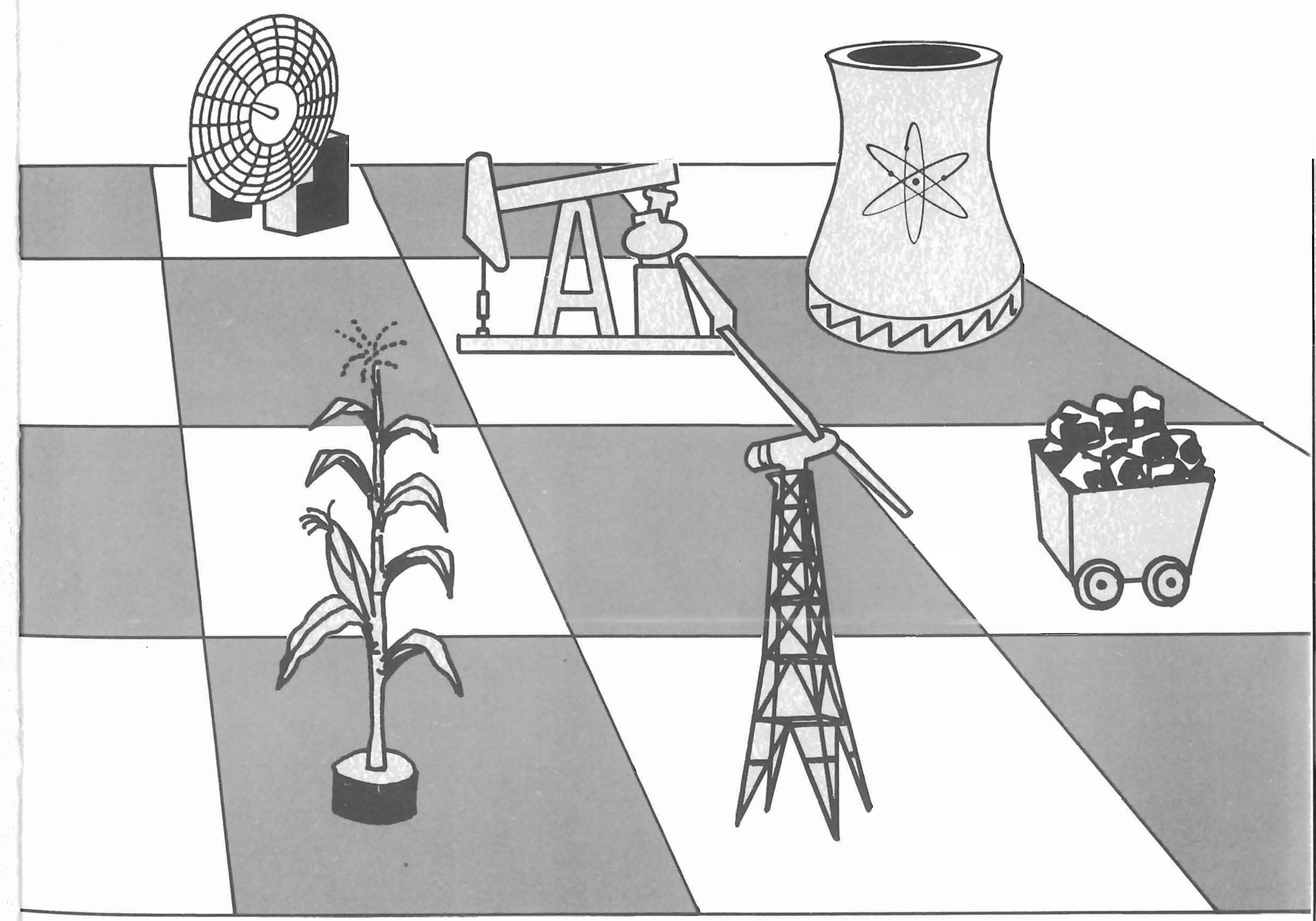
PLAYING WITH ENERGY

CLASSROOM GAMES & SIMULATIONS



National Science Teachers Association

PLAYING WITH ENERGY

Classroom Games and Simulations

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PREFACE

<u>Playing With Energy</u> is a collection of five games and simulations for students in grades 9-12. All of these games/simulations deal with an important energy concept and all have been drawn from teacher-written and classroom-tested learning packets developed by NSTA's Project for an Energy-Enriched Curriculum (PEEC) with support from the U.S. Department of Energy.

Energy and energy education are by nature interdisciplinary, and the PEEC focuses on developing a multifaceted approach to a variety of energy topics. The games appearing here have been selected for their emphasis on science content and then have been adapted from their packet format with an eye to the particular perspective of the science classroom. The result, we hope, is a collection of games that the science teacher will find accessible and pertinent to existing course curriculum.

The book employs a "bare bones" format in effort to economize on space and facilitate use. The essential, skeletal components of each game are provided in a ready-to-duplicate form. They beg, however, to be "fleshed out" by a diet of comprehensive introduction, extended research, and skillful interweaving with current course content and world events. Science teachers are especially well-equipped with the kind of information that makes games like these valuable additions to the usual lecture-laboratory classroom sequence.

Introductions to each game are collected in the beginning of the volume and contain information about instructional objectives, major concepts, length of playing time, extent of teacher preparation required, and so on. Part of this information is designed to help the teacher decide if and when a particular game or simulation is appropriate to introduce into the classroom, but other parts of the introductions are integral to the games themselves and are not repeated in the individual game sections.

The general introductions are immediately followed by the individual games. Each game is self-contained and includes a title sheet, rules or procedures, and a review sheet. Beyond that, the materials provided vary depending on the game.

The title sheet common to all the games states the major energy concept to be acquired in playing the game, supporting facts garnered to elaborate the major concept, related science themes from general science curricula, the AAAS science process skills engaged in playing the game, a brief suggested method for using the game, and necessary game materials listed in the order in which they are required. This title sheet is the backbone of the bare bones provided.

The review sheets provided are intended to initiate the game debriefing process which is, in the words of Minneapolis Public Schools Science Consultant Joe Premo, "the meat of these activities." The questions included are only suggestive of the range of subjects that might be explored in game review sessions, although an effort has been made to bring each game's central points to the fore.

Mr. Premo and other noted science educators have indicated the reluctance with which many science teachers approach the prospect of using games and simulations in their classrooms. For some, it is a question of a game's dubious rationale or instructional gain. For others, it is a matter of feeling inadequately versed in group dynamics and other simulative techniques. This kind of preparation and rationale is beyond the scope of Playing With Energy, but some good references do exist for the teacher who is interested in finding out more about the how and why of gaming in the classroom. A smattering of these references is listed at the end of this preface along with the address for PEEC learning materials corresponding to the games in this volume.

If these games and simulations have a common theme, it is that of alternative energy resources and technologies. The alternatives explored vary from game to game in kind and depth of presentation. Here are included hard and soft path energy strategies, base and peak load energy providers, personal and public energy products, local and global resources and concerns.

The central intent of the volume is to convey the idea that, in terms of our energy future, we do have a choice; there are alternatives to a continued reliance on fossil fuels and the problems inherent in it. Of course, these games can only begin to communicate this awareness. We hope you find them a good beginning.

For more information about how to use games in your classroom, you might consult the following:

Carter, Lynne C. and Lee, Rhona Tye. " 'Game Plans' for Science." The Science Teacher. November 1979, pp. 30-34.

Ellington, H.I., Addinall, E., and Percival, F. Games and Simulations in Science Education. New York: Nichols Publishing Company, 1981.

Hounshell, Paul B. and Trollinger, Ira. "Games for Teaching Science." Science and Children. October 1977, pp. 11-14.

For the PEEC learning packets corresponding to the games in this volume plus PEEC's Factsheets on alternate energy technologies and other energy materials, write:

U.S. Department of Energy
Technical Information Center
Post Office Box 62
Oak Ridge, TN 37830

CONTENTS

INTRODUCTIONS

ENERGY PATHS is a game for grades 9-12 about U.S. foreign oil dependence and what can be done about it. It was originally developed as part of the PEEC learning packet, Making Decisions About Synfuels.

A working vocabulary of alternative energy strategies is introduced and then reinforced by playing the game. The technology of the various strategies is not detailed, but the science teacher can use the game as a departure point for investigating alternative technologies.

The energy strategies are grouped according to whether they follow what Amory Lovins has called "hard" or "soft" energy paths. Examples of hard path strategies include using synthetic fuels from coal or electricity from nuclear generating plants. Soft path strategies include active and passive solar technologies and energy-conserving steps like car pooling.

In the background material for the teacher, some characteristics of each path are noted and comparative analysis is invited, but neither path emerges as the "victor" over the other. An awareness of the environmental impacts and lead time requirements of different energy strategies is encouraged.

The game itself is a simple game of chance which requires only some dice, some hard and soft energy path cards, and some assiduous scorekeeping on the part of the students. The object of the game is to symbolically reduce U.S. foreign oil dependence as quickly and as benignly as possible by accumulating energy points for "using" (drawing) energy alternatives to oil. The person with the most energy points at the end of the game wins; the game can be expected to last approximately one class period.

The energy path cards require some time and effort (and paper, preferably two different colors) to duplicate and cut apart; each group of four students needs 72 cards to play the game. The master sheets provided for the cards, however, should be ready to duplicate without modification. If you and your students are ambitious, enough cards can be generated to involve the whole class in the game; otherwise, the basic unit of play is one set of four students.

The science teacher could use this game as an extension of a lesson on synthetic fuels from coal or as an introduction to a research project on alternative energy technologies. Although the game content is science-oriented, economic and social consequences of the various technologies introduced are implied and invite further exploration. Sharing the game, and particularly the review process, with a social science class could lend an additional perspective.

The Review Sheet for this game, as for other games in this volume, uses a two-column format to save space while permitting easy duplication. When making copies, a blank sheet of paper may be slipped over the right column (guidelines for the teacher), leaving only the student questions in the left column in view (plus some space for student responses).

Through using this game, the teacher can introduce a spectrum of essential new terms and concepts in a meaningful context within a short period of time. The expected student outcome is more awareness than mastery, but the overview provided by the game is a valuable prerequisite to any deeper examination of alternative energy sources and technologies.

CONSULTANTS, INC. is a simulation for grades 9-12 of a power company's Board of Directors decision-making process, featuring the hiring of an outside private research firm to gather and present information vital to the decision being made. The simulation was originally developed as part of the PEEC learning packet, Energy as an Investment Choice.

The decision the simulation centers on is what mode of electrical generation should be used to meet increased power needs. A rudimentary glossary has been prepared as an introduction to the seven different technologies presented and the criteria by which they will be judged. Depending on the familiarity of your students with such terms and technologies, a much more extensive introduction may be in order. The information contained in this simulation is a good next step in the process of increasing awareness about energy alternatives begun in the previous game, Energy Paths.

The simulation process may be as elaborate or simple, formal or informal as you and your students desire. Presentations may be conducted using charts and graphs, microphones and rostrums, and all the other accoutrements of "officialdom." A more relaxed round-table approach might, on the other hand, be just as valuable a learning tool in some classroom contexts.

The Procedure for the simulation has been designed to set up an edge of competition resembling that encountered in the real world of board meetings and consulting agencies. Thus, the report groups must draw up their presentations without access to the Board's criteria or the other groups' prospectuses. Before the actual presentations and evaluation process, however, everyone gets a copy of everything so that as the simulation is brought to a close, all class members are fully informed not only about their own particular roles, but about the parts taken by others in the simulation. This Procedure may, of course, be adjusted to serve other objectives.

The science teacher may use this simulation as a way to introduce the technical aspects of any one or more of the electricity-producing technologies presented by the report groups. The politics and economics of energy production are interdisciplinary themes closely related to the focus of this simulation.

SELLING ENERGY is a classroom simulation for grades 9-12 of writing television advertisements for various energy-related products aimed at a range of target audiences. The simulation was originally developed as part of the PEEC learning packet, Critical Thinking on Energy.

Students are grouped into ad writing teams responsible for researching, writing, and presenting an advertisement for an energy-related product. The presentation may be either narrative or dramatic, depending on the teacher and the class, but in either event, classmates judge the effectiveness of each commercial basing their judgements in part on criteria contained on an Evaluation sheet.

The idea justifying the simulation's use in the science classroom is that behind most marketing approaches employed to sell energy related products (and many others), there lies a scientific principle that has been identified and "translated" into the language of advertising--a language that often relies more on propaganda techniques and emotional appeals than does the quantified, relatively objective language of science.

The role of the science student in the simulation is to ferret out the significant science factors related to a particular energy product, decide how these factors impact upon a particular consumer group, and then to effectively communicate the most important features using a television commercial format.

The Product Cards have been designed to present in one column examples of the kinds of science factors pertinent to promoting the respective products. The column of related Consumer Impacts on each card (appearing opposite the Science Factors) may be covered when duplicating for students to encourage more open-ended research of the Science Factors listed. Besides those listed, other product factors and consumer impacts--science-related and otherwise--are certainly worth investigating and advertising.

Because marketing research has demonstrated that a specific group of consumers is more likely to purchase any given product if approached skillfully and specifically, the ad writing teams are required to design their commercial to appeal to a particular target audience. The descriptions of these target audiences have been deliberately overdrawn to make their point while adding an element of fun to the simulation.

Teacher preparation for the simulation is limited to duplicating the Product and Target Audience cards in the quantities appearing here, plus duplicating five other sheets in quantities sufficient for the entire class. Of these five sheets, one is a Sample Script included to help students visualize their own final presentation and to enhance the self-instructive aspect of the simulative process. Another is the Script Format sheet on which students are to finalize their advertisements; extra copies of these formats are likely to be needed.

The simulation should require approximately four days from start to finish, depending on the degree of research called for by the teacher's objectives and pedagogical approach (and considering class capabilities). Two days might be allotted for researching the ads, one day for drafting and finalizing them, and another day for presentation and evaluation. An Evaluation Sheet and a Review Sheet help pull together the many implications of the simulation.

CANMEXUS is a card game for grades 9-12 about traditional and not-so-traditional energy resources in Canada, Mexico, and the United States. In playing this game, students consider some of the costs and tradeoffs involved in utilizing a resource, be it foreign or domestic. The game was originally developed as part of the PEEC learning packet, CanMexUs: Energy Mix or Mixup?

Although most of the game involves the development and utilization of conventional energy sources like coal and oil, the background material for the teacher contains an extended overview of three alternative energy resources presented in the game: geothermal, tidal, and solar energy. These three sources are less familiar to the North American public even as they are less used by it, and although the degree of their potential contribution to the total energy supply is limited, these limits could be loosened somewhat by increased awareness of the alternatives.

The overviews presented here may be used as a springboard for further research into these and other energy alternatives as well as into the technologies necessary to develop these resources. Other projects might investigate the political, environmental, and economic circumstances which often influence energy production at all levels--international, national, and local. Energy resources transcend national boundaries even as energy shortages do. This global aspect enlarges the energy question, and this game may serve as a pivot point upon which to outline this enlargement--a point of transition between issues of national and international importance, between energy independence and interdependence.

Six players play the game at one time. These six play in pairs, each representing one of the three North American countries indicated in the game title. The object of the game for each of the three countries is to attain or exceed their national goals for energy production.

The achievement of this objective as well as the game's general trend of events is relatively simple: cards are dealt, then drawn from the deck, played or discarded. At the end of the game, points are totaled from the cards played (representing resources developed) and adjusted for accidents or disasters that have occured during the course of play. The team that exceeds its production goal by the greatest number of points wins. More than one round can be played in a class period, and conceptual understanding will increase with the length of playing time. Indeed, the first several rounds are likely to proceed predictably and unimaginatively as students acquaint themselves with the method and purpose of playing. Strategy emerges as awareness increases.

Preparing the cards for play will take time and either opaque duplicating paper or several decks of unwanted playing cards. Each group of six players requires 132 cards. Students can help duplicate, cut, and paste, in the process familiarizing themselves with the cards and discussing any unfamiliar or incompletely understood terms appearing on the cards. The master sheets provided offer facsimilies of the needed cards and indicate the number of times each sheet should be duplicated to yield proportions of cards established according to relative quantities of resources, degrees of technological development, etc. The scenarios for the Accident and Disaster cards can be specified by the students, an exercise that will encourage thought while varying the game from class to class, year to year.

The implications of such scenarios as well as of other features of the game are the focus of the Review questions. These questions can serve to initiate a discussion that may be deepened by further research and broadened by an interdisciplinary approach.

CO_2 AND CLIMATE is a board game for grades 9-12 about an environmental consequence of burning fossil fuels known as the "greenhouse effect." The game, and a more complicated and realistic simulation called LORAGECO (for LOng RAnge and Global Effects of CO_2), were originally developed as part of the PEEC learning packet, Fossil Fuels and the Greenhouse Effect.

The CO_2 issue is one of the more complex and less well understood problems surrounding fossil fuel dependency. The background material for the teacher summarizes the problem and outlines possible effects of CO_2 buildup in the earth's atmosphere.

The board game approach is intended to organize some of the complexities and uncertainties of the problem into a simple format familiar to students. At the same time, it introduces some alternatives to the continued compounding of the problem by encouraging non-fossil fuel resource development. Seven of these non-fossil fuels are defined in the glossary for this game and appear on the playing surface of the game board. Many of these resources have been explored in a more localized context elsewhere in this volume; here they figure as potential components of a global energy strategy intended to free the world not only from fossil fuel dependency, but from its environmental ill-effects.

The game itself employs a playing board (which may be duplicated as is or enlarged on oak tag by artistically inclined students); cards representing some of the conditions of life (food, technology, capital, fuel, and climate); and dice (representing the element of uncertainty). The object of the game is to symbolically reduce dependence on fossil fuels in all five regions of the world represented. This objective is achieved by acquiring monopolies of non-fossil fuel energy resources. Each player will recognize regional advantages in gaining independence from fossil fuels by acquiring such monopolies. As the game progresses, the five players will experience additional collective advantages when they all become independent of fossil fuels.

An important point that the game can demonstrate is the need for global cooperation in resolving the CO_2 problem. The game will likely start out slow and self-interestedly. (Typically 70-75 minutes is required to fully develop the game.) As impatience with the process sets in--and, perhaps, awareness of its intent--a spirit of cooperation will likely emerge; regional alignments may develop; and the game will gather momentum. What happens to this cooperation and momentum when the world declares independence from fossil fuels may make an interesting departure point for a pithy post-game discussion.

Besides the fact that fully 273 cards are required for every five-student game, the teacher may want to limit the number of games in session at any one time so that questions may be addressed as they arise and so students are afforded an opportunity to consider the issues of the game without being enmeshed in its mechanics.

In addition to changing players, the game may be changed in a number of other ways from class to class or year to year. If different regions of the world are used, care should be taken to adjust initial resource allocations to reflect relative situations in the global scenario at the time. With extended research, students could detail the Climate cards more closely or variably as more is discovered about the effects of atmospheric CO_2 buildup. Even if the game is used as is, the outcome will differ with each playing and thus the element of uncertainty will be reinforced even as the review session will be enhanced.

ENERGY PATHS

MAJOR CONCEPT	U.S. foreign oil dependence must be reduced.
SUPPORTING FACTS	• Energy alternatives to foreign oil do exist. • These alternatives may be classified according to whether they follow a "hard" or "soft" path to energy self-sufficiency. • Hard and soft energy paths have different effects ("impacts") on the environment, require different investments of money and time to implement, and yield different quantities and qualities of energy. • These differences comprise a wide-ranging energy mix; they point to a need for both choice-making and cooperating. No single alternative could or should take the place of oil; that, after all, is one of the lessons of oil dependency.
RELATED SCIENCE THEME	Synthetic fuels from coal, one of several energy alternatives to imported oil and one of the hard path energy strategies.
SCIENCE PROCESS SKILLS ENGAGED	Observing, classifying, using numbers, communicating, predicting, inferring, defining operationally, formulating hypotheses, interpreting data.
METHOD	1. Relate Background Material to current course content. 2. Warm up to the game by introducing glossary and acrostic exercises. 3. Play the game. 4. Wind up the game with Review Sheet.
MATERIALS For the teacher:	Background Material
For each student:	Glossary Acrostic exercises 1 and 2 Rules Scoresheets Review Sheets
For every four students:	One die Two decks of energy path cards (one hard path and one soft path, preferably of different colors) One deck = 36 cards; 72 cards total

BACKGROUND MATERIAL

Perhaps the most appropriate time to use this game is during or following a unit about making synthetic fuels ("synfuels") from coal. Synfuels are highly-touted substitutes for the petroleum-based fuels we use in transportation, industry, electrical generation, and commercial and residential heating. During the last part of the Carter Administration, synfuels received an overwhelming vote of confidence from the U.S. Congress which appropriated $20 billion for their development and production. Because of their interchangeability with oil-based products, and because of the relative abundance of coal, synthetic fuels from coal have been heralded as the "answer" to the energy crisis--in particular, the crisis of U.S. dependence on foreign oil.

But synfuels are not the only answer to the energy question. Many alternatives to oil and oil-like energy sources exist, although these alternatives are not nearly as well-known or well-developed as are liquid fuels.

Some people argue that the alternatives are not as viable as the fuels they are meant to replace, particularly in terms of vehicular transportation. It is true, of course, that it would, for example, be impossible to propel a car by means of tidal power: the tides cannot be harnessed for use on a scale as small (i.e., decentralized) as an individual automobile (unless its route were along the beach!)

But large-scale tidal powered plants might produce electricity to replace that which is currently being generated from oil, thus freeing the oil resources for the car to use. Or the car itself might be redesigned to run on electricity generated by the tidal power plant.

The point is that resource diversity is essential to energy security, a point well-illustrated by the disturbing outcome of our exclusive over-reliance on oil in the past. Nevertheless, synfuels have emerged as a kind of panacea to a nation in need of energy but still unwilling to seriously conserve.

Various energy alternatives should be considered in tandem with, not in opposition to, the push for synfuel development. Some of the most promising energy alternatives are described in the student glossary for this game and then appear on the energy path cards which comprise the game.

These alternatives can be generally grouped according to whether they follow "hard" or "soft" paths to energy self-sufficiency. The hard and soft path concept was coined and elaborated by Amory Lovins in his book, <u>Soft Energy Paths: Toward A Durable Peace</u>.

According to his schema, most hard path technologies involve large-scale systems that produce huge amounts of energy. Following the hard paths usually takes many years from the time an idea occurs to the time it results in energy production (i.e., a long <u>lead time</u> is required). Hard path strategies include a rapid expansion of three resource technologies: coal (for electricity and synthetic fuels), oil and gas (from the Arctic and offshore wells), and nuclear technologies.

Soft path energy strategies, on the other hand, involve the use of renewable energy resources like trees, sunshine, wind, geothermal energy, and even urban trash. Relatively uncomplicated technology and smaller scale energy production characterize the soft energy paths. Because of their scale, soft paths are more easily pursued and more quickly traversed, but they don't yield the great amounts of energy that hard path strategies do.

When estimating the value of any energy strategy, the lead time required between its inception and implementation is but one of the central considerations to be made. As implied in the descriptions of the two energy paths, the impact of the strategy upon the environment is of primary concern; i.e., does it deface the land, pollute the air or water, displace wildlife, emit great quantities of CO_2 into the atmosphere, yield hazardous waste that might be inappropriately disposed of, etc. ?

Other considerations include the amount of energy generated or conserved; the usefulness (or "quality") of the energy; the kind of energy needed by the society; the state of technical understanding attained and required; the cost of the process per unit of energy produced; and the impact on society; i.e., does the strategy cost or create jobs; do people want it in their neighborhoods; does it increase, decrease, or reroute traffic; does it require people to change their life styles; etc. ? You and your class can think of other considerations, particularly from the scientist's point of view.

All these concerns have bearing on the energy value of the strategy employed. They also all influence, to one degree or another, the success rate of any given strategy. Within the game, these concerns are reflected by the number of points assigned to the various strategies on the hard and soft path cards. For the students, accumulating these points depends on chance: they roll the die to determine which kind of path card to pick up and then again to find out how many energy points the card is worth. They lose turns for long implemental lead times and take extra turns for short ones. Finally, their accumulated points are adjusted for the net effect of environmental impact.

The frustration the students will likely feel upon being buffeted about by so many chance considerations can be instructive: if the energy future is left to chance, frustration of our national objective--energy self-sufficiency--is likely to result.

On the other hand, the information on the energy path cards and in the glossary can give the students a working knowledge of the energy options open to us at this time. The exercise of choice over chance is afforded an opportunity on the student Review Sheet, where students are asked to outline their own ideas about our energy future.

We encourage you to elaborate the "science" of the various energy alternatives cursorily introduced in the game. You and your students might find the following references helpful in furthering your research:

Landsberg, Hans H., Study Group Chair. Energy: The Next Twenty Years, A Study Group Report to The Ford Foundation. (Administered by Resources for the Future.) Cambridge, MA: Ballinger Publishing Company, 1979.

Lovins, Amory B. Soft Energy Paths: Toward A Durable Peace. Cambridge, MA: Ballinger Publishing Company, 1977.

GLOSSARY

ACTIVE SOLAR HEATING AND COOLING: Methods using flat plate collectors and water or rock heat storage devices and relying upon mechanical means of distribution like fans or pumps to heat and cool buildings.

ANAEROBIC DIGESTION: Use of bacteria to produce methane (a substitute for natural gas) from local vegetation or animal waste.

BREEDER REACTORS: Nuclear reactors designed to produce more fuel than they use. In this production, they use neutrons produced by fission to convert non-fissionable matter (like uranium) into a new element (plutonium) which can be used as a fuel in a nuclear reactor (i.e., which is fissionable).

COAL GASIFICATION: Converting coal to a gas suitable for use as a fuel or feedstock.

COAL LIQUEFACTION: Converting coal into liquid hydrocarbons and related compounds, usually by adding hydrogen. The liquid form can then be used as a fuel or feedstock.

COGENERATION: The simultaneous production of both electric power and heat from a single energy conversion system.

DISTRICT HEATING: The process of using waste heat (from an electrical generating plant, for instance, or local industry) to heat a group of buildings lying in close proximity to the heat-producing facility.

DOMESTIC SOURCES OF OIL: These have grown progressively more scarce and less accessible from the time of the first big gushers to now, the time of out-of-balance oil imports and wringing oil from rocks. Domestic sites now advantageous and necessary to tap include those offshore from the east, west and gulf coasts and those in the Alaskan Arctic.

ENVIRONMENTAL IMPACT: The effect any given technology or strategy to save or produce energy has upon the environment.

GEOTHERMAL ENERGY: The natural heat of the earth harnessed from concentrated pockets such as underground hot springs, geysers, and beds of hot rocks.

HYDROGEN: A future intermediate form of energy (as is electricity) which will be derived from water by electrolysis, and which will be useful for energy storage, as a transportation fuel, as a substitute for some uses of natural gas, etc.

LARGE-SCALE ETHANOL PRODUCTION: Growing crops specifically to be converted to great quantities of ethanol to be used as a liquid fuel replacement for oil or natural gas.

LARGE-SCALE HYDROELECTRIC POWER PRODUCTION: Using large dams and reservoir installations to produce great amounts of electricity for an entire region.

LEAD TIME: The time that elapses between the inception of an energy-producing or -conserving idea, process, etc., and the implementation of it to actually produce or conserve energy.

MUNICIPAL WASTE: Literally, city trash which can be used as an energy source when burned.

NUCLEAR FISSION: The process of releasing energy by splitting heavy nuclei (such as uranium) into lighter nuclei (such as strongtium or cesium).

NUCLEAR FUSION: The process of releasing energy by combining two lighter nuclei (such as hydrogen) to form a heavier nucleus (such as helium).

OIL SHALE: A sedimentary rock found mostly in the U.S. West which can be heated to release an oil-like material, kerogen.

PASSIVE SOLAR HEATING AND COOLING: Methods of solar heating and cooling which require no mechanical devices to operate, like buildings designed and constructed to collect and store solar energy themselves.

PHOTOVOLTAIC ENERGY CONVERSION: The direct conversion of sunlight to electricity by means of certain absorbent materials (cells) which use sunlight to produce a small differential voltage.

SMALL-SCALE ETHANOL PRODUCTION: The distillation of ethanol (a form of alcohol) by individuals or small groups of people (like farmers using a crop-fed still) for a localized use like supplementing or replacing the liquid fuel used in tractors, etc.

SMALL-SCALE HYDROELECTRIC POWER PRODUCTION: Using small dams to produce electricity for a localized area.

SOLAR POWER SATELLITE: Vehicle orbiting in space which will beam solar energy to earth in the form of microwaves, which will then be converted to electricity.

TAR SANDS: Sandy geologic deposits that contain a low-grade heavy hydrocarbon, bitumen.

TIDAL POWER PRODUCTION: Harnessing the energy of the daily tides by means of massive power plants designed to produce electricity.

ACROSTIC 1

After studying the glossary, use the following clues to complete this puzzle. When you have completed the puzzle correctly, three words will appear in the vertical column of letters that are boxed. These words describe one way to approach our energy future. Each clue serves as an example of this approach.

1. _ _ _ _ _ [ ] _ _ _ _
2. _ _ [ ] _ _ _ _ _ _ _ _ _
3. _ _ [ ] _ _ _ _ _ _ _
4. _ _ [ ] _ _ _

5. [ ] _ _ _ _ _ _
6. _ [ ] _   _ _ _ _ _ _ _
7. _ _ _ [ ] _ _ _ _
8. _ _ _ [ ] _ _ _

9. _ _ [ ] _ _ _ _ _ _ _
10. _ [ ] _ _ _ _ _
11. _ _ _ [ ] _ _ _ _ _ _ _ _ _
12. _ _ _ _ _ _   [ ] _ _
13. _ _ _ [ ] _ _ _ _ _ _
14. _ _ _ [ ] _ _ _ _ _ _ _ _
15. _ _ _ _ _ _ [ ]   _ _ _ _ _
16. _ _ _ [ ] _ _ _ _

Answer Key

1. S M A L L [S] C A L E
2. P H [O] T O V O L T A I C
3. E F [F] I C I E N C Y
4. A C [T] I V E

5. [P] A S S I V E
6. C [A] R   P O O L I N G
7. D I S [T] R I C T
8. M E T [H] A N E

9. I N [S] U L A T I O N
10. E [T] H A N O L
11. H Y D [R] O E L E C T R I C
12. M O V I N G   [A] I R
13. G E O [T] H E R M A L
14. C O G [E] N E R A T I O N
15. B U R N I N [G]   T R A S H
16. B I C [Y] C L E S

(Cover lower part of page when duplicating for students.)

CLUES

1. Two words which describe the size of energy systems suitable for a localized area only.

2. Converting radiant energy from the sun directly into electric energy by means of this kind of cell.

3. Getting the most [work] for the least [time, money, energy input].

4. Describes the kind of solar heating and cooling system that uses flat plate collectors, heat storage devices, and other hardware.

5. Describes the kind of solar heating and cooling system that puts the structure of buildings to work.

6. Sharing automobile space to save gas.

7. A heating system which uses waste heat from a central building to heat a group of buildings located nearby.

8. The gas produced from the anaerobic digestion of vegetation or animal waste.

9. Any material that has the ability to retard the movement of heat through it, especially important in building construction.

10. The form of alcohol produced from the fermentation of agricultural products.

11. Describes electricity produced using water, in this context by small dams for a single community.

12. Two words which could be used to describe the wind.

13. The kind of energy that comes from underground hot springs and geysers.

14. The production of heat and electricity by a single facility at the same time.

15. How to get more heat from municipal waste.

16. The highest gas-mileage vehicles in America.

In the blanks below, write the words that appear in the vertical column:

___ ___ ___ ___   ___ ___ ___ ___   ___ ___ ___ ___ ___ ___ ___ ___

ACROSTIC 2

After studying the glossary, use the following clues to complete this puzzle. When you have completed the puzzle correctly, three words will appear in the vertical column of letters that are boxed. These words describe one way to approach our energy future. Each clue serves as an example of this approach.

```
 1.                    _ _ _ _ [ ] _ _ _
 2.                          _ [ ] _ _ _ _ _ _ _ _ _ _
 3.                      _ _ _ [ ] _ _ _ _ _ _ _ _ _
 4.                    _ _ _ _ [ ] _ _ _
 5.                            [ ] _ _ _ _ _ _ _ _ _
 6.                        _ _ [ ] _   _ _ _ _ _ _
 7.        _ _ _ _ _ _ _ _ _ _ [ ] _ _ _
 8.                  _ _ _   _ [ ] _ _ _
 9.                        _ _ [ ] _ _ _
10.                            [ ] _ _ _ _
11.                        _ _ [ ]   _ _ _ _ _
12.                          _ [ ] _ _ _ _ _ _ _
13.                          _ [ ] _ _ _ _ _
14.                    _ _ _ _ [ ]   _ _ _ _ _
15.        _ _ _ _ _ _ _     _ [ ] _ _
16.                          _ [ ] _ _ _ _ _ _
```

Answer Key

```
 1.                    O F F S [H] O R E
 2.                          G [A] S I F I C A T I O N
 3.                      H Y D [R] O E L E C T R I C
 4.                    B R E E [D] E R S
 5.                            [P] R O D U C T I O N
 6.                        C O [A] L   M I N I N G
 7.        L I Q U E F A C     [T] I O N
 8.                  O I L   S [H] A L E
 9.                        F U [S] I O N
10.                            [T] I D A L
11.                        T A [R]   S A N D S
12.                          S [A] T E L L I T E
13.                          E [T] H A N O L
14.                    L A R G [E]   S C A L E
15.        N A T U R A L     [G] A S
16.                          H [Y] D R O G E N
```

(Cover lower part of page when duplicating for students.)

CLUES

1. Where oil found in coastal waters is drilled.

2. The conversion of coal into a gas suitable for use as fuel.

3. Describes electricity produced using water, in this context by large dam/reservoir systems for an entire region.

4. Nuclear reactors designed to produce more fuel than they use.

5. Opposite of consumption: same as generation.

6. The extraction of America's most abundant fossil fuel. (Two words.)

7. The conversion of coal into a form that could be used as liquid fuel or feedstock.

8. Oil-bearing rocks. (Two words.)

9. The process of releasing energy by combining two lighter nuclei to form a heavier nucleus.

10. Describes the kind of power produced by channeling the daily gravitational flow of water through massive power plants.

11. Sandy geologic deposits that contain low grade heavy oil. (Two words.)

12. A space device which will beam solar energy to earth in the form of microwaves, which will then be converted to electricity.

13. Industrial installations could convert large quantities of crops to this form of alcohol, useful as a fuel.

14. Two words which refer to the production of energy in huge quantities.

15. A fossil fuel, commonly used in residential heating and cooking. (Two words.)

16. The lightest of the elements, and one which may be used as an intermediate energy form sometime in the future.

In the blanks below, write the words that appear in the vertical column.

__ __ __ __ __ __ __ __ __ __ __ __ __ __ __ __

RULES

1. Divide into groups of four.

2. Each group should have 1 die, 2 decks of energy path cards--one hard and one soft--turned face down, and 4 scoresheets, one for each member of the group.

3. Throw the die to determine who goes first; highest throw begins.

4. First player: Throw the die. If 1,2, or 3: Take Soft Path card
   If 4,5, or 6: Take Hard Path card

   Record which kind of card you take on your scoresheet.

5. Turn card over; everyone can see. For example:

Energy Strategy	CAR POOLING					
	Environmental Impact: Low +1					
Second Roll of Die	⚀	⚁	⚂	⚃	⚄	⚅
Energy Points Gained	5	10	15	20	25	30
	Lead Time: Short				Take An Extra Turn	

6. Record on your scoresheet what kind of energy strategy you drew; in this example, it is car pooling.

7. Record the environmental impact value (in this instance, +1) in the appropriate column on your scoresheet. Your score will be adjusted for these cumulative values at the end of the game.

8. Throw the die again; record on scoresheet the number of energy points corresponding to what you roll. If a zero appears in the box corresponding to what you roll, this means that the energy strategy failed and no points are gained.

   [As the game progresses, note to yourself the "failure rate" (the number of zeroes on the cards) of your energy strategies as you draw them from the path cards. Think of reasons why the various strategies might not work--and think about how they might be made to work. After the game, you will have a chance to discuss some of your ideas.]

9. Record on your scoresheet the lead time required for your energy strategy.
   - If long: You lose a turn
   - If short: Take an extra turn
   - If average: Take your turn as usual the next time around

   In the case of the example card, the first player would repeat steps 4-9 before turning the die over to the second player.

10. When you have recorded all the necessary information from the card, discard it face up beside the pile you drew it from.

11. Moving clockwise from the first player, players 2, 3, and 4 should take their turns, completing steps 4-9 above.

12. Play proceeds in a clockwise fashion, allowing for extra turns or missed turns dictated by the lead time factor on the cards drawn.

13. Players should keep a running total of their energy points in the corresponding column on their scoresheets.

14. Play continues until someone accumulates 700 energy points. If decks of energy path cards are exhausted before this time, turn over the appropriate discard pile, shuffle, and continue playing.

15. When someone gets 700 energy points, stop playing. Make sure each player has kept an accurate running total of energy points. For example:

Energy Points This turn	Running Point Total
0	0
20	20
40	60
0	60

16. Then each player should take a net total of his or her environmental impact column. For example:

Environmental Impact Value
+1
+1
0
-1
+1

17. Multiply the net environmental impact by a factor of 50 and adjust your total energy points accordingly. For example:
    +1 x 50 = 50 + 60 (from running point total) = 110

18. After this adjustment has been made, the player with the highest score wins.

19. Keep your scoresheet and use the information recorded there to help answer the questions on the Review Sheet.

SCORESHEET

Kind of Card: Hard or Soft	Energy Strategy	Environmental Impact Value	Energy Points This Turn	Running Point Total	Lead Time Required: Long, Short, Average

Duplicate these pages 2 times each.

SOFT PATH CARDS

Card	Environmental Impact	Die 1	Die 2	Die 3	Die 4	Die 5	Die 6	Lead Time
SMALL-SCALE HYDROELECTRIC POWER	Low + 1	0	0	15	20	25	30	Average
SMALL-SCALE ETHANOL PRODUCTION	Low +1	0	0	0	40	50	60	Average
PASSIVE SOLAR HOMES	Low +1	0	0	0	60	75	90	Average
INCREASE HOME INSULATION	Low +1	10	20	30	40	50	60	Short — Take An Extra Turn
WIND POWER	Low +1	0	0	0	40	50	60	Average
DISTRICT HEATING	Low +1	0	0	0	40	50	60	Long — Lose A Turn
ACTIVE SOLAR ENERGY	Low +1	0	0	0	80	100	120	Average
INCREASE USE OF BICYCLES	Low +1	5	10	15	20	25	30	Short — Take An Extra Turn
INCREASE CAR POOLING	Low +1	5	10	15	20	25	30	Short — Take An Extra Turn

Card	Environmental Impact	Die 1	Die 2	Die 3	Die 4	Die 5	Die 6	Lead Time
SOLAR AIR CONDITIONING	Low +1	0	0	0	60	75	90	Long — Lose A Turn
IMPROVE EFFICIENCIES IN HOME APPLIANCES	Low +1	0	10	15	20	25	30	Short — Take An Extra Turn
CLEANER, MORE EFFICIENT WOOD BURNING	Low +1	0	0	0	40	50	60	Short — Take An Extra Turn
IMPROVE EFFICIENCIES IN INDUSTRY	Low +1	0	0	30	40	50	60	Short — Take An Extra Turn
BURNING OF TRASH AS ENERGY SOURCE	Medium 0	0	0	30	40	50	60	Average
PHOTOVOLTAIC ELECTRICITY FOR BUILDINGS	Low +1	0	0	0	0	75	90	Long — Lose A Turn
COGENERATION OF HEAT AND ELECTRICITY	Medium 0	0	0	0	60	75	90	Long — Lose A Turn
METHANE GENERATION	Low +1	0	0	30	40	50	60	Average
GEOTHERMAL ENERGY	Low +1	0	0	0	0	50	60	Average

HARD PATH CARDS

Card	Environmental Impact	1	2	3	4	5	6	Lead Time
NUCLEAR FISSION PLANT	Medium 0	0	0	0	0	100	120	Long — Lose A Turn
LARGE-SCALE HYDROELECTRIC PLANT	Medium 0	0	0	0	0	100	200	Long — Lose A Turn
LARGE SCALE TIDAL POWER PLANT	Medium 0	0	0	0	0	0	100	Long — Lose A Turn
COAL GASIFICATION	High -1	0	0	0	0	75	90	Average
COAL LIQUEFACTION	High -1	0	0	0	0	75	90	Long — Lose A Turn
LARGE-SCALE ETHANOL PRODUCTION	Low +1	0	0	0	0	0	90	Long — Lose A Turn
SOLAR SPACE SATELLITE	Medium 0	0	0	0	0	0	120	Long — Lose A Turn
OIL PRODUCTION IN THE ARCTIC	High -1	0	0	0	0	75	90	Average
OIL PRODUCTION OFFSHORE	High -1	0	0	0	0	75	90	Average
HYDROGEN AS FUEL FOR TRANSPORTATION	Low +1	0	0	0	0	0	120	Long — Lose A Turn
ELECTRIFY TRANSPORTATION SYSTEM	Medium 0	0	0	0	0	0	180	Long — Lose A Turn
TAR SANDS	High -1	0	0	0	0	0	90	Long — Lose A Turn
OIL SHALE	High -1	0	0	0	0	0	90	Long — Lose A Turn
NEW COAL MINING	High -1	0	0	0	0	50	60	Average
NEW NATURAL GAS DISCOVERY	Medium 0	0	0	0	0	50	60	Average
BREEDER REACTOR	Medium 0	0	0	0	0	0	250	Long — Lose A Turn
FUSION REACTOR	Medium 0	0	0	0	0	0	500	Long — Lose A Turn
RELAX ENVIRONMENTAL STANDARDS	High -1	0	0	0	0	0	60	Short — Take An Extra Turn

REVIEW SHEET

(Cover when duplicating for students.)

1. Who won? Why? In terms of the U.S. energy future, are there different ways to "win," that is, to conquer the energy crisis?

2. How many of your hard path technologies were successful?_______
How many failed?_______
Calculate your hard path failure rate as a percentage of all the hard path cards you drew:_______
Do the same for your soft path cards.
Soft path successes_______
Soft path failures_______
Failure rate_______

3. Compare the hard path strategies with the soft path strategies in terms of the following:
   - Environmental Impact
   - Lead Time Requirement
   - Energy Points

   Make a generalization about each of these considerations based on your comparison.

4. Energy points were assigned to the various strategies based on a combination of factors. In addition to lead time and environmental impact, what are some other factors that would be worth some energy points?

5. During the game, you were forced to follow the energy paths dictated by the chance throw of the die. Now you have an opportunity to choose the paths that make the most sense to you. Review the factors you named in #4. Which are most important to you? Based on what you have learned, describe your personal hope for the energy future. Would you describe your ideas as following a hard or soft path to energy self-sufficiency? How likely do you think your hopes are to succeed in America's energy future? What would be required to make them succeed?

Answers:

1. Possible explanations include short lead times and hence more opportunities (turns) to gain points; high rolls, hard paths and big energy point payoffs; etc.

2. OPTIONAL ACTIVITY: "Choose some hard or soft path energy strategies you are interested in. Research their success and failure rates. On what factors are these rates based? Do you get conflicting reports from different sources? What might explain these differences? How do the rates you get from your research compare with the rates obtained from the game data?"

3. The hard path strategies have a greater environmental impact and require longer lead times than do the soft path strategies. In terms of energy points, the soft path strategies have a generally lower failure rate than do the hard path strategies, but when the hard paths do succeed they pay off big!

4. Some possible factors include the amount of energy generated or conserved, energy quality, energy needs, technical state of the art, cost of the process per unit of energy produced, societal impact, etc.

5. OPTIONAL ACTIVITY: "Are you aware of others whose energy ideas are similar to your own? If so, there is likely a national group formed to promote these ideas. Find out if such a group exists and write to them for more information about their energy strategy, technologically and politically speaking. If you are interested, it may be possible for you to start or join a local chapter of the group, or to help with a local project."

CONSULTANTS, INC.

MAJOR CONCEPT

Electricity can be generated in a variety of ways, many of which do not involve the direct conversion of oil.

SUPPORTING FACTS

- Electricity is supplied by generally two different strata of generating facilities: baseload or peak load power plants.
- Baseload plants are typically large-scale, centralized energy technologies like coal and nuclear power. Their primary purpose is to produce the greatest amount of energy required for the least amount of money; their chief characteristic is their stability.
- Peak load plants are of various types and can employ fossil fuels or renewable resources in classic centralized or innovative decentralized configurations. Their primary purpose is to provide supplemental energy during peak demand periods; their chief characteristic is flexibility.
- Decisions about new power supply involve isolating the nature of the power needed in terms of these strata; this step is the broadest application of the idea of matching energy sources to end uses.
- Besides their stratification, modes of electrical generation further differ in terms of capital costs, fuel costs, lead time requirements, and environmental impacts. Decision-makers accord each of these factors varying degrees of importance depending on both personal and professional outlook.

RELATED SCIENCE THEME

How electricity is generated.

SCIENCE PROCESS SKILLS ENGAGED

Observing, classifying, using numbers, communicating, predicting, inferring, defining operationally, interpreting data.

METHOD	1. Use Glossary, Major Concept sequence, and Problem Statement to introduce issues of simulation. 2. Divide class into groups; allow time for additional research. 3. Conduct role playing simulation. 4. Wind up the exercise with the Review Sheet.
MATERIALS For each student	Glossary Problem Statement Procedure 1 copy of each Prospectus--disseminate as Procedure indicates. Technology Comparison Chart--disseminate as Procedure indicates. Review Sheet

GLOSSARY

BASELOAD: The amount of generating capacity required to meet the level of demand for electricity that is relatively constant, regardless of the time, day, or season. The baseload capacity requirement will vary from region to region, depending primarily on the number of people to be serviced by any single baseload facility and on what these people do in their work and play.

BTU: British thermal unit; a unit of heat energy equal to the quantity of heat necessary to raise the temperature of one pound of water one degree Fahrenheit.

CENTRALIZED: Characterizes baseload facilities and relates to their massive size, their huge start-up expense, their consequent constancy of energy output, and their economy per unit of energy produced.

DECENTRALIZED: Characterizes many peak load facilities and relates to their smaller size, their flexibility, and their greater operating expense per unit of energy produced.

JOULE: A metric unit of work or energy; the energy produced by a force of one newton operating through a distance of one meter.

PEAK LOAD: The amount of energy required to meet the level of demand for electricity at its highest, over and above the baseload provision. Peak load requirements are determined in response to careful calculations during peak demand periods which fall during certain times of the day, week, and year. Midday--about 2 pm--is the daily demand peak; Monday is the peak demand day of the week; and winter is the North's peak season while summer is the South's.

RECOVERABLE RESOURCE: That portion of a resource expected to be recovered by present-day techniques and under present economic conditions. Includes geologically expected but unconfirmed resources as well as identified reserves.

RESERVE: That portion of a resource that has been actually discovered and that is at present technically and economically extractable.

RESOURCE: The total estimated amount of a mineral, fuel, or energy source, whether or not discovered or currently technologically or economically extractable.

WATT: A unit of power.
1 watt (W) = one joule of work/second.
1 kilowatt (kW) = 1000 W
1000 kW = 1 megawatt (MW)
1 Wp = one peak watt, or the number of full-capacity watts able to be produced by solar technologies on a clear day at midday.

PROBLEM STATEMENT

The area in which you live is experiencing a potential energy shortage of 500 MW. The regional electric utility--Mattawoman Power and Light--must decide if and how this shortage may be compensated for. There are several alternatives open to the utility, but one alternative has been ruled out by the government. Because of the scarcity, expense, and politically charged aspect of oil, the utility is prohibited from solving its shortage problem the way it might have once responded: it is not authorized to build an electric generating plant dependent on the use of oil for fuel.

The utility could try simply asking its customers to conserve more electricity, enough to make up the amount of the shortage. But, of course, the customers may already be conserving the maximum amount of energy possible, or they may be unwilling to conserve any more than they are. In either event, the shortage would still exist.

The utility could build another big electrical generating plant to provide the additional 500 MW of energy needed. This time, though, the plant would have to be powered with either coal or nuclear energy. In either case, construction would take years, and the utility would have to raise its rates--not only upon completing the plant, but in the process of building it. And, if the increase in demand for electricity continues to drop in coming years the way it has decreased over the last decade, the utility could end up with one more power plant than it needed--a very expensive "extra."

Or the utility could elect to implement a combination of "alternative energy technologies," each of which could be instituted more readily than its baseload counterparts; adapted to a particular geographical area; and adjusted for particular levels of demand on different days, weeks, or years. Because these alternative technologies are for the most part new, they would involve an element of risk that would be heightened by the amount of money at stake.

Besides time and money, for each of these choices there are other factors that must be considered--things like the environmental impact; the impact on the people involved; the impact on current fuel supplies; and so on--you can think of more.

Obviously this is not going to be an easy decision to make! In effort to get some help with the decision making process, Mattawoman Power and Light has referred the matter to the Board of Directors which has, in turn, sought further information from Consultants, Inc., a private research firm.

Large consulting firms often have one set of people engaged in research, while another entirely different set of people is responsible for "marketing" that research. You in the report groups will act as the public relations staff, dedicated to presenting the work of the research teams in the best possible light. In your role, you will be expected to be thoroughly conversant with your subject matter without being required to pose as experts. It's now up to you to help bring this decision making process to a close. The procedure you should use follows.

PROCEDURE

1. The class should divide into eight groups of equal numbers. One group will serve as the utility Board of Directors and the other seven will each present one of seven different reports prepared by the private research firm, Consultants, Inc.

2. Each member of the Board of Directors should receive a copy of the Technology Comparison Chart. They should meet to discuss the criteria set out on the chart in addition to other criteria relevant to the decision now facing them: how best to meet the coming power shortage. Their discussion should produce the basis on which they will receive and evaluate the reports presented by the various fuel groups.

3. While the Board is meeting, each of the seven report groups should also meet to discuss their respective technologies for generating electricity without oil. Each member of a group should receive a copy of the prospectus to be presented, and the content and format of the report to the Board should be a group effort to the extent possible. For the actual report, however, each group should select one member to make the presentation.

4. None of the seven report groups is privy to the Board's criteria sheet, and each group is familiar with only the prospectus it is responsible for presenting.

5. The individual group reports will, of course, vary according to the prospectus involved, the interpretation of the problem, and the knowledge and perspective brought to bear by each group member. The variance will be structured to a certain degree by the Board criteria and questioning, but by no means should uniformity of presentation be expected.

6. When everyone is prepared, the Executive Session of the Mattawoman Power and Light Board of Directors should be opened. Prior to the presentation of group reports, Technology Comparison Charts should be distributed to all class members to fill in as each report is given. The general trend of events would include the following:

   - Chair of the Board opens session, states problem, introduces first (and subsequent) potential solution along with the first group representative.

   - Group representative makes presentation without interruption.

   - Board members may question representative, who may confer with other group members, if necessary, in responding.

   - After all reports are presented and questions posed, the Board members must debate among themselves the merits of the different technologies presented. This should take place in the presence of all, but must proceed without further reference to the report groups. During the discussion, however, the report group members will likely want to take notes on points of controversy that arise.

- Finally, each report group should place its written prospectus on file with the Board (and with the rest of the class), which then retreats to make its final decision. While the Board is out, the class should familiarize itself with the balance of prospectuses in order to enhance the quality of the Review discussion. The Board decision could be announced in a variety of ways--in a classic "form letter," in the school newsletter or newspaper, etc. Usually such an announcement contains some form of rationale, an opportunity this Board will likely want to exploit. The Board should also publish the criteria upon which its decision was based sometime prior to the Review session.

PROSPECTUS: SOLAR THERMAL

TO: Mattawoman Power and Light Company
RE: Solar Thermal Conversion Prospectus

After striking the earth, the radiant energy of the sun can be converted to many different forms of energy. It can be used for heating and cooling as well as for generating electricity. Sunlight focused on a central point or line yields radiant heat energy which can be used to produce steam. Then the steam can be used to power turbines which in turn can generate electricity.

In terms of fuel costs, the sun's radiant energy is free. The technology for converting this energy into electricity is the primary cost factor. Currently there are two technologies for using the sun's energy to generate electricity on a large scale.

(1) Central Receiver. In this system solar energy is gathered by focusing mirror-collectors on a central receiver. The radiant energy is optically transmitted (reflected by the mirrors) to the receiver, where it is absorbed as thermal energy and used to make steam.

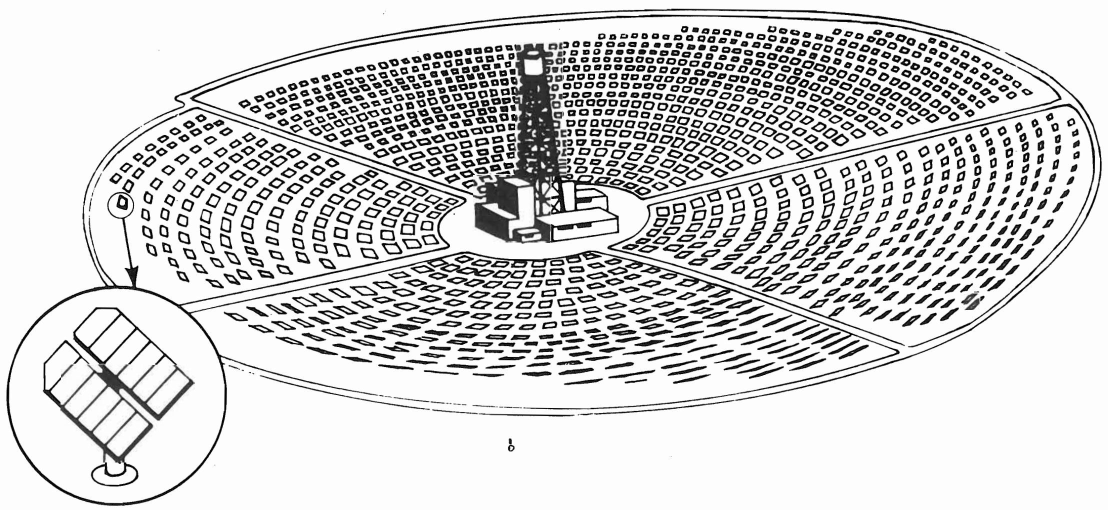
(2) Distributed Receiver. Radiant solar energy is converted into thermal energy by the collectors themselves, and is transmitted to the power plant by an "absorbing medium" or "working fluid." The absorbing medium can be air, water, oil, or liquid metal.

Both of these systems require large land areas. A solar thermal electrical generating facility of 10 MW would require about 40 acres for collection. The central receiver, the "power tower," is the more efficient of the two systems because the energy transfer is more direct. It works best in full sunlight but can also operate on diffuse sunlight. One drawback of this system is that to date, our technology for heat storage is still not sophisticated enough to provide energy during long periods of cloudy weather.

These solar thermal energy systems are currently more expensive than conventional energy production systems. The 10 MW power tower being built near Barstow, California should cost about $120 million. At this price a 1000 MW plant would cost about $12 billion ($12,000/kW). However, the Barstow tower is the first of its kind. Subsequent power towers should cost significantly less and may be able to compete economically with conventional energy production systems.

Also, power towers do not have to compete economically with baseload coal-fired and nuclear plants. Since the brightest sun (midday) coincides fairly well with peak electrical demand, power towers could be used to replace the expensive oil- and natural gas-fired generators that are now being used to meet the peak demand. Because it would be replacing two scarce fossil fuels, solar thermal technology could warrant a steeper initial investment than we would be willing to place in other, more conventional technologies.

The environmental impact of solar energy is generally low. Environmental costs for which solar is indirectly responsible will come from associated industries--for example, increased production of glass for mirrors at the power tower.



PROSPECTUS: SOLAR PHOTOVOLTAIC

TO: Mattawoman Power and Light Company
RE: Solar Photovoltaic Prospectus

Solar radiation can be converted directly to electricity. The device which accomplishes this conversion is the solar photovoltaic cell. A typical solar cell measures 10 cm x 10 cm (4" x 4"). The power output of a single cell is very small (about 1W), so many cells must be connected in an array to produce adequate power for regular use.

Most of the commercially available solar cells are made of silicon, a common, abundant element. However, the silicon must be pure and each solar cell must be made of a single silicon crystal to provide the uniform structure necessary for converting sunlight into electricity.

Present technology requires that solar photovoltaic cells be made by hand by highly skilled workers. Several different methods are being explored to reduce the cost of processing silicon wafers. Expected increases in the market for solar-generated electricity will also help bring costs down. At present, an installed solar array costs $16-18/Wp. (These figures are computed by using a system based on peak watts, Wp. A peak watt is a measure of the maximum solar power output when the sun is directly overhead on a clear day.)

The largest existing installed system of solar cells is the 60 kW solar array at Mt. Laguna Air Force Station east of San Diego. It consists of 2366 solar cells covering 12,000 square feet. The nation's first solar powered radio station, WBNO in Bryan, Ohio, was completed in June 1979 and is powered by an array of 33,600 solar cells which covers a third of an acre. Seventy to ninety percent of the station's annual power needs should be met by this solar cell system. Other systems are now being constructed. At Phoenix International Airport, for instance, the Arizona Public Service Company is building a 283 kW system under a $6.5 million contract with the Department of Energy. This is currently the largest system of its kind.

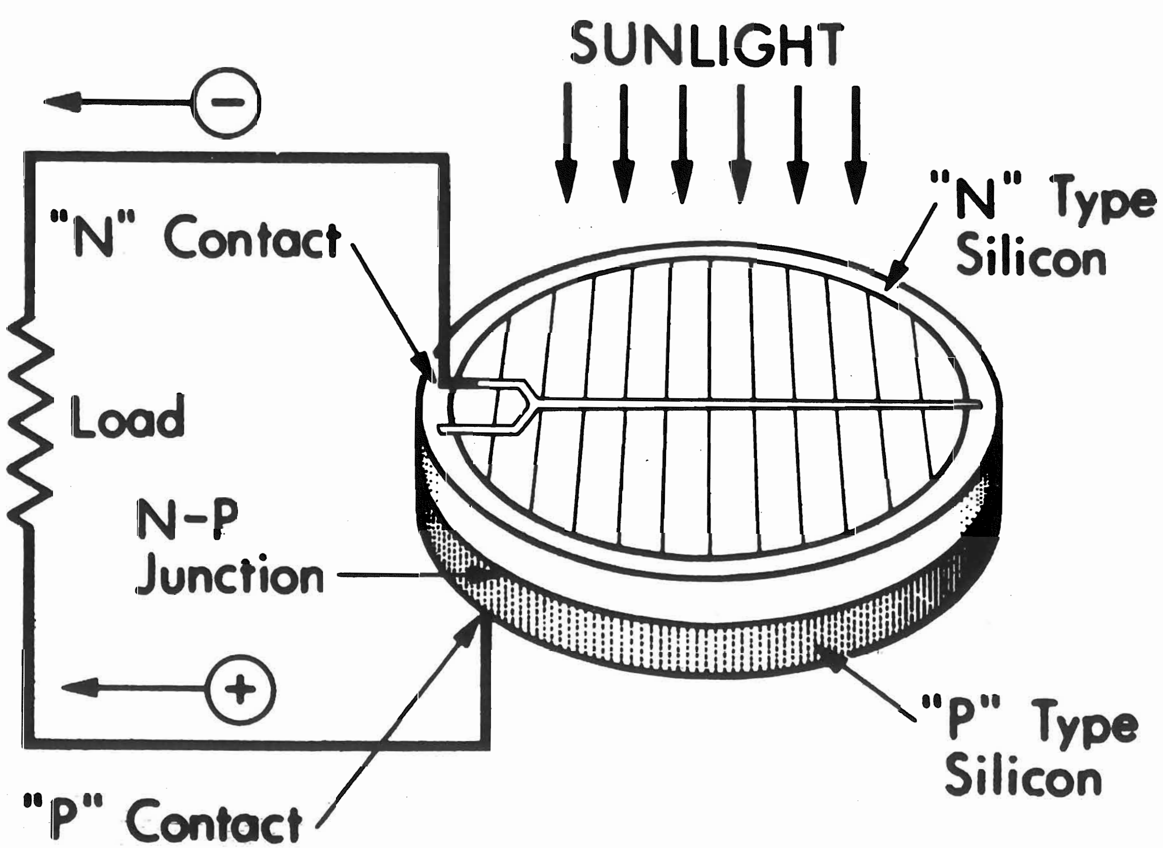
These solar installations cost ten to twenty times more than the least expensive energy-producing systems (e.g., baseload coal-fired or nuclear powered plants). The photovoltaic array for the Phoenix airport will cost about $2300/kW. But these costs are steadily decreasing. The Department of Energy's photovoltaic program has established the ambitious goal of $1 to $2/Wp solar cells by 1982 and $0.50/Wp in 1986.

At these prices, solar cell devices will become competitive as peak power supplements for utilities. Like solar thermal electric technology, photovoltaics can replace the expensive oil- and gas-fired intermediate and peaking load generators because the maximum solar availability coincides with peak demand. We could therefore afford to initially invest somewhat more in photovoltaics than we would be willing to invest in a technology that converted more expensive, nonrenewable energy resources.

Solar cells will have some environmental impact, but not much. The biggest problem will be the large amount of land needed for the array. If electrical generation doubled by the year 2000, and if 1% of that increase were produced by 10% efficient solar cells, 256,000 acres of land would be required. (This is, however, just a small portion of the nation's 2310 million acres.) If the efficiency of the cells can be doubled, the land use will be cut in half.

Converting the sun's energy directly to electricity yields no noxious wastes. Backup power sources (since photovoltaic cells produce electricity only when the sun shines) may be an indirect source of pollution. If conventional energy sources are used as backup systems, they will make less of an impact on the environment than they do now because they will be used less.

Although solar cells are not very efficient (15% for single crystal silicon cells), they collect and convert a free fuel with minimal environmental impact. Additionally, solar cell systems are expected to be simple to operate and maintain.



PROSPECTUS: CONVENTIONAL NUCLEAR

TO: Mattawoman Power and Light Company
RE: Conventional Nuclear Reactors Prospectus

Conventional nuclear reactors release the energy of heavy nuclei such as uranium by fissioning (splitting) them, in the process converting some of their nuclear mass into energy. In almost all U.S. reactors the primary fuel is the rare isotope of uranium--U^{235}. This element makes up less than 1 percent of all uranium ore. Fissioning one pound of enriched uranium (uranium in which the concentration of U^{235} has been increased from its natural 0.71 percent to 3 or 4 percent) produces about 36 billion Btu (38 trillion joules) of energy. This is three million times the energy that can be produced from one pound of coal.

In 1979, nuclear reactors accounted for almost 50,000 MW of generating capacity in the United States, and a total of 70,200 MW worldwide. The Department of Energy forecasts that the U.S. capacity could grow to 196,000 MW by 1995.

The U.S. has an estimated 29 percent of the world's supply of uranium reserves, those resources that have been discovered and measured. How long we will be able to draw on these reserves depends on geology and economics. Even though higher prices will serve to open up greater uranium supplies, there will, of course, be an upper limit to the expansion of the reserves. Each year some reserves are used up and cannot be replaced. Increases in price cannot create uranium; they can only serve to stimulate its discovery and recovery.

The actual construction of a 1000 MW nuclear power plant takes about seven years. More time is required for obtaining permits, securing government clearance, and so on. Construction costs are high. A plant put into operation in 1976 cost nearly $600 million. Capital costs for plants completed in 1978 were $895 million; in 1985 capital costs will be well over $1 billion. Inflation rates and construction delays have to be calculated into cost estimates. Delays push the price up by subjecting projects to the effects of inflation longer than usual. Delays also require the continued outlay of funds to sustain the requisite labor force. New government regulations concerning safety and environment will probably greatly increase the construction costs of conventional reactors. Overall, utilities estimate that the costs for construction will continue to rise at the rate of 20 percent per year.

Although nuclear plant construction is more expensive than the construction of coal- or oil-fired plants, the fuel costs for nuclear power plants are lower than coal and oil prices. In 1979, a coal-fired generating plant cost about twice as much to fuel as did a nuclear plant. Oil-fired plants cost even more. Utility owners expect the gap to widen, at least for the next few years. The cost of electricity, however, depends on both fuel and construction costs.

Throughout the 70's controversy grew over the siting of nuclear plants and the wisdom of relying on nuclear energy. The possibility of a very damaging nuclear accident has created much opposition to nuclear power. This opposition has increased significantly since the Three Mile Island episode. Uncertainties about the future handling of nuclear wastes and perceived dangers of nuclear weapon proliferation have added to the political conflict.

Nuclear proponents point to the plants' overlapping safety systems and claim that no fatalities have resulted from accidents in commercial nuclear plants. They cite the relatively small amount of air pollution produced by nuclear plants compared with coal- or oil-fired power plants. Nuclear proponents also emphasize that with a combination of conventional reactors and the "breeder" reactors (now being developed), huge amounts of energy for thousands of years can be produced from our domestic uranium supplies. And, since it takes a lot less uranium to get the same amount of energy we get from coal, uranium strip mines will ultimately have a smaller impact on the land than will coal strip mines.

Nuclear power plants cost about $895/kW to build. They are more expensive to build than coal-fired plants because their design is more complex, but their fuel cost is low. After all factors are taken into account, the price of electricity from a nuclear power plant should be roughly equal to the price of electricity from a baseload coal burning plant. The actual costs will vary geographically (coal is probably cheaper in Wyoming; nuclear power in Maine), and they will vary from utility to utility and from year to year. The cost in dollars and cents does not reflect all the costs of either technology.

Pressurized water reactor (PWR)

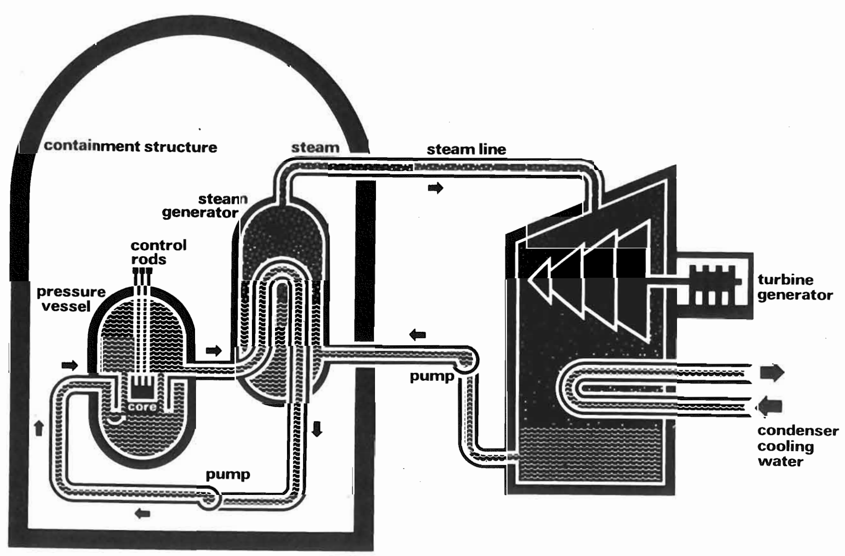


Diagram courtesy Atomic Industrial Forum, Inc.

PROSPECTUS: BREEDER

TO: Mattawoman Power and Light Company
RE: Breeder Reactor Prospectus

A breeder reactor starts with a fissionable fuel like uranium or thorium. From that it produces not only useable energy but also more fuel, thereby engendering a cyclic energy-making process. This ability makes the breeder an attractive offering at a time when people everywhere are realizing that there is a finite supply of traditional energy sources.

Unlike the Liquid Metal Fast Breeder Reactor or LMFBR, a conventional reactor like the Light Water Reactor (LWR) requires large amounts of uranium ore from which it can use only the U^{235}. On the other hand, the LMFBR could use almost all the uranium. Some of the contrasts between the fuel needs of LWRs and LMFBRs are shown in the following table.

Type of Reactor	Expected Lifetime	Tons of Uranium Fuel	No. of 1000 MW Reactors Reserve** Supplies of Uranium Would Be Able To Fuel Over Their 30-Yr. Lifetimes
Conventional (LWR)	30 years	5500 (before enrichment*)	170 reactors
Breeder (LMFBR)	30 years	100 (enriched)	9360 reactors

* Enrichment is the processing of raw uranium into a useful fuel.
** Reserves are resources that have been discovered and measured. These numbers are based on 1980 data.

As the table shows, the breeder uses uranium more efficiently; therefore, it could provide all of the nation's electrical needs for hundreds or even thousands of years. The breeder uses 50-60 percent of the potential energy present in uranium ore, while the conventional reactor uses only about one percent of the potential energy. Breeders essentially make uranium an almost inexhaustible energy resource. Thus, it is one of the few energy technologies that is not resource limited, sharing this distinction with fusion and solar energy.

Breeder reactors are expected to cost more to build than conventional reactors do. For one thing, their specifications are more exacting. Further, the technology associated with the breeder is not as well developed as conventional technology. Breeders will initially cost more than $1000/kW. However, the continuing fuel cost will be low. When breeders are fully commercialized, electricity from breeder reactors is expected to cost about the same as electricity from a conventional reactor.

All costs, however, cannot be calculated in terms of dollars and cents. The breeder raises some serious safety and environmental questions. The most serious of these concerns the use of plutonium, the fissionable material the breeder reactor produces from the uranium fuel. As well as fueling the reactor, plutonium can be used (and only a very small amount is needed) as the raw material for nuclear weapons. Since using breeder reactors and reprocessing fuel will involve the manufacture, handling, and transport of thousands of tons of plutonium, security becomes a very real problem for plant designers and utility owners. And if used worldwide, breeders could contribute to an increase in the number of nations with access to nuclear weaponry. In addition to the plutonium problem, breeder reactors share with conventional reactors questions about reactor safety and difficulties posed by hazardous waste production and disposal.

In terms of the environment, the breeder has some advantages over the conventional reactor. It uses uranium more efficiently so that even fewer acres of land are laid waste. In fact, enough uranium has already been mined to fuel breeders for 100 to 200 years. To the extent that uranium fueled reactors were to replace coal-fired power plants, the hazards of coal-mining (e.g., air pollution, disruptive land use, and risk to coal miners) would be avoided.

Ultimately, the big energy payoffs of nuclear power will have to be weighed against its safety and environmental costs.

Liquid metal fast breeder reactor (LMFBR)

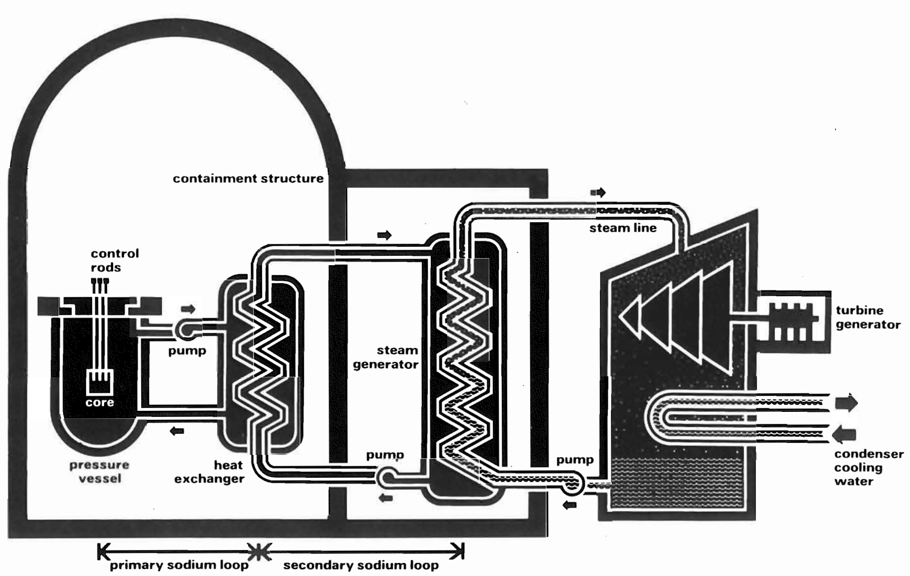


Diagram courtesy Atomic Industrial Forum, Inc.

PROSPECTUS: COAL

TO: Mattawoman Power and Light Company
RE: Coal Burning Prospectus

Coal is our most abundant fossil fuel. The known coal reserve in the U.S. has been established and measured at 440 billion tons. Estimates of "ultimately recoverable" coal exceed 1.1 trillion tons. At the current rate of use, these coal reserves can be expected to last at least until the year 2300. However, new demands will be placed on the coal industry and increased yearly demands will, of course, reduce the lifetime of the nation's coal supply. At least 100 years of expanding production will elapse, however, before ultimately recoverable coal deposits have to be tapped.

Over 50 percent of the coal produced in the United States is used by electric utilities. The rest is used to produce steel, to fuel trains, to heat homes and commercial installations, and to export (only about 12 percent). The East is well-known for its large deposits of coal, but much larger coal reserves lie west of the Mississippi River.

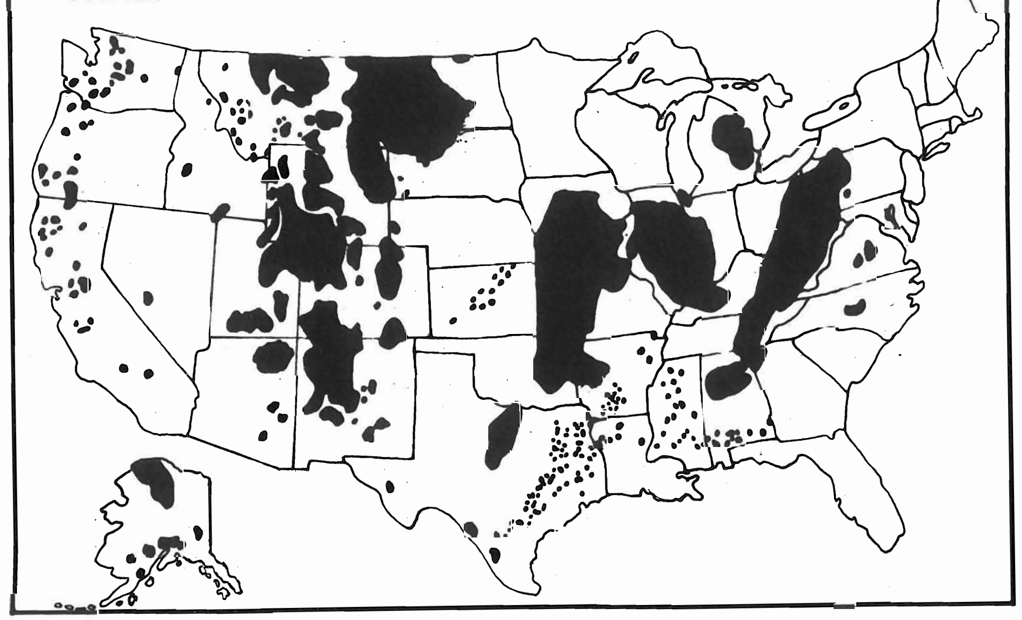
Eastern coal tends to have a higher heat value, but western coal contains much less sulfur which when burned creates the noxious pollutant, sulfur dioxide (SO_2). This and other of the sulfur oxides change to sulfuric acid in contact with water, creating acid rain which threatens health and property.
The Clean Air Act prohibits the production of more than 1.2 lbs of SO_2 per million Btu of energy generated. Western coal releases on the average 0.7 lbs sulfur dioxide per million Btu, while eastern coal releases an average of 3 lbs of it for each million Btu. To compensate for this environmental hazard, scrubbers are required installations in utilities burning coal with a high sulfur content. These scrubbers, which reduce the amount of SO_2 sent into the air, add to the cost of plant construction and the cost per kWh of electricity produced. The scrubbers will not, however, reduce the amount of CO_2 released into the atmosphere as a product of burning coal. Coal burning adds more CO_2 to the atmosphere per Btu produced than any other fossil fuel, a property which may develop into a real drawback as more understanding is gained about the "greenhouse effect" and the impact of CO_2 on the global climate.

Other disadvantages of coal burning include its formation of nitrogen oxides (pollutants which are not currently controlled) and small particles of minerals, called "particulates", which escape present controls. These particulates are often the nucleus around which sulfuric acid forms and the vehicle by which the acid is carried to earth. In addition, above-ground strip mining, which produces about half the coal used, requires the disruption of large areas of land.

Mining coal underground is very hazardous, involving risks of mine collapse, toxic and explosive gas build-up, and black lung. At the same time, coal mining is labor intensive and thus the use of coal as a fuel provides more jobs per dollar than oil, natural gas, or nuclear energy.

Most electric utilities estimate a lead time of eight years or more to construct an 800 MW coal-fired plant. Such a plant cost $600 million in 1978, or $750/kW. Costs will probably reach $1 billion by 1985, depending on such factors as inflation, labor and construction costs, costs of coal, the level of demand for electricity, and the costs of pollution control for coal-fired plants. The number of variables increases the difficulty of projecting costs, and some costs cannot be estimated in dollars or cents.

Coal Reserve Areas in the United States



PROSPECTUS: FUEL CELL

TO: Mattawoman Power and Light Company
RE: Fuel Cell Prospectus

A fuel cell is a device something like a battery. Both convert the chemical energy of a fuel directly to electricity without going through the heat-to-mechanical energy conversions of turbine-generator electric production. However, batteries operate from a fixed supply of energy contained within the battery cell and must be recharged when that supply is gone; fuel cells are continuously fed chemical energy in the form of a hydrogen-rich gas (either natural gas or gas from coal gasification).

Like a battery, a fuel cell has two electrodes. One is positive (the cathode) into which the oxygen (usually air) is fed; the other is negative (the anode) and receives the fuel. Between the electrodes is an electrolyte, a substance that allows only ions (electrically charged atoms or molecules) to pass through. When the fuel comes in contact with the electrolyte, its molecules break up; the resultant ions pass through the electrolyte to the cathode, and the electrons that are freed flow through an external circuit as an electric current. At the cathode an hydrogen ion joins an oxygen ion (made of an incoming oxygen molecule and several incoming electrons) to form water, H_2O.

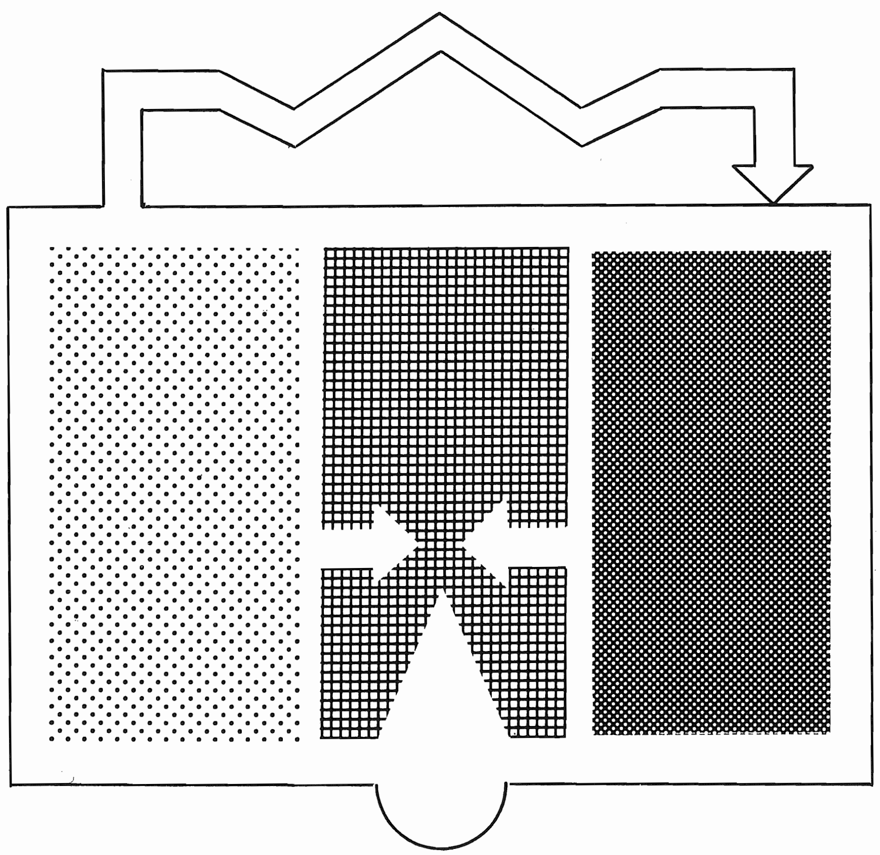
Fuel cells are currently fueled by natural gas and gas made from oil. Therefore, they are subject to the same problems of energy supply as other fossil fuel power plants. Fuel cells are somewhat more efficient than other fossil fuel power plants because they bypass two energy consuming conversions. Fuel cell power plants are small (5 acres can house a 27 MW unit), so they can be located close to the point of use, thereby reducing transmission and distribution losses. And if unconventional sources of methane materialize, a large new supply of fuel for fuel cells may become available. Unconventional methane sources include western tight sands (gas trapped in sandstone), gas in Devonian shale and conventional coal seams, and gas dissolved in the geopressured brines along the Gulf Coast.

Fuel cells have other advantages. Since they can be sited at the point of use, they can be used for cogeneration, the provision of both heat and electricity from one conversion system. This capability enhances both efficiency and economy. Since water and carbon dioxide are the main products of generating electricity with fuel cells, they can be characterized as non-polluting. In addition, fuel cells require little land and are quiet.

Fuel cells are modular and so can be mass produced instead of made to order as coal and nuclear power plants must be. Unlike solar technologies, fuel cells can be used for baseload electric generation.

A 4.5 MW demonstration fuel cell power plant, scheduled to begin operation in 1981, is sited in lower Manhattan. It will cost about $68 million, somewhat more than $1300/kW. A first-of-a-kind unit like this one requires more capital investment than will subsequent units, especially if the latter are mass produced. The target capital cost for a 10 MW unit is $350-400/kW, involving a lead time of 2 years.

Fuel Cell Schematic



PROSPECTUS: WIND

TO: Mattawoman Power and Light Company
RE: Wind Energy Prospectus

Windmills have been used for thousands of years to grind grains and pump water. Since the 19th century they have been used to generate electricity. Before rural electrification, the windmill was an integral part of a farming operation. From that time until recently, wind machines fell into disuse and stood as reminders of a bygone era. Their day may, however, be returning.

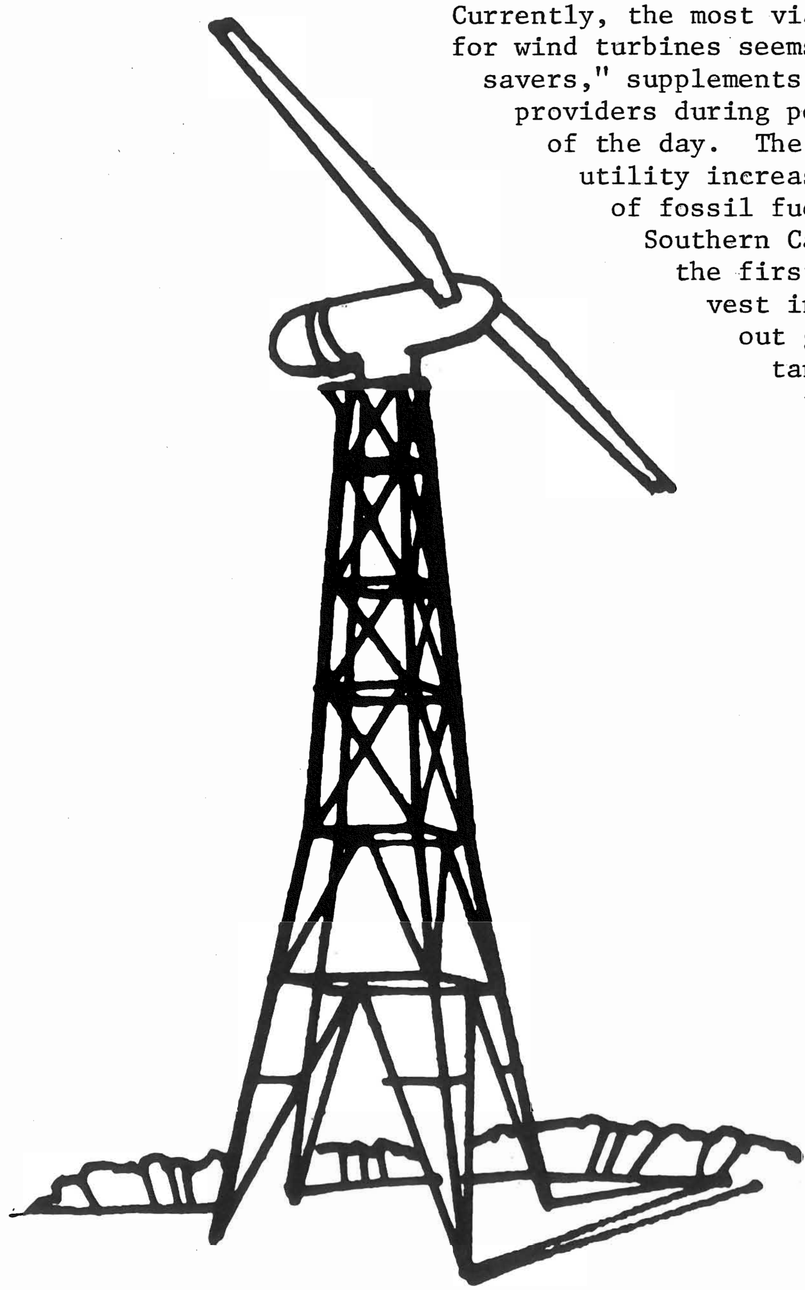
In the U.S. as much as 2 trillion watts of energy is available from the wind. This is 1.8×10^{13} kWh, about 10 times the amount of electricity we used in 1978. Each wind machine needs an operating area about five times the area swept by the rotor-turbine (the blade which takes the place of the turbine used in steam electric generation)--about 12 acres--and wind speeds of at least seven miles per hour. Sites that meet these specifications are fairly plentiful in the U.S.

Wind machines must be designed for the work they are to do. Windmills for grinding or pumping must be able to exert sufficient initial force to overcome (lift) a heavy load. For generating electricity, however, high speeds and less force are needed. There are two basic types of wind turbines--horizontal axis (HAWT) and vertical axis (VAWT). HAWTs must have a mechanism to keep them in line with the wind--like the vane on a farm windmill. The blades are connected to the generator by a series of gears; the entire turbine-generator assembly is mounted on a tower; and the machine is situated downwind (in the direction opposite the usual air current). Large windmills for utility power generation will be HAWTs, while VAWTs will be used for small on-site needs.

The environmental effects of wind power are quite small at this time. If enough wind turbines were built to capture the theoretical amount of energy available from the wind, about 23 million acres of land would be used--one percent of the U.S. land area. Wind-generated electricity would not change the climate or pollute the environment. Wind turbines are artificial structures added to the natural landscape, which may or may not be aesthetically pleasing to nearby residents. In North Carolina, the metal blades of the demonstration wind turbine, MOD-1, interfered with television reception, a problem that can be avoided by using cables for television transmission or alternate materials (like fiberglass) for blade construction. The main environmental effects of using large-scale wind machines would result indirectly from the manufacturing industries associated with constructing the machines.

There has been a recent upsurge of interest in wind machines. The U.S. Department of Energy has tested several machines of different sizes: a 100 kW machine in Sandusky, Ohio; three machines each rated at 200 kW; and a MW machine in Boone, North Carolina. Three clustered turbines planned for the state of Washington are rated at 2.5 MW each.

This turbine cluster will cost $15 million, but Boeing, the designer of the turbines, predicts that when mass produced, these machines will be competitive with the anticipated cost of oil. The Boone, North Carolina wind machine cost about $2000/kW. Like some of the other alternative technologies that are now being considered, this was a first-of-a-kind machine. After 100 or so have been built, the cost should drop to $400-900/kW. The savings over oil-generated electricity accruing to the owner-utility depends on how much the wind turbines are used. The cluster of wind machines to be built in Washington state is the largest yet built; achieving the baseload capacity of coal and nuclear electric generation will require substantially larger clusters. A single MW wind machine currently requires about 2 years to build, although this too will drop with eventual mass production.



Currently, the most viable application for wind turbines seems to be as "fuel savers," supplements to the baseload providers during peak demand hours of the day. The benefit to the utility increases as the price of fossil fuel escalates. Southern California Edison, the first company to invest in wind power without government assistance, estimates that its 3 MW machine will save about 10,000 barrels of low-sulfur crude oil per year--a continuously escalating savings of at least $300,000.

TECHNOLOGY COMPARISON CHART

Rating (1-7)	Proposed Technology	Current Cost per kW	Estimated Future Cost	Lead Time for Construction	Fuel Availability	Environmental and Other Concerns	Peak or Base Load Capacity

REVIEW SHEET

(Cover when duplicating for students.)

1. What were some of the criteria the Board considered applying to the different technologies presented? Were the criteria applicable across the board?

1. Some across-the-board considerations not appearing on the Technology Comparison Chart might include stockholder preferences, current prime interest rates, population growth projections, and government regulatory prospects.

2. How did the groups decide what to include in their reports to the Board? Did they later discover Board interests different from the concerns presented?

2. Some groups might have taken a strictly quantitative approach to their presentations, while others might have emphasized qualitative features. Some may have conducted research beyond their prospectuses in anticipation of more widely-ranging Board questions and concerns, while others may have limited their reports to the information contained within the prospectuses.

3. Which (if any) alternative technology was selected by the Board to solve the problem of regional electricity shortage? Why was this technology selected over the others?

3. The presentation techniques examined in #2 as well as others employed should be evaluated for their effectiveness. In many cases, the force of predetermined criteria is tempered or even abandoned entirely in the face of a well-argued or extremely persuasive position.

4. Certainly the Board criteria reflect both personal and "professional" considerations of the various members, and the reports were undoubtedly influenced by the individual personalities at work in the groups, but what about the private research teams that prepared the prospectuses? What interests--vested or otherwise--might they bring to their work? Can you identify any biases present in the prospectuses individually or as a group? If so, did these perceived biases affect the outcome of the Board meeting? How?

4. OPTIONAL ACTIVITY: "Not only private sector companies hire firms like Consultants, Inc. The government itself is a big client of such agencies. If you're interested, find out more about these agencies--how and for whom they work."

SELLING ENERGY

MAJOR CONCEPT

Behind nearly every energy marketing device there lies some scientific principle and a lot of applied psychology.

SUPPORTING FACTS

- Many things having to do with energy can be measured, and such quantification lends itself to comparison.
- Comparisons of, for instance, energy efficiencies are sometimes complicated by factors not immediately apparent in considering a product or service.
- Energy product comparison can be further complicated or obscured by marketing techniques which highlight features and issue appeals outside the realm of the purely scientific aspects of the product.

RELATED SCIENCE THEMES

Energy efficiency; energy conservation; energy alternatives.

SCIENCE PROCESS SKILLS ENGAGED

Observing, classifying, using numbers, measuring, using space-time relationships, communicating, predicting, inferring, defining operationally, formulating hypotheses, interpreting data.

METHOD

1. Discuss the ways in which various products are advertised and consider whether energy product promotion differs significantly from the norm.
2. Discuss how scientific principles are reflected or obscured, explored or exploited in the advertisement of selected products.
3. Put students to work researching, writing and presenting television advertisements for energy-related products.
4. Evaluate the ads and examine the role of science in each.

MATERIALS

For the class:

10 Target Audience cards
10 Product cards

For each student:

Procedure
Sample Script
Script Format
Evaluation Sheet
Review Sheet

PROCEDURE

Your advertising team has two class periods to research, design and write a 150-200 word (about one handwritten page) television advertisement based on the information on the cards you will draw and on the discoveries you make in your research.

1. Class should divide into 5 groups, each of which will function as a television advertisement writing team.

2. Each team should randomly select one Product Card and one Target Audience Card with which to shape its ad. Because the advertising business is very competitive, the information on these cards should not be shared with members of other ad writing teams.

3. Research. Each Product Card lists some Science Factors as examples of the kinds of information that ad writers might seek in developing a product's consumer appeal. Sometimes these factors are highlighted and sometimes they are downplayed, depending on what is being sold to whom. In either event, the factors must be known before they may be effectively manipulated.

   Each team should research the sample Science Factors and/or other factors that have implications for the Target Audience selected. More important than finding exact answers to the questions posed is discerning the impact of the answers on consumers. These impacts will vary with different groups of consumers; sample Consumer Impacts may or may not be provided to the ad writing teams depending on the teacher's approach. (Research can also proceed working from perceived consumer needs back to the science implicit in satisfying those needs.)

   Whether highlighted or downplayed, the way in which science factors are "translated" into "commercialese" is important to examine. The science student may accept the challenge of communicating science concepts in a way the consumer can recognize, understand, and relate to. Or the student may interpret the advertising challenge as a purely commercial venture. Such decisions about the advertising approach will be a product of many considerations; the effectiveness of the approaches taken will be considered later in the Evaluation process.

4. After researching the product, each team should work together in deciding on the most effective way to present what has been learned to the Target Audience stipulated. Your advertisement must mention both the strengths and the weaknesses of your product, but the way you do this is up to you.

5. Television is a visual medium and your team's actions may be as important as your words. Draft your advertisement with both visual and audible components in mind. The Sample Script should be used as a guide in developing an audiovisual presentation not to exceed three minutes in length (most TV commercials last only a single minute or less).

6. After drafting its advertisement, each team should confer with the teacher before finalizing the ad on the Script Format sheet. The teacher may offer advice, technical assistance, a go-ahead, or a rejection (urging the team to try again).

7. When the go-ahead has been received, each team should transfer the final ad copy onto the Script Format sheet.

8. Finished Formats may either be read aloud or dramatized in class. Evaluation Sheets should be distributed to all class members prior to class presentations and used to rate each advertisement. After each presentation, time should be allowed to complete the questions appearing on the Evaluation Sheet.

9. After all presentations have been made and evaluated, each team's product should be announced for rating by applause. A discussion of the finer points of evaluation may be combined with a discussion of the questions on the Review Sheet.

TARGET AUDIENCE CARDS

STATUS SEEKER

Members of this target audience want to be associated with the latest "in things." Read Vogue and Bazaar and clip out the pictures. Only wear shirts and pant that have the name on the outside. Have all the status credit cards, though seldom actually use them. Will buy anything new or different, particularly if sold in limited editions. Have never set foot in a chain store.

SUPERINTELLIGENT

Members of this audience take great pride in their brainpower. Tend to like complex crosswords and never miss reading "How To Increase Your Word Power." Have trouble talking to anyone without a comparable IQ. Think chess should be the new national pastime and totally distrust simple, straightforward statements. Must have all sides of issues presented along with supporting documents before making a decision.

WILD AND CRAZY

Members of this audience consider Steve Martin their guru. Everything is a joke and life is for fun. Spend money like it's going out of style and resist having any serious thoughts. "Boogie today, worry later" is their motto. Travel in large, loud groups and can't stand to be alone for more than half an hour.

NOSTALGIA BUFF

Members of this audience long for the "good old days." Can often be heard using sayings from the first half of the century. Don't trust anything new unless it relates to something from yesteryear. Particularly love old movies and old houses. Can't wait for parties and Halloween so they can wear 1940's clothes. Frequent secondhand stores for wardrobe and home decorations.

ENGINEERING NUT

Members of this audience spend all their time taking things apart and analyzing function. Buy most of their furniture and appliances in kit form and assemble them at home. Impressed by data, charts and graphs. Often sit for hours staring in awe at new slide rules, calculators, and home computers.

MONEY CONSCIOUS

Members of this audience have one question: "What's the bottom line?" Greatly impressed with a bargain and spend hours over the newspaper in search of grocery store coupons. Have trouble dining out for worrying if the waiter will figure the bill correctly.

TECHNICAL EXPERTS

Include certain kinds of government officials, economists, business executives and scientists. Best characterized by their ability to disagree on solutions to problems. Want numbers to back up statements. Can-Do people who never let technology impede progress.

ECO-FREAK

Members of this audience would like to see entire world designated a wilderness area. Own only denim shirts and hiking boots and are not comfortable unless sleeping under canvas. Like simplicity and sweat. Worship the sun and recyclables. Ask often, "But what's the environmental impact?"

SOCIAL BUTTERFLY

Members of this audience spend all their time trying to find out where and when the next party is, regardless whether they're invited or not. Try to be totally value free so as not to offend anyone. Buy things in quantities and for convenience.

JUST PLAIN FOLKS

Members of this group are hard to characterize--that seems to be their most characteristic trait. Best described as being able to fit into any crowd, any time, anywhere. No distinctive clothes, cars, or houses. Very home-centered and won't go anywhere the whole family can't go.

PRODUCT CARD

NATURAL GAS HOME

Several builders backed by a regional natural gas association are offering an all natural gas home energy package with discounts on the heating system, range, refrigerator, and dryer if purchased as a unit. At the time of this offer, the local supply of natural gas appears to be stable. Develop an advertisement for these "all natural gas homes."

SCIENCE FACTORS	CONSUMER IMPACTS
1. What are the life expectancies of the various gas appliances being offered? What are the gas supply projections for your area? Before the natural gas were actually depleted, what impact would shortage make upon the price?	1. Short term capital savings may be outweighed by long-range drawbacks and hidden costs. On the other hand, natural gas is a clean, convenient energy source currently in good supply and favorably priced.
2. What unconventional sources of methane have been discovered?	2. Natural gas supplies may be extended by the development of technologies designed to extract methane from such unusual sources as coal seams, geopressured brines, Devonian shale, and tight sands.
3. What natural gas substitutes exist or are on the horizon?	3. Natural gas supplies may, in some instances, be supplemented or replaced by such future energy sources as biomass, gasified coal, or hydrogen.
4. For both #2 and #3, how long would it take to develop these technologies for use in a home appliance system like the one being promoted?	4. Some of these sources are already commercialized (e.g., urban waste, biomass) for use in this form, but in general, the lead time required to develop such technologies to the point of commercialization is great, and even when fully developed, some of the new sources mentioned will require more refining than natural gas does to be well matched to home appliance end use.
5. Can natural gas heating systems be retrofitted for other fuels? At what cost?	5. During the past few years, seasonal shortages of natural gas have developed and in some parts of the country, natural gas supplies have for the most part been exhausted. Natural gas supplies are finite and when they run out, an all natural gas system would require alterations varying in degrees of complexity and expense to retrofit.

PRODUCT CARD

SOLAR HEATING SYSTEM

A local company is placing on the market an active solar heating system which utilizes a roof-mounted flat plate collector, hot water storage, and a forced air space heat distribution system. The system may be built into new homes or retrofitted into older dwellings. The system is being introduced during a time of fuel oil shortages and increases in monthly electric bills. Your job is to develop an advertisement for the system.

SCIENCE FACTORS

1. What energy conversions occur to make sunshine into space or water heat?

2. How does the system work? What are the relationships among the various components of the system? What is the capacity of the storage unit?

3. Compare a solar system like the one described above with a conventional heating system of your choice in terms of:
   1) initial investment
   2) fuel cost for one year (use current local rates)
   3) lifetime systems cost, taking into account:
      a. initial investment
      b. life expectancy of system
      c. fuel costs, including projected increases for the expected life of the system.
      d. other cost factors, e.g., tax incentives for solar implementation.

CONSUMER IMPACTS

1. The system uses the most abundant and "renewable" energy resource on earth--sunlight.

2. The system can provide 100% of the hot water needs and 80% of the space heating needs for a household during any given year. The system performs poorly during cloudy weather and thus may require a backup conventional heating system.

3. The initial cost of an active solar heating system is high, about twice the cost of a conventional system. The fuel cost, however, is nil, and thus the lifetime cost of the solar system is less than that of the conventional system.

PRODUCT CARD

ENERGY CONSERVATION SERVICE

A company is offering a spectrum of services each designed to conserve energy, thus improving the efficiency of any given space conditioning system. The company will conduct a home or business energy audit, make prescriptions for improving the structure's utilization of its current energy supply, and then implement the prescribed improvements. The range of services offered includes insulation, weather stripping, storm window/door installations, double lock entry systems, and thermostat timers for water heaters and furnaces, etc. Name this service company and convince people they need it.

SCIENCE FACTORS

1. Suppose you paid this company $1200 for a complete weatherization job. In the first year, you saved 400 gallons of heating oil over the previous year. At $1.50 a gallon, how long would it take to make back your investment?

2. Calculate what it would cost your class to insulate your classroom ceiling. Figure labor at the average rate of pay for class members in their part-time jobs. Price insulation for an R-value of R-26 to R-30. Measure the ceiling area carefully.

3. Go back to the oil heated home you weatherized in #1. Suppose instead you decided to install an active solar system for $2400. Such a system requires no oil to operate; in these terms alone, how long would it take you to make back your investment?

CONSUMER IMPACTS

1. Winter heat losses can be cut by 50 percent or more if a thorough-going weatherization is carried out. At this rate, weatherization is a capital investment that will pay big dividends in the relatively short term.

2. It is always cheaper to do such weatherization yourself, but you do have to know what you're doing.

3. In terms of savings on oil alone, an equal amount of time is required to offset the capital investment in the solar heating system as in weatherization. Of course, to be most effective, the solar heated house must also be weatherized, but the savings accruing from the use of solar energy transcends the money factor--nonrenewable fossil fuels are not just conserved but preserved.

PRODUCT CARD

MICROWAVE COOKING SYSTEM

This new product uses microwaves to cook food rapidly and a conventional electrical system to sear and brown meat. It also has a special food defrosting feature, making the system a complete freezer-to-table operation with no special carriers or holders required.

SCIENCE FACTORS

1. What is a microwave? How does it work? How is it different from other "waves"--sound waves, alpha waves, etc?
2. Compare the energy efficiency of microwaves with that of conventional electric convection.
3. Why can't metal cookware be used in microwave ovens?
4. How and of what is the microwave system constructed?

CONSUMER IMPACTS

1. The system has a relatively short cooking time. The radiation from microwaves may present health risks.
2. The system uses slightly less energy than an all-electric oven.
3. Paper or plastic utensils and cookware must be used.
4. The system costs about one and a half times as much as a conventional oven.

PRODUCT CARD

COMPACT CAR

A major automobile manufacturer is announcing the introduction of a new compact car designed to achieve high gasoline mileage. The vehicle is of the "shoe" design with the capacity to hold four people in a very small space. Your job is to name the vehicle and advertise it.

SCIENCE FACTORS

1. Obtain a spec sheet for a "shoe" prototype like the VW Rabbit or the Dodge Omni Miser (their respective dealers would have such a sheet, or you could find them in back issues of automotive magazines like Motor Trend). Select some of the specifications and find out what they mean. Now translate these meanings into implications for the consumer.
2. Now, compare the "shoe" car's spec sheet with one for a car built 10 years earlier--say, a 1970 Pontiac GTO or Ford Mustang.
3. Calculate and compare the life cycle costs of a "shoe" type car that costs $8000 new and averages 40 mpg with a car that costs $4000 new and averages only 20 mpg. Assume both cars are driven 15,000 mi/yr for 10 years and that gas averages $1.75/gal for the period.

CONSUMER IMPACTS

1. Many different features--including the engine size and type, emissions controls, fuel injection system, mode of transmission, carburetion, exhaust system, frame and body size, construction and composition--work together to allow this car to achieve gas mileage in the top one percent of all vehicles (over 40 mpg). The turning radius allows for easy parking in congested areas. The wheel base limits the amount of leg room available and hence inhibits passenger comfort. The acceleration specs indicate little available pick-up on grades or when filled to capacity. The body and frame size and composition, while abetting high gasoline mileage, also serve to ensure high damage and fatality rates in moving accidents. And so on.
2. Some cars that used to be among the most popular in the country are now not even being built, while other former "muscle" cars have been completely modified to now deliver a different kind of "high performance"--i.e., good gas mileage. The very features that used to sell cars are now, in many cases, considered liabilities.
3. Although there are many other factors to consider, the "shoe" type cars not only save the consumer money in the long run, they also use up less of the world's nonrenewable fossil fuel supply. Apparently these factors are important enough to many consumers to encourage them to invest in their cars significantly more capital than they would necessarily have to.

PRODUCT CARD

NEW MOTOR OIL

This new motor oil is being marketed during a time of gasoline price increases as well as new car price peaks. It contains a new ingredient not found in other motor oils. Your task is to name the product (and the active agent) and then advertise it.

SCIENCE FACTORS	CONSUMER IMPACTS
1. What are the characteristics of motor oil? Consider properties like viscosity, weight, pour point, etc. How do these factors bear on the price and performance of motor oil?	1. A motorist currently using 10W40 weight motor oil could get away with using 10W30 weight of the new oil without sacrificing performance. The new oil could lengthen the intervals between necessary oil changes.
2. What does motor oil do? How does it function and what is its relationship to the workings of the automobile?	2. The new motor oil could act to increase engine lifetime as well as gas mileage.
3. What fraction of crude oil is motor oil derived from; i.e., how much do you have to refine crude to get this (or any other) motor oil? How does this consideration relate to the "energy intensity" of motor oil?	3. Oil is oil; the new oil does not eliminate the need for crude and may, in fact, escalate refinery requirements. The small savings realized from improved mileage and fewer oil changes is hardly enough to offset the energy expended to refine crude to the quality of this product.

PRODUCT CARD

ELECTRIC CAR

This vehicle is being introduced during a time of long gas lines and high gas prices ($1.50 per gallon) in cities and suburban areas. Your task includes naming the vehicle as well as describing it. The vehicle is a compact, battery operated car with a range of forty miles and a battery charging cycle of twelve hours.

SCIENCE FACTORS	CONSUMER IMPACTS
1. How and of what is the car constructed? What kind of maintenance does it require?	1. The vehicle is expensive to buy; it requires expensive batteries that must be changed yearly; the mechanical components of the electrical system require frequent cleaning and maintenance.
2. What kind of battery is used in such vehicles? What element in the composition of the battery dictates the 12 hour recharge cycle? How could this be changed or improved?	2. The long battery recharge period limits the amount of time the vehicle is available for use.
3. What kind and level of emissions result from electric vehicles? Gas-powered vehicles?	3. The electric vehicle contributes significantly less to air pollution than its gas-powered counterpart.
4. Calculate and compare the cost per mile for an electric vehicle like the one described here with a gas-powered vehicle that gets 20 mpg. Use current local rates for gas and electricity.	4. Electric automobiles can provide low cost per mile transportation.
5. Get a map of your area and chart points within a 20 mile radius of your home. Map the shortest route to various points of interest--work, school, grocery, bank, etc.	5. The vehicle's short range limits its usefulness almost exclusively to urban areas.

PRODUCT CARD

BICYCLE

A major marketing campaign is being developed to boost the sales of a ten-speed bicycle designed for commuting short to medium distances. The bicycle is equipped with a ten-speed gear system; panniers capable of carrying packages up to briefcase size; safety reflectors; mirrors; positive braking system; and a comfortable saddle. Your job is to design a television advertisement to promote bicycle sales.

SCIENCE FACTORS	CONSUMER IMPACTS
1. What energy conversions occur in the process of riding a bike?	1. The bicycle is powered by human mechanical power and is both fuel and money conserving. Riding bicycles is an excellent form of human exercise.
2. How do the gears work? What are the advantages of having ten? What constitutes a positive braking system?	2. The complexity of the bicycle's construction enhances its ride while complicating its maintenance.
3. Consider aerodynamics in terms of bicycle design (dropped handlebars, seat placement, frame design and composition, tires, etc.). What are their implications for energy efficiency in riding a bike? Calculate the maximum possible speed of any given bicycle and rider.	3. The bicycle is the most efficient form of vehicular travel, although it has a "speed ceiling" much lower than that of an automobile.
4. A motorist and a cyclist both have 15 miles to travel to work in a large city. When moving, the motorist travels 30 mph while the cyclist travels only 15 mph. But the person in the car spends approximately 40 minutes of the total trip into work at a dead standstill, while the cyclist spends only about three minutes completely at rest. Considering these factors, how long does it take each of them to make the same trip into work?	4. Even though the theoretical speed ceiling of the bicycle is significantly lower than that of the automobile, in commuting traffic a real speed ceiling is enforced on autos by the number of vehicles on the road. This ceiling can be easily transgressed by a cyclist not constrained to stop behind lines of cars at lights, etc., and thus speed is not the absolute determinant of travel time.
5. Calculate the foot-pounds of force exerted upon impact with a stationary object by a 200 lb. body traveling 20 mph. Calculate the same for a 5000 lb. body. Which could better sustain the absorbed force of impact?	5. Despite improved safety and comfort features, bicycles are much less passenger safe than are cars.

PRODUCT CARD

CAR POOLING SYSTEM

A government agency in a large urban area is introducing a "Rideshare" program which uses a computer to match up prospective car pool participants by neighborhood and destination. One incentive for the program is a preferential lane treatment which allows cars with four or more riders to use an express lane during rush hours. Your task is to develop a television commercial giving the telephone number of "Rideshare" and requesting people to call in and sign up.

SCIENCE FACTORS	CONSUMER IMPACTS
1. Using a load of one passenger per car, calculate the average "auto density" of each lane of a four lane route servicing a mobile population of 100,000. Now calculate the auto density of a designated express lane if one quarter of the population engaged in car pooling with a ridership of four passengers per car.	1. Participants will lessen their commuting time by using express lanes and reducing the number of cars on the road.
2. How much (in terms of fuel costs alone) would it cost you personally to travel 30 miles per day round trip in your present car? How does this amount compare with the cost of sharing expenses with three other people for a trip of the same distance in vehicles averaging 20 mpg?	2. Participants will save both money and gasoline and reduce maintenance on personal vehicles.
3. What are some necessary engineering features of an expressway facilitating car pooling--e.g., express lane barriers, double access ingress/egress, signs, etc.?	3. Express lanes would benefit car poolers while penalizing single riders, but all would be assessed for the institution and maintenance of such lanes.
4. Suppose you make $30,000 a year for a nine to five job with a two week vacation. Calculate your hourly "wage" in the world of work. In order to participate in a car pool, you must leave a half hour earlier every morning and arrive home a half hour later every evening than you would were you driving only yourself. How does this "overtime" compare with the amount of savings you figured earlier?	4. Participating in a car pool lessens personal flexibility, a valuable commodity that has variable market value.

PRODUCT CARD

MASS TRANSIT RIDERSHIP

A middle-sized urban area has supported a full-service bus system for several years. The system suffers, however, from a low-appeal public image and hence, financial insecurity. Recent local bond issues have acted to upgrade the bus service in effort to enhance the system and increase ridership. Rider density must increase before the system will become cost effective. Develop an ad to promote riding the bus.

SCIENCE FACTORS

1. Consider and try to calculate the factors governing the cost per mile to operate a city bus. Include in your considerations:
   a. capital investment
   b. fuel costs
   c. operation and maintenance costs
   d. gas mileage
   e. distance traveled daily
   f. labor and administrative costs

2. Using your calculations, try to gauge the optimum average and rush hour passenger loads--the loads that would enable the system to pay for itself. Assume the average round trip fare is $1; that the average bus seating capacity is 50; and that there is an average differential of 50% between rush hour and non-rush hour loads.

CONSUMER IMPACTS

1. Taxpayers must support the bus system if it can't support itself. The bus system provides jobs, but the net economic benefit is negative unless the buses are used more.

2. In general, throughout the nation's bus systems, ridership must increase 20-30% in order for a system to become self-sustaining. If this optimum increase were achieved, several benefits would accrue to the community: overall community fuel consumption would stabilize or decrease; rush hour traffic congestion would decrease; personal economy could be enhanced for those with access to a busline but without access to a car pool.

SAMPLE SCRIPT

VIDEO	AUDIO
Opening scene is in black and white and shows a Model T (4 people) slowly creeping into a covered bridge. Then the scene turns to color and the new car comes out the other end.	Remember those quiet picnics in the country with your family? Out in mother nature's finest with your mother's finest homemade pies and bread? Now you can share this beloved experience with your family, and you can get there in the new Wolverine. The new Wolverine has improved mileage performance that rates in the top 1 percent of all cars. This mileage makes it the most economical way to travel for four people.
The new car pulls over to roadside and people begin to unload various picnic paraphernalia (4 people).	With the money saved on gas, these trips to the country can become a regular thing. And the roominess of the Wolverine is best suited for those short jaunts to the country.
Show late afternoon with people packing up picnic remains and loading car. Plenty of space shows in an otherwise crowded parking lot.	Along with great mileage, the Wolverine is maneuverable and can handle those tight parking spaces. The acceleration is ideal for short trips, like back and forth to the store.
New car, now loaded up, drives off into the sunset.	So come to your dealer tonight and test drive a Wolverine.

SCRIPT FORMAT

Writers of TV commercials use a story board to sketch out the sequence of a commercial in order to get a clear idea of how the message will be communicated. Write your ideas on this sheet. Use the left column to describe your commercial's actions and the right column for the corresponding words.

VIDEO	AUDIO

EVALUATION SHEET

Select from the following lists the Product and Target Audience each advertising team was working with in its commercial presentation. Then, using your own paper, answer each question posed for <u>each</u> team commercial, including the one you participated in developing.

PRODUCTS	TARGET AUDIENCES
1. New Motor Oil	1. Wild and Crazy
2. Energy Conservation Service	2. Super Intelligent
3. Electric Car	3. Engineering Nut
4. Mass Transit Ridership	4. Just Plain Folks
5. Compact Car	5. Money Conscious
6. Solar Heating System	6. Technical Experts
7. Bicycle	7. Nostalgia Buff
8. Microwave Cooking System	8. Status Seeker
9. Natural Gas Home	9. Social Butterfly
10. Car Pooling System	10. Eco-Freak

	Product	Target Audiences
Team 1	____________	____________
Team 2	____________	____________
Team 3	____________	____________
Team 4	____________	____________
Team 5	____________	____________

1. How did you recognize who the audience was? Are you ever part of this audience?

2. What does this ad want you to do? How would you respond on the basis of the ad's approach?

3. What were the energy advantages of this product (or service)?

4. What were the disadvantages?

5. Do you think important facts were left out?

6. Were any methods of propaganda used? Point out where important facts were downplayed (by omission, or by confusing the issues or diverting the audience's attention). Were certain facts intensified by repetition or association? What other techniques were used?

7. Did the ad encourage clear thinking? If not, how could the ad be changed to better inform the public?

8. Was the ad deceptive? If so, what changes could make it into a more balanced presentation?

9. Would making the changes suggested in #7 and 8 add to or take away from the effectiveness of this commercial message?

REVIEW SHEET

1. Did you feel the simulation approximated reality? Why or why not?
2. What skills did you use to develop and present your advertisements?
3. How could you further develop these skills?
4. Do you think the same feelings, frustrations, skills, and lack of skills that you experienced are found in the real advertising world?
5. How can you recognize when you are part of a target audience? Why is it important to know this?
6. Do you feel there is any relationship between audience and product promotion? Does the pre-selection of an audience help sell a product?
7. What special effects make some ads memorable, whether or not the product itself is appealing?
8. How can you recognize when a product is actually being promoted or whether it's an attitude or feeling that's being "sold?"
9. How can you recognize whether or not an ad presents information in a balanced way?
10. Often an advertisement presents the strengths of the product and not its weaknesses. How can you obtain more information and other opinions on a product or service?
11. How can advertising help people? Can advertising hurt people? Do people need to be protected from certain kinds of promotional techniques? What kind of strategies can consumers employ to resist such techniques?
12. What factors make an ad deceptive?
13. The Federal Trade Commission (FTC) can require advertisers to "cease and desist" from airing deceptive and misleading commercials on TV. What kind of regulations should be enforced to govern commercials about energy-related goods and services?
14. What kind of advertising regulations should be maintained to protect a developer's right to sell a product?
15. What would you change in TV commercials if you had the chance?

CANMEXUS

MAJOR CONCEPT	Just as different energy resources are unevenly distributed among Canada, Mexico, and the United States, so are different resource needs and consumption patterns manifest in these countries.
SUPPORTING FACTS	• Resource development depends on technology. • Development of some resources will be affected by environmental considerations. • Unpredictable factors (accidents, disasters, political and economic constraints) can affect resource development. • Resource development will increasingly require international trade or cooperation, and thus involve additional expenditures of energy, money, and/or other "commodities" like political consideration. • As conventional energy resources are depleted, other resources like solar, geothermal, and tidal energy will become more important components of the international energy mix.
RELATED SCIENCE THEMES	The geology and geography of resource distribution; unconventional future sources of energy.
SCIENCE PROCESS SKILLS ENGAGED	Observing, classifying, using numbers, communicating, inferring.
METHOD	1. Relate Background Material to current course content. 2. Discuss new terms on game cards as students help duplicate and cut them apart. 3. Play the game. 4. Wind up the game with Review Sheet.
MATERIALS For the teacher:	Background Material
For each student:	Rules List of Cards Sample Rounds Review Sheet
For every six students:	1 deck of 132 cards

BACKGROUND MATERIAL

CanMexUs provides a good opportunity to explore the politics of science in an area with which students are most familiar--North America. The dynamics among nations on this continent promise to be a source of increasing interest and importance with the advent of the Reagan Administration. Increased dialogue with Mexico is already receiving executive priority, and a U.S.-Canadian summit meeting is being discussed. Energy dynamics provide one important way to focus such current considerations. At the same time, this game offers an introduction to future energy resources which transcend national boundaries and hence, their political limits.

The number of each kind of energy resource cards available for play is based on quantitative estimates of actual amounts of coal, oil, uranium, etc. existing in Canada, Mexico, and the United States. The number of cards helps students infer that there are limits to the supplies of domestic resources and that different energy resources are no more evenly distributed among the three nations than are population and the rate of energy consumption. In playing the game, students are required to consider some of the tradeoffs involved in utilizing a resource, negotiating a trade, buying energy from another country, or developing new energy resources.

Although most students are familiar with conventional sources of energy like coal and oil, they may not be aware of some of the new resources being considered for development by North American nations. In the game, few tidal, geothermal, and solar energy resource cards are available for students to play because only a small portion of North America's total energy supply is currently derived from these resources. As students rush to exploit the conventional sources, however, and encounter the attendant difficulties of resource depletion, import tariffs, and environmental hazards, they may find themselves in a situation in which it would be wise to develop an alternative to the energy standbys. If so, they will perhaps be more willing to grant the increased future contribution of seemingly unlikely resources to the international energy mix.

Geothermal energy, for example, is relatively plentiful in North America. Recent U.S. Department of Energy projections estimate its eventual capacity to be as much as 10% of all U.S. energy production, particularly in the West.

There are two basic uses for the heat obtained from the earth's core. First, the heat can be pumped to houses, stores, and factories and used to heat the buildings. Second, the heat can be used to produce electricity. In order to use geothermal heat for heating buildings, a geothermal site must be drilled close to a population center and must contain steam and/or hot water. In Boise, Idaho, for example, geothermal springs have heated some sections of the town since the turn of the century. The hot steam is circulated to as many buildings as possible and then returned to the well after it has condensed into water.

Producing electricity from geothermal energy is less simple. First the well must produce only steam, not a mixture of steam and water. The steam is used to turn a turbine-generator, producing electricity. The steam condenses into water after it passes through the turbine. A reinjection well starts the process over again.

Compared to other sources of energy, geothermal energy has relatively few problems associated with its use. Some of the dissolved minerals contained in the steam and hot water, however, are corrosive or form a scale on surfaces when the geothermal water is cooled. Such minerals could damage pipes in conventional plumbing systems and, unless properly contained, might enter the water supply. Other problems include noise from escaping steam and strong odors from the decomposed organic matter dissolved in the water.

Most geothermal energy cannot be harnessed, but interest in those areas where it can be utilized is increasing. Geothermal energy is being used today to a limited extent in both the United States and Mexico. As technological refinements are made and geothermal energy becomes economically competitive with conventional energy sources, the earth's energy could become a significant component of these national energy mixes.

Tidal power is found everywhere there are tides. Using the energy that is released each time the tides come in and go out, however, is difficult. So far, scientists have only been able to harness the power of the extreme tides such as those in the Bay of Fundy in Canada. As the water comes in with the high tides, it is used to run a series of turbines which have been carefully placed in the water. The turbines can be turned, which can then turn a generator, which can then produce electricity. The turbines must be reversible, so that they can also turn when the tides are going out. In this way, electricity can be produced by both incoming and outgoing tides.

Although tidal electricity may seem like a good idea, its uses are quite limited. Only a few sites in the world have the potential for tidal power plants. In some cases, the sites that are good for producing electricity are areas where little electricity is needed because there are so few people. The timing of the tides presents another problem: since the tides come in and go out only twice a day, there are times in every day when electricity cannot be produced. Because of this, a tidal power plant must be used in partnership with some other power plant. In addition to that expense, the costs of building the tidal power plant itself are high, mostly because the engineering and construction has to take place with waves and tides all about. Constructing a tidal power plant can be likened to building a sand castle in the middle of the ocean. Once the tidal plant were built, however, the tides could provide clean and safe electricity for a localized area. There would be no fuel shortage since the tides themselves are the fuel, and there would be no pollution from fuel combustion.

More promising than the tides is the radiant energy of the sun which can be used to heat and cool buildings and produce electricity. Electricity can be produced thermally by exposing an absorbing medium (like water) to sunlight and using the collected heat to make steam to turn a turbine. Solar electricity can also be produced by photovoltaic cells. As their name suggests, photovoltaic cells convert the sunlight they capture directly into electrical energy without a thermal conversion step.

Sunlight can also heat and cool homes and other buildings. The buildings must have some device to collect the sunshine. If an active system is installed, roof-mounted flat plate collectors, through which an absorbing medium flows, collect the heat which is then distributed around the house. If a passive system is used, the home has solar collection features built into it (like an especially massive brick, water or cement wall that will collect and store solar energy and then gradually radiate that heat to the house). Unlike solar electric production, solar heating and cooling is commercially viable and available.

Environmental problems with solar energy are few. Collection, especially for the solar electric technologies, requires quite a bit of land area. Some indirect environmental impacts will result from the increases in manufacturing materials from which to build collectors. Aside from that, using solar energy affects the environment about as much as not using it--the sun shines in either event.

These three energy resources, like their conventional counterparts, require technological development before they may be utilized. "Technology" involves a number of things, including not only the mechanism by which energy is converted to a useable form, but also the lead time required to create this means and the capital that must be invested. In the game, these stipulations are satisfied by the requirement of having to play a Technology card before developing (playing) a resource.

Regardless whether conventional or new, domestic or imported energy resources are used, the quickest, cheapest, least controversial and most environmentally sound way to conserve valuable fuel supplies is to use them more efficiently and thus, in smaller quantities. Students infer the advantages of energy efficiency by adding points to their totals when they play Efficiency cards on any resource.

RULES

For each country, the object of the game is to reach or exceed its particular resource goal, indicative of its levels of energy production and consumption. RESOURCE GOALS:

Mexico	1000
Canada	1500
United States	2500

The team that exceeds its resource goal by the greatest number of points wins. (Thus, if all teams scored 1500 points, Mexico would be declared the winner.)

1. Three teams with two players each represent Canada, Mexico and the United States. The two partners of each team should position themselves opposite one another for ease of play. These two partners play as a team building on one another's moves. All rules apply on a "per team" basis.

2. All 132 cards are shuffled into one deck. Each player is dealt six cards. Players keep six cards in hand at all times.

3. Disaster or Accident cards dealt at the outset should be returned to the deck and replaced with different cards from the deck.

4. Player to left of dealer draws a card from the balance of the deck not dealt. Player must play or discard any one card.

5. Normally, the first card played by any team is a Technology card, since a Technology card must be played before each different resource (e.g., coal, oil and natural gas, hydro, etc.) may be developed (played)--foreign or domestic.

6. If the first player elects to discard instead of play, the discard should be placed face up beside the drawing pile.

7. The second and third players may then either take the discard or draw from the deck; then they, too, must either play or discard any one card. Discarded cards may be picked up by a subsequent player only as long as they are on top of the discard pile.

8. Fourth, fifth, and sixth players play as others except that in playing their cards, they should place their cards on top of their partner's cards, thus playing as a team (i.e., instead of starting their own resource development piles).

9. After a team plays a Technology card, resource development may begin by playing a Resource card on the Technology card. Each resource developed by each country (team) has its own playing pile.

10. After a resource has been developed (i.e., after a Resource card has been played on a Technology Card) by a team, subsequent resource cards of that type may be played without additional Technology cards.

11. Before a team may develop (play) a foreign resource, both a Technology and an Import card must be played.

12. Subsequent foreign Resource cards of the same kind must be preceded by an Import card, although the technology, once in place, need not be played again.

13. An Environment card must be played by each team before it develops a Coal resource. After an Environment card has been played and Coal has been developed by a team, subsequent Coal cards may be played without playing additional Environment cards.

14. An Environment card played on any resource besides Coal results in extra points.

15. An Efficiency card played on any resource adds to total points.

16. A Barter card entitles the holder to take any one top card from another team's playing piles. The card taken must be played immediately (although the Barter card itself may be held until a team plays a card the holder wants), and the Barter card must be placed with it on the table. Each Barter card may be used only once.

17. If an Accident or Disaster card is drawn by any player, it must be played immediately. It should be played on the resource pile related to the nature of the accident or disaster. If the resource implicated by the Accident or Disaster card has not been developed by the country drawing the card, it may be discarded.

18. When the last card is drawn from the deck, play continues until no more cards can be played by anyone. Any remaining cards in the discard pile cannot be used. Any card left in players' hands that can't be played should simply be discarded; their points are neither added nor subtracted from the teams' scores.

19. Each team adds total points on cards played and subtracts points for accidents or disasters. The team that exceeds its resource goal by the greatest amount wins.

LIST OF CARDS

For each group of six students, the following cards are required:

Number of Cards	Kind of Card	Point Value
16	Technology	0
8	Environment	0 With Coal +100 Otherwise
3	Disaster!	-200
8	Accident!	-100
4	Barter	0
14	Import	0
5	Efficiency	200
32	RESOURCE: Coal 20-U.S. 12-Canada	100
24	RESOURCE: Oil & Natural Gas 14-Mexico 7-U.S. 3-Canada	100
6	RESOURCE: Uranium for Nuclear Power 3-U.S. 3-Canada	100
7	RESOURCE: Hydroelectric 5-Canada 2-U.S.	100
3	RESOURCE: Solar Power All Countries	100
1	RESOURCE: Geothermal Power All Countries	100
1	RESOURCE: Tidal Power U.S. or Canada	100
132	TOTAL NUMBER OF CARDS	

SAMPLE ROUNDS

CARDS DEALT

A Canada (Technology, US Oil, US Oil, Canadian Hydro, US Coal, Tidal)

B Mexico (Technology, Technology, Mexican Oil, US Oil, Canadian Oil, Import)

C United States (Import, Technology, US Oil, US Coal, US Coal)

D Canada (Import, Technology, US Oil, Mexican Oil, Solar, US Coal)

E Mexico (Import, Import, Efficiency, Mexican Oil, US Oil, US Coal)

F United States (Import, Import, Environment, Canadian Coal, Canadian Coal, US Oil)

FIRST ROUND

A draws US Coal; plays Technology

B draws US Coal; plays Technology

C draws Mexican Oil; plays Technology

D draws US Oil; plays Import on A's Technology

E draws Mexican Oil, plays it on B's Technology

F draws US Coal; plays Environment on C's Technology

SECOND ROUND

A draws US Oil, plays it on D's Import

B draws Technology, plays it next to Mexican Oil Resource playing pile

C draws Canadian Hydro; plays US Coal on F's Environment

D draws US Oil; plays Technology next to Imported US Oil playing pile

E draws Canadian Oil; plays Mexican Oil on Mexican Oil

F draws Canadian Hydro; plays US Coal on US Coal

THIRD ROUND

A draws Canadian Uranium; discards US Coal

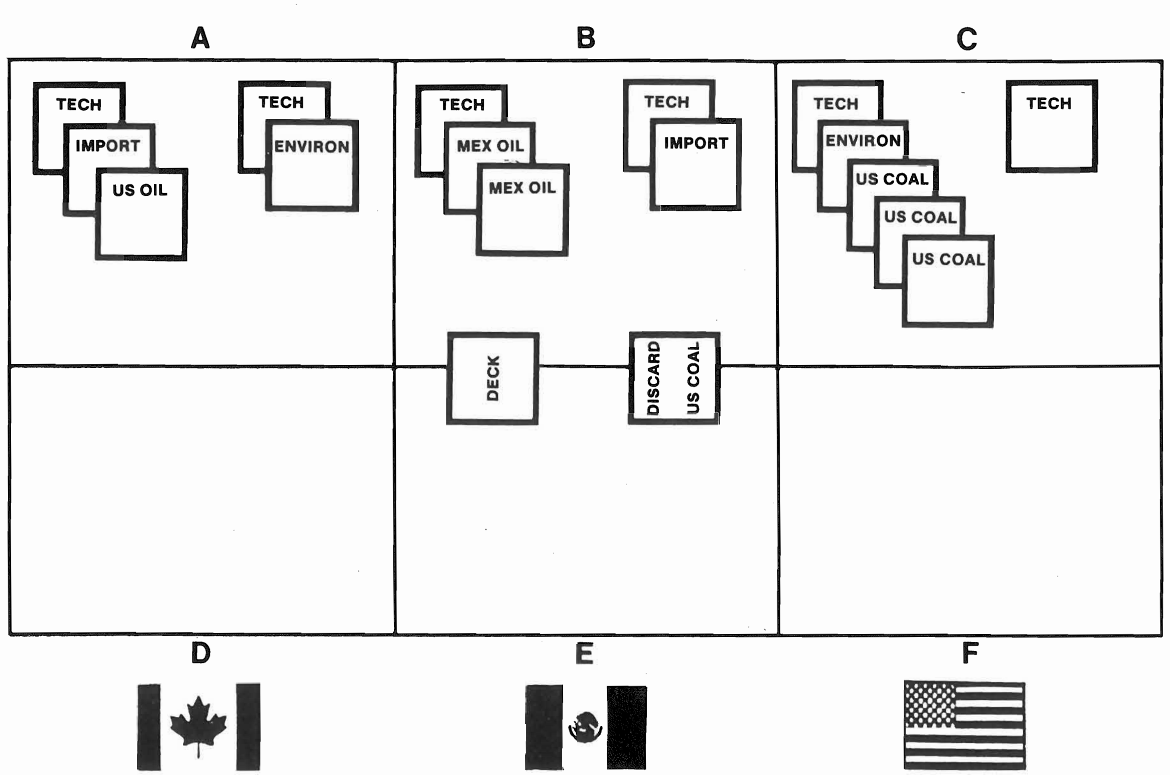
B draws Barter Card, holds it for future use, discards US Coal

C draws discarded US Coal, plays it on US Coal

D draws Environment, plays it on Technology

E draws Environment; plays Import on Technology

F draws Technology, plays it next to US Coal playing pile



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TECHNOLOGY  Must be played before playing any Resource Card.	TECHNOLOGY  Must be played before playing any Resource Card.
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SAMPLE ROUNDS

CARDS DEALT

A Canada (Technology, US Oil, US Oil, Canadian Hydro, US Coal, Tidal)

B Mexico (Technology, Technology, Mexican Oil, US Oil, Canadian Oil, Import)

C United States (Import, Technology, US Oil, US Coal, US Coal)

D Canada (Import, Technology, US Oil, Mexican Oil, Solar, US Coal)

E Mexico (Import, Import, Efficiency, Mexican Oil, US Oil, US Coal)

F United States (Import, Import, Environment, Canadian Coal, Canadian Coal, US Oil)

FIRST ROUND

A draws US Coal; plays Technology

B draws US Coal; plays Technology

C draws Mexican Oil; plays Technology

D draws US Oil; plays Import on A's Technology

E draws Mexican Oil, plays it on B's Technology

F draws US Coal; plays Environment on C's Technology

SECOND ROUND

A draws US Oil, plays it on D's Import

B draws Technology, plays it next to Mexican Oil Resource playing pile

C draws Canadian Hydro; plays US Coal on F's Environment

D draws US Oil; plays Technology next to Imported US Oil playing pile

E draws Canadian Oil; plays Mexican Oil on Mexican Oil

F draws Canadian Hydro; plays US Coal on US Coal

THIRD ROUND

A draws Canadian Uranium; discards US Coal

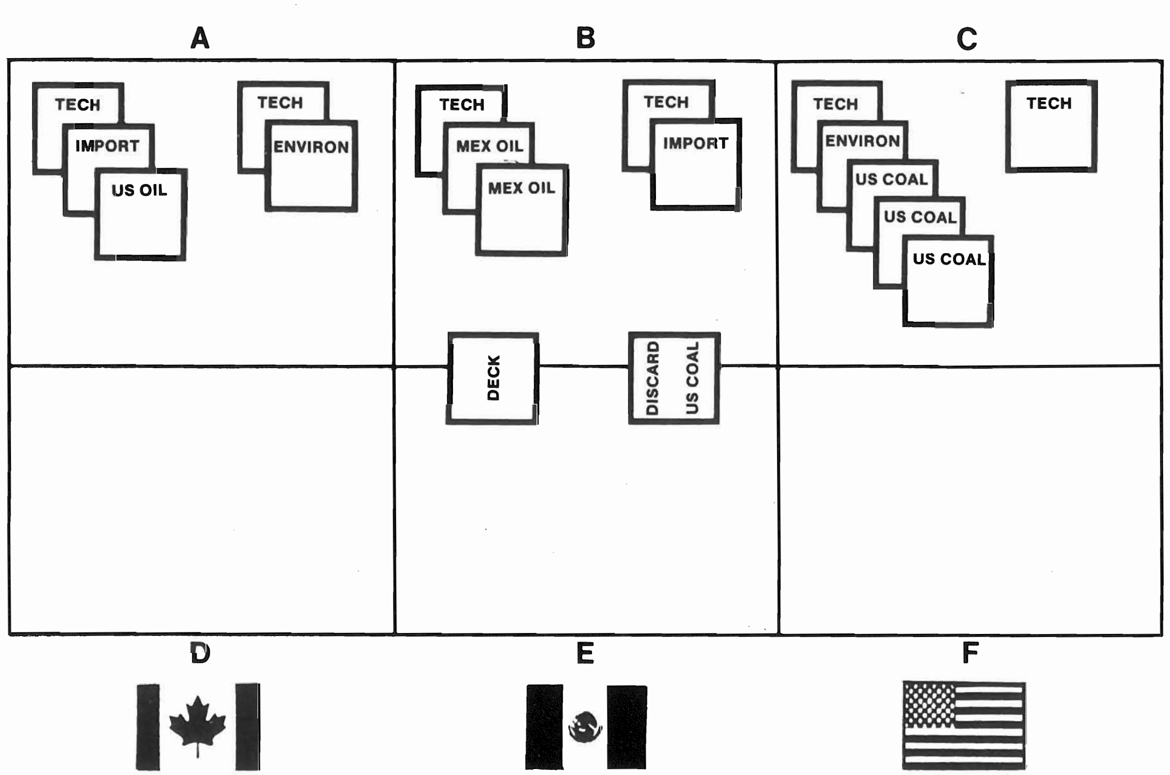
B draws Barter Card, holds it for future use, discards US Coal

C draws discarded US Coal, plays it on US Coal

D draws Environment, plays it on Technology

E draws Environment; plays Import on Technology

F draws Technology, plays it next to US Coal playing pile



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TECHNOLOGY  Must be played before playing any Resource Card.	TECHNOLOGY  Must be played before playing any Resource Card.
TECHNOLOGY  Must be played before playing any Resource Card.	TECHNOLOGY  Must be played before playing any Resource Card.

Duplicate this page 4 times.

ENVIRONMENT 0 with Coal +100 otherwise Must be played with Coal; optional with other resources.	ACCIDENT! -100 Nation's largest coal mine collapses; 300 miners killed.
ENVIRONMENT 0 with Coal +100 otherwise Must be played with Coal; optional with other resources.	ACCIDENT! -100

Duplicate this page 5 times.

RESOURCE: Coal +100	RESOURCE: Coal +100
RESOURCE: Coal +100	RESOURCE: Coal +100

Duplicate this page once.

EFFICIENCY

+200

Play on any resource; savings in one energy arena results in savings for all.

EFFICIENCY

+200

Play on any resource; savings in one energy arena results in savings for all.

EFFICIENCY

+200

Play on any resource; savings in one energy arena results in savings for all.

EFFICIENCY

+200

Play on any resource; savings in one energy arena results in savings for all.

EFFICIENCY

+200

Play on any resource; savings in one energy arena results in savings for all.

Duplicate this page once.

RESOURCE:
Hydroelectric
Power

+100

RESOURCE:
Hydroelectric
Power

+100

RESOURCE:
Hydroelectric
Power

+100

RESOURCE:
Hydroelectric
Power

+100

RESOURCE:
Hydroelectric
Power

+100

Duplicate this page once.

RESOURCE:
Solar Power

+100

RESOURCE:
Solar Power

+100

RESOURCE:
Solar Power

+100

RESOURCE:
Geothermal
Power

+100

RESOURCE:
Tidal Power

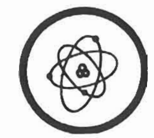
+100

RESOURCE:
Oil & Natural Gas

+100

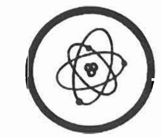
Duplicate this page once.

RESOURCE:
Uranium for
Nuclear Power



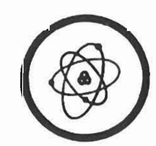
+100

RESOURCE:
Uranium for
Nuclear Power



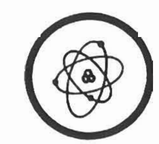
+100

RESOURCE:
Uranium for
Nuclear Power



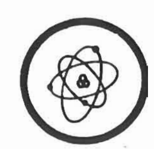
+100

RESOURCE:
Uranium for
Nuclear Power



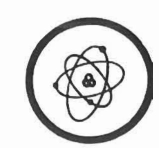
+100

RESOURCE:
Uranium for
Nuclear Power



+100

RESOURCE:
Uranium for
Nuclear Power



+100

Duplicate this page once

RESOURCE:
Oil & Natural Gas

+100

RESOURCE:
Oil & Natural Gas

+100

RESOURCE:
Oil & Natural Gas

+100

RESOURCE:
Oil & Natural Gas

+100

RESOURCE:
Oil & Natural Gas

+100

RESOURCE:
Oil & Natural Gas

+100

Duplicate this page once.

DISASTER!

-200

Political unrest in Middle East creates worldwide oil shortage.

RESOURCE:
Oil & Natural Gas

+100

DISASTER!

-200

RESOURCE:
Oil & Natural Gas

+100

DISASTER!

-200

RESOURCE:
Oil & Natural Gas

+100

BARTER

You may take the top card from any team.

BARTER

You may take the top card from any team.

BARTER

You may take the top card from any team.

BARTER

You may take the top card from any team.

RESOURCE:
Hydroelectric Power

+100

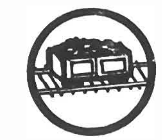
RESOURCE:
Hydroelectric Power

+100

RESOURCE:
Coal

+100

RESOURCE:
Coal

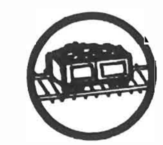


+100

RESOURCE:
Coal

+100

RESOURCE:
Coal



+100

RESOURCE:
Coal

+100

RESOURCE:
Coal

+100

Duplicate this page 7 times.

IMPORT  Must be played before using a foreign resource.	IMPORT  Must be played before using a foreign resource.
 RESOURCE: Oil & Natural Gas  +100	 RESOURCE: Oil & Natural Gas  +100

REVIEW SHEET

(Cover when duplicating for students.)

1. Why were different resource goals set for each of the three countries? What are the implications of these differences?	1. To reflect the different rates of energy production and consumption in the three countries. These rates depend on many factors, including population; level of industrialization; energy efficiency; standard of living; etc. Such factors influence the outcome of the game in a variety of ways. For instance, although the energy resources of the U.S. appear to be great, the country has a large population with an even larger energy appetite and thus, an energy imbalance is indicated.
2. Which country met or exceeded its goal? Did more than one nation do so? What enabled countries to meet their goals?	2. A variety of reasons may be cited, depending on the course of the game. Canada could win by virtue of its variety of resources; Mexico because of its modest goals and wealth of oil; the U.S. by dint of its quantity and variety of resources despite its high goal.
3. Which countries failed to meet their goals? Why?	3. Mexico might fail due to its limited variety of resources; Canada because of its relatively higher goal, smaller number of total resources, or susceptibility to accidents; the U.S. because of its disproportionately high resource goal, susceptibility to accidents, or large number of imports.
4. Which card had to be played before resources could be developed? Why?	4. The Technology cards signify the idea that before a country can use an energy resource, the nation must have the equipment and people capable of recovering it, refining it if necessary, and then using it to best advantage. In this light, technology comprises labor and capital as well as hardware and software.

5. Which card had to be played before coal could be used? Why?

5. Many environmental restrictions are specifically related to the extraction and use of coal, including strip mining regulations, miner safety standards, emissions standards for electric utilities using coal, and so on. Environmental safeguards for coal are necessities, not "bonuses;" hence why no points are given for playing Environment cards on coal.

6. What was the purpose of the Import card?

6. In the game, the Import card is played before a foreign resource may be developed and takes up one turn without yielding points. Importing an energy resource requires an additional expenditure of time, money, and energy in negotiating with another country, transporting the energy resource, etc. The Import card represents those extra expenses not necessary when using native resources.

7. The effect of a Disaster or Accident card was to take away energy points. Tell how accidents such as mine cave-ins, nuclear radiation leaks, or oil spills actually affect energy supplies.

7. A cave-in shuts down production at a mine site; a radiation leak mandates the temporary cessation of nuclear power production; an oil spill loses some oil--but all of these have secondary effects. The oil spill contaminates the water in the vicinity with implications for the fish, birds, and people of the area; the cave-in likely results in the death and/or injury of miners and sometimes necessitates the migration of mining families to new mining sites; the nuclear radiation leakage could prove dangerous to plant workers, residents, and the environment.

8. Efficiency means extending resources by using them in a way that wastes as little as possible. Give an example of efficiency in coal mining, oil extraction, natural gas production and uranium production.

8. Coal mining: strip mining methods remove more coal than do underground techniques; some underground machines are more efficient than manual extraction.
Oil extraction: injecting liquids

into oil-containing rock can force more oil out of a particular site.
Natural gas production: instead of burning off natural gas at an oil site, it may be pressurized and piped.
Uranium production: uranium can be reprocessed after use in a nuclear reactor, "enriched," and used again; the breeder reactor would extend supplies of uranium by creating part of its own fuel in the course of generating electricity.

9. A barter is actually a trade. In this game, when the barter card was used, the person whose card was taken got nothing in return. Describe what might happen in an actual barter situation.

9. People from the two countries involved negotiate a trade or a price for the resource exchanged. In order to procure a resource, a country may have to promise something not usually considered a liquid commodity--e.g., political considerations, military assurances, jobs or contracts, etc. Or a country may have to borrow money which has to be guaranteed by a third party, thus necessitating further negotiations.

10. Some of the resource cards were present in greater numbers for one country than another. For example, there were 20 U.S. Coal cards, 12 Canadian Coal cards, and 0 Mexican Coal cards. What do the relative numbers indicate?

10. The number of cards is proportioned to reflect estimated resources of each country in each resource category. These estimates are based upon a combination of sources, since such estimates vary depending on who is doing the projection.

11. There were very few of some kinds of resource cards. What were they and why so few?

11. The small number of Solar, Geothermal, and Tidal Power cards represents the limited contribution these sources currently make to the total North American energy supply. This could change in the future for solar and geothermal energy, but is not likely to change appreciably for tidal power.

CO_2 & CLIMATE

MAJOR CONCEPT

In addition to the fact that they are scarce and nonrenewable, fossil fuels should be burned as little as possible to minimize the amount of CO_2 their use releases into the atmosphere.

SUPPORTING FACTS

- Increases in the carbon dioxide content of the earth's atmosphere due to burning fossil fuels cannot be reversed.
- Although increased atmospheric carbon dioxide from continued reliance on fossil fuels is reasonably sure to increase the temperature of the earth's atmosphere, the consequences of this temperature increase are highly uncertain.
- Because the consequences of using fossil fuels are global, the entire world must cooperate in reducing their use.
- By eliminating world dependence on fossil fuels, the uncertain consequences of using them can also be eliminated.
- A wide variety of alternatives to burning fossil fuel exists.

RELATED SCIENCE THEMES

Structure and composition of the atmosphere; properties and behavior of CO_2; weather and climate.

SCIENCE PROCESS SKILLS ENGAGED

Observing, classifying, using numbers, communicating, inferring, defining operationally.

METHOD

1. Relate Background Material to current course content.
2. Introduce glossary.
3. Play the game.
4. Wind up the game with Review Sheet.

MATERIALS

For the teacher: Background Material

For each student: Glossary, Rules, Review Sheets

For every five students:

Two dice	54 Food cards
One game board	54 Fossil Fuel cards
Five markers	24 Climate cards
60 Technology cards	21 Non-Fossil Fuel cards (3 each of seven energy sources)
60 Capital cards	

BACKGROUND MATERIAL

CO_2 and Climate is designed to simulate possible long range and global consequences of increasing the carbon dioxide concentration of the earth's atmosphere by burning fossil fuels.

For the purpose of this game, five regions of the world are simulated: North America, Europe, Asia, Middle East, and Latin America. These regions represent a cross-section of the world in terms of resource poverty and wealth. Each region is given cards representing fossil fuels, food, technology, and capital in accordance with its resources and needs. As players move their markers around the game board, they gain or lose resources as the result of problems or achievements and have the opportunity to acquire the ability to develop non-fossil fuels. Provision for "foreign aid" is also made for players unable to pay their penalties.

The direct consequence of burning fossil fuels is a change in the temperature of the earth's atmosphere. Studies project a doubling of carbon dioxide concentration in the atmosphere in 50 years if fossil fuels are used at an annual increase of 4.3%. This buildup of CO_2 would trap infrared radiation from the sun that is normally bounced (reradiated) back into space by the earth. The trapped radiation would result in a world temperature increase from $1^{o}C$ to $5^{o}C$.

However, the ultimate consequences are likely a decline in world food productivity due to climate change and a negative effect on capital or technology due to flooding. Although we can predict with a fair amount of reliability the temperature change of the atmosphere resulting from increased carbon dioxide, we are extremely uncertain about the agricultural and economic consequences that would result. For this reason, these consequences are determined by the draw of climate outcome cards each time a player lands on or passes the "decade" square.

"Decade" indicates the long-range aspects of the CO_2 problem; climatic effects of burning fossil fuels are not likely to be seen next week or next year, but they are ultimately inevitable and must be anticipated. Because the consequences of burning fossil fuels are global, all regions (players) must suffer the consequences of drawing climate outcome cards regardless whether they are dependent on fossil fuels or not. Because the way in which a world temperature increase would affect climate and weather is uncertain, the Climate cards dole out different rewards and penalties for a variety of weather and climate conditions that may result.

Development of non-fossil fuels (represented in the game by the acquisition of monopolies) offers an alternative to the highly uncertain long-range and global effects of CO_2 buildup. The seven non-fossil fuels used in this game and defined in the glossary can give students a working knowledge of non-fossil fuel energy options. Playing the game can bring a distant and esoteric scientific problem into the students' immediate ken and prompt an otherwise easily-deferred awareness and consideration of the issues.

For further information on this complex subject, you and your students may want to consult the following sources:

Baes, C.F., et al. "Carbon Dioxide and Climate: The Uncontrolled Experiment," American Scientist 65, 310 (May - June 1977).

Energy and Climate. Studies in Geophysics. A Report of the Geophysics Study Committee, National Research Council. Washington, DC: National Academy of Sciences, 1977.

GLOSSARY

BIOMASS: Material that was recently part of a living system--such as garbage, agricultural wastes, or specially-grown crops--from which energy may be derived.

FOSSIL FUEL: Any fuel derived from material once part of a living system which has decayed under the influence of high pressure and temperature within the earth for hundreds of millions of years. The fossil fuels are natural gas, oil, and coal.

FISSION: The process of releasing energy by splitting heavy nuclei (such as uranium) into lighter nuclei (such as strontium or cesium).

FUSION: The process of releasing energy by combining two lighter nuclei (such as hydrogen) to form a heavier nucleus (such as helium).

GEOTHERMAL ENERGY: The natural heat of the earth harnessed from concentrated pockets such as underground hot springs, geysers, and beds of hot rocks.

GREENHOUSE EFFECT: The trapping of infrared radiation (from the sun and normally bounced--or reradiated--back into space by the earth) by carbon dioxide and water vapor built up in the earth's atmosphere.

HYDROELECTRICITY: Energy released in the form of electricity when water falling to a lower level is caused to turn a turbogenerator.

SOLAR ENERGY: Energy derived directly from the sun, either in the form of direct heating or electricity.

WIND POWER: Energy derived from the winds by means of windmills.

RULES

1. Divide into groups of five.

2. Each group should have one pair of dice, one game board, and one set of cards.

3. Each player throws the dice once. The players choose the regions they represent in order of highest throw.

4. Players sit around the game board in the following order of regions, from right to left: Asia, Latin America, Middle East, Europe, North America. These regions were chosen because they comprise a cross-section of the world in terms of resource poverty and wealth.

5. Each player is given resource cards as follows:

REGION	Technology	Capital	Food	Fossil Fuel
North America	12	12	12	6
Europe	7	7	7	3
Middle East	5	6	2	15
Latin America	5	5	5	7
Asia	5	6	5	5

6. All players place their markers on Decade.

7. Each player takes a turn, beginning with Asia and proceeding to the left, by throwing the dice and moving a marker the appropriate number of spaces clockwise around the game board.

8. Players must follow the instructions on the spaces on which they land. If an <u>unowned</u> non-fossil fuel space is landed on, it may be purchased for the following prices:

   Hydroelectric, Wind, Geothermal, Biomass > 2 Capital cards, 2 Technology cards

   Fission, Fusion, Solar > 3 Capital cards, 3 Technology cards

   If an <u>owned</u> non-fossil fuel space is landed on, the owner must be paid one Capital card.

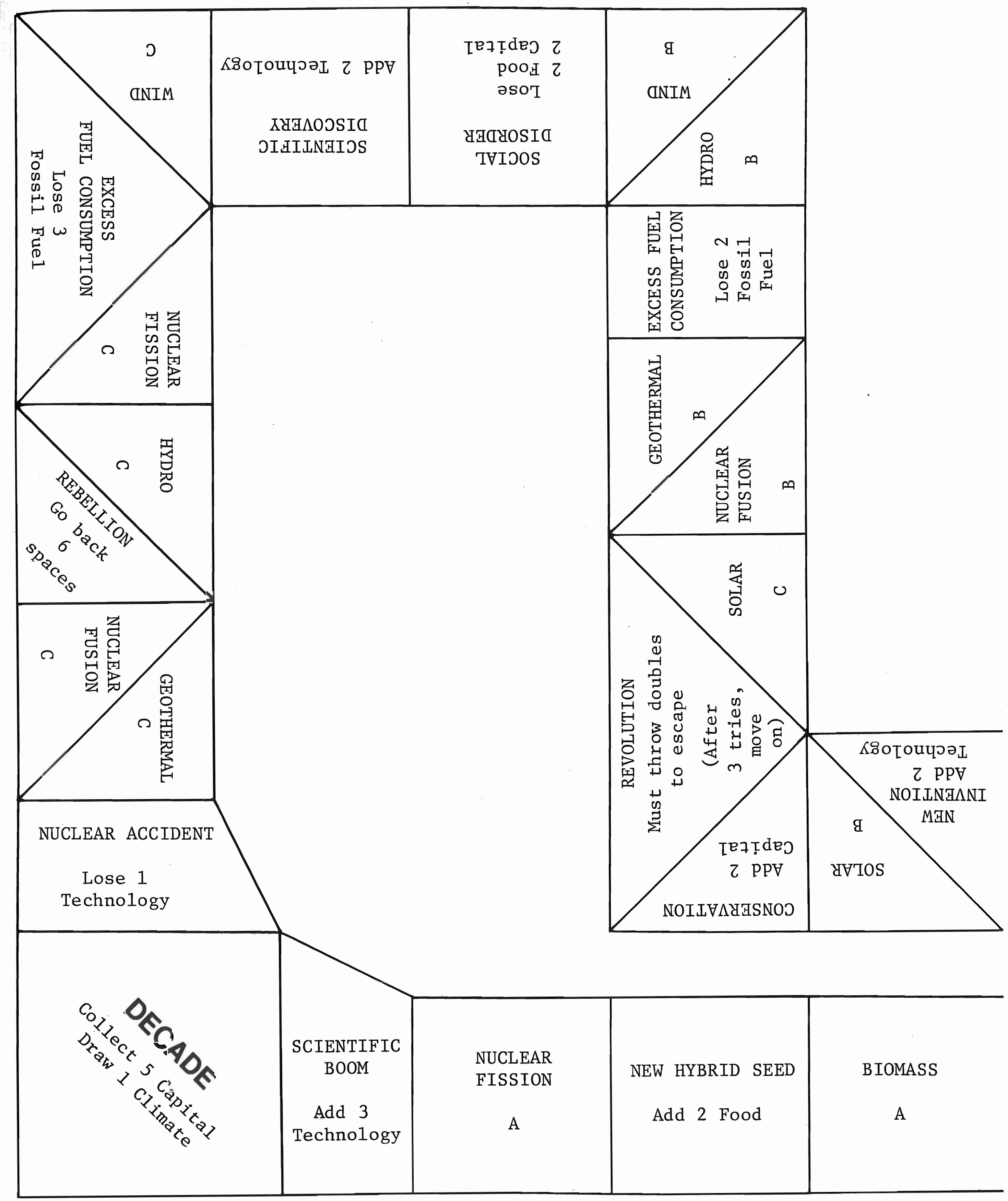
9. Players may trade cards among themselves at any time.

10. Whenever a player acquires all three spaces of the same non-fossil fuel, through either purchase or trade, a monopoly of that energy source is attained. Any player holding a monopoly on a non-fossil fuel is said to have become independent of fossil fuel-related penalties. (Example: The player need not pay penalties for oil spills and fires, but must pay penalties for nuclear accidents.) The player may also exchange Fossil Fuel cards for an equal number of Capital cards.

11. Whenever players land on or pass Decade, they each collect five additional Capital cards and draw one Climate card and follow its instructions. If all five players become independent of fossil fuels by acquiring monopolies of non-fossil fuels, no more Climate cards need be drawn.

12. If a player is unable to pay a penalty, either with cards in stock or obtained in trade, the obligation to pay the penalty passes to the left until it is paid. (Example: If Asia is short two Food cards to pay a penalty and Latin American has only one, Latin American pays its one Food card and the Middle East must pay the other.) Players need not compensate other players who are required to pay their penalties in this way.

13. The game can be ended in any of the following ways:
    a. One player obtains 25 Capital cards and becomes the winner.
    b. All players except one become bankrupt.
    c. A time limit is agreed upon, and the player who then has the largest number of cards (Capital, Technology, Food, and Fossil Fuels) is the winner, with non-fossil fuel squares valued at their purchase price.



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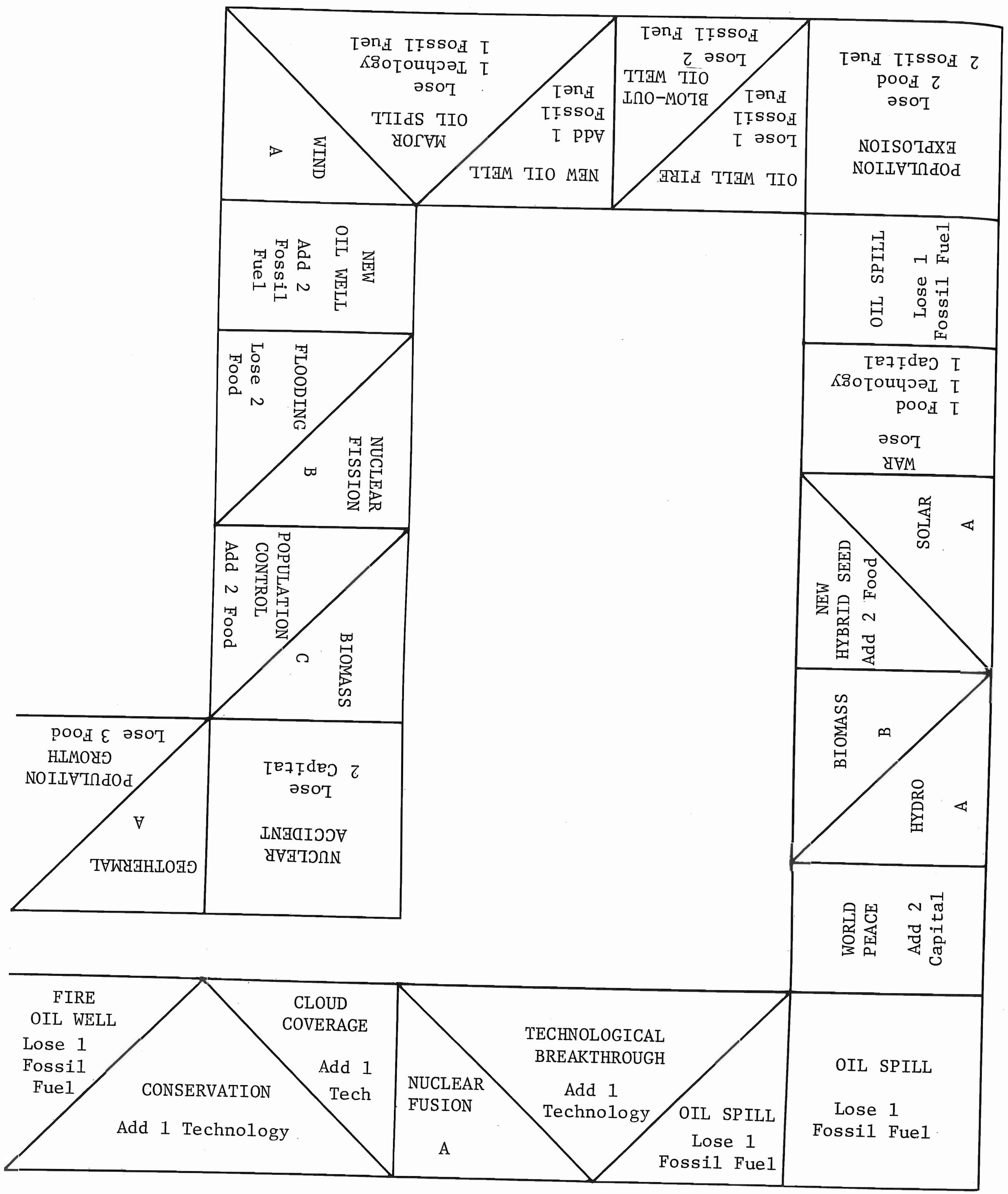
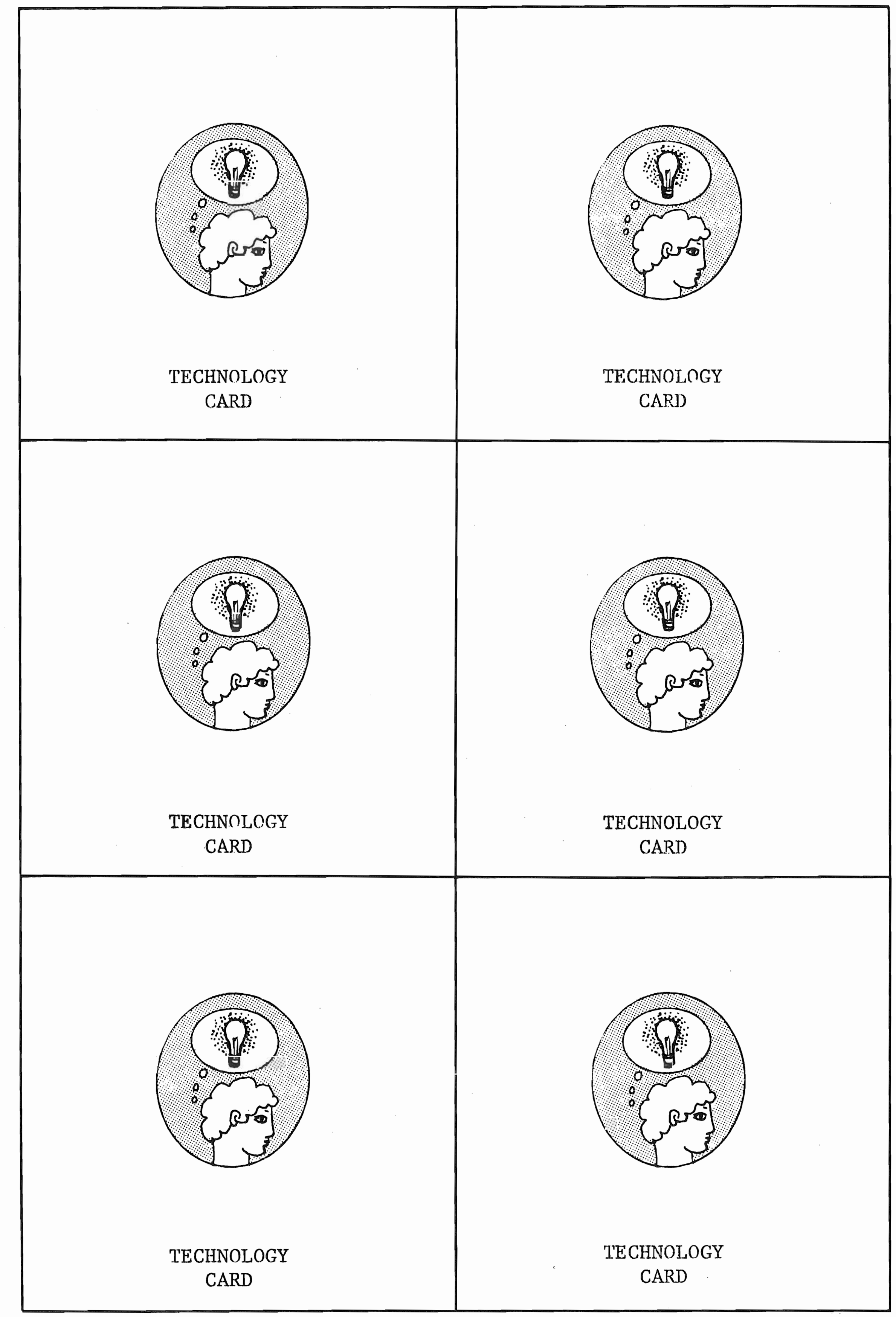




CAPITAL CARD

CAPITAL CARD

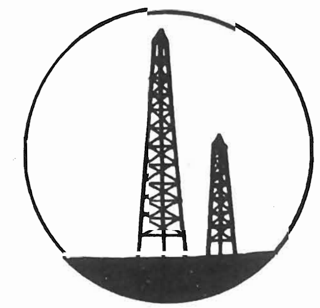
CAPITAL CARD

CAPITAL CARD

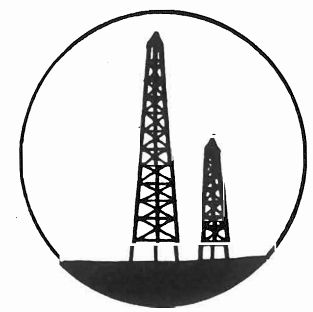
CAPITAL CARD

CAPITAL CARD

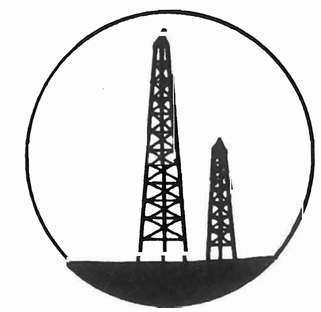
FOSSIL FUEL
CARD



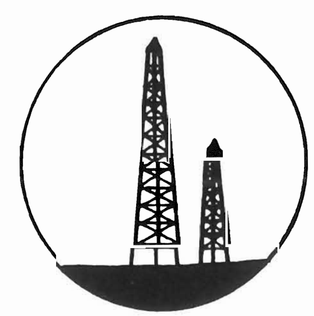
FOSSIL FUEL
CARD



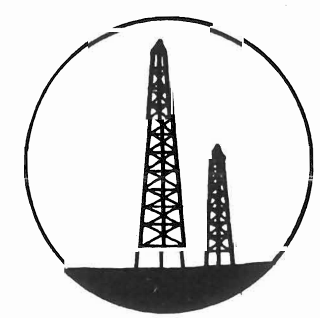
FOSSIL FUEL
CARD



FOSSIL FUEL
CARD



FOSSIL FUEL
CARD



FOSSIL FUEL
CARD

Duplicate this page 9 times.

 FOOD CARD	 FOOD CARD
 FOOD CARD	 FOOD CARD
 FOOD CARD	 FOOD CARD

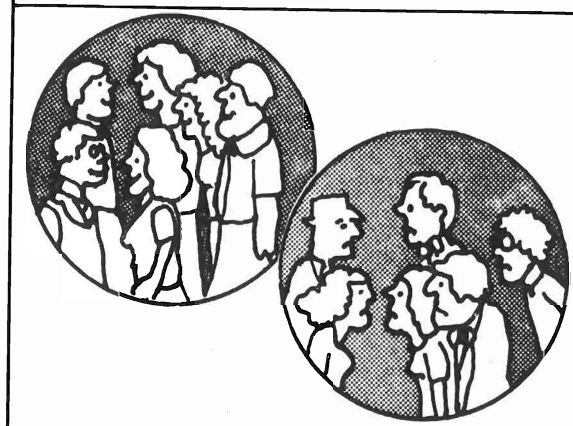
Duplicate this page once.

 CLIMATE CARD Temperature Increase Lose 3 Food	 CLIMATE CARD Temperature Increase Flooding Lose 2 Food Lose 2 Capital
 CLIMATE CARD Increased Rain Flooding Lose 3 Food	 CLIMATE CARD Temperature Increase Corn crop parched Lose 2 Food
 CLIMATE CARD Temperature Increase Growing season lengthens Gain 3 Food	 CLIMATE CARD Increased Rain Semi-Desert becomes arable Gain 2 Food

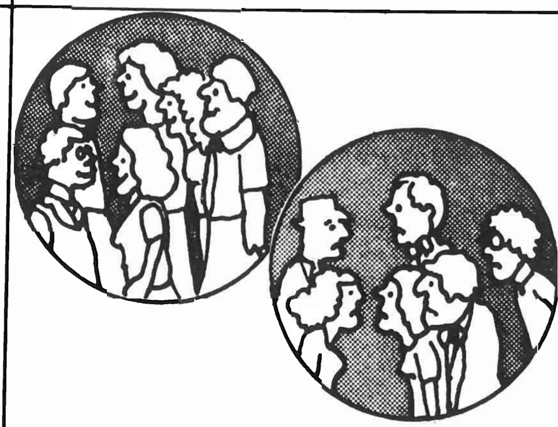
Duplicate this page once.

CLIMATE CARD
Increased Rainfall
Gain 2 Food
Gain 1 Capital

CLIMATE CARD
Decreased Cloud Coverage
Gain 3 Food
Gain 2 Capital
Gain 2 Technology



CLIMATE CARD
Temperature Increase
Gain 3 Food
Lose 2 Capital



CLIMATE CARD
Polar Ice Caps Melt
Gain 3 Food
Lose 4 Technology

CLIMATE CARD
Temperature Increase
Lose 3 Food

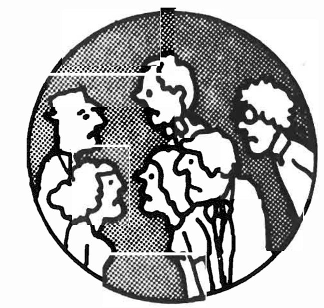
CLIMATE CARD
Temperature Increase
Lose 5 Food

Duplicate this page once.

CLIMATE CARD
Decreased Rain
Drought
Lose 2 Food

CLIMATE CARD
Climatic Disaster
Lose 2 Food
Lose 2 Capital
Lose 2 Technology

CLIMATE CARD
Increased Cloud Coverage
Solar plant out of commission
Lose 3 Food
Lose 2 Technology



CLIMATE CARD
Increased Cloud Coverage
Potato crop rots; no harvest
Lose 3 Food
Lose 2 Capital

CLIMATE CARD
Polar Ice Caps Melt
Lose 3 Food
Lose 4 Capital
Lose 2 Technology

CLIMATE CARD
Increased Cloud Coverage
Lose 5 Food
Lose 3 Technology

CLIMATE CARD
Flooding
Lose 2 Food
Lose 2 Capital

CLIMATE CARD
Climate Disaster
Lose 3 Food
Lose 3 Capital
Lose 3 Technology

CLIMATE CARD
Temperature Increase
Gain 5 Food

CLIMATE CARD
Decreased Rain
Semi-Desert Conditions
Lose 4 Food

CLIMATE CARD
Decreased Rain
Swamp lands drain
Gain 2 Food
Gain 1 Capital

CLIMATE CARD
Decreased Rain
Flood plain becomes arable
Gain 3 Food
Gain 2 Capital

A FISSION ENERGY	**A** FUSION ENERGY
B FISSION ENERGY	**B** FUSION ENERGY
C FISSION ENERGY	**C** FUSION ENERGY

A HYDROELECTRICITY	**A** GEOTHERMAL ENERGY
B HYDROELECTRICITY	**B** GEOTHERMAL ENERGY
C HYDROELECTRICITY	**C** GEOTHERMAL ENERGY

A BIOMASS ENERGY	**A** SOLAR ENERGY
B BIOMASS ENERGY	**B** SOLAR ENERGY
C BIOMASS ENERGY	**C** SOLAR ENERGY

Duplicate this page once.

A WIND ENERGY
B WIND ENERGY
C WIND ENERGY

REVIEW SHEET

(Cover when duplicating for students.)

1. Who won? Why? In terms of the world's energy future, are there different ways to "win," that is, to avoid the uncertain consequences of burning fossil fuels?

2. How many regions developed non-fossil fuel options (in the sense of acquiring a monopoly)? How many failed? Compare each region's success in developing non-fossil fuel options with its availability of capital and technology.

3. Upon passing or landing on the "decade" square, players who have eliminated their dependence on fossil fuels by acquiring a monopoly of a non-fossil fuel still have to draw a Climate card and suffer its consequences until <u>all</u> players have eliminated their dependence on fossil fuels. Is this fair? Is it realistic?

4. In the game, the Climate cards each name a possible environmental effect of CO_2 buildup in the atmosphere. Why are these effects so different from one another? Are any of them related? Consider reasons for the stated penalties and rewards on these cards as they relate to the indicated environmental impact.

1. Possible explanations include the different types of non-fossil fuel options and the need for capital and technology (in short supply in some regions) to develop them. One essential ingredient for avoiding the uncertain consequences of burning fossil fuels is international cooperation.

2. Possible explanations would include the chance elements of the game, but there will probably be some correlation between capital and technology and the success in developing non-fossil fuel options.

3. This may not seem fair, but it <u>is</u> realistic. The consequences of burning fossil fuels are global. The consequences of the behavior of one region are felt by all.

4. The variable consequences reflect the current uncertainty surrounding the actual effect on the world's climate of a massive atmospheric buildup of CO_2. This uncertainty extends to the relationship among possible effects and thus, the rewards and penalties associated with them. For instance, temperature and rainfall are likely related; as temperature increases rainfall is expected to decrease. At the same time, however, the water supply from another source would be differently affected: glacial melting is an anticipated outcome from a significant increase in world temperature. Each of these factors bears upon agricultural considerations, but again, in different ways. In some regions of the world, a temperature increase would serve to beneficently

extend the growing season, while elsewhere it could act to burn crops on the vine. The associated decrease in rainfall would be similarly variable in consequence. The floods likely to result from glacial melting, however, would be devastating across the board--not just to food crops but to the land where people live and work (hence the penalties costing capital and technology). More negative than positive effects on the climate are expected from increased CO_2 buildup; hence the proportion of Climate cards for each general outcome. A few cards, true to form, have a mixture of rewards and penalties to emphasize both the uncertainty and interconnectedness of the issues.

5. You have no doubt heard something about the "greenhouse effect." How can CO_2 function as the glass on a greenhouse? Why won't people and their enterprises fare as well as, say, a hothouse tomato?

5. A greenhouse glass admits both heat and light, but reradiates only light. The heat it stores and allows to be put to use within the greenhouse to create an artificially warm environment for growing plants. A layer of CO_2 in the atmosphere would behave similarly, blocking the earth's reradiation of hot infrared rays back into space. The increase in temperature resulting from the blocked radiation would create an unknown climatic circumstance surrounded by uncertain consequences. Unlike a greenhouse, which is carefully controlled and controllable for temperature, air circulation, humidity, etc., the earth's climate and the weather issuing from it cannot be similarly controlled. What we can control is the rate and level at which CO_2 is released into the atmosphere by the burning of fossil fuels.