutions – are sometimes **change agents**. Often, though, their role is to recognize new directions coming from the grassroots and bring about new laws, programs, and products to support and extend change.

One way to bring about a safe and just world for all, forever, is to use sustainability thinking when making choices about meeting our basic human needs. First, we need to challenge ourselves on seeing the difference between wants and needs and ask ourselves hard questions about which wants we really need to meet. Once we are clear on that commitment, there are several excellent tools available that we can all use, as individuals and as groups – including students and classroom or school communities.

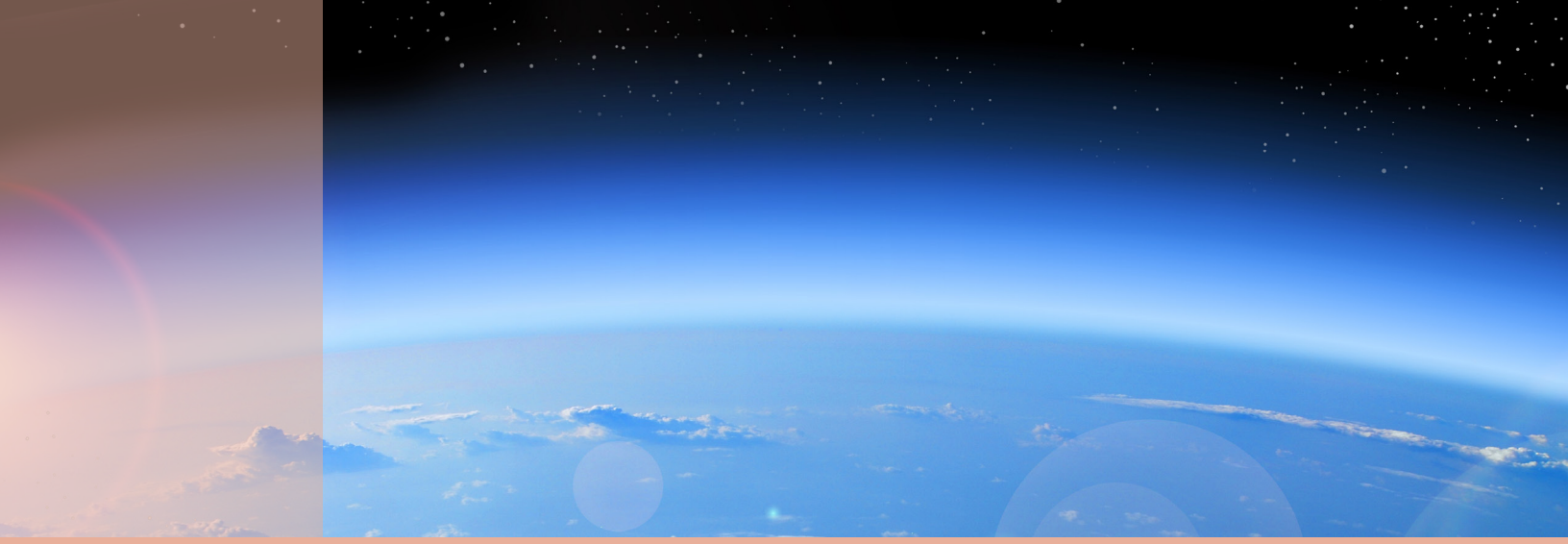
We use systems thinking skills: seeing how things are connected instead of seeing only separate, unrelated events and objects is a fundamental part of sustainability. Also, the big ideas of sustainability provide a useful framework for questioning how our needs are met. And Earth Charter values can prompt new directions for thinking and exploring how our choices affect others. The questionnaire below can be used to guide this questioning when you are making choices about meeting your wants and needs. Feel free to add your own questions and ideas. You are the grassroots!

change agent:

A person who works to bring about change in a system or organization.

grassroots:

People at the local level who form the basis for political or economic action.



Sustainable Decision Questionnaire

Meeting My Needs While Respecting the Needs of Others

Sustainability Big Ideas

1. ***Nature Connection*** How do my choices change when I think of myself as part of an ecosystem – or many interconnected ecosystems? How would nature address my need?
2. ***Respect for Limits*** Are my choices within Earth's limited capacity to supply all species with clean air, fresh water, food, energy, and the ability to recycle waste?
3. ***Universal Responsibility*** What is a responsible choice that meets my needs and contributes to a safe and just world for all, forever?
4. ***Equity and Justice*** Who benefits and who may be disadvantaged by the choices I make or the products I use? Do my choices support equity and justice for future generations and other species?
5. ***Health and Resiliency*** Which choice would support the well-being of living things, nature, and society? How can I make a choice that helps myself and my community build resiliency?
6. ***Interconnectedness*** What living things and natural or social systems are connected to my choices? How do they work together? Where do I fit into those interconnections?
7. ***Local to Global*** How do my local choices affect people, nature, society, and economies in other parts of the world? What universal human values – a desire for safety, love of family and community, spirituality, a desire for peace and justice, and so on – are reflected in my choices?
8. ***Peace and Collaboration*** How does my choice give me the opportunity to respect the needs of others – today and in the future – as equally important as my own? Does my choice consider the power that humans have over other living things? Can I work together with others to bring about more sustainable choices?

Earth Charter Principles

How can I make a choice that considers the community of life; ecological integrity; social and economic justice; and democracy, nonviolence, and peace? Earth Charter principles were created to address these matters; some of these principles are listed below. These principles offer pointers for thinking more deeply about the interconnectedness of our choices. The full list of these principles is available online at http://earthcharter.org/discover/the-earth-charter/.

1. Respect Earth and life in all its diversity.
2. Care for the community of life with understanding, compassion, and love.
4. Secure Earth's bounty and beauty for present and future generations.
5. Protect and restore the integrity of Earth's ecological systems, with special concern for biological diversity and the natural processes that sustain life.
6. Prevent harm as the best method of environmental protection, and when knowledge is limited, apply a precautionary approach.
7. Adopt patterns of production, consumption, and reproduction that safeguard Earth's regenerative capacities, human rights, and community well-being.
10. Ensure that economic activities and institutions at all levels promote human development in an equitable and sustainable manner.
12. Uphold the right of all people, without discrimination, to a natural and social environment supportive of human dignity, bodily health, and spiritual well-being, with special attention to the rights of indigenous peoples and minorities.

Think About It!

Use the Sustainable Decision Questionnaire, including your own additions, to consider a sustainability issue in your school or community.

We do not live in a perfect world – although we do live in an amazing world. Ideal solutions are not available in every situation. Even so, we can make conscious, thoughtful choices given what is possible in the real world. And we can work to expand what is possible so that in the future, we have better options from which to choose.

Youth Profile

Molly Freed

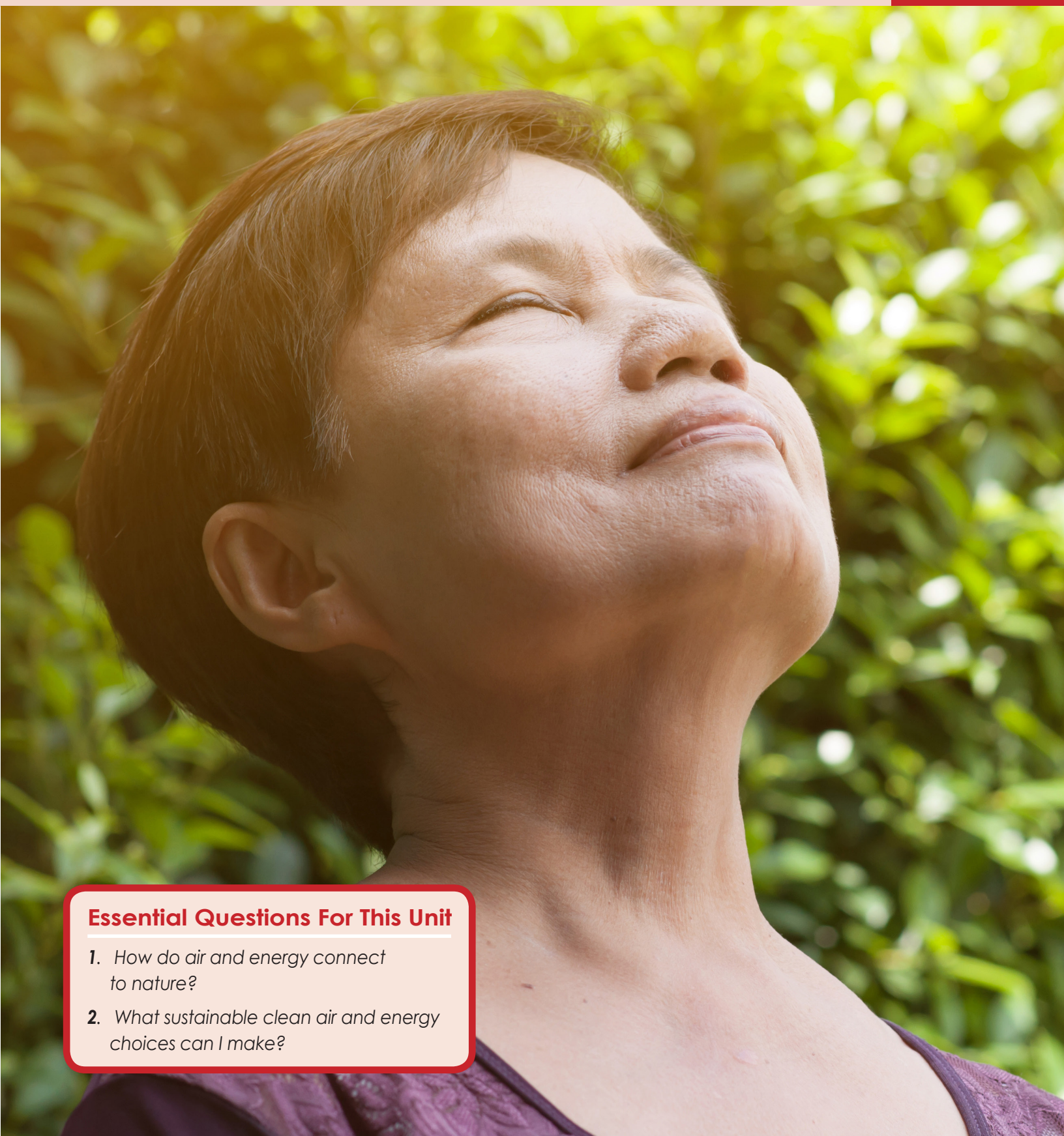
In 2010, Molly and 12 other high school juniors around the country were chosen for the Bezos Scholars Program. The program selects students and faculty members from public schools across the United States to participate in a dialogue on global leadership at the Aspen Ideas Festival held in the scenic Rocky Mountains. Journalists, scientists, religious figures, Supreme Court justices, and academics present to attendees. When she returned to her home in Seattle, Washington, after the trip, Molly decided to create World Water Week as her way of actively engaging her community in the issues she learned about at the festival.

Along with a group of volunteers, Molly organized World Water Week at her then school, Chief Sealth International High School, to increase awareness of water issues and commemorate International World Water Day. Throughout the week, different activities engaged the school community on the topic. Featured events included speeches by members of a local Native American tribe and professionals working in the water industry, and a school-wide challenge called "Carry 5," in which students and staff carried one to five gallons of water around the school's track for 45 minutes to mimic what over a billion people must do each day in order to collect fresh water for their families. Over 75% of those who attended said that they would change the way they used water, from favoring reusable bottles to taking shorter showers.

Thanks to Molly Freed and the Chief Sealth community, World Water Week continues to be a success at the school.

Unit 2

Air and Energy



Essential Questions For This Unit

1. *How do air and energy connect to nature?*
2. *What sustainable clean air and energy choices can I make?*

Think About It!

Read the Earth Charter principles below, keeping them in mind as you read this unit. Where do they apply? How can air and energy issues be understood from the Earth Charter perspective?

EC6. Prevent harm as the best method of environmental protection and, when knowledge is limited, apply a precautionary approach.

EC7. Adopt patterns of production, consumption, and reproduction that safeguard Earth's regenerative capacities, human rights, and community well-being.

Clean Air

Air for Life

Air: the breath of life. Few things feel better than a deep breath of good, clean air. That inflow of oxygen keeps our bodies going, turning food into the energy we need to move, think, grow, and more. When we exhale, we release carbon dioxide (CO_2) as a waste product.

Carbon dioxide becomes part of a cycle that links us through our breath to all of life. Plants use our waste product as a raw material, taken in through their own **respiration** (breathing). They draw CO_2 in through their leaves and convert it, using energy provided to create the complex materials of leaves, flowers, seeds, roots, bark, and stems or trunks. Trees and other plants then release oxygen as a waste product, providing animals with essential oxygen and completing one of nature's many cycles of interconnection. Air, which contains these and other gases, supplies these essential needs of land-based life.

Think About It!

Air and breath are often used in popular sayings and metaphors. Some examples include "take a deep breath," "catch some air," and "I'm floating on air." What other examples can you think of in which air and breath are mentioned in everyday conversation? What do these phrases tell us about our relationship with air?

The Atmosphere

The atmosphere is an important part of Earth's ability to support life. The atmosphere keeps Earth's surface temperature within a comfortable range by trapping heat from the sun and blocking excess sun rays. Holding the sun's heat within the atmosphere is known as the **greenhouse effect**.

greenhouse effect:
Warming of Earth due to carbon dioxide and other gases in the atmosphere.

A Planetary Air and Energy Show

The aurora borealis, also known as the Northern Lights, is an atmospheric wonder – and one of the most beautiful and mysterious sights on Earth. Auroras occur in the far northern and southern parts of the planet around the poles, as nearly identical matched pairs. Their colorful, shifting glow is caused by the interaction of energy and particles from the sun with oxygen and nitrogen molecules.

Aurora Borealis

Life and the Atmosphere: Evolving Together

Scientists believe that early life forms created the atmosphere as we know it today. Atmospheric oxygen was likely produced by a new kind of bacteria that evolved about 2.7 billion years ago, when oxygen first appeared in the atmosphere. This bacteria was able to use the energy from sunlight to convert atmospheric carbon dioxide, or CO_2, into food; the bacteria then released oxygen as a waste product. It took another one billion years for enough oxygen to collect in the atmosphere for animal life to evolve.

A Common Resource for All

Air is a resource shared by all. As with any **common resource**, if everyone takes care of the air we share, we can all benefit from it. All species have the right to breathe clean air, now and in the future. Unlike fresh water, which can be collected behind dams and distributed through pipes, air circulates over the entire globe, unrestricted by most physical barriers. All of us share the air to a much greater degree than we share any other resource.

What is Air Pollution?

Air pollution occurs when harmful or irritating gases, dust, fumes, or odors become concentrated in the atmosphere in amounts that can harm the health of humans, animals, or plants; damage human or natural materials or systems; or cause some other kind of nuisance. The unwanted materials in the air are called **air contaminants**. Have you ever walked into a freshly painted room and felt your eyes and nose sting? Those strong fumes are actually air contaminants, which have effects ranging from irritation to longer-term serious illnesses like asthma and cancer. Some air contaminants can alter the function of the atmosphere by shifting the balance of compounds naturally found in the air, as in climate change. Most air pollution is caused by human activity, although volcanic eruptions, forest fires, and dust storms do also contribute.

For generations, people believed that the atmosphere was big enough to absorb anything we put into it. When human population was small and spread out over large areas, this belief was understandable. Wind or natural dispersion – spreading out – would keep the air clean. However, over time, our population has grown, as have our cities. We have greatly increased the number of air contaminants we put into the air. As a result, air contaminants can become concentrated and cause pollution.

Learning from Nature: How the Atmosphere Cleanses Itself

The atmosphere has several ways to remove pollutants. The following processes can remove dust and small particles and can also change hazardous compounds into safer ones.

Dispersion: Wind, weather and planetary air currents mix the atmosphere, spreading out local concentrations of smoke, dust, or other materials. While dispersion does help clear the local air after a wildfire or volcanic eruption, dispersion also spreads some particles across a larger area.

Gravity: Larger particles often clump together with similar particles and become heavier, eventually falling back to Earth.

Rain: Raindrops falling through the atmosphere come in contact with smaller particles in the air, including air contaminants. These particles tend to be absorbed by the raindrops, which carry them to the Earth's surface.

Conversion to Other Compounds: The atmosphere contains particles that clean the air through a chemical reaction, converting some air pollutants into less harmful materials.

Absorption by Trees: When trees take in carbon dioxide, they also absorb air pollutants. Small dust particles may also temporarily stick to tree leaves or needles.

These cleansing methods work slowly. Smoke from wildfires and ash from volcanic explosions can linger in the atmosphere for days, weeks, and even months. Learning from nature, we need to recognize that the materials we put in the atmosphere are likely to stay there for a long time.

Types of Air Pollution

Smog

Most outdoor pollution is known as **smog**. Smog – generated from the words "smoke" and "fog" – is heavy air pollution that can persist for an extended period of time, especially in warmer climates. It is often trapped in areas surrounded by hills or mountains, such as Los Angeles or Athens, and over densely-populated cities, like Beijing and Delhi. One common ingredient in smog is ozone. **Ozone** is formed when two air

smog:

A broad term that includes most outdoor air pollution, including smoke, particles, and air contaminants.

ozone:

An air contaminant that harms the lungs and is linked with many illnesses, including asthma and heart disease. Ozone is made up of three oxygen molecules. This unstable arrangement makes it very easy for ozone to react with other materials; this reactivity is part of the reason ozone is hazardous. The U.S. Federal Clean Air Act limits the amount of ozone that can be in the atmosphere at ground level. In the upper atmosphere, ozone provides protection from excess radiation from the sun.

pollutants, **nitrogen dioxide** (NO_2) – a pollutant produced by burning fuels – and **volatile organic compounds** (VOCs) – harmful carbon-based chemicals that evaporate easily – are mixed together on hot, sunny days.

volatile organic compounds:

A group of natural and manufactured carbon-based compounds that evaporate easily at room temperature. Some harm human health or the environment. These compounds react with NO_2 to form ozone.

Vehicles are a major cause of smog. Worldwide, more than 1 billion cars and trucks are in use each day, and over 80 million new vehicles are added each year.[72] Vehicles, factories, and electricity generation create pollution when **fossil fuels** including coal, oil, and natural gas are burned. Evaporation of paints and chemicals from factories also contribute to smog.

nitrogen dioxide:

A gas that is formed when fossil fuels are burned. Nitrogen dioxide (NO_2) contributes to the formation of ozone – another air contaminant – and small particulates. NO_2 also harms the human respiratory system. The United States Federal Clean Air Act limits the allowable amount of NO_2 – along with several other air contaminants – in the atmosphere.

fossil fuels:

Combustible energy sources formed from the remains of ancient living organisms – in particular, oil, coal, and natural gas.

Think About It!

When have you experienced the cleanest, clearest air? Think about how it felt physically and emotionally. Have you experienced air pollution in your community? What did that feel like? Which is more common where you live – clean or dirty air?

Sustainability Big Idea: Local to Global

Air Pollution from China Reaches the United States

In the past few decades, China has greatly increased the number of goods it manufactures, including many products used by Americans. As manufacturing has increased, so has air pollution; China now has severe air quality problems. The government has promised to address the growing pollution by adopting new laws and enforcing existing ones.

A recent scientific study on Chinese air pollution demonstrated one of the big ideas of sustainability: local events have global impacts. The study showed that up to a quarter of air pollutants found in the Western U.S. came from China. The scientists looked further to see how much of China's pollution came from manufacturing goods to export, compared to manufacturing goods for its own citizens' use. It turned out that about 7% of China's pollution is created when they manufacture goods for the U.S. Who's polluting whom? In this case, pollution travels both ways.

Indoor air pollution

In the developing world, **biomass** – crop husks, straw, dried animal dung, or wood – is often used for cooking and heating. In India, for example, 75% of all households use stoves fueled by biomass. Smoke and soot from these stoves create **particulates**, very small particles that can lodge deeply in the lungs and cause disease. Because of these smoky stoves, air pollution is now the leading environmental cause of early death, outpacing a lack of a clean water supply and poor sanitation. Indoor air pollution is also caused by chemicals evaporating from cleaning products, personal care products like hairspray, and even **off-gassing** from furniture and building materials.

Climate Change

Climate change may be the most far-reaching change humans have made to the planet. Earlier, we saw that the atmosphere provides a greenhouse effect, trapping heat to keep the planet warm. The greenhouse effect is caused by different chemical compounds in the air, including carbon dioxide, methane, and others. **Global warming** occurs when these greenhouse gases build up in the atmosphere, trapping more heat than usual and raising the Earth's temperature. A warmer Earth can lead to a loss of polar ice sheets, sea level rise, increased droughts and wildfires, loss of species habitat, and other impacts.

climate change:
Disruption of longstanding climate patterns, such as temperatures and rainfall, due to increasing emissions of greenhouse gases like carbon dioxide and methane.

global warming:
Increases in the average temperature of Earth's atmosphere due to increased amounts of greenhouse gases in the atmosphere.

United Nations Sustainable Development Goals

The United Nations Sustainable Development Goals, created in 2015, provide a framework of sustainable development to reduce poverty, bring about peace, and heal the planet. The goal for air quality states:

Goal 13 – Take urgent action to combat climate change and its impacts.

Steps needed to achieve this goal include education, awareness-raising, fund-raising, action, and building resilience. [75]

Human activities have already caused the planet to heat up. In 2015, the overall temperature measured across the planet was warmer than the 20th century average by 0.9°C (1.6°F). The period from 2005 to 2014 was the warmest decade ever recorded and followed two decades of increasing heat.[76] Although a 0.9°C temperature rise seems small, consider how achy your body feels with even a small fever. Or consider a planetary example: during the last ice age, Canada was covered with ice sheets as thick as those in Antarctica today. At that time, the global average temperature was only 5.5°C (10°F) lower than it is today.[77] Relatively small temperature changes lead to major Earth system changes.

Scientists from the International Panel on Climate Change, the major international scientific organization studying climate change, are 95% certain that global warming is caused by human activities. Ninety-seven percent of scientists working on climate change agree with this conclusion.[78] The main way that these harmful greenhouse gases are created is by burning fossil fuels – coal, oil, and natural gas. Agricultural practices and deforestation are also important contributors.

In 2015, the historic Paris Agreement on climate change was reached among 195 nations – virtually every country in the world. These countries agreed to reduce their greenhouse gas emissions as soon as possible. The agreement is an important first step in bringing together all countries in the world to address a common threat.[79]

Impacts of Air Pollution

Air pollution has severe local impacts on the health of plants and animals. In humans, respiratory illnesses like asthma are made worse by smog. Air pollution can contribute to heart disease, cancer, and even early death. Pollution has economic consequences when it causes sickness and keeps people home from work. In China, pollution-related illnesses cost the economy an estimated $1.2 billion per year in lost work and increased health care costs.[80]

Air pollution impacts tend to fall most on people living in poverty. Sources of pollution like factories and freeways are often located in economically marginalized communities. This pattern plays out globally as well. As manufacturing has moved to countries where workers earn low wages, laws have not kept pace with increasing pollution.

Think About It!

How do the Earth Charter principles tie in with air pollution and climate change?

Local Air Quality

Air quality in any specific area is influenced by the sources of pollution, the amount of pollution entering the air, and the local geology and weather. Windy or rainy areas may experience less pollution because the air contaminants are dispersed by wind or washed away by rainfall. Mountains can trap pollutants, thereby blocking wind patterns. Hot, sunny regions can experience more ozone. Dry, dusty areas can create natural particulates.

Protecting Your Health

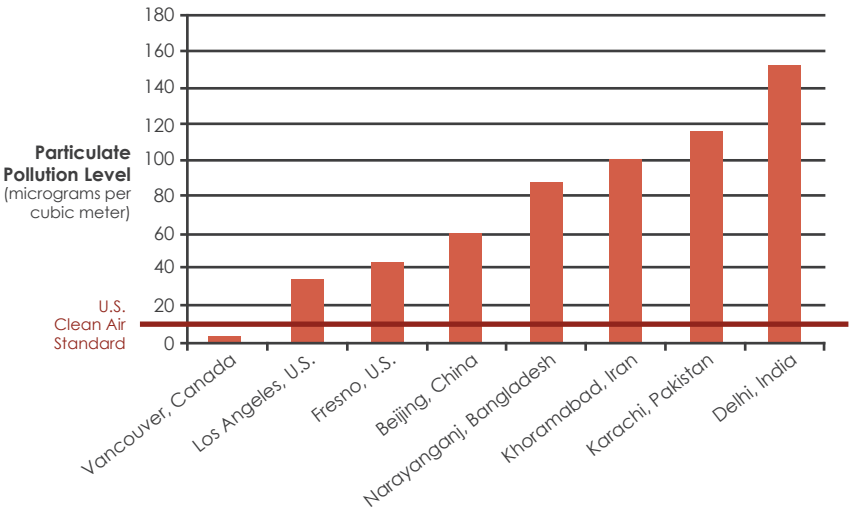
The U.S. Environmental Protection Agency (EPA) has developed a tool to help the public understand local air quality in their region: the Air Quality Index (AQI). An AQI rating of 100 means that air pollution is at the highest level that does not affect public health; any more pollution would be unhealthy. When air quality is good, we can get outside and get active. When air quality is poor, we can protect ourselves from the effects of air pollution by staying indoors and avoiding exercising. Also, staying away from roadways with heavy traffic can help to avoid air pollution.

Air Quality Around the World

Air quality varies widely around the world. The figure below compares air pollution in those cities with the highest average levels in the world. Worldwide, particulate pollution is most common, so the graph focuses on that air contaminant. Peak levels can go much higher than the average levels shown. The graph also shows some cleaner cities for comparison. Vancouver, Canada, is an example of a very clean large city. Fresno, U.S., has the highest

particulate pollution in this country. Los Angeles, U.S., is included since people often think of it as the U.S. city with the dirtiest air. For this particular pollutant – particulates – Los Angeles is among the dirtiest cities in the U.S., but not the worst one. The graph shows that even the dirtiest U.S. cities are much cleaner than many other cities in the world. It is important to remember that U.S. cities once experienced much worse air quality than they do today. The contrast of air pollution levels across the planet shows the success of U.S. air quality laws, which have required cars, trucks, factories, electric power plants, and many products to become much cleaner.

Air Quality Around the World [82]



Success Stories: Clearing the Air

In many instances, air quality is improving. Gasoline-powered vehicles have contributed most of the lead in the atmosphere, although some has also come from industrial processes. Lead was once added to gasoline because it increased gasoline's efficiency and power. But lead causes serious health problems and can lead to permanently decreased learning ability. Japan was one of the first countries to stop using lead in gasoline. Phase-out in the U.S. began in the 1970s, and leaded gasoline was found in only a few areas of the country by 1986. Many other countries have since followed Japan's example, and lead levels in blood have dropped significantly in most parts of the world.

Similar improvements have occurred in atmospheric ozone depletion and acid rain. Ozone – the same compound that creates smog at ground level – shields the Earth from excess sunlight in the upper atmosphere. This ozone layer was damaged after certain chemicals like those once used in refrigeration and spray cans were released and reached the upper atmosphere. The chemicals reacted with the ozone molecules, damaging enough of them to create a hole in the ozone layer. The extra sunlight reaching Earth's surface could cause an increase in skin cancer and eye problems and could affect ocean ecosystems. An international agreement led to strict limits on these chemicals, and the ozone layer is stabilizing.

In another example, sulfur dioxide and other chemicals caused rainwater to become acidic, harming plant life, making waterways too acidic for aquatic life, and damaging buildings and statues. Acid rain is caused by fossil fuel emissions, especially from coal. U.S. laws resulted in large coal-burning power plants reducing their sulfur dioxide emissions by 80%, even as fuel use increased. [83] Large East Asian cities, however, continue to experience acid rain due to the rapidly expanding use of cars and trucks.

Systems Thinking and Air Pollution

A **system** has components, or parts, that work together as a whole and serve a function. We can see how the components fit together by using a **stock and flow diagram**. The figure below shows a stock and flow diagram of air pollution. A stock and flow diagram shows us the structure of a system. Stocks are components of the system; they can increase or decrease over time. We can think of a stock as a bathtub that can be filled or drained. Stocks are represented by boxes. Flows are actions or changes that affect the amount of the stock, like turning a faucet on or off. In fact, flows are represented by a valve symbol. Flows represent how stocks interconnect with other components or the environment. Stock and flow diagrams help us understand possible changes to systems.

The figure shows that changes in the flow of emissions will increase or decrease the amount of pollution that enters the atmosphere. Increases in rain or wind – natural cleansing processes – can decrease pollution once it has entered the atmosphere. This kind of diagram helps us see that we have two ways to reduce pollution: by minimizing air contaminant emissions or by waiting for natural cleansing to take place.[80]

Air Pollution Stock and Flow Diagram

Think About It!

Considering the various sources of indoor and outdoor air pollution, what products or activities in your life could you change to reduce air pollution?

Air and Sustainability

One definition of sustainability is a safe and just world for all, forever. One way of looking at sustainability is to consider impacts on the environment, the economy, and society. Clean air is necessary for all living things and is fundamental to social, economic, and environmental stability.

Society

Society is impacted when air pollution affects people with limited financial resources more significantly than it affects people with more wealth. Often, sources of pollution like factories, power plants, and highways are built in areas where more people live in poverty.

Society is also affected by a practice known as ***exporting pollution***, in which goods used by one country are manufactured in another country with fewer air pollution limits. This practice reduces manufacturing costs by avoiding costs for pollution control and makes products less expensive. However, it shifts the health burden to people who do not benefit from using the products.

Air pollution in economically disadvantaged neighborhoods does not always bring about changes in laws and business practices, since the affected communities tend to have little influence on decision-making processes. ***Environmental justice*** calls for all people to have equal access to a healthy environment.

environmental justice:
Equitable sharing of decision-making on and impacts of pollution.

Economy

The economy is affected through lost work time because of increased sickness, as well as costs of pollution control. Air pollution is expensive. A recent study estimated that U.S. clean air rules have produced annual benefits of $1.3 trillion compared to costs of $53 billion. China's annual financial losses due to air pollution have been estimated at $1.2 billion in lost work and increased health care costs.[85]

The economy is also affected through ***environmental externalities***. An environmental externality is a cost or benefit that is not included in a product's price, but instead affects society as a whole. In air quality, the full costs of pollution-related health and environmental impacts are paid by the individuals whose health is affected and by society instead of by those entities who create pollution.[86] Society pays costs when sick workers are absent, causing work to slow down; food becomes more expensive because of pollution-related crop damage; or shared resources like forests are damaged.

environmental externalities:
A broad term that includes most outdoor air pollution, including smoke, particles, and air contaminants.

Environment

Environmental impacts include stunted growth in plants, loss of resistance to insects in forests, and wide-ranging impacts of climate change. Also, acid rain can damage buildings, public artwork, forests, and farm crops.

Pathways to Progress: Air

Air pollution is increasing in countries that are industrializing. Many already industrialized countries have found ways to significantly reduce air pollution. This progress is encouraging: it shows that we have solutions and that people can work together to solve a common problem. It also shows that the underlying attitudes that allow pollution to occur – the worldview – have not changed in many areas.

Laws

We have described nature's methods for cleaning up the air: rain, wind, and other methods work well but take time. The best approach is to prevent pollution in the first place. That is the idea behind air quality laws, which limit the amount of pollution that is allowed from factories, vehicles, products, and power plants.

Air quality laws in the U.S. have made a real difference. The U.S. Environmental Protection Agency estimates that in a single year – 2010 – the county's major air quality law, the Clean Air Act, prevented 164,000 early deaths, 130,000 heart attacks, and 13,000,000 lost work days due to illness. Overall, the law provided $30 in benefits for each $1 in costs. U.S. air quality laws have reduced emissions of air contaminants significantly, even while the population and economy have grown.

New air quality laws are in place in Delhi, India, the city with the worst air pollution in the world. One new law assigns permission to drive cars to even or odd days, depending on the last digit of a car's license plate number. China has also taken a strong stand against air pollution after experiencing serious episodes of air pollution.

Voluntary Reductions

Some manufacturers have reduced their air pollution emissions without being required to do so by law. These reductions came about because customers asked for healthier products. Manufacturers of paints, for example, have created products that emit much less pollution, largely in response to consumer demand.

Individual Actions

For ideas about actions you can take to improve air quality, see Pathways to Progress at the end of this unit.

Think About It!

What other environmental, economic, or social impacts of air quality can you think of?

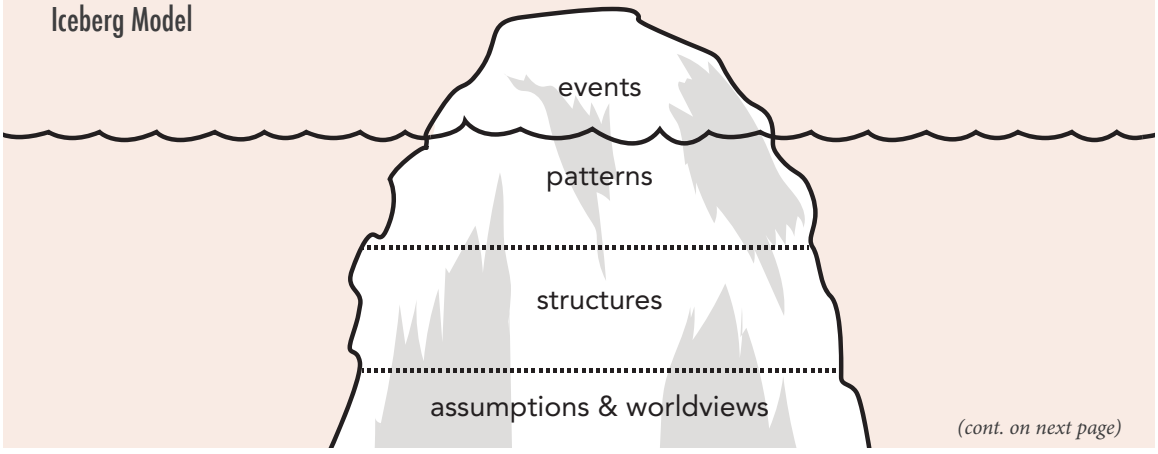
Sustainability Skill Building: The Iceberg Model

In systems thinking, we look beyond single events and instead look for patterns. Recognizing patterns can help us see events as linked, which can reveal underlying causes. Once we understand underlying causes or worldviews, we can take actions that go beyond the immediate situation and create deeper change.

The Iceberg Model: This way of thinking can be represented by an iceberg. We know that an iceberg has only a small amount of its total mass above the water, while most of the iceberg is underwater. Ocean currents push against the massive portion underwater, causing movement at the iceberg's tip. If we think of a sustainability issue as an iceberg, we would say that at the tip, above the water, are events that we have seen or heard about.

In air quality, we have seen new products being made, one at a time, which met people's wants and needs. Lead reduced knocking in new automobile engines. Refrigerants kept our food from spoiling. Manufactured products and electricity made people's lives easier. Over time, we also saw health problems from lead exposure, a damaged ozone layer from refrigerants, increased heart disease from smog, and increased global temperatures from carbon dioxide emissions. We became aware of these impacts one at a time, seeing only the tip of the iceberg. We have also seen events like the U.S. Federal Clean Air Act and the Paris Agreement on climate change being created to control air pollution.

Iceberg Model



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Think About It!

What other underlying patterns, structures, and worldviews can you think of which contribute to air pollution or improvements in air quality? Use the iceberg model to explore a sustainability issue in your school or community.

Sustainability Skill Building: The Iceberg Model *(cont.)*

When we look at all of these events together, we can see that they repeat, forming a pattern. We see a pattern of materials contaminating the atmosphere, causing harmful health effects, followed by new laws being created. These patterns are like the part of an iceberg just below the water line.

Once a pattern becomes clear, we want to know what causes it. This question leads us to the structure of the situation. Structures are the rules that govern the situation. Structures can be actual rules or laws, or structures can be informal habits or practices. The structures in our example are the routine practices of putting unlimited materials into the air, the scientific and media processes that inform people about impacts, and the governmental system through which laws are adopted.

Finally, at the very base of the iceberg are the worldviews that have created or sustained the structures that are in place. A worldview is the set of beliefs, knowledge, values, and behavior. In the air quality example, societies hold an underlying belief that the atmosphere can absorb any amount of pollution without consequences. There may be a lack of knowledge about health and environmental effects of air contaminants that allows people to continue the behavior of producing pollution. Values could include health and care for the environment. Sometimes values like economic gain, convenience, or need – compared to other values – could make pollution seem like an acceptable trade-off.

Like the different levels of an iceberg, deep beneath the patterns are the underlying structures or root causes that create or drive those patterns. By looking at root causes, we can start to understand and address long-term solutions. With air quality issues, we need to think through potential consequences before we adopt new technologies. We have seen many examples of materials being emitted into the atmosphere and causing harm: lead, materials evaporating from paint, by-products from burning fossil fuels, and even carbon dioxide. Most of these were believed to be safe when they were first produced. It was only over time that the negative effects became clear. Now that we know this pattern, we can question the practice of releasing other new materials into the atmosphere. Rather than finding out after the fact that new materials cause further harm, we could practice the **precautionary principle**. This principle tells us that the people who wish to release new materials into the air are responsible for proving that it is safe to do so; it is not the responsibility of the people who object to prove that harm will occur. Using this principle would prevent new air contaminants from entering the atmosphere and prevent new, unanticipated health and environmental effects.

precautionary principle:

The idea that products, policies, or actions that may harm people or the environment should not go forward until they can be proven to be safe.

Looking back at the iceberg model, recall that ocean currents push against the large portion of the iceberg that is underwater. Pushing against this mass causes movement at the iceberg's tip. Applying this metaphor to sustainability issues, we can see that the greatest **leverage**, or influence, occurs by bringing about movement, or change, at the deepest levels. Changing worldviews, or even structures, is the most effective way to bring about change in events.

Energy

Think About It!

Have you ever considered how amazing it is that our entire planet is powered by a star 150 million kilometers (93 million miles) away? Take a short walk outside. Note that all the things you see, including cars, trucks, birds, trees, people – and you – are powered by the sun. Notice for a moment how the sun's warmth feels. Observe the play of light and shadow. Sunlight is beautiful, and it feels good. It could not be more significant, and at the same time, it is such a simple, everyday thing: something to be grateful for.

Energy: A Basic Human Need

Energy is one of the most basic human needs. First and foremost, we use food energy in our bodies to stay alive. Energy provided by the foods we eat powers the basic operations of our cells and allows our bodies to function on a day-to-day basis. The amount of energy in our bodies also determines our ability to fight off disease and think clearly.

Beyond using energy for our physical survival, we use outside sources of energy to perform work and be comfortable. For example, we use energy to charge our computers, light and heat our homes, and fuel our transportation. Energy is also required to manufacture goods like medicine, clothing, and food.

Energy from the Sun

The sun is the main source of energy on Earth. Sunlight is captured by **photosynthesizing** organisms like plants and algae, which use sunlight to produce chemical energy. Humans and other animals that cannot directly use energy from the sun can get the energy they need by eating plants or other animals that feed off plants.

When humans discovered how to make fire, they were learning how to use another form of energy from the sun. Solar energy had been captured in the wood and brush that was used to make the fire. The fire released that energy as heat and light.

What Is Energy?

In our everyday conversations, we often use the term "energy" to describe many different things: our mood, a sports drink, electricity, and so on. But what is energy, really? Scientists define energy as the ability to do work. This means that some form of energy is required for an object or a system to move or generate heat or light.

There are many different forms of energy such as light, heat, motion, and chemical energy. One type of energy can be transformed into another type of energy, or it can be transferred to a different object. However, energy is never created or destroyed. In fact, there is a constant amount of energy in our universe.

Consider these facts of global energy production and consumption:[90]

- From 1830 to 2010, while Earth's population increased by a factor of five, energy use rose by a factor of twenty-five.
- More than 1.3 billion people – 18% of the world's population – do not have electricity. The vast majority of them live in Sub-Saharan Africa and parts of Asia.
- More than one-third of all the people in the world use wood, peat, and other dried plant materials for daily cooking.

Think About It!

Think about all the ways you use energy in a day or over the course of a year. Now imagine that you had to collect enough wood, leaves, or other dried plant material to burn to meet your needs. How much of your day would you likely have to spend collecting this material? What would your life be like without modern sources of energy like electricity and gasoline?

Fossil Fuels

Coal, oil, and natural gas are known as **fossil fuels**. Fossil fuels were created about 290 to 360 million years ago. Slow geologic processes converted plants and algae into coal, oil, and natural gas, greatly concentrating the amount of energy contained in the plants. As a result, burning fossil fuels releases a large amount of energy compared to burning plant matter directly. This quality is known as the **energy density** of a fuel. Fossil fuels are not **renewable resources**: they cannot be replaced as they are used up.

Fossil Fuel Use Worldwide

Today, fossil fuels meet 84% of energy needs worldwide.[91] Fossil fuels are used to generate electricity; fuel transportation; power industrial processes; and light, warm, and cool homes and businesses. The United States, Russia, and China have the largest reserves of fossil fuels.

China is now the top energy consumer in the world, using 20% of all energy. The United States is a close second at 18%, with Russia following at 6%.[92] The figure below shows energy use per person for different regions around the world. To get a feel for how much energy this represents, the graph also shows how many driving trips across the United States could be taken with the amount of energy used by an individual from each region.

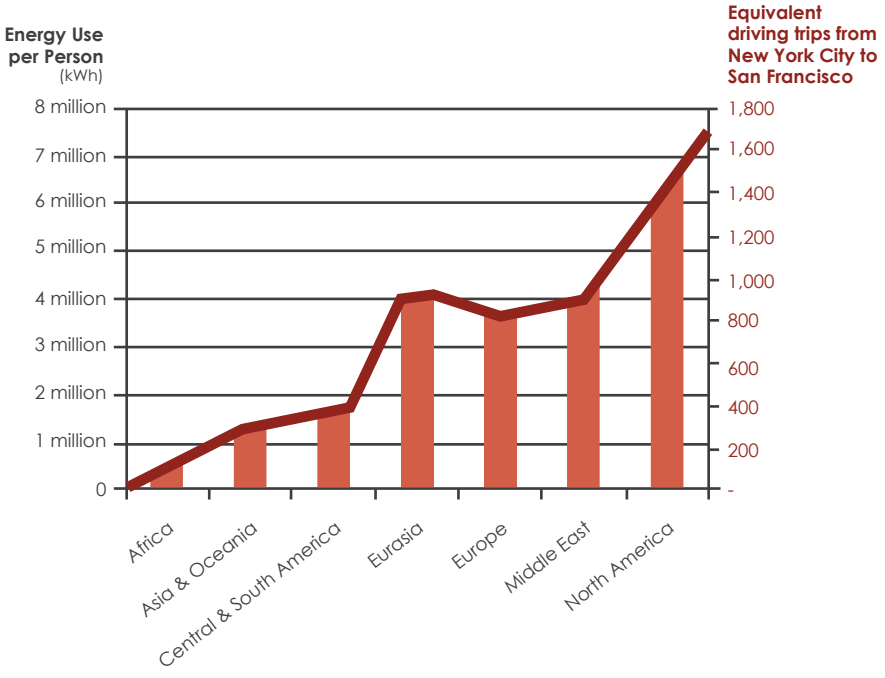
Fossil Fuels and Sustainability

***Economy*:** Fossil fuels are convenient and relatively inexpensive. A mature system supports drilling, refining, transporting, selling, and using these fuels. Also, they can be stored for use at any time, and their energy density is high. However, the costs of pollution-related illness, associated health care, and the value of lost work are high; one estimate showed these costs totaling $118 billion annually.[97]

renewable resource:

A natural substance with economic value that can be replaced in roughly the same timeframe in which it is used.

Regional Energy Use per Person[93]



Think About It!

What does it mean for the future of the Earth if millions more people become dependent on fossil fuels?

One reason fossil fuels are inexpensive is because they receive significant **subsidies** from world governments, including the United States government, estimated at $750 billion a year. These funds reduce the purchase price of fuel to the consumer, offset costs of exploring for energy sources, and reduce tax payments. These subsidies make it harder for renewable sources to compete.

Also, as discussed in the Air Quality section above, fuel costs do not include externalities, or costs paid by society. These externalities include the costs of air pollution and related health and environmental effects; these costs are paid by the people directly affected by pollution and by society, not by the fuel user.

Think About It!

How might people's energy choices be affected if these hidden costs were included in the price of fuel?

***Environment*:** The most urgent concern with fossil fuels today is their contribution to climate change. Burning fossil fuels releases carbon dioxide, a greenhouse gas. Of the three fossil fuels, burning coal releases the most carbon dioxide, followed by oil, then natural gas. Natural gas also contributes to climate change through leaks in drilling wells and the pipeline system. When natural gas – made up primarily of a compound called methane – enters the atmosphere, it produces 25 times the climate impact of carbon dioxide. Methane is the second most common greenhouse gas emitted in the U.S., after carbon dioxide. Most methane emissions come from the natural gas and petroleum system. [99]

Burning these fuels also releases other forms of air pollution, contributing to smog and acid rain. Coalmines can release methane – a greenhouse gas – into the atmosphere.

hydraulic fracturing, or fracking:

A natural gas or oil extraction technology that involves fracturing, or breaking apart, underground rock formations so they will release the fuel.

Extracting fossil fuels also creates environmental problems. Coal extraction can result in dirt and debris in valleys or in waterways, causing damage to ecosystems, wildlife, and water quality. In oil and gas production, a new extraction technology called **hydraulic fracturing**, or **fracking**, has helped engineers capture natural gas that is trapped in shale formations. However, if wells are not properly installed, they have the potential to leak chemicals into nearby water sources and ecosystems. Wastewater from fracking is often disposed of in deep wells; this practice can cause earthquakes. The U.S. Geological Service estimates that some areas in Oklahoma and Kansas with many wastewater wells – used in fracking as well as other oil and gas production activities – are now as likely to have earthquakes as parts of California. [100]

Oil spills can occur while extracting or transporting oil. Spilled oil can harm or kill wildlife; animals – including people – that eat food contaminated by oil can also be harmed. People whose livelihoods depend on fishing and tourism can face severe economic consequences from an oil spill. One of the biggest oil spills in history was triggered by an explosion on the Deepwater Horizon oil rig in 2010. This caused an oil leak that released oil and gas into the Gulf of Mexico at a rate of 11,350 tons per day into coastal waters.[101]

Society: As with all nonrenewable resources, there is a limited supply of fossil fuels. This scarcity can increase competition for this resource and can even lead to international conflict. Also, the positive and negative impacts of fossil fuel use are not distributed equitably, or fairly, among countries or among people living in poverty and people with wealth. These impacts include physical risk and possible disease. For example, coal miners can be trapped if the ground above them collapses. Also, exposure to years of coal dust can cause health problems such as black lung disease.

United Nations Sustainable Goal 7

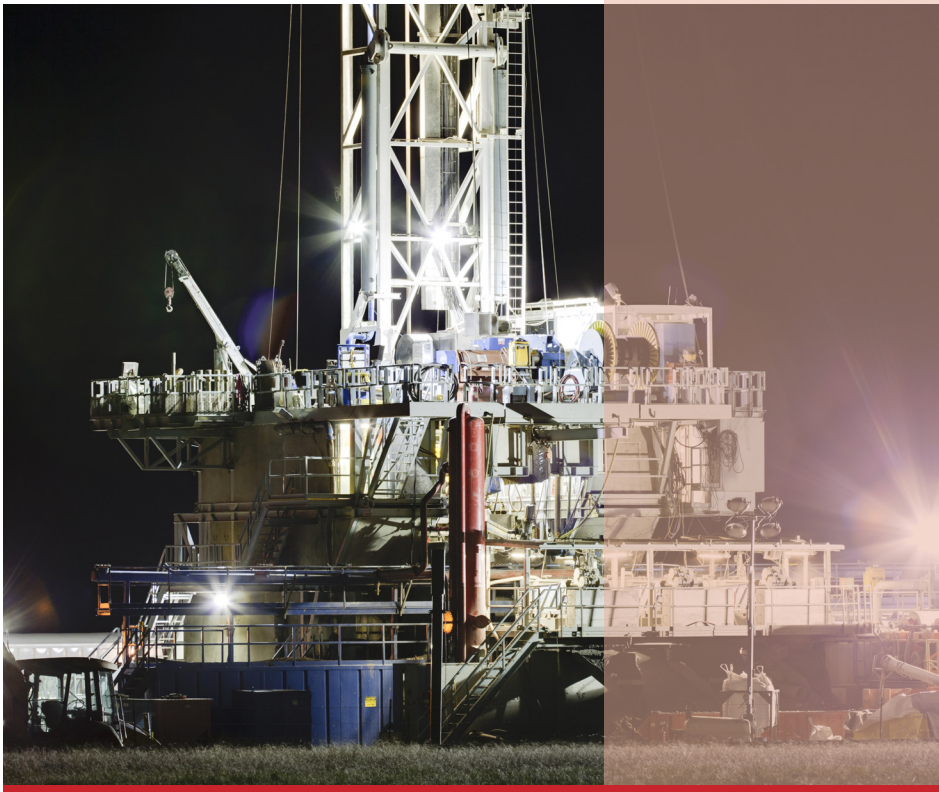
Ensure access to affordable, reliable, sustainable, and modern energy for all.

This goal seeks to expand renewable energy use, improve energy efficiency, and provide modern electricity to all by 2030. [94]

Sustainability Big Idea: Energy and Water Interconnections

Energy and water supply: two of humanity's most basic needs. The two are intertwined: it takes energy to provide clean water to people, and many of our energy sources require water to produce them. In the U.S., nearly half of our fresh water consumption is used to cool power plants that generate electricity. [95] Meanwhile, some of that electricity goes to producing and delivering clean water. Water from lakes and rivers needs to be filtered, sanitized, and pumped to consumers and businesses.

When fresh water is scarce, people are increasingly building **desalination** facilities. These facilities provide drinking-quality water by removing salt from seawater. Desalination uses 7 to 23 times more energy to get clean water than using lake or river supplies.[96] Finding sustainable ways to provide energy and water is a fundamental aspect of providing a safe and just world for all, forever.



Nuclear Energy

Nuclear energy is gaining attention as an alternative to fossil fuels. Nuclear energy generates electricity by capturing the large amount of heat released when uranium atoms are broken apart. Thirty countries around the world operate nuclear plants, which generate 11% of the world's electricity.[102]

Nuclear power produces electricity from atomic reactions. Nuclear power does not create greenhouse gases and other air pollutants, although this pollution is formed from the fossil fuels typically used in extracting and refining uranium – the fuel for nuclear power. However, nuclear power plants generate nuclear waste, some of which can remain radioactive for hundreds of thousands of years.[103]

Radioactivity is rays or particles that are released when certain atoms break apart. Radiation can cause cancer, radiation sickness, or even, in extreme cases, death. Recall that humans only began farming 10,000 years ago, and it becomes very clear that we cannot predict the lifestyles and societies of the people we expect to manage our waste – without their agreement. There is no permanent disposal site for the highly radioactive waste in the United States, and most of this waste is stored at nuclear power plants.

Nuclear power drew the world's attention in 2011, when the Japanese Fukushima nuclear power plant lost power following an earthquake and tsunami. Four of the power plant's nuclear reactors were permanently closed due to damage, and there were high releases of radiation. Fourteen cities near the plant were evacuated, and over one hundred additional cities needed to be decontaminated.[104] This kind of accident represents another risk of nuclear energy.

Renewable Energy

We live in a time of great transition with respect to energy. For the past few hundred years, coal, oil, and natural gas have powered industrialized countries. These fuels have brought about enormous wealth and opportunity for some people and countries. At the same time, we now understand that carbon dioxide emissions from these fuels are dangerously warming the planet.

Renewable energy depends on an ongoing source, generally the sun, rather than a limited source like fossil fuels. Most renewable sources ultimately come from the sun. Solar energy captures sunlight to create electricity or warm homes. Wind is created by the sun's uneven heating of Earth's surface. Hydroelectric power uses the flow of rivers; the sun's energy evaporates water, which falls as rain and fills the rivers. Geothermal energy is unusual, coming from the heat under Earth's surface. These renewable energy sources are mostly used to produce electricity, although some can be used directly to create heat.

Renewables on the Rise

Energy from the sun is now taking hold in many countries, especially those that are developing their energy infrastructure. Worldwide, 22% of all electricity came from renewable sources in 2013.[105] Many new power plants are being built to run on renewable energy; in 2015, two-thirds of new electricity-generating capacity in the U.S. came from wind and solar power.[106]

Of course the sun does not always shine, and the wind does not always blow. Wind and sunlight vary depending on the time of day, season, location, and weather. This inconsistent pattern of energy flow is one of the challenges of making a full-scale transition to renewable energy. However, scientists from Stanford University have studied the potential for renewable energy for each of the fifty states in the United States, as well as one hundred thirty-nine countries. Their work shows that the proper mix of renewables – unique to each state and country – can result in 100% renewable power by 2050. The scientists also show that in many cases, these transitions would reduce pollution and associated health problems, create jobs, and cost less than conventional power.[107] Another way to balance out the ups and downs of renewable energy is storage: engineers and researchers are exploring ways to store electricity generated during sunny and windy periods for use at other times.

Governments and businesses are committing to renewable energy goals. In 2015, California passed a law requiring its electric utilities to obtain half of the state's electricity from renewable sources by 2030.[108] San Diego, California, is the largest U.S. city to commit to 100% renewable energy, pledging to reach that level by 2035.[109]

Sunshine, wind, the flow of water in rivers, and geothermal energy are all free and non-polluting, although building the machinery to capture these forms of energy does produce waste and require energy. Renewables are not dense like fossil fuels, so developing the needed technology at a cost equivalent to fossil fuel-powered electricity takes time. Progress is being made: the cost of solar energy has fallen dramatically in the past several years. Still, in many places, electricity from renewable sources is more expensive than conventional electricity. In some places, government programs pay part of the cost of installing solar energy; for example, California's solar energy incentive programs offer a total of $2.4 billion in rebates over 10 years.[110] Also, as nations transition to renewable energy, workers in fossil fuel industries will need to be retrained for other work. Helping workers find new employment is known as a "just transition."

Benefits of Renewables

Renewable energy can help the environment by reducing air and water pollution, reducing waste from extracting energy sources from the ground, and eliminating carbon dioxide emissions that cause climate change. Renewables also help the economy by creating jobs and, increasingly as technology costs come down, saving consumers money on their electricity bills. Renewable energy can make nations more secure by enabling them to meet their own energy needs, avoiding the need to import fossil fuels. In areas without electricity, renewables can deliver power with small, local systems. These systems may be quicker and less expensive to install than large, centralized power plants and do not need pipelines or roads to bring in fuel supplies. Local systems can also work in industrialized countries.

Solar Energy

It's easy to imagine the power of the sun by thinking of everyday experiences: an ice cube melting quickly on a hot day or the sting of a sunburn after spending a few hours outdoors. Earth receives an enormous amount of energy from the sun: eighteen days worth of sunshine across the planet equals the energy in all known reserves of coal, oil, and natural gas.[111]

Passive solar energy harnesses the sun's energy by designing homes and other buildings to capture winter sun and deflect summer sun.

For years, humans have been building homes and shelters to take advantage of the sun. For example, ancient Roman bathhouses were built facing south toward the sun so they would stay warm.

Solar energy can also be used directly to generate electricity. **Photovoltaic cells**, or solar cells, convert sunlight to electricity. Solar cells can be installed on homes or businesses; any extra solar energy can be sent back to the city's electrical grid. Large-scale projects can deliver power to entire regions. Currently, solar cells can convert up to 24% of the sun's energy into electricity.[112]

As costs have come down, solar energy has become a fast-growing source of renewable energy. Photovoltaic systems deliver power at equivalent costs to traditional electricity sources in about thirty countries around the world.[113] Many countries including China, India, Jordan, Dubai, South Africa, Peru, and Mexico have plans to increase solar power use. In the U.S., solar energy powered 37% of new electricity generating stations.[114]

Wind

Wind blows because the sun heats the surface of the earth unevenly, causing air to circulate. **Wind energy** is created when wind turns the blades of a wind turbine, and a generator converts the mechanical action into electricity. Wind turbines can be installed in large groups called wind farms; sometimes these wind farms are built on floating platforms on the ocean. Wind turbines can also be made small enough to install on the roof of a house.

While wind is plentiful and free, wind turbines require large amounts of land. Wind farm opponents are concerned that wind turbines ruin the landscape and cause noise pollution. Also, wind turbines can kill migrating birds or, at offshore wind farms, sea birds.

Eighty-five countries worldwide use wind energy. In the U.S., wind power generates enough electricity to power 18 million homes.[115]

Geothermal

Geothermal energy is one renewable form of energy that is not derived from the sun. **Geothermal energy** comes from heat produced below Earth's surface. This heat can be used to provide heat in homes or create steam to generate electricity. There is an incredible amount of geothermal energy available. In the U.S., potential geothermal energy is equivalent to 30,000 times that country's annual energy use.[116] Globally, geothermal energy facilities already in operation create enough electricity to power over 6 million average U.S. homes. Most of the world's geothermal energy is produced in the United States.[117]

Geothermal energy has a big advantage over other renewable energy sources: it offers a constant flow of energy. Unlike sunlight and wind, which vary over days or years, Earth continually generates heat. This feature could make geothermal an important part of a renewable energy mix, filling in gaps when solar or wind power do not produce electricity.

There are a few potential drawbacks to geothermal energy. This type of energy can produce very small amounts of air emissions if steam from hot underground streams is collected to make electricity. This steam may contain naturally occurring sulfur, which can cause odors or contribute to acid rain. Also, geothermal energy is not available everywhere, and the cost of exploratory drilling and the initial setup of power plants can be high. There is some concern that underground drilling could contribute to earthquakes.[118]

Hydroelectric Power

Hydroelectric (hydro meaning water) power refers to the kinetic energy of moving water, including fast-flowing water, waterfalls, ocean tides, and waves. The most common type of hydroelectric energy comes from freshwater dams, which hold back the flow of rivers in **reservoirs**. Gates open to release the stored water, which flows past turbines to generate electricity. Because the flow of water is renewed naturally through Earth's water cycle, hydroelectric power is considered a renewable energy source.

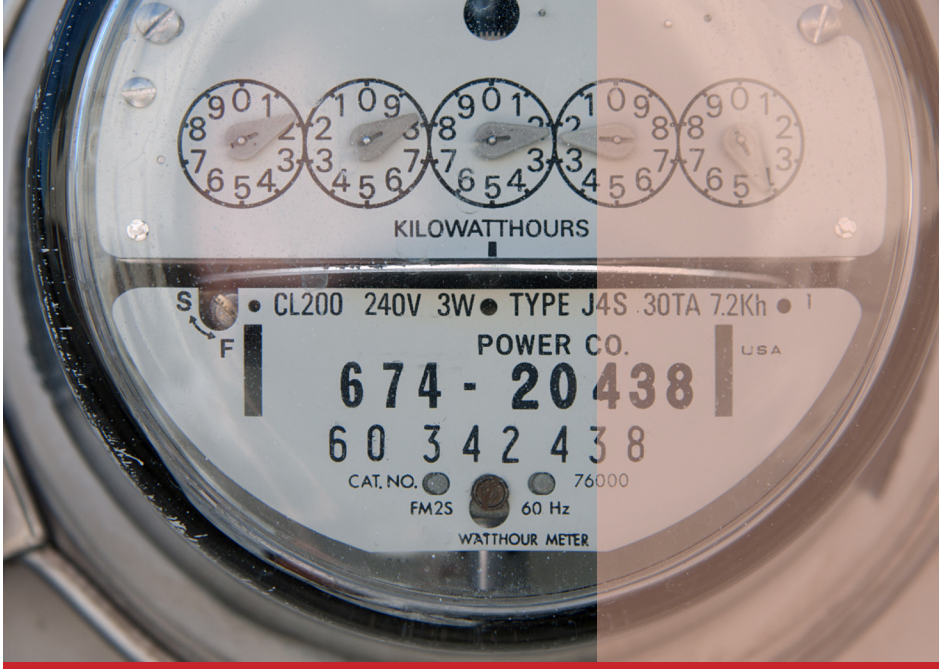
Many countries around the world have built dams in order to generate hydroelectric power. China produces the most hydroelectricity in the world and has created the largest hydroelectric dam in existence: the Three Gorges Dam on the Yangtze River. Hydroelectricity provides about 16% of worldwide electricity production and about 7% of U.S. electricity, making it the most widely used form of renewable energy.[119]

Hydroelectric systems can operate at any time of the day or night, year round, as long as there is water in the dam. Once a dam is built, hydroelectric power is the least costly way to produce electricity today. Their equipment is simple and easy to maintain.

However, building large dams can have high monetary, ecological, and social costs. Often people who live in the area must move to allow land to be flooded to create a reservoir. It is estimated that over 1.4 million people were displaced from their homes by the construction of the Three Gorges Dam.[120] Also, soil, sand, and leaves settle in the bottom of reservoirs, reducing water quality for organisms that live in the water. Blocking a river affects any organisms dependent on that river. In response to these ecological concerns, there have been some efforts to remove dams and restore rivers and their surrounding ecosystems to their natural state. For instance, the Elwha Dam in Washington State was removed in 2012 to help restore the river and fisheries.

Learning from Nature: Energy from the Sun

Learning about energy from nature is very straightforward: nature uses no power plants, no electrical lines, and no gas stations. In nature, energy comes from the sun and is transferred from one organism to another through food webs. We can tap into solar power through renewable energy technologies. Earth has been very successful while using only the sun's energy. We can be, too.



Conservation/Efficiency

Have you ever heard the saying, "reduce, reuse, recycle?" This foundational idea of sustainability reminds us to explore ways to simply use less. **Energy conservation** and **efficiency** address this idea. Behaviors and actions that save or use less energy – such as turning off the lights when you leave a room – are referred to as **energy conservation. Energy efficiency** refers to completing a specific task with less energy input than usual. For example, an energy-efficient light bulb – such as a light-emitting diode (LED) or compact fluorescent lamp (CFL) light bulb – requires less energy to produce the same amount of light as other light bulbs.

Conservation and efficiency need to be top priorities for reducing environmental, economic, and social impacts of energy use, because even renewable energy sources have environmental impacts. Conservation and efficiency usually cost less than building new power systems and often save money by cutting energy bills. In many countries, conservation and efficiency resulted in an average of 58% lower energy use between 1973 and 2005, compared to energy that would have been used without these measures.[121]

Point - Counterpoint

Is nuclear power a sustainable energy choice?

Point	Counterpoint
Yes[122]	**No**
• **Nuclear power is the only non-fossil fuel that can replace coal-fired power plants and reduce greenhouse gas emissions.** Wind and solar energy are not constantly available. Using nuclear power would eliminate many greenhouse gas emissions, reducing climate change. • **Nuclear energy costs are equivalent to other forms of electricity generation,** according to the World Nuclear Association, which represents the nuclear industry worldwide. • **According to the World Nuclear Association, there have been only three major accidents in the 50 years that people have been generating nuclear power.** These three accidents happened in Three Mile Island, Chernobyl, and Fukushima. This number is small considering there has been nuclear reactor operation in 30 countries. Large-scale testing and analyses have shown that, when an accident does occur, less radioactivity actually escapes from fuel than initially assumed.	• **Nuclear power creates both low- and high-level radioactive waste.** This waste can be dangerous for generations. There is no permanent storage available for this waste in the U.S., and there is no way to guarantee that it can be safeguarded for the long period during which it will be dangerous. • **Nuclear energy is not worth the investment.** According to the Union of Concerned Scientists, a group of environmentally-focused researchers and students from the Massachusetts Institute of Technology, the cost of a proposed plant in Florida skyrocketed from $3.5 billion to $22.5 billion.[123] Energy efficiency measures could offset much of the need for the nuclear plant's electricity at a much lower cost. • **Accidents at nuclear power plants can release radioactivity and harm people and ecosystems.** In 1986, a nuclear reactor exploded in the town of Chernobyl, Ukraine. The reactor released radioactivity that some experts believe was equivalent to 200 Hiroshima and Nagasaki atomic bombs. Millions of people were exposed to this radiation, and hundreds of thousands of people had to leave their homes.[124] The World Health Organization estimated that as many as 9,000 early deaths from cancer could occur because of this accident. Also, 5,000 cases of thyroid cancer have been diagnosed in people who were children at the time of the accident.[125]

Think About It!

As you consider the pros and cons of nuclear energy, notice the organizations that represent each point of view. What are their worldviews? How would this worldview influence their opinions and the data they would select? How do you decide which position you agree with – what is your worldview? Consider the Earth Charter principles at the beginning of this unit. What position do you think would best support those principles?

Case Study

Barefoot Solar Engineers[126]

Envision a college where young people, parents, and even grandparents – most of whom cannot read or write – are admitted to train to become solar engineers, water specialists, dentists, doctors, teachers, mechanics, architects, artisans, masons, computer programmers, and accountants.

Barefoot College was founded 1972 to help impoverished rural communities become self-sufficient and sustainable. Located in the village of Tilonia in Rajasthan, India, the college seeks to halt the mass migration of unemployed people to overcrowded cities and urban slums, retaining them in their villages with meaningful work. Because the organization believes that successful development must be rooted and managed by the community, their approach is to listen to what communities need and then train through apprenticeships so that people return to their communities prepared to thrive and help others do the same.

The process begins with an interested community forming a Village Environmental Energy Committee. This committee communicates with villagers about solar power and will collect a small monthly payment from families participating in the subsidized program. The committee and community select individuals to attend a six-month, in-residence training program at Barefoot College's campus. The college often encourages communities to pick people who struggle to find employment such as single mothers or widows. Upon completion the "Barefoot Solar Engineers" return home, manage the project, and earn a monthly stipend.

Let's see how this innovative college fits in with the big ideas of sustainability.

Nature Connection: Solar power uses the renewable energy of the sun.

Interconnectedness: The program keeps people in their communities, valuing their traditions and relationships. The program links environmental, economic, and social issues by seeking out people who have difficulty finding employment.

Universal Responsibility: The college addresses concerns that are not its direct responsibility, using its staff members' skills to address societal problems like poverty, unemployment, health, and migration to urban areas.

Respect for Limits: By focusing on solar energy, Barefoot College recognizes limits to Earth's materials.

Equity and Justice: The program seeks to help villages stay vital and to help economically- marginalized people like widows and single mothers gain skills to support themselves and their families financially. One of the Barefoot College's non-negotiable values is equality.

Local to Global: The United Nations and many businesses and charities from around the world support and fund the Barefoot College. Their approach and global connections help guide programs worldwide.

Peace and Collaboration: The organization respects local people, with rural, illiterate youth eventually leading many aspects of the work. Collective decision-making is another one of Barefoot College's non-negotiable values.

Health and Resiliency: The college addresses personal and public health and energy and supports people who were already strong leaders in their communities. These approaches make each participating village more resilient, or able to adjust to change.

Pathways to Progress

Government policies

The U.S. government has established energy efficiency standards and guidelines to reduce energy use. For example, Corporate Average Fuel Economy (CAFE) standards require vehicle manufacturers to improve **fuel efficiency**. CAFE standards have more than doubled passenger vehicle average fuel efficiency, with further improvements to come.

Career Profile

Organization Founder

Stacy Noland wants to see major change in the way society powers homes and the work force. After receiving a bachelor's degree in psychology and working as a manager at Microsoft, he founded the Moontown Foundation. The Moontown Foundation is a nongovernmental organization (NGO) that creates initiatives with a dual goal: to empower individuals through experiential education and to make immediate impact on climate change and environmental degradation in the communities that need it most. As Stacy states, "It's my personal mission to get the people in poverty to adopt energy conservation; healthy, sustainable living; and alternative transportation, first. Those are the hardest people to reach."

Stacy Noland

The Foundation's YES Program (Young Ecopreneurs in Sustainability) and SWITCH Program are focused on creating careers in home energy efficiency and solar energy. They introduce young adults to the mechanics of energy-saving technologies, including solar paneling, weatherizing, and low-flow shower heads. Other projects focus on working with entire communities and considering how to create sustainable solutions to problems. One of these is the Storm Surge project, a documentary film about bringing sustainability to the southeastern states.

Another federal program is the Energy Star labeling system, which helps consumers compare the energy costs and efficiency of new appliances.

Public Investment

Governments can encourage renewable energy choices through subsidies and incentives. For example, California's Go Solar program offers residents and businesses funds to pay a portion of the installation costs to install new solar photovoltaic systems.

Citizen Action

Citizens can influence governments, businesses, and individuals to take action.

Do Your Part

There are many ways you can help clear the air and reduce energy use. The following ideas are just a few solutions.

- Commute by foot, bike, public transportation, or carpool.
- Don't forget the basics: turn off lights when you are not in a room, and avoid unnecessarily heating or cooling your space.
- Unplug appliances, electronic devices, and chargers when not in use, or plug them into a power strip with an on/off switch. Five to ten percent of home energy use may be used in this kind of standby power.
- Educate your community about what they can do to address energy conservation.
- Be a savvy consumer: First, use your sustainability worldview to help decide whether you need to make any given purchase. Be aware that all products require energy – usually produced by fossil fuels – to manufacture and transport. When you do choose to make purchases, consider air quality. Buy non-toxic household products and low-VOC materials.

Think About It!

Look back at the Earth Charter values noted at the beginning of the unit. What opportunities have you seen in this material to apply these values?

Activities

Meeting Human Needs Sustainably
Activity Section

Food Web Mind Map

Activity

1. **Introduction:** Introduce the idea of systems; see page 11 for background information. Introduce the idea of interconnections as a Big Idea of Sustainability; see page 4 or, for a more detailed explanation, please see https://www.facingthefuture.org/pages/interconnectedness.

2. **Identify common foods.** Ask the class to name foods they eat regularly. Try to get responses that represent different types of food:

    a. animal products, including meat, dairy, and eggs

    b. plant-based products, including fruits, vegetables, nuts, and grains

    c. processed packaged foods, including sodas, chips, candy, and cookies

    Some options, like hamburgers or burritos, may include various types – that's fine.

3. **Choose representative foods.** Ask the class to choose one representative of each of the food types. The packaged food example should be as heavily processed – and as far-removed from natural ingredients – as possible.

4. **Start a mind map.** Start a mind map on the class whiteboard or other display that all learners can see. Place "food" in the center, and add your animal product selection as a link. Ask the students to create a similar mind map on a sheet of paper or in their Field Books.

5. **Add social connections.** Ask the class to name the closest connections that bring this food to them and take away its waste products. In this step, focus on social connections, including people, businesses, and social institutions. It may be helpful to think of connections step by step, from those nearest the consumer to up the chain to the actual source of the food. Ask students, "Where does that product or energy come from?" and "Where does that product or energy go when the consumer or other user is finished with it?"

    Using the example of a hamburger as an animal product, social connections could include:

    a. Restaurant or store

    b. Truck driver

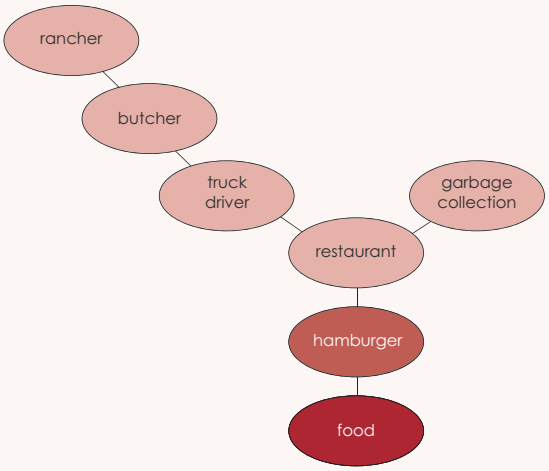
    c. Packaging manufacturer

    d. Butcher

    e. Rancher

    f. Garbage collector

    Add these links to the class mind map, and ask students to add the links to their mind maps as well. Your mind map should look something like the one shown below:



You can choose to conduct this activity at the beginning of class as a kick-off for the unit, then follow with having students create their Field Books. This sequence will require students to tape or glue their mind maps into their Field Books. You could also choose to have learners prepare the Field Books first and use them in this activity. This activity is not included in the Student Edition.

Summary

Learners brainstorm interconnections between the food they eat, human systems, and ecosystems. The learners document these interconnections in individual and whole class mind maps. Seeing interconnections is a fundamental part of systems thinking, which is based on seeing the functioning of the whole system rather than focusing on separate parts.

Time Required

- 30 minutes

Objectives

- To identify interconnections between food, society, and nature.
- To map the steps between the consumer and nature for common food products.
- To recognize humans' place in the planet's food web.

Inquiry/Critical Thinking Questions

- How is my food connected with other human activities and with nature?
- How is my body connected with nature through the food I eat?

Materials

- Blank paper or Field Books
- Colored pencils, optional

6. **Add natural connections.** Moving further up the chain of links that bring the food product to the consumer, ask learners to think about what links are "upstream" of the social connections. What natural processes and organisms are needed to produce the food product and to dispose of waste products. Examples can include:

   a. The animal producing the product

   b. The food the animal eats

   c. Sunshine

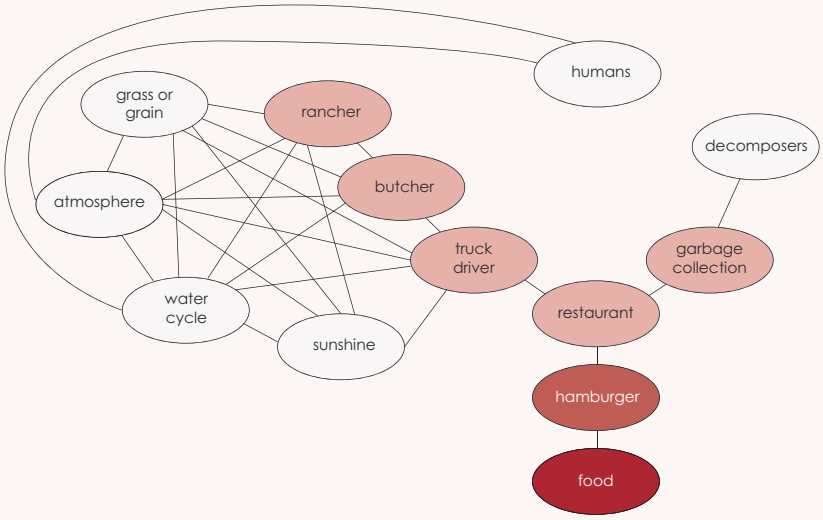
   d. The atmosphere

   e. The water cycle

   f. Decomposers

   g. Humans

   Continue to explore where the product comes from and where it goes when the consumer is finished with it. Add these links to the class and individual mind maps. Many links are possible; some possibilities are shown in the diagram below:



7. **Divide students into groups to add other food choices to their mind maps.** Divide the class into pairs or small groups of 3 to 4 learners. Ask each group to add their plant-based and processed food choices to their mind maps, connecting these foods directly with the "food" bubble as the animal product did. Have the groups go through the same process as above to identify social and natural interconnections for these food choices. They can link with their existing nature connections or, if it helps keep the mind maps clear, they can add new ones.

8. **Share results.** Reconvene as a group. Ask learners to share with the group the connections they identified. Add these to the class mind map, and ask learners to add any new connections to their individual mind maps.

9. **Explore further links.** Look for extended links between social and human connections. For example, truck drivers rely on the atmosphere to burn fuel and dispose of exhaust. Ranchers rely on the water cycle and, of course, cattle. There may also be links from social to natural connections, such as fertilizer or pesticides linking to a crop. Ask learners to identify other interconnections between social and natural links and add these interconnections to their mind maps.

10. **Add mind maps to Field Books.** After the discussion, ask students to tape or glue their mind maps into their Field Books if necessary.

Discussion Questions

- According to the map, how far is each food item from something in nature?
- Which food items are closer to nature? Which require more human steps between nature and the consumer?
- How does eating food connect you with nature?
- Are your food choices close to nature or processed through manufacturing?
- Does it matter if your food choices are close to nature? Why or why not?
- How do human methods of meeting the basic need of nourishment compare with the ways animals meet this need in the wild?

Field Book

- Tape or glue the mind map into the Field Book

Activity One

Set Up Field Book

Activity

1. **Create Your Field Book.**[127]

   a. ***Create a Cover page.*** Include:
      i. The module's title, "Meeting Human Needs Sustainably"
      ii. Your name
      iii. Name of class
      iv. School term and year
      v. Illustration, collage, or other artwork representing the module's topics

   Tape your cover to your Field Book.

   b. **Make a Table of Contents page.** This page will be completed over the course of the unit. Include the pages described below and leave room for additional note pages and classwork to be added.

   c. **Make a Questions page.** Note any questions you have about the upcoming unit. Add questions to this page as you go through the unit.

   d. **Make a Learning Links page.** This is a two-page spread; when the binder is open, both pages can be seen, as shown below. Write the essential questions near the middle of the page. For Unit 1, "Food and Water: Necessities of Life," these questions are:

      i. How is my body connected to nature through food and water?
      ii. How are food and water issues related to each other?
      iii. How can food and water be produced and shared sustainably, now and into the future?
      iv. Where do my food and water come from?

Students will record their work, add in work papers, write reflections, and create a nature journal in their Field Book. It is meant to be a record of academic work and reflections, analysis, and creativity. It should document their explorations, curiosity, and evolving understanding of the opportunities humanity has to learn from the natural world.

Daily activities have a Field Book section at the end. These sections include prompts for nature journaling, references to Think About It boxes in text, and some other reflection questions or activities. You may also choose to ask students to write about some of the Discussion Questions listed under daily activities instead of discussing them in class.

Please encourage the use of color to highlight key insights and connections, drawings and sketches, charts and graphics, and even snippets of song lyrics that relate to the subject, as well as note-taking and assignment completion.

When you have handouts, students can add them to a binder/notebook fastened with brads or tape or glue them to pages in a spiral-bound notebook/composition book.

Summary

In this unit, learners will explore the following essential questions:

1. How is my body connected to nature through food and water?
2. How are food and water issues related to each other?
3. How can food and water be produced and shared sustainably, now and into the future?
4. Where do my food and water come from?

At the end of the unit, learners will be asked to respond to these questions.

Students will set up a Field Book that they will use throughout the unit to record their work, write reflections, and document daily observations of nature.

Time Required

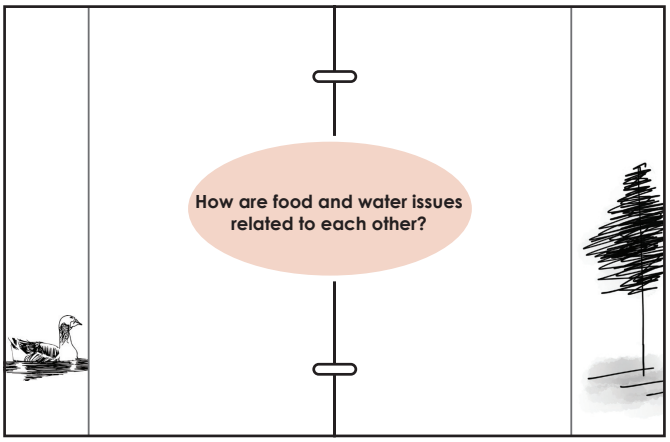
- 15-20 minutes

Objectives

- To create a record of their work.
- To document any changes in their sustainability worldview.
- To provide evidence for self-assessments and formal assessment.

Materials

- For each student: 1" binder, or 8-1/2" x 11" composition book, or 3 brads, or a spiral-bound notebook. If students use spiral binders, they will need to tape or glue work papers into the notebook.
- Lined paper, as needed
- Blank paper for the cover
- Colored pencils
- Tape or glue



As you work through the unit, create a mind map using text, drawings, and graphs. This page lets you document your developing answer to the primary question as you go through the unit. Include preliminary conclusions and evidence to support them. Draw arrows and lines to link elements.

e. **Add work papers as needed.** Generally, right-hand pages will be for notes, information, tables, and other analytical work. Left-hand pages will be for drawings, reflections, Field Book notes described in activities, or other reflections or artwork.

f. **On all your pages, leave wide margins**–about 1-1/2 inches each–at the top, bottom, and outside edges. These margins will be used in a later activity.

2. **Add your notes from today's class activity to your Field Book.** These will be your first Work Papers pages. Add the title, "My Food Webs" at the top of your notes and add page numbers to your note pages. Add this title and the page number of the first page to your Table of Contents. In the same way, you will add your daily classwork and homework to your Field Book throughout the unit.

3. **Create a new Reflection page.** Write a paragraph about the following topics:

   a. What do you know about connections between food and water issues?

   b. What do you know about sustainable food production?

   c. What do you know about where your food and water come from?

Add the page to your Table of Contents.

Field Book

1. Write responses to the **Think About It** boxes on pages 2 and 5.

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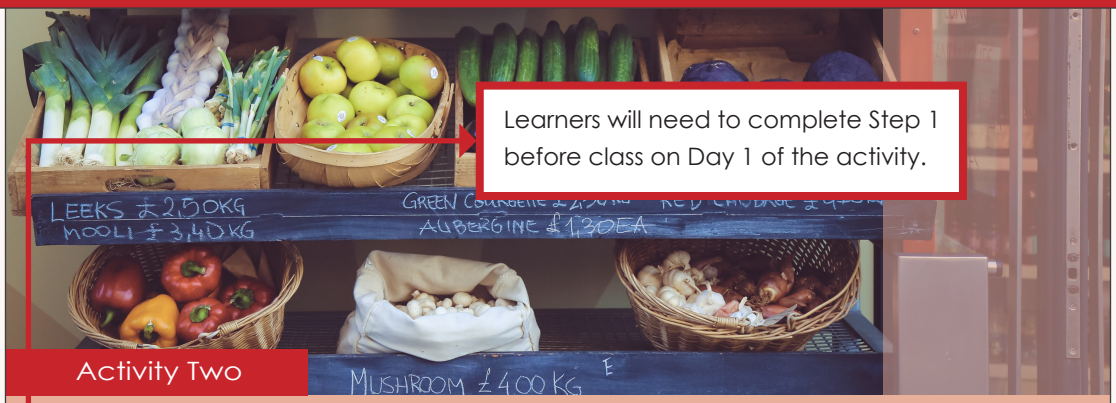

Learners will need to complete Step 1 before class on Day 1 of the activity.

Activity Two

My Food Impacts

Set-Up

1. **Set up a Food Log in your Field Book.** With your Field Book in landscape orientation, make a table on the right-hand page. Title the table "Food Log" and create six columns with the following headings:
   - Meal
   - Food
   - Plant/Animal/Processed Food
   - Amount (grams or ounces)
   - Amount Disposed (grams or ounces)
   - Disposal Method
2. **Record your food consumption and disposal.** Write down all food you eat from the end of one class period until the beginning of the next class period. Use the following guidelines:
   a. **Meal:** Note whether you ate the food at breakfast, lunch, dinner, or as a snack.
   b. **Food:** Briefly describe the food. If you ate combination food like a sandwich, include bread and the filling separately. You may need several entries, like meat, cheese, tomato, and lettuce.
   c. **Plant/Animal/Processed Food:** Note whether the food came directly from a plant or animal or was a processed, packaged food. For example, a packaged fig cookie would count as a processed food, although it has some fruit in it; a fresh orange would count as a plant-based food.
   d. **Amount (grams or ounces):** Estimate the weight of the food consumed. Assume that 28 grams of food (1 ounce) is about the size of your thumb. Also, 84 grams of food (3 ounces) is about the size of the palm of the hand of an average woman or a deck of playing cards.[128]
   e. **Amount Disposed (grams or ounces):** Estimate the weight of food waste from your meal.
   f. **Disposal Method:** Describe briefly how you disposed of uneaten food. Usual options include trash or compost. Do not include food packaging.

Introduction: Let students know the following information about food's interconnection with the environmental:

- **Water:** 70% of freshwater used by people goes toward raising food crops and animals.[127a]
- **Climate Change:** Agriculture makes up about 13% of global greenhouse gas emissions, making it the second-largest contributor. The largest contributor is fossil fuel energy use, including electric power generation and transportation.[127b]
- **Land Use:** 38% of all land on Earth is used for human food production. As human population has grown, the fraction of land used in food production has grown as well. For example, in 1700, only 7% of Earth's land was used to produce human food.[127c]

Summary

Learners will track their food consumption and food waste for one day, then calculate the environmental impacts of their choices.

Time Required

- Time outside class to record food intake and disposal
- Three 50-minute class periods

Reading Prior to Assignment

- Preparation Day: None
- Day 1: pages 2-7
- Day 2: pages 7-12
- Day 3: pages 13-18

Key Concepts

- Sustainability Big Idea: Local to global
- Environmental impacts of food consumption, production, and waste

Objectives

- To recognize the choices students make in food consumption.
- To estimate environmental impacts of food choices.
- To build a sense of connection between personal food consumption, food production, and food disposal.

Materials

- Calculators or electronic spreadsheet technology
- Blank, unlined paper for each learner
- Tape or glue for Field Book and work papers
- Colored pencils, optional
- A copy of the "My Food Impact" work paper for each student; see page 79A
- Copies of the Seasonal Produce Table as needed; see page 79B

Hand out a copy of the "My Food Impact" work paper to each student.

Activity

Day 1

1. **Estimate the impacts of your food choices.**

   a. **Copy your food items and amounts to the "My Food Impact" work paper to be provided by your teacher.** Also, write in the measurement units you use in the spaces provided in the heading boxes. For example, if you use metric units, write grams in the "Amount" column.

   b. **Calculate the water, greenhouse gas emission, and land use impacts for each of your food choices.** Use the figures on the Environmental Impacts of Food Table below to calculate your impacts.

      The following example shows how to calculate your water impact, assuming you ate 115 g of beef.

      i. Water Impact

food amount		water use impact factor (liters of water/ gram of food)	=	water used to produce your food (liters)
115g beef	X	*0.5 liters of water/ gram of beef*	=	*57.5 liters of water used*

If you measured your food in ounces, you would use the water impact factor given in gallons of water per ounce of beef; your answer would be in gallons of water.

Record your results on the Food Impact work paper.

Tape or glue your Food Impact work paper into your Field Book.

   c. **Total your water, greenhouse gas emission, and land use impacts.**

   d. **Total your total amount of food** eaten and your amount of food disposed from your Food Log in your Field Book. Calculate the percentage of food that was disposed of.

Field Book

Day 1

1. **Nature Journal:** When you are outside today, notice any wild plants or animals. You may see weeds or "volunteer" plants and birds on a utility wire, or you may see a vacant lot or a wild path by a stream. In any case, these wild plants are food for something; what could it be? What do the wild animals eat – even if they are in a city? What do insects eat? See if you can observe a wild creature hunting or eating food. Write about it or sketch it in your Nature Journal.

2. Write responses to the **Think About It** boxes on pages 6 and 10.

The units of measurement for greenhouse gases are g CO_2e/g food. CO_2e is a climate change term read as "carbon dioxide equivalent." The term recognizes that different greenhouse gases contribute to climate change to different degrees. Scientists have calculated conversion factors that allow quantities of different greenhouse gases to be added together in spite of their different impacts. For example, beef production creates emissions of methane and carbon dioxide, two greenhouse gases. Because these gases affect the climate differently, their impacts cannot be added together directly. Instead, the Greenhouse Gas Impact Factor of 27 grams CO_2e/gram for beef reflects the amount of climate change that would occur if 27 grams of carbon dioxide were emitted. This figure includes impacts from the actual amounts of methane and carbon dioxide.

Work in pairs or small groups.

Activity

Day 2

1. **Design low-impact meals for one day in each season.** Use the following guidelines to create your meals:

    a. Use the Environmental Impacts of Food table to design meals for a day that create the lowest-impact.

    b. Use your existing knowledge of nutrition to make sure the meals are healthy and well-balanced, or use the United States' Department of Agriculture's My Plate guidelines. These guidelines include filling half of your plate with whole fruits and vegetables and choosing whole grains for half of your grains.

    c. Choose food or dishes that you would like to eat!

    d. Make notes on possible meals in your Field Book.

    e. Describe your meals on a blank page; include sketches or collages.

    f. Select a person in your pair or group to present your meals. The presentation should include:

        i. Your food selections

        ii. The overall water, greenhouse gas, and land impacts for each meal

        iii. An explanation of nutritional considerations

        iv. An explanation of the way you used seasonal produce

    Also, select one of the meal pages to include in a class food planner.

You may want to provide more details from:

https://www.choosemyplate.gov/MyPlate

Have students visit the website themselves, or have them visit another nutrition-focused website.

Field Book

Day 2

1. **Nature Journal:** When you eat something today – preferably fresh produce – try to imagine that food as part of a growing plant. Imagine the food developing from a flower, small leaf, or small root into harvestable food. Imagine the sun warming the plant and providing it with energy to grow and photosynthesize. Imagine the plant taking in carbon dioxide from the atmosphere, absorbing carbon and converting it into leaves, fruit, stem, and roots. Imagine the roots in the soil, absorbing water and providing the plant with physical support. Visualize the many soil organisms keeping the soil healthy: algae, bacteria, fungi, and insects. Imagine other organisms in the plant's ecosystem: bees, birds, lizards, and other creatures. In the margins of a Field Book page or two, write notes about where your food came from or sketch different aspects of your food's development.

2. Write responses to the **Think About It** boxes on pages 12 and 14.

Hand out blank paper to learners.

Select produce that is in season in your area. Explain that seasonal produce is generally fresher and more nourishing than out-of-season produce. Also, seasonal produce is usually grown locally, so it doesn't need to be transported long distances. Transportation often uses fossil fuels, resulting in greater environmental impacts and higher costs. You can provide students with the Seasonal Produce Table on page 79B or have them visit:

https://snaped.fns.usda.gov/seasonal-produce-guide

Discussion Questions

1. Which foods have the highest impacts in each environmental category on the Environmental Impacts of Food table? Which foods have the lowest impacts?

2. Which foods eaten by the class have the highest impacts in each environmental area? Which foods have the lowest impacts?

3. The average American daily food intake requires about 5,000 liters (1,320 gallons) of water to produce. How did yours compare?[131a]

4. To put students' greenhouse gas emissions in context, visit:

   https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

   if you have Internet connection. Select the "If You Have Emissions Data" tab, select units for CO_2, and enter an amount of calculated CO_2 emissions. You can use the low-impact meal results, aggregate student data, or a standardized healthy meal estimate of 11 kg CO_2e/day.[131b]

Extension

- Ask learners to work with their families to try some meals from the class meal planner. Have them explain to their families the reasons for choosing low-impact, seasonal foods. After one or two weeks, discuss the learners' experiences and results as a class.

Activity

Day 3

1. **Share results.** Pairs or groups share their low-impact meals with the class.

2. **Reflection:** Compare the impacts of your actual meals to the impacts of meals you designed. Write responses on a Reflection page in your Field Book.

   a. Which foods do you choose based on nourishment? On taste? On convenience?

   b. Were you able to find lower-impact choices that you would like to eat?

   c. Which of your food choices have the greatest environmental impact? Which choices have the least impact?

   d. What changes might you make?

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Field Book

Day 3

1. **Nature Journal:** Think about a time you have been hungry. The need for food is a basic, driving force affecting all living things. What did you do to satisfy your hunger? How difficult or easy was it to find food? Think about people in your community who experience hunger: How might they find food? What about people in countries that experience chronic food insecurity? Think about animals in the wild and how much of their time is spent foraging or hunting for food and trying to avoid being food for another creature. Spend a moment being aware of your body, reflecting on the biological need for food that humans have in common with other animals. Write about your responses to these questions or sketch images that represent your responses in the margins of a page or two in your Field Book.

2. Write responses to the **Think About It** boxes on pages 16 and 17.

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- Collect the Meal Planner Pages, collate them into a Class Meal Planner, and make a copy for each learner. If you have the technology available, learners can use digital media to create the Class Meal Planner.

Environmental Impacts on Food

Food	Water Used per unit of Food[129]		Greenhouse Gases Produced per Unit of Food[130]	Land Use per Unit of Food[131]	
	liters of water per gram of food (1/g)	gallons of water per ounce of food (gal/oz)	grams of cabon dioxide equivalent per gram of food (g CO_2e/g food)	square meter of land per gram of food (m^2/g)	square feet of land per ounce of food (ft^2/oz)
Meat, Poultry, Eggs, Fish, and Dairy					
Average Meat	0.3	62	27	0.047	14
Beef	14.3	106	27	0.092	28
Lamb	11.5	85	39	N/A	N/A
Pork	5.5	41	14	0.021	6.3
Chicken	2.3	17	7	0.027	8.1
Eggs	1.6	12	3	0.018	5.4
Average Fish	N/A	N/A	4	N/A	N/A
Average Dairy	0.7	6	2	0.021	6.3
Cheese	3.2	24	13	N/A	N/A
Grains and Beans					
Average Grains, Bread, and Cereals (pasta, tortilla, rice, etc.)	2.1	16	2.5	0.003	0.9
Average Beans	3.0	22	2.5	0.006	1.8
Vegetables and Fruits					
Average Vegetable	0.23	1.7	0.31	0.006	1.8
Average Fruit	0.37	8	0.165	0.006	1.8
Snack Foods					
French fries	0.41	3.0	5.8	N/A	N/A
Chocolate	17	129	6.8	N/A	N/A
Chips, cookies, energy bars	7.6	56	6.5	N/A	N/A
Soda	0.52	3.8	1.2	N/A	N/A

Additional Resources

- U.S. Department of Agriculture's Choose My Plate website at:
  https://www.choosemyplate.gov/MyPlate
- U.S. Environmental Protection Agency's Greenhouse Gas Equivalencies Calculator website at:
  https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

My Food Impact

Name: _____

Food	Amount Eaten (Units: _____)	Water Impact (Units: _____)	Climate Change Imapct (Units: _____)	Land Imapct (Units: _____)
Total:				

Percent of food disposed of: _____

Seasonal Produce Table[131c]

Name: _____

Winter	Spring	Summer	Fall
Apples	Apples	Apples	Apples
Avocado	Apricots	Apricots	Bananas
Bananas	Asparagus	Avocado	Beets
Beets	Avocado	Bananas	Bell Peppers
Brussels Sprouts	Bananas	Beets	Broccoli
Cabbage	Broccoli	Bell Peppers	Brussels Sprouts
Carrots	Cabbage	Blackberries	Cabbage
Celery	Carrots	Blueberries	Carrots
Grapefruit	Celery	Carrots	Cauliflower
Kale	Collard Greens	Cantaloupe/ Muskmelons	Celery
Leeks	Garlic	Celery	Collard Greens
Lemons	Greens (cooking)	Cherries	Cranberries
Onions	Lettuce	Collard Greens	Garlic
Oranges	Mushrooms	Corn	Ginger
Parsnips	Onions	Cucumbers	Grapes
Pears	Peas	Eggplant	Greens (cooking)
Pineapple	Pineapple	Garlic	Green Beans
Potatoes	Radishes	Green Beans	Kale
Pumpkins	Rhubarb	Honeydew Melon	Lettuce
Rutabagas	Spinach	Kiwifruit	Mangos
Sweet Potatoes and Yams	Strawberries	Lima Beans	Mushrooms
Turnips	Swiss Chard	Mangos	Onions
Winter Squash	Turnips	Nectarines	Parsnips
		Okra	Peas
		Peaches	Pears
		Plums	Pineapple
		Raspberries	Potatoes
		Strawberries	Pumpkins
		Summer Squash & Zucchini	Radishes
		Tomatillos	Raspberries
		Tomatoes	Rutabagas
		Watermelon	Spinach
			Sweet Potatoes and Yams
			Swiss Chard
			Turnips
			Winter Squash

Summary

Students will adopt a daily practice of noticing and recording an example of wild nature in their everyday lives, throughout the duration of the module.

Time Required

- 5 to 10 minutes per day

Key Concepts

- Nature is everywhere
- I am part of nature

Objectives

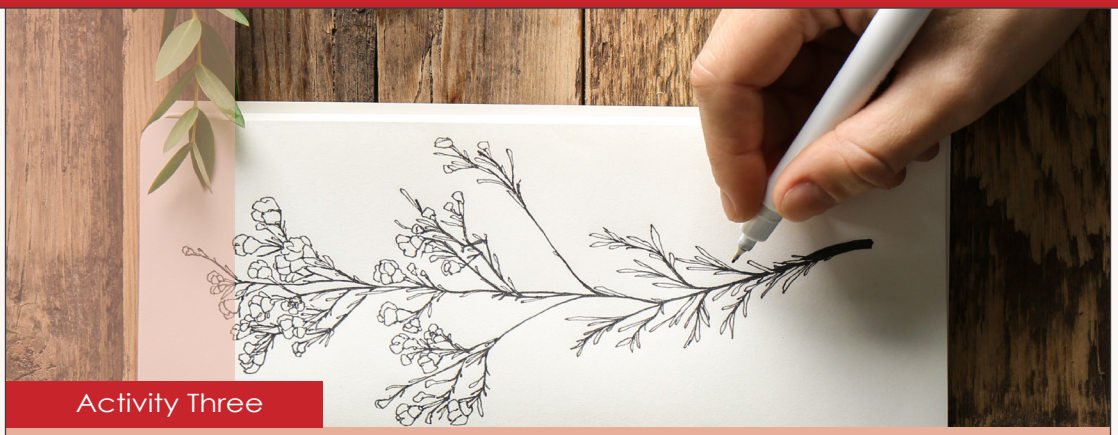
- To create a sense of belonging in and awareness of the student's local place.
- To build a habit of recognizing nature's continual presence in everyday life.
- To bring an appreciation of natural beauty to students.

Inquiry/Critical Thinking Questions

- Do I live in wild nature?

Materials

- Colored pencils



Activity Three

Nature Journal

Activity

1. **Observe wild nature.** Each day, look for an example of wild nature in your daily life. You might notice a bird on a nearby tree, hear rain falling on the roof, or spot a weed pushing up through cracks in the sidewalk. The only requirement is that the observation not reflect a manufactured object or anything made with a manufactured object.

   One option is to choose something to observe every day over the 4 weeks of the unit. You could notice the phases of the moon, the time and location of the sunset, the presence of birds or insects, patterns of wind or clouds, or something else that catches your interest.

Here is a mindfulness-based process you can use for observing wild organisms and building a sense of nature connection:

> Step outside with the intention of experiencing yourself as part of nature. Try to let your thoughts run in the background of your mind without focusing on them. As you step outside, use your entire field of vision to take in your surroundings. Notice everything, living and non-living alike. Tune in to all of your senses. Notice sights, smells, sounds, temperature, wind, and sun. Allow some living organism to draw your attention. Keep your focus on it for at least 10 to 15 seconds, longer if you can. Just silently observe. Notice the organism in its ecosystem, linked with other creatures. Notice yourself similarly surrounded by your ecosystem, linked with others – including, in some way, this organism. As your attention shifts away, see if you feel gratitude for this other living creature.

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One way to use this activity is to ask students to respond to the prompts in the Field Book sections of each activity. These prompts are intended to help learners see connections between themselves and nature in ways that relate to the content.

You can also choose to have students use this activity for finding a daily nature connection, making their own informal observations or – if they choose – using the mindfulness-based observation process below. Daily nature observation helps build a sense of nature connection and often reduces stress. The instructions below guide students in this method of nature journaling.

You can have students spend the first five minutes of class writing or drawing in their nature journal. Or they can complete the journal at home. Have colored pencils available, or have students have a set at home or at school.

You are also welcome to observe in your own way or to use the prompts that are offered in the Field Book sections of the activities.

2. **Record your observation.** In your Field Book, write a few sentences each day describing your observation of wild nature. You can describe what you saw as a scientist would, including details of shape, color, movement, location, and other aspects of nature that were present. You can also write a personal journal about your feelings or reaction to your observation. Another possibility would be to write a short poem, haiku, or fast fiction story about what you observed, centering on the natural elements.

   Sketch pictures to accompany your daily entries, using colored pencils, colored pens, or crayons. This activity isn't a drawing contest; it's just a way to document what you saw. Artistry is welcome if you are inspired, but not needed. You can include in your sketch your subject's surroundings and interconnections or fill in details like a snowflake or bird feather. On some days you may just want to fill in the margins with the colors of the day.[132]

   Record your observations and sketches in the margins of your daily work pages. Use the top, side, and bottom margins, and fill them in with images, color, and text. Weaving your observations in with your analytical work helps create a visual message that nature itself is woven throughout human society. It also can make your work pages look artistic and beautiful. You can draw a straight line on the three outside edges of your pages to create a margin, or use your creativity to design artistic borders. You can also write longer observation notes or add sketches at the bottom of pages or on entire sheets of your reflection pages, if you like.

Field Book

Nature Journal: Record your observations or responses to the prompts in your nature journal. For today, you can take in an overview of your natural surroundings – even if you live in a city. What natural elements do you see around you?

Summary

Causal loops show cause and effect relationships in systems and show how feedback occurs in systems. Learners practice creating causal loop system diagrams and using the diagrams to analyze and solve problems. Learners will create the diagrams based on the text's content on sustainable agriculture, deepening their understanding of this material.

Time Required

- One 50-minute class period

Reading Prior to Activity

- Pages 11-14

Key Concepts

- Causal loop diagram
- Systems thinking
- Feedback
- Resiliency
- Sustainable agriculture

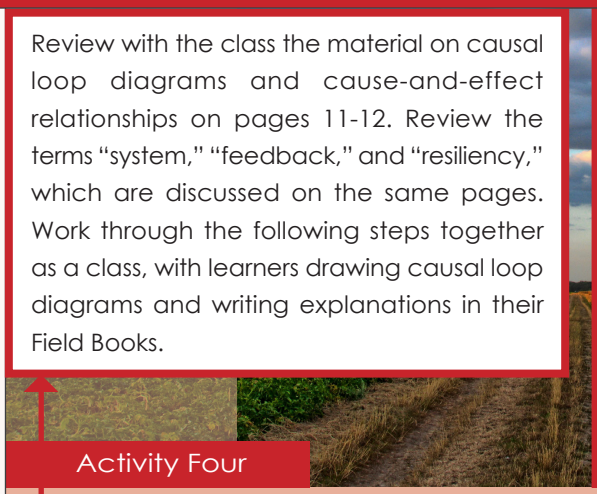
Objectives

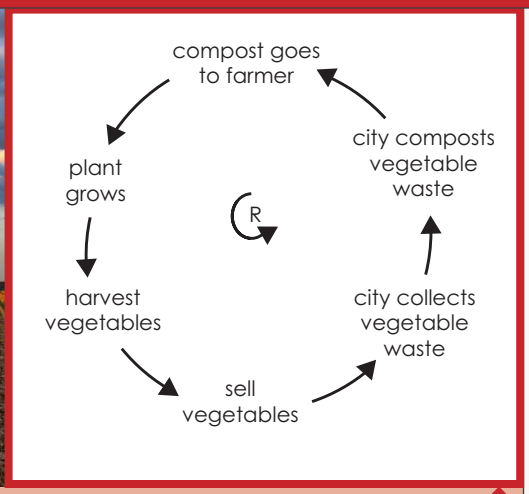
- To learn how to create causal loop diagrams.
- To recognize feedback in systems.
- To use cycles and feedback as problem-solving tools.

Inquiry/Critical Thinking Questions

- How do causal loop system diagrams help us understand and analyze issues?
- What is feedback?
- How does feedback help systems to be resilient?
- What makes sustainable agriculture – including permaculture – different from conventional agriculture?

Review with the class the material on causal loop diagrams and cause-and-effect relationships on pages 11-12. Review the terms "system," "feedback," and "resiliency," which are discussed on the same pages. Work through the following steps together as a class, with learners drawing causal loop diagrams and writing explanations in their Field Books.





Activity Four

Casual Loop Diagrams and Sustainable Agriculture

Activity

1. **In your Field Book, draw a causal loop diagram.** In sustainable agriculture, especially permaculture, farmers often collect seeds from their crops. Collecting seeds reduces costs, minimizes outside inputs to the farm system, and increases resiliency. The elements in the seed-collecting system are seed planting in soil, plant growth, crop harvest, and seed collection.

2. **Add an output from system.** Systems – and the causal loops that represent them – often have inputs and outputs that are outside the immediate area of interest. In this example, the farmer will sell most of the vegetables, reducing the supply of seeds. However, the farmer wouldn't need the seeds from all of the produce and would likely want to make some money.
3. **Create another loop.** Let's take a step back from the above example and consider a city that collects food waste as part of its waste disposal collection. Suppose the food waste was composted – broken down to be used as a fertilizer and soil builder. What components and relationships could you place in a causal loop diagram representing this city compost system? What components might the new loop share with your previous causal loop diagram?
4. **Combine the two causal loop diagrams into one larger system diagram.** Causal loop diagrams can work together, helping us understand larger, interconnected systems.

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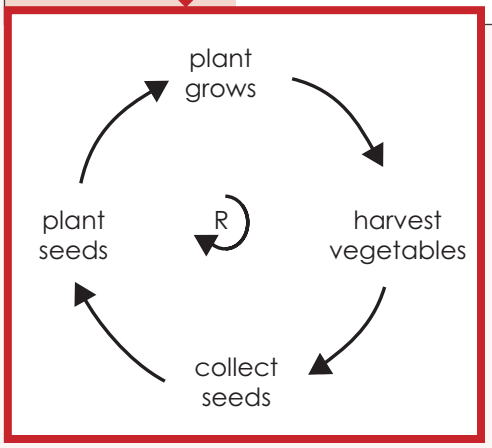
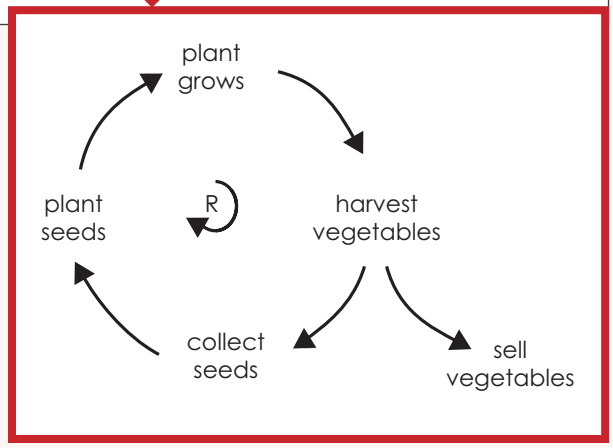
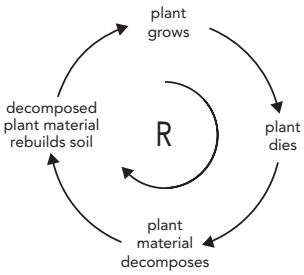




5. **Use a causal loop to analyze a system.** In natural systems, plants live, grow, and die in a cycle. In this cycle, fallen plant matter stays on the soil. The plant matter creates a layer of mulch, which prevents water in the soil from evaporating. The mulch layer also blocks wind or rain from carrying the soil away. Also, as the plant matter breaks down, it provides food for plants and soil organisms that help keep plants healthy. This cycle is represented by a causal loop diagram on page 11, which is also provided below.



In conventional agriculture, single crops are grown in large fields. The soil is kept clear of plant debris, because that debris can draw decomposers like snails or slugs. These decomposers may also feed on the crop plants. But because conventional agriculture loses the benefits of recycling plant material, conventional farms must add fertilizer and water to their soil.

How could this diagram be used to explain the need for added fertilizer?

6. **Build a balancing loop.** Many cycles in nature are balancing rather than reinforcing. In a reinforcing loop, change is reinforced with each step through the cycle: an increase in one component leads to an increase in the next component. In a balancing cycle, changes tend to balance out: an increase in one component leads to a decrease in another component. These cycles are able to stay in balance even when conditions change.

An example of a balancing cycle occurs in most predator-prey relationships, including relationships between plants and herbivores – animals that eat plants. Agriculture has done its best to remove herbivores from the plant lifecycle shown above. Draw a causal loop diagram adding an animal to eat some of the harvest. Replace the "R" in the center with a "B" to show that the loop represents a balancing cycle.

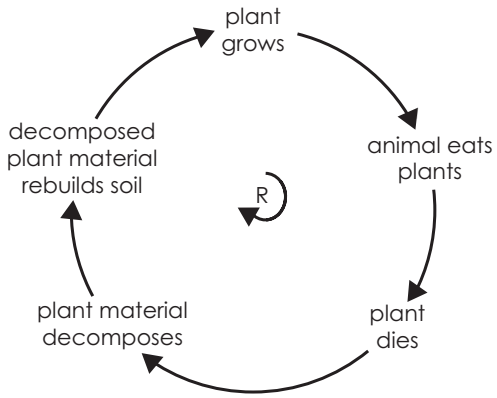
Field Book

1. **Nature Journal:** Look for an opportunity to give a gift of food today. For many people, sharing food is a fundamental act of community. Can you share some of your lunch? Can you prepare food for someone? Can you help a hungry person ease their hunger pangs? Write about how it felt to give food as a gift.

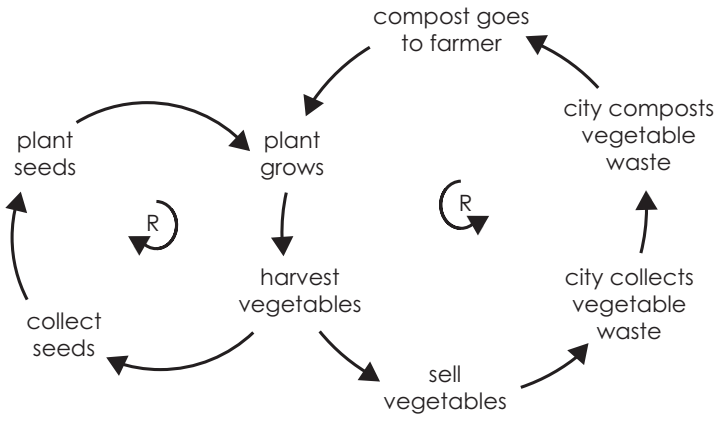
2. Write responses to the **Think About It** boxes on pages 18 and 20.

Discussion Questions

- How can causal loop diagrams help us recognize and understand systems?
- What other causal – or feedback – loops can you think of in the food system as a whole? Can you draw them?



Have students talk through the cycle step by step to see what happens as each component changes. Here is one way of talking through the cycle: As more plants grow, more animals will enter the food system because of the increased food supply. Fewer plants will die in place because more have been eaten. Less plant material will decompose, so less plant matter will be available to rebuild the soil. Fewer – or smaller – plants will grow. Animals will move to other areas to seek out more food. With fewer animals to eat the plants, the plants will grow more vigorously. Eventually, more animals will return to the area. The cycle continues, but the plant and animal populations stay in balance.



In a reinforcing cycle – represented by the "R" in the center – a decrease in one component leads to a decrease in the next element, and so on around the cycle. By removing fallen and decomposed plant material from the cycle, the system component that leads to plant growth – decomposed plant material – is decreased or even eliminated. The causal loop diagram tells us that plant growth will also decline. In this example, the loop is actually broken.

Summary

Learners will create nested system diagrams reflecting their local water system.

Time Required

- One 50-minute class period

Reading Prior to Activity

- Pages 22-25

Key Concepts

- Interconnection
- Water Cycle

Objectives

- To identify interconnections between water-related human and natural systems.

Inquiry/Critical Thinking Questions

- What social and natural systems are needed to bring water to my community?
- What social and natural systems are needed to manage wastewater in my community?

Materials

- Colored pencils, optional

Preparation

You can choose to prepare the following material or have students conduct the research.

- Identify sources of drinking water in your area. These sources may be local lakes and reservoirs, rivers and streams, groundwater, wells, or aqueducts. Bottled water is also a drinking water source.
- Identify processes used to clean and deliver drinking water. These processes may include a city treatment plant, home methods such as boiling or using iodine tablets, pipelines, trucks, or other measures.
- Identify processes to clean and dispose of wastewater.

Activity Five

Nested Systems and My Water Supply

Review nested systems as explained on page 23.

Activity

1. **As a class, list local sources of water, cleaning and delivery processes, and wastewater cleaning and disposal processes.** Write these lists in your Field Book.
2. **Working on your own, create a diagram showing the listed items as nested and overlapping systems.** See the diagram on page 23 as an example. Recall that nested systems are completely contained within a larger system, while overlapping systems share only some characteristics.

Field Book

1. **Nature Journal:** Notice where there is water around you: from weather; dew; irrigation; drinking fountains; beverages; indoor faucets, sinks, and toilets; or other sources. Try to keep your attention open to noticing water throughout a 24-hour period. How often do you see natural sources of water? How often do you drink water? How often do you use water for washing or cleaning? Do you have to make any special effort to access water?
2. Write responses to the two **Think About It** boxes on page 23.

Use colors to represent different groupings, like natural systems and social systems; different levels, like global and local; or different phases of the human water cycle, including supply, transportation, use, and disposal.

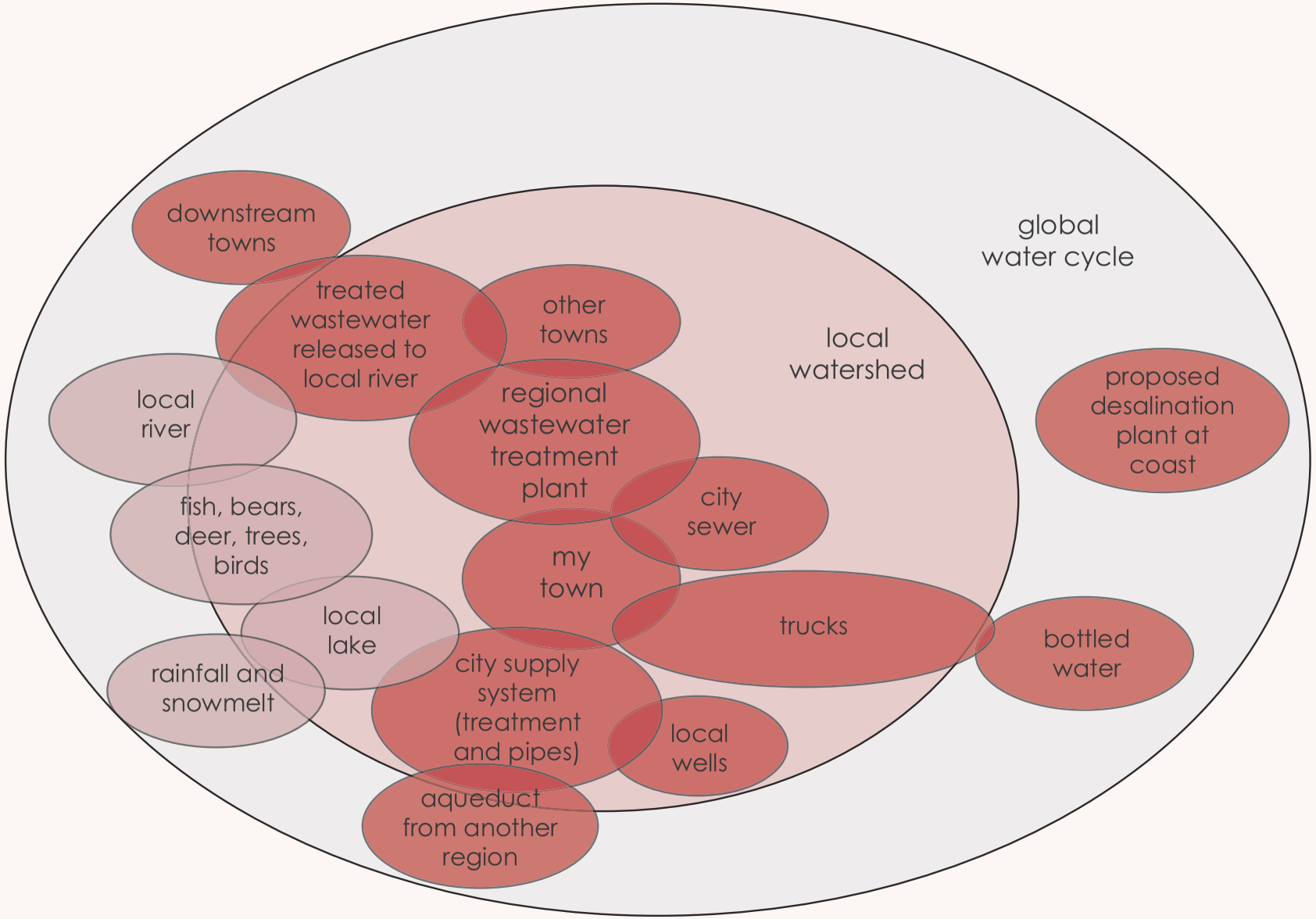
A sample diagram is shown on page 84A.

As you talk through the discussion questions below, work with the class to make any needed additions or changes to their diagrams.

Discussion Questions

- What other people and species depend on the same water that our city or town depends on?
- How do our water supply and water disposal systems link with the global water cycle?
- Are there social issues relating to water supply in your area, such as laws or conflicts over supplies?
- How has your water system changed over time? How might it need to change in the future?

Sample Nested and Overlapping System Diagram



Summary

Learners will grapple with the competing demands of jobs, well-being, and a clean environment through a mock City Council meeting in a city with a polluted river.

Time Required

- One 50-minute class period

Reading Prior to Activity

- Page 4, Big Ideas of Sustainability
- Page 26, Contamination and Pollution
- Page 27, Think About It box
- Page 34-35, Wastewater

Key Concepts

- Water pollution
- Tradeoffs between jobs, economy, and the environment
- Regulations
- Sustainability worldview

Objectives

- To understand the different ways people see the benefits and costs of a robust economy, a strong community, and a healthy environment.

Inquiry/Critical Thinking Questions

- How do people and communities balance the need for jobs with the need for well-being and a healthy environment?

Materials/Preparation

Students will adopt different roles in this activity. You can assign the roles, or students can select roles for themselves. A list of roles and some background information for each role is provided below on the Role Descriptions sheet; see pages 87A-87B.

Students should be given a copy the information relevant to their role but not to other roles. Students can develop any remaining points of view on their own. People in any role can have a sustainability worldview or can put other concerns, such as jobs or wealth, ahead of sustainability concerns.Many people value all of these concerns and struggle to set priorities depending on the situation. Students should feel comfortable taking positions that reflect the difficulty of making trade-offs, rather than adopting a stereotypical point of view.

Review the Cuyahoga River pollution information on pages 23 in the Contamination and Pollution section and on page 27 in the Think About It box. Then assign learners to different roles, including the following:

- Factory Owner
- Factory Employee
- Children
- Naturalist
- Community Member not employed at the factory
- City Council member
- Entrepreneurs wanting to bring in new businesses
- Community elders
- People living downstream

More than one learner can represent the same role, and you and the class can identify other roles as well. If you have a large class, you may ask students representing the same role to appoint one spokesperson, since each person or role addressing the City Council should speak for no more than 3 minutes.

Activity Six

Pollution, Economics, and Society: Cleaning Up a Polluted River

Activity

Day 1

In this activity, your class will take part in a mock City Council meeting at which different interests try to balance the need for a healthy economy, community, and ecosystem. Use the following information as the basis for your discussion.

Mock City Council Meeting Scenario

The city of Centerburg is home to a few hundred thousand people, several factories, and a close-knit community. Most of the city's residents work directly for the factories or work for companies that supply the factories with materials, energy, transportation, or other support. Some people work in services like doctors' offices, movie theaters, restaurants, and schools. A river runs through the city. In the past, the river has been used for fishing and recreation; on the outskirts of town, wildlife like cougars, foxes, and coyotes could often be seen near the water. Over the past 20 years, however, pollution from the city's factories has become severe. People no longer fish along the river: fish are rarely seen, and the water is so polluted that people would not want to eat the fish that live in the river. Centerburg has had to build a pipeline to bring drinking water to the city from far upstream, away from the factories. Several other industrialized cities are located upstream and downstream from Centerburg. There are currently no laws limiting the amount of pollution that can be released into the river.

1. **Decide on a discussion question for the mock City Council meeting.** As a class, decide on the specific question that will address the need to balance the community's need for jobs, a strong community, and a healthy environment.

2. **Brainstorm a worldview and a position on the discussion question for the role you are representing.** Once you have been given your role, spend a few minutes brainstorming the worldview – knowledge, capabilities and desires, values, and behavior – of the person you are portraying. Note that any role can have a sustainability worldview or another worldview. Note also that many people would value a strong economy and a healthy economy. The challenge is setting priorities when these values seem to conflict, or finding ways to satisfy both values.

Also develop a position for your role on the discussion question: What solution do they recommend? Why? Are there solutions that others might suggest that your role would not support? Why not?

You may work alone or with other students who are representing the same role. Make some notes about key points you would like to make in a discussion with the City Council and other community members about how to balance jobs and prosperity, community well-being, and a healthy environment. Each person – or role, if your class is large -- will have no more than three minutes to address the City Council. Consider the following questions and ideas; some of these ideas will be background information you can use to decide what you would like to say to the City Council.

a. **Knowledge:**

i. What do you know about jobs, wealth, and the economy?

ii. What do you know about the health and ecological effects of pollution, impacts on other species, and impacts on future generations?

iii. What do you know about what makes your community strong and resilient – able to continue to function when conditions change?

b. **Capabilities:**

i. What do you like and dislike?

ii. What do you want?

iii. What are your attitudes about work, community, the natural world, and money?

iv. What are your intentions?

v. What are you capable of doing or willing to do?

c. **Values:**

i. What are the values of people with each worldview regarding their community, the economy, and the environment?

ii. How do people with each worldview value people of future generations and other species?

iii. How do people with each worldview value human wants and needs?

iv. How do people with each worldview consider the perspectives of people and other species who are not able to take part in making decisions that affect the commons – shared resources like water and air?

v. How do people balance econimic, social. and environmental concerns?

d. **Behavior:**

i. What kinds of actions might people with each worldview take?

ii. Why do people sometimes behave in ways that seem to contradict their worldview?

iii. What kind of behavior changes could help satisfy the need for both a healthy economy and a healthy environment?

e. Consider economic benefits, like disposable income and wealth generation.

f. Consider non-economic benefits, like stronger interconnections, nature connection, and well-being.

g. Where do security, status, well-being, and enjoyment come from in your worldview?

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Field Book

Day 1

1. **Nature Journal:** Notice sources of water that wild animals – including birds, insects, small mammals, and other animals – could use. How easy or difficult would it be for wild animals to find water in your community? If you can't see any sources of water these wild creatures could use, where do you think they find water?

2. Write responses to **Think About It** boxes on pages 25 and 27.

Activity

Day 2

1. **Hold a mock City Council meeting.**

    a. **City Council members will open the discussion with the chosen question.**

    b. **Community members will address the City Council, presenting their solutions.** Limit comments to three minutes.

    c. **City Council members will begin an open discussion, including both City Council members and community members.** City Council members will facilitate the discussion. All students can suggest solutions that represent the best interests of the community. Be sure to follow the following guidelines of constructive communication:

        i. Always speak courteously and constructively.

        ii. Respect different points of view, even if they are opposed to your point of view.

        iii. Listen to all other participants and allow them to finish before speaking.

        iv. Try to address as many different interests and concerns as possible in any solution.

        v. To get an idea of support for any promising solutions, City Council members can ask for a show of hands of people who could live with the proposed solution.

Field Book

Day 2

1. **Nature Journal:** How does rainfall change your local environment? If it is raining this week, notice the changes in light, plant life, buildings, the air, and activity of any wild animals before, during, and after a rain. Think about sounds, smells, sights, and feelings. If it is not raining this week, think back to the last rainfall you remember. Write or sketch about these changes in your Field Book.

2. Write responses to **Think About It** boxes on pages 28 and 29.

Discussion Questions

- Were you able to come to an agreement that satisfied everyone?
- What helped or hindered the class from coming to an agreement?
- What insights did you gain about balancing jobs, community needs, and a healthy environment?
- Is it possible for both a healthy economy and a healthy environment to exist? Why or why not?

City Council Meeting

Role Descriptions

Factory Owner(s):

- Proud of employing many people at living wages that allow them to support their families.
- Business taxes support local schools, fire and police departments, libraries, and parks.
- Concerned that costs of reducing pollution would increase the price of products, causing the factory to lose business and to lay off employees.

Factory Employee(s):

- Appreciates having job security and financial security.
- Appreciates strong community as shown by good relationships among factory employees and neighbors, many community activities like community theater, school sports teams, and well-respected local police and fire departments.

Children:

- Appreciate community activities like the good library and parks.
- Want good jobs when they grow up.
- Dislike being near the river, as it is unsightly and smelly.

Naturalist(s)

- Concerned that river water is unlivable for fish, otter, frogs, and other water life.
- Understands that all of nature is joined in a web of life; what is unhealthy for one species is unhealthy for others – including humans.
- Supports sustainability worldview.
- Believes the needs of other species are as important as those of humans.
- Has the following description of the polluted river, originally written to describe the Cuyahoga River:

> Large quantities of black heavy oil floating in slicks, sometimes several inches thick, are observed frequently. Debris and trash are commonly caught up in these slicks forming an unsightly floating mess. The discharge of cooling water increases the temperature by 10 to 15°F [5.6 to 8.3°C]. The velocity is negligible, and sludge accumulates on the bottom. Animal life does not exist. Only the algae *Oscillatoria* grows along the piers above the water line. The color changes from gray-brown to rusty brown as the river proceeds downstream. Transparency is less than 0.5 feet [0.15 m] in this reach. This entire reach is grossly polluted.[132a]

City Council Meeting

Role Descriptions

Community Member(s) Not Employed at the Factory:

- Appreciates the financial strength that supports the community, even those who don't work directly at the factory.
- May have personal experience fishing, swimming, or otherwise enjoying the river.
- May have a variety of priorities for the community, their own businesses, their families, or the natural environment.

Entrepreneur(s):

- Wants to make the riverfront an entertainment district with shops, restaurants, a conference center, a bicycle path, and a boardwalk.
- Wants the river cleaned up.
- Wants to provide jobs and a new source of income.
- Wants to draw tourists and business visitors to the city.

City Council member(s):

- Wants to make sure that the city can provide jobs for everyone over the many years to come.
- Wants to make sure that the city is attractive for visitors and tourism.
- Wants to make sure the city can provide healthy drinking water to its residents.
- Wants to make sure the city can continue to provide benefits like good schools, parks, libraries, and fire and police services.
- Is responsible for developing new laws, like those that might be needed to control water pollution.

Community elder(s):

- Remembers fishing and playing in and along the river as children.
- Remembers the river before it was polluted.
- Believes a clean river adds to the community's strength by giving beauty, nature connection, recreation, and enjoyment.
- Considers the needs of future generations.

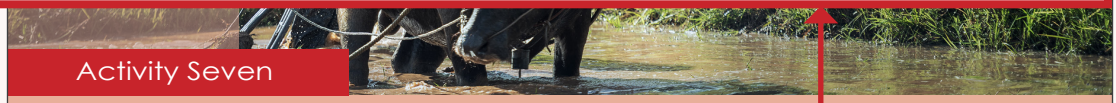
Review sustainability tools with the learners, including:

- Big Ideas of Sustainability
- Earth Charter Principles
- The Sustainable Decision Questionnaire

Introduce the idea of "wicked problems"– issues that may:

- have no clear solution
- include conditions that change frequently
- consist of related smaller problems that must be solved before the larger problem can be resolved
- involve people or groups with competing or conflicting interests or needs

Perfect solutions often are not possible for wicked problems; instead, we try to find solutions that improve the situation without necessarily solving it. In these situations, we often need to rely on judgment and wisdom at least as much as – or more than – factual knowledge. Their food and water choices may fall into the category of wicked problems.



Activity Seven

Making Sustainable Decisions

Activity

1. **Review your Food Diary from Activity Two and your Watershed Nested Systems diagram from Activity 5.**
2. **Examine your food and water use using the Sustainable Decision Questionnaire on pages 38-39.** Write answers to each question under the Sustainability Big Ideas and Earth Charter Principles Sections.
3. **Plan for change.** Based on your answers in Step 2 above, identify three to five ways you can make your food and water use more sustainable.
4. **Reflections:**
   a. **Write a paragraph reflecting on your insights about how sustainable your food and water choices are.** What are your most sustainable and least sustainable habits? Were you surprised to find that your habits are more or less sustainable than you might have expected? How do you feel about the Big Idea of Universal Responsibility – taking responsibility for your actions and their impacts on other living things?
   b. **Write a paragraph** answering the questions, "Are food and water use issues wicked problems? Why or why not?"

Field Book

1. **Nature Journal:** Do you use local rainfall for anything? If so, what? If not, why not? Do you rely on rainfall from another place for your water needs?
2. Write a response to the **Think About It** box on page 34.

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Summary

Learners will examine their food and water use using Big Ideas of Sustainability and Earth Charter Principles, as described in the Sustainable Decision Questionnaire on pages 38-39.

Time Required

- Two 50-minute class periods

Reading Prior to Activity

- Review pages 37-39

Key Concepts

- Big Ideas of Sustainability
- Earth Charter Principles
- Decision-making using sustainability tools

Objectives

- To use sustainability tools to develop solutions for real-world problems.

Inquiry/Critical Thinking Questions

- How can Big Ideas of Sustainability and Earth Charter principles be applied to real-world situations?

Discussion Questions

- What food and water habits did the students identify that were most and least sustainable?
- What are the most common sustainable and unsustainable habits among the students?
- Are food and water use issues wicked problems? Why or why not?
- What might make it hard to make the changes they are considering? How can these obstacles be overcome?
- How can the class support one another in making change?

What changes would they like to make?

Extension

- Let the class know that you will follow up with them in two weeks and again in one month on their plans for change. Encourage them to support each other in making lasting change. Also, encourage them to share their changes along with the reasoning behind their choices with family members and friends.

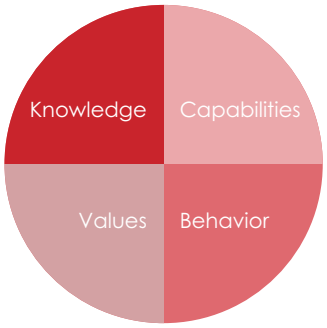
Activity Eight

Unit Reflections, Self-Assessment, and Commitments

Activity

In your Field Book, respond to the following questions and prompts:

1. **Write one paragraph in response to each of the unit's essential questions:**
   a. How is my body connected to nature through food and water?
   b. How are food and water issues related to each other?
   c. How can food and water be produced and shared sustainably, now and into the future?
   d. Where do my food and water come from?
2. **How can you use your understanding** of food and water sustainability in your life, at school, at home, or in your community? With whom can you share this knowledge?
3. **A sustainability worldview is based on knowledge, capabilities, values, and behavior. Think about how your worldview has changed** through what you have learned about food and water. Make a circle and divide it into quarters. Write one of the elements of a sustainability worldview in each quarter. Note any changes that have taken place in these areas; use arrows to show interconnections between the four quarters. Use colors.



MODULE THREE 89

Summary

Students examine next steps they would like to take and reflect on their learning.

Time Required

- One 50-minute period

Reading Prior to Assignment

- Review pages 1-40
- Review Field Book work

Key Concepts

- Food and Water Sustainability
- Big Ideas of Sustainability
- Earth Charter Principles

Objectives

- To reflect on learning and changes in worldview.
- To transfer learning outside of class.

Inquiry/Critical Thinking Questions

- How is my body connected to nature through food and water?
- How are food and water issues related to each other?
- How can food and water be produced and shared sustainably, now and into the future?
- Where do my food and water come from?

Materials

- Colored pencils, optional

4. **Look back at the Questions page in your Field Book.** Are there unanswered questions? How can you get them answered? What else would you like to know about sharing the planet with nature in the future?

5. **How have the daily nature connection activities affected you?**

6. **What parts of the Food and Water: Necessities of Life unit represented your best work?** What would you like to do differently?

7. **Review the text sections and your own work that suggest possible actions along with:**

    a. Pathways to Progress on pages 19-20.

    b. Pathways to Progress and What You Can Do on pages 35-36.

    c. Your work on Activity Seven, Sustainable Decision-Making.

    What, if any, actions would you like to take to support food and water sustainability? Write down concrete action steps, goals, and timing for any commitments you would like to make. What might make it difficult for you to take these steps? How can you overcome these obstacles?

Field Book

1. **Nature Journal:** Think about a time you were thirsty. What did thirst feel like in your body? How often are you thirsty? How easy or difficult is it for you to satisfy your thirst? Think about other people who live in places with water scarcity. Reflect on the basic biological need for water that all living things share.

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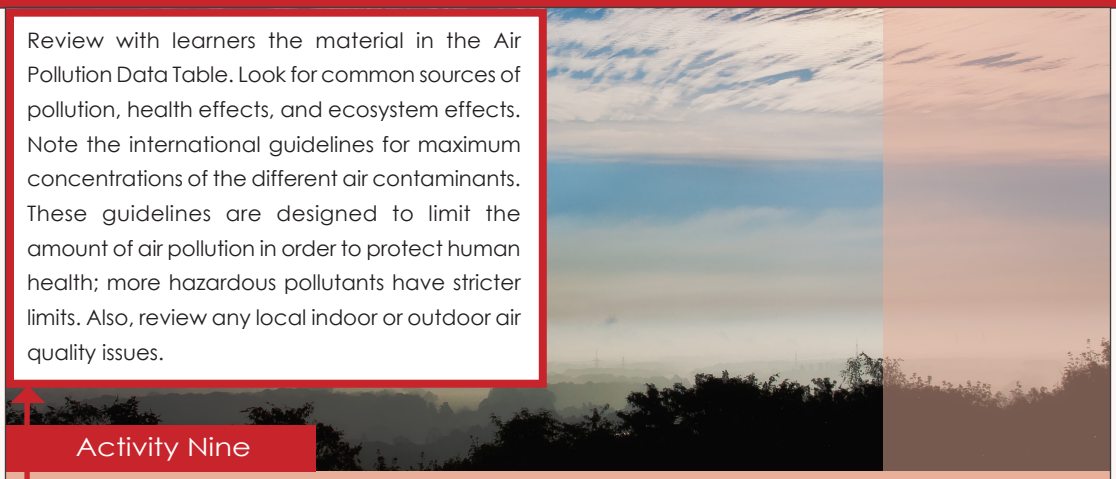
Review with learners the material in the Air Pollution Data Table. Look for common sources of pollution, health effects, and ecosystem effects. Note the international guidelines for maximum concentrations of the different air contaminants. These guidelines are designed to limit the amount of air pollution in order to protect human health; more hazardous pollutants have stricter limits. Also, review any local indoor or outdoor air quality issues.



Activity Nine

Air Pollution Infographic

Activity

Divide the class into groups to design their infographics.

Day 1

In this activity, you will create an air pollution infographic. The purpose of the infographic will be to explain the sources and impacts of air pollution; if you have local air pollution data, the infographics should also point out the most significant local air contaminants.

1. **Create an infographic.** Working with your group, use the following steps to design and make your infographic.[133]

   a. **Study your data.** Become familiar with the information presented in the Air Pollution Data Table below, as well as information provided in the text. Add any additional information you and your group know about local air quality issues. Decide which information is most important to present. Notice any links, overlaps, or trends in the information that could make your infographic more powerful. Include sustainability ideas if and as they fit with your message. Try to select data that will be clear, accurate, informative, and useful.

   b. **Come up with a visual metaphor** to use to present your data. To come up with ideas, try the following prompts:

      i. Air pollution in our area is like a …

      ii. Air pollution in our area mostly comes from…

      iii. Air pollution in our area mostly affects…

      iv. Our hope for clean air is …

      Use this metaphor as the foundation for your design.

   c. **Design your infographic.** Use different types of fonts, colors, sizes, and shapes to help the viewer understand your message. Sketch out a rough draft before you start your final version.

   d. **Make your infographic.**

Summary

Learners will deepen their understanding of air pollutants, sources of pollution, health effects, and links between pollutants by designing an air pollution infographic.

Time Required

- Two 50-minute class periods

Reading Prior to Assignment

- Pages 42-51

Key Concepts

- Air pollution is caused by the products humans use, the burning of fossil fuels, farming practices, and other sources.
- Air pollution harms human and ecosystem health.
- Air pollution generally harms the respiratory and cardiovascular systems.
- Most air pollution is caused by a limited number of human activities.

Objectives

- To know the major types of air contaminants, their sources, and their health and ecological effects.

If possible, research local levels of the pollutants shown on the attached Air Pollution Data Table.

If you teach in the United States, you can find data on the Environmental Protection Agency's Air Data page at:

https://www.epa.gov/outdoor-air-quality-data

Click on the Concentration Plot link under "Visualize Data." You can obtain charts for different pollutants by city or county. Once you enter your data selections and click on the "Plot Data" button, you will see data charts. You can present the charts to learners and have them estimate a best-fit annual average pollutant concentration.

If you scroll down below the charts, you will see a data link that allows you to download the chart data in a spreadsheet format. In the spreadsheet, you can calculate an annual average of the air contaminant's concentration levels found in Column H. Be aware that the data link is only active for ten minutes. You may also be able to find data from a state or regional air quality agency.

If you teach in another country, you may able to find similar air pollution data from a national, provincial, or local air agency.

Inquiry/Critical Thinking Questions

- What are common air pollutants?
- What human activities cause air pollution?
- How does air pollution affect human health and ecosystems?

Materials

- Blank paper or poster board
- Colored pencils
- Markers
- Colored paper
- Drawing tools, including compasses, triangles, and rulers
- Tape or glue
- Scissors
- Digital technology and graphics software

Field Book

Day 1

1. **Set up new sections in your Field Book for Unit 2, Air and Energy.**
    a. Set up a new Learning Links page with the unit's essential questions in the center:
        i. How do air and energy connect to nature?
        ii. What sustainable clean air and energy choices can I make?

    Note any thoughts you have about these questions as the unit begins.

    b. Set up a new Questions page.
2. **Nature Journal:** Take a couple of deep breaths. Spend a moment being aware of your breath. Expand your awareness to include people near you who are also breathing. Consider people in your town and your state, breathing just as you are. Think about other living things near and far, sharing the air. Imagine all the movement, growth, and metabolism that is being powered as oxygen is inhaled. Visualize animals breathing in oxygen and breathing out carbon dioxide, while plants and trees are breathing in carbon dioxide and breathing out oxygen. Imagine the blanket of air that covers the planet. Think about this global exchange that supports such a wide diversity of life. Picture it in your mind. Be aware of your body and feel the common breath that supports all of life.

    In the margins of your Field Book, make some notes or sketches describing your experience and thoughts about this layer of life-giving air and the ways it supports life across the planet.
3. Write responses to the **Think About It** boxes on pages 42 and 47.

Activity

Day 2

1. **Complete your infographic.**
2. **Post infographics around the classroom.** Hold an art walk to give students time to view all the infographics.

Field Book

Day 2

1. **Nature Journal:** Notice the atmosphere as part of weather, carrying wind, rain, snow, and humidity. Sketch or write about these weather patterns locally and globally.
2. Write responses to the **Think About It** boxes on pages 50 and 52.

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Air Pollution Data Table[134]

Pollutant	Sources	Health Effects	Ecosystem Effects	International Guidelines to Air Contaminant Maximum Concentrations[135] (micrograms/meter cubed or parts per million)
Nitrogen Dioxide (NO_2)	Burning fossil fuels in cars, trucks, buses, industry, and power plants.	Irritates air passages, make asthma worse or contributes to development of asthma, makes it easier to get respiratory infections. Also, NO_2 can lead to the formation of $PM_{2.5}$. NO_2 is toxic at concentrations over 200 ug/m^3	Contributes to the formation of acid rain, which can harm ecosystems; makes the air hazy; contributes to water pollution when NO_2 particles fall into waterways.	40 ug/m^3 annual mean (40 ppb) 200 ug/m^3 1-hour mean (200 ppb)
Volatile Organic Compounds (VOCs)	Carbon-based chemicals that evaporate easily, like paints, cleaning products, arts and crafts supplies like glues and markers, cosmetics, building materials, furniture, gasoline vapors, and motor vehicle exhaust.	Irritation of eyes, nose, and throat; headaches; nausea, damage to liver, kidneys, and central nervous system. Some VOCs are suspected of causing – or are known to cause – cancer. Others have no known health effects.	VOCs contribute to formation of ground-level ozone and $PM_{2.5}$	Not applicable
Ozone (O_3)	NO_2 + VOCs + sunlight.	Lung disease, asthma, shortness of breath.	Slower tree growth, disease, damage from insects, loss of species diversity.	100 ug/m^3 8-hour mean (100 ppb)
Sulfur Dioxide (SO_2)	The major source is burning coal and oil in power plants and industries, as well as in heavy equipment like trains and ships. SO_2 is also produced when some mineral ores are processed.	Damage to the respiratory system, difficulty breathing, eye irritation, and aggravation of asthma and bronchitis. SO_2 can lead to the formation of $PM_{2.5}$	Decrease plant growth, damage foliage, make the air hazy, and contribute to the formation of acid rain.	20 ug/m^3 24-hour mean (200 ppb) 500 ug/m^3 10-minute mean (500 ppb)
Greenhouse Gases (GHGs), including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O)	Burning fossil fuels to produce electricity, transportation, and heat; deforestation, and agriculture, including cattle and burning crop waste.	Not applicable	Warming of Earth's climate, melting of polar ice caps, making oceans more acidic, reduced biodiversity and changing wildlife habitats.	Not applicable
Particulates < 2.5 microns in diameter ($PM_{2.5}$)	NO_2, SO_2, burning biomass, dust, smoke from fires, burning fossil fuels.	These very small particles can move deeply into the lungs and even into the bloodstream. Long-term exposure can contribute to heart and respiratory diseases and lung cancer. $PM_{2.5}$ can contribute to early death in people with heart or lung disease, aggravate asthma, decrease lung function, irritate airways, and cause nonfatal heart attacks.	Create haze in the air, make lakes and rivers acidic when particulates land on the water surfaces, reduce soil nutrients, reduce ecosystem diversity, and damage forests and farm crops.	10 ug/m^3 annual average (10 ppb) 25 ug/m^3 24-hour average (25 ppb)

Extension

After the class has viewed one another's work, post the infographics in the school library, cafeteria, hallways, or other school location.

Summary

Learners participate in a case study to explore the links between social, economic, and environmental issues, as well as environmental externalities – costs paid by people or species other than those benefitting from the product or action in question.

Time Required

- Two 50-minute class periods

Reading Prior to Activity

- Pages 50-54
- Activity 10 Case Study Background Paper, page 96

Key Concepts

- Environmental externalities
- Costs and benefits of air pollution controls and regulations
- Systems thinking

Activity Ten

Pollution, Economics, and Society, Part 2
Case Study: Air Quality in a Developing Country

Review with the class the social, economic, and environmental impacts of air quality on page 53. Review in particular the idea of environmental externalities. You may want to have the class work in small groups or pairs for Activity Steps 1 and/or 2 below.

Activity

Day 1

1. **In your Field Book, make a Big Ideas of Sustainability table.** Set up the table with two columns, one titled "Big Ideas of Sustainability" and the other "Case Study Examples." Make a row for each of the Big Ideas of Sustainability described on page 4. List as many examples from the Case Study of each Big Idea as you can.

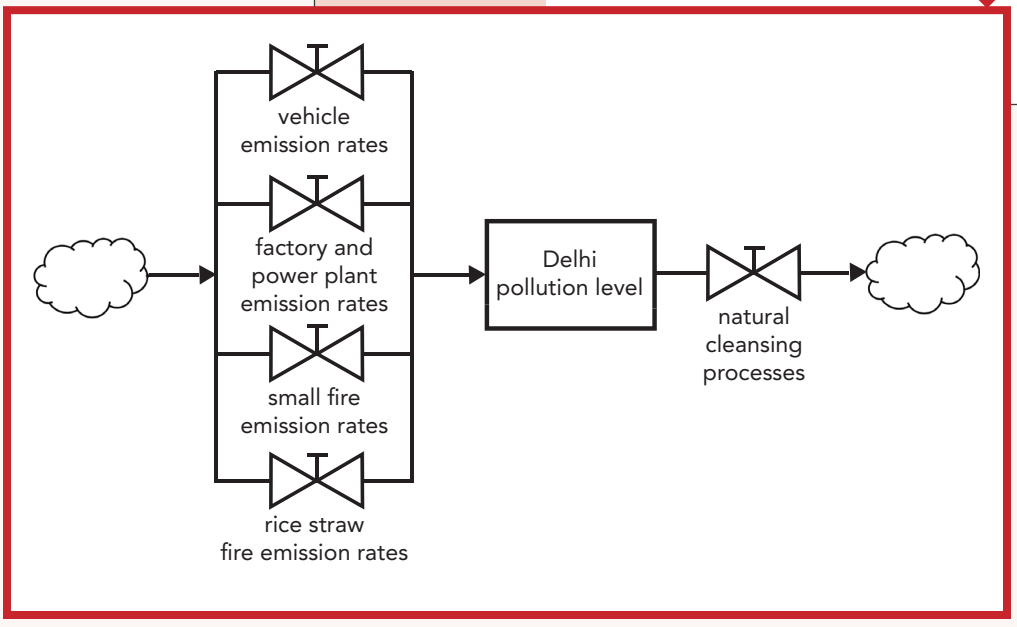
See the Case Study Big Ideas of Sustainability Table below for sample responses.

2. **In your Field Book, draw a stock and flow diagram.** Recall that stocks are amounts; they can be thought of as the amount of water in a sink. Flows are actions or changes that affect the amount of the stock, like a faucet can be opened or closed to increase or decrease the amount of water flowing into a sink. Similarly, a drain can be opened or closed to increase or decrease the flow of water out of a sink. We use cloud symbols to represent parts of a system that we do not need to consider at this time.

   a. **Diagram 1 – Air Pollution in Delhi:** Show air pollution in Delhi as the primary stock. Show the various sources of pollution and natural cleansing processes as flows in or out of the stock. Use the diagrams on pages 28 and 52 as examples.

   b. **Diagram 2 – Farm-based Pollution:** Create a stock and flow diagram showing the air pollution created at farms and the solutions described in the Case Study Background Paper.

   c. **Write a paragraph** about what these diagrams show regarding pollution in the city and on farms. How can the diagrams help you understand these two situations?



The diagrams show the relationships between the different elements in the system. They show which factors can be changed to influence one another.

Field Book

Day 1

1. **Nature Journal:** What are the main ways nature cleanses the atmosphere in your area? Look back at page 45 if you need to review those processes. Draw or sketch these processes at work in your community.
2. Write responses to the **Think About It** boxes on pages 54 and 55.

Activity

Day 2

1. **Write one-paragraph responses to each of the following questions:**
    a. **How would you recommend reducing pollution from farms near Delhi?** What combination of laws, incentives, fines, financial help, social change, technology development, or other measures would you set up to reduce these emissions? Explain why your solution would work.
    b. **Who should pay for the cost of any pollution reduction at the farms:** farmers, city residents, other creators of pollution like businesses or truck drivers, foreign buyers of goods made in Delhi factories, or others? Explain your reasoning.
    c. **Who should pay for the costs of health impacts and medical care for people whose health is affected by pollution:** farmers, city residents, other creators of pollution like businesses or truck drivers, foreign buyers of goods made in Delhi factories, or others? Explain your reasoning.
    d. **What are environmental externalities in this situation?** What is your evidence?

Field Book

Day 2

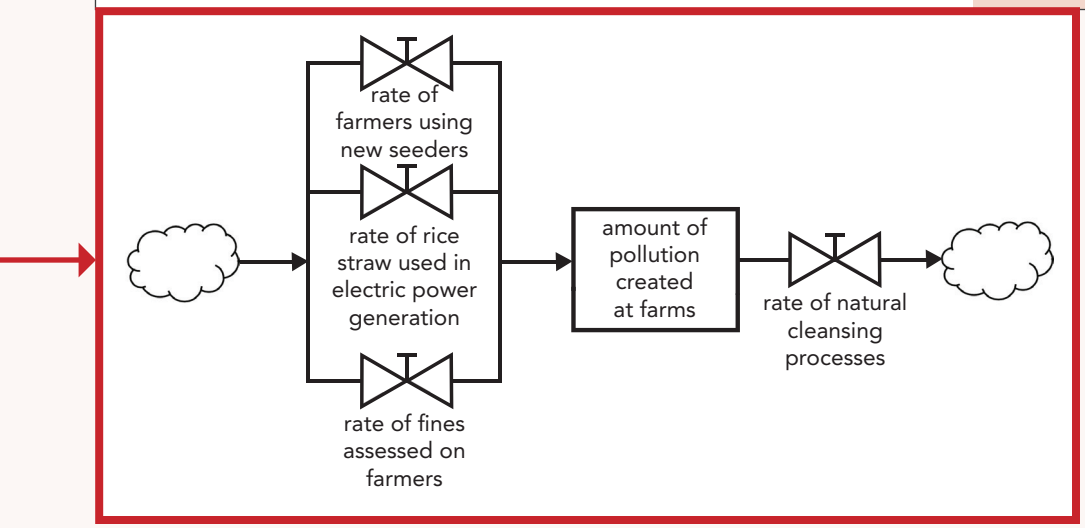
1. **Nature Journal:** Take some deep breaths. Notice how slowly or rapidly you are breathing. Think about a time when you were breathing hard – maybe you were running, exercising, or playing hard. Visualize oxygen as the fuel your body uses. Think of all the energy released because of the oxygen you breathe. Imagine the reactions throughout your body where oxygen is burning carbohydrates, releasing energy for your body to use. Imagine each of those reactions as a brief spark. Draw yourself and the flow of oxygen through your body.
2. Write responses to the **Think About It** boxes on pages 57 and 58.

Objectives

- To look for solutions that balance social, economic, and environmental needs.
- To use systems thinking and other sustainability tools to solve a real-world problem.

Inquiry/Critical Thinking Questions

- How are costs and benefits of polluting activities spread across society?
- How do the costs of air quality regulations compare with the benefits of regulations?



Discussion Questions

- Who should pay the financial costs of air pollution impacts?
- Who should pay the costs of air pollution control costs?
- How does society make decisions about who pays these financial costs?
- Are the costs of air quality regulations worth the benefits? Why or why not?

Background Paper:

Air Quality in a Developing Country

Like many other cities in developing countries, Delhi, India has experienced rapid growth. Its population doubled from 1990 to 2014, reaching 25 million people.[136] Many people commute in personal cars to jobs in the city from the surrounding suburbs. Trucks are used extensively to bring goods into the city. Manufacturing has increased as well. The value of industrial products produced there – mostly complex manufactured goods like automobiles, petroleum products, and industrial machines – tripled from 2005 to 2015.[137]

Along with population and economic growth, air pollution has also increased: Delhi has become one of the most polluted cities in the world. Peak pollution levels are as much as 16 times above India's pollution limits; breathing this polluted air for long periods of time would affect the lungs as much as smoking two packs of cigarettes a day.[138] Health experts estimate that air pollution costs the city and its residents $6.4 billion a year in work absences, medical expenses, and project delays. The high levels of fine particulates in the air cause 120,000 emergency room visits and shorten lives for almost 50,000 people per year.[139]

Major sources of air pollution include trucks, factories, electric power plants, and small fires used for cooking and keeping warm. To try to reduce pollution, the city has taken steps like eliminating the use of private cars for two-week periods, requiring all new power plants to be built outside the city, requiring use of fuels that emit less pollution, and phasing out older vehicles.

Another source outside the city limits also contributes to Delhi's severe pollution: hundreds of thousands of farmers burn the straw left behind after their rice crops are harvested. This traditional practice not only clears the fields for planting wheat, the next season's crop, but burning the crop residue also helps reduce plant diseases, controls weeds, increases plant productivity, and reduces water needs. However, burning the straw contributes about one- quarter of the city's smog during winter months. During the burn season, the level of small particulates – $PM_{2.5}$ – can reach four to ten times India's legal limit.

One alternative is a tractor-mounted seeder that plants wheat seeds with the rice straw left in place. Leaving the straw in place follows one of nature's patterns: recycling of material. As the straw breaks down, it adds organic matter to the soil, reducing the need for fertilizers and irrigation. Farmers who have used the seeder have found that their fields produced more wheat and rice.

Most farmers would be happy to use the new seeder. They understand the impact the smoke from their fires has on the city, and their families' health is affected by the smoke as well. But with a price tag of $1,900, a new seeder costs about the same amount of money as a typical farmer earns from a year's rice harvest. A government program is in place to pay half the cost of the seeders, but the program does not have enough funding to help many of the farmers. Getting seeders to each farmer would cost $1.5 billion.[140] However, since the planting season lasts for four weeks, four farmers could share one seeder. And while the up-front cost is high, the seeders can be assumed to last for about 20 years.

Another possible solution is to use the waste straw as a fuel for power plants – with emission controls. The city has built seven of these plants and has plans to build six more. However, even with all the power plants up and running, only 1.5 million of the 20 million tons of straw produced each year would be needed. And getting the straw to the power plants costs the farmers much more than burning it in place costs.[141]

A third solution is to fine the farmers for burning the straw. Legally, the state can charge farmers fines of $40 to $225 for the practice, although fines are rarely applied.[142]

Case Study

Big Ideas of Sustainability Table

Big Ideas of Sustainability	Case Study Examples
Nature Connection	All living things on land need clean air to breathe.
Respect for Limits	The atmosphere has a limited ability to clean up pollution.
Universal Responsibilities	Many people, businesses, and institutions are responsible for Delhi's air quality problems. Each responsible party should take action to reduce their contribution to the city's pollution.
Equity and Justice	The individuals who bear the health impacts and associated costs of air pollution may or may not be the people who receive the benefits of the practices that cause pollution.
Health and Resiliency	Air pollution severely impacts health in Delhi and on farms where crop residues are burned.
Interconnectedness	Farmers, truck drivers, residents driving personal cars, industries, and government entities are all interconnected in their contributions to air pollution. The atmosphere across the state – and the world – is interconnected, allowing pollution to move from one area to another.
Local to Global	Delhi is part of the growing global economy. The city's rapid growth has resulted in its pollution problem. Costs of pollution control and health costs may affect the price of goods made in Delhi and sold in other parts of the world. Countries may export manufacturing to countries with less strict environmental regulations in order to reduce costs.
Peace and Collaboration	Businesses, residents, government, farmers, and international businesses and buyers need to work together to ensure a healthy life for Delhi residents.

Summary

Learners will use the traditional sustainability tool, the Iceberg Model, to understand and analyze a real-world situation.

Time Required

- One 50-minute class period

Reading Prior to Activity

- Pages 55-56

Key Concepts

- The Iceberg Model
- Using models for analysis

Objectives

- To understand and analyze a sustainability issue using the iceberg model.

Inquiry/Critical Thinking Questions

- What underlying issues might be causing observable conditions?
- How can we use a model to guide thinking and analysis?
- When do we use a particular model?
- What are the limits of the model?

In this activity, the class will use the Iceberg Model to look more deeply at the Delhi air pollution case study in Activity 10. Alternatively, you can choose a local air quality issue to examine or have the class choose an air quality issue with which they are familiar.

Events include routine high and increasing levels of air pollution in Delhi and health effects on the population. Actions have been taken by local government to improve air quality, but these actions have not kept up with increasing pollution and growth.

The pattern here is one of rapid growth in population, vehicle use, and industry, with laws and requirements coming into effect after pollution and growth have increased. Although good programs are in place – new power plants designed to use crop waste, funding programs to help farmers buy new seeders, and even fines if needed – it seems to be hard for these programs to keep up with the city's rapid growth.

The structure is the long-time practice of burning agricultural waste on farms without restrictions. This farming practice conflicted with another social structure: the overall social trend of people moving into cities from outlying areas. As the population of the nearby city increased, pollution from other sources entered the atmosphere. The added pollution overwhelmed the natural system's ability to clean the atmosphere. The habits of drivers, factory owners, power plant operators, homeowners and small businesses operating dirty electricity generators, and others to emit pollutants without concern for the overall quality of the atmosphere also contributed. And while there have been attempts to change laws – for example, by setting up funding to buy new seeders and initiating fines – the traditional structure of burning waste has been difficult to change.

Knowledge included the understanding that farms and other pollution sources were affecting the health of city and farm residents. We do not know the capabilities, preferences, or values of the people involved. We do know that, in some way, the farmers were not able to buy enough new seeders to reduce pollution. To address the problem thoroughly, we would need to learn more about the knowledge, capabilities, preferences, values, and behaviors of the people and institutions involved.

Activity Eleven

Using the Iceberg Model

Activity

1. **Sketch an iceberg diagram in your Field Book,** using the image on page 55 as an example. Leave plenty of room for notes inside or around your iceberg.
2. **Identify events** described in the Activity 10 Case Study Background Paper. Note them on or next to the "events" area on your iceberg diagram.
3. **Identify patterns** linking the events you have identified. Write them down on or next to the "patterns" area on your diagram.
4. **Identify structures** that cause the pattern. Structures can be laws, rules, habits, or routine practices that govern the situation. Write the structures on your diagram.
5. **Identify worldviews** that determine the structures. What knowledge, capabilities and preferences, values, and behaviors have put the structures in place? Note them on your diagram.
6. **Write a paragraph or draw a mind map, stock and flow diagram, or causal loop diagram** representing some ways that change could be made in this situation. Recall that the Iceberg Model calls for understanding the deep levels of the iceberg because – like deep ocean currents can move an iceberg – society can affect change at this level. What societal changes at the level of worldview or structure could change the patterns identified above?

Field Book

1. **Nature Journal:** Try to be aware of air today. Notice how it carries sound and smell, how you see through it, how it feels against your skin. Reflect on how fundamental this unseen, unnoticed part of Earth's systems is always there, supporting life.

Discussion Questions

- When would this model be helpful?
- What are its limits?

Summary

Learners will create a mind map showing the inter-connections between air, water, and energy.

Time Required

- One 50-minute class period

Reading Prior to Activity

- Pages 57-67

Key Concepts

- Air, water, and energy are interconnected

Objectives

- To visually link planetary air and water systems with human energy systems.

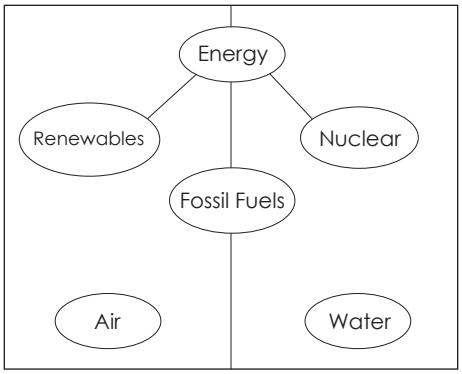
Inquiry/Critical Thinking Questions

- How are air, water, and energy interconnected?
- Which energy sources have the largest and smallest impacts on air and water?
- How can the availability and quality of air and water affect energy supply?

Materials

- Colored pencils, optional

A page set-up like the one below will allow students to visually see the different numbers and types of interconnections between the different energy sources, water, and energy.



Activity Twelve

Air, Water, and Energy Interconnections

Activity

1. **In your Field Book, create a mind map showing interconnections between air, water, and energy.** Use a full two-page spread. Set up three circles in the center of your pages: one for air, one for water, and one for energy. Use colored pencils if possible. Write small – there are a lot of interconnections! Consider the following interconnections:
   a. **Energy**
      i. Consider fossil fuel-based energy sources, renewables, and nuclear energy.
      ii. In what ways is water used to extract, refine, distribute, use, and dispose of waste products from energy sources? How do these processes affect water quality and supply
      iii. How do energy extraction, refining, distribution, use, and disposal of waste products affect air quality? How is air used in these processes?
   b. **Air**
      i. How are air quality, water quality, and water supply interconnected?
      ii. How can air or other atmospheric factors affect energy supply, use, and disposal of waste products?
   c. **Water**
      i. How is water quality related to air quality?
      ii. How are water quality and supply related to energy?

Field Book

3. **Nature Journal:** Sit near a window and feel the sunlight on your body. Enjoy it – even if it's wintertime. Notice how the sunlight makes you feel. Sketch images or designs in the margins of a page or two of your Field Book. You may just want to blend colors together to give the feel of sunlight today.
4. Write responses to the **Think About It** boxes on page 60.

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1. Air absorbs pollution from all aspects of fossil fuel use.
2. The atmosphere, weather, and water cycles are affected by greenhouse gas emissions from burning fossil fuels.
3. The atmosphere's natural cleansing processes remove air contaminants.

1. Wastewater from fossil fuel extraction often contains hydrocarbons. If this wastewater is stored in open tanks or collection ponds, the hydrocarbons may evaporate and cause air pollution.
2. Contaminated waterways may not support healthy ecosystems; lack of trees can affect local air quality.

1. In many regions, a large amount of energy is used to collect, clean, and distribute water.

Possible links include:

1. Water is used in extracting fossil fuels, especially in fracking. Wastewater is disposed of primarily underground.
2. Fossil fuel-powered and nuclear electric power generating stations use large amounts of water to create steam to run generators and to cool systems. This warm water is often released into oceans, causing temperature increases.
3. Underground pipelines used to transport fossil fuels can leak into water supplies.
4. Hydroelectric energy is produced by the flow of water.
5. Geothermal energy uses water to bring heat to Earth's surface.
6. Energy-related processes may discharge pollution into waterways.
7. Industrial processes to manufacture energy infrastructure, including solar cells and wind turbines as well as fossil fuel and nuclear infrastructure, may cause water pollution.
8. Cooling water used in nuclear power plants can become contaminated with radioactivity, which must be stored carefully for long periods of time so the radiation does not contaminate nearby water sources.

1. Air contaminants can fall onto, or be absorbed into, lakes, rivers, and streams.
2. Acidic air contaminants can create acid rain, which can affect water quality in lakes, streams, and rivers.
3. Air quality is impacted by fossil fuel energy used to deliver water supply.

1. Wind can be used to produce electricity.
2. Wind can disperse pollutants.
3. The oxygen in air is an essential part of the combustion process.
4. Renewables and nuclear energy do not produce local air pollution, although pollution is created in manufacturing equipment and other aspects of production.

Discussion Questions

- Which sources of energy have the most connections with air and water? Which ones have the least?
- From looking at your mind maps, which energy sources have the most sustainable interconnections with air and water?

Summary

Learners use sustainability tools and systems thinking to examine different views on the links between fossil fuel use and climate change.

Time Required

- One 50-minute class period

Reading Prior to Activity

- Pages 48-49, Climate Change
- Pages 59-61, Fossil Fuels
- Pages 63-67, Renewables and Conservation/ Efficiency

Key Concepts

- Interconnectedness
- Local to Global
- Universal Responsibility
- Climate Change
- Earth Charter Values
- Systems Thinking

Objectives

- To evaluate society's response to climate change using sustainability tools and systems thinking.

Inquiry/Critical Thinking Questions

- How can systems thinking tools help us address climate change?
- How is climate change seen through Earth Charter values?

Activity Thirteen

Making Societal Decisions: Fossil Fuel Use and Climate Change

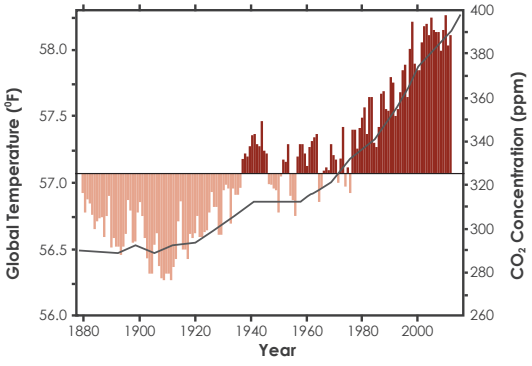
Background

The scientific process supports rigorous standards for scientific studies; public, published review of important studies; and ongoing research to validate or dispute scientific findings. Scientists rarely feel that their work leads to final, unquestionable answers. Instead, scientists usually talk about probabilities – the likelihood of certain outcomes.

For this reason, we cannot say that every question regarding climate science is resolved, once and for all. Scientists themselves continue to debate questions and search for better data and theories.

The leading group of scientists from around the world that reviews and analyzes climate research takes part in the Intergovernmental Panel on Climate Change (IPCC). Their recent work reviewed over 9,200 scientific studies on climate change and was carried out by over 1,000 experts.[143] Their review is the most comprehensive study of climate change science available. The IPCC concluded that "human influence on the climate system is clear... Warming of the climate system is unequivocal."[144]

Global Temperature and Carbon Dioxide in the Atmosphere[145]



Source: Globalchange.gov

One way we can tell that humans are affecting the climate is by comparing measured global temperatures with the amount of carbon dioxide in the atmosphere. As the graph shows, global temperatures have increased in parallel with increases in the amount of carbon dioxide in the atmosphere.

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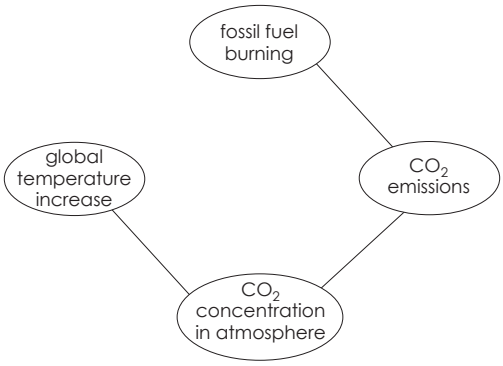
Components include:

a. Fossil fuel burning

b. CO_2 emissions

c. CO_2 concentration in atmosphere

d. Temperature increase



The components do not form a closed loop. A closed loop would mean that there is feedback through the system: changes in one component affect other components. The system above is linear, meaning that influences only flow in one direction. In this limited system, there is no way for information about global temperature increases to influence the amount of fossil fuel burning.

Activity

1. **Create a mind map** showing fossil fuel emissions and atmospheric temperature increases. Identify the components – or parts of the system – that you need to include, and decide which factors affect one another. For this mind map, only link components that directly affect one another. Use lines with arrows to show cause and effect.

   Can you form a closed loop linking the components and their effects on one another like we see in a causal loop diagram? What does a closed loop tell us about the relationship between the components?

2. **Add components that could close the loop.** In a closed loop, feedback – or information – flows in a complete cycle. Effects from change in one area flow around the entire loop. Draw a causal loop diagram including your original list of components and the added ones.

3. **Consider the disagreements that continue to affect public action on climate change.** The causal loop diagram shows two paths to affecting the amount of fossil fuel use: through voluntary citizen and business decision-making and through required government action. Both of these paths are based on scientific evidence. If the contribution of scientific evidence is limited for any reason, voluntary actions and public policy are likely to decline as well.

   Causal loop diagrams can help us understand social factors as well as physical factors. Let's use this tool to explore the components that can affect the ability of scientific evidence to influence behavior. List factors that can affect whether scientific evidence is available, understood, and acted upon.

   Create a second loop representing the factors that can support behavior based on scientific evidence. Sketch this diagram with the arrows going in the opposite direction than they went in your first diagram. You may want to use a different color to sketch this second diagram. Is this loop a balancing loop or a reinforcing loop?

4. **Combine the diagrams.** To see how the two loops can affect one another, combine them. Both loops include the "laws and citizen/business voluntary actions" component. Again, use a different color for the second loop if you like, so you can see the two loops more distinctly.

5. **Look for opportunities to make change.** One of the benefits of causal loop diagrams is making visible the system components, interconnections, and opportunities feedback.

Field Book

1. **Nature Journal:** If possible, take a short walk outside. Notice all the energy being spent by living organisms and manufactured objects alike. Does any of this energy come from sources other than the sun? Imagine sunlight powering everything around you. If all that sunlight were shining right now, how bright would it be? What can you draw that represents these images?

2. Write a response to the **Think About It** box on page 63.

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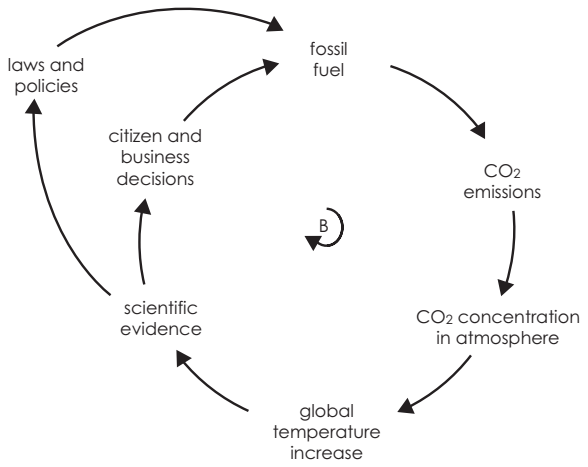
Possible added components include scientific studies, laws or public policies, and choices by consumers and businesses.

In this loop, scientific evidence drives development of laws and policies by government and decision-making by citizens and businesses. These decisions, laws, and policies can affect how much fossil fuel energy is used.



Factors include:

a. business, citizens, and/or government take actions to increase scientific knowledge (develop research departments, make donations, create grant programs)

b. these groups provide funding to conduct studies

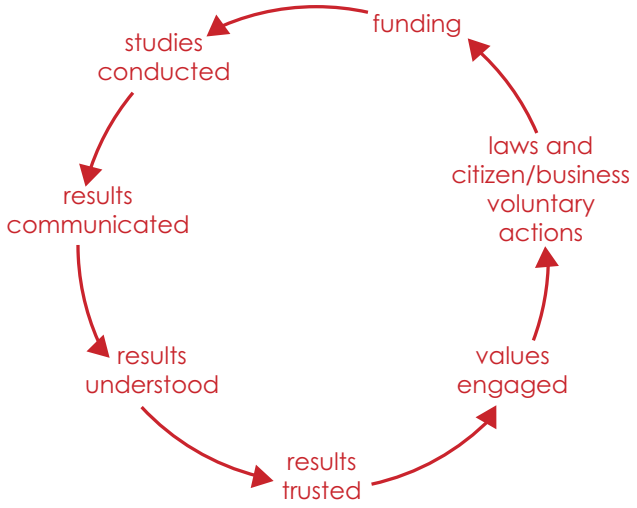
c. scientists conduct studies

d. news organizations and scientific organizations communicate results

e. citizens, government representatives, and business people understand the scientific results

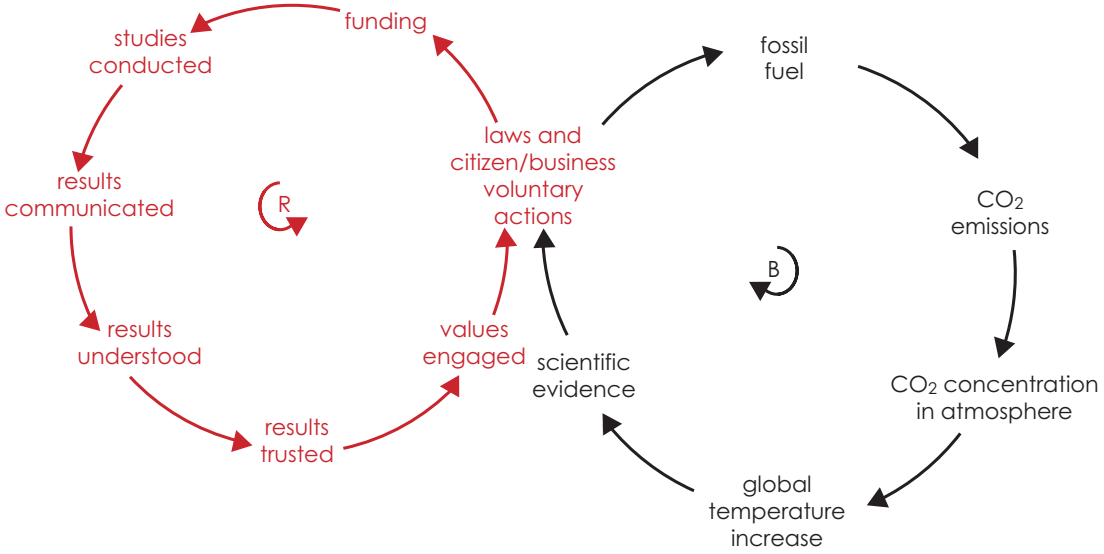
f. people trust the accuracy, relevance, completeness, and conclusions of studies

g. results support the values of decision-makers, including citizens, business people, and government leaders



Ideally, this loop should be a reinforcing one, with change being reinforced as the process travels around the loop. The results of scientific studies, after moving through the rest of the cycle, would influence development of laws and choices regarding fuel use. Citizens, businesses, and government would also base their views of earlier scientific studies on their decisions to contribute to further scientific studies.

However, it is possible that outside factors affect these components, so that results may not be communicated or understood, people may not trust the results, or the results may conflict with the values that drive people's decisions.



Discussion Questions

- What factors do you think are most likely to keep the existing fossil fuel-based energy system in place?
- Where on these two loops could the systems be changed to limit the contribution of fossil fuels to climate change?
- What Big Ideas of Sustainability tie in to fossil fuel use and climate change?
- What Earth Charter principles could guide societal and personal decisions about fossil fuel use?
- How should we make societal decisions when scientific information is incomplete, disputed, or not trusted?

Summary

Students will prepare a briefing paper promoting use of renewable energy, fossil fuels, or a combination of energy sources for their community.

Time Required

- One 50-minute class period

Reading Prior to Activity

- Pages 57-71

Key Concepts

- Fossil fuels
- Renewable energy

Objectives

- To explore the benefits and challenges of different energy sources.
- To prepare a persuasive piece promoting and supporting a position.

Inquiry/Critical Thinking Questions

- How do we get from today's energy sources to a fully sustainable energy system?

Optional: If you have Internet access and are located in the United States, you can research what energy sources generate the electricity used in your community. Visit the U.S. Environmental Protection Agency's Power Profiler at:

https://www.epa.gov/energy/power-profiler

Enter your zip code to find your local power sources. You can also compare your local mix of power sources with the national average. If your students have the technology, they can research this information themselves. Find air emissions from your home or school electricity use (if you have home or school monthly kilowatt-hour usage) and compare emissions to national averages.

Optional: If you have Internet access, you can review the renewable energy mix recommended for your region by The Solutions Project. For schools located in the United States, go to:

http://thesolutionsproject.org

and select your state. Outside the United States, go to:

http://thesolutionsproject.org/resource/139-country-100-infographics

Activity Fourteen

Renewable Energy, Fossil Fuels, or Both?

Introduction

Briefing papers are often prepared for decision-makers like government officials, business executives, or nonprofit leaders. In this activity, you will prepare a briefing paper for the audience of your choice, recommending which energy sources should be emphasized in your community in the near future (5 to 10 years) and in the longer term (15 to 50 years): fossil fuels, renewable energy (specify the types), nuclear energy, and/or conservation and efficiency. If you recommend changes, how quickly should these changes be made? How will they be paid for? Consider the following factors:

- **Environment:**
  - How will your recommendations affect the natural environment?
  - How can any negative impacts be reduced?
  - How will your recommendations affect other species?
- **Economy:**
  - Will your proposal support existing or new jobs?
  - Will new skills, products, or supports be needed?
  - If you recommend changes from the current system, how will people who work in the current system be helped through the transition to the new system?
  - Will electricity under your proposal be more or less expensive than electricity is today, in the short- and long-term?
- **Society:**
  - Will your proposal provide long-term energy security?
  - Is your energy source available locally?
  - How will your recommendations affect future generations?

Discussion Questions

- Is there an energy approach that represents most or all of the students?
- What are the strengths and weaknesses of any consensus approach?
- What are key issues that prevent a consensus?
- How could those issues be overcome?

Extension

- Check Air Emissions from Power Use at the U.S. Environmental Protection Agency's Power Profiler:

  https://www.epa.gov/energy/power-profiler

  You or your students can also find air emissions from your home or school electricity use. You will need home or school monthly kilowatt-hour usage. You can also compare emissions to national averages.

- Send position papers – or student speakers – to local city government meetings to present their proposals.

Activity

Day 1

1. **Prepare an outline.** Based on information provided in the text, on your understanding of sustainability principles, and on your values, identify the power sources you believe would be best for your community in the short and long terms. Draft an outline explaining your proposal and supporting your point of view with evidence. Use the following guidelines to be sure your outline is complete:
   a. **Proposals:**
      i. Be clear
      ii. State benefit(s) of carrying out proposal
      iii. Be realistic
      iv. May be inspirational or push currently available technology
   b. **Rationale for Proposals:**
      i. Adequately support the proposal
      ii. Be clear
      iii. Be logical
      iv. Be factual and accurate
      v. Be relevant
      vi. Consider short and long term impacts
      vii. Consider both geographically local and distant impacts
      viii. Consider impacts to society, economy, and the environment
      ix. Acknowledge who benefits and who could be harmed
      x. Address possible problems that could occur if the proposal were implemented and must offer solutions
      xi. Appeal to emotions, logic, and/or values
   c. **Conclusion**
      i. Must restate proposal
      ii. Must encourage specific action(s)
2. **Write your position paper.** Use formal language, and be sure to support your position with accurate, relevant information and/or data.

Field Book

Day 1

1. **Nature Journal:** Notice how other living creatures use energy. How do they make use of the sun's energy? Make some sketches to show what you observe.
2. Write a response to the **Think About It** box on page 68.

Activity

Day 2

1. **Selected students present their position papers to the class.** Students in the audience will act as the group, defined by the speaker, to whom the proposal is being made. Audience members use the proposal guidelines above to craft courteous questions of the presenter. Challenging questions should be asked respectfully.

Field Book

1. **Nature Journal:** How energetic do you feel today? Why? Do you feel more energetic when you have time outside in the sunshine and fresh air? What energizes you?
2. Write a response to the **Think About It** box on page 71.

Ask for volunteers, or choose students, to present their briefing papers to the class. Try to get a representative sample of positions, including – as available in your class – strong support for continuing fossil fuel use, strong support for renewables, strong support for nuclear energy, gradual replacement of fossil fuels with renewables, and other points of view. Students should present their positions as if persuading the audience to adopt their proposal.

As each student presents their briefing paper, the rest of the class listens from the point of view of the target audience of the paper. They should respectfully question the presenter based on the guidelines for the proposal provided above. Student presenters should be prepared to answer questions about their proposal. If you feel it is appropriate for your class, students in the audience can courteously note at the end of the question and answer period whether or not they were persuaded to adopt the proposal.

Activity Fifteen

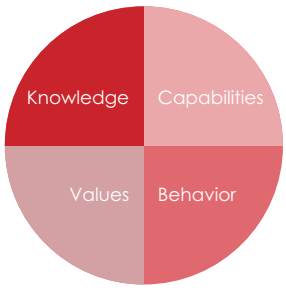
Unit Reflections, Self-Assessment, and Commitments

Activity

In your Field Book, respond to the following questions and prompts.

1. **Write one paragraph in response to each of the unit's essential questions:**
   a. How do air and energy connect to nature?
   b. What sustainable clean air and energy choices can I make?
2. **How can you use your understanding** of air and energy sustainability in your life, at school, at home, or in your community? With whom can you share this knowledge?
3. **A sustainability worldview is based on knowledge, capabilities, values, and behavior. Think about how your worldview has changed** through what you have learned about food and water. Make a circle and divide it into quarters. Write one of the elements of a sustainability worldview in each quarter. Note any changes that have taken place in these areas; use arrows to show interconnections between the four quarters. Use colors.
4. **Look back at the Questions page** in your Field Book. Are there unanswered questions? How can you get them answered? What else would you like to know about sharing the planet with nature in the future?
5. **How have the daily nature connection activities affected you?**
6. **What parts of the Air and Energy unit represented your best work?** What would you like to do differently?
7. **Review the text sections and your own work that suggest possible actions.** Also review:
   a. Air Quality Pathways to Progress on page 54.
   b. Energy Pathways to Progress on pages 70-71.

Based on your work and the readings, what, if any, actions would you like to take to support air and energy sustainability? Write down concrete action steps, goals, and timing for any commitments you would like to make. What might make it difficult for you to take these steps? How can you overcome these obstacles?



Summary

Students examine next steps they would like to take and reflect on their learning.

Time Required

- One 50-minute class period

Reading Prior to Activity

- Review pages 41-71
- Review Field Book work

Key Concepts

- Air and Energy Sustainability
- Big Ideas of Sustainability
- Earth Charter Principles

Objectives

- To reflect on learning and changes in worldview.
- To transfer learning outside of class.

Inquiry/Critical Thinking Questions

- How do air and energy connect to nature?
- What sustainable clean air and energy choices can I make?

Materials

- Colored pencils, optional

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