BRITANNICA
GLOBAL GEOGRAPHY
SYSTEM

Overview

BGGS Overview

BGGS is the ***Britannica Global Geography System***, a modular electronic learning system which combines the latest pedagogical approach to geography learning with interactive multi-media materials enabling students and teachers to immerse themselves in exciting geographic investigations. BGGS is made up of the following components:

- *Geographic Inquiry into Global Issues* (GIGI) Student DataBooks
- Teacher's Guides with Overhead Transparencies in a three-ring binder
- Laminated Mini-Atlases to accompany each module
- BGGS CD-ROM with User's Manual
- 3 BGGS Videodiscs with Barcode Guides
- 3 thematic posters

This section of your Teacher's Guide will examine each component and demonstrate how the components work together to facilitate some very exciting geography learning for you and your students!

I. GIGI

Geographic Inquiry into Global Issues (GIGI) is the foundation of the BGGS. GIGI is a series of modules developed at the Center for Geographic Education at the University of Colorado at Boulder. The modules are independent of one another and can be presented in any order. They use an inquiry approach and are organized around ten world regions:

South Asia
Southeast Asia
Japan
Former Soviet Union
East Asia
Australia/New Zealand/Pacific
North Africa/Southwest Asia
Africa-South of the Sahara
Latin America
Europe

Each GIGI module is centered around a particular question, such as "Why are people in the world hungry?" and "Is freedom of movement a basic human right?" The lead question is explored in one region of the world, then, in most modules, in a second region, before being investigated in North America.

The modules can be used in geography classes, or selected modules can be used in other courses, such as Earth Science, Global Studies, or Economics. Twelve modules constitute ample material for a full year's geography course. Each module is accompanied by sets of laminated mini-atlases which students can write on with dry-erase markers (provided by the teacher), then wipe clean to be re-used by the next class. This activity works well with cooperative groups of students.

Each module comprises a Teacher's Guide in a three-ring binder which includes Handouts and Activity masters for duplication and Overhead Transparencies; twenty-five Student DataBooks (additional Student DataBooks available) and the Mini-Atlases all packaged in a sturdy box suitable for storage when the class moves on to the next module. Since the Student DataBooks are soft-covered three-hole punched, non-consumable books, we recommend that each student have a binder to protect them. BGGS binders are available from Britannica, or you might ask each student to obtain one at the beginning of the course to keep the books in good condition for the next group of students that will use them. As the class completes a module, you can collect the Student DataBooks, place them in their storage box, and distribute the next module's DataBook to be placed in the student's binder.

GIGI print materials are organized in a unique fashion. The Teacher's Guide explains procedures to use in presenting the material found in the GIGI Student DataBook. Miniature layouts of student pages show the teacher how many pages of student material correspond with a given Teacher's Guide page. The Teacher's Guide includes Activities and Handouts to be copied and passed out to the class and Overhead Transparencies to enhance each lesson. All of a module's Activities, Handouts, and Overheads are located behind the third tab divider in each Teacher's Guide.

The teacher needs to become familiar in advance with both Teacher and Student material in order to effectively engage the class in meaningful geographic inquiries. There is a comprehensive "Memo to the Teacher from the GIGI Staff" in each Teacher's Guide which explains in detail the goals and principles behind the inquiry approach to geography learning.

The electronic components of the ***Britannica Global Geography System*** further empower students and teachers alike to engage in meaningful investigations. They are explained in detail in the following section.

II. BGGS CD-ROM

The **BGGS CD-ROM** is a resource manager and reference tool designed to help both teachers and students get maximum impact from the ***Britannica Global Geography System.*** This CD-ROM contains the text of the GIGI Student DataBooks in both Spanish and English, as well as Britannica's innovative geography reference program Geopedia™ all on a single disk. Here are some of the ways you and your class can use this software:

- When preparing to teach a module, you can access the GIGI Student DataBook on the CD to find which other elements of the BGGS are keyed to that lesson. For example, if you are teaching Lesson 3 in the Population and Resources module (What is overpopulation and how is it distributed?), accessing that lesson on the CD-ROM will reveal that there is one clip on the *Economic Development* videodisc called "Population/Wealth Correlation." With this information, you can plan when to reserve your department's videodisc player to preview the clip and show it to your class.

Furthermore, you will discover that there is one GIGI mini-atlas activity related to this lesson, five articles in the Geopedia database, ten entries in

Geopedia's World Data, five maps in the Geopedia Atlas, and five learning activities in the Geopedia BrainTeasers. You may want to assign each student or small group of students a research project using these extra resources to be done over the course of the module, or you can create a set of questions which the students must complete using the information found in Geopedia.

These activities can serve as a performance-based assessment of what students have learned in studying each module.

Since many schools have a limited number of computers with CD-ROM drives available, you may wish to devise a rotating schedule or sign-up system to ensure that each student has a chance to get at the BGGS CD-ROM. If it takes 15 class periods for a class of twenty-five students to do one module, students working in pairs can each have one turn at the computer if they schedule their time at the outset of the module. Using the CD-ROM's resource managing capability, you will have a very good sense of what resources you have at your disposal and how to make the most of them.

- All GIGI lessons are indexed by word and by key topic. If your class is studying food shortages in the Hunger module, you can key in the word hunger, and immediately learn where else in the GIGI modules this word or key topic appears. You can go directly to those occurrences in the text. You will also be directed to appropriate Geopedia references and Brain Teaser activities. Figures, Maps and Tables from GIGI print modules do not appear in the CD-ROM. However, the caption describing each of them is part of the online text.
- If Spanish is the primary language of your students, GIGI lessons can be accessed and printed out in Spanish from the BGGS CD-ROM. The BGGS Videodiscs have a Spanish soundtrack as well.

III. BGGS Videodiscs

More than ever before, today's students are visual learners. The GIGI modules explore issues and regions of the world with which many students are unfamiliar. With this in mind, we have produced three videodiscs, one to correspond to each of three major strands we have identified in GIGI: *Earth's Environment and Society; Economic Development;* and *Global Political and Cultural Change.*

These videodiscs, with English and Spanish soundtracks, can take you and your class to the parts of the world you are investigating with the wave of a barcode wand. Your class will hear how Amazon native peoples feel about the exploitation of the tropical rain forests where they live, witness the eruption of a volcano, and see first-hand the environmental disasters human beings have brought about.

The Barcode Guide which accompanies each disc enables you to access with a light pen or barcode reader, segments which pertain to the lesson being investigated. The Guide includes barcodes in both English and Spanish. Teachers can use the segments to enrich lessons, and students can make use of segments to enhance a report or group presentation.

There is a full-color poster to accompany each videodisc cluster which engages the students by asking "How do these images connect to you?" The posters can provide a colorful springboard for classroom discussion.

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BRITANNICA GLOBAL GEOGRAPHY SYSTEM

GIGI

Geographic Inquiry into Global Issues

Global Climate Change

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TEACHER'S GUIDE

Regional Case Study

Australia/New Zealand/Pacific

Britannica

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Contents

Memo to the Teacher from the GIGI Staff

You have in your hands the GIGI Teacher's Guide. Teaching with GIGI is a departure from teaching with a conventional textbook. By taking the time to study this memo—about 30 minutes—you will gain a good understanding of the kind of teaching that's needed to be successful with GIGI. We hope you have a rewarding and enjoyable experience!

Goals

The three major goals of *Geographic Inquiry into Global Issues* (GIGI) are to help you teach your students the following:

1. Responsible citizenship
2. Geographic knowledge, skills, and perspectives
3. Critical and reflective thinking

We believe you can accomplish these goals as well as others by teaching real-world issues. GIGI presents these issues with an inquiry approach, using the information, concepts, skills, and perspectives of geography.

GIGI and the Britannica Global Geography System

GIGI offers you two instructional modules for each of ten world regions (Figure 1 on pages vi and vii). There is no necessary sequence of modules; each one is independent, so you can use them in any order you wish or put together smaller clusters of modules to fit your needs. A leading question frames the issue of each module, and student inquiry proceeds through a sequence of lessons, each of which requires one or more daily periods of class time.

Color photographs at the beginning and end of each Student DataBook graphically illustrate the topic under inquiry.

Modules typically begin with a broad introduction to the global issue. Then, a major case study of three to four lessons examines the issue in a real place within the selected world region. Students also explore, usually in a single lesson, a comparative case study in a *different* region, which gives a variant of the issue and a sense of its global nature. Modules also bring the students "back home" to focus on the issue as it may appear in the United States or Canada. We do this because although North America is not one of the 10 GIGI regions, frequent comparisons to North America throughout each module achieve additional instruction on this "home region."

Each GIGI module requires from two to three weeks of teaching time (10 to 15 class periods of 50 minutes) and contains a Student DataBook, Teacher's Guide, and Mini-Atlas. These GIGI print materials are at the heart of the Britannica Global Geography System (BGGS), which extends and enhances the inquiry approach to real-world issues with a CD-ROM and three videodiscs.

The BGGS CD-ROM puts the text of the GIGI Student DataBooks on line in both English and Spanish, then enables both teacher and students to search the text by lesson, key topic, or word to find the resources in the system that will enhance each. Geopedia™, Britannica's multimedia geography program, is provided in the CD-ROM for follow-up research. It features an atlas with more than 1,000 new maps, an encyclopedia with more than 1,200 geography-related articles, statistical information on every country from Britannica World Data Annual, a chartmaker for creating charts and graphs, a selection of video clips exploring cities and regions, and an electronic notepad allowing teachers and students to clip and edit text right on the screen.

Three videodiscs, designed to electronically transport students to the regions of the world where GIGI case studies are focused, are another part of the BGGS. The discs emphasize three major strands of the GIGI investigations: *Earth's Environment and Society, Economic Development,* and *Global Political and Cultural Change.* Each videodisc has two soundtracks, English and Spanish, and is accompanied by a Barcode Guide that enables teachers and students to access the segments that accompany the GIGI lesson with a wave of the barcode reader. A poster accompanies each videodisc to reinforce the connnections between your students and the issue being studied.

A full explanation of the Britannica Global Geography System components and how they work together is located in the BGGS overview in the front section of this Teacher's Guide.

Geographic Inquiry into Global Issues (GIGI)
Issues, Leading Questions, and Case Study Locations

South Asia	**Population and Resources** *How does population growth affect resource availability?* Bangladesh (Haiti)	**Religious Conflict*** *Where do religious differences contribute to conflict?* Kashmir (Northern Ireland)
Southeast Asia	**Sustainable Agriculture** *How can the world achieve sustainable agriculture?* Malaysia (Cameroon, Western United States)	**Human Rights** *How is freedom of movement a basic human right?* Cambodia (Cuba, United States)
Japan	**Global Economy*** *How does trade shape the global economy?* Japan (Colombia, United States)	**Natural Hazards** *Why do the effects of natural hazards vary from place to place?* Japan (Bangladesh, United States)
Former Soviet Union	**Diversity and Nationalism*** *How do nations cope with cultural diversity?* Commonwealth of Independent States (Brazil, United States)	**Environmental Pollution** *What are the effects of severe environmental pollution?* Aral Sea (Madagascar, United States)
East Asia	**Population Growth*** *How is population growth to be managed?* China (United States)	**Political Change** *How does political change affect peoples and places?* Hong Kong (South Korea, Taiwan, Singapore, Canada)

* Under development

Figure 1 Matrix showing GIGI modules. Geographic issues are in bold and leading questions are in italics. Major case study locations are followed by comparison examples in parentheses.

Geographic Inquiry into Global Issues (GIGI)

Issues, Leading Questions, and Case Study Locations

Australia/ New Zealand/ Pacific	**Global Climate Change** *What could happen if global warming occurs?* Australia and New Zealand (Developing Countries, U.S. Gulf Coast)	**Interdependence*** *What are the causes and effects of global interdependence?* Australia (Falkland Islands, United States)
North Africa/ Southwest Asia	**Oil and Society*** *How have oil riches changed nations?* Saudi Arabia (Venezuela, Alaska)	**Hunger** *Why are people hungry?* Sudan (India, Canada)
Africa—south of the Sahara	**Building New Nations*** *How are nation-states built?* Nigeria (South Africa, Canada)	**Infant and Child Mortality** *Why do so many children suffer from poor health?* Central Africa (United States)
Latin America	**Urban Growth** *What are the causes and effects of rapid urbanization and urban growth?* Mexico (United States)	**Development** *How does development affect peoples and places?* Amazonia (Eastern Europe, U.S. Tennessee Valley)
Europe	**Regional Integration*** *What are the advantages of and barriers to regional integration?* Europe (United States, Mexico, Canada)	**Waste Management** *Why is waste management both a local and global concern?* Western Europe (Japan, United States)

* Under development

Figure 1 (continued)

The **Student DataBook** contains the following features:

- Memo to the Student from the GIGI Staff
- An overview of the key questions and places explored in the module
- Lesson objectives
- Data presented in a variety of forms, including text, maps, graphs, tables, photographs, and cartoons
- Questions
- Glossary
- References

Students are not expected to learn the GIGI curriculum through the Student DataBook alone. Rather, they derive meaning from the DataBook when you use the Teacher's Guide to work through the curriculum with them. You may want to explain this process to students. Point out that you will be directing them to carry out various activities that are not specified in their text but are important in the sequence of learning.

Prior to teaching the first lesson, be sure students read the "Memo to the Student from the GIGI Staff" and the two-page overview, which gives the module's objectives in question form. Point out the Glossary and encourage its use as you work through the module, noting that glossary words are listed at the beginning of each lesson. So that students will know what they are expected to learn, they need to read carefully and understand the objectives listed at the beginning of each lesson.

This **Teacher's Guide** contains the following sections:

- Preparing to Teach This Module, a synopsis of the module's leading question, themes, and activities
- Module Objectives
- Number of Days Required to Teach the Module
- Suggestions for Teacher Reading
- Extension Activities and Resources

Most lessons include the following sections:

- Time Required
- Materials Needed
- Glossary Words
- Getting Started (suggested anticipatory sets)
- Procedures (for group and individual work)
- Modifications for older or younger students (in a different type face, printed in color)
- Questions and Answers (shown in tinted boxes)
- For Further Inquiry (suggestions for extensions and/or assessments)

- Masters of Overhead Transparencies and Activity masters and keys (located at the back of the Teacher's Guide)

Each module has its own accompanying **Mini-Atlas,** which provides four-color maps designed especially for use with that module. The Teacher's Guide explains how to use these maps. No additional atlases are required to teach the module, but large wall maps are highly recommended for your classroom. In addition to the maps in the Mini-Atlas, you will find numerous maps in the Student DataBook.

Intended Grade Levels

We believe GIGI enables you to probe global issues in various degrees of depth. This allows for the modules' use both over several grade levels (7–12) and over varying lengths of time at a grade level. The Teacher's Guides suggest alternatives for modifying instruction for different grade levels where appropriate. The reading level varies within each module: The Student DataBooks are approximately at grade 9 level, but some extracts from other sources are more challenging. These extracts are important because they show students that many people have contributed to the data, but younger students may need more time and help to understand them. The Teacher's Guides also include extension activities and resources that can maximize the grade-level flexibility of each module. Using the visuals included in the BGGS videodiscs and the activities built into the CD-ROM, you can further tailor instruction to your students. Obviously, you will determine whether particular lessons suit your students' abilities. When a range of required teaching time is given for a module, for example, 10 to 12 days, the greater amount of time should be planned for younger students. If you believe a lesson might be too difficult for your students, eliminate or simplify it. Rarely will the elimination of a lesson render a module ineffective. On the other hand, try to utilize the suggested extensions if the lesson does not adequately challenge your students.

Issues-Based Geographic Inquiry

In order to foster active learning and higher-level thinking, GIGI stresses issues-based geographic inquiry. Inquiry is essentially the method of science and of good detective work: It poses questions and proposes answers about the real world and it tests its answers with real data. Students do this with GIGI. Because this approach may be different from what students are familiar with, you may wish to prepare them by describing the process and its connection to the real world. Also, their reading and discussion of the "Memo to the Student from the GIGI Staff" will help them understand the inquiry approach. GIGI is based on Frances Slater's inquiry activity planning model (1993). To reach GIGI's goals, your students study specific global issues by pursuing answers to geographic questions (Figure 2). They answer these questions by analyzing and evaluating data, using geographic methods and skills. This "doing geography" approach leads to significant outcomes in knowledge, skills, and perspectives. The progression from questions to generalizations "is crucial as a structure for activity planning and as a strategy for developing meaning and understanding. Meaning and understanding define the process of tying little factual knots of information into bigger general knots so that geography begins to make sense, not as a heap of isolated facts but as a network of *ideas and procedures*" (Slater 1993, page 60).

In truly free inquiry, students work independently, but with GIGI posing questions and providing data, you and your students explore the issues together. This approach supports and encourages your students in learning geography.

By using issues-based inquiry, you promote the development of a critical perspective in your students. They learn the habits of critical and reflective thinking. Multiple and opposing positions are inherent

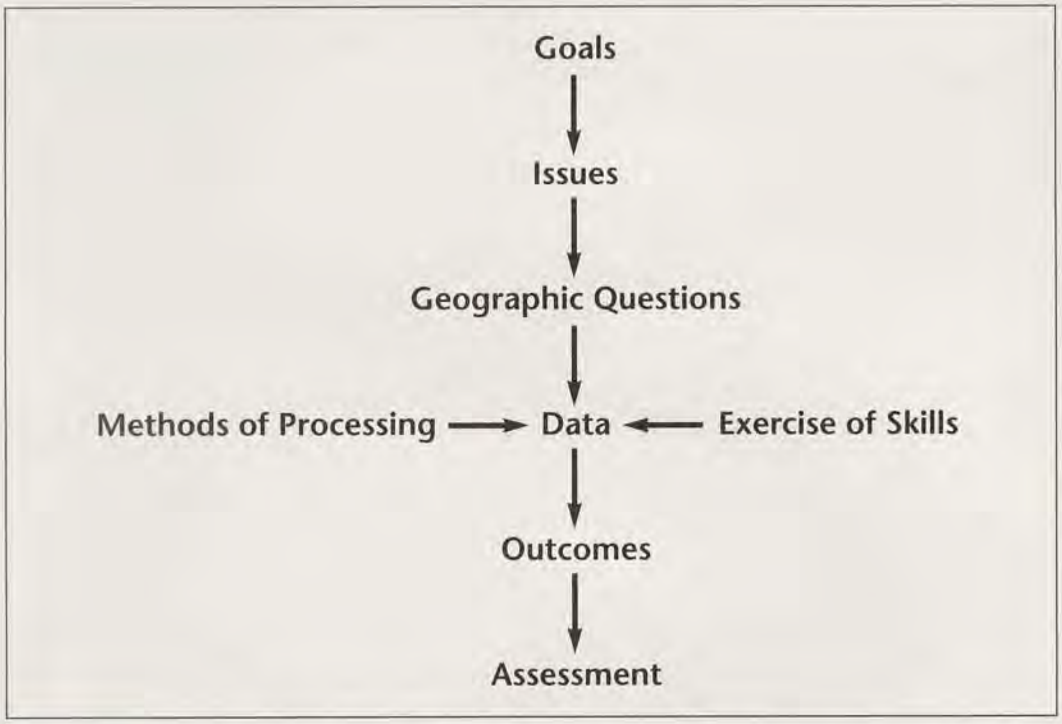


Figure 2 GIGI's model for issues-based geographic inquiry (after Slater 1993).

in these issues. Facts can be used to support different points of view. This is the context in which the habits of the critical perspective can develop, and *interpretation* is the key activity. With GIGI you foster these habits and abilities as you help your students interpret data guided by hypotheses, propositions, arguments, or questions.

An essential element of data-based, issues-oriented inquiry is to challenge your students by giving them opportunities to

- raise new questions,
- question the quality of the data,
- seek more useful or current data,
- articulate relationships they perceive,
- explain their processes of investigation, and
- defend their positions, decisions, and solutions.

Why These Issues Were Chosen

In planning GIGI, we sought timeless issues that are truly global in scope and that are of special concern to geographers. In this way, GIGI fosters what the National Geography Standards calls "the geographically informed person" needed by modern global citizenry (Geography Education Standards Project 1994).

The major case study, chosen to give solid grounding to the issue, is focused on a region where the issue is clearly expressed. The secondary case studies, based in other regions including the United States and Canada, show the *global* scope of the issue.

It is important to stress that, although GIGI contains a wide selection of case studies in all major regions (Figure 1) as well as frequent references to the global distribution of many geographic phenomena, GIGI is not a traditional regional geography. It does not attempt to provide basic geographic information for each region, such as one finds in traditional regional geography textbooks. In teaching a GIGI module, it is important to keep the emphasis on the issue and not get distracted with extraneous regional information.

Role of Questions

Each GIGI module is divided into six to eight lessons, each titled by a question; subquestions head individual sections of the lessons. Questions guide inquiry in order to merge the process of investigation with the drawing of conclusions. Directly linking questions and answers helps achieve an intellectually satisfying understanding of a problem (Slater 1993). When students are asked to learn only conclusions without learning how they are drawn, we perpetuate the tradition of an answer-centered education bereft of higher-level thinking. Therefore, it is important that students understand they are not always expected to answer the questions when they first appear, but rather to keep them in mind as guides when they are reading or discussing.

GIGI asks both convergent and divergent questions, trying to reach a balance between the two. Supplement the questions in GIGI by asking your students many more of the types of questions suggested by Slater (1993). These are questions that encourage

- recall,
- classification and ordering,
- the use of data to draw conclusions,
- awareness of the limitations of data or of evaluation of data, and
- awareness of the processes of reasoning used.

According to the National Geography Standards, the "geographically informed person applies a comprehensive spatial view of the world to life situations" (Geography Education Standards Project 1994). In order to foster such a view of the world, GIGI asks *geographic* questions that ask where things are and why. By asking such geographic questions and by having students learn to ask them, you will reinforce GIGI's approach. A good question to begin with is: Where is this issue located? Then proceed to questions such as the following:

- Why does it take place there?
- How and why does this issue affect the people in this place?
- In what other places do people confront this issue?
- How and why are these places related?
- What alternatives do people have to improve their situation, and which alternatives do you recommend?

Fundamental Themes of Geography

In recent years, many geography teachers have learned that the five "fundamental themes" (Joint Committee on Geographic Education 1984) help them ask geographic questions. The theme of **Location** asks where things are and why things are located where they are. **Place** is the theme that inquires into human and physical characteristics of locations. **Human-Environment Interaction** examines how and why humans both adapt to and modify their environments as well as the consequences of these actions. **Movement** investigates not only how and why places are connected but also what is the significance of those interactions. The theme of **Region** seeks to identify and explain similarities and differences among areas and how and why these form and change. An extended explanation of the themes and their concepts, interrelationships, and applications is given in Hill and McCormick (1989). The themes are useful because they encourage the kinds of questions required to help students develop the geographic perspective.

Importance of Local Examples

GIGI is a world geography, but it shows that issues work at various geographic scales—personal, local, regional, national, and global. Because it is sometimes difficult for younger students to identify with faraway places, success with GIGI in part depends upon the ability of both you and your students to relate the issues to examples in your local community. We strongly recommend that you refer in class to local examples of the issue being investigated. Just as important, we encourage you to have your students conduct local field studies related to this issue whenever possible. Issues having important geographic dimensions abound in every community (see the Extension Activities and Resources section at the end of this Teacher's Guide for examples). Peak educational experiences often come when students see things in the field that relate to their classroom studies. We discuss other reasons for local involvement in the next section.

Familiar people can be as important as familiar places in motivating students. The quality of personal engagement is at the crux of successful instruction. Using the BGGS videodisc segments that accompany most GIGI lessons is a powerful way to help your students find relevance by identifying the GIGI issues with real people. Similarly, you can connect GIGI issues to everyday life at a human scale, especially at the students' own age levels, by using current newspaper accounts or magazines that address the student's perspective.

As you gain familiarity with teaching local examples, as you develop field exercises for your students, and as you learn how to put a human face on these materials, you will begin to customize the GIGI modules to fit your particular environment. Our trial teachers reported that the more they taught GIGI modules, the more comfortable they became in adapting them to fit their needs.

Fostering Optimistic and Constructive Perspectives

The seriousness and complexity of the global issues studied in GIGI can overwhelm students unless you take care to foster optimistic and constructive perspectives toward issues. "Gloom and doom" needs to be balanced with examples of success and prospects for positive change. It is important to help your students develop a sense of personal efficacy, an attitude that their actions can make a difference in solving global problems. The maxim, "Think Globally, Act Locally," speaks to the need to help students organize and conduct constructive actions that address local variants of the issues they are studying. As we noted earlier, student involvement in local projects enriches their educational experience. There is also good evidence that it actually produces an optimistic feeling—that their actions *can* make a difference—to help them deal with the often difficult and sometimes depressing world issues. GIGI modules often include lessons and activities to show possibilities for positive action.

Certain perspectives foster student optimism and constructive behavior. Geography students, especially, should learn to respect other peoples and lands, and they should come to cherish environmental unity and natural diversity. They should also learn to be skeptical about simplistic explanations, such as the theory that attempts to explain human characteristics and actions in terms of the physical environment alone, which geographers call "environmental determinism." Most important, optimistic and constructive perspectives accompany the development of empathy, tolerance, and open-mindedness. These traits are fostered by avoiding sexist and racist language, discouraging ethnocentricity, and challenging stereotypes, simplistic solutions, and basic assumptions.

References to Data

Unlike most textbooks, GIGI attributes its sources of data with in-text citations and full reference lists, which is another way of encouraging the critical perspective. In the Student DataBook, material that has been extracted from original sources is indented and printed in a different typeface. Long extracts are highlighted with background color. Use of these sources helps your students learn that real people construct ideas and data and that their concepts and information are not immutable. Instead, they often change through the critiques and interpretations of various people. By using these scholarly conventions, we intend to encourage your students to appreciate the tentativeness of knowledge and to value scholarship and academic integrity.

Updating

Real data quickly become obsolete. GIGI addresses this fact by discussing historical trends of data and by stressing concepts. You should reinforce this bias for concepts and also freely acknowledge the datedness of information by explaining why it is still used (for example, the lags between research and writing and publication and use; the lack of more recent data). Whenever possible, guide students to update materials. Britannica's Geopedia, on the BGGS CD-ROM, contains data based on Encyclopædia Britannica's World Data Annual, which is also available in print form. Have students use these sources to supplement and update GIGI data.

Assessing Learning

Evaluation of student achievements with GIGI can be focused on two broad areas. The first is the developing ability of students to undertake geographic inquiry. The second is the acquisition of knowledge and perspectives about the module issue.

The ability of students to undertake inquiry in geography can be related to the primary questions that guide geographical study. They are noted earlier in this memo. As students work through the module, they are likely to become increasingly adept at asking and answering geographic questions. Seek to extend your students' competence in several clusters of skills that facilitate geographic inquiry. These clusters include the following:

- Identifying problems and issues. This may be done through observation, asking questions, brainstorming, reading, and in other ways.
- Inquiring into the problems and issues in many ways such as through map reading and interpretation, making surveys, and using results of surveys done by others.
- Making decisions and taking action, for example, through reviewing alternatives, establishing priorities and criteria, and communicating cooperatively with people in other ways.
- Reflecting at all stages of the process of inquiry, especially through careful consideration of diverse sources of evidence.

Students will acquire knowledge of the module issue as they make their inquiries. This knowledge can be tested and graded. Assessments may be based on the following:

- Knowledge and skills shown by work on Activities included in this Teacher's Guide and on questions in the Student DataBook.
- Observations of student participation in groups and in class discussions.

Specific assessment ideas are given at the end of some lessons in the section called For Further Inquiry. In addition, the Teacher's Guide ends with Extension Activities and Resources. Some of these extension activities can serve as authentic assessments.

Potential Uses

In addition to the flexibility offered by the free-standing nature of the modules, GIGI has a number of other characteristics that encourage widespread use. Modules can be extended and enhanced with the BGGS CD-ROM, videodiscs, and posters. Because GIGI's issues-based approach integrates several topics (for example, population, economic, political, physical, and cultural geography) in a single module, the modules are not conducive to using an approach in which topics are taught separately. On the other hand, GIGI may be used with a world regional approach because there are modules for each of 10 world regions. A year-long world geography or global studies course will have more than enough material by using 12 modules. Five to seven modules may constitute a one-semester, issues-based geography course covering several regions. You can define clusters of modules for your own curricular purposes. We have identified three clusters for interdisciplinary studies within the Britannica Global Geography System, each comprising six or seven GIGI modules. They are *Earth's Environment and Society, Economic Development,* and *Global Political and Cultural Change.* BGGS includes a videodisc and poster for each cluster. These strand packages could well be used in Social and Environmental Studies, Earth Science, Global Studies, and Area Studies classes. Activities in the modules also support math, language arts, and arts curricula.

GIGI encourages and facilitates the development of a variety of geographic skills that transfer widely into the natural and social sciences. Among these are skills of asking geographic questions and developing and testing geographic generalizations. These require other GIGI skills including examining and making a variety of maps; analyzing photographs; constructing and interpreting graphs and tables of spatial data; and collecting, interpreting, and presenting geographic information.

Finally, GIGI promotes a wide variety of linguistic, numeric, oral, creative, and social skills as well as geographic skills. In particular, GIGI emphasizes cooperative learning. We believe that one of the great strengths of the GIGI modules is that they give students practice in both group and individual problem solving. As students become more familiar with the global issues, they learn that finding solutions to world problems requires people to work together cooperatively.

References

Geography Education Standards Project. 1994. *Geography for Life: The National Geography Standards.* Washington, DC: Geography Education Standards Project.

Hill, A. David, and McCormick, Regina. 1989. *Geography: A Resource Book for Secondary Schools*. Santa Barbara, CA: ABC-Clio, Inc.

Joint Committee on Geographic Education. 1984. *Guidelines for Geographic Education: Elementary and Secondary Schools*. Washington, DC: Association of American Geographers and National Council for Geographic Education.

Slater, Frances. 1993. *Learning through Geography*. Revised. Indiana, PA: National Council for Geographic Education.

Preparing to Teach This Module

Global Climate Change

What could happen if global warming occurs?

The potential for global warming may have an impact on society during your students' lifetimes. The module's main goal is for students to realize that action can be taken now to develop policies that (1) reduce the causes and (2) adapt to the effects of the potential global warming.

It is assumed that students know that Earth's environment is not static. Students may also be aware that environmental systems—especially climate—undergo certain changes over long time scales. However, such long-term changes neither directly affect society nor are affected by humans. The focus here is on shorter-term (during the next 50 years), potentially harmful changes resulting from human activities. The theme of *Human-Environment Interaction* is basic to this module and is stressed in Lesson 1. The lesson also lists the activities that may be leading to climate change. We encourage you to challenge your students to make a personal connection to this issue by devising a contract, in which students agree to modify some aspect of their own life styles for the duration of the module.

Lesson 2 shows evidence for the greenhouse effect and the increasing concentration of greenhouse gases. The key point is that these are both well-documented scientific facts. Whether or not an "enhanced" greenhouse effect will lead to global warming in the next few decades is not certain. Be sure students grasp the difference between scientific fact and hypothesis. Lesson 3 provides text detailing why global warming is, at present, only a hypothesis.

Lesson 4 uses Australia and New Zealand to show how human actions in developed countries cause emissions of the problem gases. The point here is that many activities in developed countries, some essential to the life style to which we are accustomed, lead to greenhouse-gas emissions. Lesson 5 uses maps derived from global climate models to explore the potential soil moisture, and hence, the agricultural changes that Australia may experience by 2030.

Lesson 6 emphasizes the global nature of the problem by looking at how deforestation in the developing world also adds to the problem. Here it is assumed that your students comprehend the differences between *developed* and *developing* countries; these terms are worth reviewing if their meanings are not clear to your class.

The theme of *Region* is used to describe areas of world economic development, and perspectives are drawn throughout the module to the way the issue of global climate change may be perceived by countries in different regions.

Lesson 7 has a mapping activity to investigate problems that could occur from raised sea levels in Louisiana. A key objective here is for students to see that not all societies will be equally capable of adapting to the problems posed.

With the complexity of the issue in mind, students proceed to Lesson 8. Four policy strategies for dealing with global warming are presented. Student groups familiarize themselves with these strategies and engage in a debate, contrasting the positions of developed regions to developing regions. Students should recognize the necessity of international cooperation in addressing this issue. To help give students faith that they can make a difference, the resolution of their debate can be communicated to local, state, and national policymakers.

Important Note to Teachers of Grades 7–8: Some material in this module may be too advanced for the reading level of your students. We suggest three strategies to deal with this, if it arises. First, lead the class through some of the more challenging material, checking for comprehension often. This may lengthen the module somewhat. Second, use cooperative learning groups throughout the module. Within groups, blend in good readers with poorer readers so students can help each other. Finally, several lessons lend themselves well to team-teaching with a science or Earth science class.

Using the BGGS CD-ROM can simplify lesson planning by making it easy to access the resources the system provides for each lesson. It shows exactly which Geopedia™ data and learning activities can be used in long-range and short-term assignments, and which videodisc clips will provide visual reinforcement for each GIGI lesson. The CD-ROM can also show you ways in which a lesson in one module relates to a lesson in another module. And it indicates where to find every reference in GIGI, Geopedia™, the Mini-Atlas maps, and the videodiscs to any key topic—for example, "tsunami" or "Bangladesh." The students will also be able to use the BGGS CD-ROM for further research and short-term or long-term range assignments. The BGGS multimedia components and their uses are explained fully in the tabbed BGGS section in the front of this Teacher's Guide.

The following are general modifications recommended for younger students:

- Plan for fifteen days because the activities will require more teacher explanation and support.
- Provide directions for homework assignments and monitor students' understanding and progress.
- Prior to assigning written activities requiring students to draw conclusions and summarize their findings, ask guiding questions and develop a sample outline on the chalkboard.

Module Objectives

- Identify the human activities believed to be causing global warming.
- Locate on a map areas that may experience changes to agricultural and coastal resources due to global warming.
- List examples of the problems in the scientific data used to predict global warming.
- Identify possible strategies for responding to the issue of global warming.
- Describe how policy options for dealing with global warming may differ between developed and developing countries.
- Describe how individuals can help to reduce the threat of global warming.

Number of Days Required to Teach *Global Climate Change*

Approximately fourteen 50-minute class periods (grades 9–12). Grades 7–8 may need a few extra days.

Suggestions for Teacher Reading

Annual Editions: Environment. These books reprint nontechnical articles from many periodicals. Available from The Dushkin Publishing Group, Inc., Sluice Dock, Guilford, CT 06437. Also see T. D. Goldfarb, editor (1989), *Taking Sides,* from the same publisher.

Flavin, Christopher. 1989. *Slowing Global Warming: A Worldwide Strategy.* Worldwatch Paper 91. Washington, DC: Worldwatch Institute. This book includes an excellent discussion of energy policies, should you wish to extend the module or combine it with a unit on energy. Cost: $4.00 from Worldwatch Institute, 1776 Massachusetts Avenue NW, Washington, DC 20036.

The Math and Science Teacher's Hotline (1-800-877-4777) is a helpful service. If you have questions about the material, or if student questions stray into unfamiliar territory, this hotline may be able to give a useful, emergency response.

National Geographic. 1990. Under the sun. October.

Schneider, Stephen H. 1988. Doing something about the weather. *World Monitor,* December: 28–37. A clearly written summary of the problem from one of the leading voices in climatology. Includes a good duscussion about the way climate models operate.

World Resources Institute. 1990. *World Resources 1990–91.* New York: Oxford University Press. In addition to an extensive chapter on the atmosphere itself, sections throughout the book emphasize how global climate change is interrelated with other environmental issues, such as deforestation, coastal planning, and agriculture. Each edition comes out every two years, updating and summarizing available data on greenhouse-gas emissions. The World Resources Institute has published a companion teacher's guide to their 1990–91 edition, which has more lessons on global climate change.

Suggestion: Dozens of stories about global warming show up in the popular press. More will appear like magic if we have more warm summers, as we did in 1988. No single event created as much awareness about the problem as did that drought. In short: Keep your eyes peeled. And be sure to ask students to clip relevant articles that appear while doing the module.

Lesson 1

What human activities may cause Earth's climate to warm up?

Time Required

One 50-minute class period

Materials Needed

Copies of Activity 1 for all students

Glossary Words

carbon dioxide (CO_2)

chlorofluorocarbons (CFCs)

climate

global warming

greenhouse effect

greenhouse gases

methane (CH_4)

nitrous oxide (N_2O)

Getting Started

- Have the students read the Memo to the Student and the overview on pages 2–3 in the Student DataBook prior to beginning the module. Also make students aware that there is a Glossary in the back of their DataBooks.
- To get the class thinking about how humans adapt to weather conditions, ask five students to predict how much heavy outer clothing other members of the class will wear on the first day of the module. Arrange this with the selected group the night before. Ask them to watch the weather prediction on the nightly news and determine, for example, how many classmates will wear sweaters or coats (perhaps a cold day) and how many will wear only light clothes (a hot day).

  The predicting group gives you their guesses before class begins; you need to compile the results before class. At the start of class, before handing out Student DataBooks, ask another group of students to survey the entire class, asking how much heavy outer clothing the students wore that day. You can then reveal the predictions for comparison. If the weather report was correct, then the predictions should match the survey reasonably well.

  Ask the class how the predicting group knew what people would wear. This should illustrate the reliability of short-term weather forecasts and the idea that people instinctively grasp that heavy clothing is not a good idea on a hot day but is on a cold day.

  Finally, ask the class to predict what they will be wearing one year from today . . . 10 years from today . . . 50 years from today. Will they know what the weather will be like? Having established that long-term forecasts of the weather are uncertain, and having planted the idea that we adapt to our weather expectations in certain ways, begin the module.

Procedures

What's the problem? (pages 4–5)

A. Have a student read the opening quote and text on pages 4–5. This outlines the general nature of the climate change issue.

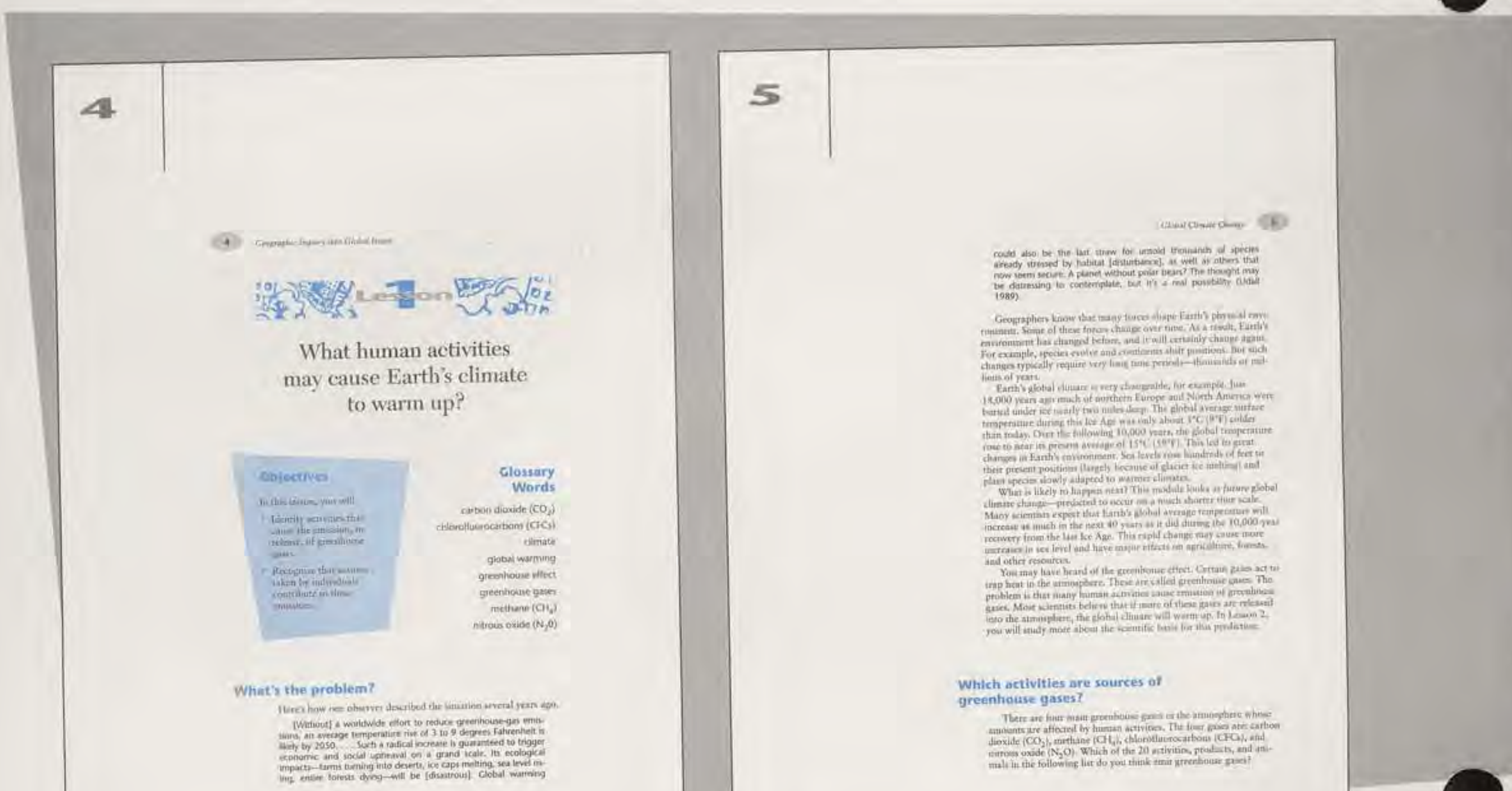
Which activities are sources of greenhouse gases? (pages 5–6)

B. Have students pair off and examine the list of 20 human activities and products on page 6. To gauge student preconceptions of the problem, challenge students to list *only* those items that contribute to greenhouse-gas emissions. After students are done, take a show of hands on selected activities. This list includes well-publicized sources (such as fossil-fuel combustion), which students may have already heard about, as well as less obvious sources, including deforestation, plastic packaging (commonly known by the trademark *Styrofoam*), rice cultivation, and livestock ranching. The trick is that *all* 20 activities listed are part of the problem.

Have a student read the quote from Revkin on page 6. Ask students to explain what he means. Emphasize that most of the activities responsible for the increase in greenhouse gases are part and parcel of our civilization. Thus any attempts to curtail these gases may have extensive repercussions.

Note: If students have questions about why these things are sources of greenhouse gases, refer to the *Background Note* that follows. A brief mention of the carbon cycle illustrates why burning anything that contains carbon—such as coal, oil, natural gas, or trees—releases CO_2 into the air (numbers 1–5 on the list). Methane and nitrous oxide are also produced by deforestation and fossil-fuel combustion. (Remind students that *fossil fuel* is an umbrella term for coal, oil, and natural gas.) Why items 6–20 on the list are sources of these gases may be less well known. Explain these as needed to answer student questions.

> **Background Note**
>
> ACTIVITIES THAT GENERATE GREENHOUSE GASES
>
> - *The Carbon cycle (items 1–5):* Plants take up CO_2 from the atmosphere. In photosynthesis, they convert carbon into organic molecules (carbohydrates) to build plant tissue. Burning fossil fuels, which are composed of concentrated hydrocarbon remains of plants and animals that lived millions of years ago, oxi-



4

Lesson 1

What human activities may cause Earth's climate to warm up?

Objectives

Glossary Words

carbon dioxide (CO_2)
chlorofluorocarbons (CFCs)
climate
global warming
greenhouse effect
greenhouse gases
methane (CH_4)
nitrous oxide (N_2O)

What's the problem?

Here's how one observer described the situation several years ago.

[Without] a worldwide effort to reduce greenhouse-gas emissions, an average temperature rise of 3 to 9 degrees Fahrenheit is likely by 2050. . . . Such a radical increase is guaranteed to trigger economic and social upheaval on a grand scale. Its ecological impacts—farms turning into deserts, ice caps melting, sea level rising, entire forests dying—will be [disastrous]. Global warming

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could also be the last straw for untold thousands of species already stressed by habitat [disturbance], as well as others that now seem secure. A planet without polar bears? The thought may be distressing to contemplate, but it's a real possibility. (Udall 1989)

Which activities are sources of greenhouse gases?

There are four main greenhouse gases in the atmosphere whose amounts are affected by human activities. The four gases are: carbon dioxide (CO_2), methane (CH_4), chlorofluorocarbons (CFCs), and nitrous oxide (N_2O). Which of the 20 activities, products, and animals in the following list do you think emit greenhouse gases?

dizes the stored carbon, releasing CO_2. (The reaction is $C^{+4} + 2O^{-2} \rightarrow CO_2$.) For the past century, the release of carbon to the atmosphere from human activities has exceeded the uptake of carbon by vegetation and the oceans. As a result, carbon dioxide has been accumulating in the atmosphere (Brown and Postel 1987).

- *Coal mining and natural gas transport:* Methane is released during the production processes of coal and natural gas.
- *Rice cultivation and landfills:* Methane is produced under anaerobic (oxygen-free) conditions, which occur under water (rice paddies) or under landfills.
- *Termites and livestock:* Anaerobic bacteria in these herbivores' guts digest the plants' cellulose, producing methane. Cattle, sheep, and goats release the methane via belches and flatulence (students will love this). As livestock populations increase, so does methane emission. As for termites, evidence suggests their populations are exploding in the deforested tropics.
- *Cement:* Limestone is the main ingredient in cement. To produce cement, limestone is subjected to intense heat, releasing CO_2, because limestone is composed of carbonate minerals.
- *Fertilizer:* Nitrogen-based fertilizers are used widely in industrial agriculture. Some 10 percent of the N_2O emitted into the atmosphere comes from chemical reactions of these fertilizers with soil.
- *Nylon:* Nitrous oxide is used to manufacture nylon, a plastic used not only for clothing but also for tires, carpets, and other items.
- *Refrigerators and air conditioners:* CFCs are the main ingredients in these devices' coolant systems. Unless CFCs are captured and recycled when air conditioners and refrigerators are repaired or junked, they escape into the atmosphere.
- *Foam packaging, cushions, and insulation:* CFCs are the chemical blowing agents that produce the rigid- or flexible-cell structure of these plastic foams.
- *Cleaning solvents:* Some CFCs are highly effective degreasers and solvents used in the manufacture of high-tech items, such as computer chips, where even the tiniest impurity can ruin the product.

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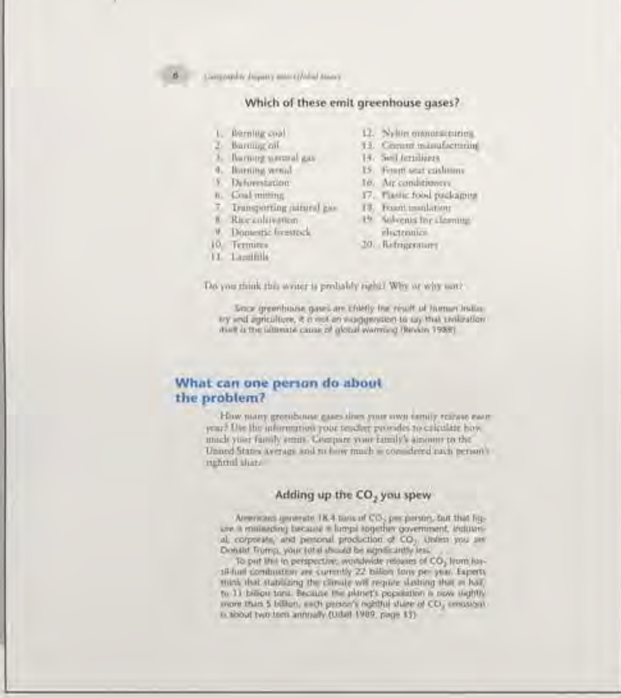

Which of these emit greenhouse gases?

1. Burning coal
2. Burning oil
3. Burning natural gas
4. Burning wood
5. Deforestation
6. Coal mining
7. Transporting natural gas
8. Rice cultivation
9. Domestic livestock
10. Termites
11. Landfills
12. Nylon manufacturing
13. Cement manufacturing
14. Soil fertilizers
15. Foam seat cushions
16. Air conditioners
17. Plastic food packaging
18. Foam insulation
19. Solvents for cleaning electronics
20. Refrigerators

Do you think this writer is probably right? Why or why not?

Since greenhouse gases are chiefly the result of human industry and agriculture, it is not an exaggeration to say that civilization itself is the ultimate cause of global warming (Revkin 1988).

What can one person do about the problem?

How many greenhouse gases does your own family release each year? Use the information your teacher provides to calculate how much your family emits. Compare your family's amount to the United States average and to how much is considered each person's rightful share.

Adding up the CO_2 you spew

Americans generate 18.4 tons of CO_2 per person, but that figure is misleading because it lumps together government, industrial, corporate, and personal production of CO_2. Unless you are Donald Trump, your total should be significantly less.

To put this in perspective, worldwide releases of CO_2 from fossil-fuel combustion are currently 22 billion tons per year. Experts think that stabilizing the climate will require slashing that in half, to 11 billion tons. Because the planet's population is now slightly more than 5 billion, each person's rightful share of CO_2 emissions is about two tons annually (Udall 1989, page 33).

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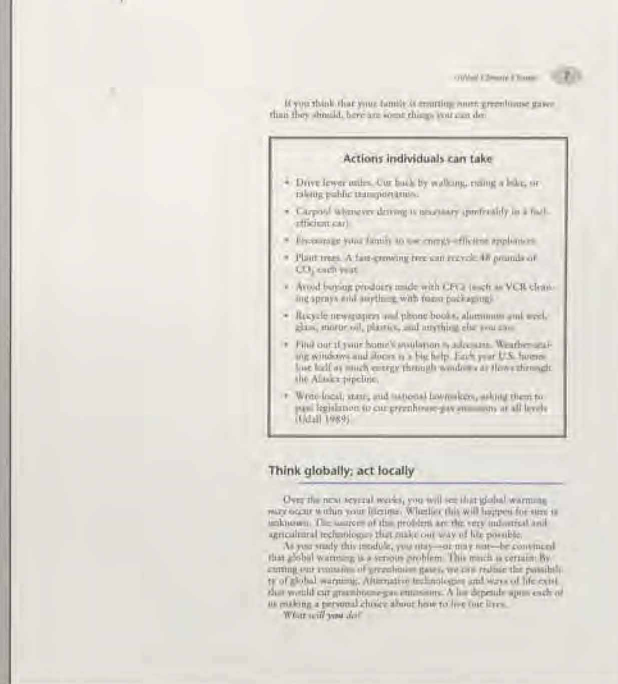


If you think that your family is emitting more greenhouse gases than they should, here are some things you can do:

Actions individuals can take

- Drive fewer miles. Cut back by walking, riding a bike, or taking public transportation.
- Carpool whenever driving is necessary (preferably in a fuel-efficient car).
- Encourage your family to use energy-efficient appliances.
- Plant trees. A fast-growing tree can recycle 48 pounds of CO_2 each year.
- Avoid buying products made with CFCs (such as VCR cleaning sprays and anything with foam packaging).
- Recycle newspapers and phone books, aluminum and steel, glass, motor oil, plastics, and anything else you can.
- Find out if your home's insulation is adequate. Weather-sealing windows and doors is a big help. Each year U.S. homes lose half as much energy through windows as flows through the Alaska pipeline.
- Write local, state, and national lawmakers, asking them to pass legislation to cut greenhouse-gas emissions at all levels (Udall 1989).

Think globally; act locally

Over the next several weeks, you will see that global warming may occur within your lifetime. Whether this will happen for sure is unknown. The sources of this problem are the very industrial and agricultural technologies that make our way of life possible.

As you study this module, you may—or may not—be convinced that global warming is a serious problem. This much is certain: By cutting our emissions of greenhouse gases, we can reduce the possibility of global warming. Alternative technologies and ways of life exist that would cut greenhouse-gas emissions. A lot depends upon each of us making a personal choice about how to live our lives.

What will you do?

What can one person do about the problem? (pages 6–7)

C. Prior to the calculation activity (**Activity 1**), read aloud, "Adding up the CO_2 you spew" on page 6. The actual exercise of adding up one's family's contributions requires preparation. Give students this Activity on the first day of the module to allow them time to gather the data. Students should ask their parents for a copy of any month's utility bill and for the other information needed before this activity is done in class. Collect and discuss the Activities after students have had a few days to complete it. [The monthly totals of gas and electric use must be converted to annual numbers (multiply by 12). This isn't strictly accurate, but then this is only a rough estimate. For most U.S. families, even the most conscientious, the per capita emissions are likely to be far higher than a global mean of two tons per person.]

This calculation exercise may be more than younger students can handle. If so, skip it or go through the steps with *your own family's* data. Many personal activities listed (such as driving less often) are clearly inappropriate for younger students as well.

D. Read the list, "Actions individuals can take" on page 7. Challenge the class to come up with more suggestions that individual citizens can do to save energy and thereby reduce greenhouse-gas emissions. [Turning out lights; turning down the thermostat in winter and wearing warmer clothes indoors, etc.]

E. Have students read the closing paragraphs, "Think globally; act locally." Challenge each student to undertake a personal behavior contract. Ask them to try to reduce or eliminate (as much as possible) those activities that emit greenhouse gases. This might mean taking shorter showers, starting to recycle newspapers, or riding a bike to school instead of driving. Contracts can take the form of signed agreements. After the period of the contract (perhaps a week or two, as long as the module lasts), students should evaluate what the impact on his or her life has been and whether she or he plans to continue these changes.

Lesson 2

Is the greenhouse effect a fact or a theory?

Time Required

Three 50-minute class periods. Younger students may need an extra day if the scientific concepts are unfamiliar.

Materials Needed

Copies of Activity 2 for all students
Transparency of Overhead 1

Glossary Words

carbon dioxide (CO_2)
chlorofluorocarbons (CFCs)
enhanced greenhouse effect
global warming
greenhouse effect
greenhouse gases
longwave radiation
methane (CH_4)
nitrous oxide (N_2O)
shortwave radiation

Procedures

What is the greenhouse effect? (pages 8–11)

This will be a review for students who know the basics of the greenhouse effect. More time may be needed for younger students, perhaps two full periods. Consider co-teaching this part of the lesson with a science class. It may help if the science teacher explains the concepts of longwave and shortwave radiation.


8

8 Geographic Inquiry into Global Issues

Lesson 2

Is the greenhouse effect a fact or a theory?

Objectives

In this lesson, you will:

- Explain the greenhouse effect.
- Describe how the amount of greenhouse gases in the atmosphere has increased since the Industrial Revolution.
- Understand why many scientists expect increased amounts of greenhouse gases to cause global warming over the next few decades.
- Recognize the difference between a scientific fact (greenhouse effect) and an unproven scientific hypothesis (global warming).

Glossary Words

carbon dioxide (CO_2)
chlorofluorocarbons (CFCs)
enhanced greenhouse effect
global warming
greenhouse effect
greenhouse gases
longwave radiation
methane (CH_4)
nitrous oxide (N_2O)
shortwave radiation

What is the greenhouse effect?

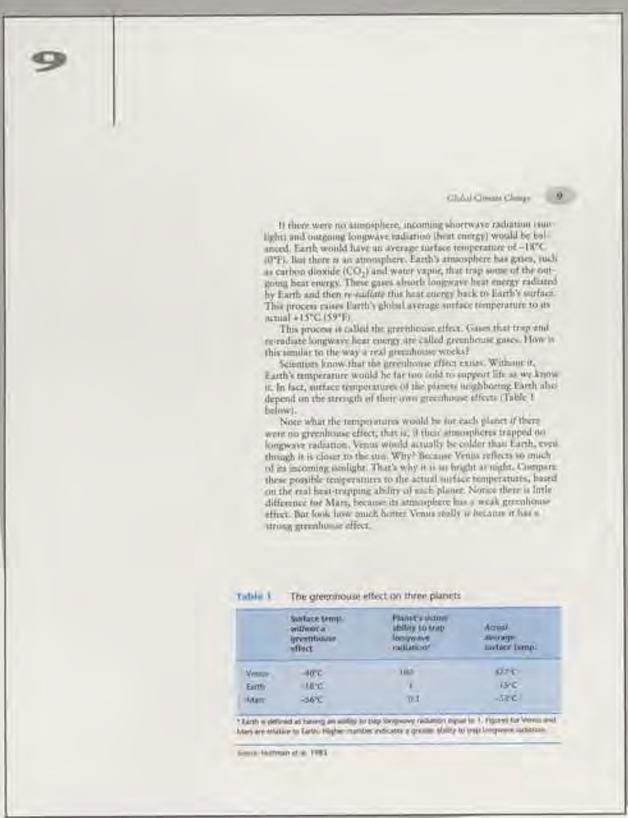
Earth's global average temperature is caused by: (1) sunlight received; (2) sunlight reflected; and (3) heat energy trapped and re-radiated back to Earth by the atmosphere (Figure 1 on page 10).

A. Have students read the text on pages 8–9. Figure 1 on page 10 provides a graphic summary of the process described in this text. You may wish to have students, working in pairs, write in their own words a description of the greenhouse effect, based on the text and figure.

B. Emphasize that the greenhouse effect is not a theory, but a scientific fact supported by empirical evidence. This evidence is described in Table 1 on page 9. To analyze this evidence, it may help to have the class speculate: *Why is Venus hotter than Earth?* Students may share the popular misconception that Venus is hotter than Earth because it is nearer to the sun. In fact the actual surface temperatures of the planets are related more to their atmospheres' abilities to trap longwave radiation (heat) than to their distance from the sun.

   Have students compare the "Surface temperature *without* a greenhouse effect" column for the three planets. This figure is what the temperature would be if temperature were controlled only by the amount of sunlight received and reflected (as in the top diagram on Figure 1). Venus receives more sunlight than Earth, which receives more than Mars (a function of distance from the sun). But much more sunlight is reflected by Venus than by either Earth or Mars (which is why Venus is so bright). If the planets did not differ in their ability to trap heat, Venus would actually be about 22°C *colder* than Earth. But, as Table 1 shows, the planets have very different heat-trapping abilities, accounting for their actual temperatures. The extract "The Goldilocks Phenomenon" on page 11 summarizes this. Discuss Questions 1–2.

   Note: To help students with temperature references, a comparison of the Celsius and Fahrenheit scales is provided as **Overhead 1.**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Global Climate Change 9

If there were no atmosphere, incoming shortwave radiation (sunlight) and outgoing longwave radiation (heat energy) would be balanced. Earth would have an average surface temperature of −18°C (0°F). But there is an atmosphere. Earth's atmosphere has gases, such as carbon dioxide (CO_2) and water vapor, that trap some of the outgoing heat energy. These gases absorb longwave heat energy radiated by Earth and then *re-radiate* this heat energy back to Earth's surface. This process raises Earth's global average surface temperature to its actual +15°C (59°F).

This process is called the greenhouse effect. Gases that trap and re-radiate longwave heat energy are called greenhouse gases. How is this similar to the way a real greenhouse works?

Scientists know that the greenhouse effect exists. Without it, Earth's temperature would be far too cold to support life as we know it. In fact, surface temperatures of the planets neighboring Earth also depend on the strength of their own greenhouse effects (Table 1 below).

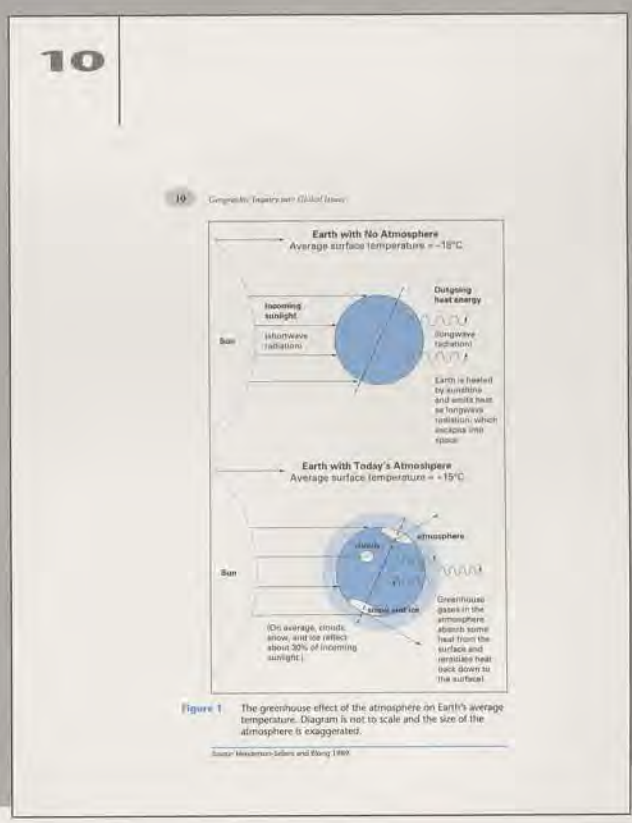
Note what the temperatures would be for each planet *if* there were no greenhouse effect; that is, if their atmospheres trapped no longwave radiation. Venus would actually be colder than Earth, even though it is closer to the sun. Why? Because Venus reflects so much of its incoming sunlight. That's why it is so bright at night. Compare these possible temperatures to the actual surface temperatures, based on the real heat-trapping ability of each planet. Notice there is little difference for Mars, because its atmosphere has a weak greenhouse effect. But look how much hotter Venus really *is* because it has a strong greenhouse effect.

Table 1 The greenhouse effect on three planets

	Surface temp. without a greenhouse effect	Planet's relative ability to trap longwave radiation*	Actual average surface temp.
Venus	-40°C	100	477°C
Earth	-18°C	1	15°C
Mars	-56°C	0.1	-53°C

* Earth is defined as having an ability to trap longwave radiation equal to 1. Figures for Venus and Mars are relative to Earth. Higher number indicates a greater ability to trap longwave radiation.

Source: Hoffman et al. 1983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10 Geographic Inquiry into Global Issues

Figure 1 The greenhouse effect of the atmosphere on Earth's average temperature. Diagram is not to scale and the size of the atmosphere is exaggerated.

Source: Henderson-Sellers and Blong 1989

Questions and Answers for page 11

1. How do you suppose the actual temperatures were measured for Mars and Venus?
   - The "actual" temperatures on Venus and Mars were measured by space probes, which reached these planets in the 1970s.

2. Why has the name "The Goldilocks Phenomenon" been given for comparing the temperatures of the three planets? Is it appropriate? Why or why not?
   - This question can be used as a review to test understanding. Be sure students are clear that Venus is as warm as it is because of its strong greenhouse effect (its atmosphere is about 97 percent CO_2). This makes for an environment not conducive to life as we know it. In contrast, Mars has a minimal atmosphere with a very weak greenhouse effect. Its surface temperature is nearly identical to that expected in the "Surface temp. *without* a greenhouse effect" column in Table 1. Finally, Earth has enough of a greenhouse effect to create a surface temperature that is some 33°C warmer than that expected without an atmosphere. This moderate surface temperature is "just right" for life as we know it to exist on Earth. Whether students think this "Goldilocks" analogy is useful is up to them.


11

Global Climate Change 11

The Goldilocks Phenomenon

Mars—a planet with a thin . . . atmosphere—has an [average] temperature well below that of most deep freezers. Venus—with a very thick . . . atmosphere—has a temperature hotter than an oven. Earth—with a moderate amount of atmosphere—contains liquid water, [comfortable] temperatures, and abundant life. Mars is too cold, Venus is too hot, and Earth is just right—what some planetary climatologists call the Goldilocks Phenomenon, which is well understood to be a result of the greenhouse effect (Schneider 1988, pages 29–30).

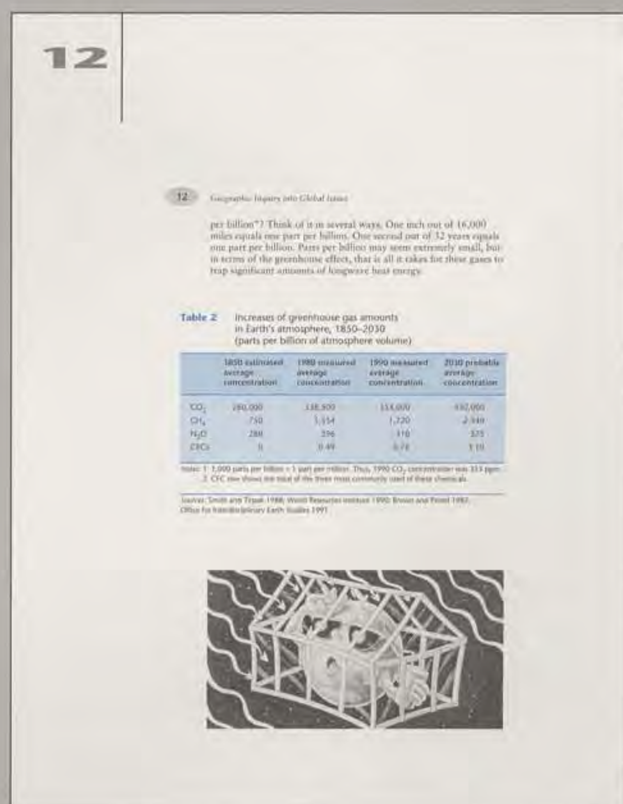
1. How do you suppose the actual temperatures were measured for Mars and Venus?
2. Why has the name "The Goldilocks Phenomenon" been given for comparing the temperatures of the three planets? Is it appropriate? Why or why not?

What gases cause the greenhouse effect?

Carbon dioxide (CO_2) and water vapor aren't the only greenhouse gases in Earth's atmosphere. Two other important greenhouse gases are methane (CH_4) and chlorofluorocarbons (CFCs). Carbon dioxide and methane come from both natural sources and human activities. CFCs are synthetic gases that began being manufactured in the 1940s. They are used in refrigeration, foam packaging, and many other products. Water vapor mainly comes from evaporation of the oceans.

Three gases—CO_2, CH_4, and CFCs—account for about 86 percent of all human greenhouse-gas emissions. Other greenhouse gases, including nitrous oxide (N_2O), represent the remaining total of about 14 percent of all human greenhouse-gas emissions (World Resources Institute 1990; Shea 1988).

The amounts of all these gases have increased since the Industrial Revolution began (Table 2 on page 12). Concentrations of gases in the atmosphere are given in "parts per billion." For comparison, remember that *percent* means "parts per hundred." What is a "part


12

12

per billion"? Think of it in several ways. One inch out of 16,000 miles equals one part per billion. One second out of 32 years equals one part per billion. Parts per billion may seem extremely small, but in terms of the greenhouse effect, that is all it takes for these gases to trap significant amounts of longwave heat energy.

Table 2 Increases of greenhouse gas amounts in Earth's atmosphere, 1850–2030 (parts per billion of atmosphere volume)

	1850 estimated average concentration	1980 measured average concentration	1990 measured average concentration	2030 probable average concentration
CO_2	280,000	338,500	353,000	[illegible]
CH_4	750	1,554	1,720	2,340
N_2O	288	296	310	325
CFCs	0	0.49	0.78	1.10

Notes: 1. 1,000 parts per billion = 1 part per million. Thus, 1990 CO_2 concentration was 353 ppm.
2. CFC row shows the total of the three most commonly used of these chemicals.

What gases cause the greenhouse effect? (pages 11–13)

C. This part of the lesson shifts to the idea of the enhanced greenhouse effect. The text on pages 11–12 names the four major trace greenhouse gases. *Note:* A fifth greenhouse gas, ozone in the lower atmosphere (troposphere), is not discussed in this module. Its discussion may confuse students, who must differentiate between tropospheric ozone (a dangerous pollutant and greenhouse gas) and stratospheric ozone (the beneficial layer in the upper atmosphere that blocks ultraviolet radiation).

Clarify the meaning of *parts per billion* (ppb) and *parts per million* (ppm). Compare these measures of concentration with the more familiar parts per hundred (percent). Note that 1,000 ppb = 1 ppm. The text on pages 11–12 gives a few examples to help. Note that some pollutants have such low concentrations that it is only possible to measure them in ppm or ppb, but that doesn't mean the amounts are insignificant. Point out that some elements are toxic at extremely low concentrations (e.g., plutonium). Greenhouse gases effectively trap longwave radiation even at low concentrations.

D. Have students describe what Table 2 on page 12 shows. [Concentrations of the key greenhouse gases are increasing.] Pass out **Activity 2** and have students graph concentrations for CO_2 for 1850 (representing preindustrial times), 1980, 1990, and 2030. Students should then answer Questions 3–6.

Older students can do more analysis on Table 2. Students could graph all four gases and calculate the percentage rate of growth for each. [For comparison, the actual annual rates of growth of these gases are methane, 12 percent per year; CFCs, 57 percent per year; and carbon dioxide, 0.5 percent per year.]

Questions and Answers for page 13

3. On your graph of the CO_2 data, which line segment is steeper: the segment for 1850–1980 or the segment for 1980–1990? What does the change indicate? How does the segment for 1990–2030 compare to the other two segments—is it steeper or more gradual? What does this show you? Why is this important?
   - In rank order, the line segment from 1990–2030 is the steepest, followed by the period 1980–1990, and finally, 1850–1980 (see *Key for Activity 2*).

4. What conclusion can you draw about the *trend* in the rate of growth of carbon dioxide? Is it similar to or different from the trends for the other gases?
   - Steeper line segments on the graph indicate more rapid growth. The graph demonstrates that the rate of growth for CO_2 is increasing. Students should be able to compare *qualitatively* the trends in the other gases and conclude that the pattern is roughly similar.

5. The 1850 concentrations are probably similar to what the atmosphere contained before the Industrial Revolution. All these "preindustrial" concentrations are estimates, except for the CFCs. How do we know their preindustrial concentration was zero?
   - We know the preindustrial concentration of CFCs was zero because they were invented in the 1940s.

6. What would you most like to know about these trends?
   - Answers here will vary. The question we hope students will ask, of course, is: "Why are these gases increasing?"

What effect will an increase in greenhouse gases have? (pages 13–16)

E. Review material covered so far. By this point, students should see that the greenhouse effect itself is an accepted fact. It is also established that the amounts of greenhouse gases are increasing. The final sections of the lesson get into speculation. The scientific controversy arises when the accepted facts are used to hypothesize the likelihood of global warming. In sum, greenhouse effect = scientific fact; global warming = scientific hypothesis. Tell students to think of themselves as jurors judging evidence at a trial as they go through the following activities.

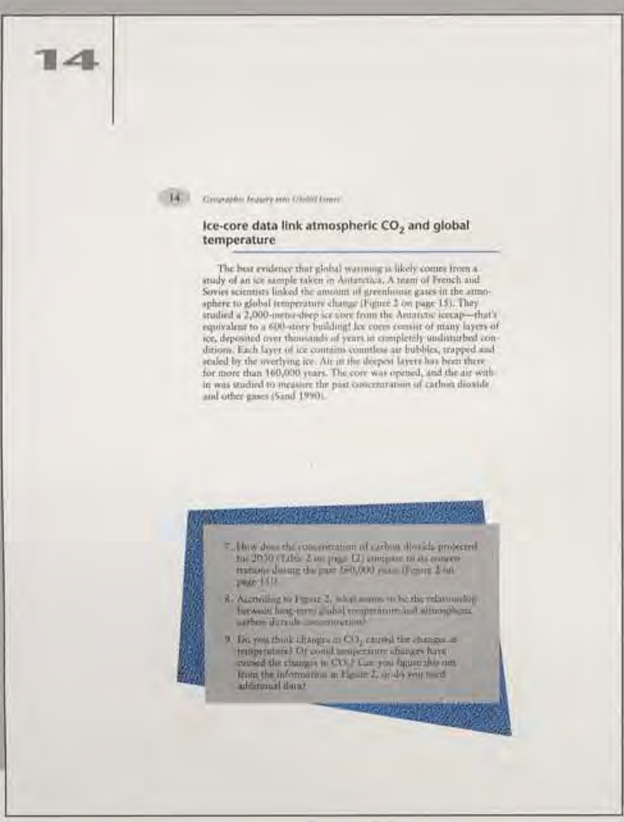
Have students read "Ice-core data link atmospheric CO_2 and global temperature" on page 14, which explains how the data shown in Figure 2 were obtained. Note that the same ice-core samples were used to calculate both the prehistoric temperatures and CO_2 concentrations. Discuss Questions 7–9.


13

What effect will an increase in greenhouse gases have?

The greenhouse effect causes Earth to be warmer than it would be if it had no atmosphere. Also, the concentrations of greenhouse gases have been increasing steadily since the mid-nineteenth century. These are scientific facts.

But will Earth get warmer as the atmosphere traps more and more heat? Will Earth's atmosphere re-radiate so much heat back to the surface that the whole planet heats up? Many scientists think that it will—they call this the "enhanced" greenhouse effect. The hypothesis, or theory, that the enhanced greenhouse effect will cause Earth to heat up is called global warming. What evidence supports this theory?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Ice-core data link atmospheric CO_2 and global temperature

The best evidence that global warming is likely comes from a study of an ice sample taken in Antarctica. A team of French and Soviet scientists linked the amount of greenhouse gases in the atmosphere to global temperature change (Figure 2 on page 15). They studied a 2,000-meter-deep ice core from the Antarctic icecap—that's equivalent to a 600-story building! Ice cores consist of many layers of ice, deposited over thousands of years in completely undisturbed conditions. Each layer of ice contains countless air bubbles, trapped and sealed by the overlying ice. Air in the deepest layers has been there for more than 160,000 years. The core was opened, and the air within was studied to measure the past concentration of carbon dioxide and other gases (Sand 1990).

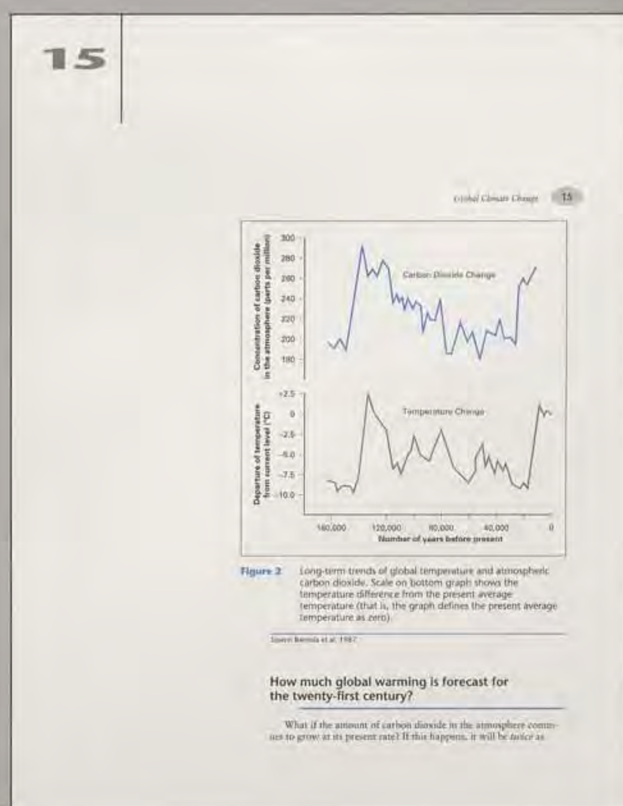
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Figure 2 Long-term trends of global temperature and atmospheric carbon dioxide. Scale on bottom graph shows the temperature difference from the present average temperature (that is, the graph defines the present average temperature as zero).

How much global warming is forecast for the twenty-first century?

Questions and Answers for page 14

7. How does the concentration of carbon dioxide projected for 2030 (Table 2) compare to its concentrations during the past 160,000 years (Figure 2)?

   - By comparing Figure 2 with Table 2, students can discover that the concentration of carbon dioxide forecast for the twenty-first century (450 ppm) will be much higher than anything experienced on Earth in the last 160,000 years (280 ppm).

8. According to Figure 2, what seems to be the relationship between long-term global temperature and atmospheric carbon dioxide concentration?

   - On Figure 2, students should note the close historical correspondence between changes in CO_2 concentration and surface temperature. Both seem to change together.

9. Do you think changes in CO_2 caused the changes in temperature? Or could temperature changes have caused the changes in CO_2? Can you figure this out from the information in Figure 2, or do you need additional data?

   - This question may be too difficult for younger students. Because of the rough time scale of the graph, there is no way to tell *from this graph* whether increased concentrations of CO_2 actually cause warmer temperatures. This is really only a correlation (variables are related, but causality is not implied). Students ought to recognize, however, that because carbon dioxide is known to contribute to the greenhouse effect, it is *likely* that increases of CO_2 have historically triggered warmer temperatures.

     If students ask *why* CO_2 has fluctuated historically, it is related to the expansion and contraction of glaciers during the Ice Ages. As glaciers expand, there is less vegetation on land to absorb CO_2, so the amount of the gas in the atmosphere increases. This leads to increased temperatures, which reduces the size of glaciers. As glaciers shrink, more land is exposed and vegetation returns. More atmospheric CO_2 is absorbed, decreasing the concentration of the gas in the atmosphere.

F. Have students read the text on pages 15–16. Discuss Questions 10–11 with the class.

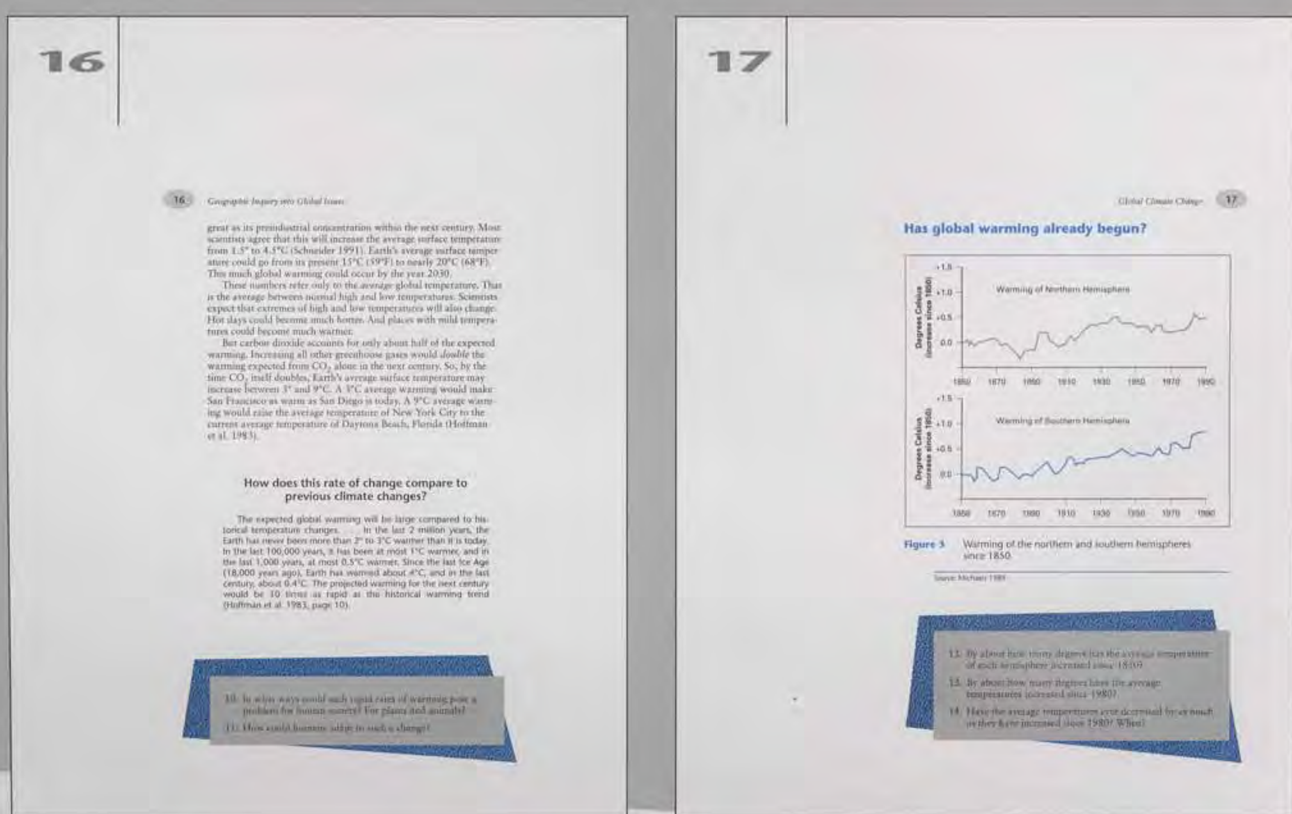
Questions and Answers for page 16

10. In what ways could such rapid rates of warming pose a problem for human society? For plants and animals?
    - In society, clothing and housing, and sometimes social activities, are often geared to climatic concerns. Humans are generally capable of rapid adaptation to such changes because they can adapt culturally. But for other species, which are ecologically adapted to the modern climate, rapid change may be impossible.

11. How could humans adapt to such a change?
    - This question can be left as an open question for discussion or thought, or assigned as a homework writing assignment. In discussion, you might plant the idea that some strategies for adapting to warmer climates (e.g., moving to a more comfortable climate or using air conditioning) require money.

Has global warming already begun? (pages 17–18)

G. The final section of the lesson gives evidence that the warming has begun (Figure 3 on page 17). Discuss Questions 12–14 with the class.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16 *Geographic Inquiry into Global Issues*

great as its preindustrial concentration within the next century. Most scientists agree that this will increase the average surface temperature from 1.5° to 4.5°C (Schneider 1991). Earth's average surface temperature could go from its present 15°C (59°F) to nearly 20°C (68°F). This much global warming could occur by the year 2030.

These numbers refer only to the *average* global temperature. That is the average between normal high and low temperatures. Scientists expect that extremes of high and low temperatures will also change. Hot days could become much hotter. And places with mild temperatures could become much warmer.

But carbon dioxide accounts for only about half of the expected warming. Increasing all other greenhouse gases would *double* the warming expected from CO_2 alone in the next century. So, by the time CO_2 itself doubles, Earth's average surface temperature may increase between 3° and 9°C. A 3°C average warming would make San Francisco as warm as San Diego is today. A 9°C average warming would raise the average temperature of New York City to the current average temperature of Daytona Beach, Florida (Hoffman et al. 1983).

How does this rate of change compare to previous climate changes?

The expected global warming will be large compared to historical temperature changes. . . . In the last 2 million years, the Earth has never been more than 2° to 3°C warmer than it is today. In the last 100,000 years, it has been at most 1°C warmer, and in the last 1,000 years, at most 0.5°C warmer. Since the last Ice Age (18,000 years ago), Earth has warmed about 4°C, and in the last century, about 0.4°C. The projected warming for the next century would be 10 times as rapid as the historical warming trend (Hoffman et al. 1983, page 10).

10. In what ways could such rapid rates of warming pose a problem for human society? For plants and animals?
11. How could humans adapt to such a change?

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Global Climate Change 17

Has global warming already begun?

Figure 3 Warming of the northern and southern hemispheres since 1850.

Source: Michaels 1989

12. By about how many degrees has the average temperature of each hemisphere increased since 1850?
13. By about how many degrees have the average temperatures increased since 1980?
14. Have the average temperatures ever decreased by as much as they have increased since 1980? When?

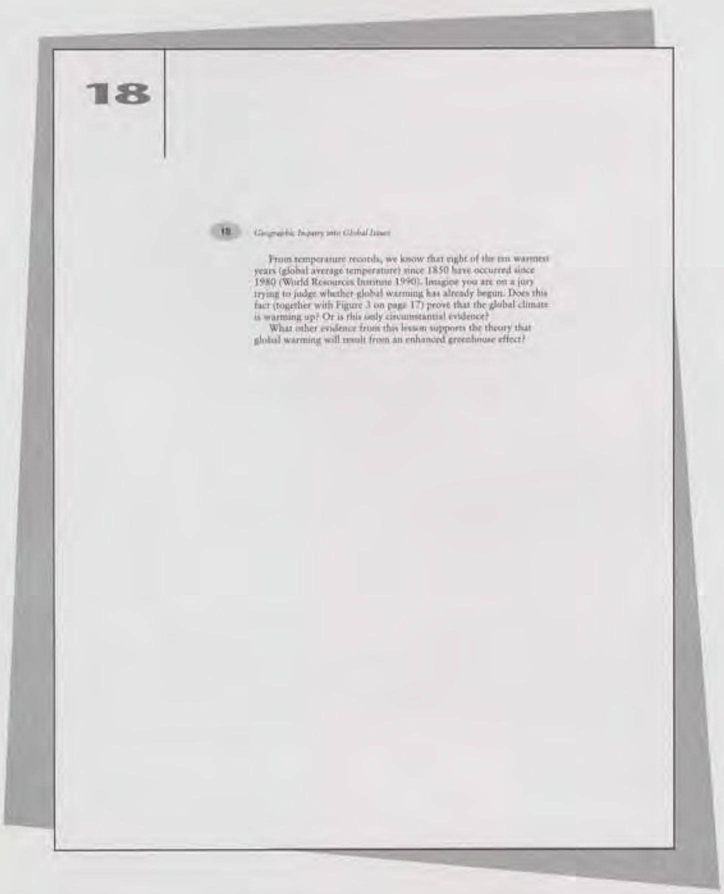
Questions and Answers for page 17

12. By about how many degrees has the average temperature of each hemisphere increased since 1850?
    - Since 1850, average temperatures have increased between 0.5 and 1.0°C.

13. By about how many degrees have the average temperatures increased since 1980?
    - Since 1980, average temperatures have increased about 0.3°C.

14. Have the average temperatures ever decreased by as much as they have increased since 1980? When?
    - Yes, there have been periods where as much cooling took place as the warming that occurred since 1980. (For example, 1880–1890; 1900–1910; 1940–1960.)

H. End the lesson by asking students, the jurors, the closing questions on page 18, to get student opinion whether these data are proof that a global warming trend has begun. [Student opinion will, of course, vary. Note that the data presented to make the case for global warming are only circumstantial. But taken together, the data displayed during this lesson make for a stronger case. These include the Goldilocks Phenomenon, the ice-core records, and the fact that some warming has already occurred since the Industrial Revolution (coinciding with the 25 percent increase in preindustrial CO_2).]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18 *Geographic Inquiry into Global Issues*

From temperature records, we know that eight of the ten warmest years (global average temperature) since 1850 have occurred since 1980 (World Resources Institute 1990). Imagine you are on a jury trying to judge whether global warming has already begun. Does this fact (together with Figure 3 on page 17) prove that the global climate is warming up? Or is this only circumstantial evidence?

What other evidence from this lesson supports the theory that global warming will result from an enhanced greenhouse effect?

Lesson 3

Is global warming unavoidable?

Time Required

One 50-minute class period

Materials Needed

Two cardboard boxes
Two high-powered lights
Two thermometers
A large sheet of heavy paper (big enough to cover a box)
Cotton
A large jar of water

Glossary Words

carbon dioxide (CO_2)
chlorofluorocarbons (CFCs)
climate models
global warming
greenhouse effect
greenhouse gases
longwave radiation
methane (CH_4)

Getting Started

This lesson summarizes the scientific debate about global warming. Remind students of the points made in Lesson 2: There is scientific verification of the greenhouse effect and careful measurements have shown that greenhouse gases are increasing. Whether this will lead to global warming remains controversial. In this lesson, students will read three major criticisms of the computer models used to make climate change forecasts. The two simple demonstrations that follow may help illustrate these critiques. These demonstrations can be coordinated with a science class for younger students. To make this more of a hands-on project, select some students to conduct the demonstrations.

Demonstration 1

The first criticism is that the models don't account for how clouds affect temperature. To show the effect of clouds, set up one cardboard box with a light shining directly into it (representing the sun). Use a thermometer to record the temperature inside the box (let the box heat up a bit before starting). On the other box, place the heavy paper with the cotton-ball "clouds" glued onto it between the thermometer and the light. The "clouds" will block the "sun," keeping the temperature inside the box lower. This demonstrates that cloudiness can reflect incoming radiation.

Demonstration 2

The second major criticism of the computer climate models is that they don't accurately represent the influence of oceans on global temperatures. Again, you need the two cardboard boxes, the two high-powered lights, and the two thermometers. Also, you need a large jar containing water, which must be at room temperature.

To show how water moderates temperatures, set up a control box, with just the thermometer and light, which in this case represents sunlight striking a land surface. In the other box, place the thermometer inside the room-temperature jar of water. The temperature should not increase in this box as rapidly as it does in the box representing a land surface, mirroring how the oceans act as a heat "sink."

With these two demonstrations fresh in their minds, students may be able to understand what the models' critics are saying.

Procedures

What is the scientific controversy about global warming? (pages 19–20)

A. Have students read this text, which introduces the reasons for the scientific uncertainty.

What are the flaws in the computerized climate models? (pages 20–23)

B. Divide the class into small groups. Each person in a group will be responsible for reading one of the three sections: Criticism A about clouds, Criticism B about oceans, and Criticism C about data inconsistencies. Within each group, each student reads one of the criticisms and becomes an "expert" on his or her topic. That student then briefs the others in the group. Each expert plays the role of teacher within the group, explaining the material and asking the questions that follow each section. Together, the student groups work to answer the questions. Suggested answers follow. If you wish, reconvene the entire class at the end and allow time for discussion.

Criticism C is tougher than the others, in part because it covers a lot of ground. If the reading level is above your class, *skip this section.* Students can simply discuss the first two critiques.


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Global Climate Change 19

Lesson 3

Is global warming unavoidable?

Objectives

In this lesson, you will

- Examine the scientific controversy about global warming.
- Understand that there are many questions about the reliability of climate change models.

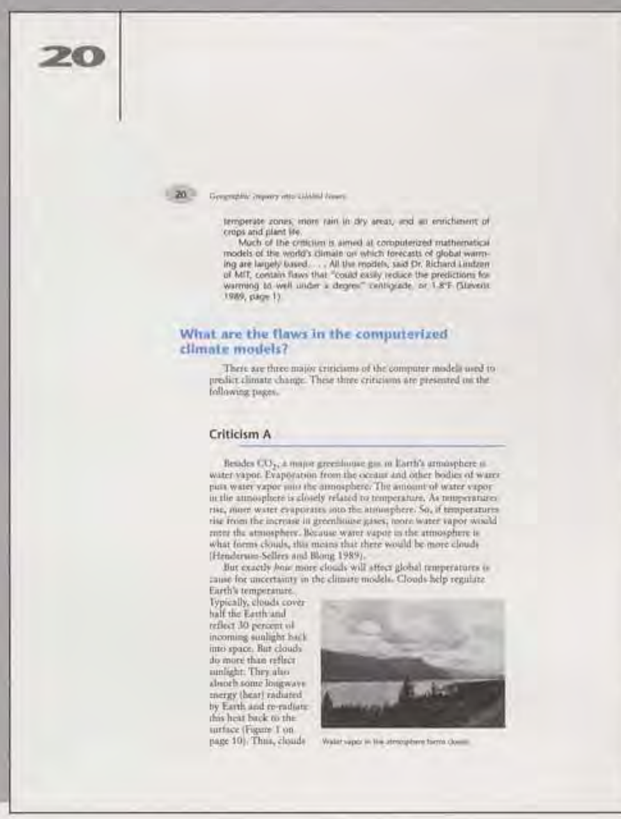
Glossary Words

carbon dioxide (CO_2)
chlorofluorocarbons (CFCs)
climate models
global warming
greenhouse effect
greenhouse gases
longwave radiation
methane (CH_4)

What is the scientific controversy about global warming?

Not long ago many scientists thought the climate was cooling, not warming. However, evidence now suggests to some scientists that the twenty-first century may be warmer. The greenhouse effect is known to exist and the concentration of greenhouse gases is known to be increasing. But other scientists debate whether the increase in greenhouse gases will actually cause global warming in the next 40 years.

Skeptics contend that forecasts of global warming are flawed and overstated and that the future might even hold no significant warming at all. Some say that if the warming is modest, as they believe likely, it could bring benefits like longer growing seasons in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20 Geographic Inquiry into Global Issues

temperate zones, more rain in dry areas, and an enrichment of crops and plant life.

Much of the criticism is aimed at computerized mathematical models of the world's climate on which forecasts of global warming are largely based. . . . All the models, said Dr. Richard Lindzen of MIT, contain flaws that "could easily reduce the predictions for warming to well under a degree" centigrade, or 1.8°F (Stevens 1989, page 1).

What are the flaws in the computerized climate models?

There are three major criticisms of the computer models used to predict climate change. These three criticisms are presented on the following pages.

Criticism A

Besides CO_2, a major greenhouse gas in Earth's atmosphere is water vapor. Evaporation from the oceans and other bodies of water puts water vapor into the atmosphere. The amount of water vapor in the atmosphere is closely related to temperature. As temperatures rise, more water evaporates into the atmosphere. So, if temperatures rise from the increase in greenhouse gases, more water vapor would enter the atmosphere. Because water vapor in the atmosphere is what forms clouds, this means that there would be more clouds (Henderson-Sellers and Blong 1989).

But exactly *how* more clouds will affect global temperatures is cause for uncertainty in the climate models. Clouds help regulate Earth's temperature. Typically, clouds cover half the Earth and reflect 30 percent of incoming sunlight back into space. But clouds do more than reflect sunlight. They also absorb some longwave energy (heat) radiated by Earth and re-radiate this heat back to the surface (Figure 1 on page 10). Thus, clouds

Water vapor in the atmosphere forms clouds.

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make their own greenhouse effect. However, at present the reflective behavior of clouds is greater than their greenhouse effect. So, clouds currently have an overall cooling effect on Earth's average surface temperature (World Resources Institute 1990).

Will this cooling effect from clouds remain if global warming occurs? It depends on the height of the clouds. High clouds (called cirrus clouds) trap Earth's heat well. But low- to mid-level clouds (stratus and cumulus) reflect incoming solar radiation. So, if global warming increases the amount of high clouds, the present cooling effect might be reduced or even changed to a warming effect. This would add to the world's overall global warming. On the other hand, increasing the amount of low- and mid-level clouds might increase the cooling effect and counteract any global warming (World Resources Institute 1990).

Computerized climate modeling is not yet advanced enough to make dependable predictions of the change in cloud heights if global warming occurs. We just don't know which possibility—greater heating or greater cooling from clouds—will occur in a world with more greenhouse gases.

1. Note that clouds can both reflect light and hold surface heat. Explain how these two effects might counteract one another.
2. Summarize Criticism A in one or two sentences.
3. What would be a good title for Criticism A? Why?

Criticism B

About 70 percent of Earth's surface is covered by oceans. The average depth of the oceans is over 4 kilometers. So, there is a huge amount of water that would have to be heated before global warming occurs. But water takes much longer to heat up than air does.

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The following quote explains why this leads to uncertainty about the accuracy of computerized climate models:

> The heating of the upper part of the ocean (the top 70 meters or so) can be represented by a warming body of water, like a vast swimming pool. [We] understand quite a lot about how this top slice of the ocean will warm; but there is almost four kilometers below this, which is called the "deep ocean." This deep ocean has a circulation of its own, which has to be modeled in the same way as we model the atmospheric circulation. All we can say with confidence so far about the deep ocean circulation is that it acts in such a way that warm water is pulled down very deeply. The net result of this is that the deep ocean circulation is effectively removing heat from the climate system. Of course, eventually all the deep ocean will warm, but we do not know how long this will take (Henderson-Sellers and Blong 1989, pages 47–49).

How long will it take the deep ocean temperatures to rise to the new surface temperature? Most scientists estimate that warming of the deep ocean will take from 80 to 100 years. But some scientists think it will take only 20 years, and others think it may take as long as 500 years. However long it takes for the deep ocean to heat, it will slow global climate change down a bit (Henderson-Sellers and Blong 1989).

Models of ocean circulation are less advanced, and therefore less accurate, than models of the atmosphere. Predictions about the atmosphere can be tested against observations of other planets. But there is no other ocean in the solar system that can be used to test scientific predictions about our oceans (Henderson-Sellers and Blong 1989).

4. You read that water takes a longer time to heat up than air does. Think of an example to show that water temperatures are usually cooler than air temperatures.
5. Summarize Criticism B in one or two sentences.
6. What would be a good title for Criticism B? Why?

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Criticism C

The atmospheric amounts of both CO_2 and CH_4 have risen enormously since 1950. All CFCs came from human actions during the past 50 years. But the record of temperature increases since 1850 (Figure 3 on page 17) shows that most of the warming that occurred during the past century happened *before* 1950 and the huge increases in greenhouse gases. In fact, the northern hemisphere shows no overall change after about 1940. During this period, CO_2 amounts increased from about 300 ppm to 350 ppm (Michaels 1989).

In addition, temperatures in the higher latitudes (toward the poles) have not increased during this century as predicted. The evidence shows that there was a rise in temperature *before* there was a significant increase in greenhouse gas emissions. This temperature rise was actually followed by a decline in temperature in higher latitudes. A study in Alaska showed that there was no measurable trend in temperature change since 1950 (Michaels 1989).

Predictions of warming are often based on the similarity of past climate changes to the CO_2 record, as shown by ice cores taken from Antarctica (Figure 2 on page 15). However, one cannot actually determine from these records whether changes in CO_2 came *before* or *after* changes in temperature.

In addition, human actions also produce substances that counteract the warming. Some of these are common air pollutants in urban areas. For example, molecules of sulfur dioxide can serve as centers around which water vapor condenses, forming clouds. These pollutants can thus brighten clouds. This could increase the reflection of sunlight and reduce the warming from increased greenhouse gases. In fact, this could explain why the northern hemisphere has not yet warmed up as much as predicted, since most sulfur dioxide emissions occur in the industrialized northern hemisphere (Michaels 1989).

7. Sulfur dioxide is known as a major source of acid rain. If Criticism C is correct about the effect of this substance on global warming, should it still be considered a pollutant? Why do you think as you do?
8. Summarize Criticism C in one or two sentences.
9. What would be a good title for Criticism C? Why?

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Lesson summary

Climatologist Reid Bryson had this to say about climate models:

> A statement of what the climate is going to be in the year A.D. 2050 is a 63-year forecast. Do the models have a demonstrated capability of making a 63-year forecast? No. A 6.3 year forecast? No. Have they successfully simulated the climatic variability of the past century and a half? No. They are marvels of mathematics and computer science, but rather crude imitators of reality (Brookes 1989, page 100).

10. Do you think that the evidence that supported the models (covered in Lesson 2) is enough to outweigh the criticisms in this lesson?
11. Clearly scientists are not in agreement. What should governments do in the face of this uncertainty? Do you think more research will solve the problem? Why or why not?

How long will it take for scientists to be sure?

> It will take at least five years to build the . . . atmosphere, ocean, biosphere, land-surface, sea-ice, and chemistry submodels that are needed if scientists are to have any hope of predicting the evolving regional climatic changes. Five to ten years may be necessary to get computers large enough to run such models routinely to determine the quality of their forecasts. Also, some five to ten years will pass before major data-gathering projects begin to provide data to validate the various subcomponents of such modeling. Thus, 10 to 20 years is suggested as the time required for everything to come together and for detailed predictive skill to become credible (Schneider 1991, page 27).

What's your opinion? Should we wait until we are certain that global warming will occur before we take any action? Or do you think the problems of climate change are severe enough that some action should be taken now? Why do you think as you do?

Questions and Answers for pages 21–23

1. Note that clouds can both reflect light and hold surface heat. Explain how these two effects might counteract one another.
   - *Criticism A (Clouds):* Reflecting clouds act to cool the planet by cutting down the incident sunlight, so there is less longwave radiated by the planet. And, like other greenhouse gases, water vapor in clouds acts to trap heat by absorbing and reradiating longwave radiation.

2–3. Summarize Criticism A in one or two sentences. What would be a good title for Criticism A? Why?

   - Summaries and names of the criticism will vary.

4. You read that water takes a longer time to heat up than air does. Think of an example to show that water temperatures are usually cooler than air temperatures.
   - *Criticism B (Oceans):* Possible examples of how water takes longer to heat up than air include a swimming pool being colder than the air on a hot day (or lakes, the ocean, etc.).

5–6. Summarize Criticism B in one or two sentences. What would be a good title for Criticism B? Why?

   - Summaries and names of the criticism will vary.

7. Sulfur dioxide is known as a major source of acid rain. If Criticism C is correct about the effect of this substance on global warming, should it still be considered a pollutant? Why do you think as you do?
   - *Criticism C (Data inconsistencies):* The question really has no correct answer and is open for group discussion. One point that should emerge is how complex modeling the atmosphere really is, because we don't yet know how all of its various chemical components interact. Thus, chemicals that do harm in one arena, such as sulfur dioxide, may also actually counteract warming.

8–9. Summarize Criticism C in one or two sentences. What would be a good title for Criticism C? Why?

   - Summaries and names of the criticism will vary.

Lesson summary (page 24)

C. Students should read the text on page 24. Questions 10–11 can form the basis for class discussion, or groups can try to reach a consensus, which could be part of their reports. Have students decide whether waiting for certainty is best or if the problem is worth acting on immediately. If you wish, ask students to write a short essay explaining the rationale behind their opinions.

Questions and Answers for page 24

10. Do you think that the evidence that supported the models (covered in Lesson 2) is enough to outweigh the criticisms in this lesson?
    - Answers will vary.

11. Clearly scientists are not in agreement. What should governments do in the face of this uncertainty? Do you think more research will solve the problem? Why or why not?
    - Answers will vary.

Lesson 4

How do developed countries add greenhouse gases?

Time Required

Two 50-minute class periods

Materials Needed

Colored pencils (some dark and some light shades)
Copies of Activities 3 and 4 for each group of students
Mini-Atlas map 1

Glossary Words

carbon dioxide (CO_2)
chlorofluorocarbons (CFCs)
deforestation
developed country
greenhouse gases
methane (CH_4)

Getting Started

- Introduce the module's major case study by asking students which of the 20 activities listed on page 6 in Lesson 1 might be engaged in by Australians or New Zealanders.

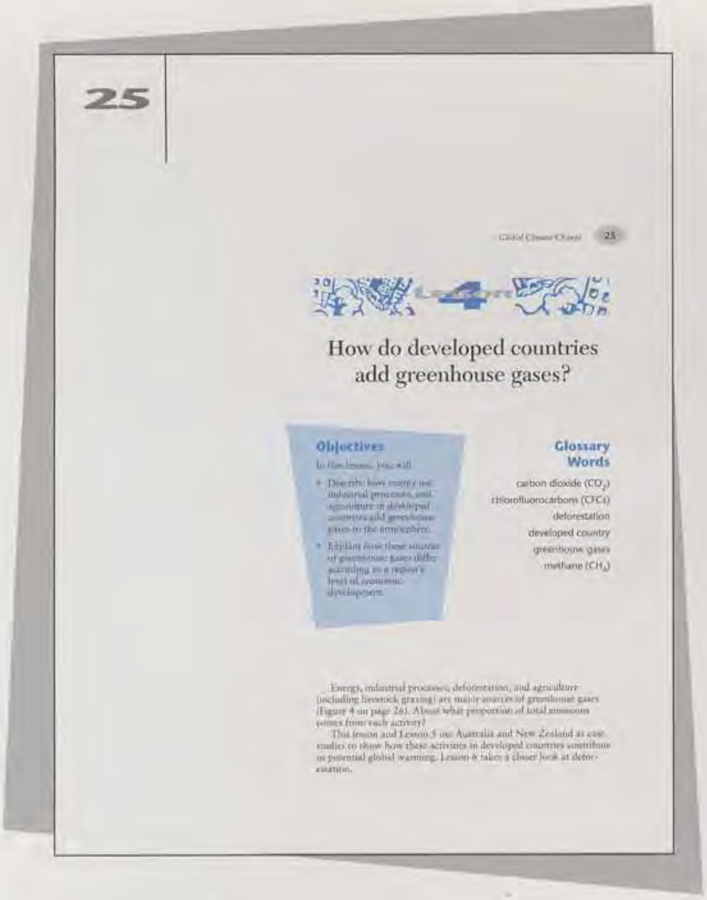
  Suggestion: Show a video that illustrates what life is like in Australia. Possibilities include the installment on Australia from *Global Geography;* a program from *National Geographic* entitled "The Continents—Australia"; or even any travel video about Australia or New Zealand.

- Discuss how Australian life is similar to that in the United States. Students should see that Australia and New Zealand are economically similar to the United States. It is appropriate to use Australia and New Zealand as case studies, because (as students will discover) they have among the world's highest per person emissions of greenhouse gases. Two reasons for this emerge in this lesson: (1) As industrial nations, Australia and New Zealand use many of the same products and processes that the United States does; and (2) Australia and New Zealand rely heavily on livestock ranching. The data in the lesson emphasize that Australia and New Zealand typify developed countries in that they contribute significantly to greenhouse-gas emissions. Be sure students recognize that, as citizens of the United States, they may face many of the problems associated with climate change that are described for the case study.

Procedures

A. Figure 4 on page 26 summarizes the source of greenhouse gases by activity. Have students evaluate this illustration. They should see that energy accounts for about half of the emissions and industrial processes account for about 25 percent.

   Before going on, be sure students are familiar with the conceptual difference between *developed* and *developing* countries, and have students give examples of places that fit each category. Ask whether the activities shown in Figure 4 are more likely to be found in developed or developing countries.

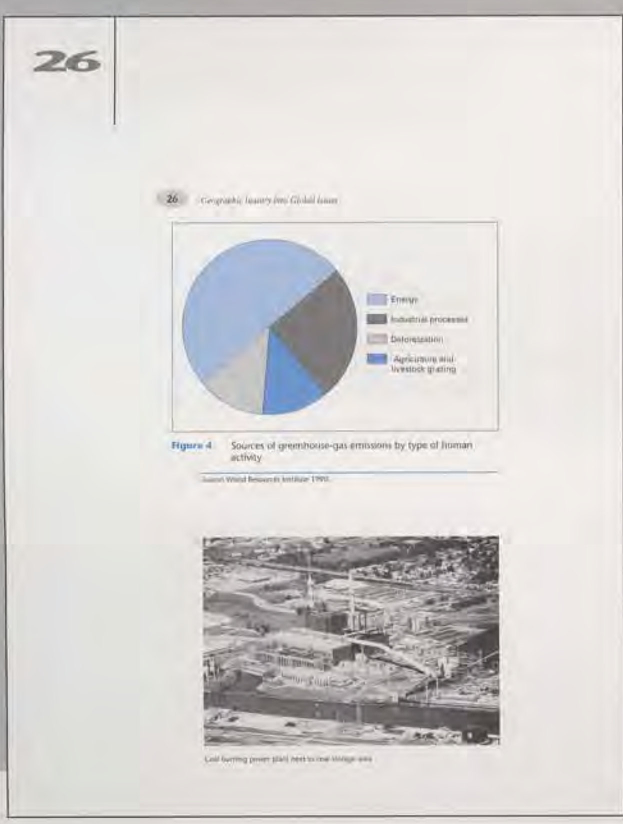


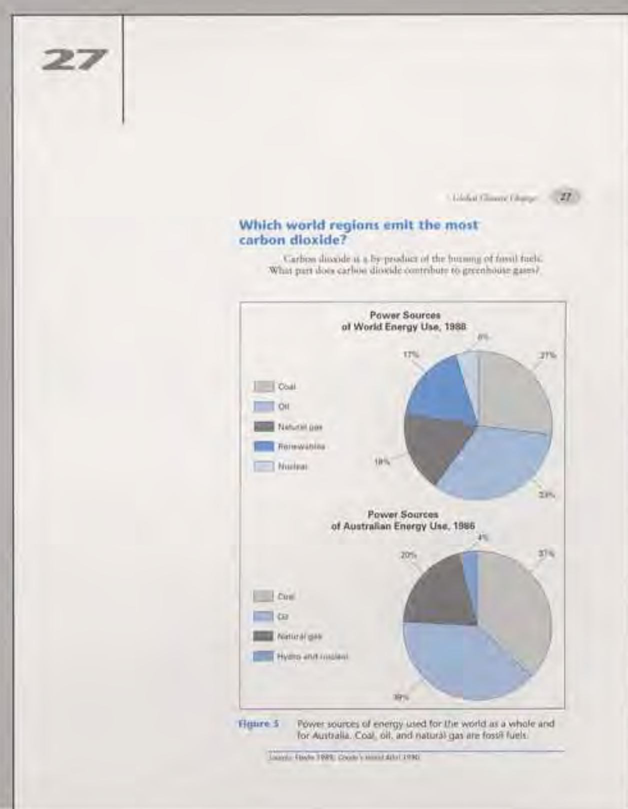
Which world regions emit the most carbon dioxide? (pages 27–28)

B. Divide the class into cooperative learning groups of about four students each for the duration of the lesson. Have each group work independently with Figure 5 on page 27 and Table 3 and answer Questions 1–3 on page 28. Pass out copies of **Activity 3** to each group as well. One group member should be designated as recorder, and another can be chosen to plot the graph on the Activity.

Explain the concept of the "fair share" line on Activity 3. The idea is that if each region used the same proportion of energy as it had of the world's people, you would get the straight line shown on Activity 3 (e.g., 25 percent of world population uses 25 percent of world energy, and so on).

To compare the proportions of energy use and population by region, have each group plot a scattergram of the two percentage columns given in Table 3 on page 28. To do this, a dot should be placed on the graph at the (x, y) coordinates, where the x-axis is the percent of world population and the y-axis is the percent of world energy use. Groups should





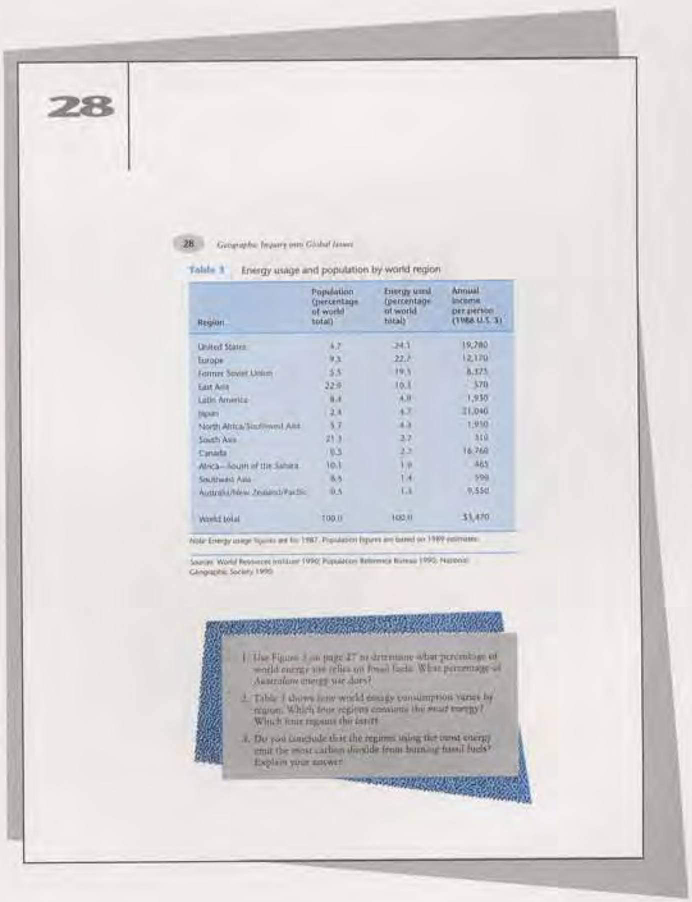
Questions and Answers for page 28

1. Use Figure 5 to determine what percentage of world energy use relies on fossil fuels. What percentage of *Australian* energy use does?
   - Figure 5 shows the percentages of fossil-fuel based energy, which is the sum of everything *but* nuclear and renewable sources (78 percent for world; 96 percent in Australia).

2. Table 3 shows how world energy consumption varies by region. Which four regions consume the *most* energy? Which four regions the *least*?
   - The most energy is consumed in the United States, Europe, the former Soviet Union, and East Asia. Australia, Southeast Asia, South Asia, and sub-Saharan Africa use the least, in terms of the absolute quantity of consumption.

3. Do you conclude that the regions using the most energy emit the most carbon dioxide from burning fossil fuels? Explain your answer.
   - Because fossil fuels are the source for most of the world's energy, it is fair to conclude that the regions that use the most energy also contribute the bulk of energy-related greenhouse gases.

then decide which regions are using more than their fair share of energy (and which less) and draw circles around the points accordingly. One possible grouping is shown on the *Key for Activity 3*. [Groups classify each region as developed or developing using the per person income data in Table 3. The developed regions are the United States, Europe, the former Soviet Union, Japan, Canada, and Australia/New Zealand. All developed regions—those with more than the global average per person income—use more energy than their proportion of population. Similarly, all developing regions use less than their fair share. Students may conclude that developed regions emit a disproportionate share of greenhouse gases by burning fossil fuels for energy.]



Which countries emit the most CFCs? (page 29)

C. Now have the student groups examine Figure 6 and answer Questions 4–5. Note that the data are on CFC *consumption*, not on emissions, per se. It is assumed, however, that these are closely related.

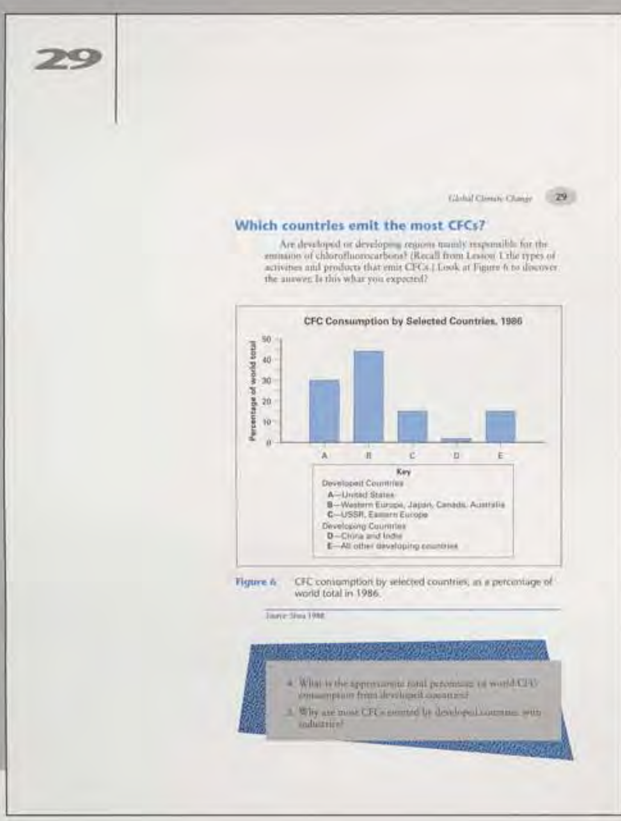
Questions and Answers for page 29

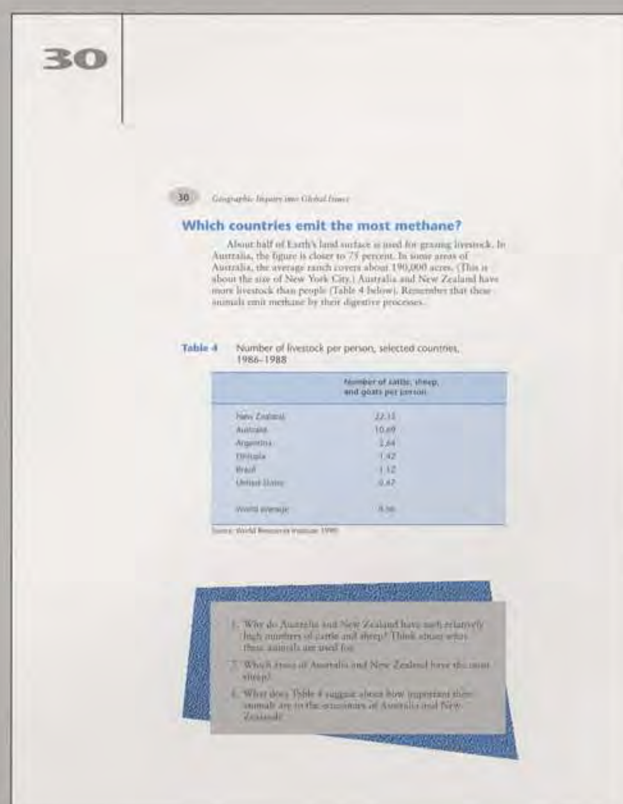
4. What is the approximate total percentage of world CFC consumption from developed countries?
   - Approximately 85 percent of CFCs are consumed by the countries classified as more developed in Activity 3 (countries A–C in the key on Figure 6).

5. Why are most CFCs emitted by developed countries with industries?
   - Industrialized or developed countries use the most CFCs because these synthetic chemicals are employed primarily in industrial manufacturing processes, such as cleaning electronic microcircuits and manufacturing plastic foams used in packaging and insulation. Developed countries also have more refrigerators, air-conditioning systems, and so forth. (Most developed nations, however, have already banned CFCs as aerosol propellants and have commited to reducing CFC use in other applications.)

Which countries emit the most methane? (page 30)

D. Have student groups examine Table 4 to discover the importance of livestock ranching in Australia and New Zealand. Distribute **Mini-Atlas map 1** of world cattle and sheep distribution to each group to help them with Questions 6–8.





Questions and Answers for page 30

6. Why do Australia and New Zealand have such relatively high numbers of cattle and sheep? Think about what these animals are used for.
   - The key conclusion from these data is that Australia and New Zealand have far more livestock than their own populations can use directly. Students can speculate on the reasons for the abundance of livestock in these countries.

7. Which areas of Australia and New Zealand have the most sheep?
   - Most sheep are concentrated in the eastern part of Australia. All areas of New Zealand have sheep populations. Have students use **Mini-Atlas map 1** to note other countries with large numbers of cattle and sheep.

8. What does Table 4 suggest about how important these animals are to the economies of Australia and New Zealand?
   - Students may recognize that livestock animals yield many products that can be sold at a profit. (You might cue younger students by telling them that Australia and New Zealand rank 1–2 in the world in wool and beef exports.) The key point is for students to recognize that these animals are important to these countries' economies.

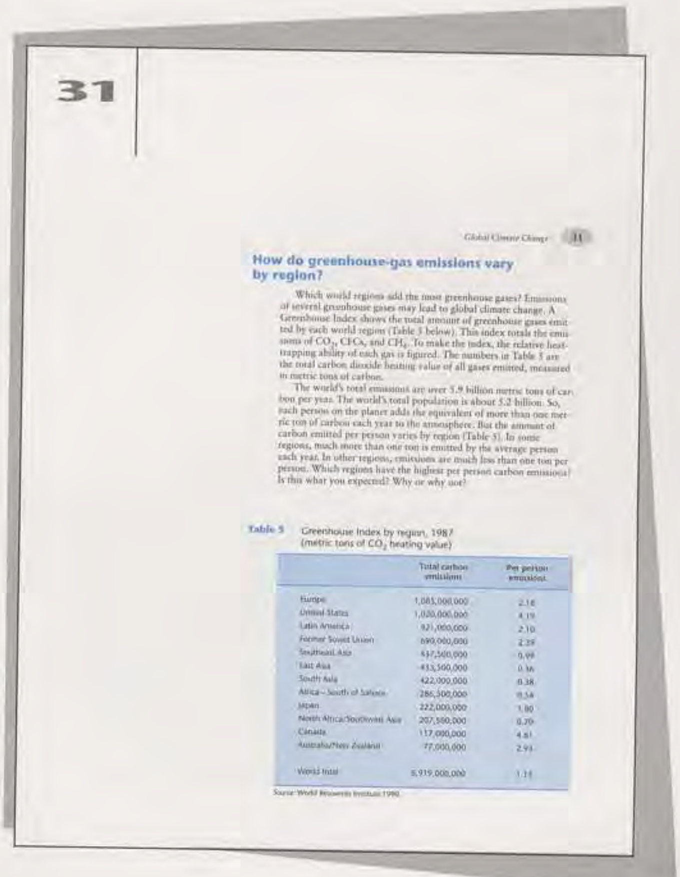
How do greenhouse-gas emissions vary by region? (pages 31–32)

E. Groups should read the text on page 31, which explains the rationale for analyzing emissions data with the Greenhouse Index (Table 5). This index weights the contributions by the relative proportion of each gas. Groups can then complete Questions 9–11. See answers for Questions 9–11 on the following page.

On a separate sheet of paper, groups should classify each region according to the per person Greenhouse Index (Table 5), making the following three groups:

- Regions with per person emissions more than twice the world average;
- Regions with emissions between one and two times world average; and
- Regions with emissions less than the world average.

Pass out the blank world map (**Activity 4**) and colored pencils to each group. On the blank world map, have students color in the regions according to these groups. Have them use a dark color for Group A, a light color for



31

Global Climate Change 31

How do greenhouse-gas emissions vary by region?

Which world regions add the most greenhouse gases? Emissions of several greenhouse gases may lead to global climate change. A Greenhouse Index shows the total amount of greenhouse gases emitted by each world region (Table 5 below). This index totals the emissions of CO_2, CFCs, and CH_4. To make the index, the relative heat-trapping ability of each gas is figured. The numbers in Table 5 are the total carbon dioxide heating value of all gases emitted, measured in metric tons of carbon.

The world's total emissions are over 5.9 billion metric tons of carbon per year. The world's total population is about 5.2 billion. So, each person on the planet adds the equivalent of more than one metric ton of carbon each year to the atmosphere. But the amount of carbon emitted per person varies by region (Table 5). In some regions, much more than one ton is emitted by the average person each year. In other regions, emissions are much less than one ton per person. Which regions have the highest per person carbon emissions? Is this what you expected? Why or why not?

Table 5 Greenhouse Index by region, 1987 (metric tons of CO_2 heating value)

	Total carbon emissions	Per person emissions
Europe	1,085,000,000	2.18
United States	1,030,000,000	4.19
Latin America	921,000,000	2.10
Former Soviet Union	690,000,000	2.39
Southeast Asia	437,500,000	0.99
East Asia	433,500,000	0.36
South Asia	422,000,000	0.38
Africa—South of Sahara	286,500,000	0.54
Japan	222,000,000	1.80
North Africa/Southwest Asia	207,590,000	0.70
Canada	117,000,000	4.61
Australia/New Zealand	77,000,000	2.93
World total	5,919,000,000	1.15

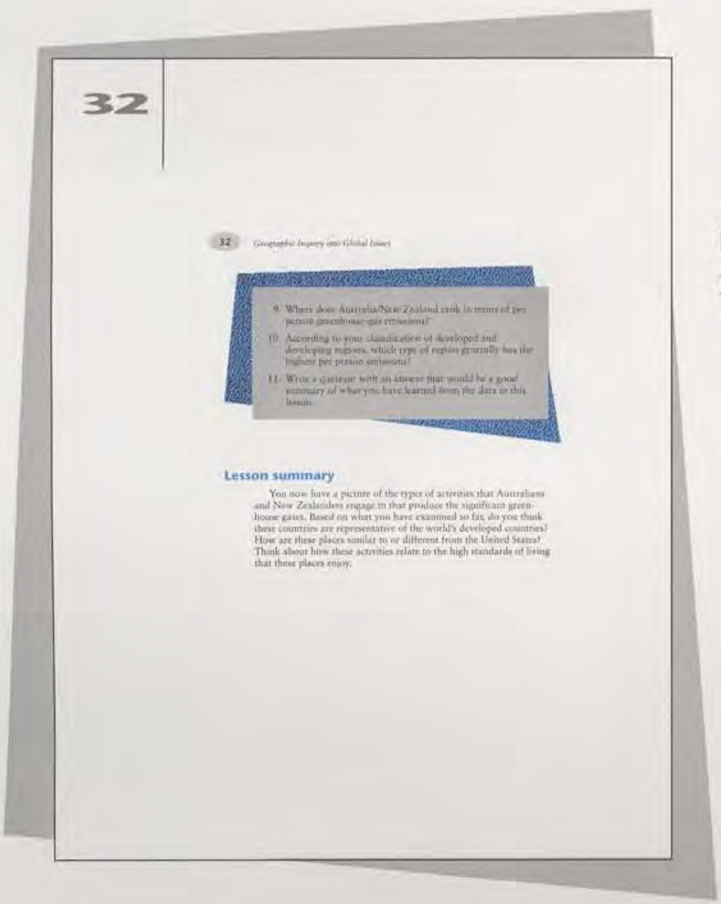
Source: World Resources Institute 1990

Questions and Answers for page 32

9. Where does Australia/New Zealand rank in terms of per person greenhouse-gas emissions?
   - Australia/New Zealand ranks only behind the United States and Canada in terms of per person greenhouse-gas emissions.

10. According to your classification of developed and developing regions, which type of region generally has the highest per person emissions?
    - The other high per person scores are for Europe and the former Soviet Union (also developed). Developing regions all have low per person scores, excepting Latin America (very high CO_2 from deforestation).

11. Write a question with an answer that would be a good summary of what you have learned from the data in this lesson.
    - Answers will vary here; accept any reasonable summary question.


32

32 *Geographic Inquiry into Global Issues*

9. Where does Australia/New Zealand rank in terms of per person greenhouse-gas emissions?
10. According to your classification of developed and developing regions, which type of region generally has the highest per person emissions?
11. Write a question with an answer that would be a good summary of what you have learned from the data in this lesson.

Lesson summary

You now have a picture of the types of activities that Australians and New Zealanders engage in that produce the significant greenhouse gases. Based on what you have examined so far, do you think these countries are representative of the world's developed countries? How are these places similar to or different from the United States? Think about how these activities relate to the high standards of living that these places enjoy.

Group B, and no color for Group C. The heavy lines on the Activity define each region. [Group A (dark color) includes Australia, Canada, the United States, and the former Soviet Union. Group B (light color) includes Latin America, Europe, and Japan. Group C (no color) includes Southeast Asia, South Asia, East Asia, North Africa/Southwest Asia, and Africa.]

Lesson summary (page 32)

F. Hang the completed maps (Activity 4) around the room and reconvene the class. To sum up, discuss why this geographic pattern emerged. [Examples of generalizations that might arise in discussion include: High rates of energy consumption and industrial technologies account for the highest Greenhouse Index scores. The former Soviet Union has relatively high carbon dioxide emissions in part because it relies on polluting technologies. The oil-producing countries of Southwest Asia (along with Canada and Australia again) have high CO_2 and methane emissions because of their energy facilities. In the developing world, CO_2 from deforestation causes the bulk of emissions. Although in some places, especially in Latin America, emissions are quite high per person, in general the developing world's per person Greenhouse Index scores are much lower than in the developed regions. In short, a fairly clear (but not absolute) developed/developing region dichotomy exists in terms of greenhouse-gas emissions.]

Students may conclude that Australia and New Zealand are representative of developed regions with respect to their use of activities and products that generate greenhouse gases. High energy consumption per capita, high CFC usage—and, in the case of Australia and New Zealand, high livestock numbers and CH_4—are patterns found throughout the industrialized world.

Have students consider what the tie between these activities and a country's standard of living suggests about the possibility of stopping global warming. For example, these countries emit lots of methane because of their livestock industry, but at the same time, they would probably be unwilling to reduce the numbers of livestock to cut these emissions, because of the economic value of ranching.

One way to start discussion is to have students think about what life would be like without the amenities that cause greenhouse-gas emissions. Consider, for example, the mobility provided by cars, the food variety allowed by refrigeration, and the expanded opportunities for travel, shopping, and residency afforded by air conditioning. Ask, for example, what effect the presence of air conditioning might have had on the migrations of U.S. residents to Arizona and Florida.

The upshot of this discussion is that many of the uses of greenhouse gases have become ingrained in the consumption patterns of the developed world. Eliminating use of those gases is unlikely, so substitutes for them are surely necessary.

For Further Inquiry

- Make a game by having each group come up with a list of questions about the data in this lesson, and then play the game *Jeopardy!* Each group would compete with the other groups, trying to answer the others' questions.
- Have students create a list of their personal actions that contribute to the greenhouse gases. Give them a night to compile their first list, then collect these and respond. Many students will overlook that, for example, if they eat meat, they are indirectly contributing by supporting the livestock industry. Ask leading questions, such as "How do you get to school each day?" and "How are eggs packaged?" to help elicit such indirect connections. Students may need to be reminded that using electricity also adds CO_2 to the atmosphere, because the electricity is usually generated by burning fossil fuels (unless your local power plant generates electricity from hydropower, nuclear power, solar power, wind power, or other alternatives). The goal of this exercise is really to have students see just how pervasive are the activities in our society that generate greenhouse gases.
- Check on students' progress on their contract to change one aspect of their own life style, which they began in Lesson 1.

Lesson 5

How might global warming affect Australia?

Time Required

Two 50-minute class periods

Materials Needed

Butcher paper
Copies of Activity 5 for each group of students
Copies of Activity 6 for all students
Mini-Atlas maps 2 and 3

Glossary Words

carbon dioxide (CO_2)

chlorofluorocarbons (CFCs)

climate

climate models

environmental system

global warming

greenhouse effect

greenhouse gases

methane (CH_4)

nitrous oxide (N_2O)

Getting Started

Have the class speculate about the likely impacts of global warming. Some students may already have heard that sea levels would rise, for example. Ask students to consider what warmer temperatures might mean for farmers and ranchers and others who need to make plans based on the climate.

Procedures

This lesson can be co-taught with a science class if younger students do not have the background to understand the relationship among soil moisture, temperature, and precipitation as discussed in the Student DataBook.

What will happen if global warming occurs? (pages 33–35)

A. Have students read pages 33–35 (up to Table 6), which introduces climate change computer models. Table 6 shows the predictions for average global increases of temperature and precipitation from three different models, which were used to map the forecasts of Australian soil moisture used in this lesson. Emphasize that these are global *averages*. Some regions will become drier and/or cooler while others become warmer and/or wetter. The point of this lesson is to show how uncertain climate forecasting is at the regional scale. Ask students which model they would cite if they wanted to support an argument that global warming would (or would not) be a severe problem. Discuss Questions 1–4.

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Lesson 5

How might global warming affect Australia?

Objectives

In this lesson, you will

- Understand why computer models of global warming show a wide range of predicted climatic effects for Australia
- Analyze the difficulty in planning for these possible effects
- Recognize that not all effects would be harmful—in some places global warming could generate economic benefits

Glossary Words

carbon dioxide (CO_2)
chlorofluorocarbons (CFCs)
climate
climate models
environmental system
global warming
greenhouse effect
greenhouse gases
methane (CH_4)
nitrous oxide (N_2O)

What will happen if global warming occurs?

The big question is, given the [relentless] buildup of [greenhouse] gases . . . what will the specific effects be? It's hard to say, because the relationship between worldwide climate and local weather is . . . complex. . . . The chaotic patterns of [air and ocean circulation] governing the weather still [confuse] meteorologists;

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in fact, weather more than two weeks in the future is thought by some to be inherently unpredictable. So far, the best answers have come from computer models that simulate the workings of the atmosphere (Revkin 1988, page 51).

Climate scientists, known as *climatologists*, use computers to model Earth's climate. The goal is to create a model that is accurate enough to predict the future, given changes in specific conditions—such as a doubling of CO_2 in the atmosphere. But environmental systems are very complicated, and models have to simplify them. Even the most powerful computers have limitations. If the workings of the system are not completely understood or represented, then the model won't be perfectly accurate. This means that the model's predictions will be less certain. Although climatologists have a good idea of how climate works, not all factors are completely known.

To predict effects from global warming, models first simulate current conditions. Then the amount of carbon dioxide in the model atmosphere is doubled. The computer runs until new atmospheric conditions stabilize and no further changes occur. The model makes a map of expected changes in temperature and precipitation under the simulated conditions of doubled CO_2.

In this lesson, you will work with some of these maps, showing how Australia might change in a warmer climate. Three climate models predict global *average* increases in temperature and precipitation (Table 6 on page 35). These models were created by climatolo-

Climatologists at the National Center for Atmospheric Research develop models to predict effects from global warming.

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gists working at major research centers of climate modeling. Each model is named after the research center. *Note that the models make different predictions.* This is partly because they use slightly different equations to model Earth's present atmosphere.

Table 6. Predictions from three climate models for doubled CO_2 (global averages)

Model	Temperature increase (°C)	Temperature increase (percentage of present)	Precipitation increase (percentage of present)
NCAR	3.5	+23.3	+7.1
OSU	2.8	+18.6	+7.8
UKMO	5.2	+34.6	+15.0

Key: NCAR = National Center for Atmospheric Research (Boulder, Colorado)
OSU = Oregon State University (Corvallis, Oregon)
UKMO = United Kingdom Meteorological Office (London, England)

Note: Based on a present global average temperature of 15°C (59°F).

Source: Henderson-Sellers and Blong 1989

1. What is the range (high to low) of predicted temperature and precipitation increases?
2. Think about how precipitation forms. Why would an increase in global temperatures cause an increase in global precipitation?
3. How do the models' predictions in Table 6 illustrate this relationship?
4. Consider the idea of global average precipitation and temperature. Do you think knowing the expected global changes helps people make plans for their own community or region? Explain your answer.

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What do the models predict for Australia?

The three climate models (Table 6 on page 35) have each produced maps showing how the temperature and precipitation might change in a warmer Australia. Such maps show results of simulations for a doubling of atmospheric CO_2 over its preindustrial level. The models simulate an enhanced greenhouse effect from all gases, including methane, CFCs, and nitrous oxide. Predictions are usually made for two seasons—winter and summer. (Remember that in Australia, winter begins in June and summer begins in December.)

Imagine you are a planner in the Ministry of Agriculture in one of Australia's states. Your job is to plan what type of agriculture will be possible in the future, warmer world. Unfortunately, temperature and rainfall predictions alone are not enough to figure out how productive a place will be for farming. Farmers and ranchers need to know about other aspects of climate. Perhaps most important is the amount of soil moisture available for plants to use (Henderson-Sellers and Blong 1989). For example, the present pattern of soil moisture in Australia corresponds closely to present land uses (Figure 7 on page 37).

Predicting soil moisture if CO_2 doubles is even harder than predicting temperature or rainfall. Soil moisture depends upon both temperature and rainfall, which are both expected to increase. More rain means more water will go into the soil, increasing soil moisture. But higher temperatures mean more soil moisture will evaporate into the atmosphere, drying out the soil. Trying to predict soil moisture in any one place is complicated by these opposite effects.

Any uncertainty in rainfall predictions means even greater uncertainty in predicting soil moisture. Also, soil moisture in the real world depends upon how much moisture is actually drawn from the soil and then released back to the atmosphere by the plants themselves. To date, computers can model how plants use water in only a very simple manner. It shouldn't be surprising, then, to see the wide range of predictions for soil moisture changes in Australia if CO_2 is doubled (Figure 8 on page 38).

Farmer feeds his sheep oats and wheat in the Australian outback.

Questions and Answers for page 35

1. What is the range (high to low) of predicted temperature and precipitation increases?
   - The UKMO model predicts the greatest increases and the OSU model predicts the least. This is a significant difference, because the UKMO model predicts nearly twice as much warming and precipitation as the OSU model.

2. Think about how precipitation forms. Why would an increase in global temperatures cause an increase in global precipitation?
   - Warmer temperatures should lead to more precipitation because greater evaporation would create more clouds.

3. How do the models' predictions in Table 6 illustrate this relationship?
   - Note that the UKMO model predicts both the greatest temperature and the greatest precipitation increase.

4. Consider the idea of global average precipitation and temperature. Do you think knowing the expected global changes helps people make plans for their own community or region? Explain your answer.
   - This question hints at the difficulty of forecasting climate meaningfully. Knowing the global average temperature and precipitation increases may not mean much at a regional scale, as the following activity demonstrates.

What do the models predict for Australia? (pages 36–38)

B. The text on page 36 emphasizes how difficult forecasting precipitation is for Australia. Split the class into groups of three or four. Have groups work with **Mini-Atlas maps 2** and **3** to see what variables influence climate in Australia. [These include topography and proximity to ocean.] The key here is that students see how the narrow belts of precipitation patterns in the real Australia differ from the models' treatment of the world as a set of average changes.

C. Next have each group represent the Ministry of Agriculture for one Australian state or territory (if some states are represented by more than one group, that's OK). Have groups try to devise a plan for agriculture in their state, given predictions of the effects of global warming on Australian soil moisture.

   Students should read the text on page 36, which explains Figures 7 and 8 (pages 37–38). Hand out copies of **Activity 5** to each group, which provides questions the groups can use as a guide. Their first job is to familiarize themselves with their state's existing land uses. Using Figure 7 and Mini-Atlas maps 2 and 3 of Australia, they can spot a close relation between soil moisture levels and types of land use. In addition, the location of major cities also influences the position of cropland. Each group should summarize what types of land uses are found in their state and how these are related to the variables of soil moisture and urban areas.

D. Next, have each group attempt to reach a consensus about what changes the climate models predict for summertime soil moisture in their state (Figure 8). If students ask how the models predict soil moisture changes on a regional scale, tell them each model divides the continent into smaller pieces and factors in the expected change in temperature and precipitation. The models differ because they are based on different predictions of temperature and precipitation change, and because they subdivide the continent in different ways.

First, students need to decide if the models generally forecast an increase or decrease. This won't be easy for some states, such as Western Australia and Queensland, in which the models differ quite a bit. Failing to reach consensus is acceptable; it helps drive home how regional planning based on these models is very difficult.

Once consensus (or an agreement to disagree) is reached, the "agricultural planners" should determine what the forecasts would mean for their state *in relation to the existing conditions*. For example, greater moisture in a desert area may not mean much (perhaps a slight increase in available rangeland), but greater moisture in a well-watered place could mean much more agricultural productivity. On the other hand, drier conditions could devastate already marginal range areas or make existing cropland less productive. Answers here will vary as each group decides what the maps say about their state and how they relate this to existing conditions.

Note: Owing to the generality of these maps, smaller states do not have as complex or interesting patterns as larger states. It may be better to have one group represent Tasmania and Victoria together and divide Western Australia and Queensland into two groups each (perhaps representing north and south portions of each large state) in order to more equitably distribute the assignment.

E. Reconvene the entire class for debriefing. Place a sheet of butcher paper on the wall, with columns for each state. Have each group summarize on this chart what the models predict for soil moisture in their state. If no consensus was reached, then the group should report the discrepancies among the models.

Groups should explain what these predictions mean in terms of their state's agricultural land uses. Ask each group to describe what kinds of problems and opportunities the forecasted moisture changes would present. Ask what farmers might need to do if the soil moisture changed the way it is forecast for their state. Would they need to irrigate more or less often? Focus discussion on the problems with the predictions' variability. How, for example, could farmers in Northern Territory make plans, given such a variety of forecasts?

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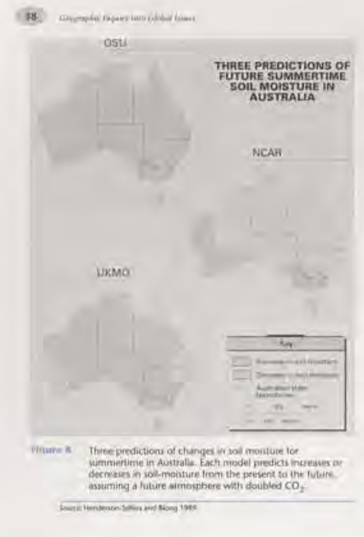
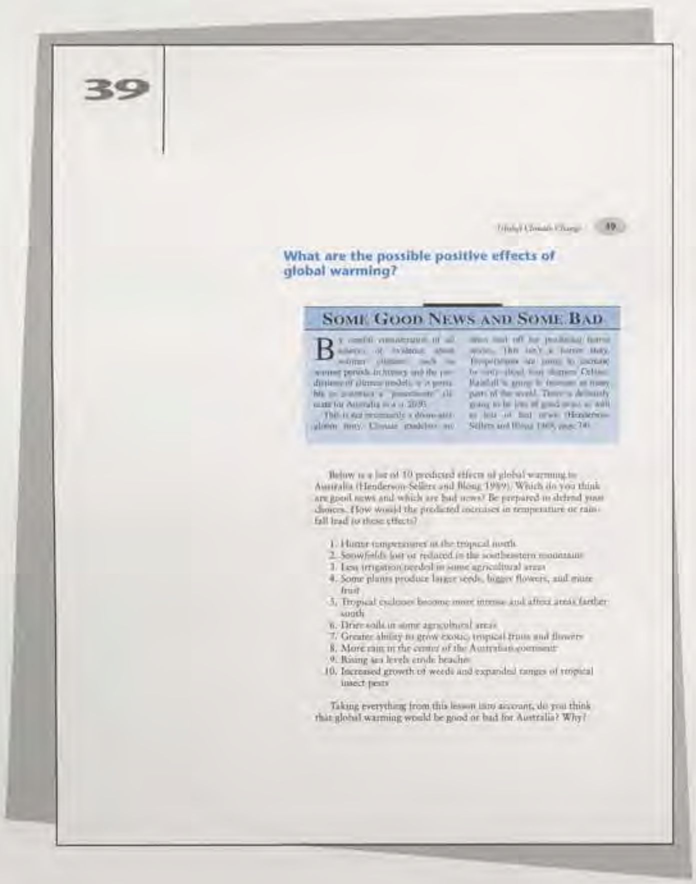


What are the possible positive effects of global warming? (page 39)

F. Use the reading "Some Good News and Some Bad" to discuss the ramifications of global warming. After the students read this, have them classify the 10 impacts listed on page 39 as *good, bad,* or *not sure.*

Afterward, initiate discussion leading toward a tentative consensus on the question: Will global warming help or harm Australia? Taking a vote might be a fun way to resolve disagreements. If desired, the state groupings used in this lesson could be brought back into play. "Representatives" from different states might take differing perspectives on the issue depending on how "their" state is affected. One goal of this lesson is to have students comprehend how complex the issue is. Regions with opposing interests might react very differently to the prospect of a warmer climate.

The weight of the list tilts slightly toward the *bad,* because that is the general conclusion of the book from which this list was derived. Some impacts may not be intuitively connected to warmer climates, and you may need to explain them. See the *Background Note: Explanations of Good and Bad News* on this page for details.



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What are the possible positive effects of global warming?

SOME GOOD NEWS AND SOME BAD

Below is a list of 10 predicted effects of global warming to Australia (Henderson-Sellers and Blong 1989). Which do you think are good news and which are bad news? Be prepared to defend your choices. (How would the predicted increases in temperature or rainfall lead to these effects?)

1. Hotter temperatures in the tropical north
2. Snowfields lost or reduced in the southeastern mountains
3. Less irrigation needed in some agricultural areas
4. Some plants produce larger seeds, bigger flowers, and more fruit
5. Tropical cyclones become more intense and affect areas farther south
6. Drier soils in some agricultural areas
7. Greater ability to grow exotic, tropical fruits and flowers
8. More rain in the center of the Australian continent
9. Rising sea levels erode beaches
10. Increased growth of weeds and expanded ranges of tropical insect pests

Taking everything from this lesson into account, do you think that global warming would be good or bad for Australia? Why?

Optional Assignment

Activity 6 relies on the detail of a textbook, world almanac, or encyclopedia. Certain economic activities should be listed in most texts or almanacs: mining of bauxite and coal, fruit and grain crops, and wool and beef exports. Note that coal and livestock industries contribute to the greenhouse gases. These industries could be severely restricted if major efforts are made to reduce the enhanced greenhouse effect. Conversely, Australia's vast uranium reserves may become more valuable if there is a worldwide push for noncarbon energy sources like nuclear fission.

Have students write a paragraph to summarize what they believe the net impacts of global warming on Australia and New Zealand might be. Encourage students to stress regional differences in impacts where possible.

Background Note

EXPLANATIONS OF GOOD AND BAD NEWS

Good News—Because plants process carbon dioxide to synthesize tissue, an enriched-CO_2 atmosphere could lead to greater plant productivity. Thus, some plants could grow larger seeds, flowers, and fruit. Less irrigation would be needed because when CO_2 increases, plants don't need to open the stomata in their leaves as often, so they lose less water. More rain in the center of Australia will also enhance agricultural possibilities. Warmer temperatures farther south would expand the range of tropical fruit cash crops.

Bad News—Warmer oceans account for more frequent and intense cyclones; warmer temperatures account for drier soils; and rising sea levels account for eroded beaches. Snowfields (and recreational income) would be reduced if precipitation falls as rain rather than snow. Increased temperatures in tropical areas could render some areas less habitable. And while crops would be stimulated by greater CO_2, so would weeds; while the range of bananas expands south, so would the range of tropical insect pests.

Lesson 6

How do developing countries add greenhouse gases?

Time Required

One 50-minute class period

Materials Needed

Mini-Atlas maps 4, 5, 6, and 7

Glossary Words

carbon dioxide (CO_2)

chlorofluorocarbons (CFCs)

deforestation

developing country

greenhouse gases

methane (CH_4)

Getting Started

Prior to having students open their books, conduct a multiple-choice survey. Ask the class what they think the percentage of total greenhouse-gas contribution is from the world's developing regions. Put up a series of choices on the board (say, 5 percent, 20 percent, 45 percent, 75 percent, or something similar) and take a vote. Having completed the case study of a developed country, students may be inclined to underestimate the actual contribution from developing regions. [It is close to 45 percent.] Explain that the role of the developing regions in potential climate change will now be investigated.

Procedures

How do developing countries contribute to greenhouse-gas emissions? (pages 40–42)

A. The opening paragraph on page 40 may run counter to some people's expectations. Review Table 5 in Lesson 4 (page 31) to remind students that the per person additions of greenhouse gases from developing regions were generally low. Have the class study Figure 9 on page 41. (The regions not graphed exhibit similar patterns between developed and developing regions.) Then have students discuss Questions 1–4.

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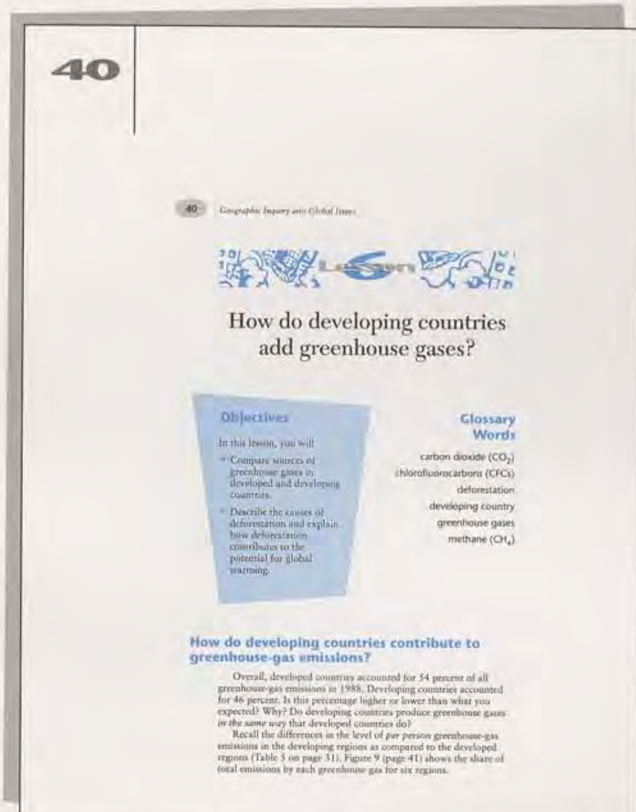


40 Geographic Inquiry into Global Issues

Lesson 6

How do developing countries add greenhouse gases?

Objectives

In this lesson, you will

- Compare sources of greenhouse gases in developed and developing countries.
- Describe the causes of deforestation and explain how deforestation contributes to the potential for global warming.

Glossary Words

carbon dioxide (CO_2)
chlorofluorocarbons (CFCs)
deforestation
developing country
greenhouse gases
methane (CH_4)

How do developing countries contribute to greenhouse-gas emissions?

Overall, developed countries accounted for 54 percent of all greenhouse-gas emissions in 1988. Developing countries accounted for 46 percent. Is this percentage higher or lower than what you expected? Why? Do developing countries produce greenhouse gases *in the same* way that developed countries do?

Recall the differences in the level of *per person* greenhouse-gas emissions in the developing regions as compared to the developed regions (Table 5 on page 31). Figure 9 (page 41) shows the share of total emissions by each greenhouse gas for six regions.

Questions and Answers for page 41

1. Which greenhouse gas accounts for most of the emissions from developing regions?
   - Carbon dioxide clearly accounts for the majority of greenhouse gases from developing regions.

2. Why don't CFCs make up a large proportion of greenhouse-gas emissions from developing regions?
   - CFC emissions are much higher in developed regions, because industrial processes are the source of these gases. You may wish to ask why Australia has relatively higher methane emissions. [Because of its large livestock population and its numerous coal mines]

3–4. According to Figure 9, which regions—developed or developing—appear to be contributing the most to the problem? Is this misleading? Why or why not? What important information does Figure 9 fail to show?
   - Students may be aware that a graph like this is misleading by itself, because it doesn't show the *total* quantity of gases emitted, only percentages. Figure 9 might make it seem that the main source of greenhouse gases is developing countries.

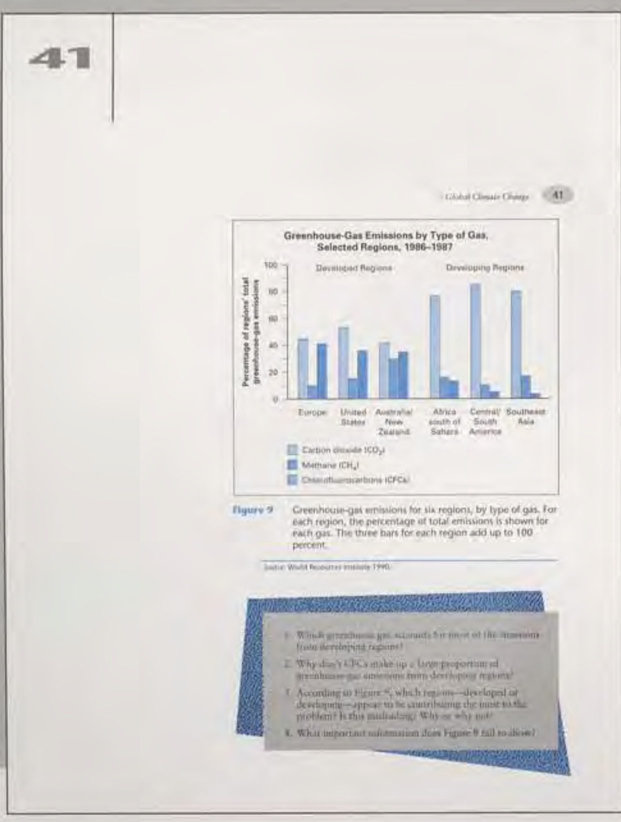
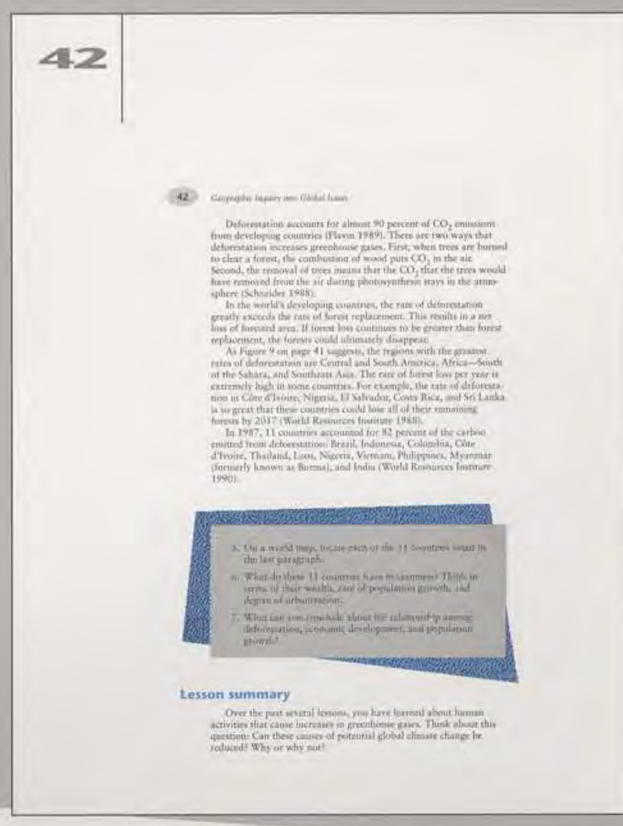


Figure 9 Greenhouse-gas emissions for six regions, by type of gas. For each region, the percentage of total emissions is shown for each gas. The three bars for each region add up to 100 percent.

Source: World Resources Institute 1990.



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Deforestation accounts for almost 90 percent of CO_2 emissions from developing countries (Flavin 1989). There are two ways that deforestation increases greenhouse gases. First, when trees are burned to clear a forest, the combustion of wood puts CO_2 in the air. Second, the removal of trees means that the CO_2 that the trees would have removed from the air during photosynthesis stays in the atmosphere (Schneider 1988).

In the world's developing countries, the rate of deforestation greatly exceeds the rate of forest replacement. This results in a net loss of forested area. If forest loss continues to be greater than forest replacement, the forests could ultimately disappear.

As Figure 9 on page 41 suggests, the regions with the greatest rates of deforestation are Central and South America, Africa—South of the Sahara, and Southeast Asia. The rate of forest loss per year is extremely high in some countries. For example, the rate of deforestation in Côte d'Ivoire, Nigeria, El Salvador, Costa Rica, and Sri Lanka is so great that these countries could lose all of their remaining forests by 2017 (World Resources Institute 1988).

In 1987, 11 countries accounted for 82 percent of the carbon emitted from deforestation: Brazil, Indonesia, Colombia, Côte d'Ivoire, Thailand, Laos, Nigeria, Vietnam, Philippines, Myanmar (formerly known as Burma), and India (World Resources Institute 1990).

Lesson summary

Over the past several lessons, you have learned about human activities that cause increases in greenhouse gases. Think about this question: Can these causes of potential global climate change be reduced? Why or why not?

Questions and Answers for page 42

5. On a world map, locate each of the 11 countries listed in the last paragraph.
   - Using **Mini-Atlas map 4,** students can locate the 11 countries mentioned on page 42.

6. What do these 11 countries have in common? Think in terms of their wealth, rate of population growth, and degree of urbanization.
   - Students can use **Mini-Atlas maps 5–7** to note these possible answers: location in tropical latitudes, low GNP per capita, rapid population growth, and low urbanization.

7. What can you conclude about the relationship among deforestation, economic development, and population growth?
   - Each group should write a short description that summarizes how tropical deforestation is related to the combination of rapid population growth and low economic development. (For other GIGI modules that address deforestation, see the section *Extension Activities and Resources.*)

B. Have students read the text on page 42, which describes why deforestation causes CO_2 emissions. Allow time for a short discussion of this problem. A way to get people thinking about the problem is to ask how rapid population growth is connected to deforestation. [The search for food is key. Growing crops for subsistence and for income, providing range for livestock, and gathering fuelwood for heating and cooking all cause forest clearance.]

Questions 5–7 can be answered by students working in small groups using Mini-Atlas maps 4–7.

Lesson summary (page 42)

C. To close the lesson, reconvene the entire class for a brief discussion. Ask students whether they feel optimistic that global warming is preventable. After Lessons 4, 5, and 6, they may not. Developed countries rely heavily on greenhouse-gas emitting energy sources and CFCs; developing regions have what might be considered more pressing problems of population growth and poverty.

Lesson 7

How might global warming affect the U.S. Gulf Coast?

Time Required

One or two 50-minute class periods

Materials Needed

Baking dish, Legos, and water for sea level rise demonstration
Colored pencils
Rulers
Copies of Activity 7 for each group of students
Transparencies of Overheads 2 and 3
Mini-Atlas map 8

Glossary Word

global warming

Getting Started

Create a simple model of a coastline in a baking dish or other shallow container. The model should have an extensive coastal plain backed by landforms of greater elevation. The model can be constructed from Legos or other durable material. Set sea level below the flat coastal plain. Next, add enough water to increase the water depth by about one inch. Say that this represents an increased sea level. Enough of the coastal plain area should be flooded so that the point is made: In low-lying coastal plains and river deltas, even a modest rise in sea level could have devastating impacts.

Procedures

How would global warming cause a rise in sea level? (pages 43–46)

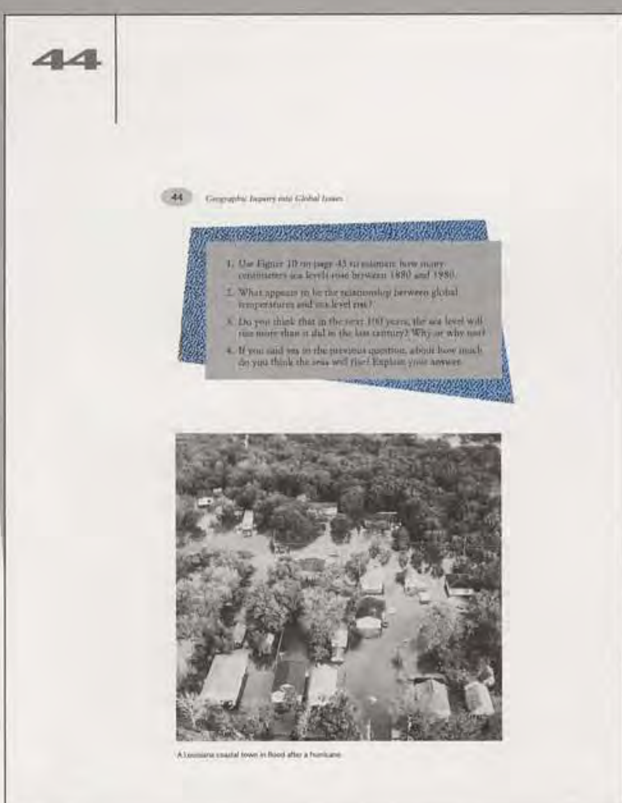
A. Have a couple of students read the bulleted statements on page 43 aloud. Discuss Figure 10 and have students answer Questions 1–4.

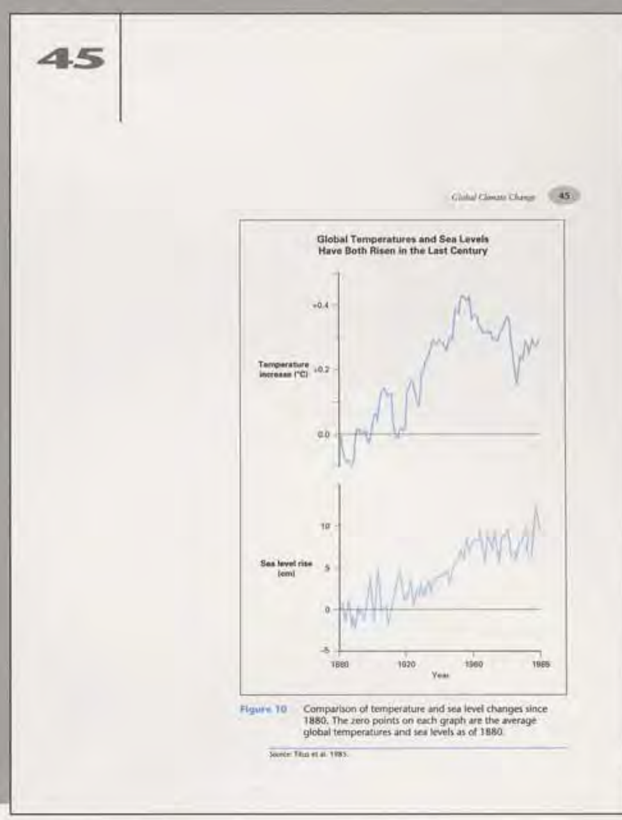
Questions and Answers for page 44

1. Use Figure 10 to estimate how many centimeters sea levels rose between 1880 and 1980.
   - Figure 10 shows that sea levels have risen about 10 cm since 1880, during which time temperatures have risen about 0.3°C.

2. What appears to be the relationship between global temperatures and sea level rise?
   - Sea levels have risen along with the global increase in temperatures.

3–4. Do you think that in the next 100 years, the sea level will rise more than it did in the last century? Why or why not? If you said *yes*, about how much do you think the seas will rise? Explain your answer.
   - Given that the predicted temperature rise for the next century is 5 to 15 times greater than that of the last 100 years (i.e., temperatures are expected to increase 1.5° to 4.5°C), one might expect a rise in sea levels of between 50 and 150 cm. Although this seems reasonable, students should be cautious—the premise on which this conclusion is based remains speculative.





B. After answering Questions 1–4, students should read the text, "The rising seas" on page 46, which confirms the ballpark estimate made in Question 4. Students may understand why melting ice caps would raise sea levels. But also significant is a lesser-known point: Global warming would decrease the density of ocean water. This would increase the oceans' volume and raise sea levels, because the same amount of water takes up more space. Discuss Questions 5–6.

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The rising seas

If global average temperatures increase from 1.5 to 4.5°C by the year 2030, world sea level may rise from 20 to 140 centimeters during the following decades. Sea level rise would be caused by two things. First, the level would increase slightly because warmer water expands. This is the same principle that causes mercury to rise in a thermometer when it is warmed. Second, sea level would rise because some of the ice now frozen in glaciers and ice caps would melt. This rise in sea level would have major effects on the world's coasts.

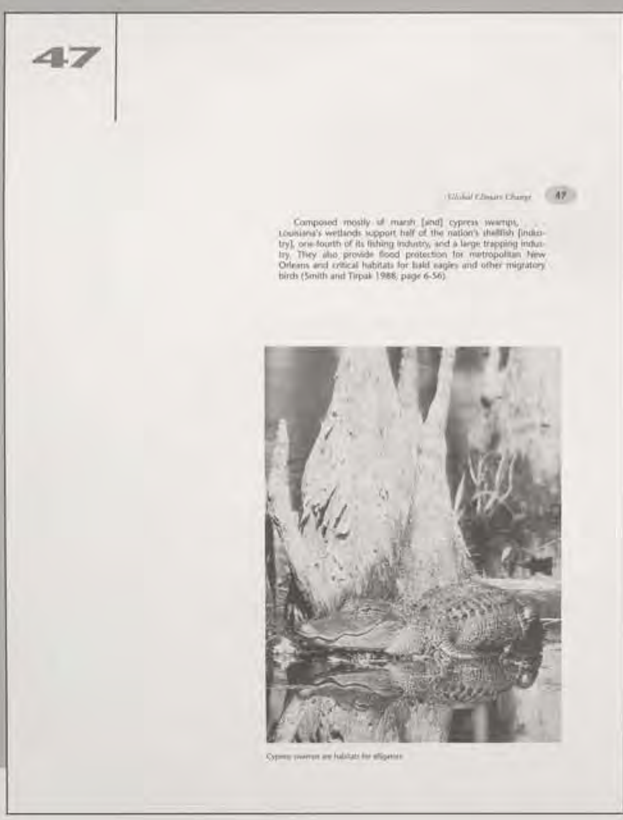
5. [illegible]

6. [illegible]

What effect will sea level rise have on the U.S. Gulf Coast?

A 55-centimeter (1.8 feet) rise in sea level would submerge almost all of the Mississippi Delta (Figure 11 on page 48). New Orleans would become more vulnerable to hurricanes because most of the city already lies below sea level and is only protected by levees. Levees are wide earthen embankments erected along rivers and coasts to prevent land from being flooded. For example, the area around Morgan City, Louisiana, is circled by major levees (Figure 12 on page 49).

A one-meter (39.37 inches) rise in sea level would flood at least 30 percent of the Gulf's coastal wetlands and up to 4,600 square miles of dry land. About half of the total wetland loss would be in Louisiana. With a two-meter rise in sea level, Louisiana would lose up to 80 percent of its wetlands and over 10,000 square miles of land (Smith and Tirpak 1988). Why are the coastal wetlands so important?



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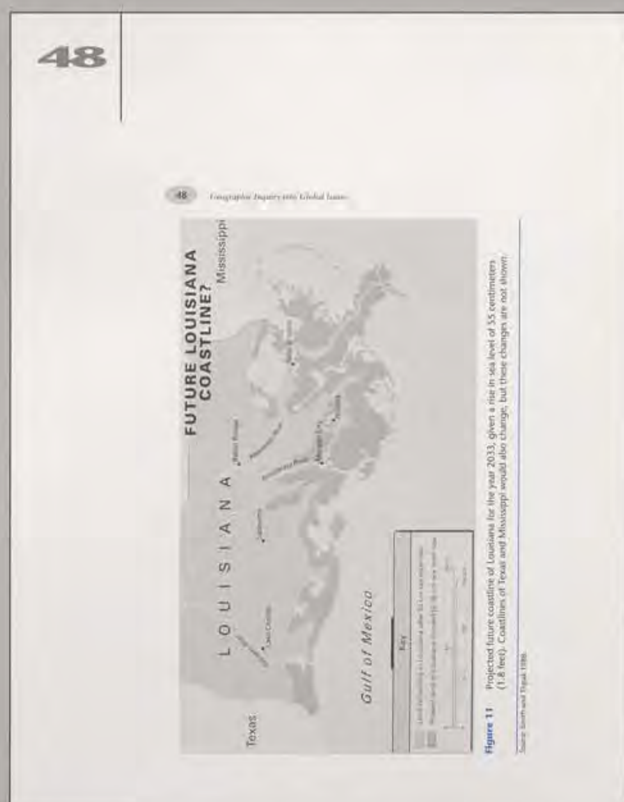
Composed mostly of marsh [and] cypress swamps, Louisiana's wetlands support half of the nation's shellfish [industry], one-fourth of its fishing industry, and a large trapping industry. They also provide flood protection for metropolitan New Orleans and critical habitats for bald eagles and other migratory birds (Smith and Tirpak 1988, page 6-56).

Cypress swamps are habitats for alligators.



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48 *Geographic Inquiry into Global Issues*

Figure 11 Projected future coastline of Louisiana for the year 2033, given a rise in sea level of 55 centimeters (1.8 feet). Coastlines of Texas and Mississippi would also change, but these changes are not shown.

Source: Smith and Tirpak 1988.

Questions and Answers for page 46

5. Compare the predicted rate of sea level rise to the rate of rise during the past century (Figure 10). About how much faster is the sea expected to rise in the next century as compared to the past century?
   - The predicted rate of rise is 2 to 14 times greater than the historical rate.

6. What do you think the effects of sea level rise would be?
   - In discussion, the problems of coastal flooding, beach erosion, greater damage from storm waves, and other effects might come up. Use **Overhead 2** to clarify how rising sea levels will inundate low-lying coasts and increase saltwater intrusion.

What effect will sea level rise have on the U.S. Gulf Coast? (pages 46–50)

C. Using **Mini-Atlas map** 8 or a wall map of U.S. physical features, ask students which areas in the United States have a large flat coastal plain. These areas are most likely to be affected by small rises in sea level. Students can see that the southeastern coasts would be harder hit by global warming than other parts of the United States. The text on pages 46–47 explains some impacts; Figure 11 shows what may happen to the Louisiana coastline.

D. Divide the class into pairs or groups of three or four. Hand out **Activity 7** (a copy of Figure 12) to each group. Project **Overhead 3** onto a screen in front of the class. This shows the

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Global Climate Change 49

Figure 12 Selected land uses around Morgan City, Louisiana.

Source: Morgan City USGS topographic map, 15-minute series, 1955 edition.

How much of the Gulf Coast is actually flooded will depend upon how many new levees people build. Floods occur when streams overflow their banks or when sea levels are raised by high waves during storms. Most of the Gulf Coast is currently protected from these storm waves by levees that are 10 to 15 feet high (Figure 12 above).

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50 *Geographic Inquiry into Global Issues*

These levees are over 300 feet wide at their base. Building levees this big can cost over $3 million *per mile*. More money must be spent afterward on maintenance, to keep the levees effective (U.S. Army Corps of Engineers, New Orleans District).

In order to cope with sea level rise along the Gulf Coast, the United States would have to spend a great deal of money. Consider this: Will the poorer nations of the world be able to deal with potential effects of sea level rise as well as the richer, more-developed nations? Why or why not?

contour lines (elevation) for this area. The heavy black line represents the 5-foot contour (that's as high as this region gets).

a. With a ruler, each group can estimate the present level of coastal protection. [At a scale of about 2 inches = 3 miles, there are roughly 30 miles of levees currently around Morgan City, mainly along Bayou Shaffer, the Lower Atchafalaya River, and Stouts Pass.]

b. Each group can take turns going up to the overhead projector and overlaying their copy of Activity 7 atop the contour lines on the overhead. The groups should trace the 5-foot contour onto their Activity copy. Back at their desks, students can then color in all areas that will be inundated by a 5-foot sea level rise. [Only parts of a few existing islands—where Morgan City and Berwick towns themselves are—will remain. Some of the land uses at risk include oil and gas wells, an airfield, a major highway (U.S. route 90), farms and plantations, and several cemeteries.]

c. Estimates of the total cost to protect the Morgan City area will vary, depending upon how many more levees each group decides would be needed to keep the sea out. [One rough way to do this would be to build levees along all of the waterways appearing on the map surrounding Morgan City. This amounts to about 40 miles of additional protection, costing $120 million. Accept any reasonable effort here.]

d. From Figure 11 on page 48, students can see that this area is one small part of a longer threatened shore. According to the *World Almanac*, Louisiana has a total shoreline of about 7,700 miles. [If Morgan City's protection cost of $120 million for a coastline of some 70 miles is assumed to be representative, then the total for the state would be 100 times that, or over $12 billion. Note that these admittedly rough estimates are still extremely conservative. According to Smith and Tirpak (1988), the total cost of holding back the sea will be anywhere from $42 to $75 billion by the year 2100.]

E. End the lesson with discussion of the closing question on page 50. Ask if it may be harder for developing countries to deal with the problem than countries that have greater financial resources. Coastal protection, such as levees, is costly. Some caution is advisable here, because developed countries may have much more at risk than developing countries. In other words, coastal flooding would damage more property in Miami than it would in countries with little coastal development. At the same time, richer countries are better able to afford protecting those resources at risk. Poorer countries may have less property at risk, but they may not have the funds to protect what they do have. The goal is to have students realize that the problems posed by global warming could have a more severe impact upon those countries least able to afford it.

For Further Inquiry

- Have students create concept maps to show the connections between increased greenhouse gases and some of the direct and indirect effects mentioned in the module. For example, direct effects include partial melting of ice caps and warmer, less dense seawater. These lead to sea level rise. Indirect effects of sea level rise include coastal inundation, increased storm surges, and reduced productivity in wetlands.
- Assign this question for a short overnight writing assignment: If sea level rise is considered to be a negative effect of climate change, does that mean that present sea levels are ideal? Why or why not? (The idea is that societies have adapted to the present levels. The economic impact of adjusting to new sea levels is likely to be very great, especially in certain countries. Some of these countries are the least able to afford these impacts.)

Lesson 8

What should be done about global warming?

Time Required

Three 50-minute class periods

Materials Needed

Two decks of playing cards and play money or chips (optional)

Glossary Words

carbon dioxide (CO_2)

chlorofluorocarbons (CFCs)

climate

climate models

developed country

developing country

global warming

greenhouse gases

methane (CH_4)

ozone hole

Getting Started

- The global warming issue presents a difficult choice: How do we plan for change when we don't know exactly what the changes will be? Illustrate this with a contrasting scenario: Ask students to imagine that they are in a car approaching a cliff. What would they do? No doubt the replies will stress that this situation calls for making a decision to avoid certain catastrophe. The point is that it is much easier to plan when you know the outcome. Set the stage for the ensuing discussion about policy options by posing the questions: Is global warming a serious problem? If so, how much is it worth to fix it?
- *Optional Activity:* If you enjoy playing the card game "Twenty-one" (also known as "Blackjack"), give students a feel for the dilemma of planning in the face of uncertainty. You act as dealer; the students are the players. Stack the deck to give yourself an ace showing. Explain to students how "insurance" works, and offer them the chance to purchase it to protect their hands. Give students chips to represent their resources. Students can take the chance that you won't have Twenty-one (symbolizing the occurrence of global warming), or they can decide to invest their resources for protection against this event. Give more chips to some students (representing developed regions) and less to others (developing). If you opted to give yourself Twenty-one, show your hand after all insurance choices are made. Only those students who bought insurance will come out even, so they will still have ample resources. Students who opted not to buy insurance lose their bet, leaving them with fewer resources.

Procedures

Younger students may have difficulty with the reading in this lesson. If so, reduce the reading load or have students read and discuss the material aloud. Check for comprehension frequently.

What strategies have been proposed to deal with global climate change? (pages 51–56)

A. Quickly review with the class how both developed and developing regions contribute to the problem (Lessons 4 and 6) and will be affected either positively or negatively should global warming occur (Lessons 5 and 7).

B. Divide the class into cooperative learning groups of four students each. Within each group, each student is responsible for reading one of the four strategies (pages 52–56). Then each student briefs the others in his or her group about this strategy. Together, each group then answers Questions 1–5 on page 52 for each strategy. See answers for Questions 1–5 on the following page.

Also, assign each student to be a representative from a specific world region. Two members of each group can be from developing regions and two from developed regions. During the debate activity which follows, students who do not take part in the debate itself can act as representatives from each type of region and determine which strategy best represents their interests.

Alternatively, you can set up the debate more informally. Select one student to describe each strategy to the remainder of the class. The other students can then react to each strategy and you can lead discussion of the five questions with the class as a whole. Ask students to consider how people in different regions of economic standard of living (developed or developing) would probably react to each strategy. Encourage students also to express their own opinions about each strategy.

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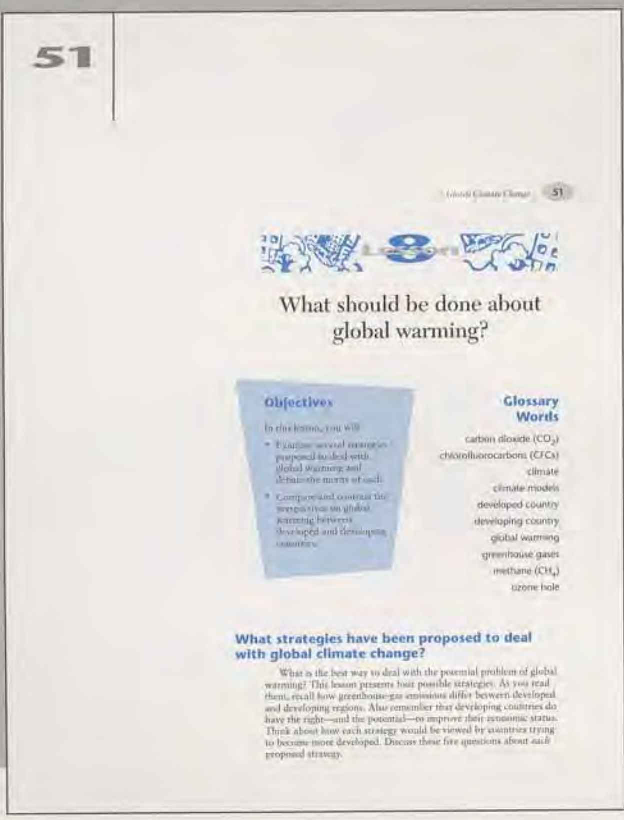
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Lesson 8

What should be done about global warming?

Objectives

Glossary Words

carbon dioxide (CO_2)
chlorofluorocarbons (CFCs)
climate
climate models
developed country
developing country
global warming
greenhouse gases
methane (CH_4)
ozone hole

What strategies have been proposed to deal with global climate change?

What is the best way to deal with the potential problem of global warming? This lesson presents four possible strategies. As you read them, recall how greenhouse-gas emissions differ between developed and developing regions. Also remember that developing countries do have the right—and the potential—to improve their economic status. Think about how each strategy would be viewed by countries trying to become more developed. Discuss these five questions about *each* proposed strategy.

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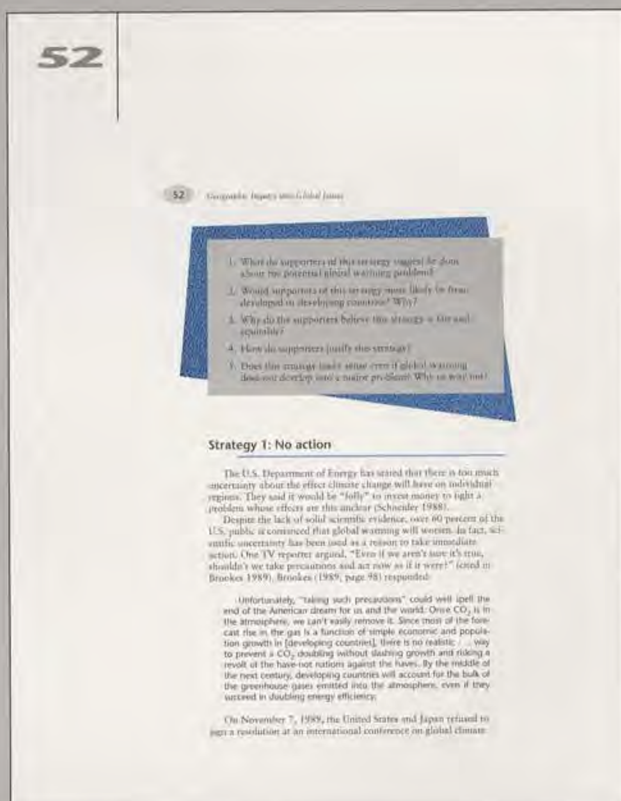
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Strategy 1: No action

The U.S. Department of Energy has stated that there is too much uncertainty about the effect climate change will have on individual regions. They said it would be "folly" to invest money to fight a problem whose effects are this unclear (Schneider 1988).

Despite the lack of solid scientific evidence, over 60 percent of the U.S. public is convinced that global warming will worsen. In fact, scientific uncertainty has been used as a reason to take immediate action. One TV reporter argued, "Even if we aren't sure it's true, shouldn't we take precautions and act now as if it were?" (cited in Brookes 1989). Brookes (1989, page 98) responded:

Unfortunately, "taking such precautions" could well spell the end of the American dream for us and the world. Once CO_2 is in the atmosphere, we can't easily remove it. Since most of the forecast rise in the gas is a function of simple economic and population growth in [developing countries], there is no realistic . . . way to prevent a CO_2 doubling without slashing growth and risking a revolt of the have-not nations against the haves. By the middle of the next century, developing countries will account for the bulk of the greenhouse gases emitted into the atmosphere, even if they succeed in doubling energy efficiency.

On November 7, 1989, the United States and Japan refused to sign a resolution at an international conference on global climate

Questions and Answers for page 52
(answer Questions 1–5 for each strategy)

1. What do supporters of this strategy suggest be done about the potential global warming problem?

2. Would supporters of this strategy more likely be from developed or developing countries? Why?

3. Why do the supporters believe this strategy is fair and equitable?

4. How do supporters justify this strategy?

5. Does this strategy make sense even if global warming does *not* develop into a major problem? Why or why not?

Strategy 1: No action—Proponents argue that the problem is overblown, or may not even materialize, and in any case is too costly to address. Both developed and newly industrializing countries take this position, although these countries probably are not at risk from possible impacts. Costs and uncertainties justify the strategy, and it is deemed fair because it doesn't cut off development options for poorer nations. If the warming doesn't occur, this strategy certainly makes sense.

Strategy 2: Adaptation—Proponents argue that we should plan for inevitable changes. Most likely it is the richer developed countries, who could afford these steps, who promote this. Developing countries would need much money to build seawalls, for example. This is justified as both a realistic and prudent strategy, but spending large sums on planning and building protective structures makes no sense if the warming doesn't happen.

Strategy 3: Prevention—Proponents argue that we must reduce the source of the problem, eliminating it where possible. Most likely, developing nations at great risk would support these moves. It is equitable in that nations unable to afford planning measures would be spared global warming's effects. Among the justifications for this idea are the three points listed and the Maori perspective about the wholeness of Earth. Unlike the previous two strategies, it assumes the net effects of warming will be negative. But if the warming fails to materialize, this radical strategy would not be sensible.

Strategy 4: "Tie-in"—This idea is that by limiting the growth of greenhouse gases by measures that have *other* benefits, we buy time for research to ascertain the certainty of global warming, to develop alternative energy sources, to find ways to slow deforestation, and so on. Both developed and developing nations have embraced this idea. It is seen as fair because, with minimal disruption to development, many benefits can be realized. This makes sense regardless of whether the climate warms.

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change. The resolution had called for a limit on emissions of greenhouse gases by the year 2000. The U.S. position was that "we should not move forward on major programs until we have a reasonable understanding of the scientific and economic consequences of those programs."

Then-president Bush said: "You can't take a policy and drive it to the extreme and say to every country around the world: You aren't going to grow at all" (Brookes 1989, page 57). The U.S. and Japanese position was supported by some 30 developing nations. Many developing countries see the "threat" of global warming as an excuse to prevent their development.

The Environmental Protection Agency has said tax increases of 30 percent on oil and coal would be needed just to maintain U.S. CO_2 emissions at current levels. To reduce U.S. CO_2 emissions by 20 percent, a tax of $25 per barrel on oil and $200 a ton on coal would be needed. This would double the cost of energy in the United States (Brookes 1989). Recent estimates of U.S. costs of a 20 percent reduction in CO_2 emissions range between $800 billion and $3.6 trillion (Sebenius 1990).

Strategy 2: Adaptation

> During the past century temperatures have risen about 0.5°C and sea level has risen about 10–15 cm. Current levels of greenhouse-gas emissions may already have committed the Earth to another 0.5° C temperature increase and another 10–30 cm of sea level within the next 50 years—even if the composition of the atmosphere is stabilized now (Wellington Conference on Climate Change 1988).

People at that conference in Wellington, New Zealand, concluded that the most realistic policy is to accept these predicted climate changes as inevitable. To prevent climate change would require too severe a disruption in present life styles. The conference decided that planning for the changes was the best strategy. Examples of planning measures for sea level rise and agriculture follow.

Sea level rise

Most people at the conference agreed that planners should include sea level rise predictions in zoning decisions. Engineers should take predicted sea level rise into account when designing new coastal structures (Wellington Conference on Climate Change 1988).

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Agriculture

The workshop concluded that the productivity of plants in New Zealand would increase in an atmosphere that contains more carbon dioxide. To take advantage of the warmer environment, growers may need to relocate. Increased diversity in crop production may be possible. For example, fruit species new to the area, such as bananas and other subtropical fruits, could be grown. Tree and livestock species better suited to warmer environments could be established. Identification of possible losses and gains in export markets should begin immediately.

Despite the uncertainty of climate changes over the next few decades, farmers must adapt to the changes. The most important adaptation will be to use different plant breeds and crops. This is especially true for farmers in countries in higher latitudes (such as New Zealand and the United States), where climate change may be most severe. Farmers should shift to crops adapted to warmer conditions, to take advantage of the expected longer growing seasons. In some places, summer drought may become a problem. Farmers should change from crops that grow only in summer to those that grow in other seasons. To make such changes, farmers will need money. Better predictions for climate changes at a regional level are also needed. Government help will be needed when farmers' own resources of know-how and money are insufficient (World Resources Institute 1990).

Strategy 3: Prevention

> This [strategy] begins from two premises. The first is that trend is not destiny; what has been caused by human activity can be mitigated by more appropriate human activity. The second is that [rapid] climate change will, overall, be harmful. Despite local opportunities that may be created, . . . we are generally better adapted to the climate we have lived with for generations than to any other (Fitzsimons 1988, page 1).

Here are three reasons why preventing climate change is better than adapting to a future warmer climate:

1. We are too uncertain exactly what climate will occur, so it is impossible to know just *what* to adapt to. Climate models do not do a good job predicting what will happen on a local level. Unpredictable local changes in rainfall or storm frequency may be more important than temperature.
2. Adaptation strategies are useful only in the immediate future, perhaps the next 50 years at best. But this is just one point on

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a longer time scale, and the rate of change may quicken. People may be able to adapt to a 2°C increase, but will the same strategies work if temperatures increase 5°C?

3. The people who are most at risk from changing climates do not necessarily have the money to adapt to these changes. It is unfair to expect African farmers, who already are troubled by droughts and famines, to adapt to climate change as easily as farmers in richer countries (Fitzsimons 1988).

The Maori are New Zealand's aboriginal people. Betty Williams, a Maori representative at a conference on climate change, stated the Maori position. She said the conference lacked a vision for the future because it addressed only the human problems related to climate change. She argued that the conference should look at the problem in the total context of Earth.

The Maori vision is to restore and maintain the integrity and life-energy strength *(mauri)* of nature. The Maori believe that human survival depends upon maintaining Earth's mauri. According to the Maori, humans have reduced the mauri of all natural resources, such as the atmosphere and its gases. In Maori terms, Earth can correct any imbalance of its mauri, given the chance. This can be achieved by a policy of prohibiting the production and use of all human-made things that have diminished the mauri (Wellington Conference on Climate Change 1988).

Maori woman cooks in a thermal spring.

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Strategy 4: "Tie-in"

Scientists agree that some climate changes are unavoidable because the atmosphere has already changed. But the *rate* of change *can* be affected by actions that people take now and in the future (Wellington Conference on Climate Change 1988).

The main goal should be to *slow* the rate of increase of greenhouse gases, so that we can delay global warming. For example, if CO_2 increases at a rate of 3 percent per year, its concentration will double by 2036. But if the increase rate is slowed to 1 percent per year, then the doubling won't happen until the year 2100 (Fitzsimons 1988). This extra 60 years would give us more time—time to do more research, to predict problems before they occur, and to develop adaptation plans, such as breeding drought-resistant plants and building seawalls (Udall 1989).

> The Earth's climate is far from being understood. Natural [reactions] to the warming, like increased cloud cover, might come to the rescue by damping down any greenhouse effect. But why bet on it? The greenhouse warming may not arrive for several decades, or it may already have started. . . . Either way, the precautionary measures already at hand are cheap insurance against risks of such magnitude (Editorial, *The New York Times*, Jan. 27, 1989).

The most sensible precautionary measures to deal with potential rapid climate change are called "tie-in" strategies. A tie-in strategy is an action that reduces the amount of greenhouse-gas emissions and *at the same time* also gives society other benefits not related to climate change (Schneider 1988).

The most important tie-in strategy is to use energy more efficiently. Any fossil fuel that is *not* burned produces no CO_2. At the same time, no pollutants or acid rain are produced to cause health problems. Also, there is no dependence on imported oil. And the less energy it takes to manufacture a product, the lower its cost. This makes the product cheaper to sell, which makes it more attractive to buyers (Schneider 1988).

Other possible tie-in policies to slow the rate of greenhouse-gas emissions include banning CFCs; using renewable energy sources, such as solar power; beginning a global effort at reforestation; and helping developing countries to advance themselves using renewable rather than fossil fuels (Udall 1989). Banning CFCs, for example, both reduces a major greenhouse gas and removes the major cause of the ozone hole.

C. *Closing first day of lesson:* Reorganize students into the four groups that will take opposing sides in the debate on the second day. These strategy groups represent each strategy. Students join a group according to the strategy they were assigned to read. Each group should designate two spokespeople who will argue for that strategy in the class debate on the next day. Strategy groups could begin to formulate their arguments at this time and complete this preparation task in the first minutes of the second day, if needed. All remaining students, those not designated as spokespeople in the actual debate, will become the debate judges, each acting in their role as representative from a developed or developing region.

If desired, you could also assign a brief written essay as homework to all students. Having discussed the strategies in their groups, students could address the question "What ought to be done?" in this essay. Ask each student to consider this from two perspectives: as a representative from either a developed or developing region (based on his or her assignment) and as an individual, expressing his or her own opinion. Suggest that students think about the following questions:

- Why is there disagreement regarding the potential for global warming?
- Does a problem exist? (Recall that not all people view global warming, even if it should occur, as a problem. Some view its potential benefits as being greater than its potential costs.)
- If there is a problem, what actions can be taken to prevent or limit the problem? What adaptation measures might be necessary?

The following procedures are suggested should you wish to have the class debate the four strategies. Alternatively, you may wish to have the class as a whole simply discuss all four choices. This option may work better for younger students if the reading proved too difficult.

D. *Define the debate:* "Resolved—the threat of global warming is serious enough that we must immediately reduce emissions of greenhouse gases." The debate is four-sided, with each strategy group arguing its points and making a brief rebuttal following presentations by other groups. Allow three minutes for each group's first presentation and one minute for each rebuttal, for a total of 15 minutes. The eight students designated as spokespeople make their arguments based on what their strategies say. The rest of the class are judges, acting as representatives from developed and developing regions. In effect, this is a mock international conference.

The following four guidelines will help define the scope of the debate and the rationale for judgment.

GUIDELINES FOR CONDUCTING AND JUDGING THE DEBATE

These points were made at the Wellington (New Zealand) Conference on Climate Change in 1988. These are worth noting to your class as they debate about global warming.

1. *Don't be trivial.* The effects of climate change will include relatively minor problems, such as the loss of some ski resorts, but will also involve major disruptions to some people's lives (such as the total submergence of the Republic of Maldives).
2. *Don't be parochial.* There is a tendency to think only in terms of how the problem might affect one's region or country. Remember that it's a global issue.
3. *Don't be simplistic.* Climate change is linked to many other issues, including ozone depletion, Third World development, deforestation and desertification, population growth, and energy dependence. In sum, simple solutions won't work.
4. *Don't be shortsighted.* Change will be gradual, and the climate will continue to adjust to changed conditions. We cannot simply plan for a climate that will be a little warmer in 2030, because climates may continue to change depending on what we do now and in the future.

E. *After the debate:* After listening to the arguments, the judges can vote for the strategy that they feel best suits their region's needs. If you like, this vote can be loaded, based on your preference. More weight can be given to rich industrial regions (giving priority to economic power) or more weight can be given to poorer regions that desire development by any means possible (emphasizing world population and UN numbers).

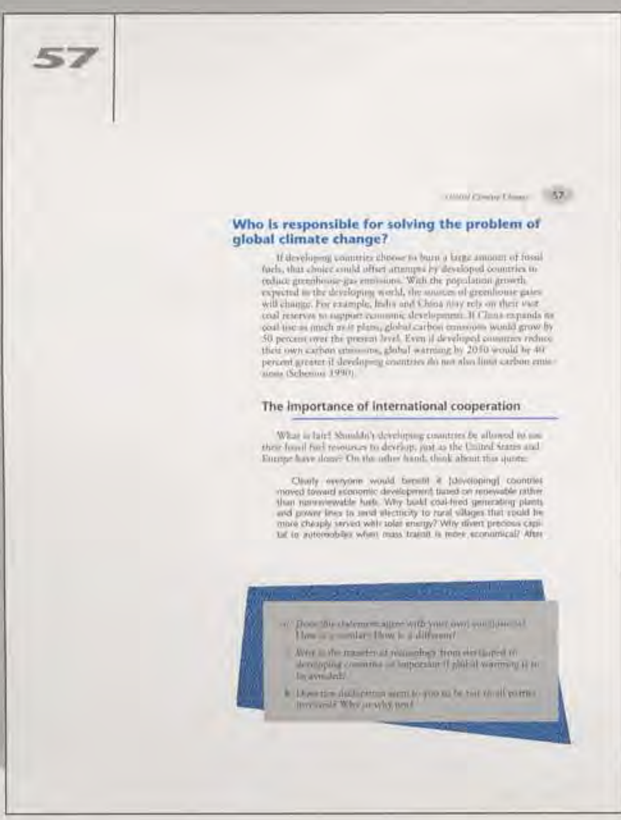
Encourage students to come to some personal closure about the issue. Is the potential of global warming critical enough to make it worth "buying some insurance" now? Or are the uncertainties too great to make the substantial changes in our agroindustrial economies that would be needed to reduce greenhouse gases? Students can see if they have a consensus opinion about this issue and debate their own viewpoints.

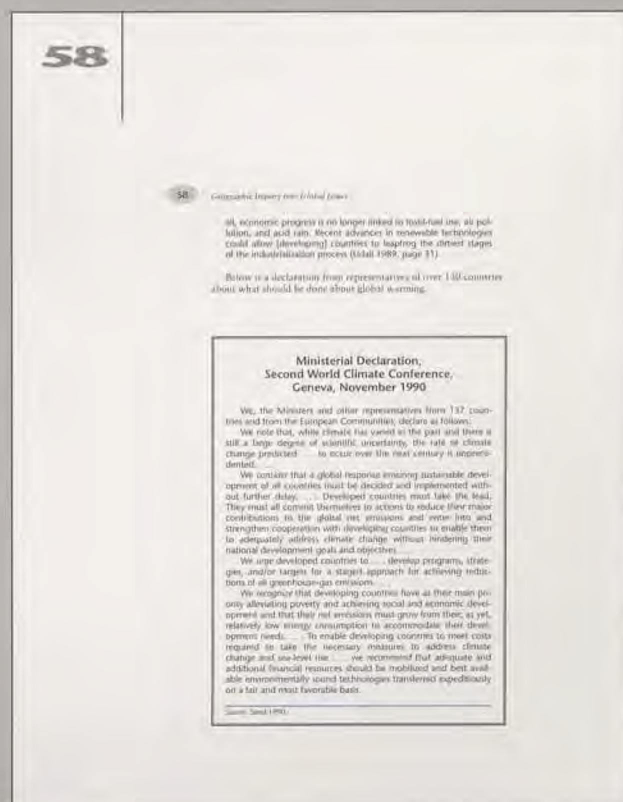
> The readings are somewhat biased in their emphasis. Students may be led to conclude that the problems are serious enough to warrant some actions that reduce greenhouse-gas emissions while also helping to remedy other issues (Strategy 4). Challenge older students to identify this bias and to find sources that advocate other positions.

Who is responsible for solving the problem of global climate change? (pages 57–58)

F. Have students read "The importance of international cooperation" on page 57. Discuss why technology transfer must be part of the solution (Question 7 on page 57). You can add the following fact not mentioned in the module as another illustration: Consider that only about 10 percent of Chinese households now have refrigerators. The Chinese government wants to increase that to 100 percent by 2000. These refrigerators must be able to make use of the best available non-CFC technology so that the reductions made in other countries are not overwhelmed.

Use Questions 6 and 8 on page 57 to generate discussion. Ask the class to consider the inequities of development in the world. How can we avoid worsening the potential for global warming while, at the same time, raising the standard of living in developing countries? Or are these two problems intractable? Can developing countries reach the levels of development of the industrialized world without increasing the chances for global climate change?





Questions and Answers for page 57

6. Does this statement agree with your own conclusions? How is it similar? How is it different?
   - Answers will vary.

7. Why is the transfer of technology from developed to developing countries so important if global warming is to be avoided?
   - Developing countries can use technologies from the developed countries to avoid the polluting emissions of fossil fuels used for industry.

8. Does this declaration seem to you to be fair to all parties involved? Why or why not?
   - Answers will vary.

G. Read aloud the "Ministerial Declaration" on page 58. This is the actual consensus of an international conference. If you wish, have the class compare this consensus to their own opinions about the issue.

What have the world's developed countries decided to do about global climate change? (pages 59–61)

H. Have students look at Figure 13 on page 59. Discuss the cartoon's symbolism (e.g., Uncle Sam) and have the class decide what the cartoonist is saying about the U.S. reaction to the climate change issue.

59

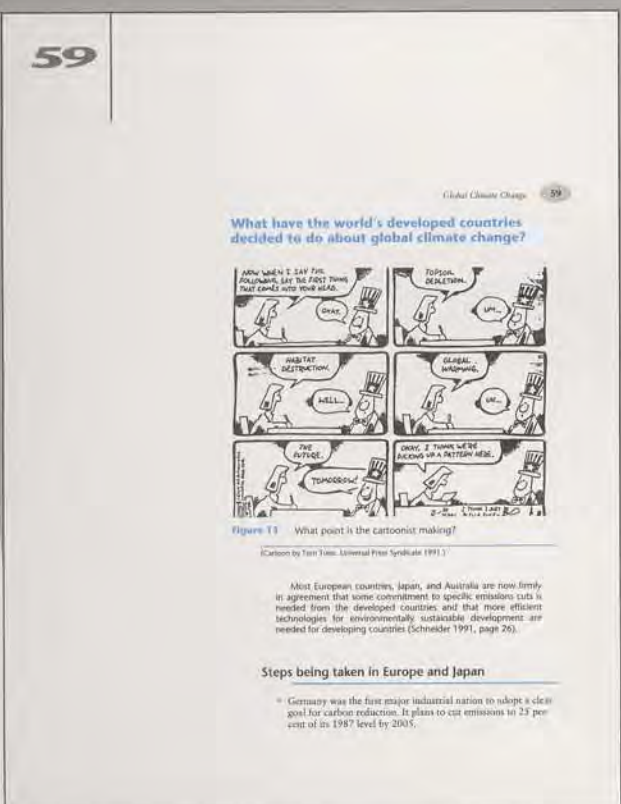


Figure 13 What point is the cartoonist making?

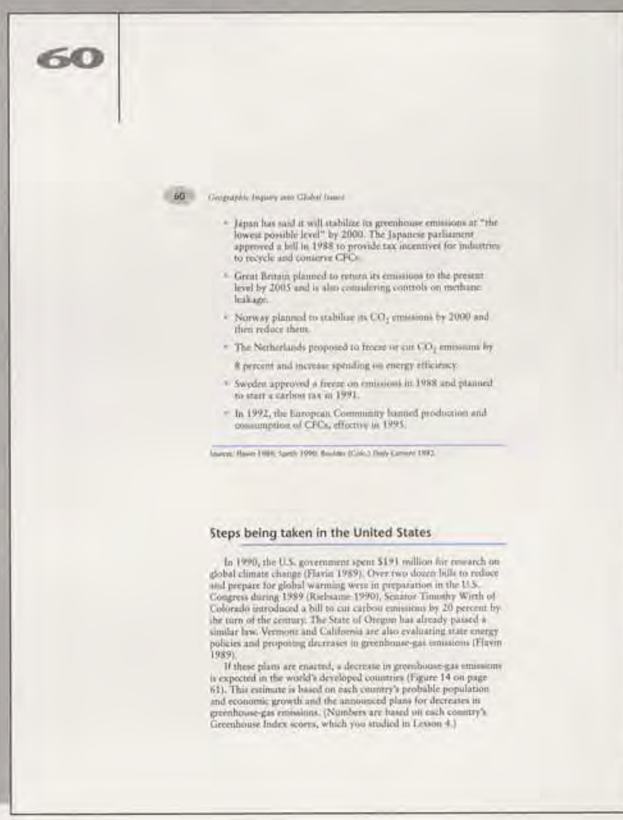
(Cartoon by Tom Toles. Universal Press Syndicate 1991.)

Most European countries, Japan, and Australia are now firmly in agreement that some commitment to specific emissions cuts is needed from the developed countries and that more efficient technologies for environmentally sustainable development are needed for developing countries (Schneider 1991, page 26).

Steps being taken in Europe and Japan

- Germany was the first major industrial nation to adopt a clear goal for carbon reduction. It plans to cut emissions to 25 percent of its 1987 level by 2005.

60



60 Geographic Inquiry into Global Issues

- Japan has said it will stabilize its greenhouse emissions at "the lowest possible level" by 2000. The Japanese parliament approved a bill in 1988 to provide tax incentives for industries to recycle and conserve CFCs.
- Great Britain planned to return its emissions to the present level by 2005 and is also considering controls on methane leakage.
- Norway planned to stabilize its CO_2 emissions by 2000 and then reduce them.
- The Netherlands proposed to freeze or cut CO_2 emissions by 8 percent and increase spending on energy efficiency.
- Sweden approved a freeze on emissions in 1988 and planned to start a carbon tax in 1991.
- In 1992, the European Community banned production and consumption of CFCs, effective in 1995.

Sources: Flavin 1989; Speth 1990; Boulder (Colo.) Daily Camera 1992.

Steps being taken in the United States

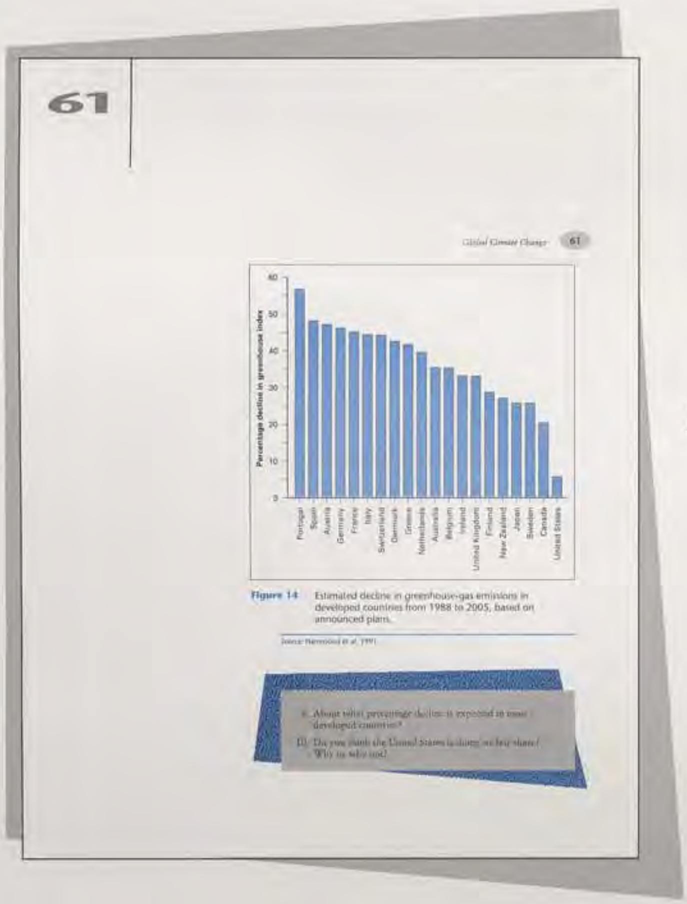
In 1990, the U.S. government spent $191 million for research on global climate change (Flavin 1989). Over two dozen bills to reduce and prepare for global warming were in preparation in the U.S. Congress during 1989 (Riebsame 1990). Senator Timothy Wirth of Colorado introduced a bill to cut carbon emissions by 20 percent by the turn of the century. The State of Oregon has already passed a similar law. Vermont and California are also evaluating state energy policies and proposing decreases in greenhouse-gas emissions (Flavin 1989).

If these plans are enacted, a decrease in greenhouse-gas emissions is expected in the world's developed countries (Figure 14 on page 61). This estimate is based on each country's probable population and economic growth and the announced plans for decreases in greenhouse-gas emissions. (Numbers are based on each country's Greenhouse Index scores, which you studied in Lesson 4.)

Questions and Answers for page 61

9. About what percentage decline is expected in most developed countries?
    - Most countries in Figure 14 are planning reductions of at least 25 to 40 percent in their greenhouse-gas emissions.

10. Do you think the United States is doing its fair share? Why or why not?
    - The U.S. plans (as of 1990) were for about a 5 percent reduction. From these data, students may conclude that the United States is not yet doing its fair share, especially considering its rank in the world in terms of absolute and per person emissions of greenhouse gases.



I. Have students read the lists of steps already being taken in Europe, Japan, and the United States on pages 59–60. Have the class compare European and Japanese actions to those of the United States. Ask which of the four strategies discussed earlier these lists represent. [Bits of Strategies 3 and 4]

   The impact of these measures (as planned and announced) on the Greenhouse Index of several countries is shown in Figure 14 on page 61. Higher numbers indicate that the country is planning a greater reduction of its greenhouse-gas emissions. Discuss Questions 9–10.

J. To close the module, if students have determined that the United States is not doing enough, in their opinion, about reducing the chances for global climate change, have the students draft a letter to their congressional representatives or to the president. Encourage the class also to continue the changes in their own personal habits that they contracted in Lesson 1, if they feel strongly that action is needed to reduce the likelihood of global climate change. Many students will feel that the problem is not serious enough to warrant changing behaviors, and this is also a fair conclusion.

For Further Inquiry

Assign any of the following essays as closure for the module:

a. What are the potential global environmental impacts of economic development in developing countries?

b. What are the potential environmental costs of consumer patterns in the developed world?

c. Take a position for or against this statement: Any policy chosen to deal with global warming should at the same time have other, more immediate benefits.

d. Take a position for or against this statement: Nothing needs to be done about global warming because there is too much uncertainty about the scientific projections.

1 2 3 4 5 CP 99 98 97 96 95

Extension Activities and Resources

1. **Related GIGI Modules**
   - The largest amount of forest loss occurs in Brazil, with an estimated 2.6 million hectares of deforestation in 1989. The GIGI module *Development* explores deforestation in Brazil in more detail.
   - Deforestation in Africa, besides adding greenhouse gases, also leads to soil erosion, desertification, and damage to freshwater resources. The GIGI module *Hunger* examines the way in which these factors contribute to Africa's food supply shortages and famines.
   - The sustainability of food supply can be explored further in the GIGI module *Sustainable Agriculture.*

2. **Britannica Global Geography System (BGGS)**

   BGGS provides myriad extension activities to enhance each GIGI module. For a complete description of the BGGS CD-ROM and videodiscs and how they work with the GIGI print modules, please read the BGGS Overview in the tabbed section at the beginning of this Teacher's Guide.

3. **Related Videos**
   - EBEC offers the following videos about the issues and regions explored in the Global Climate Change module: "Problems of Conservation: Air"; "Problems of Conservation: Acid Rain"; "Children of New Zealand: Living in the High Country"; "U.S. Regions: The Southeast"; "Evidence for the Ice Ages"; "The Ways of Water"; "The Water Cycle"; and "The Earth in Change: The Earth's Crust."

     For information, or to place an order, call toll-free, 1-800-554-9862.
   - Other related videos include: Program 5, "The Air Conditioning" (*Spaceship Earth* series, PBS); "Is It Hot Enough for You?" (*Nova* series, PBS); and "Living Planet" (IMAX).

4. **Additional Activities**
   - The following table summarizes what one scenario of climate change might mean for people living in the five largest cities in Australia. Use this to get students thinking about the social impacts of climate change. Ask what life might be like for urbanites who may be subject to much different climates than what the city was designed for. For example, if Melbourne were to become warmer and drier, what effects could that have on local water supplies? Or what would happen in Sydney on the demand for air conditioning

Climate Changes in Australia's Largest Cities

City (State)	Probable Climate Changes in Doubled CO_2 World	1990 Population
Sydney (NSW)	warmer, wetter, less windy	3,391,600
Melbourne (Vic.)	warmer, drier, windier	2,604,000
Brisbane (Qld.)	warmer, wetter, less windy	1,157,200
Perth (WA)	warmer, drier, less windy	1,001,000
Adelaide (SA)	warmer, drier, less windy	987,100

Sources: Henderson-Sellers and Blong 1989; National Geographic Society 1990.

in summer? These and similar questions can be used to bring home how these changes could affect daily lives. Ask students to imagine their own climate much warmer or wetter (or drier) than the present. How would their lives possibly be different?

- Have students find out how their local power is generated. Is the power plant fired by coal, oil, natural gas, or by one of the noncarbon-generating alternatives?
- The discussion concerning how air-conditioning and refrigeration have relied on greenhouse-gas emitting chemicals can be greatly expanded. Among other options, students could interview residents at a senior center to learn more about what life was like prior to the widespread availability of these amenities.
- Have students conduct additional study into the ecological and economic importance of wetlands. This could be done in conjunction with a life science or STS class.
- Have students look back at late summer 1988 issues of *Time, Newsweek,* and other popular periodicals to examine the mass media's reaction to the 1988 drought and global warming scare. Other sources include *Time*'s 1988 "Planet of the Year" issue and *National Geographic*'s end of 1988 report on environmental problems. Students can explore the role of the popular media in making people aware of an issue. Were all sides covered adequately? How were data presented?
- Contact public relations representatives from energy industries and/or CFC-producing industries. Ask them to come to your class to explain their industry's perspective in more detail. Have them describe the economics of their business and their concerns about greenhouse-gas regulations.

The following Extension Activities would be useful in promoting civic participation and citizenship education.

- Contact the World Wildlife Fund (202-293-4800) to find out if it still has a program to save one acre of rainforest for $25.00. The class could undertake fundraising activities to support this cause.

- Have students create a 30–60 second audio and/or video advertisement to promote awareness of global warming. Try to get local radio and TV stations to air the spot as a public service announcement.
- Have the class conduct a survey in the school to see how other students perceive the global climate change issue. Are their peers familiar with it? Do they see it as a major problem?
- Have students chart the trends in average annual temperatures in your area. Students can ask local meteorologists (perhaps by writing to local TV weatherpeople) and/or librarians for data on the region's temperature records spanning the years 1900 to 1990. Have students graph the data and judge whether the region has already experienced warming during this century.
- Have students investigate where their local, state, and national politicians stand on this issue. Many cities have already enacted ordinances to force reductions in CFC usage by local industry. What measures, if any, has your city taken to cut CFCs? Has there been any action taken by your state legislature? Where do your state's senators stand on bills that have been introduced to set national goals for carbon dioxide reductions?
- Organize a Global Warming Awareness Day at your school. Have the class prepare informative posters and other materials to educate the rest of the school about the complexity of the issue.
- Use the *Optional Extension Worksheet* on the following two pages. This activity illustrates the point that, if global warming occurs, temperature extremes are likely to be more severe. The greatest change in winter temperatures in the southeastern United States is inland, away from the coasts. Warmer winters will probably mean a reduction in energy use, as less heating would be needed. As for summer, everywhere in the southeastern United States can expect about a month more hot weather. This would greatly increase energy use for air-conditioning. The net effect in both cases is that energy use would increase. Smith and Tirpak (1988) calculated that because of higher temperatures, the Southeast's demand for electricity would rise about 10 percent by 2055. The costs of providing this electricity range from $77 to $110 billion by 2055. Ask how this might further worsen global climate change. [More energy needed for air-conditioning could mean more fossil-fuel use.]

Optional Extension Worksheet

What Could Be the Effects of Global Warming in Southern Cities?

The Southeastern United States is one of the few areas that spends as much money on air-conditioning as on heating. Even in January, about half the region experiences average temperatures above 50°F, Frequency of Hot and Cold Days for Selected Southern Cities: Present Conditions Compared to Doubled CO_2

	Number of Winter Days with Daily Low Less than 32°F		**Number of Summer Days with Daily High Greater than 90°F**	
	Present	Doubled CO_2	Present	Doubled CO_2
Atlanta, GA	38	21	17	53
Birmingham, AL	36	8	34	73
Charlotte, NC	42	24	23	57
Jackson, MS	34	6	55	83
Jacksonville, FL	9	2	46	81
Memphis, TN	41	8	51	75
Miami, FL	<1	0	30	84
Nashville, TN	43	15	11	20
New Orleans, LA	15	4	55	85

Source: Smith and Tirpak (1988)

and almost the entire region has a typical daily high above 50°F. With the exception of the mountains of Tennessee and North Carolina, global warming would increase the number of days during which temperatures would be unpleasantly warm (see the following table).

Optional Activity

1. Locate each of these cities on the following map and label the dot for each on your worksheet.
2. From the two columns under "Daily Low Less than 32°F," figure out the total decrease in number of cold winter days for each city in the doubled-CO_2 scenario. Write this number *in blue* next to the city's dot.
3. From the two columns under "Daily High Greater than 90°F," figure out the total increase in number of hot summer days for each city in the doubled-CO_2 scenario. Write this number *in red* next to the city's dot.
4. Examine the pattern on the map and answer the following questions on a separate sheet of paper:
   a. Which parts of the southeastern United States are likely to experience the greatest change during the winter?
   b. How will warmer winters affect energy use in these areas?
   c. Which parts of the southeastern United States are likely to experience the greatest change during the summer?
   d. How will hotter summers affect energy use in these areas?

Name ________________

Adding Up the CO_2 You Spew

Gasoline

Find out how many miles your family's car was driven last year. Divide the total miles by the approximate miles per gallon to get the total number of gallons used. Each gallon of gasoline produces 20 pounds of CO_2.

Example: A car for a family of four was driven 20,000 miles last year. It gets 20 miles per gallon, so that means it used 1,000 gallons. That equals 20,000 pounds of CO_2.

Electricity

Find out from one of your family's electric bills how many kilowatt-hours your household consumed last year. If your power comes from coal-fired power plants, then each kilowatt-hour produces two pounds of CO_2. (If your family's power comes from hydropower, nuclear power, or solar power, then no carbon was emitted. Your local utility can tell you how your family's power is produced.)

Example: This family of four used about 12,000 kilowatt-hours. That's 24,000 pounds of CO_2 emitted to produce this power.

Natural gas

Again, you'll need a utility bill if natural gas was used for heating, hot water, the stove, or electricity in your home. Burning 100 cubic feet of natural gas produces 12 pounds of CO_2. (One hundred cubic feet equals one therm, which is the unit many utilities use for billing.)

Example: The family used about 1,000 therms of natural gas, producing 12,000 pounds of CO_2.

Indirect production

You must next account for the greenhouse gases produced by activities other than those related to energy. These include purchasing goods and services based on agricultural and industrial processes that produce CO_2, CH_4, and CFCs. Recall that these other sources account for half of total greenhouse emissions. Thus, you must double your total from the energy usages above to approximate the total greenhouse gases emitted into the atmosphere by your family.

Example: The total CO_2 emitted from gasoline usage, electricity, and natural gas by our sample family of four was 56,000 pounds. Double that to account for all indirect emissions for a total of 112,000 pounds.

Convert to per person usage

Take the total of all direct energy and indirect activities and convert it to tons of greenhouse gas produced (1 ton = 2,000 pounds). Divide by the number of people in your family to get the per person greenhouse emissions, in tons, for your family.

Example: The family of four emitted 112,000 pounds. This equals 56 tons, or 14 tons per person.

Activity 2 •••

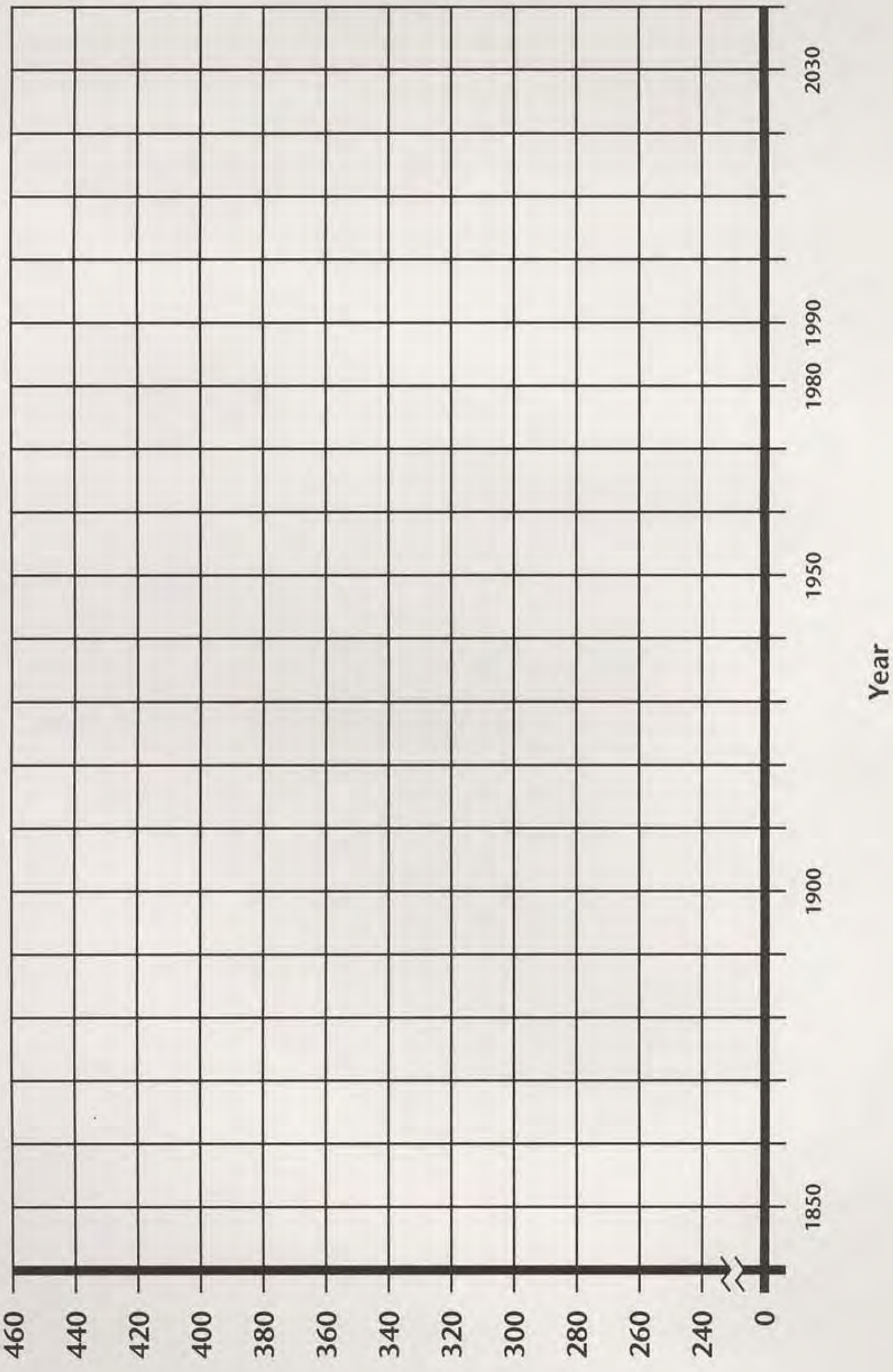
Name ____________________

GIGI

Global Climate Change

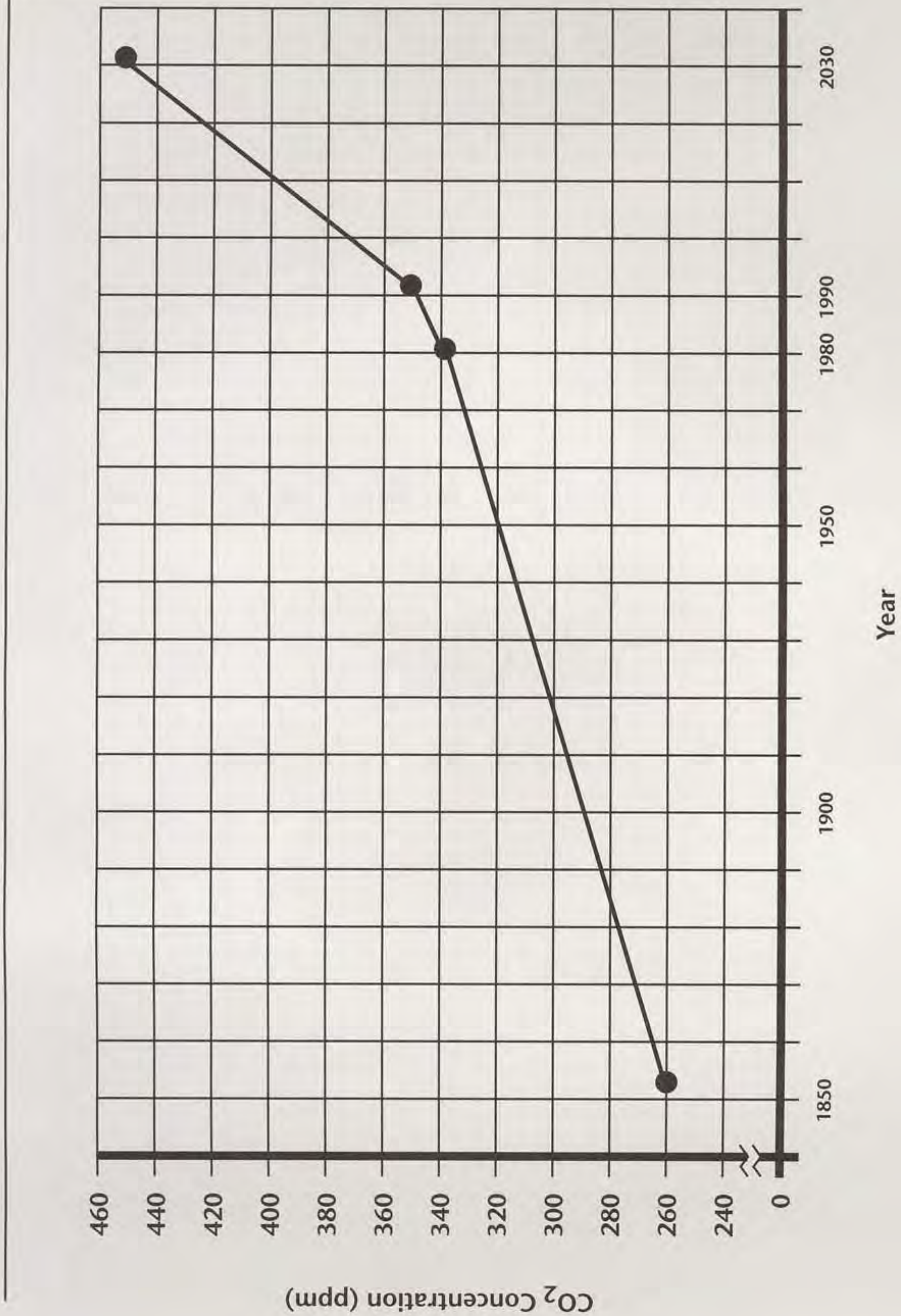
Lesson 2

Trend of CO_2 Abundance in the Atmosphere, 1850–2030



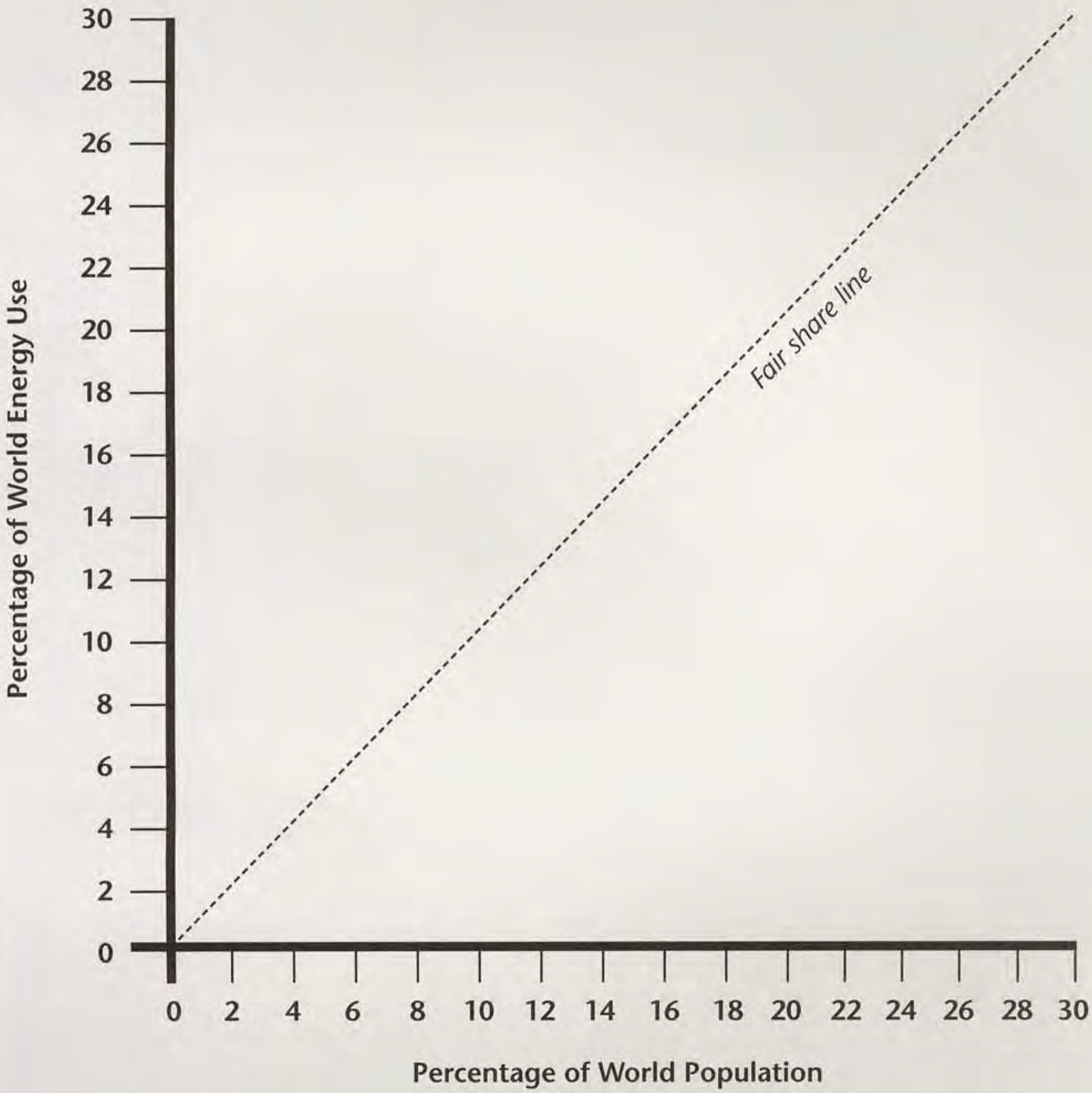
Sources: ____________________

Trend of CO_2 Abundance in the Atmosphere, 1850–2030



Sources: Smith and Tirpak 1988, World Resources Institute 1990, Brown and Postel 1987, Office for Interdisciplinary Earth Studies 1991.

Comparison of Energy Consumption and Population by Region



Sources: ____

Instructions and Questions

On Activity 3, you get a different view of Table 3. The dotted, diagonal line represents a "fair share" line. This shows how much energy would be used by a region if it used the same percentage of the world's energy as it had of the world's people. In other words, the *fair share* means that if a region had 10% of the world's people, it would use 10% of the world's energy.

A. Compare each region's income per person (Table 3) to the world average ($3,470). Classify each region by its wealth. Call a region *developed* if it has more than the world average income per person. If the region has less than the world average income per person, classify it as *developing*.

B. Using Table 3 and Activity 3, graph the percentage of energy use by region and the percentage of world population by region. Plot a point on your worksheet, one for each region, at the intersection of its percentage of energy use and its percentage of population.

C. Draw one circle around the points that you think use more energy than their fair share. Draw a second circle around the points that you think use less energy than their share.

D. Compare your classification of development (Question A) to your results from Question C (regions using more or less than their fair share of energy). What is the relationship between each region's wealth and its amount of energy usage?

____

____

E. How is a region's level of economic development related to its emission of carbon dioxide from burning fossil fuels?

____

____

____

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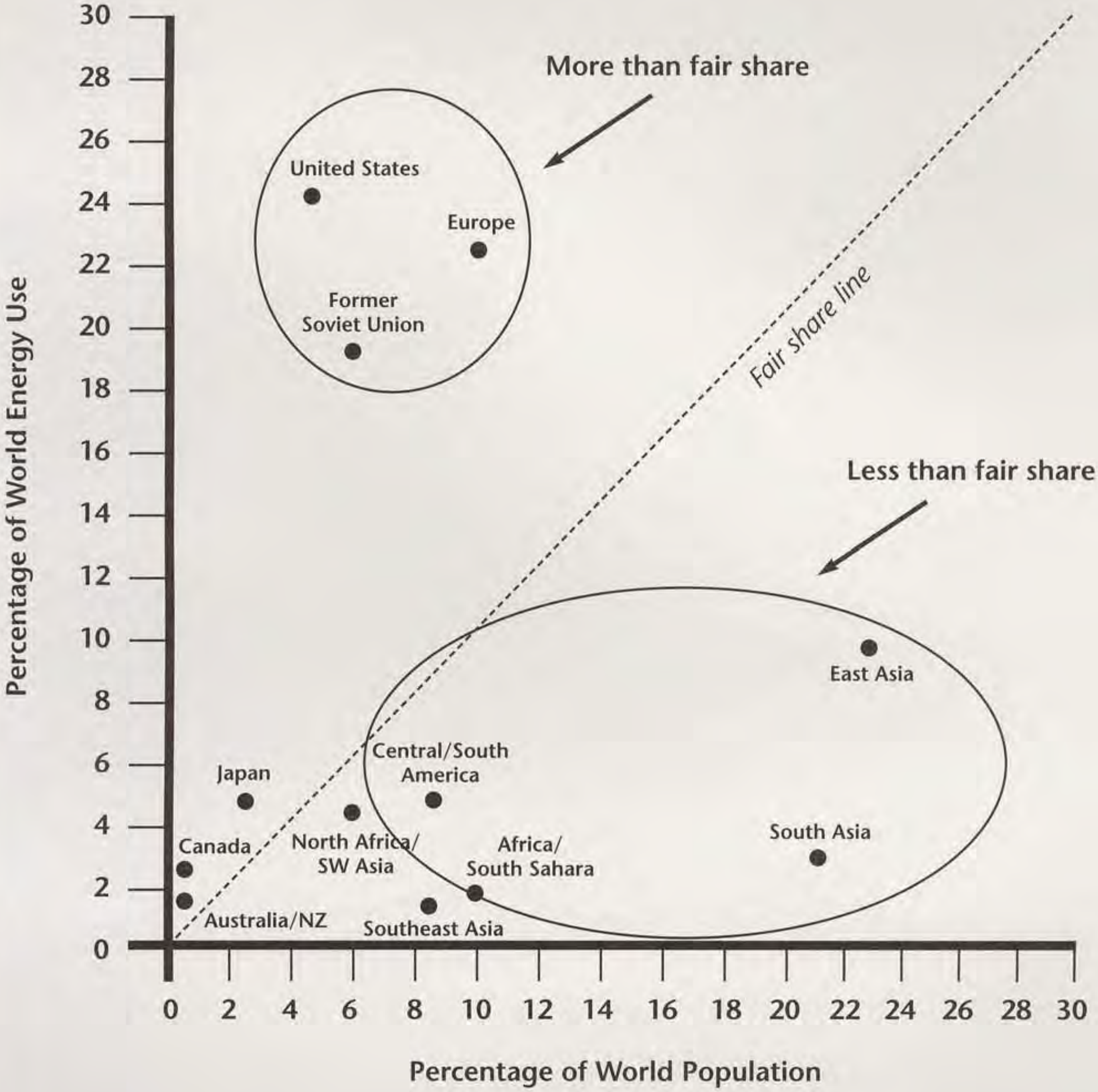
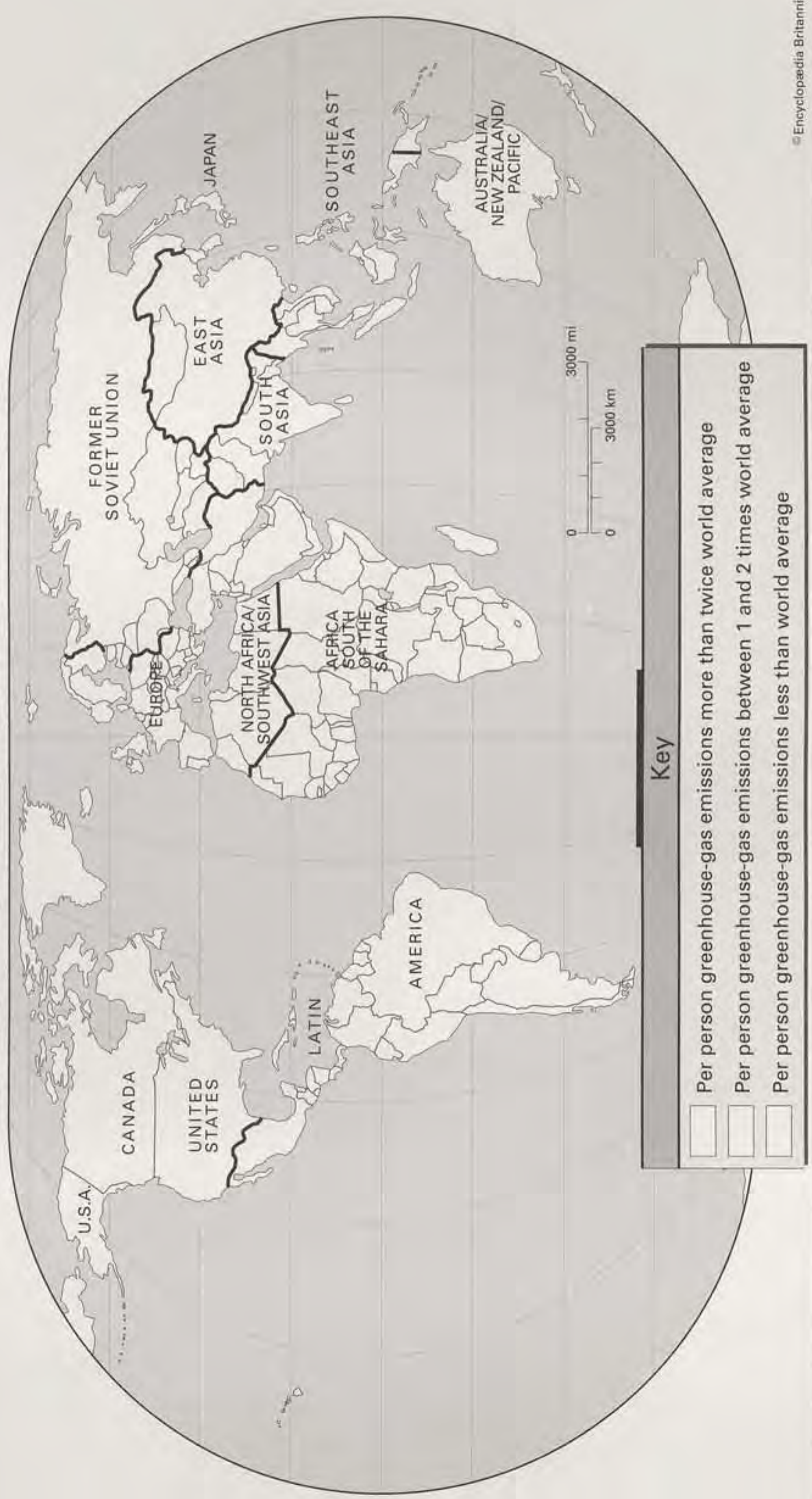
Comparison of Energy Consumption and Population by Region



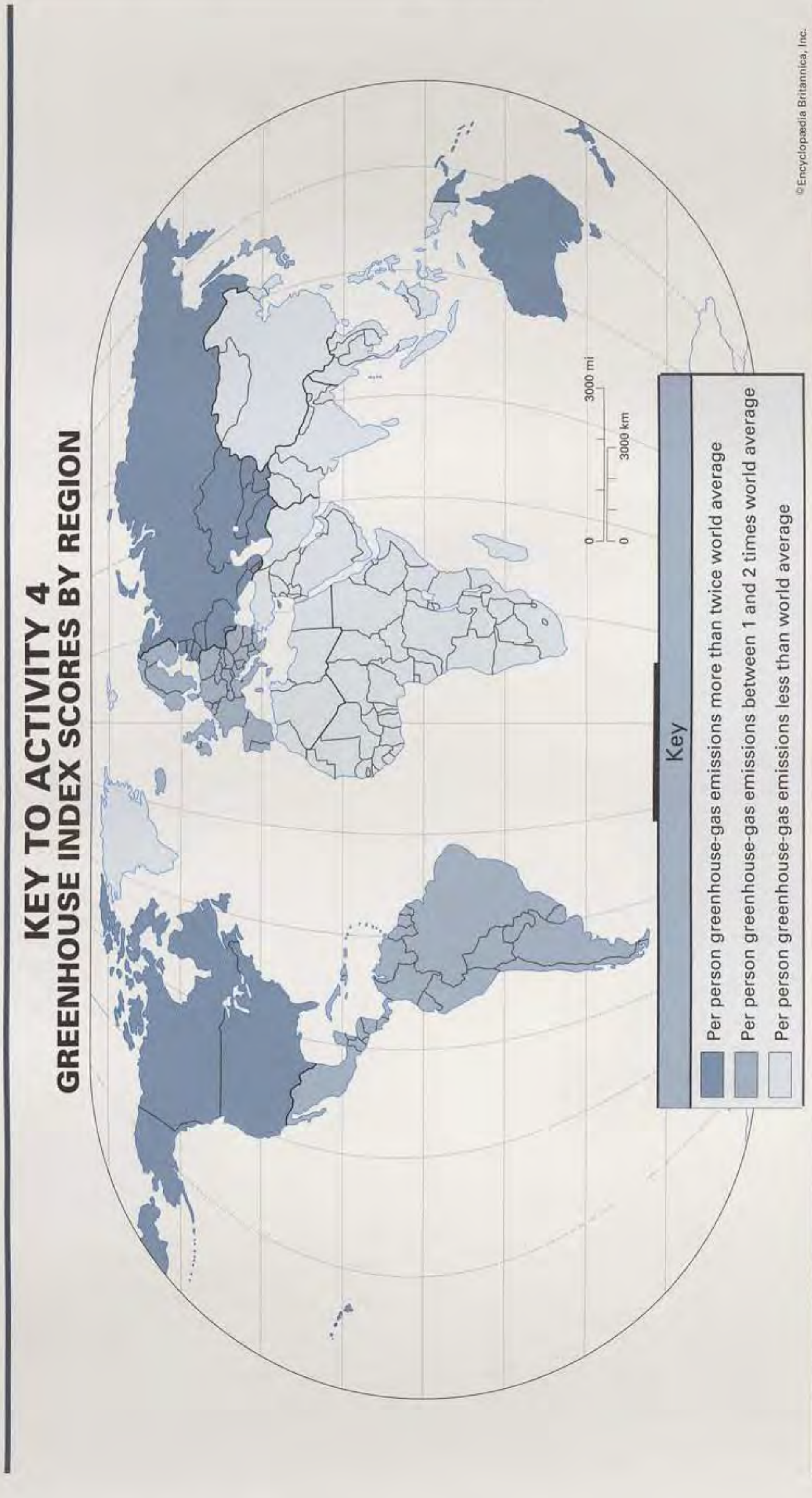
Sources: World Resources Institute 1990; Population Reference Bureau 1990; National Geographic Society 1990.

World Map

ACTIVITY 4
GREENHOUSE INDEX SCORES BY REGION



World Map


KEY TO ACTIVITY 4
GREENHOUSE INDEX SCORES BY REGION
0 3000 mi
0 3000 km
Key
Per person greenhouse-gas emissions more than twice world average
Per person greenhouse-gas emissions between 1 and 2 times world average
Per person greenhouse-gas emissions less than world average
© Encyclopædia Britannica, Inc.

Questions on Figures 7 and 8

a. What kinds of land use are most commonly associated with areas of *low* soil moisture?

b. What kinds of land use are most commonly associated with areas of *medium* soil moisture?

c. What kinds of land use are most commonly associated with areas of *high or very high* soil moisture?

d. According to the OSU climate model, what states of Australia will experience an increase in soil moisture if global warming occurs? What states will have a decrease?

e. According to the NCAR climate model, what states of Australia will experience an increase in soil moisture if global warming occurs? What states will have a decrease?

f. According to the UKMO climate model, what states of Australia will experience an increase in soil moisture if global warming occurs? What states will have a decrease?

Questions on Figures 7 and 8

a. What kinds of land use are most commonly associated with areas of *low* soil moisture?

[Deserts and some rangeland]

b. What kinds of land use are most commonly associated with areas of *medium* soil moisture?

[Mainly rangeland]

c. What kinds of land use are most commonly associated with areas of *high or very high* soil moisture?

[Cropland and forests]

d. According to the OSU climate model, what states of Australia will experience an increase in soil moisture if global warming occurs? What states will have a decrease?

[*Increase* — all states

Decrease — none]

e. According to the NCAR climate model, what states of Australia will experience an increase in soil moisture if global warming occurs? What states will have a decrease?

[*Increase* — westernmost Western Australia; Victoria, Tasmania, parts of New South Wales and South Australia

Decrease — Northern Territory Queensland, most of New South Wales and South Australia, easternmost Western Australia]

f. According to the UKMO climate model, what states of Australia will experience an increase in soil moisture if global warming occurs? What states will have a decrease?

[*Increase* — Northern Territory, South Australia, Tasmania, Victoria, nearly all of Queensland, New South Wales, and Western Australia

Decrease — westernmost Western Australia, parts of Queensland and New South Wales]

Lesson 5 Quiz

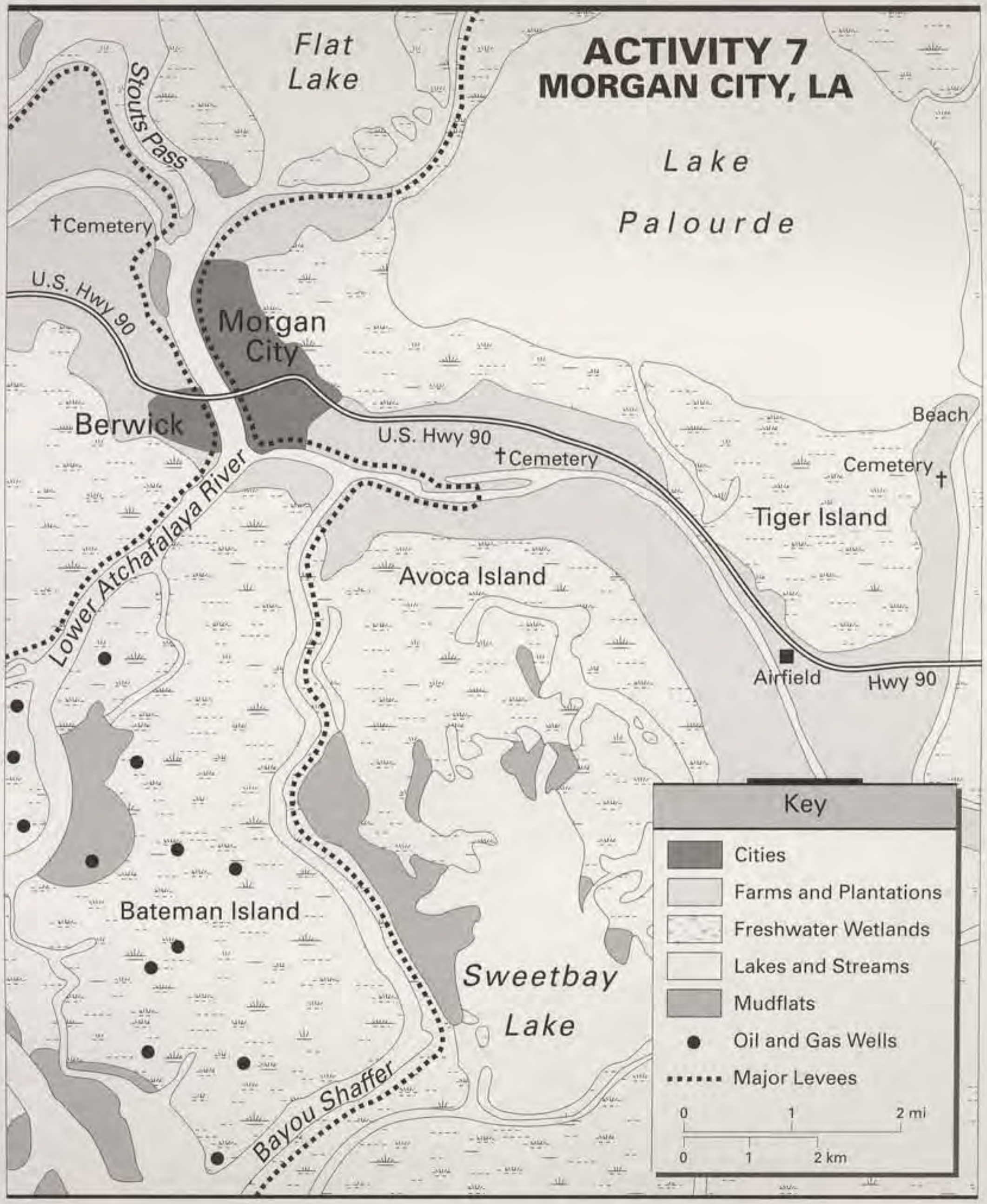
Answer all questions on a separate sheet of paper.

1. Use an almanac to identify the principal economic resources of Australia and New Zealand. Make a list of these under the categories crops, mining, and animal products.
2. Underline those that your almanac describes as major export products.
3. Star those economic activities that add greenhouse gases to Earth's atmosphere.
4. Some people believe that activities that add greenhouse gases should be stopped in order to reduce the chances for global warming. What kind of impact would such a policy have on Australia's and New Zealand's present economies?
5. (a) Australia ranks fifth in the world in coal reserves, after the United States, Russia, Germany, and China. How would worldwide efforts to lower fossil-fuel emissions affect this resource?

   (b) Australia ranks second in the world in uranium reserves, after the United States. How might world efforts to use nuclear fission as an alternative to fossil-fuel energy sources affect this resource?

   (c) If you were an economic planner in Australia, which type of energy source, coal or nuclear, would you try to promote?
6. Write a paragraph discussing this question: Taking into account everything that you have heard and read about so far, do you think that global warming will be good or bad for Australia and New Zealand?

Selected Land Uses Around Morgan City, Louisiana



Instructions and Questions

a. Use the map scale on the first page of Activity 7 (which is a copy of Figure 12 in the student DataBook) to estimate the total length of *existing* levees, in miles, in the Morgan City area.

____

b. On your Activity map, color in the area that would be flooded by a 5-foot rise in sea level. Look at the area around Morgan City. What kinds of land uses would be lost in this area if the sea rose 5 feet?

____

____

____

c. Estimate how many *more* miles of levees would need to be built to protect all of these land uses. At $3 million per mile, what could be the total cost to protect the Morgan City area?

____

____

____

d. Refer back to Figure 11 (page 48). The present shoreline of Louisiana is about 7,700 miles in length. The shoreline around Morgan City shown on Figure 12 is about 1 percent of this total. Estimate how much money would need to be spent to protect all of the Louisiana coast.

____

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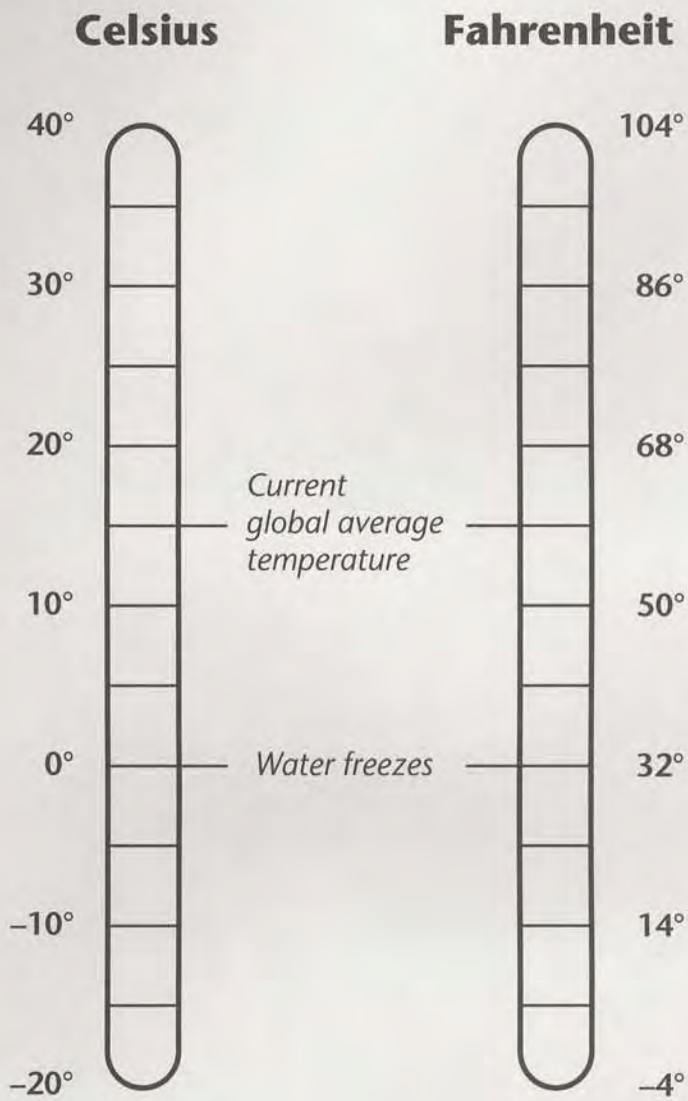
A Comparison of Celsius and Fahrenheit Scales



Equivalent temperature in Celsius and Fahrenheit can be found by simply placing a ruler across the two scales.

If you need to find equivalences for temperatures over 40°C (104°F) or under –20°C (–4°F), use the formulas below.

Conversion of Celsius to Fahrenheit: $°F = (9/5 \times °C) + 32$
Conversion of Fahrenheit to Celsius: $°C = 5/9 \times (°F - 32)$
(a change of 5° on Celsius scale equals a change of 9° on Fahrenheit scale)

Two Effects of Rising Sea Level

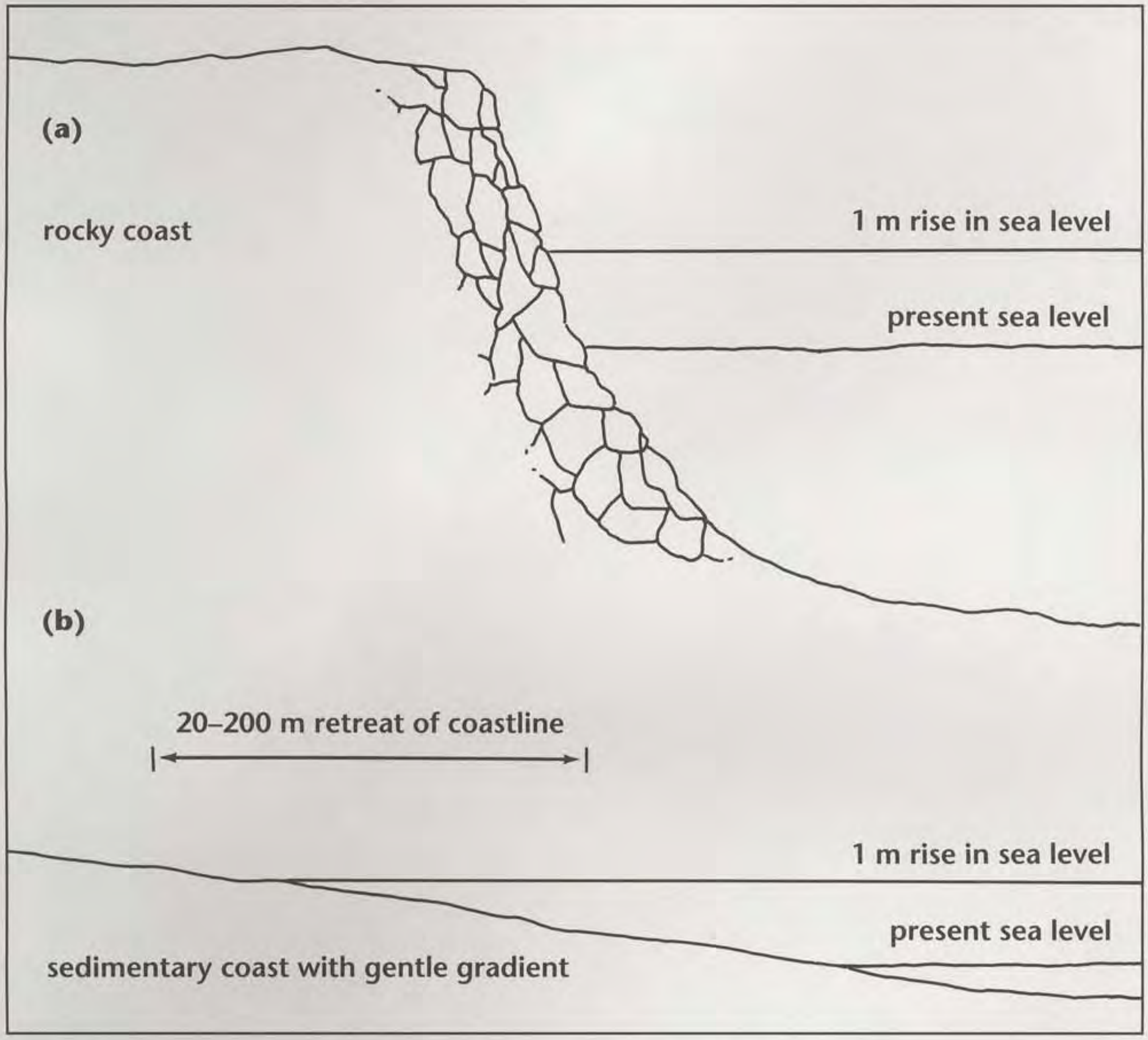


Figure A On a rocky coast (a) a 1-meter rise in sea level has little effect, but on gently sloping sedimentary coasts (b) a coastline retreat of 20–200 meters can be expected.

Source: Henderson-Sellers and Blong 1989.

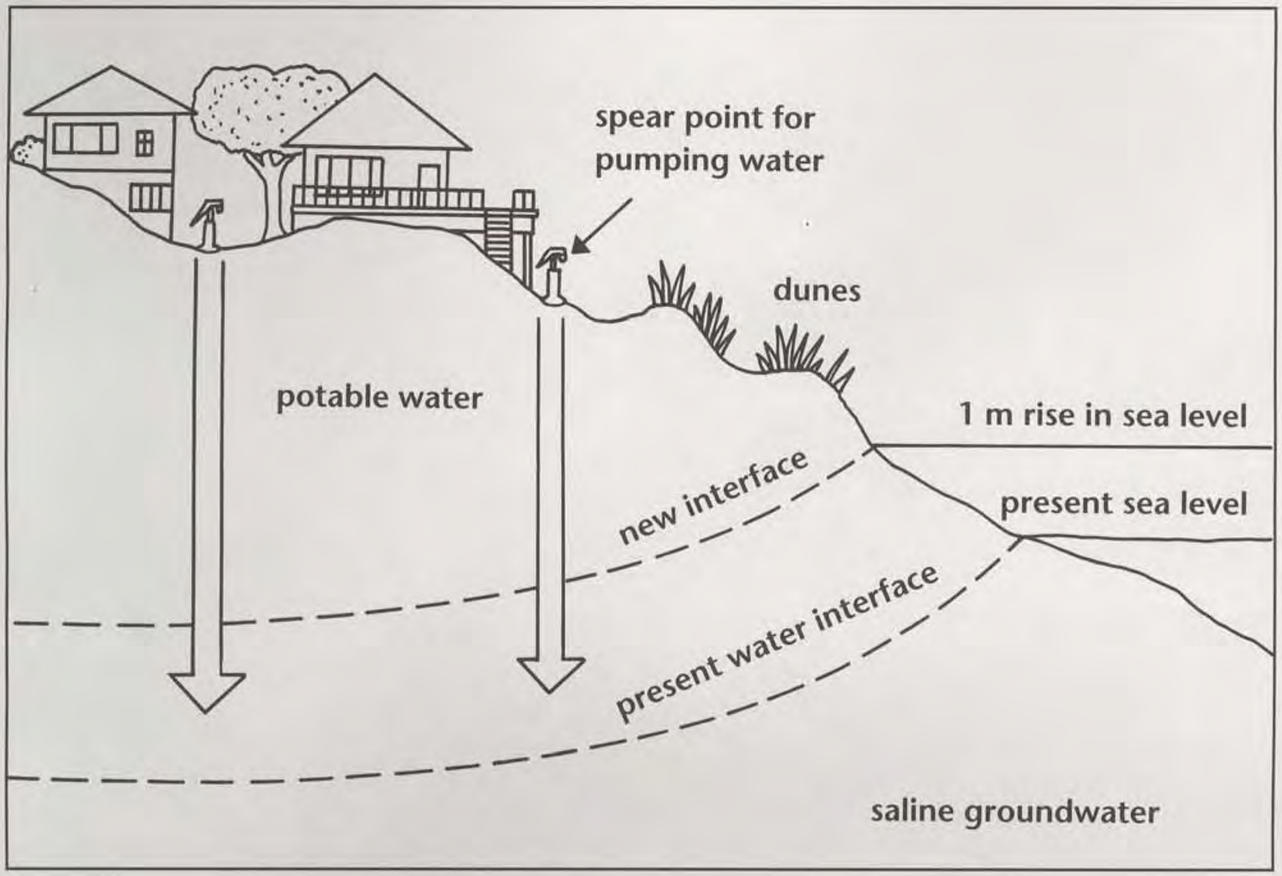
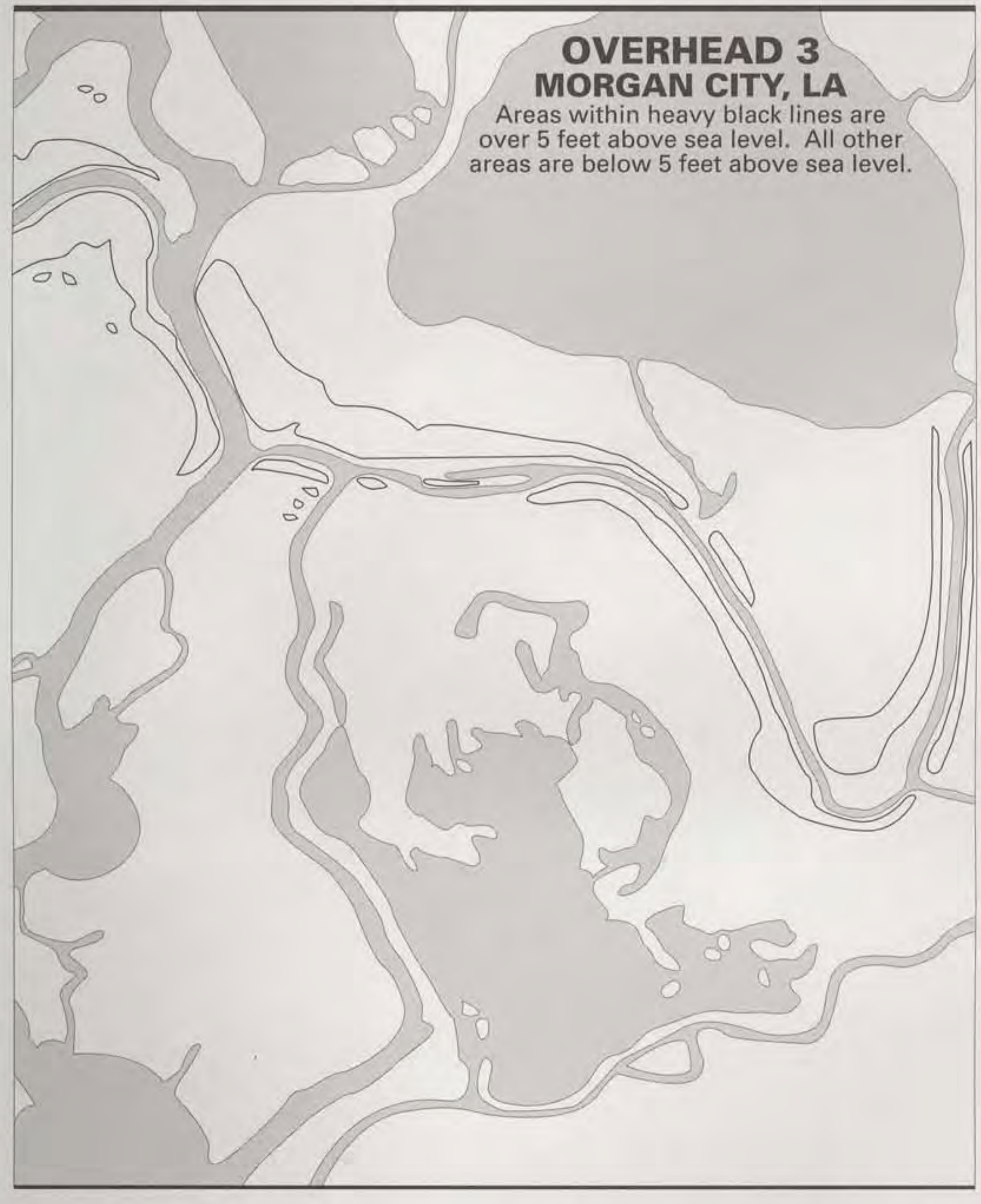


Figure B The rise in sea level will allow greater penetration of saline waters into areas where fresh groundwater is currently an important resource.

Source: Henderson-Sellers and Blong 1989.

Contour Map of Morgan City, Louisiana



Morgan City, LA, region corresponding to area shown in Figure 12 (Activity 7).

Heavy lines define areas with elevation between 5 and 10 feet. Light lines show position of present sea level (elevation = zero). All areas outside heavy lines would be submerged by 5-foot sea level rise.

BRITANNICA GLOBAL GEOGRAPHY SYSTEM

GIGI

Geographic Inquiry into Global Issues

Global Climate Change

Program Developers
A. David Hill, James M. Dunn, and Phil Klein

Regional Case Study
Australia/New Zealand/Pacific

Britannica
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Memo to the Student from the GIGI Staff

GIGI stands for *Geographic Inquiry into Global Issues,* which is the name of a series of modules. Each module inquires into a different world issue. We wrote this memo to explain that GIGI is different from most textbooks you have used.

With GIGI, you can have fun learning if you think like a scientist or detective. The main business of both scientists and detectives is puzzle-solving. They use information ("data" to the scientist and "evidence" to the detective) to test their solutions to puzzles. This is what you do with GIGI. GIGI poses many puzzles about important global issues: Each module centers around a major question, each lesson title is a question, and there are many other questions within each lesson. GIGI gives you real data about the world to use in solving these puzzles.

To enjoy and learn from GIGI, you have to take chances by posing questions and answers. Just as scientists and detectives cannot always be sure they have the right answers, you will sometimes be uncertain with GIGI. But that's OK! What's important is that you try hard to come up with answers, even when you're not sure. Many of GIGI's questions don't have clear-cut, correct answers. Instead, they ask for your interpretations or opinions. (Scientists and detectives are expected to do this, too.) You also need to ask your own questions. If you ask a good question in class, that can sometimes be more helpful to you and your classmates than giving an answer.

The data you will examine come in many forms: maps, graphs, tables, photos, cartoons, and written text (including quotations). Many of these come from other sources. Unlike most textbooks, but typical of articles in scientific journals, GIGI gives its sources of data with in-text references and full reference lists. Where an idea or piece of information appears in GIGI, its author and year of publication are given in parentheses, for example: (Gregory 1990). If the material used is quoted directly, page numbers are also included, for example: (Gregory 1990, pages 3–5). At the end of the module you'll find a list of references, alphabetized by authors' last names, with complete publication information for the sources used.

To help you understand the problems, GIGI uses "case studies." These are examples of the global issue that are found in real places. "Major case studies" detail the issue in a selected world region. You will also find one or two shorter case studies that show variations of the issue in other regions.

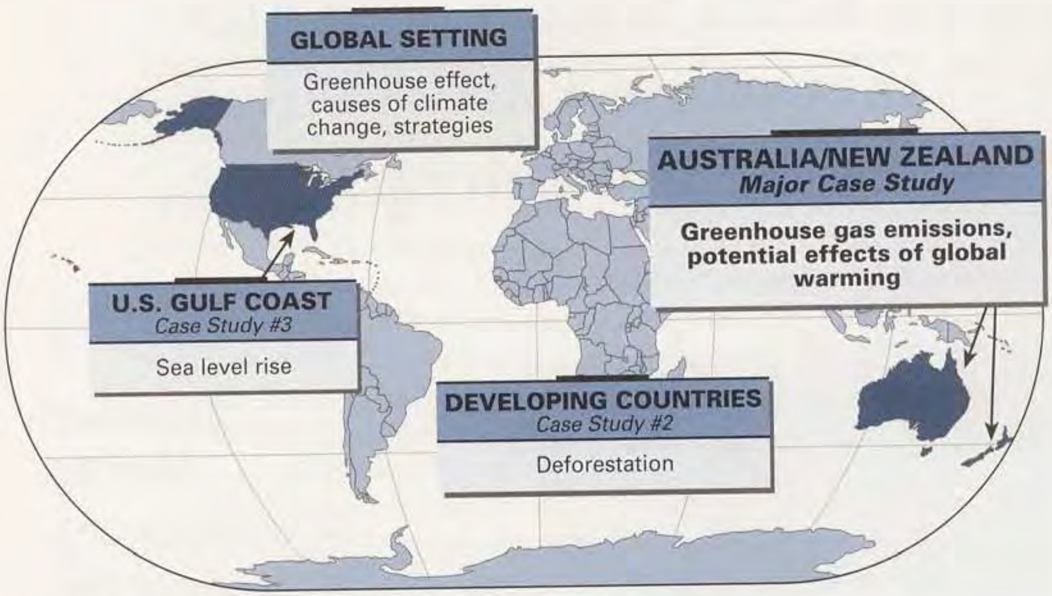
We hope your geographic inquiries are fun and worthwhile!

Global Climate Change

What could happen if global warming occurs?

- What human actions are causing Earth to warm up?
- What could happen if world temperatures get hotter?
- Should something be done about global climate change? What?
- What can you do to help?

In this module, you will explore the issue of global warming. Human activities are changing Earth's atmosphere, but scientists don't know exactly how this will affect world climates. It is possible, however, that global climate change will have an impact on society during your lifetime. A case study of Australia and New Zealand shows how developed countries produce the gases that may cause global warming. You will also see how less-developed countries produce these same gases. Other lessons examine potential impacts from global warming. To end the module, you will debate what the best strategy is for dealing with this issue.



Questions You Will Consider in This Module

- Which human activities are thought to be causing global warming?
- What are the arguments for and against the evidence of global warming?
- Where are the impacts from global warming likely to be the most severe?
- What strategies are possible for dealing with global warming?
- How can poorer countries cope with problems from global warming?
- What can individuals do to reduce the likelihood of global climate change?

Lesson 1

What human activities may cause Earth's climate to warm up?

Objectives

In this lesson, you will

- Identify activities that cause the emission, or release, of greenhouse gases.
- Recognize that actions taken by individuals contribute to these emissions.

Glossary Words

carbon dioxide (CO_2)
chlorofluorocarbons (CFCs)
climate
global warming
greenhouse effect
greenhouse gases
methane (CH_4)
nitrous oxide (N_20)

What's the problem?

Here's how one observer described the situation several years ago.

> [Without] a worldwide effort to reduce greenhouse-gas emissions, an average temperature rise of 3 to 9 degrees Fahrenheit is likely by 2050. . . . Such a radical increase is guaranteed to trigger economic and social upheaval on a grand scale. Its ecological impacts—farms turning into deserts, ice caps melting, sea level rising, entire forests dying—will be [disastrous]. Global warming

> could also be the last straw for untold thousands of species already stressed by habitat [disturbance], as well as others that now seem secure. A planet without polar bears? The thought may be distressing to contemplate, but it's a real possibility (Udall 1989).

Geographers know that many forces shape Earth's physical environment. Some of these forces change over time. As a result, Earth's environment has changed before, and it will certainly change again. For example, species evolve and continents shift positions. But such changes typically require very long time periods—thousands or millions of years.

Earth's global climate is very changeable, for example. Just 18,000 years ago much of northern Europe and North America were buried under ice nearly two miles deep. The global average surface temperature during this Ice Age was only about 5°C (9°F) colder than today. Over the following 10,000 years, the global temperature rose to near its present average of 15°C (59°F). This led to great changes in Earth's environment. Sea levels rose hundreds of feet to their present positions (largely because of glacier ice melting) and plant species slowly adapted to warmer climates.

What is likely to happen next? This module looks at *future* global climate change—predicted to occur on a much shorter time scale. Many scientists expect that Earth's global average temperature will increase as much in the next 40 years as it did during the 10,000-year recovery from the last Ice Age. This rapid change may cause more increases in sea level and have major effects on agriculture, forests, and other resources.

You may have heard of the greenhouse effect. Certain gases act to trap heat in the atmosphere. These are called greenhouse gases. The problem is that many human activities cause emission of greenhouse gases. Most scientists believe that if more of these gases are released into the atmosphere, the global climate will warm up. In Lesson 2, you will study more about the scientific basis for this prediction.

Which activities are sources of greenhouse gases?

There are four main greenhouse gases in the atmosphere whose amounts are affected by human activities. The four gases are: carbon dioxide (CO_2), methane (CH_4), chlorofluorocarbons (CFCs), and nitrous oxide (N_2O). Which of the 20 activities, products, and animals in the following list do you think emit greenhouse gases?

Which of these emit greenhouse gases?

1. Burning coal
2. Burning oil
3. Burning natural gas
4. Burning wood
5. Deforestation
6. Coal mining
7. Transporting natural gas
8. Rice cultivation
9. Domestic livestock
10. Termites
11. Landfills
12. Nylon manufacturing
13. Cement manufacturing
14. Soil fertilizers
15. Foam seat cushions
16. Air conditioners
17. Plastic food packaging
18. Foam insulation
19. Solvents for cleaning electronics
20. Refrigerators

Do you think this writer is probably right? Why or why not?

> Since greenhouse gases are chiefly the result of human industry and agriculture, it is not an exaggeration to say that civilization itself is the ultimate cause of global warming (Revkin 1988).

What can one person do about the problem?

How many greenhouse gases does your own family release each year? Use the information your teacher provides to calculate how much your family emits. Compare your family's amount to the United States average and to how much is considered each person's rightful share.

Adding up the CO_2 you spew

> Americans generate 18.4 tons of CO_2 per person, but that figure is misleading because it lumps together government, industrial, corporate, and personal production of CO_2. Unless you are Donald Trump, your total should be significantly less. . . .
>
> To put this in perspective, worldwide releases of CO_2 from fossil-fuel combustion are currently 22 billion tons per year. Experts think that stabilizing the climate will require slashing that in half, to 11 billion tons. Because the planet's population is now slightly more than 5 billion, each person's rightful share of CO_2 emissions is about two tons annually (Udall 1989, page 33).

If you think that your family is emitting more greenhouse gases than they should, here are some things you can do:

Actions individuals can take

- Drive fewer miles. Cut back by walking, riding a bike, or taking public transportation.
- Carpool whenever driving is necessary (preferably in a fuel-efficient car).
- Encourage your family to use energy-efficient appliances.
- Plant trees. A fast-growing tree can recycle 48 pounds of CO_2 each year.
- Avoid buying products made with CFCs (such as VCR cleaning sprays and anything with foam packaging).
- Recycle newspapers and phone books, aluminum and steel, glass, motor oil, plastics, and anything else you can.
- Find out if your home's insulation is adequate. Weather-sealing windows and doors is a big help. Each year U.S. homes lose half as much energy through windows as flows through the Alaska pipeline.
- Write local, state, and national lawmakers, asking them to pass legislation to cut greenhouse-gas emissions at all levels (Udall 1989).

Think globally; act locally

Over the next several weeks, you will see that global warming *may* occur within your lifetime. Whether this will happen for sure is unknown. The sources of this problem are the very industrial and agricultural technologies that make our way of life possible.

As you study this module, you may—or may not—be convinced that global warming is a serious problem. This much is certain: By cutting our emission of greenhouse gases, we can reduce the possibility of global warming. Alternative technologies and ways of life exist that would cut greenhouse-gas emissions. A lot depends upon each of us making a personal choice about how to live our lives.

*What will **you** do?*

Lesson 2

Is the greenhouse effect a fact or a theory?

Objectives

In this lesson, you will

- Explain the greenhouse effect.
- Describe how the amount of greenhouse gases in the atmosphere has increased since the Industrial Revolution.
- Understand why many scientists expect increased amounts of greenhouse gases to cause global warming over the next few decades.
- Recognize the difference between a scientific fact (greenhouse effect) and an unproven scientific hypothesis (global warming).

Glossary Words

carbon dioxide (CO_2)
chlorofluorocarbons (CFCs)
enhanced greenhouse effect
global warming
greenhouse effect
greenhouse gases
longwave radiation
methane (CH_4)
nitrous oxide (N_20)
shortwave radiation

What is the greenhouse effect?

Earth's global average temperature is caused by: (1) sunlight received; (2) sunlight reflected; and (3) heat energy trapped and re-radiated back to Earth by the atmosphere (Figure 1 on page 10).

If there were no atmosphere, incoming shortwave radiation (sunlight) and outgoing longwave radiation (heat energy) would be balanced. Earth would have an average surface temperature of −18°C (0°F). But there *is* an atmosphere. Earth's atmosphere has gases, such as carbon dioxide (CO_2) and water vapor, that trap some of the outgoing heat energy. These gases absorb longwave heat energy radiated by Earth and then *re-radiate* this heat energy back to Earth's surface. This process raises Earth's global average surface temperature to its actual +15°C (59°F).

This process is called the greenhouse effect. Gases that trap and re-radiate longwave heat energy are called greenhouse gases. How is this similar to the way a real greenhouse works?

Scientists know that the greenhouse effect exists. Without it, Earth's temperature would be far too cold to support life as we know it. In fact, surface temperatures of the planets neighboring Earth also depend on the strength of their own greenhouse effects (Table 1 below).

Note what the temperatures would be for each planet *if* there were no greenhouse effect, that is, if their atmospheres trapped no longwave radiation. Venus would actually be colder than Earth, even though it is closer to the sun. Why? Because Venus reflects so much of its incoming sunlight. That's why it is so bright at night. Compare these possible temperatures to the actual surface temperatures, based on the real heat-trapping ability of each planet. Notice there is little difference for Mars, because its atmosphere has a weak greenhouse effect. But look how much hotter Venus really is because it has a strong greenhouse effect.

Table 1 The greenhouse effect on three planets

	Surface temp. *without* a greenhouse effect	Planet's *actual* ability to trap longwave radiation*	*Actual* average surface temp.
Venus	−40°C	100	427°C
Earth	−18°C	1	15°C
Mars	−56°C	0.1	−53°C

* Earth is defined as having an ability to trap longwave radiation equal to 1. Figures for Venus and Mars are relative to Earth. Higher number indicates a greater ability to trap longwave radiation.

Source: Hoffman et al. 1983.

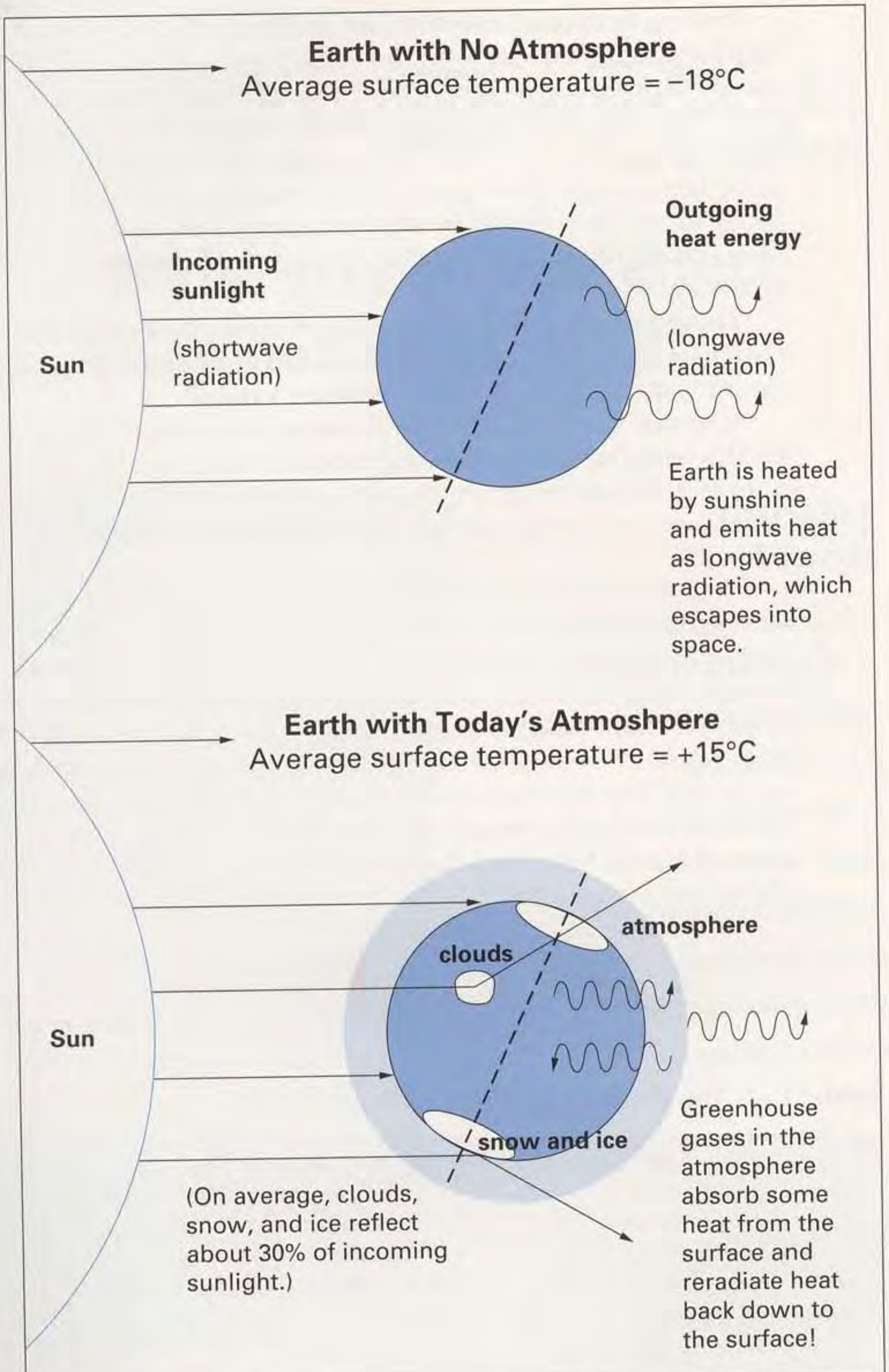


Figure 1 The greenhouse effect of the atmosphere on Earth's average temperature. Diagram is not to scale and the size of the atmosphere is exaggerated.

Source: Henderson-Sellers and Blong 1989.

The Goldilocks Phenomenon

Mars—a planet with a *thin* . . . atmosphere—has an [average] temperature well below that of most deep freezers. Venus—with a very *thick* . . . atmosphere—has a temperature hotter than an oven. Earth—with a *moderate* amount of atmosphere—contains liquid water, [comfortable] temperatures, and abundant life. Mars is too cold, Venus is too hot, and Earth is just right—what some planetary climatologists call the Goldilocks Phenomenon, which is well understood to be a result of the greenhouse effect (Schneider 1988, pages 29–30).

1. How do you suppose the actual temperatures were measured for Mars and Venus?
2. Why has the name "The Goldilocks Phenomenon" been given for comparing the temperatures of the three planets? Is it appropriate? Why or why not?

What gases cause the greenhouse effect?

Carbon dioxide (CO_2) and water vapor aren't the only greenhouse gases in Earth's atmosphere. Two other important greenhouse gases are methane (CH_4) and chlorofluorocarbons (CFCs). Carbon dioxide and methane come from both natural sources and human activities. CFCs are synthetic gases that began being manufactured in the 1940s. They are used in refrigeration, foam packaging, and many other products. Water vapor mainly comes from evaporation of the oceans.

Three gases—CO_2, CH_4, and CFCs—account for about 86 percent of all human greenhouse-gas emissions. Other greenhouse gases, including nitrous oxide (N_2O), represent the remaining total of about 14 percent of all human greenhouse-gas emissions (World Resources Institute 1990; Shea 1988).

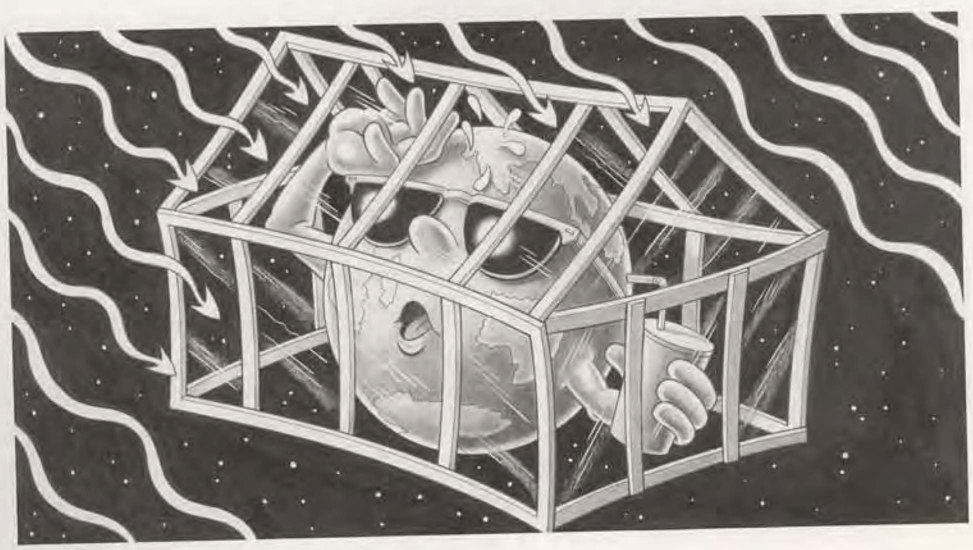
The amounts of all these gases have increased since the Industrial Revolution began (Table 2 on page 12). Concentrations of gases in the atmosphere are given in "parts per billion." For comparison, remember that *percent* means "parts per hundred." What is a "part per billion"? Think of it in several ways. One inch out of 16,000 miles equals one part per billion. One second out of 32 years equals one part per billion. Parts per billion may seem extremely small, but in terms of the greenhouse effect, that is all it takes for these gases to trap significant amounts of longwave heat energy.

Table 2 Increases of greenhouse gas amounts in Earth's atmosphere, 1850–2030 (parts per billion of atmosphere volume)

	1850 estimated average concentration	1980 measured average concentration	1990 measured average concentration	2030 probable average concentration
CO_2	260,000	338,500	353,000	450,000
CH_4	750	1,554	1,720	2,340
N_2O	280	296	310	375
CFCs	0	0.49	0.76	3.10

Notes: 1. 1,000 parts per billion = 1 part per million. Thus, 1990 CO_2 concentration was 353 ppm.
2. CFC row shows the total of the three most commonly used of these chemicals.

Sources: Smith and Tirpak 1988; World Resources Institute 1990; Brown and Postel 1987; Office for Interdisciplinary Earth Studies 1991.



3. On your graph of the CO_2 data, which line segment is steeper: the segment for 1850–1980 or the segment for 1980–1990? What does the change indicate? How does the segment for 1990–2030 compare to the other two segments—is it steeper or more gradual? What does this show you? Why is this important?
4. What conclusion can you draw about the *trend* in the rate of growth of carbon dioxide? Is it similar to or different from the trends for the other gases?
5. The 1850 concentrations are probably similar to what the atmosphere contained before the Industrial Revolution. All these "preindustrial" concentrations are estimates, except for the CFCs. How do we know their preindustrial concentration was zero?
6. What would you most like to know about these trends?

What effect will an increase in greenhouse gases have?

The greenhouse effect causes Earth to be warmer than it would be if it had no atmosphere. Also, the concentrations of greenhouse gases have been increasing steadily since the mid-nineteenth century. These are scientific facts.

But will Earth get warmer as the atmosphere traps more and more heat? Will Earth's atmosphere re-radiate so much heat back to the surface that the whole planet heats up? Many scientists think that it will—they call this the "enhanced" greenhouse effect. The hypothesis, or theory, that the enhanced greenhouse effect will cause Earth to heat up is called global warming. What evidence supports this theory?

Ice-core data link atmospheric CO_2 and global temperature

The best evidence that global warming is likely comes from a study of an ice sample taken in Antarctica. A team of French and Soviet scientists linked the amount of greenhouse gases in the atmosphere to global temperature change (Figure 2 on page 15). They studied a 2,000-meter-deep ice core from the Antarctic icecap—that's equivalent to a 600-story building! Ice cores consist of many layers of ice, deposited over thousands of years in completely undisturbed conditions. Each layer of ice contains countless air bubbles, trapped and sealed by the overlying ice. Air in the deepest layers has been there for more than 160,000 years. The core was opened, and the air within was studied to measure the past concentration of carbon dioxide and other gases (Sand 1990).

7. How does the concentration of carbon dioxide projected for 2030 (Table 2 on page 12) compare to its concentrations during the past 160,000 years (Figure 2 on page 15)?
8. According to Figure 2, what seems to be the relationship between long-term global temperature and atmospheric carbon dioxide concentration?
9. Do you think changes in CO_2 caused the changes in temperature? Or could temperature changes have caused the changes in CO_2? Can you figure this out from the information in Figure 2, or do you need additional data?

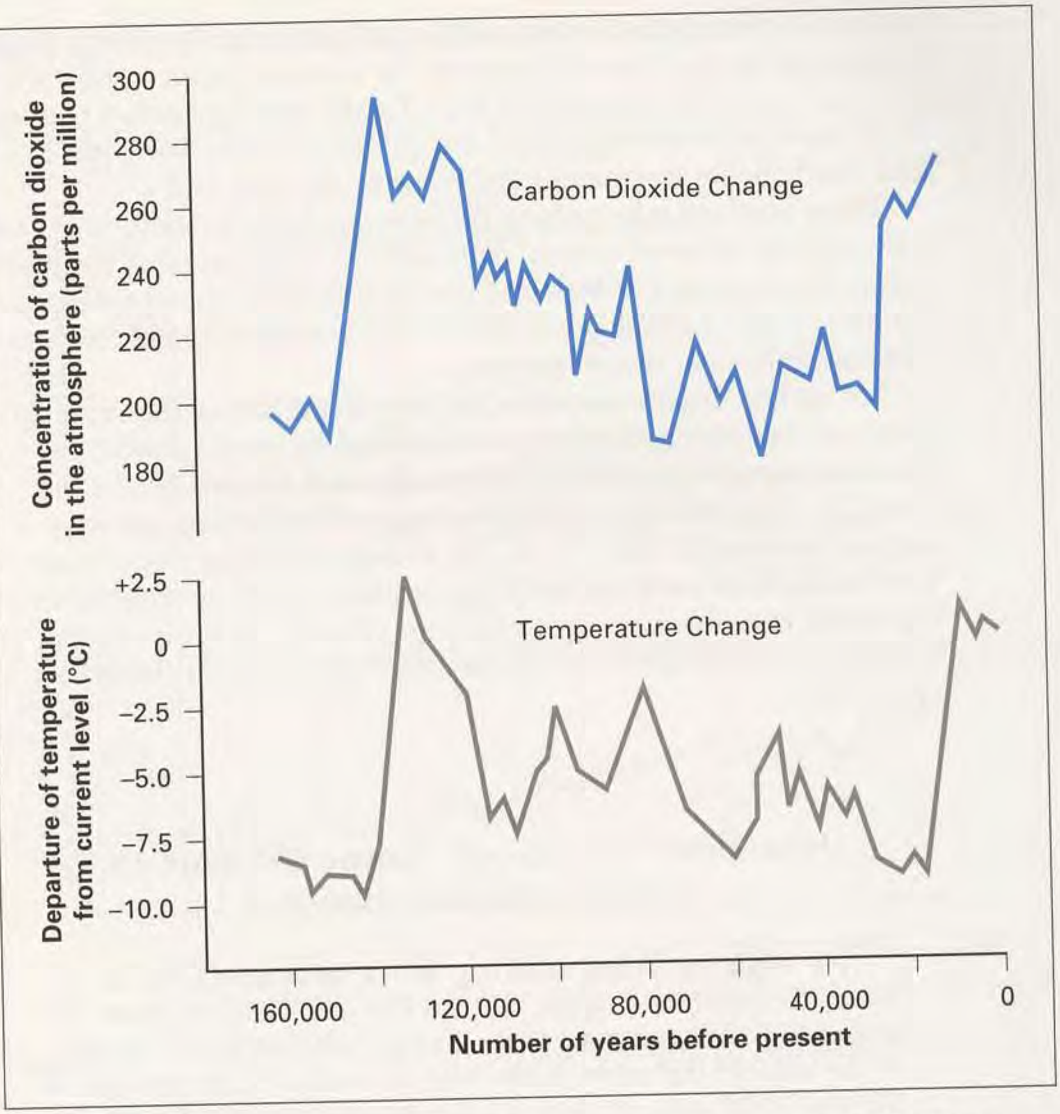


Figure 2 Long-term trends of global temperature and atmospheric carbon dioxide. Scale on bottom graph shows the temperature difference from the present average temperature (that is, the graph defines the present average temperature as zero).

Source: Barnola et al. 1987.

How much global warming is forecast for the twenty-first century?

What if the amount of carbon dioxide in the atmosphere continues to grow at its present rate? If this happens, it will be *twice* as great as its preindustrial concentration within the next century. Most scientists agree that this will increase the average surface temperature from 1.5° to 4.5°C (Schneider 1991). Earth's average surface temperature could go from its present 15°C (59°F) to nearly 20°C (68°F). This much global warming could occur by the year 2030.

These numbers refer only to the *average* global temperature. That is the average between normal high and low temperatures. Scientists expect that extremes of high and low temperatures will also change. Hot days could become much hotter. And places with mild temperatures could become much warmer.

But carbon dioxide accounts for only about half of the expected warming. Increasing all other greenhouse gases would *double* the warming expected from CO_2 alone in the next century. So, by the time CO_2 itself doubles, Earth's average surface temperature may increase between 3° and 9°C. A 3°C average warming would make San Francisco as warm as San Diego is today. A 9°C average warming would raise the average temperature of New York City to the current average temperature of Daytona Beach, Florida (Hoffman et al. 1983).

How does this rate of change compare to previous climate changes?

The expected global warming will be large compared to historical temperature changes. . . . In the last 2 million years, the Earth has never been more than 2° to 3°C warmer than it is today. In the last 100,000 years, it has been at most 1°C warmer, and in the last 1,000 years, at most 0.5°C warmer. Since the last Ice Age (18,000 years ago), Earth has warmed about 4°C, and in the last century, about 0.4°C. The projected warming for the next century would be 10 times as rapid as the historical warming trend (Hoffman et al. 1983, page 10).

10. In what ways could such rapid rates of warming pose a problem for human society? For plants and animals?
11. How could humans adapt to such a change?

Has global warming already begun?

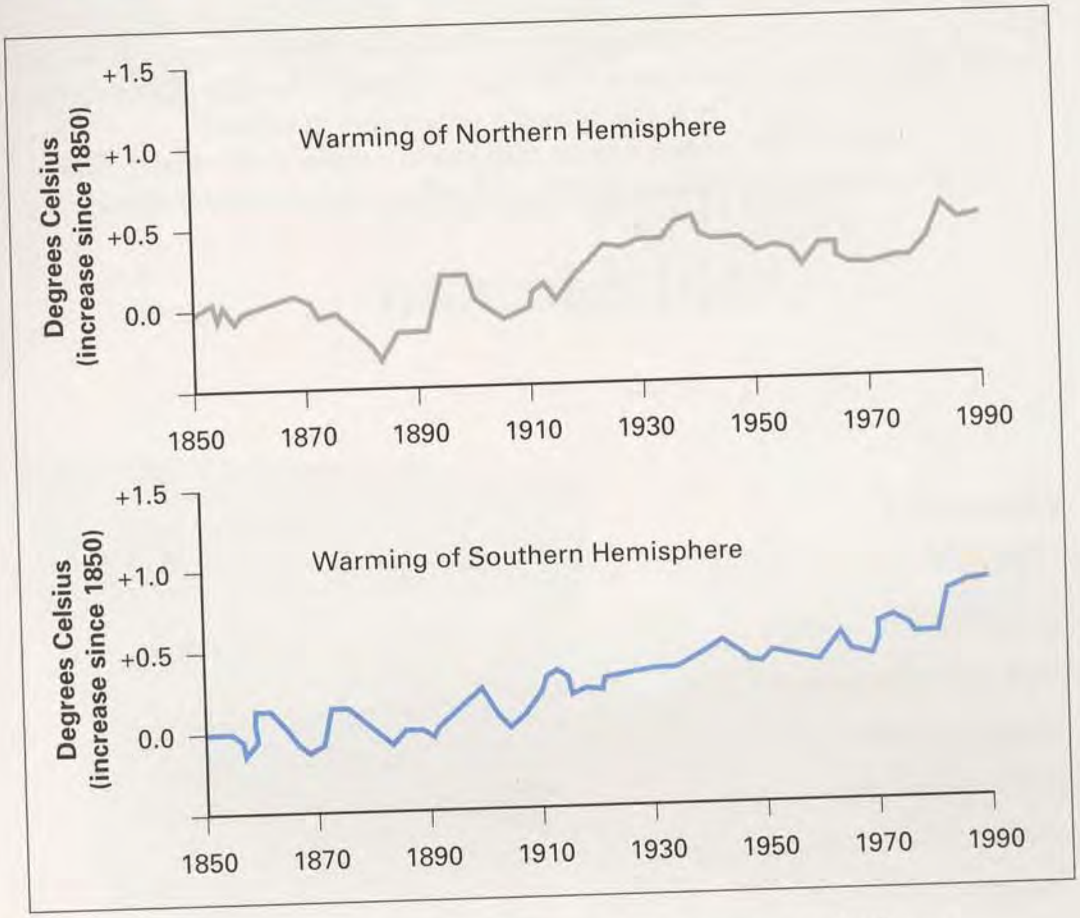


Figure 3 Warming of the northern and southern hemispheres since 1850.

Source: Michaels 1989.

12. By about how many degrees has the average temperature of each hemisphere increased since 1850?
13. By about how many degrees have the average temperatures increased since 1980?
14. Have the average temperatures ever decreased by as much as they have increased since 1980? When?

From temperature records, we know that eight of the ten warmest years (global average temperature) since 1850 have occurred since 1980 (World Resources Institute 1990). Imagine you are on a jury trying to judge whether global warming has already begun. Does this fact (together with Figure 3 on page 17) prove that the global climate is warming up? Or is this only circumstantial evidence?

What other evidence from this lesson supports the theory that global warming will result from an enhanced greenhouse effect?

Lesson 3

Is global warming unavoidable?

Objectives

In this lesson, you will

- Examine the scientific controversy about global warming.
- Understand that there are many questions about the reliability of climate change models.

Glossary Words

carbon dioxide (CO_2)
chlorofluorocarbons (CFCs)
climate models
global warming
greenhouse effect
greenhouse gases
longwave radiation
methane (CH_4)

What is the scientific controversy about global warming?

Not long ago many scientists thought the climate was cooling, not warming. However, evidence now suggests to some scientists that the twenty-first century may be warmer. The greenhouse effect is known to exist and the concentration of greenhouse gases is known to be increasing. But other scientists debate whether the increase in greenhouse gases will actually cause global warming in the next 40 years.

Skeptics contend that forecasts of global warming are flawed and overstated and that the future might even hold no significant warming at all. Some say that if the warming is modest, as they believe likely, it could bring benefits like longer growing seasons in temperate zones, more rain in dry areas, and an enrichment of crops and plant life.

Much of the criticism is aimed at computerized mathematical models of the world's climate on which forecasts of global warming are largely based. . . . All the models, said Dr. Richard Lindzen of MIT, contain flaws that "could easily reduce the predictions for warming to well under a degree" centigrade, or 1.8°F (Stevens 1989, page 1).

What are the flaws in the computerized climate models?

There are three major criticisms of the computer models used to predict climate change. These three criticisms are presented on the following pages.

Criticism A

Besides CO_2, a major greenhouse gas in Earth's atmosphere is water vapor. Evaporation from the oceans and other bodies of water puts water vapor into the atmosphere. The amount of water vapor in the atmosphere is closely related to temperature. As temperatures rise, more water evaporates into the atmosphere. So, if temperatures rise from the increase in greenhouse gases, more water vapor would enter the atmosphere. Because water vapor in the atmosphere is what forms clouds, this means that there would be more clouds (Henderson-Sellers and Blong 1989).

But exactly *how* more clouds will affect global temperatures is cause for uncertainty in the climate models. Clouds help regulate Earth's temperature. Typically, clouds cover half the Earth and reflect 30 percent of incoming sunlight back into space. But clouds do more than reflect sunlight. They also absorb some longwave energy (heat) radiated by Earth and re-radiate this heat back to the surface (Figure 1 on page 10). Thus, clouds

Water vapor in the atmosphere forms clouds.

make their own greenhouse effect. However, at present the reflective behavior of clouds is greater than their greenhouse effect. So, clouds currently have an overall cooling effect on Earth's average surface temperature (World Resources Institute 1990).

Will this cooling effect from clouds remain if global warming occurs? It depends on the height of the clouds. High clouds (called cirrus clouds) trap Earth's heat well. But low- to mid-level clouds (stratus and cumulus) reflect incoming solar radiation. So, if global warming increases the amount of high clouds, the present cooling effect might be reduced or even changed to a warming effect. This would add to the world's overall global warming. On the other hand, increasing the amount of low- and mid-level clouds might increase the cooling effect and counteract any global warming (World Resources Institute 1990).

Computerized climate modeling is not yet advanced enough to make dependable predictions of the change in cloud heights if global warming occurs. We just don't know which possibility—greater heating or greater cooling from clouds—will occur in a world with more greenhouse gases.

1. Note that clouds can both reflect light and hold surface heat. Explain how these two effects might counteract one another.
2. Summarize Criticism A in one or two sentences.
3. What would be a good title for Criticism A? Why?

Criticism B

About 70 percent of Earth's surface is covered by oceans. The average depth of the oceans is over 4 kilometers. So, there is a huge amount of water that would have to be heated before global warming occurs. But water takes much longer to heat up than air does.

The following quote explains why this leads to uncertainty about the accuracy of computerized climate models:

> The heating of the upper part of the ocean (the top 70 meters or so) can be represented by a warming body of water, like a vast swimming pool. [We] understand quite a lot about how this top slice of the ocean will warm; but there is almost four kilometers below this, which is called the "deep ocean." This deep ocean has a circulation of its own, which has to be modeled in the same way as we model the atmospheric circulation. All we can say with confidence so far about the deep ocean circulation is that it acts in such a way that warm water is pulled down very deeply. The net result of this is that the deep ocean circulation is effectively removing heat from the climate system. Of course, eventually all the deep ocean will warm, but we do not know how long this will take (Henderson-Sellers and Blong 1989, pages 47–49).

How long will it take the deep ocean temperatures to rise to the new surface temperature? Most scientists estimate that warming of the deep ocean will take from 80 to 100 years. But some scientists think it will take only 20 years, and others think it may take as long as 500 years. However long it takes for the deep ocean to heat, it will slow global climate change down a bit (Henderson-Sellers and Blong 1989).

Models of ocean circulation are less advanced, and therefore less accurate, than models of the atmosphere. Predictions about the atmosphere can be tested against observations of other planets. But there is no other ocean in the solar system that can be used to test scientific predictions about our oceans (Henderson-Sellers and Blong 1989).

4. You read that water takes a longer time to heat up than air does. Think of an example to show that water temperatures are usually cooler than air temperatures.
5. Summarize Criticism B in one or two sentences.
6. What would be a good title for Criticism B? Why?

Criticism C

The atmospheric amounts of both CO_2 and CH_4 have risen enormously since 1950. All CFCs came from human actions during the past 50 years. But the record of temperature increases since 1850 (Figure 3 on page 17) shows that most of the warming that occurred during the past century happened *before* 1950 and the huge increases in greenhouse gases. In fact, the northern hemisphere shows *no* overall change after about 1940. During this period, CO_2 amounts increased from about 300 ppm to 350 ppm (Michaels 1989).

In addition, temperatures in the higher latitudes (toward the poles) have not increased during this century as predicted. The evidence shows that there was a rise in temperature *before* there was a significant increase in greenhouse gas emissions. This temperature rise was actually followed by a decline in temperature in higher latitudes. A study in Alaska showed that there was no measurable trend in temperature change since 1950 (Michaels 1989).

Predictions of warming are often based on the similarity of past climate changes to the CO_2 record, as shown by ice cores taken from Antarctica (Figure 2 on page 15). However, one cannot actually determine from these records whether changes in CO_2 came *before* or *after* changes in temperature.

In addition, human actions also produce substances that counteract the warming. Some of these are common air pollutants in urban areas. For example, molecules of sulfur dioxide can serve as centers around which water vapor condenses, forming clouds. These pollutants can thus brighten clouds. This could increase the reflection of sunlight and reduce the warming from increased greenhouse gases. In fact, this could explain why the northern hemisphere has not yet warmed up as much as predicted, since most sulfur dioxide emissions occur in the industrialized northern hemisphere (Michaels 1989).

7. Sulfur dioxide is known as a major source of acid rain. If Criticism C is correct about the effect of this substance on global warming, should it still be considered a pollutant? Why do you think as you do?
8. Summarize Criticism C in one or two sentences.
9. What would be a good title for Criticism C? Why?

Lesson summary

Climatologist Reid Bryson had this to say about climate models:

> A statement of what the climate is going to be in the year A.D. 2050 is a 63-year forecast. Do the models have a demonstrated capability of making a 63-year forecast? No. A 6.3 year forecast? No. Have they successfully simulated the climatic variability of the past century and a half? No. They are marvels of mathematics and computer science, but rather crude imitators of reality (Brookes 1989, page 100).

10. Do you think that the evidence that supported the models (covered in Lesson 2) is enough to outweigh the criticisms in this lesson?
11. Clearly scientists are not in agreement. What should governments do in the face of this uncertainty? Do you think more research will solve the problem? Why or why not?

How long will it take for scientists to be sure?

> It will take at least five years to build the . . . atmosphere, ocean, biosphere, land-surface, sea-ice, and chemistry submodels that are needed if scientists are to have any hope of predicting the evolving regional climatic changes. Five to ten years may be necessary to get computers large enough to run such models routinely to determine the quality of their forecasts. Also, some five to ten years will pass before major data-gathering projects begin to provide data to validate the various subcomponents of such modeling. Thus, 10 to 20 years is suggested as the time required for everything to come together and for detailed predictive skill to become credible (Schneider 1991, page 27).

What's *your* opinion? Should we wait until we are certain that global warming will occur before we take any action? Or do you think the problems of climate change are severe enough that some action should be taken now? Why do you think as you do?

Lesson 4

How do developed countries add greenhouse gases?

Objectives

In this lesson, you will

- Describe how energy use, industrial processes, and agriculture in developed countries add greenhouse gases to the atmosphere.
- Explain how these sources of greenhouse gases differ according to a region's level of economic development.

Glossary Words

carbon dioxide (CO_2)
chlorofluorocarbons (CFCs)
deforestation
developed country
greenhouse gases
methane (CH_4)

Energy, industrial processes, deforestation, and agriculture (including livestock grazing) are major sources of greenhouse gases (Figure 4 on page 26). About what proportion of total emissions comes from each activity?

This lesson and Lesson 5 use Australia and New Zealand as case studies to show how these activities in developed countries contribute to potential global warming. Lesson 6 takes a closer look at deforestation.

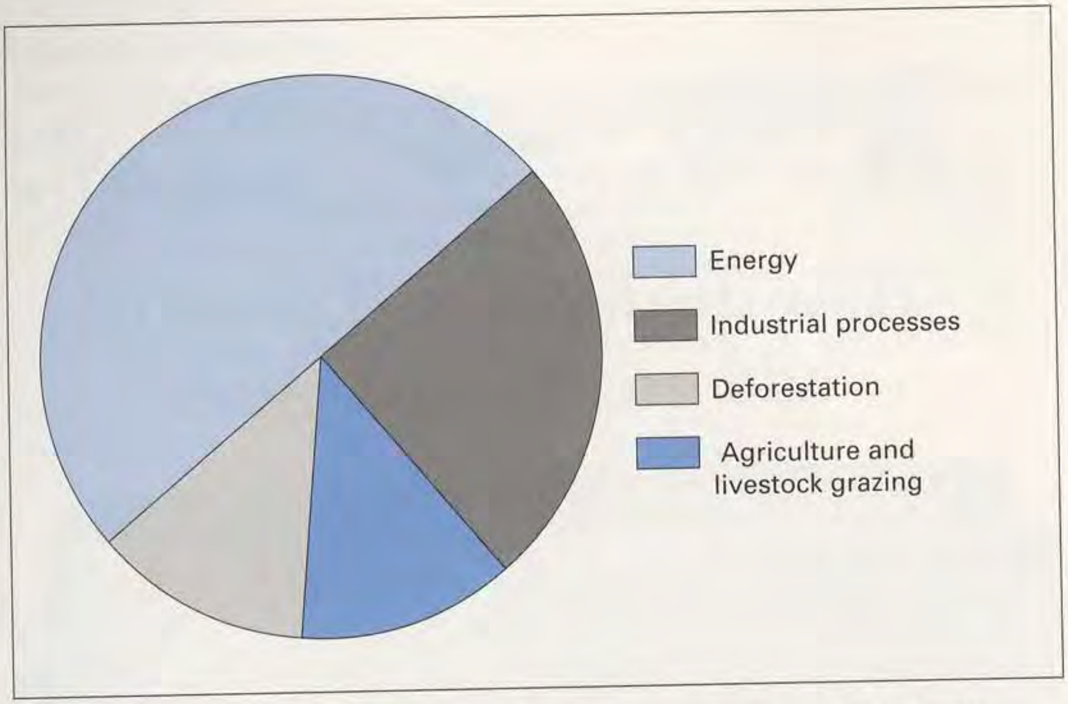


Figure 4 Sources of greenhouse-gas emissions by type of human activity.

Source: World Resources Institute 1990.

Coal burning power plant next to coal storage area.

Which world regions emit the most carbon dioxide?

Carbon dioxide is a by-product of the burning of fossil fuels. What part does carbon dioxide contribute to greenhouse gases?

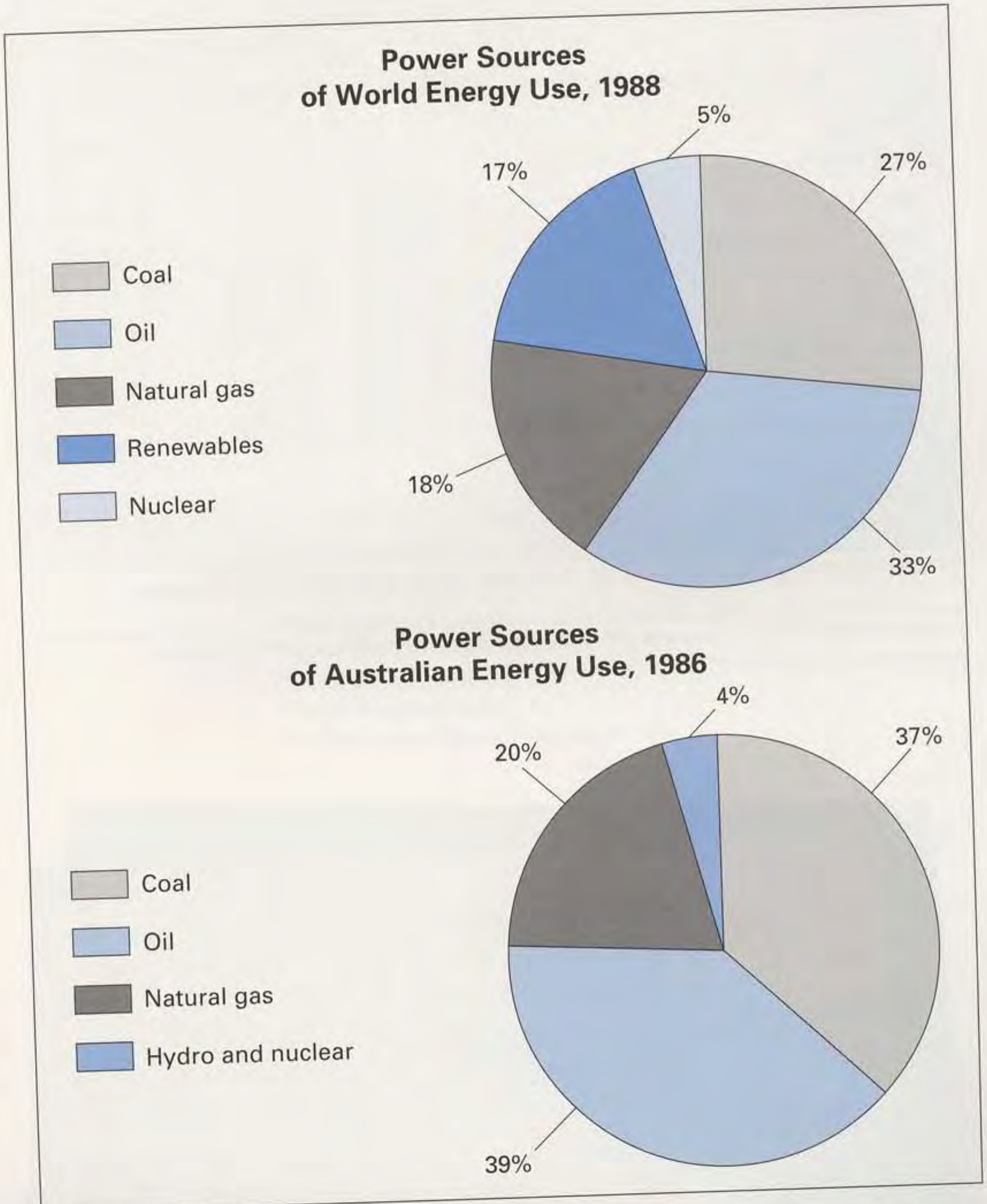


Figure 5 Power sources of energy used for the world as a whole and for Australia. Coal, oil, and natural gas are fossil fuels.

Sources: Flavin 1989; *Goode's World Atlas* 1990.

Table 3 Energy usage and population by world region

Region	Population (percentage of world total)	Energy used (percentage of world total)	Annual income per person (1988 U.S. $)
United States	4.7	24.1	19,780
Europe	9.5	22.7	12,170
Former Soviet Union	5.5	19.3	8,375
East Asia	22.9	10.3	570
Latin America	8.4	4.9	1,930
Japan	2.4	4.7	21,040
North Africa/Southwest Asia	5.7	4.3	1,950
South Asia	21.3	2.7	310
Canada	0.5	2.7	16,760
Africa—South of the Sahara	10.1	1.6	465
Southeast Asia	8.5	1.4	590
Australia/New Zealand/Pacific	0.5	1.3	9,550
World total	100.0	100.0	$3,470

Note: Energy usage figures are for 1987. Population figures are based on 1989 estimates.

Sources: World Resources Institute 1990; Population Reference Bureau 1990; National Geographic Society 1990.

1. Use Figure 5 on page 27 to determine what percentage of world energy use relies on fossil fuels. What percentage of *Australian* energy use does?
2. Table 3 shows how world energy consumption varies by region. Which four regions consume the *most* energy? Which four regions the *least*?
3. Do you conclude that the regions using the most energy emit the most carbon dioxide from burning fossil fuels? Explain your answer.

Which countries emit the most CFCs?

Are developed or developing regions mainly responsible for the emission of chlorofluorocarbons? (Recall from Lesson 1 the types of activities and products that emit CFCs.) Look at Figure 6 to discover the answer. Is this what you expected?

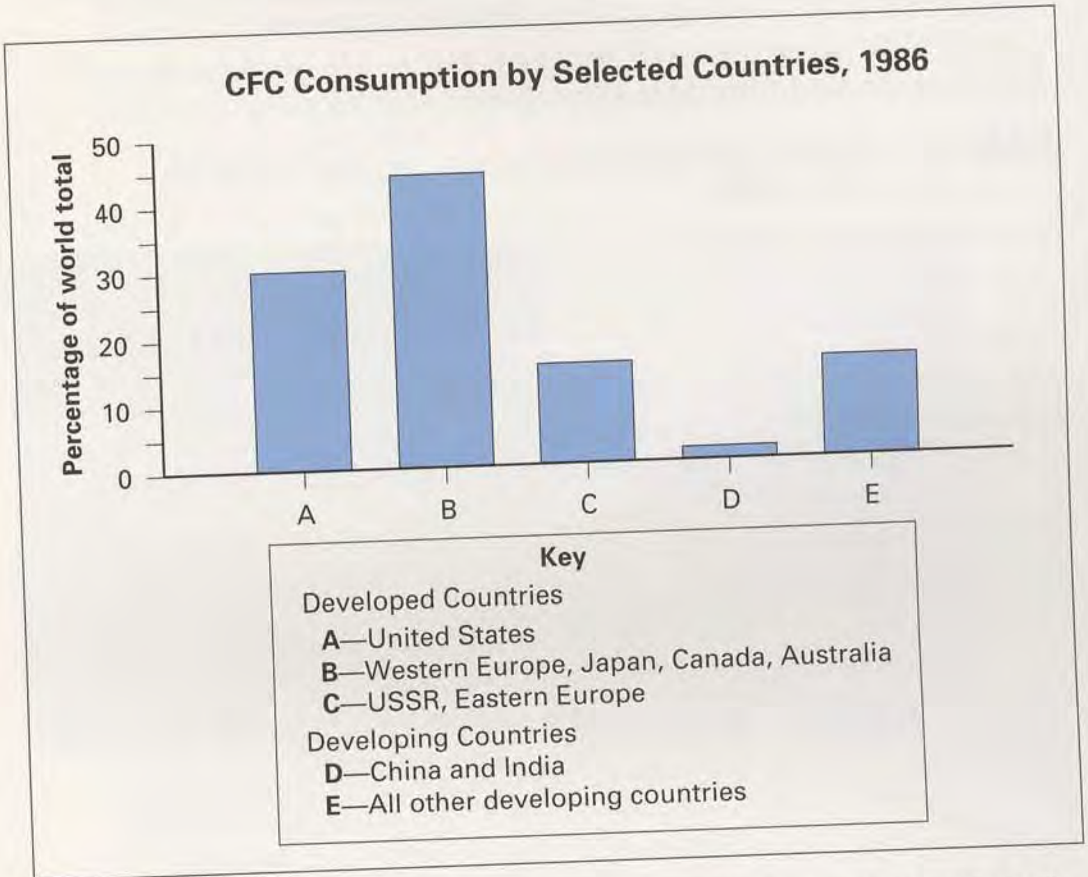


Figure 6 CFC consumption by selected countries, as a percentage of world total in 1986.

Source: Shea 1988.

4. What is the approximate total percentage of world CFC consumption from developed countries?
5. Why are most CFCs emitted by developed countries with industries?

Which countries emit the most methane?

About half of Earth's land surface is used for grazing livestock. In Australia, the figure is closer to 75 percent. In some areas of Australia, the average ranch covers about 190,000 acres. (This is about the size of New York City.) Australia and New Zealand have more livestock than people (Table 4 below). Remember that these animals emit methane by their digestive processes.

Table 4 Number of livestock per person, selected countries, 1986–1988

	Number of cattle, sheep, and goats per person
New Zealand	22.15
Australia	10.69
Argentina	2.64
Ethiopia	1.42
Brazil	1.12
United States	0.47
World average	0.56

Source: World Resources Institute 1990.

6. Why do Australia and New Zealand have such relatively high numbers of cattle and sheep? Think about what these animals are used for.
7. Which areas of Australia and New Zealand have the most sheep?
8. What does Table 4 suggest about how important these animals are to the economies of Australia and New Zealand?

How do greenhouse-gas emissions vary by region?

Which world regions add the most greenhouse gases? Emissions of several greenhouse gases may lead to global climate change. A Greenhouse Index shows the total amount of greenhouse gases emitted by each world region (Table 5 below). This index totals the emissions of CO_2, CFCs, and CH_4. To make the index, the relative heat-trapping ability of each gas is figured. The numbers in Table 5 are the total carbon dioxide heating value of all gases emitted, measured in metric tons of carbon.

The world's total emissions are over 5.9 billion metric tons of carbon per year. The world's total population is about 5.2 billion. So, each person on the planet adds the equivalent of more than one metric ton of carbon each year to the atmosphere. But the amount of carbon emitted per person varies by region (Table 5). In some regions, much more than one ton is emitted by the average person each year. In other regions, emissions are much less than one ton per person. Which regions have the highest per person carbon emissions? Is this what you expected? Why or why not?

Table 5 Greenhouse Index by region, 1987 (metric tons of CO_2 heating value)

	Total carbon emissions	Per person emissions
Europe	1,085,000,000	2.18
United States	1,020,000,000	4.19
Latin America	921,000,000	2.10
Former Soviet Union	690,000,000	2.39
Southeast Asia	437,500,000	0.99
East Asia	433,500,000	0.36
South Asia	422,000,000	0.38
Africa—South of Sahara	286,500,000	0.54
Japan	222,000,000	1.80
North Africa/Southwest Asia	207,500,000	0.70
Canada	117,000,000	4.61
Australia/New Zealand	77,000,000	2.93
World total	5,919,000,000	1.13

Source: World Resources Institute 1990.

9. Where does Australia/New Zealand rank in terms of per person greenhouse-gas emissions?
10. According to your classification of developed and developing regions, which type of region generally has the highest per person emissions?
11. Write a question with an answer that would be a good summary of what you have learned from the data in this lesson.

Lesson summary

You now have a picture of the types of activities that Australians and New Zealanders engage in that produce the significant greenhouse gases. Based on what you have examined so far, do you think these countries are representative of the world's developed countries? How are these places similar to or different from the United States? Think about how these activities relate to the high standards of living that these places enjoy.

Lesson 5

How might global warming affect Australia?

Objectives

In this lesson, you will

- Understand why computer models of global warming show a wide range of predicted climatic effects for Australia.
- Analyze the difficulty in planning for these possible effects.
- Recognize that not all effects would be harmful—in some places global warming could generate economic benefits.

Glossary Words

carbon dioxide (CO_2)
chlorofluorocarbons (CFCs)
climate
climate models
environmental system
global warming
greenhouse effect
greenhouse gases
methane (CH_4)
nitrous oxide (N_20)

What will happen if global warming occurs?

The big question is, given the [relentless] buildup of [greenhouse] gases . . . what will the specific effects be? It's hard to say, because the relationship between worldwide climate and local weather is . . . complex. . . . The chaotic patterns of [air and ocean circulation] governing the weather still [confuse] meteorologists;

in fact, weather more than two weeks in the future is thought by some to be inherently unpredictable. So far, the best answers have come from computer models that simulate the workings of the atmosphere (Revkin 1988, page 51).

Climate scientists, known as *climatologists,* use computers to model Earth's climate. The goal is to create a model that is accurate enough to predict the future, given changes in specific conditions—such as a doubling of CO_2 in the atmosphere. But environmental systems are very complicated, and models have to simplify them. Even the most powerful computers have limitations. If the workings of the system are not completely understood or represented, then the model won't be perfectly accurate. This means that the model's predictions will be less certain. Although climatologists have a good idea of how climate works, not all factors are completely known.

To predict effects from global warming, models first simulate current conditions. Then the amount of carbon dioxide in the model atmosphere is doubled. The computer runs until new atmospheric conditions stabilize and no further changes occur. The model makes a map of expected changes in temperature and precipitation under the simulated conditions of doubled CO_2.

In this lesson, you will work with some of these maps, showing how Australia might change in a warmer climate. Three climate models predict global *average* increases in temperature and precipitation (Table 6 on page 35). These models were created by climatolo-

Climatologists at the National Center for Atmospheric Research develop models to predict effects from global warming.

gists working at major research centers of climate modeling. Each model is named after the research center. *Note that the models make different predictions.* This is partly because they use slightly different equations to model Earth's present atmosphere.

Table 6 Predictions from three climate models for doubled CO_2 (global averages)

Model	Temperature increase (°C)	Temperature increase (percentage of present)	Precipitation increase (percentage of present)
NCAR	3.5	+23.3	+7.1
OSU	2.8	+18.6	+7.8
UKMO	5.2	+34.6	+15.0

Key: NCAR = National Center for Atmospheric Research (Boulder, Colorado)
OSU = Oregon State University (Corvallis, Oregon)
UKMO = United Kingdom Meteorological Office (London, England)

Note: Based on a present global average temperature of 15°C (59°F).

Source: Henderson-Sellers and Blong 1989.

1. What is the range (high to low) of predicted temperature and precipitation increases?
2. Think about how precipitation forms. Why would an increase in global temperatures cause an increase in global precipitation?
3. How do the models' predictions in Table 6 illustrate this relationship?
4. Consider the idea of global average precipitation and temperature. Do you think knowing the expected global changes helps people make plans for their own community or region? Explain your answer.

What do the models predict for Australia?

The three climate models (Table 6 on page 35) have each produced maps showing how the temperature and precipitation might change in a warmer Australia. Such maps show results of simulations for a doubling of atmospheric CO_2 over its preindustrial level. The models simulate an enhanced greenhouse effect from all gases, including methane, CFCs, and nitrous oxide. Predictions are usually made for two seasons—winter and summer. (Remember that in Australia, winter begins in June and summer begins in December.)

Imagine you are a planner in the Ministry of Agriculture in one of Australia's states. Your job is to plan what type of agriculture will be possible in the future, warmer world. Unfortunately, temperature and rainfall predictions alone are not enough to figure out how productive a place will be for farming. Farmers and ranchers need to know about other aspects of climate. Perhaps most important is the amount of soil moisture available for plants to use (Henderson-Sellers and Blong 1989). For example, the present pattern of soil moisture in Australia corresponds closely to present land uses (Figure 7 on page 37).

Predicting soil moisture if CO_2 doubles is even harder than predicting temperature or rainfall. Soil moisture depends upon both temperature and rainfall, which are both expected to increase. More rain means more water will go into the soil, increasing soil moisture. But higher temperatures mean more soil moisture will evaporate into the atmosphere, drying out the soil. Trying to predict soil moisture in any one place is complicated by these opposite effects.

Any uncertainty in rainfall predictions means even greater uncertainty in predicting soil moisture. Also, soil moisture in the real world depends upon how much moisture is actually drawn from the soil and then released back to the atmosphere by the plants themselves. To date, computers can model how plants use water in only a very simple manner. It shouldn't be surprising, then, to see the wide range of predictions for soil moisture changes in Australia if CO_2 is doubled (Figure 8 on page 38).

Farmer feeds his sheep oats and wheat in the Australian outback.

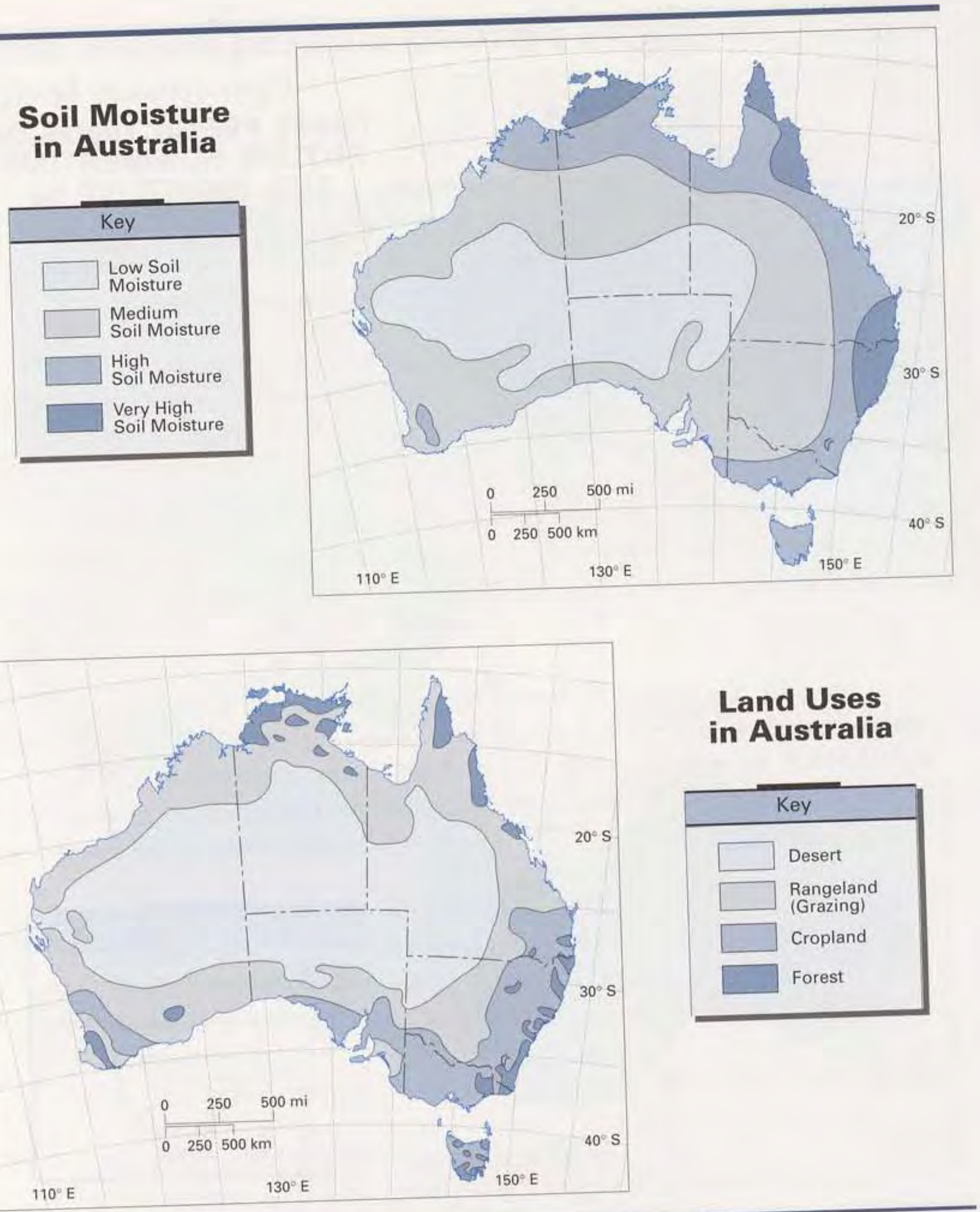


Figure 7 Australia: (a) distribution of present soil moisture and (b) distribution of present land uses.

Sources: World Resources Institute 1990; *Goode's World Atlas* 1990.

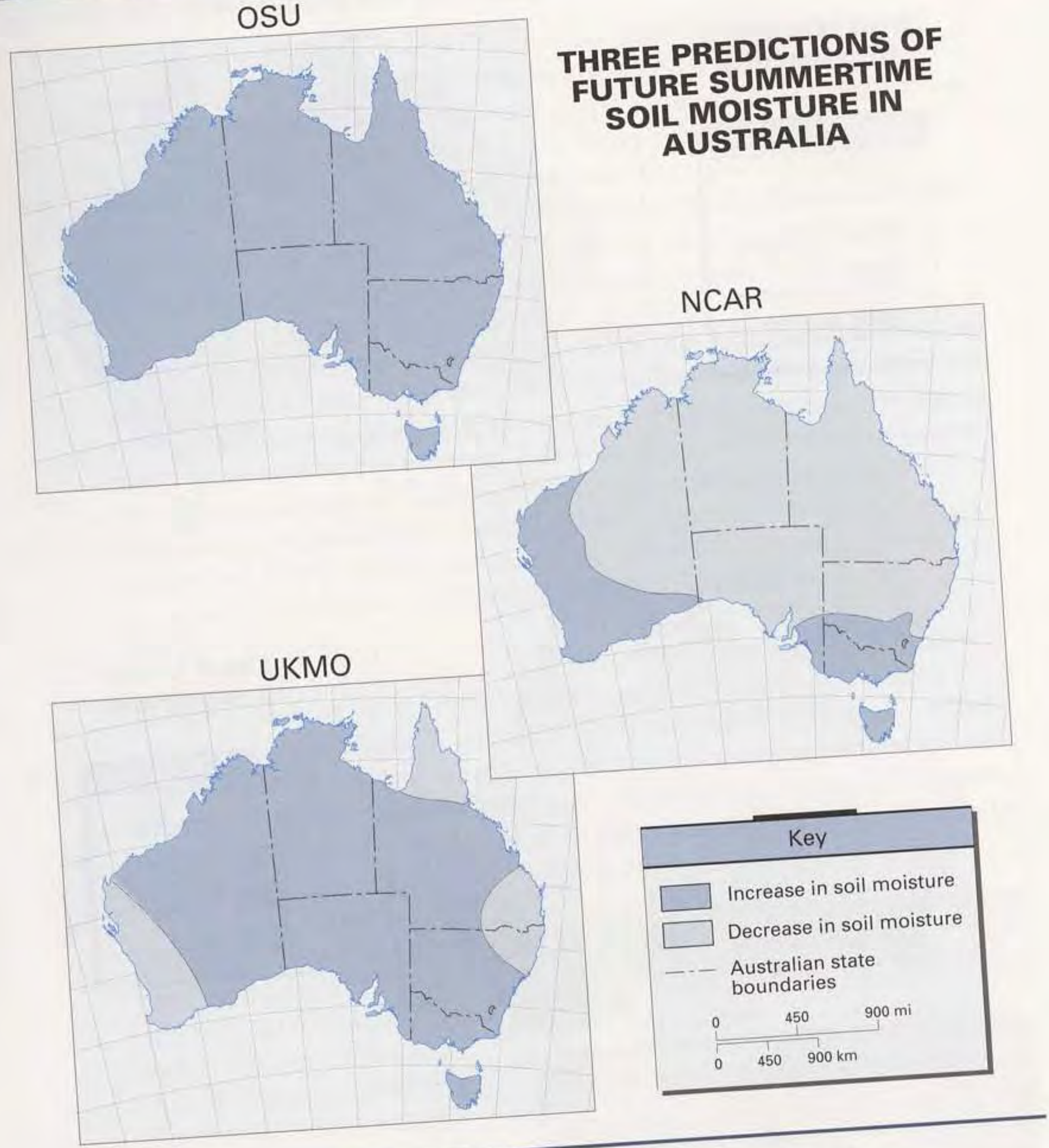


Figure 8 Three predictions of changes in soil moisture for summertime in Australia. Each model predicts increases or decreases in soil-moisture from the present to the future, assuming a future atmosphere with doubled CO_2.

Source: Henderson-Sellers and Blong 1989.

What are the possible positive effects of global warming?

Some Good News and Some Bad

By careful consideration of all sources of evidence about warmer climates, such as warmer periods in history and the predictions of climate models, it is possible to construct a "guesstimate" climate for Australia in A.D. 2030.

This is not necessarily a doom-and-gloom story. Climate modelers are often told off for producing horror stories. This isn't a horror story. Temperatures are going to increase by only about four degrees Celsius. Rainfall is going to increase in many parts of the world. There is definitely going to be lots of good news as well as lots of bad news (Henderson-Sellers and Blong 1989, page 74).

Below is a list of 10 predicted effects of global warming in Australia (Henderson-Sellers and Blong 1989). Which do you think are good news and which are bad news? Be prepared to defend your choices. How would the predicted increases in temperature or rainfall lead to these effects?

1. Hotter temperatures in the tropical north
2. Snowfields lost or reduced in the southeastern mountains
3. Less irrigation needed in some agricultural areas
4. Some plants produce larger seeds, bigger flowers, and more fruit
5. Tropical cyclones become more intense and affect areas farther south
6. Drier soils in some agricultural areas
7. Greater ability to grow exotic, tropical fruits and flowers
8. More rain in the center of the Australian continent
9. Rising sea levels erode beaches
10. Increased growth of weeds and expanded ranges of tropical insect pests

Taking everything from this lesson into account, do you think that global warming would be good or bad for Australia? Why?

Lesson 6

How do developing countries add greenhouse gases?

Objectives

In this lesson, you will

- Compare sources of greenhouse gases in developed and developing countries.
- Describe the causes of deforestation and explain how deforestation contributes to the potential for global warming.

Glossary Words

carbon dioxide (CO_2)
chlorofluorocarbons (CFCs)
deforestation
developing country
greenhouse gases
methane (CH_4)

How do developing countries contribute to greenhouse-gas emissions?

Overall, developed countries accounted for 54 percent of all greenhouse-gas emissions in 1988. Developing countries accounted for 46 percent. Is this percentage higher or lower than what you expected? Why? Do developing countries produce greenhouse gases *in the same way* that developed countries do?

Recall the differences in the level of *per person* greenhouse-gas emissions in the developing regions as compared to the developed regions (Table 5 on page 31). Figure 9 (page 41) shows the share of total emissions by each greenhouse gas for six regions.

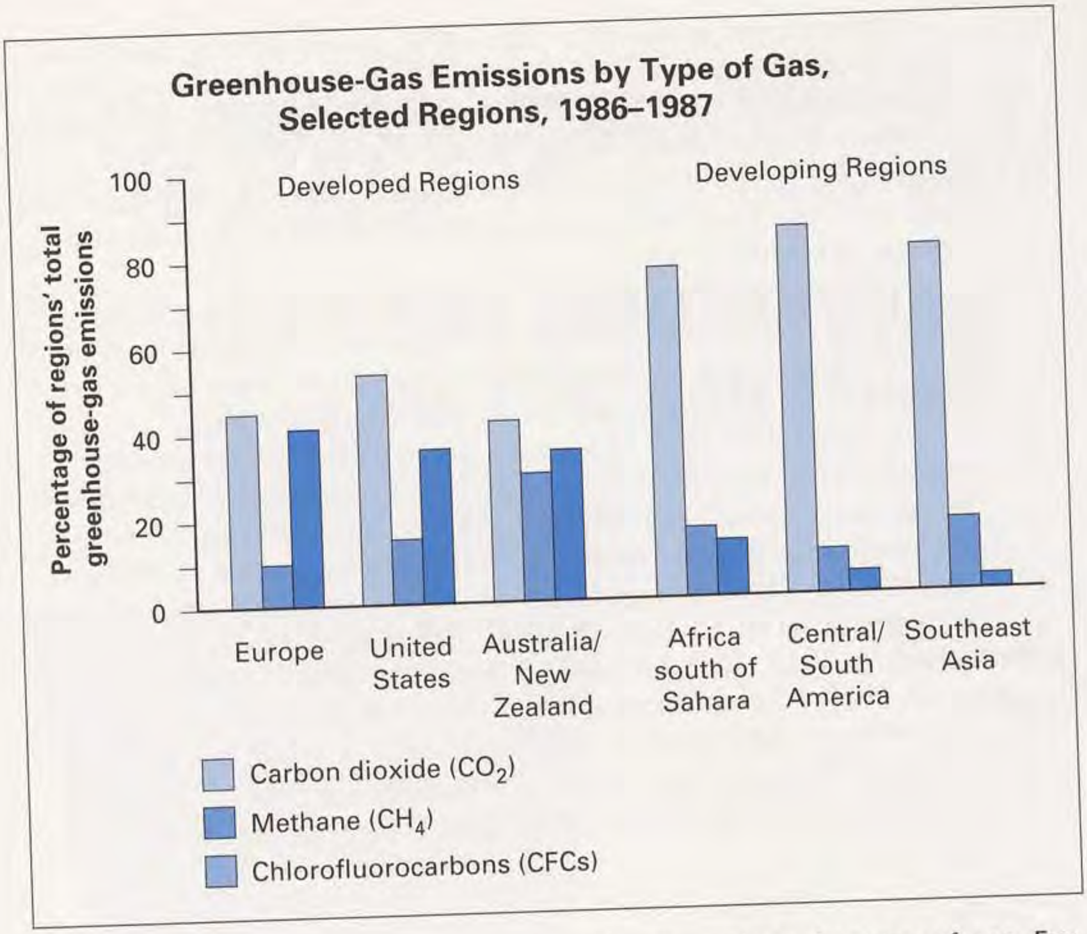


Figure 9 Greenhouse-gas emissions for six regions, by type of gas. For each region, the percentage of total emissions is shown for each gas. The three bars for each region add up to 100 percent.

Source: World Resources Institute 1990.

1. Which greenhouse gas accounts for most of the emissions from developing regions?
2. Why don't CFCs make up a large proportion of greenhouse-gas emissions from developing regions?
3. According to Figure 9, which regions—developed or developing—appear to be contributing the most to the problem? Is this misleading? Why or why not?
4. What important information does Figure 9 fail to show?

Deforestation accounts for almost 90 percent of CO_2 emissions from developing countries (Flavin 1989). There are two ways that deforestation increases greenhouse gases. First, when trees are burned to clear a forest, the combustion of wood puts CO_2 in the air. Second, the removal of trees means that the CO_2 that the trees would have removed from the air during photosynthesis stays in the atmosphere (Schneider 1988).

In the world's developing countries, the rate of deforestation greatly exceeds the rate of forest replacement. This results in a net loss of forested area. If forest loss continues to be greater than forest replacement, the forests could ultimately disappear.

As Figure 9 on page 41 suggests, the regions with the greatest rates of deforestation are Central and South America, Africa—South of the Sahara, and Southeast Asia. The rate of forest loss per year is extremely high in some countries. For example, the rate of deforestation in Côte d'Ivoire, Nigeria, El Salvador, Costa Rica, and Sri Lanka is so great that these countries could lose all of their remaining forests by 2017 (World Resources Institute 1988).

In 1987, 11 countries accounted for 82 percent of the carbon emitted from deforestation: Brazil, Indonesia, Colombia, Côte d'Ivoire, Thailand, Laos, Nigeria, Vietnam, Philippines, Myanmar (formerly known as Burma), and India (World Resources Institute 1990).

5. On a world map, locate each of the 11 countries listed in the last paragraph.
6. What do these 11 countries have in common? Think in terms of their wealth, rate of population growth, and degree of urbanization.
7. What can you conclude about the relationship among deforestation, economic development, and population growth?

Lesson summary

Over the past several lessons, you have learned about human activities that cause increases in greenhouse gases. Think about this question: Can these causes of potential global climate change be reduced? Why or why not?

Lesson 7

How might global warming affect the U.S. Gulf Coast?

Objectives

In this lesson, you will

- Understand why global warming may cause a rapid rise in the world's sea levels.
- Examine the possible impact of sea level rise on the Gulf Coast of the United States.

Glossary Word

global warming

How would global warming cause a rise in sea level?

Scientists generally agree that these two statements are true:

- The global increase in average surface temperature over the past century has been nearly one-half of a Celsius degree.
- Global average surface temperatures will rise another 1.5 to 4.5°C by about 2030.

1. Use Figure 10 on page 45 to estimate how many centimeters sea levels rose between 1880 and 1980.
2. What appears to be the relationship between global temperatures and sea level rise?
3. Do you think that in the next 100 years, the sea level will rise more than it did in the last century? Why or why not?
4. If you said *yes* to the previous question, about how much do you think the seas will rise? Explain your answer.

A Louisiana coastal town in flood after a hurricane.

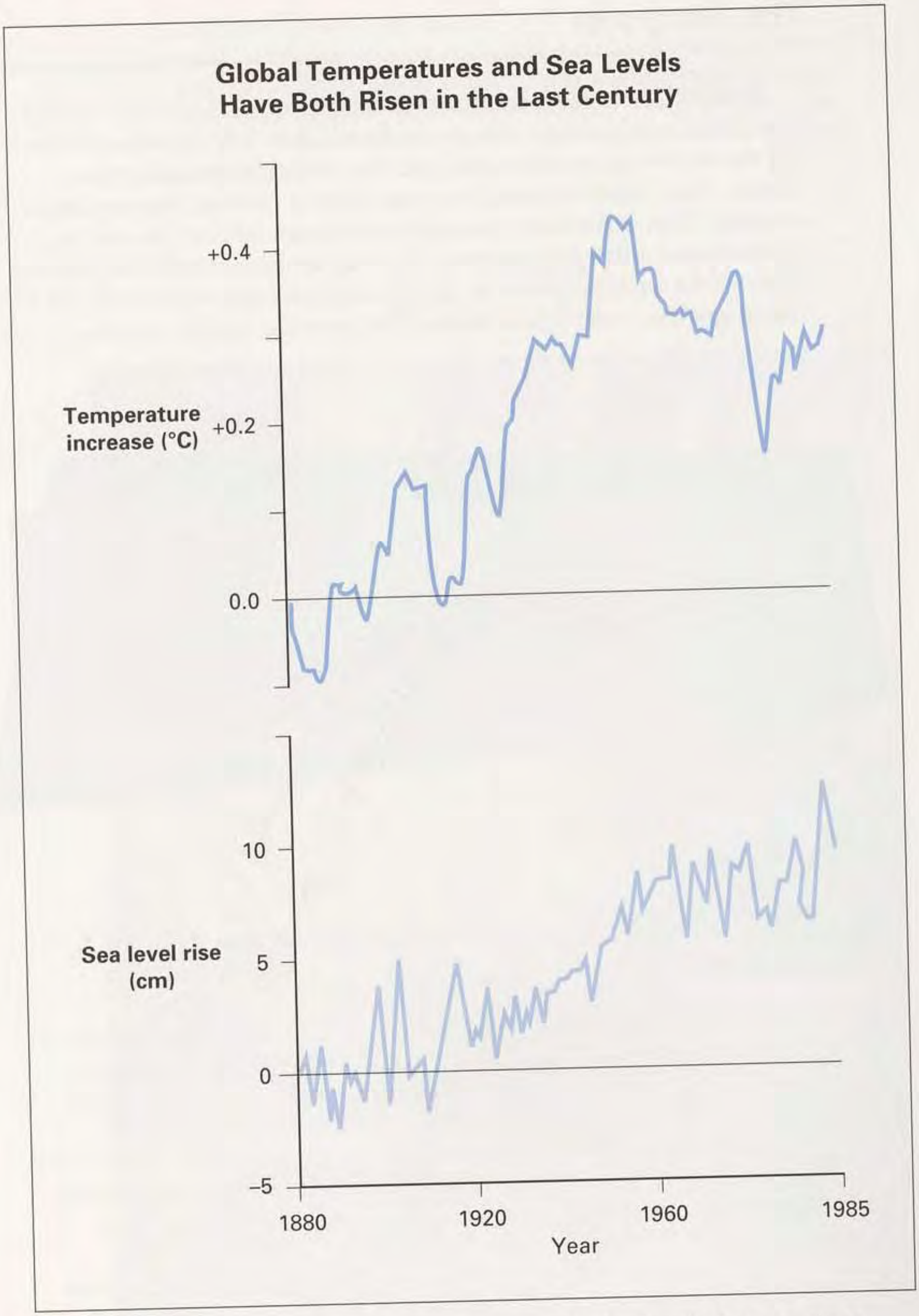


Figure 10 Comparison of temperature and sea level changes since 1880. The zero points on each graph are the average global temperatures and sea levels as of 1880.

Source: Titus et al. 1985.

The rising seas

If global average temperatures increase from 1.5 to 4.5°C by the year 2030, world sea level may rise from 20 to 140 centimeters during the following decades. Sea level rise would be caused by two things. First, the level would increase slightly because warmer water expands. This is the same principle that causes mercury to rise in a thermometer when it is warmed. Second, sea level would rise because some of the ice now frozen in glaciers and ice caps would melt. This rise in sea level would have major effects on the world's coasts.

5. Compare the predicted rate of sea level rise to the rate of rise during the past century (Figure 10 on page 45). About how much faster is the sea expected to rise in the next century as compared to the past century?
6. What do you think the effects of sea level rise would be?

What effect will sea level rise have on the U.S. Gulf Coast?

A 55-centimeter (1.8 feet) rise in sea level would submerge almost all of the Mississippi Delta (Figure 11 on page 48). New Orleans would become more vulnerable to hurricanes because most of the city already lies below sea level and is only protected by levees. Levees are wide earthen embankments erected along rivers and coasts to prevent land from being flooded. For example, the area around Morgan City, Louisiana, is circled by major levees (Figure 12 on page 49).

A one-meter (39.37 inches) rise in sea level would flood at least 30 percent of the Gulf's coastal wetlands and up to 4,600 square miles of dry land. About half of the total wetland loss would be in Louisiana. With a two-meter rise in sea level, Louisiana would lose up to 80 percent of its wetlands and over 10,000 square miles of land (Smith and Tirpak 1988). Why are the coastal wetlands so important?

Composed mostly of marsh [and] cypress swamps, . . . Louisiana's wetlands support half of the nation's shellfish [industry], one-fourth of its fishing industry, and a large trapping industry. They also provide flood protection for metropolitan New Orleans and critical habitats for bald eagles and other migratory birds (Smith and Tirpak 1988, page 6-56).

Cypress swamps are habitats for alligators.

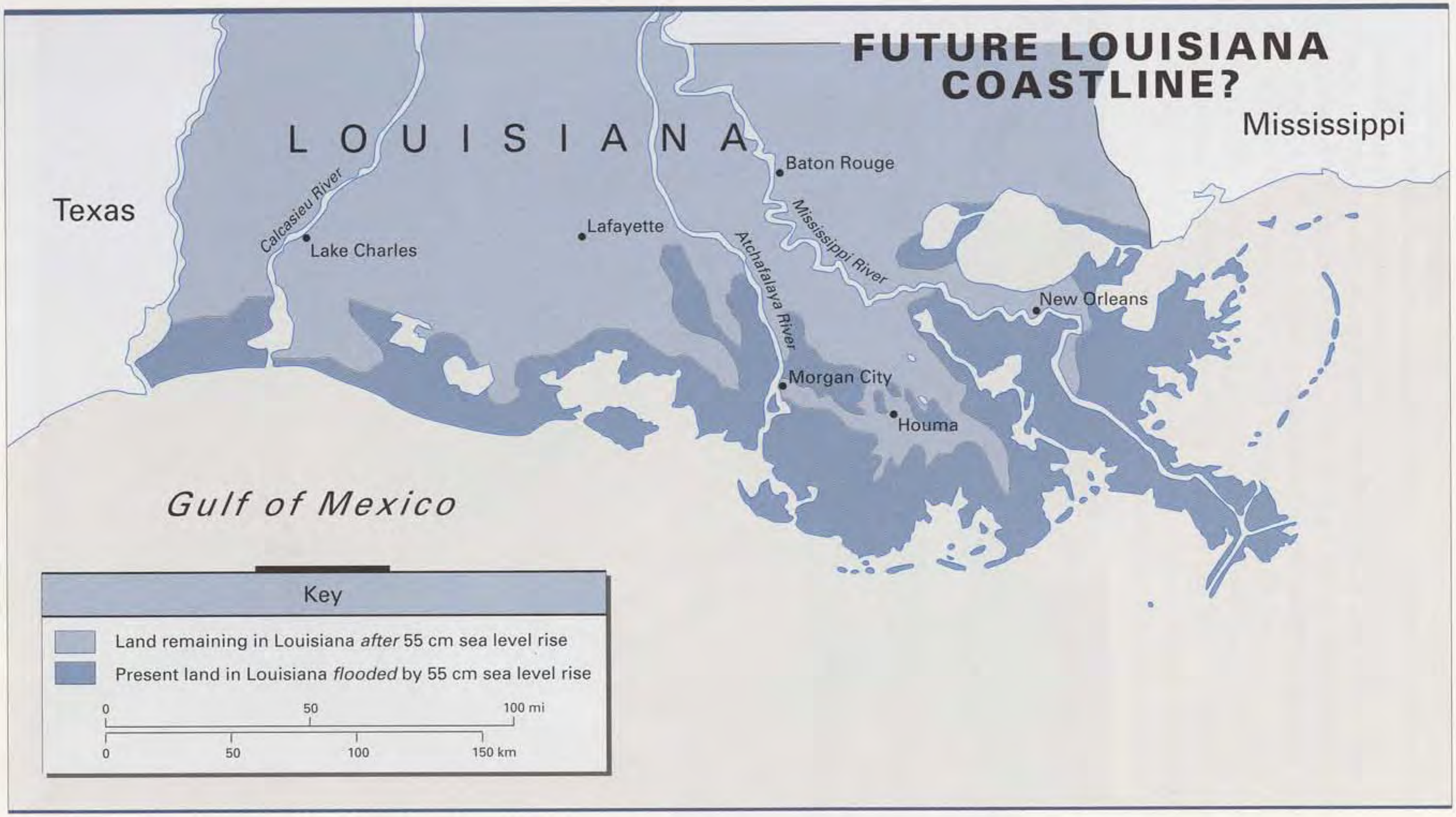


Figure 11 Projected future coastline of Louisiana for the year 2033, given a rise in sea level of 55 centimeters (1.8 feet). Coastlines of Texas and Mississippi would also change, but these changes are not shown.

Source: Smith and Tirpak 1988.

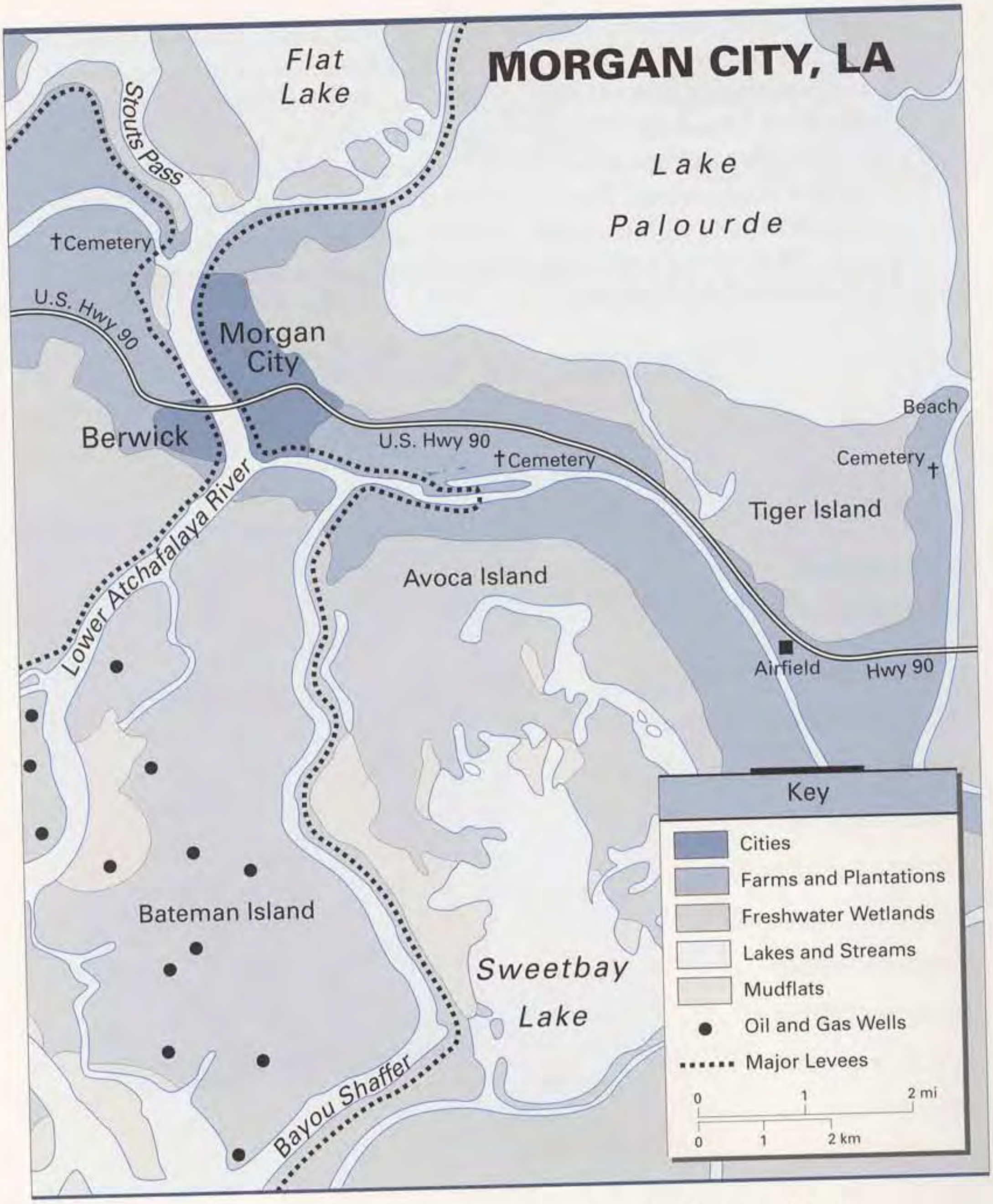


Figure 12 Selected land uses around Morgan City, Louisiana.

Source: Morgan City USGS topographic map, 15-minute series, 1955 edition.

How much of the Gulf Coast is actually flooded will depend upon how many new levees people build. Floods occur when streams overflow their banks or when sea levels are raised by high waves during storms. Most of the Gulf Coast is currently protected from these storm waves by levees that are 10 to 15 feet high (Figure 12 above).

These levees are over 300 feet wide at their base. Building levees this big can cost over $3 million *per mile*. More money must be spent afterward on maintenance, to keep the levees effective (U.S. Army Corps of Engineers, New Orleans District).

In order to cope with sea level rise along the Gulf Coast, the United States would have to spend a great deal of money. Consider this: Will the poorer nations of the world be able to deal with potential effects of sea level rise as well as the richer, more-developed nations? Why or why not?

Lesson 8

What should be done about global warming?

Objectives

In this lesson, you will

- Examine several strategies proposed to deal with global warming and debate the merits of each.
- Compare and contrast the perspectives on global warming between developed and developing countries.

Glossary Words

carbon dioxide (CO_2)
chlorofluorocarbons (CFCs)
climate
climate models
developed country
developing country
global warming
greenhouse gases
methane (CH_4)
ozone hole

What strategies have been proposed to deal with global climate change?

What is the best way to deal with the potential problem of global warming? This lesson presents four possible strategies. As you read them, recall how greenhouse-gas emissions differ between developed and developing regions. Also remember that developing countries do have the right—and the potential—to improve their economic status. Think about how each strategy would be viewed by countries trying to become more developed. Discuss these five questions about *each* proposed strategy.

1. What do supporters of this strategy suggest be done about the potential global warming problem?
2. Would supporters of this strategy more likely be from developed or developing countries? Why?
3. Why do the supporters believe this strategy is fair and equitable?
4. How do supporters justify this strategy?
5. Does this strategy make sense even if global warming does *not* develop into a major problem? Why or why not?

Strategy 1: No action

The U.S. Department of Energy has stated that there is too much uncertainty about the effect climate change will have on individual regions. They said it would be "folly" to invest money to fight a problem whose effects are this unclear (Schneider 1988).

Despite the lack of solid scientific evidence, over 60 percent of the U.S. public is convinced that global warming will worsen. In fact, scientific uncertainty has been used as a reason to take immediate action. One TV reporter argued, "Even if we aren't sure it's true, shouldn't we take precautions and act now as if it were?" (cited in Brookes 1989). Brookes (1989, page 98) responded:

> Unfortunately, "taking such precautions" could well spell the end of the American dream for us and the world. Once CO_2 is in the atmosphere, we can't easily remove it. Since most of the forecast rise in the gas is a function of simple economic and population growth in [developing countries], there is no realistic . . . way to prevent a CO_2 doubling without slashing growth and risking a revolt of the have-not nations against the haves. By the middle of the next century, developing countries will account for the bulk of the greenhouse gases emitted into the atmosphere, even if they succeed in doubling energy efficiency.

On November 7, 1989, the United States and Japan refused to sign a resolution at an international conference on global climate change. The resolution had called for a limit on emissions of greenhouse gases by the year 2000. The U.S. position was that "we should not move forward on major programs until we have a reasonable understanding of the scientific and economic consequences of those programs."

Then-president Bush said: "You can't take a policy and drive it to the extreme and say to every country around the world: You aren't going to grow at all" (Brookes 1989, page 97). The U.S. and Japanese position was supported by some 30 developing nations. Many developing countries see the "threat" of global warming as an excuse to prevent their development.

The Environmental Protection Agency has said tax increases of 30 percent on oil and coal would be needed just to maintain U.S. CO_2 emissions at current levels. To reduce U.S. CO_2 emissions by 20 percent, a tax of $25 per barrel on oil and $200 a ton on coal would be needed. This would double the cost of energy in the United States (Brookes 1989). Recent estimates of U.S. costs of a 20 percent reduction in CO_2 emissions range between $800 billion and $3.6 trillion (Sebenius 1990).

Strategy 2: Adaptation

> During the past century temperatures have risen about 0.5°C and sea level has risen about 10–15 cm. Current levels of greenhouse-gas emissions may already have committed the Earth to another 0.5° C temperature increase and another 10–30 cm of sea level within the next 50 years—even if the composition of the atmosphere is stabilized now (Wellington Conference on Climate Change 1988).

People at that conference in Wellington, New Zealand, concluded that the most realistic policy is to accept these predicted climate changes as inevitable. To prevent climate change would require too severe a disruption in present life styles. The conference decided that planning for the changes was the best strategy. Examples of planning measures for sea level rise and agriculture follow.

Sea level rise

Most people at the conference agreed that planners should include sea level rise predictions in zoning decisions. Engineers should take predicted sea level rise into account when designing new coastal structures (Wellington Conference on Climate Change 1988).

Agriculture

The workshop concluded that the productivity of plants in New Zealand would increase in an atmosphere that contains more carbon dioxide. To take advantage of the warmer environment, growers may need to relocate. Increased diversity in crop production may be possible. For example, fruit species new to the area, such as bananas and other subtropical fruits, could be grown. Tree and livestock species better suited to warmer environments could be established. Identification of possible losses and gains in export markets should begin immediately.

Despite the uncertainty of climate changes over the next few decades, farmers must adapt to the changes. The most important adaptation will be to use different plant breeds and crops. This is especially true for farmers in countries in higher latitudes (such as New Zealand and the United States), where climate change may be most severe. Farmers should shift to crops adapted to warmer conditions, to take advantage of the expected longer growing seasons. In some places, summer drought may become a problem. Farmers should change from crops that grow only in summer to those that grow in other seasons. To make such changes, farmers will need money. Better predictions for climate changes at a regional level are also needed. Government help will be needed when farmers' own resources of know-how and money are insufficient (World Resources Institute 1990).

Strategy 3: Prevention

> This [strategy] begins from two premises. The first is that trend is not destiny; what has been caused by human activity can be mitigated by more appropriate human activity. The second is that [rapid] climate change will, overall, be harmful. Despite local opportunities that may be created, . . . we are generally better adapted to the climate we have lived with for generations than to any other (Fitzsimons 1988, page 1).

Here are three reasons why preventing climate change is better than adapting to a future warmer climate:

1. We are too uncertain exactly what climate will occur, so it is impossible to know just *what* to adapt to. Climate models do not do a good job predicting what will happen on a local level. Unpredictable local changes in rainfall or storm frequency may be more important than temperature.
2. Adaptation strategies are useful only in the immediate future, perhaps the next 50 years at best. But this is just one point on

a longer time scale, and the rate of change may quicken. People may be able to adapt to a 2°C increase, but will the same strategies work if temperatures increase 5°C?

3. The people who are most at risk from changing climates do not necessarily have the money to adapt to these changes. It is unfair to expect African farmers, who already are troubled by droughts and famines, to adapt to climate change as easily as farmers in richer countries (Fitzsimons 1988).

The Maori are New Zealand's aboriginal people. Betty Williams, a Maori representative at a conference on climate change, stated the Maori position. She said the conference lacked a vision for the future because it addressed only the human problems related to climate change. She argued that the conference should look at the problem in the total context of Earth.

The Maori vision is to restore and maintain the integrity and life-energy strength *(mauri)* of nature. The Maori believe that human survival depends upon maintaining Earth's mauri. According to the Maori, humans have reduced the mauri of all natural resources, such as the atmosphere and its gases. In Maori terms, Earth can correct any imbalance of its mauri, given the chance. This can be achieved by a policy of prohibiting the production and use of all human-made things that have diminished the mauri (Wellington Conference on Climate Change 1988).

Maori woman cooks in a thermal spring.

Strategy 4: "Tie-in"

Scientists agree that some climate changes are unavoidable because the atmosphere has already changed. But the *rate* of change *can* be affected by actions that people take now and in the future (Wellington Conference on Climate Change 1988).

The main goal should be to *slow* the rate of increase of greenhouse gases, so that we can delay global warming. For example, if CO_2 increases at a rate of 3 percent per year, its concentration will double by 2036. But if the increase rate is slowed to 1 percent per year, then the doubling won't happen until the year 2100 (Fitzsimons 1988). This extra 60 years would give us more time—time to do more research, to predict problems before they occur, and to develop adaptation plans, such as breeding drought-resistant plants and building seawalls (Udall 1989).

> The Earth's climate is far from being understood. Natural [reactions] to the warming, like increased cloud cover, might come to the rescue by damping down any greenhouse effect. But why bet on it? The greenhouse warming may not arrive for several decades, or it may already have started. . . . Either way, the precautionary measures already at hand are cheap insurance against risks of such magnitude (Editorial, *The New York Times*, Jan. 27, 1989).

The most sensible precautionary measures to deal with potential rapid climate change are called "tie-in" strategies. A tie-in strategy is an action that reduces the amount of greenhouse-gas emissions and *at the same time* also gives society other benefits not related to climate change (Schneider 1988).

The most important tie-in strategy is to use energy more efficiently. Any fossil fuel that is *not* burned produces no CO_2. At the same time, no pollutants or acid rain are produced to cause health problems. Also, there is no dependence on imported oil. And the less energy it takes to manufacture a product, the lower its cost. This makes the product cheaper to sell, which makes it more attractive to buyers (Schneider 1988).

Other possible tie-in policies to slow the rate of greenhouse-gas emissions include banning CFCs; using renewable energy sources, such as solar power; beginning a global effort at reforestation; and helping developing countries to advance themselves using renewable rather than fossil fuels (Udall 1989). Banning CFCs, for example, both reduces a major greenhouse gas and removes the major cause of the ozone hole.

Who is responsible for solving the problem of global climate change?

If developing countries choose to burn a large amount of fossil fuels, that choice could offset attempts by developed countries to reduce greenhouse-gas emissions. With the population growth expected in the developing world, the sources of greenhouse gases will change. For example, India and China may rely on their vast coal reserves to support economic development. If China expands its coal use as much as it plans, global carbon emissions would grow by 50 percent over the present level. Even if developed countries reduce their own carbon emissions, global warming by 2050 would be 40 percent greater if developing countries do not also limit carbon emissions (Sebenius 1990).

The importance of international cooperation

What is fair? Shouldn't developing countries be allowed to use their fossil fuel resources to develop, just as the United States and Europe have done? On the other hand, think about this quote:

> Clearly everyone would benefit if [developing] countries moved toward economic development based on renewable rather than nonrenewable fuels. Why build coal-fired generating plants and power lines to send electricity to rural villages that could be more cheaply served with solar energy? Why divert precious capital to automobiles when mass transit is more economical? After

6. Does this statement agree with your own conclusions? How is it similar? How is it different?
7. Why is the transfer of technology from developed to developing countries so important if global warming is to be avoided?
8. Does this declaration seem to you to be fair to all parties involved? Why or why not?

> all, economic progress is no longer linked to fossil-fuel use, air pollution, and acid rain. Recent advances in renewable technologies could allow [developing] countries to leapfrog the dirtiest stages of the industrialization process (Udall 1989, page 31).

Below is a declaration from representatives of over 130 countries about what should be done about global warming.

Ministerial Declaration, Second World Climate Conference, Geneva, November 1990

We, the Ministers and other representatives from 137 countries and from the European Communities, declare as follows:

We *note* that, while climate has varied in the past and there is still a large degree of scientific uncertainty, the rate of climate change predicted . . . to occur over the next century is unprecedented. . . .

We *consider* that a global response ensuring sustainable development of all countries must be decided and implemented without further delay. . . . Developed countries must take the lead. They must all commit themselves to actions to reduce their major contributions to the global net emissions and enter into and strengthen cooperation with developing countries to enable them to adequately address climate change without hindering their national development goals and objectives. . . .

We *urge* developed countries to . . . develop programs, strategies, and/or targets for a staged approach for achieving reductions of all greenhouse-gas emissions. . . .

We *recognize* that developing countries have as their main priority alleviating poverty and achieving social and economic development and that their net emissions must grow from their, as yet, relatively low energy consumption to accommodate their development needs. . . . To enable developing countries to meet costs required to take the necessary measures to address climate change and sea-level rise . . . we *recommend* that adequate and additional financial resources should be mobilized and best available environmentally sound technologies transferred expeditiously on a fair and most favorable basis.

Source: Sand 1990.

What have the world's developed countries decided to do about global climate change?

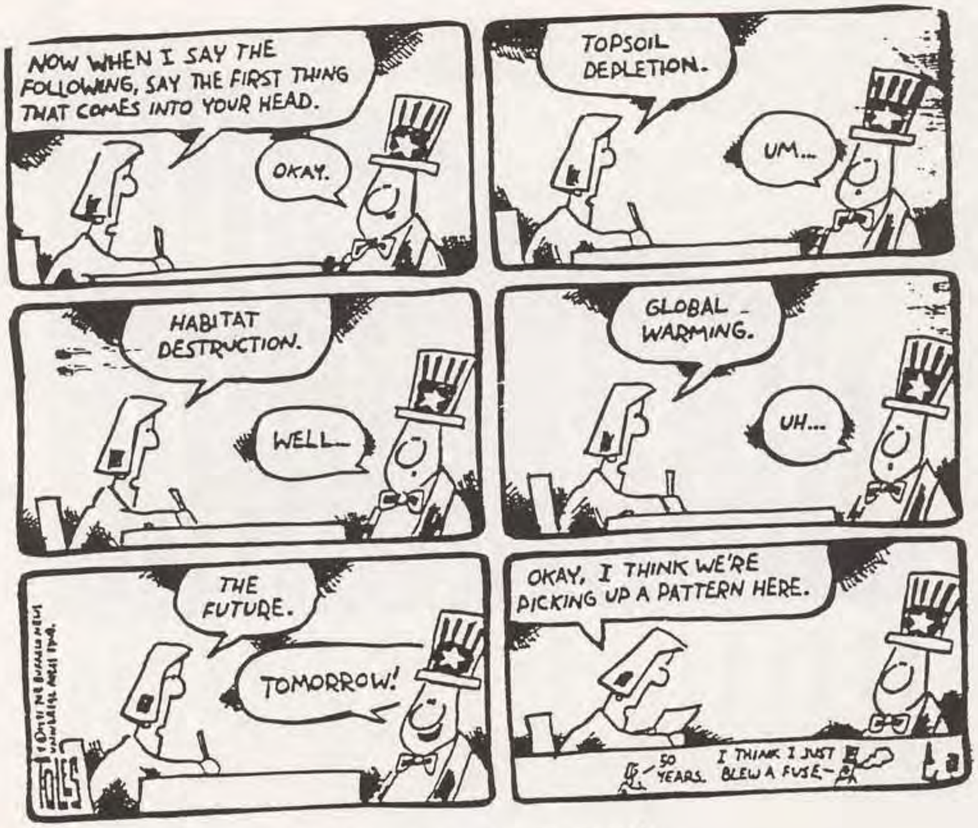


Figure 13 What point is the cartoonist making?

(Cartoon by Tom Toles. Universal Press Syndicate 1991.)

Most European countries, Japan, and Australia are now firmly in agreement that some commitment to specific emissions cuts is needed from the developed countries and that more efficient technologies for environmentally sustainable development are needed for developing countries (Schneider 1991, page 26).

Steps being taken in Europe and Japan

- Germany was the first major industrial nation to adopt a clear goal for carbon reduction. It plans to cut emissions to 25 percent of its 1987 level by 2005.

- Japan has said it will stabilize its greenhouse emissions at "the lowest possible level" by 2000. The Japanese parliament approved a bill in 1988 to provide tax incentives for industries to recycle and conserve CFCs.
- Great Britain planned to return its emissions to the present level by 2005 and is also considering controls on methane leakage.
- Norway planned to stabilize its CO_2 emissions by 2000 and then reduce them.
- The Netherlands proposed to freeze or cut CO_2 emissions by 8 percent and increase spending on energy efficiency.
- Sweden approved a freeze on emissions in 1988 and planned to start a carbon tax in 1991.
- In 1992, the European Community banned production and consumption of CFCs, effective in 1995.

Sources: Flavin 1989; Speth 1990; Boulder (Colo.) *Daily Camera* 1992.

Steps being taken in the United States

In 1990, the U.S. government spent $191 million for research on global climate change (Flavin 1989). Over two dozen bills to reduce and prepare for global warming were in preparation in the U.S. Congress during 1989 (Riebsame 1990). Senator Timothy Wirth of Colorado introduced a bill to cut carbon emissions by 20 percent by the turn of the century. The State of Oregon has already passed a similar law. Vermont and California are also evaluating state energy policies and proposing decreases in greenhouse-gas emissions (Flavin 1989).

If these plans are enacted, a decrease in greenhouse-gas emissions is expected in the world's developed countries (Figure 14 on page 61). This estimate is based on each country's probable population and economic growth and the announced plans for decreases in greenhouse-gas emissions. (Numbers are based on each country's Greenhouse Index scores, which you studied in Lesson 4.)

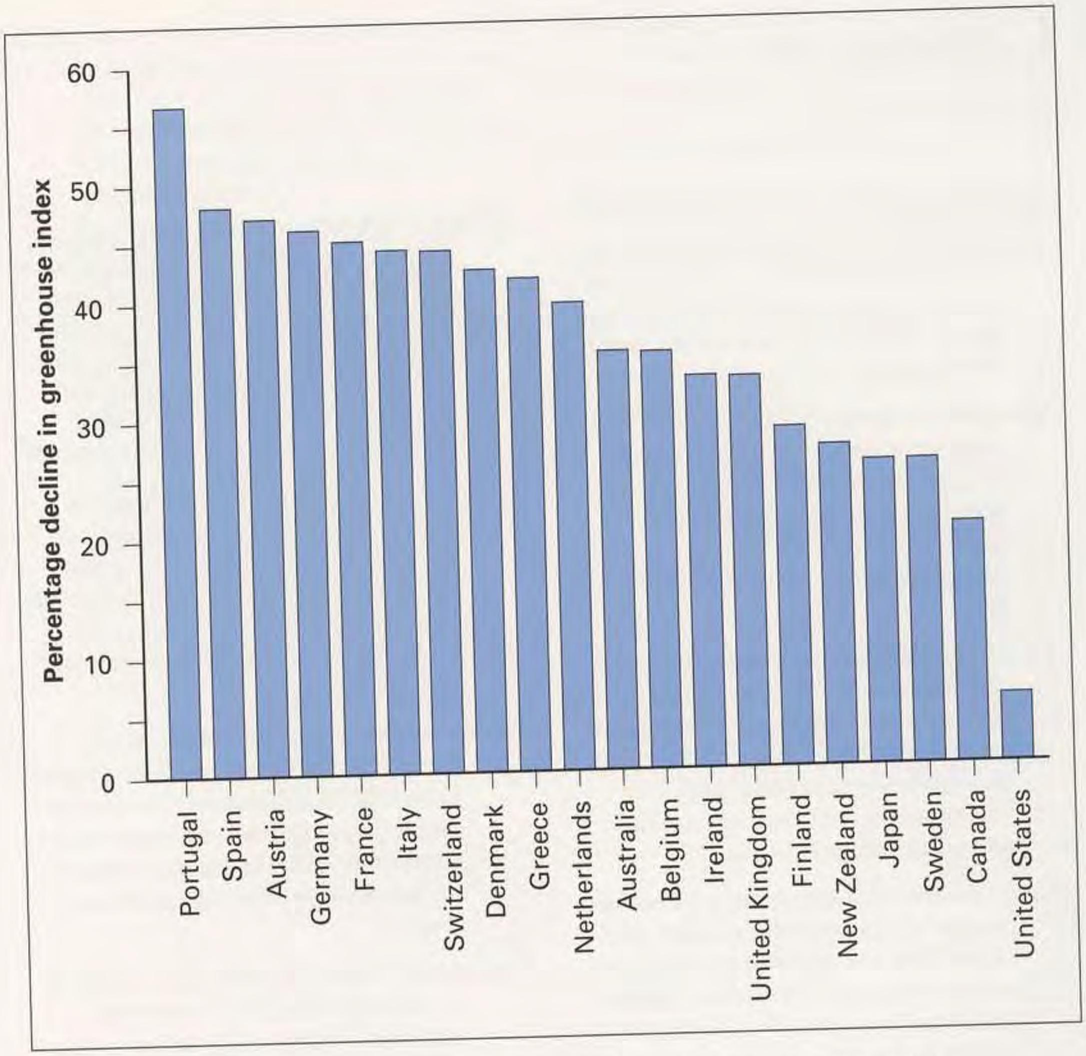


Figure 14 Estimated decline in greenhouse-gas emissions in developed countries from 1988 to 2005, based on announced plans.

Source: Hammond et al. 1991.

9. About what percentage decline is expected in most developed countries?
10. Do you think the United States is doing its fair share? Why or why not?

Glossary

Carbon dioxide (CO_2) A gas produced by numerous processes, including respiration and burning of carbon-based fuels. It is the principal greenhouse gas in Earth's atmosphere. See **greenhouse gases.**

Chlorofluorocarbons (CFCs) A family of chemicals used in a variety of industrial products. One of the major greenhouse gases in Earth's atmosphere, and also the leading cause of ozone depletion. See **greenhouse gases.**

Climate The long-term average conditions of temperature and precipitation in a region. It is a complex environmental system, involving interactions among the atmosphere, oceans, land, ice, plants, animals (including humans), and energy from the sun.

Climate models Computerized representations of the factors that control climate. They use the laws of physics to predict what could happen to the climate given any situation, such as a change in the amount of carbon dioxide in the atmosphere.

Deforestation The temporary or permanent clearance of forest for agriculture or other purposes.

Developed country A nation that has a high degree of industrialization and a relatively high level of wealth, usually expressed by a high average income per person.

Developing country A nation that has a relatively low level of industrialization and relatively low level of wealth, usually expressed by a low average income per person.

Enhanced greenhouse effect On Earth, the greenhouse effect may be enhanced or intensified if concentrations of greenhouse gases are increased by human actions. Many scientists believe that an enhanced greenhouse effect will cause global warming. See **global warming.**

Environmental system The connections and interactions among all parts of the physical and biological environment: air (the atmosphere), water (the hydrosphere), soils and rocks (the lithosphere), and plants and animals (the biosphere).

Global warming The hypothesis that Earth's global average surface temperature will increase during the twenty-first century because of a doubling of greenhouse gases in the atmosphere. See **greenhouse effect, greenhouse gases.**

Greenhouse effect The warming of a planet's surface when heat (longwave radiation) is trapped by certain gases in the atmosphere, the way the glass walls and ceiling of a greenhouse trap heat and humidity inside. These greenhouse gases let in the sun's shortwave radiation but block the emission of longwave radiation back into space. The trapped heat thus keeps the planet warm. See **enhanced greenhouse effect, greenhouse gases, longwave radiation.**

Greenhouse gases Gases in the atmosphere that trap longwave radiation. In Earth's atmosphere, these gases include carbon dioxide, water vapor, methane, nitrous oxide, and chlorofluorocarbons. See **carbon dioxide, chlorofluorocarbons, longwave radiation, methane, nitrous oxide.**

Longwave radiation As used in this module, the heat energy emitted by Earth. This heat energy can be trapped by the atmosphere, which helps keep the planet warm. See **greenhouse gases, greenhouse effect.**

Methane (CH_4) A gas produced by several processes, especially in conditions where oxygen is absent such as in swamps. It is one of the major greenhouse gases in Earth's atmosphere. See **greenhouse gases.**

Nitrous oxide (N_2O) A gas, commonly called "laughing gas," produced by a variety of processes; it is a major greenhouse gas in Earth's atmosphere. See **greenhouse gases.**

Ozone hole A reduction in the amount of ozone detected in Earth's upper atmosphere. The ozone layer protects Earth's surface from harmful ultraviolet rays emitted by the sun.

Shortwave radiation The light energy emitted by the sun, primarily in the ultraviolet and visible light portions of the spectrum.

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