NINTH EDITION
GLOBAL SCIENCE
Sustainable Earth Systems

The Need for a Revolution in American Science Education

BY JOHN W. CHRISTENSEN

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For the past 125 years, some form of the sequence of science courses offered in American high schools has been Biology-Chemistry-Physics (B-C-P) in that order. It is now so ingrained that it provides the foundation on which most state science standards and national tests are based. However, during this span of time, the United States has changed drastically. According to the 1900 census, the U.S. population was 76 million. Now it is 334 million. In 1900, well over 90% of our population lived east of the Mississippi River. Now, we span the entire country-along with having an intertwined and robust infrastructure. In 1900, much of the country was unsettled and yearned for development. Then, the air was clean, brooks babbled and the forests and prairies were mostly untouched and beautiful. Now. Air quality is threatened, water is scarce and unable to meet the demands for its use. Also, climate caused periodic flooding and tornadoes threaten large regions of our nation. Our life expectancy is dropping and the entire global ecosystem (the biosphere) is under attack. For this reason, some argue that we are living in the Anthropocene Epoch – a period during which human activity is the dominant influence on climate and the environment. For this reason, some argue we must expand our space program to colonize the Moon, Mars, and beyond to save the human race. I argue that we must revolutionize our science offerings in schools and thinking in general to prepare us for living on a sustainable planet right here on Earth. In reality, this is our ONLY option.

If one is to call for a revolution and be heard, one must speak with some authority. Briefly, here are my credentials: I graduated in 1958 from Mounds View High School in MN, fourth in my class of ~180 students. This was the spring after the USSR launched Sputnik, an event that terrorized our nation. I loved high school so much, I wanted to become a high school science or social studies teacher. Because of Sputnik, the National Defense Education Act (NDEA) offered assistance for those pursuing careers in science/math education. I chose science. I enrolled at Augsburg College in Minneapolis, MN. Augsburg was becoming known for its science offerings (and it had ice hockey). I graduated cum laude in 1962 with majors in chemistry, math, and physics. I started my teaching career in Le Sueur, MN which at the time was the national headquarters for the Green Giant Canning Company. I taught science and math for 2 years. This was followed by an Academic Year Institute (AYI) at New Mexico Highlands University. The AYI was funded by the National Science Foundation (NSF) as part of the response to Sputnik. After a year of teaching PSSC Physics, and chemistry in Colorado Springs, I spent a year as a researcher for Harvard Project Physics. Soon after, I became a developer/writer for NSTA's Project for an Energy Enriched Curriculum (PEEC). In 1972 I became a pioneer in the development of what became known as an Environmental Science curriculum. With help from various private foundations and working on the staff of several NSF funded teacher training programs at universities, my curriculum was fleshed out and published in 1980. It still exists today and is in its 9th Edition and sold as Global Science: Earth Systems Science.

I spent 30+ years in the high school classroom teaching a hands-on Earth centered curriculum as both a required and an elective course. I worked with some excellent students, but mostly with your typical high school students-good kids, but not fully academically committed. They represent well your average American high school population. These are the ones who will decide the future of our planet.

Because Global Science was selling well across the nation, I retired in 1995 at age 55 after 30 years in Colorado's retirement plan. I have been working ever since on expanding and improving the Global Science curriculum. Because the very existence of our planet is at stake, I believe a full year course in Earth Systems Science (ESS) must form the foundation for high school level science offerings. It should be taken by everyone because we all share the same planet and it is the only planet we will spend our life on. To make it sustainable, we must collectively know how it works, how we interact with our ecosystem, and what we must do to get back into natural balance. So that you know what I am proposing, let me take you on a brief tour of such a course.

CHAPTER 1: THE NATURE OF SCIENCE

Other nature of science chapters cover much of the same material, but I strongly believe some important points must be made at the start. This is because science is usually taught as a body of knowledge to be examined and often memorized. However, science is both a body of knowledge and a way of knowing. The way of knowing aspect is important to understand because science is based solely on the study of the natural world. It tries to answer questions about how the natural world works. That is it. It is not a religion or a philosophy. It gets its information by doing controlled experiments that focus on open questions. The results of our work are not absolute. They can change as new evidence is discovered. Also, scientists themselves are not perfect. Finally, the results of science do not come with instructions on how to use them. Science is ethically neutral. How the results are used are both philosophical and moral (religious) issues. We, imperfect individuals, make those choices. The purpose of science is to search for the patterns in nature.

CHAPTER 2: THE EARTH SYSTEM

I start this chapter by having students look at a photo of Earth from space (The Blue Marble) and list 3-4 things they see and/or know about Earth based on their life time of experience. We then compare notes and come up with our class list.

The class list is as follows:

1. The Earth is finite – it is only so big.
2. Everything necessary for life exists on planet Earth.
3. The components of life are in constant movement and exchange.
4. There are no obvious political boundaries-humans draw those boundaries. Nature does not respond to them.

This list forms the focus of the rest of the chapter and the course. In this chapter, students identify the basic needs of living things. They develop the concept of an ecosystem, and see that these systems are dynamic and change over time. They also should realize that humans, unlike other organisms, have some special needs.

CHAPTER 3: ENERGY FLOW AND MATTER CYCLES

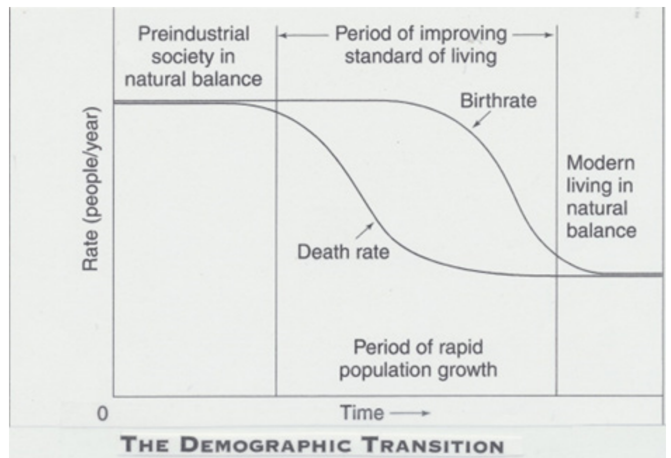
Energy flows from our Sun to Earth and is stored in plant material. Some past energy has been stored inside the Earth as fossil fuels. We use energy to perform desired tasks. In the process, we degrade energy, heat is given off and radiated into space. On the other hand, matter is not created. It exists, can be rearranged, and we use it to perform tasks. Our goal should be to use available energy and matter wisely. This is what nature does. There is no waste in nature. Energy drives the biosphere.

CHAPTER 4: MINERAL RESOURCES

Minerals play a special role in the human quest for the good life. We mine them where they are located. We can clean up and restore mine sites if we choose to. For modern technology, we utilize elements from all over the Periodic Table.

CHAPTER 5: GROWTH AND POPULATION

Students discover the properties of exponential growth by rolling dice or colored wood cubes. Unrestricted exponential growth plots as a "J" on regular graph paper and as a straight line on semi-log paper. It can be slowed and stopped. It cannot go on for long in a finite system such as on Earth. Students plot graphs of human population over time, make, examine, and compare population histograms for various countries, and then analyze the Demographic Transition.



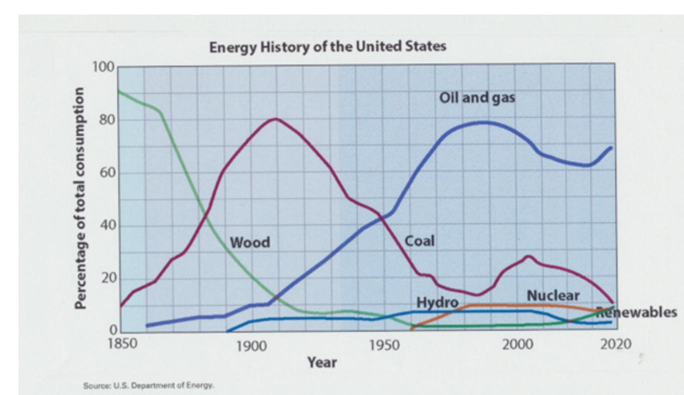
Analysis of the Demographic Transition offers hope for the future of the planet. Dictatorships have had little success in limiting their population growth. However, all those countries that allow their women reproductive freedom and offer opportunities for them to have careers cease to experience population growth. It seems people decide to limit family size so they can experience enjoyment beyond raising children. Data from the Population Reference Bureau and the U. N. confirms this.

CHAPTER 6: THE DIVERSITY AND CONTINUITY OF LIFE

In this chapter, students define what life is, focus on the characteristics of cells and seed, and why there are so many kinds of seeds-even of the same type of plant (the tomato). The conclusion is that diversity provides both variety and stability to both our life and the life of our planet's ecosystem.

CHAPTER 7: AGRICULTURE AND NUTRITION

In this chapter, students examine the strategy of agriculture and the role soil plays in growing plants. The nutritional needs of both plants and animals are listed. Students then examine their diets, how much energy they are receiving from the food they eat, and how much energy they require to do the things they like to do. Finally, they examine the world food situation and realize it is almost impossible to calculate how many people the world can feed. There are too many variables. However, the world's human population is now so large that new strategies are required if we are to both feed the population and stabilize the biosphere. These strategies are summarized in the section titled: A new Revolution in Agriculture.



CHAPTER 8: ENERGY IN TRANSITION

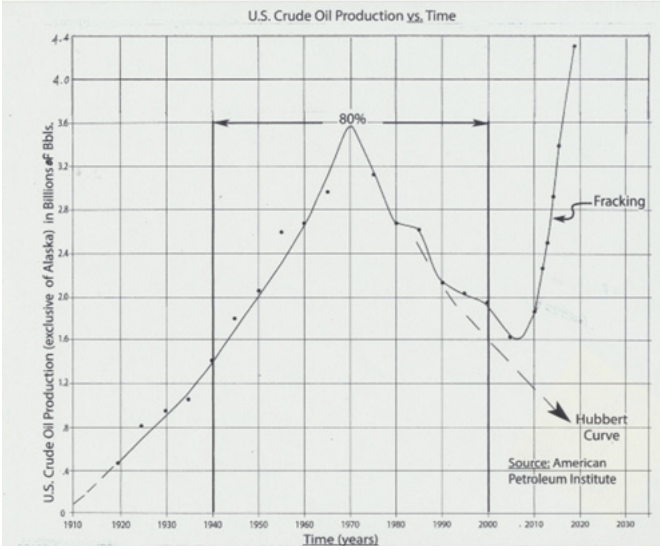
Analysis of the graph titled: An Energy History of the United States forms the basis of this chapter.

From the graph, students see that coal is rapidly being phased out as a major energy source. Oil and gas are near their peak (the slight increase is due to natural gas replacing coal at some electric power generating plants), Oil and gas should diminish as renewables grow. The future of nuclear power is uncertain. The rest of the chapter expands on this information.

CHAPTER 9: NONRENEWABLE RESOURCE DEPLETION

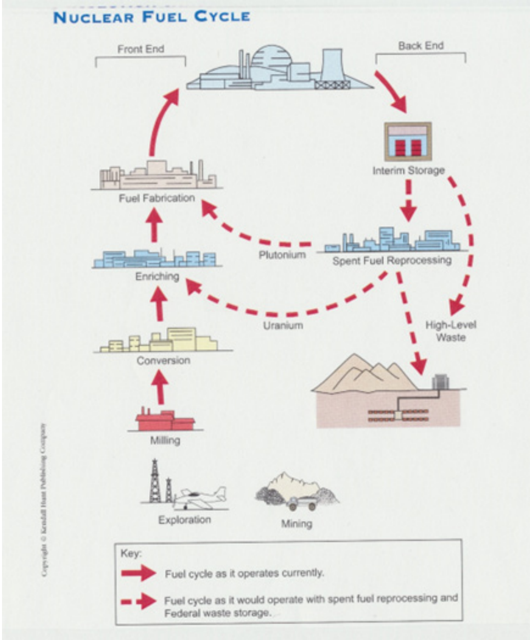
This chapter begins with the Resource Depletion Lab. Students mine in a shoe size box filled with dried field corn which has about 800 plastic pea size beads mixed in with the corn. The beads are the resource the miners want. Mining starts with one miner. 15 sec. of mining = 1 year. If a profit is made, new miners are added exponentially (1, 2, 4, 8) until profit is no longer possible. Then companies begin to drop out until we're down to one or two companies. A plot of production rate (beads/year) vs. time (years) produces a standard bell shaped curve (historically known as the Hubbert Curve in the case of U.S. Crude Oil Production). Students then plot U.S. Crude Oil Production vs. Time from 1920 to the present. See the graph below. (pg 6)

Note that U.S. crude oil production peaked in 1970 and then dropped, as expected until about 2005. Then something remarkable happened. It shot up rapidly! It quickly passed the 1970 peak. This was due to the new technology called "fracking."



The pandemic probably has slowed this some. However, it appears that fracking can now provide so much new oil and gas that we will literally trash our Earth's climate system unless we choose not to. It's our choice.

CHAPTER 10: NUCLEAR ENERGY



This chapter begins with why we believe in atoms, the atomic model, working with atomic symbols, writing nuclear equations, radioactivity, and a description of how nuclear power plants work. Fission and fusion are defined and examined. Students then analyze the Nuclear Fuel Cycle and learn that the U.S. cannot agree on where nuclear waste should be stored. Thus, at present, the wastes simply accumulate and build up at nuclear power plant sites.

The pros and cons for the continued use of nuclear power are examined and the chapter ends with a look at a new generation of nuclear power plants. For your information: Bill Gates is helping fund the rapid development of such plants. The Rocky Mountain Institute (RMI) argues that this option is not necessary.

CHAPTER 11: ENERGY ALTERNATIVES

This chapter examines the energy sources that can be alternatives to the use of oil, natural gas, coal, and nuclear power. The major focus is on solar heating and cooling of buildings, solar electricity (solar cells, and wind), and fuels from the Sun (biofuels). Students examine the potential of solar cells and design and build models of environmental homes.

CHAPTER 12: STRATEGIES FOR USING ENERGY

Students examine strategies for using energy (conservation, more efficient vehicles, energy conversion and storage.) Good strategies are as important as developing new sources. Battery storage is key to the wide use of solar and wind.

Finally, students summarize all their options and sort them into their proposed national energy plan.

CHAPTER 13: WATER QUANTITY

Students first observe a demonstration of the global water supply.

Students see that 97% of all global water is salt water in the oceans, and 2.15% is tied up in glaciers. Finally, 0.31% is in accessible ground water, and only 0.009% is in fresh surface water. We therefore are challenged to use surface water and accessible ground water wisely. Human attempts to use this water are examined (dams and reservoirs, water diversion, cloud seeding, etc.). Focus is placed on the Colorado River and water law. The western half of our nation is in a water quantity crisis.

CHAPTER 14: WATER QUALITY

Students learn about the major water pollutants and then test local water sources for quality. Pollution of aquatic ecosystems is described and the case of the Florida Everglades examined. Finally, wastewater treatment is described and students can then focus on these issues in their community.

CHAPTER 15: RESOURCE MANAGEMENT: AIR

The "Big Five" air pollutants are described and the production of acid rain examined. Strategies for reducing air pollution are summarized. Then the big topic receiving special attention is Climate Change. The Greenhouse Effect is modeled and scientific data regarding climate trends examined. A chart showing and projecting CO2 concentration in our atmosphere in ppm from 800,000 years before 1700 to the present and projected to 2050 is examined and the question raised-What should we do? See the chart. Ways of responding to climate change are then examined. Right now, climate change is the fight of our life!

Time	Event(s)	Concentration (ppm)
800,000 years Before 1700	During this time the Earth went thru 8 ice ages. (Half are shown on the graph.)	180–300
1700s	Before the industrial revolution	280
1900	Both Europe and US industrialized	295
1958	US Scientist Charles Keeling measures this level at Mauna Loa, Hawaii	315
2009	The last time CO_2 was at this level, much of the Greenland and West Antarctic ice sheets were not there. (Not shown in Figure 15.38.) This was about 25-30 million years ago.	390
2015	CO_2 levels rise more than 2ppm/year	400
2020	The pandemic slows the rate. What impact will electric vehicles have?	416
	PROJECTIONS	
2025	High probability of being reached	420s
2040	Will the "positive feedback loops" kick in? 450 ppm is the level many atmospheric scientists believe we must not exceed. James Hansen says we must then backtrack to 350 ppm to restore the climate we have. 350 ppm provides a certain level of safety.	450s
2050	What will this level be?	?

*ppm = parts per million

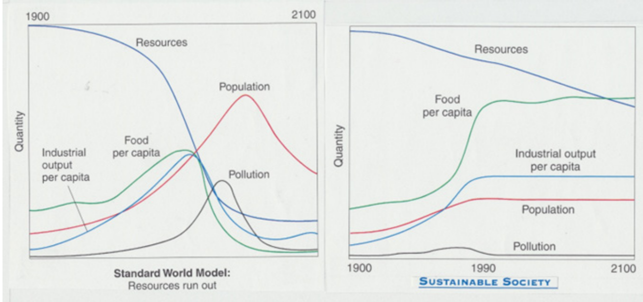
Atmospheric CO_2 Concentration vs. Time Data and Projections in Historical Context. (Assembled by John W. Christensen.)

CHAPTER 16: RESOURCE MANAGEMENT

Land Ways of classifying land use are examined along with a description of how land use decisions are usually made. Public lands are defined and land management issues listed. A focus is placed on the challenge of restoring mined land. The concepts of Island Biogeography and Land Fragmentation are developed so they can be applied as students examine land use where they live in an activity titled: Land Use Analysis. Global land management challenges are described and urban development examined as most humans now live in cities. The final focus is on the problem of waste and how we must handle it. In nature there are no wastes. This can provide the key as to what we, as humans, must do.

CHAPTER 17: THE SUSTAINABLE PLANET

The chapter begins with an activity titled: Pioneers and Their Island. About 400 years ago, 125 people left their homeland in search of a better life than what they had experienced. After some months at sea, they discovered a large uninhabited island in the South Pacific and decided to build their future there. With some background information provided, students then speculate on how they adapted for the first 400 years and project from that point what the island will look like 200 years into the future. They draw a picture of what the island is like today and make a graph which shows how their population, agricultural production, and use of nonrenewable resources changed over the first 400 years and project this 200 years into the future. This activity is then compared to the study done by the Club of Rome titled The Limits to Growth. That study examined what we as humans are doing to our planet and concluded that if we don't change some of our practices and attitudes, we are going to make Earth uninhabitable for humans. They also said that if we make certain changes, we can prevent this from happening. Their two main graphs are shown below.

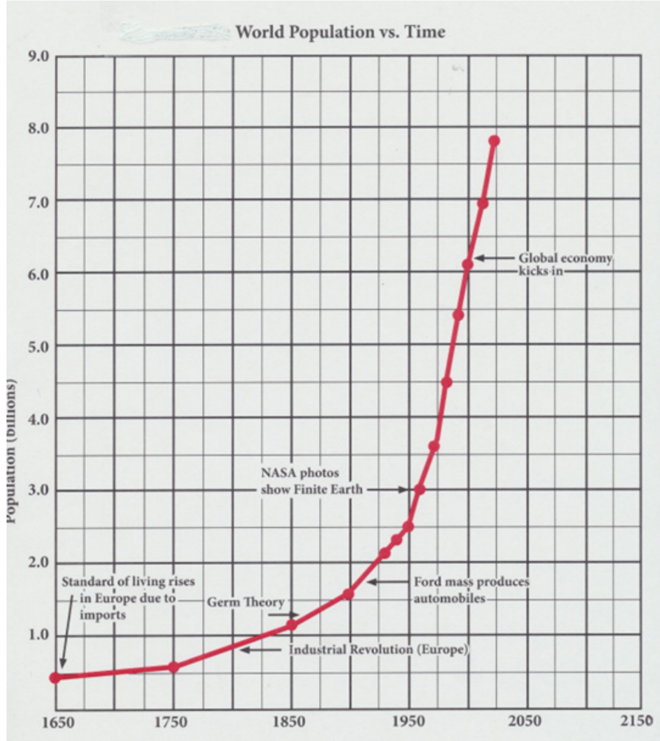


Students then examine the various options we have and consider such things as economic systems, trade-offs involving the use of resources, and conflict resolution. The conclusion is that to produce a sustainable world, we must:

1. Produce and maintain a stable world population,
2. Prevent the depletion of critical resources,
3. Maximize opportunities for all people.

The course ends with a section titled: Scientific Priorities for Building a Post-Pandemic World. The priorities are as follows:

1. Stop Catastrophic Climate Change. The stone age did not end when we ran out of stones. It ended when bronze became a better material for making tools. Similarly, the fossil fuel age can end before we run out of those fuels. We already have the alternatives, we simply must make use of them quickly
2. Stabilize human population. The following graph shows human population vs. time from 1650 to the present. It doesn't look too hopeful for life on our planet. However, we have available to us the ability to change that and change it quickly.An analysis of the Demographic Transition tells us that if women world wide are given reproductive freedom and opportunities to have meaningful careers, populations cease to grow. American women are demanding it. Iranian women are demanding it. Let's help it happen! This struggle is playing out before our very eyes.



3. Make all humans equal in terms of opportunities.At present, more and more wealth is being amassed in the hands of a smaller and smaller group of people. It is not possible to achieve stability among the masses if a larger and larger group has to struggle to just make ends meet with no hope for a happy future in sight. Poor people have shorter lifespans, work jobs that cannot be performed away from danger, face food insecurity, have limited access to good health care, or can even own a home. Is this the world we want to live in? There are societies on Earth today where this is not the norm. Maybe we can learn from them. As Rev. Pickney pointed out: My freedom depends on your being free also.
4. Restore a sense of community where we live.For a society to be stable, we need each other. Everything is connected to everything else. We all suffer when our brother suffers. Diseases cannot be eradicated if we allow many to have them. A virus cannot be eliminated if large groups don't work together to stop the spread. We all breathe the same air and share the same water.
5. We need to prepare for another pandemic.The possibility of another virus outbreak is high. However, just as we did with COVID-19, we can develop new vaccines-even faster to stop the spread – if we choose to.
6. No person left inside.To appreciate the natural world, you must experience the natural world. We must put away our iPods, cell phones, and virtual reality devices. The real reality is all around us. One must experience it to love it. There is no substitute for hearing a brook fall over stones in its way. There is no substitute for watching a butterfly, or hearing a bird sing. This is life as it should be. This is our natural world. This is what makes life possible.

The final section of the course is titled: Ensuring the Continuity of Life on Planet Earth. It asks students to again look at NASA's "Blue Marble" photo of Earth and realize again:

1. The Earth and its resources are finite.
2. Everything necessary for life exists on Earth.

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3. Everything is connected to everything else. We are tied to nature and to each other.
4. There are no political boundaries in nature. We made them ourselves and we can adjust them for sustainability if we choose.
5. On planet Earth, energy flows through our biosphere and matter cycles. There is no waste in nature.

As passengers on our global spaceship, we can ask the traveler's question-Where do we want to go? It's our choice. Choose wisely.

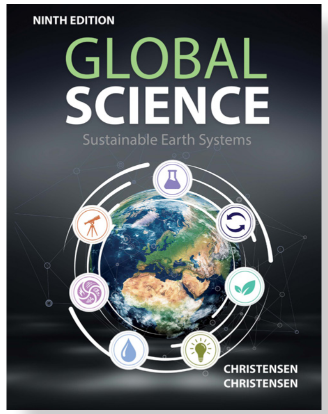
The big question is – Where do we go from here?

On Thursday, May 25, 2023, Ukrainian President Volodymyr Zelenskyy delivered a commencement address via satellite to the graduates of Johns Hopkins University. In that address, he stated that "Time is the most important asset on the planet. Some people realize this sooner, and these are the lucky ones. Others realize it too late when they lose someone or something." As humans on planet Earth, we are running out of time. We have to decide now what kind of Earth we want to live on and what we want tomorrow to look like.

Since you are an American high school, and one of your goals is to prepare your students for the future, do you offer a science course that focuses on the sustainability of our planet? If so, is that course built for use by ALL levels of your students? Is it hands-on? Can it be adjusted to be affordable to offer in your school/district? Can you honestly discuss topics such as family planning, energy sources, equity, and climate change?

Are you able to stress the accuracy and reliability of the information they read online and hear in the news? In Global Science, data generation, analysis, dialogue, questioning, and projection are all encouraged as our society must strive to pull together to take on the challenge of sustainability.

The urgency of the information outlined in the content survey is in the news all the time as we watch the glaciers melt and heat waves engulf major regions where we live. Droughts expand, water supplies shrink, and tornadoes and floods cause degradation where they strike. Let's make our course offerings relevant!



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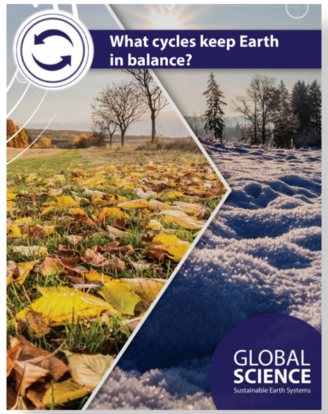
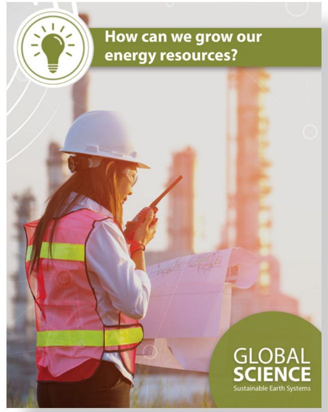
Unit 1: *What is scientifc thinking?*

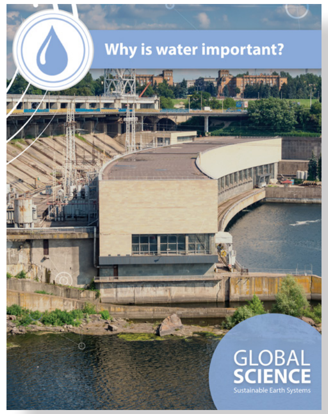


Unit 2: *What cycles keep Earth in balance?*

Unit 3: *How can we sustainably live?*

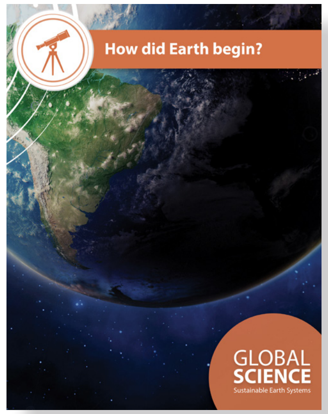


Unit 4: *How can we grow our energy resources?*



Unit 5: *Why is water important?*

Unit 6: *How do we preserve Earth?*



Unit 7: *How did Earth begin?*

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