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ABSTRACT

Following a discussion of goals of energy education and a list of characteristics describing an energy-literate citizen, 13 sections are presented identifying generalizations which might form the basis for the development of energy curricula, whether for infusion or course development. In some cases, commentary follows the generalization. Titles of sections include conversion and measurement of energy; energy flow in the biosphere; human use of energy; energy history of the United States; energy from fossil fuels; energy from nuclear reactions; energy from solar technologies; electricity as an energy carrier; economic and financial aspects of energy use; ethical issues in energy use; conservation of energy; shelter-related conservation; and transportation conservation. Titles are not meant as proposed units, courses, modules, or curricular parts, but serve as a way to organize the generalizations. Citations in brackets following a generalization refer to existing curriculum materials which treat that topic. Examples of energy-related objectives, widely-used texts, and energy curriculum materials for social studies, and science are provided along with brief comments on meeting needs of special learners. An extreme bibliography is also provided. (Author/JN)

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Comments from users and other persons interested in energy education would be greatly appreciated. They should be directed to:

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Contents

FOREWORD

Status and Need for Energy Education

Energy is rapidly emerging as a new area of study in American elementary and secondary schools and community colleges. Though energy has always been a major topic in physics and general science, and more recently in environmental studies, recent events have dramatized the usefulness of a broad, more comprehensive public understanding of energy: broad, because every citizen's contribution is important, and more comprehensive, because solutions undertaken by individuals who have only looked at part of the problem have often proved to be part of the problem. Americans need a basic understanding of energy use and supply -- not just of its physics, or economics, or technology, or social implications, or national security or environmental aspects, but of their interrelationships.

National associations, federal and state agencies, and other groups have already accomplished landmark work in energy education, but much work remains to be done, particularly at the district level.

Intended Audience and Purpose of Publication

This report is intended as a tool for curriculum specialists, writers of textbooks, and producers of other forms of curriculum material. It is not meant for the classroom teacher; still less for use by students.

In funding the preparation of this report, it was explicitly not the intention of the Department of Energy to suggest that there is one best energy education framework, or to urge the adoption of any part of the contents by any educational body. The need it was meant to fill can perhaps best be understood by looking at a different field. Imagine two social studies curriculum specialists, from school districts three thousand miles apart, meeting at a convention. Falling into a discussion of their third-grade programs, they quickly inform each other about what is new and distinctive in their programs. A single phrase, "community helpers," recalls a vast array of teaching methods that work (or have been found wanting), curriculum materials, articulation with earlier grades and later courses, alternative courses of study and arguments for and against them. What she says works is likely to be valuable to him; he can place her suggestions in the context of his district's objectives. The scope of the background the two specialists share -- exposure to decades of textbooks slowly ringing changes on the theme of community helpers, classroom experiences with dozens of attempted innovations, many years of journal reading -- greatly facilitate their communication.

For the most part, energy education has not yet accumulated such a common basis for exchange. The present report was prepared in the hope that a comprehensive and specific spelling-out of possible contents, however preliminary, would contribute to the development of a common vocabulary among energy educators, and by facilitating discussion lead to clearer identification of issues and more rapid progress in implementing effective programs at the state and local level.

ADVISORY GROUP

Institutional affiliations are provided only for purposes of identification. These individuals gave generously of their time in reviewing a document that became much larger than anyone had anticipated. Each has quashed error or added insight. They are not, obviously, responsible for the shortcomings that remain; nor does the report necessarily reflect their opinions.

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GOALS OF ENERGY EDUCATION

An ethical choice of what shall be taught rests on two judgments:

What will contribute most to the well-being of the learner during her or his lifetime?

What will contribute most to the present and future well-being of society?

Behind such choices is the assumption that when a student grows in understanding and abilities, the range of life choices open to that student increases. The quality of life in a society can be improved when individuals choose rationally among possibilities opened to them by education. By taking thought, human beings create alternative futures for themselves and their kind. Through their decisions on what shall be taught, educational policymakers make one range of futures possible -- and foreclose on others.

The human species faces an energy problem. So it always has; but today that problem is more critical. Supplies of fuelwood are dwindling in the parts of the earth where people depend upon wood as their principal fuel; and in our country the supply of our major fuel, petroleum, is full of uncertainties. These problems are certain to continue throughout the lifetimes of today's students, and probably of at least the succeeding generation as well.

To a large extent, people created the energy problem. The technology of energy use and extraction, our laws and governmental institutions, our industrial organizations -- all are the results of people taking thought, and depend on accumulated knowledge. Solving our energy problem -- making adaptive changes in energy supply and use -- will also depend on people talking thought, and on the skills they bring to that process.

Formal education excels in imparting knowledge and building cognitive skills. Because of this, it can be one of the most effective and appropriate means of smoothing our society's way through an energy transition. Individuals need to make informed, rational choices about how energy will be obtained and used.

Utilizing the formal educational system to prepare individuals to make such choices requires the identification of fundamental goals relevant to all grade levels and content areas. The following goals, three cognitive and two affective, are suggested for consideration:

1. Formal energy education should enable students to recognize energy and energy conversions and should create an awareness of its pervasive role in our lives, our economy, and our society.

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Historically, the concept of energy is at most a few hundred years old, but it has proven to be extremely powerful. A grasp of the concept of energy -- which is evidenced by the ability to recognize energy in various forms -- increases the individual's ability to deal rationally with the surroundings. For example, an individual who recognizes waste heat as a potential energy source, or who recognizes the embodied energy in durable goods, is on the way to getting more out of the energy he or she uses.

The nation would also benefit, because this understanding increases the ability of its citizens to adapt their habits, technology, and even their society to changing circumstances.

2. Formal energy education should enable the student to acquire skills in energy use and management, at home, at school, and on the job.

Particular skills can often be identified that would benefit particular groups of learners, sometimes very large groups. For example, as future consumers all students would benefit from acquiring the skills necessary to judge the return on making a higher expenditure for a more energy-efficient appliance, car, or house. Architects can benefit from acquiring skills in estimating energy use of buildings, and in employing design alternatives. When the future activities of any group of learners can be predicted in occupational terms, such as building trades or agriculture, useful energy-related skills can usually be identified.

The nation benefits from the acquisition of such skills by individuals, because the application of these skills reduces the waste of an increasingly scarce good (increasing the efficiency with which energy is used) and thus increases the wealth available to the society.

3. Formal energy education should provide students with enough scientific and technical knowledge to participate knowledgeably in the formation of public policy.

A wider understanding of basic facts could forestall fruitless effort, both individually and nationally. Some people are still buying perpetual motion machines. An important aspect of this goal is that energy education must provide students with the skills needed to keep learning about energy during their adult lives.

The nation as a whole would be the chief beneficiary of the realization of this goal, if one agrees that a democratic society functions best with a knowledgeable electorate.

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4. <u>Formal energy education should give the student realistic hopes for our energy future.</u>

Some of today's students feel that the party is over and that no matter what they do, "there is no future." In reality, there are probably more possibilities open to humankind now than ever before, and many attractive futures. These cannot be realized, however, without action; and without hope, there is no action. Energy education should give students hope by making them aware of consequences, desirable to them, which they can bring about.

Realization of such a goal would benefit individuals by giving them a sense of control over the events in their lives. It would benefit the nation by leading to action toward desirable ends.

5. <u>Formal energy education should lead students to weigh their decisions about energy supply and use in the light of their moral and ethical values.</u>

In making decisions about the production and use of energy, it should occur to students to apply the same personal values they apply to other aspects of their lives. (Notice that this goal does not call for inculcating personal values. Whether those values are prudence, fairness to others, enterprise, thrift, and self-reliance -- or hedonism, self-indulgence, macho recklessness and hubris -- is believed by many to be the business of the individual student and her family, and not of the public school.)

Realization of such a goal would contribute to the integrity of individuals, and so to their well-being. For the nation as a whole, it might contribute to the stability of policy, and to agreement on long-range ends and acceptable means in the many decisions the nation will face in the coming years.

ENERGY LITERACY

Another way of stating the goals of energy education is to describe an energy-literate citizen. Some examples of the characteristics of such a person might be:

- Understands that we can't make energy.
- Finds more efficient ways to use energy at home, at school, and on the job, for example through the use of waste heat.
- Has some historical perspective on energy use and extraction; for example, has an informed notion of where we stand on the fossil fuel depletion curve.
- Compares life-cycle costs in deciding on major purchases.
- Invests to save energy, for example by purchasing home insulation when it is cost-effective.
- Knows how much energy is being used in his/her household and where it goes.
- Is aware of the major sources of the energy used in his or her immediate job and in the economy as a whole, including their relative size.
- Understands that all energy use and production has a cost, including an environmental cost.
- Traces energy flows and thinks in terms of energy systems, not just individual components.
- Tries to match energy-quality to energy use.
- Is aware of his/her home's orientation to sun and wind, and takes whatever advantage of it is possible.
- Supports long-term national efforts to improve energy efficiency.
- Understands a variety of ways of reducing energy use in personal transport.
- Understands how active and passive solar heating work.
- Understands how refrigerators, air conditioners and heat pumps work, and uses them efficiently.
- Keeps learning about energy.

MODELS FOR THE IMPLEMENTATION OF ENERGY EDUCATION

There are two ways, not mutally exclusive, that what educators and school boards decide to teach about energy can be introduced into the curriculum:

Infusion, in which energy-related lessons and units are introduced at appropriate points in existing courses of study. This approach is exemplified in the units created by the Project for an Energy-Enriched Curriculum (National Science Teacher's Association), the Energy Education Curriculum Project (Indiana Department of Public Instruction), and others. Examples of these materials are listed in section three of this report.

Course development, in which a new course is introduced into the curriculum. Examples of such courses are the Solar Installer's Course created by California's Office of Appropriate Technology or the survey courses in energy, emphasizing science in society, which are now being taught at the freshman and sophomore levels in some colleges.

CONCEPT OUTLINES AND COMMENTARY

The following sections identify related generalizations that might form the basis for the development of energy curricula, whether for infusion or course development. In some cases, commentary follows the generalization.

Citations in brackets following a generalization refer to existing curriculum materials which treat that topic. The list of references begins on page 119. References have been included because it was felt that curriculum planners find it helpful to examine other's efforts in assessing how and whether particular content can be taught in their particular situations. Listing of a publication does not imply endorsement.

The section headings are merely a convenient way of organizing the generalizations. They are NOT meant as proposed units, courses, modules, or other curricular parts.

The generalizations are not necessarily presented in an order in which they could be most effectively taught, because the optimal sequencing varies with grade level, subject matter context, and so forth. The curriculum developer will have to work out a concept development scheme suited to the particular circumstances.

In each of the sections, the most fundamental generalizations have usually been given one-digit numbers. In some cases, subordinate items are those which are prerequisite to understanding the item on which they depend (e.g. to understand 1 the student must understand 1.2); in others they represent "enrichment" items, examples, or consequences of the main idea. No single method of outlining appeared to fit all the relationships between topics that needed to be treated.

Each section concludes with a brief list of selected reference materials that might be of value to the curriculum developer.

Selected General References

This includes general works which may be useful sources of background information for curriculum specialists. While the content may be technical, the works in this list address a general audience, and not, for example, professional engineers.

Hollander, Jack M., M.K. Simmons, and D.O. Wood, editors. Annual Reviews of Energy. Issued annually in October; volume 1 was published in 1976. Palo Alto, CA: Annual Reviews. Excellent series, each volume consisting of approximately 15-20 lengthy articles solicited from

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recognized authorities. Current volume includes a cumulative index to titles of articles in all volumes.

Loftness, Robert. 1978. Energy Handbook. New York: Van Nostrand Reinhold. A wide-ranging clipping file which brings together figures and tables from hundreds of sources; handy for standard sources, very valuable for material difficult to locate in the original.

Parker, Sylvia P. 1981. McGraw-Hill Encyclopedia of Energy, Second Edition. A broad selection of articles from the multi-volume McGraw-Hill Encyclopedia of Science and Technology, some of them revised for this publication, and augmented by a few feature articles. Well-illustrated; highly-qualified contributors, technical without assuming technical expertise.

United States Congress, 96th Congress, 2nd Session. Committee Print 96-IFC-60. The Energy Factbook. Data on Energy Resources, Reserves, Production, Consumption, Prices, Processing, and Industry Structure. November 1980. Washington, DC: U.S. Gov't Printing Office. Prepared by the Congressional Research Service, Library of Congress, for the Subcommittee on Energy and Power. One of the most up-to-date of the compendia of energy statistics.

United States, Department of Energy, Energy Information Adminstration. Issued annually, see current year. Annual Report to Congress (three volumes). Washington: U.S. Gov't Printing Office. The most up-to-date information on energy flows in the national economy.

United States, Department of Defense, Navy Energy Office. May 1979. Department of the Navy Energy Fact Book. Useful for the discussions and illustrations of newer technologies such as synthetic fuels, magnetohydrodynamics, and fuel cells.

I. CONVERSION AND MEASUREMENT OF ENERGY

1 Energy exists in many forms.
Conventionally six forms have been discussed in elementary texts. Students should not be led to believe this set is anything other than a convenience. There are numerous possible classifications.

1.1 Heat is the energy that flows between objects with different temperatures.
Like work, heat is a form of energy in transit. An object cannot contain heat any more than it can contain work, and teachers should avoid such phrasings as, "Which of these jars contains more heat?"

1.1.1 Molecules are always in random, disorderly motion. In solids this random motion takes the form of vibration around a position. Contrast this disorderly motion with the orderly motion of a mass accelerated by a force.

1.1.2 Temperature is related to the average velocity of the molecules. The faster their motion, the higher the temperature.

1.1.3 Heat can flow from one object to another by conduction, radiation (see 1.2.2 below), or convection.

1.1.3.1 The greater the difference in the temperatures of two objects, the greater the rate of heat flow between them.

1.2 Light is a form of energy. (radiant energy)

1.2.1 Light has a property called wavelength.

1.2.1.1 Some wavelengths of radiant energy are not visible to the human eye.

1.2.1.2 Substances like window glass can be transparent to light of one wavelength and opaque to light of another wavelength.

1.2.1.3 Surfaces can absorb light of one wavelength more strongly than light of another.

1.2.2 All bodies with a temperature above absolute zero emit radiant energy; the wavelength depends on the temperature.

1.2.3 The more nearly perpendicular a beam of light is to a surface, the greater the intensity.

1.3 Motion is a form of energy. (kinetic energy)
As mentioned above, heat can be considered a type of kinetic energy.

1.4 Electrical energy is a form of energy.
The kinetic energy of the moving electrons.

1.5 Energy can exist as latent or potential energy.

1.5.1 An object can store energy by virtue of its position in a gravitational field.

1.5.2 Substances can possess stored energy which is released in chemical reactions. (chemical energy). [Oak Ridge 1977a]

1.5.2.1 Chemical energy results from the arrangement of the substance's molecules.

1.6 Matter can be regarded as a form of energy. (nuclear energy) See 3.3 below and VI.

2 Energy can change from one form to another.
2.1 Example: Friction converts mechanical energy to heat.
2.2 Example: Light is converted to heat when objects absorb light.
2.3 Example: Magnetic fields are often used in the conversion of electricity to motion, and vice-versa.

3 No energy is lost in any energy conversion. (The First Law of Thermodynamics, or Law of the Conservation of Energy) Because of the fundamental importance of teaching this law, teachers should probably avoid confusing students by speaking of "producing" energy or "making" energy.
3.1 Energy cannot be made. It is converted from some pre-existing form.
3.2 Energy cannot be consumed or destroyed. When it appears to have been destroyed, it has only been converted to some nonobvious form, usually low-temperature heat.
3.3 Matter can change to energy and energy to matter.
3.3.1 $E = mc^2$
3.3.2 The mass of an object increases as it accelerates. Below the senior high school level, this is useful only as an example to satisfy student curiosity about conversion of energy to matter.

4 Human use of energy almost always involves converting it from one form to another.

5 As energy changes form, less of the energy is available for conversion to work, and more of it becomes heat. (Second Law of Thermodynamics) (This is not true of reversible changes of kinetic to potential energy, e.g., in a pendulum.)
5.1 Some energy transformations are irreversible: when work is changed to heat, not all the heat can be changed back to work.
Since all practical energy conversions involve the conversion of at least some of the energy to heat, it follows that all practical energy conversions are to some extent irreversible.
5.2 It is impossible to have a net flow of heat from colder objects to warmer ones.
5.2.1 In time, a system tends to become monotonously lukewarm as cold objects warm up and hot objects cool off.

6 When people convert energy from one form to another, some of the energy usually ends up being converted to a form the person did not want. In most practical energy conversions, some undesired heat is produced. [Energy 80, 1981; Young 1981]

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6.1 The ratio of the energy obtained in the desired form to the energy put in is called efficiency. Efficiency is often expressed as a percentage.

6.2.1 Different ways of doing the same thing can differ greatly in efficiency, for example fluorescent and incandescent lighting.

6.2.2 With the passage of time people have invented more efficient ways of converting energy from one form to another.

6.3 Every energy conversion has a maximum theoretical limit on its efficiency.

6.3.1 The practical efficiency of any energy conversion device will always be less than the theoretical efficiency of the process used.

6.3.1.1 The closer the practical efficiency comes to the theoretical efficiency, the smaller the gains likely to be achieved by further efforts to increase efficiency.

6.4 In comparing the efficiencies of various methods of using energy, we should compare the entire system and not just the parts.

6.4.1 The efficiency of a system is equal to the product of the efficencies of its parts.

6.5 At present, the chief source of mechanical power for humans is the conversion of heat to work.
Devices which convert heat to work are called heat engines. Examples are steam engines, gas turbines, and internal combustion engines.

6.5.1 In a heat engine, heat flows from a reservoir at one temperature (the source, such as a boiler) to a reservoir at a lower temperature (the sink, such as the atmosphere).

6.5.1.1 A gas or liquid is used as a working fluid to transfer the heat.

6.5.1.2 Part of the heat is changed to work.

6.5.1.4 Water wheels and windmills are also heat engines when the earth's atmosphere is considered part of the engine.

6.5.2 The maximum possible efficiency of any device that changes heat to work depends only on the temperature of the source and sink. [Hodges 1980]

6.5.2.1 In any practical heat engine, the sink can be no cooler than the temperature of the environment.

6.5.2.2 The efficiency of heat engines has been raised by raising the temperature of the source.

6.5.3 The quality of any energy source depends on the ease with which it can be converted to work.

6.5.3.1 Forms of energy that can be converted to work with a theoretical efficiency of 100%, such as electricity, are high-quality forms of energy.

6.5.3.2 A large percentage of the energy in heat

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sources that produce high temperatures can be converted to work by heat engines, so these represent a high quality source of energy.

6.5.3.3 Heat at the ambient temperature cannot be converted (net) to work, and so is a low-quality form of energy.

6.5.3.4 Converting high-quality energy sources to low-temperature heat (i.e., near the ambient temperature) involves a loss of available work.

7 Energy can be measured.

7.1 Heat energy can be measured.

Heat appears to be the easiest form of energy for students to measure, and the activity contributes to building the useful skills of thermometer and graduate reading. Unfortunately, there does not appear to be any practical way for students to measure directly in the basic Systeme Internationale (SI) unit of energy, the joule.

7.1.1 A quantity of heat can be measured by measuring the mass heated and the temperature interval if the specific heat of the mass is known. Since specific heat is defined so that water is one, this can be approached through an activity at the upper elementary level and above.

7.1.1.1 A calorie is the amount of heat needed to raise the temperature of one gram of water one degree Celsius.

(At 15°C, but this further stipulation seems unnecessary below high school physics.) A food Calorie (capital C), also called a kilocalorie or a kilogram calorie, is equal to 1000 small calories. Because this is a frequent source of confusion, it deserves some special attention.

7.1.1.2 A British thermal unit (Btu) is the amount of energy needed to raise the temperature of one pound of water one degree Fahrenheit. (At 39.1°F, which can be neglected below the senior high school level.) It is necessary to include consideration of the Btu, even though it is not an SI unit, because it is the energy unit most frequently encountered in the sources of information available to the citizen, e.g. U.S. government reports, the labels on furnaces and air conditioners, etc.

7.1.2 The heat produced by burning a given quantity of a fuel or by metabolizing food can be measured.

7.1.3 Measurements of energy can be converted from one system of units to another, e.g. from English measure to SI units.

7.2 Work can be measured.

7.2.1 A mass can be made to move only by applying a force.

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7.2.1.1 A force can be measured. It can be described by the acceleration the force produces in an object and the mass of the object.

7.2.2 Work is equal to the product of a force and the distance through which the force moves in the direction of the force.

7.3 Electrical energy can be measured.

7.3.1 Most household appliances are marked with electrical ratings, typically watts or amps, and often volts.

7.3.1 Amperes measure the strength of an electrical current (the number of electrons going by). (But the ampere is defined in terms of a force between parallel, current-carrying wires.)

7.3.2 Watts measure power, the rate at which electrical energy is being converted. (The watt is energy converted at the rate of one joule per second.)

7.3.3 Volts measure electrical potential.

7.3.4 Electrical energy is measured by stating the power and the length of time that amount of power was consumed, for example watt-second, kilowatt-hour.

7.3.4.1 The watt-second is called the joule and is the fundamental unit of energy in the SI.

7.4 A measurement of energy in one form can be converted to a measurement of an equivalent amount of energy in another form. For example, Btu's can be converted to watt-hours.

7.5 Power measurements measure the rate at which energy is being transformed. This point deserves special attention as students often confuse measurements of power and energy.

7.5.1 The watt is a measure of power; the watt-hour is a measure of energy.

7.5.2 Horsepower is a measure of power; horsepower-hours measure energy.

7.5.3 The use of simple machines changes the amount of power needed to perform a task, but not the amount of energy.

7.6 Energy measurements are necessary when energy is bought and sold.

7.6.1 Electrical energy is sold by the kilowatt-hour.

7.6.1.1 The electrical energy purchased by a household is measured by a watt-hour meter.

7.6.2 Natural gas is sold by the Btu. The unit of billing is the therm, which is another name for 100,000 Btu.

7.6.2.1 The gas meter measures the volume of gas entering the building in cubic feet.

7.6.2.2 The measurement of cubic feet is converted to therms (100,000 Btu's) by multiplying by a correction factor that takes into account the heating value of the gas (which varies) and the altitude of the meter (which affects pressure and hence heating value).

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7.6.3 Utility bills provide consumers with measurements of some of the energy they consume.
  7.6.3.1 Subtracting the former reading from the current reading gives consumption.
  7.6.3.2 Many bills indicate consumption in a comparable billing period a year ago, which can be used to assess conservation success.

Selected References

K.W. Ford, G.I. Rochlin, R.H. Socolow. 1975. Efficient Use of Energy. Part I - A Physics Perspective. AIP Conference Proceedings No. 25. New York: American Institute of Physics.

II. ENERGY FLOW IN THE BIOSPHERE

1 Almost all energy on earth has come from the sun.
The exceptions are tidal energy, which originates in the earth's and moon's kinetic energy, geothermal energy, which is largely due to radioactive decay, and human use of nuclear energy.

1.1 The sun's energy comes from a nuclear reaction: the joining of small atomic nuclei to make larger nuclei. This process is called fusion.

1.2 The output of energy by the sun is relatively constant over hundreds of millions of years.

2 Energy flows from the sun to the earth as radiation. (See I.1.2)

2.1 Sunlight warms objects it strikes: light is converted to heat.

2.1.1 Some colors absorb more sunlight than others. (Investigation)

2.1.2 Some materials are slower to heat and cool than others. (Investigation)

3 The changing spatial relation between the sun and earth is cyclical and predictable.

3.1 The apparent motion of the sun results from the earth's rotation and revolution.

3.2 The position of the sun can be specified by a vertical angle, called the altitude angle; and a horizontal angle, called the azimuth angle. (Investigation) The azimuth and altitude of the sun can be predicted for any location at any hour of any day of the year.

3.3 The altitude of the sun changes.

3.3.1 During the day, the altitude angle of the sun increases until it is at a maximum (i.e., the sun is highest in the sky) at solar noon, and then decreases until sunset.

3.3.1.1 Solar noon is not the same as clock noon.

3.3.2 Outside the tropics, during the year the maximum daily altitude angle of the sun occurs in summer, on the summer solstice. Between the winter solstice and the summer solstice the sun gets higher in the sky each day, and between the summer solstice and the winter solstice it gets lower.

3.3.3 Outside the tropics, the higher the latitude, the lower the maximum altitude angle the sun reaches.

3.4 The nearer the sun is to being directly overhead, the greater the intensity of the solar energy received on the earth's surface. (See I.1.2.3)

3.4.1 Sunlight is more intense at solar noon than at other times of day, other things (such as cloudiness) being equal.

3.4.2 Sunlight is more intense in summer than in winter.

3.4.3 Sunlight is more intense in latitudes where the sun is high in the sky than in latitudes where it is low, other things being equal. So it is warmer in the tropics (that part of the earth where the sun is sometimes directly overhead) than it is in the temperate regions.

4 Solar radiation provides the energy for the water cycle. (It has been estimated that about 23% of the mean solar power input to Earth goes into driving the evaporation-condensation cycle.)

4.1 By heating the water, sunlight promotes evaporation of water from the land and seas.

4.2 Winds transport the water vapor, which eventually condenses to form clouds, which produce rain.

4.2.1 Rising air cools as it expands.

4.2.2 In condensing, water vapor releases heat.

4.3 Since water that falls on surfaces above sea level can run down to the sea, it has potential gravitational energy.

5 Solar radiation provides the energy for the wind cycle.

5.1 Air flows between regions of the earth with different temperatures through convection, since cold air is denser than warm air.

5.2 Local winds, like sea and land breezes, blow from areas with cool surface temperatures to areas with warmer surface temperatures. Such temperature differences can be due to differences in the rate at which insolation changes the surface temperature.

5.3 Global winds blow (at the surface) from the arctic to the tropics.

5.3.1 The winds' direction is altered by the earth's rotation (Coriolis Effect).

6 Through photosynthesis, sunlight provides energy for life. (Not all life. Exceptions include certain bacteria and even some biological communities surrounding hot springs on the Pacific Ocean floor.)

6.1 All living things require energy to carry on their life activities.

6.2 Green plants convert light energy to chemical energy through a process called photosynthesis.
A vegetation-covered area converts roughly 2% of the visible light falling on it into chemical energy. Globally, through

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photosynthesis about 1,000,000,000,000,000 kWh of light energy are stored annually.

6.2.1 In photosynthesis, the energy of sunlight is used to join hydrogen atoms from water molecules and carbon and oxygen atoms atoms from carbon dioxide molecules to make complex molecules of carbohydrates. The oxygen from the water is released as a gas.

6.2.2 Green plants have special structures for obtaining the materials needed for photosynthesis, such as stomata and xylem.

6.2.3 Some of the cells in green plants have special structures called chloroplasts. Chloroplasts contain green pigments called chlorophylls which absorb the sunlight and begin the conversion to chemical energy.

6.2.4 Many green plants have special structures for storing the chemical energy produced by photosynthesis, such as tubers and the endosperm in seeds. Most of the energy humans get from their diet comes from such plant parts.

6.3 Through respiration, plants and animals obtain the energy stored in food.
The word "respiration" is used by biologists to refer to the "burning" of food to obtain energy.
Because students often fail to grasp the point, it should be emphasized that plants are just as dependent on respiration for their energy needs as animals.

6.3.1 In respiration, complex molecules are broken down into simpler ones.

6.3.2 The end result of respiration is that oxygen is combined with the remnants of the carbohydrate to produce water and carbon dioxide, and energy is released.

6.4 Photosynthesis and respiration make up a cycle, in which the materials are recycled (neglecting removal of carbon or oxygen from the cycle by geological processes).

6.5 Energy is passed from organism to organism through food webs, from plant to animal to animal. [Williams 1980]

6.5.1 Different organisms have different roles in a food chain.

6.5.1.1 Green plants, which obtain their energy directly from sunlight and convert light to chemical energy, are called producers. All food chains begin with producers.

6.5.1.2 Herbivores, organisms which eat plant tissue, are primary consumers.
6.5.1.3 Carnivores, which eat the tissue of other animals, may be secondary, tertiary, or higher consumers.
6.5.1.4 Decomposers are microscopic organisms, including fungi, that break down uneaten materials, releasing their nutrients for use by green plants.

6.5.2 At each stage of a food chain, most of the energy taken in by an organism is lost as heat and is not available to the organism that eats.
The amount of loss varies, but is approximately 90% per step. This is a biological example of the Second Law of Thermodynamics (see I.5)

6.6 The human food chain in industrialized nations has many energy inputs besides sunlight (though only sunlight is converted to the chemical energy in food). [Brock 1978; Freiberg 1980; Gray 1980; Washington State 1979]
6.6.1 Fossil fuels are used to produce fertilizers, herbicides, and pesticides.
6.6.2 Fossil fuels are used for tillage, irrigation, harvesting, and other farm operations.
6.6.3 Energy is used for off-farm processes like transportation, refrigeration, processing, and packaging.
6.6.4 Farming methods differ in their energy-intensity.
6.6.5 Diets differ in their energy-intensity.

7 Heat produced by combustion of once-living materials like firewood comes from light energy captured by photosynthesis.
7.1 Heat produced by combustion of products produced from once-living materials, such as alcohol or methane, comes from sunlight.
7.2 The energy obtained from fossil fuels reached the earth as sunlight.
7.2.1 The fossil fuels were formed from once-living materials through geological processes.
7.2.2 Most of the fossil fuels were formed millions of years ago.
7.2.3 Coal is made from plants that grew in ancient forests. (Most of the deposits in Appalachia and the Midwest were laid down 325 to 230 million years ago; those in the Rocky Mountain states, Texas, Arkansas and Lousiana, about 140 to 3 million years ago.)

7.2.3.1 Falling plant matter was covered by water and decay was arrested, forming a material like the peat in peat bogs today.

7.2.3.2 The plant matter was covered by sediments washing over it.

7.2.3.3 The area was covered with shallow seas, enabling a deepening of the sediment layers.

7.2.3.4 Depth and geological processes like mountain building put increased heat and pressure on the plant remains.

7.2.3.4.1 Some peat was changed to lignite, some lignite to bituminous coals, some bituminous coals to anthracite.

7.2.3.4.2 With each step of this progression, water content decreased, volatile matter decreased, and the percentage of carbon increased.

7.2.3.5 Plant fossils can be found in coal.

7.2.4 Oil and gas were formed from microscopic sea creatures called plankton through processes similiar to that for coal, but on the sea bed. About half of the earth's oil deposits containing 40% of the reserves, are from the Tertiary (between about 10 and 70 million years ago).

7.2.5 Fossil fuels are formed very slowly, perhaps under special climatic conditions (warmth, amount of carbon dioxide in the atmosphere).

7.2.5.1 The present rate of extraction greatly exceeds the rate of formation.

7.2.5.2 The fossil fuels are a store of carbon (and to a lesser extent hydrogen) removed from the earth's carbon cycle. Combustion returns these materials to the cycles of the ecosphere.

7.2.5.1.1 Fossil fuel combustion is increasing the percentage of carbon dioxide in the earth's atmosphere, which in turn may cause global climate changes.

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III. HUMAN USE OF ENERGY

1. All human activities require energy.

1.1 Food energy is required to sustain life.
All life activities, even sitting and thinking, require energy.
1.1.1 For normal activity, an adult human requires about 2500 kilocalories of food energy each day.
1.1.2 Physical labor increases the need for calories.
1.1.3 Changes in the rate at which the body is using energy are shown by changes in the rate of production of carbon dioxide. (See II.6.3.2) (Investigation)

1.2 For hundreds of thousands of years, humans have used fuels to provide energy for warmth and cooking.
(Remains of campfires a quarter million years old have been found.)

1.3 Humans use energy to provide artificial light.
1.3.1 People burned materials to make light, such as oil in lamps, and fats and waxes in candles.
1.3.2 The gas, petroleum and electrical industries all began as efforts to meet the demand for artificial light.

1.4 Humans use energy to obtain raw materials.
1.4.1 By at least 4000 B.C., people were using fire to extract metals from ores.
1.4.2 The group of industries that produce metals from their ores (such as smelters and refineries) is still the largest single industrial user of energy.

1.5 Humans use energy to manufacture goods and provide services.
1.5.1 Bronze Age people learned how to use fire to make pottery.
1.5.2 There is a broad correlation between consumption of energy and production of goods and services, BUT:
1.5.2.1 Countries, states, and communities differ significantly in the quantity of goods and services they produce per unit of energy consumed.
1.5.2.2 In our own country, the Gross National Product (GNP, a measure of the quantity of goods and services produced) is presently increasing faster than the increase in energy consumption.

1.6 Work (in the physicist's sense, energy that makes objects move) is a valuable form of energy to people.
1.6.1 The only source of work available to early societies was human musclepower.
1.6.2 During the Bronze Age, people learned how to use several new sources of work: domesticated animals like oxen, and sails to make the wind move a boat.
1.6.3. Windmills to grind grain may have been invented

around the seventh century (vertical axis) in Persia. The horizontal axis form was invented in the twelfth century in Northern Europe.

1.6.4 Waterwheels began to be used to grind grain around the beginning of the Christian era.

1.6.5 The first practical means of getting work from a fuel, the steam engine, was developed in the 18th century.

1.6.5.1 Practical internal combustion engines began to appear around 1860.

1.7 Humans use energy for transportation, communication and, in recent decades, information processing. [Childs, 1977; PEEC 1978]

1.7.1 Electronic data processing uses very small amounts of energy to control use of large amounts of energy, and sometimes makes possible great energy savings (for example, microprocessor control of heating, ventilating and air conditioning or of car engines).

1.8 Humans use energy to obtain energy.

1.8.1 All means of obtaining energy require the use of energy.

1.8.1.1 It is possible for more energy to be used in the obtaining of energy than is obtained.

2 Energy can substitute for other inputs in human economies, and sometimes other inputs can substitute for energy.

2.1 "Labor-saving" machinery often, but not always, means power-driven machinery. (An example of an exception is the ball-bearing, which saves labor by reducing the percentage of the mechanical energy which is converted to waste heat).

3 It is characteristic of human societies that, once energy needs for survival have been met, some energy is devoted to artistic purposes.

4 The flow of energy is a structuring force in society. (All forms of order in a society require energy for their maintenance.)

5 There has been a historical correlation between the development of specialization of labor and interdependence in a society, and its use of concentrated energy sources.

6 The ability and manner in which societies controlled energy resources often helps to explain historical developments, e.g., role of development of grain shipping technology in the rise of the Roman Empire, role of development of coal-fired ocean shipping in the British Empire, atomic energy in the postWW II era, fuel wood depletion and political developments in the Third World today.

7 Exponential growth rates in the use of energy lead to physically impossible quantities in the foreseeable future, and therefore cannot continue.

IV. ENERGY HISTORY OF THE UNITED STATES

1 Fuelwood was the major source of energy from the earliest times to 1860.
   - 1.1 Cutting down the Eastern primeval forest to create farmland provided an enormous supply of felled wood; that resulted in relatively cheap fuel wood prices. (The cost approximated the cost of the labor of cutting it, except where the wood had to be transported a considerable distance.). Note that wood was NOT treated as a renewable resource, it was mined, the object being to get rid of the forest as quickly as possible.
   - 1.2 Because of the lower cost, per capita consumption of firewood was higher in the colonies than in European countries.
   - 1.3 Wood (made into charcoal) was used to produce iron and steel.
   - 1.4 The first American steam engines, including steamboats and railroad locomotives, were wood-fired.

2 Musclepower of people and animals was the chief source of mechanical energy for most Americans until the 1900's.
   - 2.1 Treadmills were used to convert human and animal muscle power to rotation of a shaft.
   - 2.2 Animals provided energy for inland transportation, by drawing wagons, urban railcars, canal boats, and other vehicles.
   - 2.3 Animals provided the energy for farm operations.
   - 2.4 Steam engines began to gradually replace musclepower in in the 1830s.

3 Windpower has been used in special conditions from early times.
   - 3.1 Wind energy powered coastal and trans-Atlantic shipping through the middle 1800's.
   - 3.2 Some windmills were used in New York in colonial days.
   - 3.3 Wind-driven D.C. generators and water pumps were used extensively in rural areas of the Midwest and Southwest until the 1930's, when the coming of electric transmission lines to rural areas largely displaced them.

4 Waterpower was the chief source of mechanical energy for factories until the time of the Civil War.
   - 4.1 Factories tended to locate at places where there was a fall of water, e.g. the "fall line" of the Atlantic states.

5 Coal became a major source of energy in the United States almost a hundred years after it was a major source in European nations.
   - 5.1 Early settlers had discovered coal deposits.
   - 5.2 Cheap, abundant fuelwood discouraged interest in alternative fuels, except where high temperatures were needed as for smithing or metalwork, and in large coastal cities where wood was more difficult to obtain and coal could be had by ocean shipping from Europe.
   - 5.3 Because of the limited development of the transportation

system before the railroads, it was difficult to move coal from the deposits to the market.

6 The development of the railroad system in the middle 1800's stimulated the use of coal (even though the first locomotives were wood-burning).

6.1 The railroads' need for iron for rails and rolling stock greatly increased the demand for iron. Coal was used to produce the iron, replacing charcoal.

6.2 Railroads provided a means of transporting coal to market, especially to ports from which the coal could be shipped to overseas markets.

7 Around 1885, coal became the major fuel in the United States.

7.1 The price of fuel wood rose rapidly in settled areas, as less forest was available. Areas around cities were deforested first, and wood is an expensive fuel to transport.

7.2 Rapid growth in the number of steam engines greatly increased demand for fuel.

7.3 In the home, new stoves especially adapted to burning coal instead of wood became widely available.

8 Machines that made more productive use of the energy from human and animal muscles were invented in the second half of the 1800's. Examples include horse-drawn or treadmill-powered farm implements, such as the reaper and cotton gin, and the sewing machine. Note that this change somewhat preceded and was related to, but separate from, the conversion to coal.

9 Demand for artificial light increased during the nineteenth century. Factors that might have led to this include the spread of literacy, and the rise of factories.

9.1 Before 1900, Americans used a variety of fuels for light.

9.1.1 Candles were made of tallow, an animal fat.

9.1.2 Oils made from lard or from sperm whale oil, turpentine, and other flammable liquids were burnt in lamps.

9.2 A lamp oil was produced from coal by destructive distillation.

9.3 Synthetic gas was made from coal and piped as an illuminant in cities. The first American gasworks was in Baltimore in 1816.

10 In Pennsylvania in the 1860's, a cheap way of obtaining oil was discovered.

10.1 Petroleum had been a known and desired commodity since the 1700's.

10.1.1 Petroleum had been an article of commerce for most of the 1800's, often under the name Seneca oil.

10.1.2 It was originally obtained as the Indians had, by skimming the surface of streams and pools.

10.1.3 Experiments with distilling petroleum showed that an excellent lamp oil could be refined from it.

10.2 Ways of drilling wells to obtain salt water (salt was needed in those days for the preservation of meat) had been developed. On a few occasions, such wells accidentally struck oil.

10.3 In 1858, a company was formed to deliberately try to bore an oil well for the production of lamp oil.
  10.3.1 In 1859, they struck oil in the first well attempted. (The Drake well) Note that though this well was the beginning of the American petroleum industry, it was NOT the first oil well.
  10.3.2 By chance, the oil field they found was extremely shallow (the discovery well came in at 69½ feet) and contained a type of oil which could be easily refined into a good lamp oil by the primitive techniques of the time.

10.4 The Drake well lead to an oil boom in Pennsylvania.

10.5 Other oil fields were discovered in other states, notably Texas.

10.6 The United States became the major exporter of kerosene (the lamp oil made from petroleum).
  10.6.1 Some of the heavier portions of the oil could be used as lubricants.
  10.6.2 The part of the petroleum that was too volatile to use safely in a lamp (e.g., gasoline) was a waste product.

10.7 By gaining control of the transportation, refining, and distribution of oil, by the 1890's the Standard Oil Company had obtained a virtual monopoly of the oil business. In 1911, the United States Supreme Court ruled the company was in violation of the Sherman Anti-Trust Act and ordered it broken up into competing companies.

11 The invention of the internal combustion engine provided a light-weight, portable source of mechanical energy. (Commercial production of reliable engines began around 1860.)
  11.1 The internal combustion engine was much lighter, horsepower for horsepower, than the steam engines of the time.
  11.2 The first engines used gas (not gasoline). Liquids could be used provided they could be easily vaporized. Experiments revealed that gasoline was a suitable fuel and it was readily available as a waste by-product of kerosene manufacture.
  11.3 The internal combustion engine made possible the inexpensive truck and automobile.

12 The automobile has been an important influence on the development of modern American society.
  12.1 The Ford Model T (1906) made available a cheap but reliable form of personal transportation.
  12.2 The automobile increased the mobility of the average American, and changed settlement patterns.

13 Demand for energy in the form of electricity increased greatly in the 20th Century.
  13.1 Electricity was first offered for sale in the United States in a small area of New York City in September, 1882, primarily as a source of light, a substitute for gas.
  13.2 Long-distance transmission became feasible with the develop-

ment of transformers and high-voltage AC transmission (1880s and 90s).

13.3 Hydroelectric sites began to be exploited in the 1890s, with constantly increasing scale.

13.4 New technologies were invented that could be powered only by electricity, such as radio, television, and the computer.

14 Ways of making new substances from fossil fuels were discovered. These new substances replaced older materials in some cases; in other cases the new substances provided properties not previously available.

14.1 In the nineteenth century, aniline dyes and pharmaceuticals were made from coal tar.

14.2 In the middle of the 20th century there was explosive growth in the petrochemical industry, including introduction of such new materials as:

1920s -- ethylene glycol for antifreeze
1930s -- neoprene, nylon, styrene and polystyrene
1940s -- synthetic rubber
1950s -- synthetic detergents, polyethylene, polyesters, urethanes

15 Use of coal was gradually replaced, in large part, by use of petroleum during the period 1880-1980. [Brown 1978; Kennedy 1980]
In 1907, coal provided the greatest percentage of the total energy supply that it has to date (78%). In 1918, absolute production peaked as did per capita consumption (6 tons per person per year).

15.2 Transportation switched to petroleum.

15.2.1 Trucks and automobiles took more of the transportation load as the system of roads improved.

15.2.2 After World War II, railroads replaced steam locomotives, which had been mostly coal-burning (oil-burning in the Southwest) with petroleum-burning diesel locomotives.

15.2.3 Shipping switched to firing boilers with oil instead of coal.

15.2.4. Petroleum-burning airplanes began to carry passengers and to a much lesser extent freight.

15.3 Residences switched from coal to gas and fuel oil.
In 1948, coal accounted for 48% of residential and commercial energy use; in 1977, less than 2%.

15.4 Fuel oil began to be used to raise steam, replacing coal in traditional boilers.

15.5 Electrical generation became the single biggest use of coal.

16 In the latter half of the twentieth century, natural gas began to be the largest single source of energy for a number of uses.

16.1 Gas utilities existed prior to the use of natural gas, manufacturing gas from coal. This created a distribution network and customer base.

16.2 In Ohio, natural gas began to be used for industrial purposes in the early 1800s.

16.3 Beginning in the 1920's and accelerating greatly after World War II, extension of the pipeline network brought gas to a large market, including households.

16.4 Gas replaced coal as the major home-heating fuel.

16.5 Increasing air pollution from increasing fuel consumption, including coal and gasoline, brought regulations that encouraged the use of gas in utility and industrial applications instead of dirtier-burning fuels.

17 The United States has become increasingly dependent on purchases of petroleum from other countries.

17.1 In the first hundred years of the petroleum industry the United States was the major exporter of petroleum.

17.2 In 1947, consumption of petroleum exceeded domestic production and the U.S. became a net importer of petroleum, which it has since remained. During this period Venezuela and other nations in the Caribbean were our major source of imports.

17.3 The U.S. government established import quotas for oil in 1959. In 1971, price controls were put on oil and not removed until 1981. During the period of price controls the world price of oil greatly exceeded the domestic price.

17.4 In 1971, domestic oil production began the first long-term decline in its history, while consumption continued to grow.

17.5 In the period 1970-75, control of oil production in other major oil-producing nations passed from the largely American-owned multi-national oil companies to national governments. (Examples of dates of nationalization: Mexico, 1938; Iran, 1951; Algeria, 1963-70; Iraq, 1964-1972; Kuwait, 1974-80; Venezuela, 1976; Saudi-Arabia, 1981.)

17.6 Demand for oil continued strong or increased in other oil-importing nations, as Europe and Japan made a transition from coal to petroleum after World War II, and development proceeded in formerly non-industrialized nations.

17.7 In the 1970's, a cartel of the oil exporting nations (OPEC) increased the world price of oil dramatically.

17.7.1 In 1973-74, world oil prices quadrupled. During the Arab-Israeli war, Arab oil exporters embargoed the U.S. and the Netherlands for their support of Israel. The high spot market prices that followed showed that much higher prices were obtainable.

17.7.2 In 1975-78, oil prices gradually declined in real terms, and consumption rose again.

17.7.3 In 1979-80, with production curtailed due to the Iranian revolution, the cartel of oil exporters again raised prices.

17.7.4 In 1980-81, due to continuing fall in consumption, many U.S. orders for oil were cancelled. This put pressure on those producing states which needed continued income for their development programs to reduce prices.

18 Beginning in 1955, nuclear energy became a source of electricity.
- 18.1 The crash program to develop the atomic bomb during WW II provided the resources to develop an understanding of fission and to build equipment such as enrichment plants.
- 18.2 Nuclear power plants were developed by the Navy for use in submarines. These designs formed the basis for the commercialization of nuclear power.
- 18.3 In 1979, nuclear power was the source of 11.5% of the electricity generated (one percent less than the previous year.) Use of nuclear power varied greatly from state to state. Some states obtained no electricity from nuclear energy; in four others, over half the electricity generated came from nuclear reactors.
- 18.4 In the 1970's, the rate of growth of nuclear power declined.
  - 18.4.1 Nuclear power did not appear to have a decided cost advantage over the main alternative for electrical generation, coal.
  - 18.4.2 Cost of new plants and time required for construction increased greatly.
  - 18.4.3 Opposition to nuclear power spread, chiefly because of concern over release of radioactive materials due to accidents or through storage of wastes.
  - 18.4.4 The accident at Three Mile Island, near Harrisburg, PA, dramatized for the general public the possibility of reactor accidents, and emphasized to investors the financial risk.

19 U.S. energy consumption has gone through several phases.
- 19.1 From 1850 to about 1950 energy production and consumption increased on a long-term trend of about 3% a year, with a dip for the Great Depression.
- 19.2 In 1973, '74, and '75, energy consumption fell for the first time since the Great Depression.
- 19.3 After increasing in 1976, '77, and '78, it fell slightly or was stable in 1979, dropped in 1980, and continued falling in 1981.

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V. ENERGY FROM FOSSIL FUELS

1 Coal has been used intensively for only a few centuries.

- 1.1 People knew coal would burn (Chinese, circa 100 B.C., mentioned by Marco Polo around 1295 A.D.; Greco-Romans circa 300 B.C.; Europeans, 1200 A.D.; Hopi, circa 1200 A.D.) hundreds of years before it came into widespread use.
  - 1.1.1 Burning coal produced a more disagreeable smoke than did wood, the fuel people were accustomed to.
  - 1.1.2 Coal requires a stronger draft than wood or charcoal. Over the centuries, stoves and grates had been optimized for wood and were not well-suited to burning coal.
- 1.2 Developments during the Industrial Revolution in England greatly increased the use of coal.
  - 1.2.1 The invention of a way to use coal to smelt iron (by converting the coal to coke) made it possible for coal to replace wood charcoal in the iron industry (invented 1709, major improvement in 1780s, general use by 1800). Increased demand for iron could not be met by the limited supply of wood.
  - 1.2.2 The invention and gradual perfection of the steam engine provided the first practical means of getting mechanical energy from a fuel, extended the coal supply by powering pumps that kept deep mines from flooding, and provided the forced draft needed for the new steel-making processes.
- 1.3 Coal was the primary energy source used during the period 1870-1940 to create the industrial world.

2 There are different kinds of coal.

- 2.1 Coals differ in the geological processes that occurred in their formation, producing types like peat, lignite, bituminous coals, and anthracite. (See II.7.2.3)
- 2.2 Coals differ in their heating value. For example, lignite has a heating value of about 7200 Btu per ton, bituminous coal around 14,500.
- 2.3 Coals differ in the relative amounts of pollution-causing impurities which they contain.
  - 2.3.1 Some coals contain more sulfur than others. Sulfur in coal produces sulfur dioxides when the coal is burned. In general, coals from the western portion of the United States have less sulfur than eastern coals.

3 There are different ways of mining coal.

- 3.1 Coal may be mined underground.
  - 3.1.1 Some coal lies too deep for surface mining. It can only be recovered by underground mining.
  - 3.1.2 Not all the coal in a seam can be recovered by underground mining. Some is left to support the roof, for example.
    - 3.1.2.1 New mining techniques are increasing the percentage of the coal that can be recovered. For example, in short-wall mining as much as 85% of the coal in a seam is recovered.

3.1.3 Underground coal mining is one of the most hazardous occupations, both in terms of accidents and of occupational disease.
  3.1.3.1 Great variations in the accident rate exist from mine to mine, and accident rates have been higher in the United States than in Europe.
  3.1.3.2 Between 1967 and 1977, the fatality rate (per ton mined) fell 26% and the disabling injury rate rose 90%.
  3.1.3.3 About 10-20% of working underground miners show evidence of "black lung" respiratory diseases. Control of dust and diesel particulates, as legally required, is expected to lower the incidence to 5% by the year 2000.

3.2 Coal may be surface-mined.
  3.2.1 Topsoil and overburden is removed to reveal the coal seam. Almost all the coal in the seam can be recovered.
  3.2.2 Surface mining is a much safer occupation than underground mining, with far fewer deaths, injuries, and cases of occupational disease. It also employs fewer workers per ton produced.
  3.2.3 Reclamation of surface-mined land is now regulated by federal laws intended to restore the productivity of the land. Regulations differ for different types of land. In prime farmland, for example, all soil layers must be replaced in the original order. In addition to replacement of topsoil, regulations require control of drainage, revegetation, restoration of roads, and so forth.

4 Coal must be transported.
  4.1 Most coal is transported by railroad.
  4.2 To reduce transportation costs attempts have been made to pipe coal as a slurry (a powder dispersed in, for example, water).
  4.3 In some locations, coal is burned at the mine to generate electricity, and the electricity is transmitted instead of transporting the coal.

5 Coal is the most abundant of the fossil fuels; the U.S. possesses reserves great enough to last about 300 years at present rates of consumption. If the rate of consumption increases at 5% per year or more, as many expect it will, reserves may last less than a hundred years.
  5.1 Opening new mines requires considerable time, capital, and energy.
  5.2 Transporting coal from new mines can disrupt the life of communities in the transportation corridor.
  5.3 Rapid growth of coal "boom towns" makes it difficult to provide community services.

6 Use of coal creates environmental problems.

  6.1 Mining coal can create environmental problems.

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6.1.1 Underground mining can lead to destructive subsidence of the surface above.
6.1.2 Drainage of acids from mines can disrupt life in waterways.
6.1.3 Surface-mined land must be reclaimed, which can be extremely difficult, especially in arid regions.

6.2 Burning of coal can create environmental problems.
6.2.1 As coal consists chiefly of carbon, it contributes more carbon dioxide per unit of heat obtained from combustion than do fuels rich in hydrogen, such as natural gas. Increasing the percentage of carbon dioxide in the earth's atmosphere could lead to unwelcome changes in the earth's climates.
6.2.2 Burning coal produces sulfur dioxide, the most important factor in acid rain.
6.2.3 Burning coal produces particulates, which carry toxic metals, even radioactive ones.
6.2.4 Burning coal produces large amounts of solid wastes, both the ash itself and wastes produced by the pollution control processes.
6.2.5 Much of the pollution caused by burning coal can be controlled at either end of the fuel cycle.
6.2.5.1 Coal can be processed to reduce the content of impurities like sulfur. Such processes sometimes also convert the coal to a gas or liquid (synthetic fuels).
6.2.5.2 Flue gases may be processed to remove sulfur dioxide and particulates, or the sulfur may be removed during combustion in fluidized-bed units.
6.2.5.3 Controlling coal-caused pollution adds substantially to the cost of, for example, generating electricity, but it reduces other costs such as medical expenses and cleaning costs.

7 Petroleum has been in extensive use for only a century and a half.
7.1 Knowledge of petroleum had existed for thousands of years, but a cheap means of obtaining it in quantity was lacking.
7.1.1 Ancient Mesopotamia had an extensive bitumen industry, but its technology had been forgotten by the time of the Romans.
7.2 Development of distillation provided a way of making crude oil into lamp oil, a product then in demand.
7.3 Around 1860, it was demonstrated that methods used in drilling wells for brine could be used to extract inexpensively vast quantities of petroleum.

8 Petroleum is found underground.
8.1 Petroleum occurs as a liquid or gas in tiny holes in the rocks. That is, it is not ordinarily found in big pools lying in underground caves.
8.2 Petroleum can flow very slowly through the interconnecting pores of permeable rocks.

8.1.1 Underground water drives petroleum upward.
8.1.1.1 Water fills the pores of many underground rocks.
8.1.1.2 Oil floats on top of water, so petroleum tends to migrate up through permeable rocks which contain water.

8.3 Petroleum is found in places where its further migration has been stopped.
8.3.1 The migration ceases when the oil reaches the surface; then the oil appears as a seep.
8.3.2 There are many types of rock which oil cannot pass through. These are called impermeable rocks; an example is shale.
8.3.3 In some cases the oil is trapped by an overlying layer of impermeable rock shaped like a dome or top of a fold.
8.3.4 In some cases the oil is trapped because the movement of the earth along a fault has moved an impermeable strata next to a permeable one, sealing it.
8.3.5 In some cases the oil is trapped because a new cycle of erosion and deposition has created new impermeable strata that cap the old permeable strata.
8.3.6 In some cases the oil is trapped in a perme[illegible] rock that is surrounded by impermeable rock because it began as a sandbar, for example.

9 Crude oil is a mixture of hundreds of different hydrocarbons.

9.1 The substances in crude oil are composed almost entirely of carbon and hydrogen atoms, with traces of other elements. Such substances are called hydrocarbons.
9.1.1 The molecules of different hydrocarbons differ in the number of carbon and hydrogen atoms they have, and in the arrangement of the atoms in the molecule.
9.1.1.2 Different hydrocarbons have different physical properties, such as boiling point.

9.2 Crude oils from different fields differ.
9.2.1 They can differ in the proportion of different hydrocarbons they contain. For example, some crudes are high in asphalt, others contain hardly any.
9.2.2 They can differ in the amount of potential pollutants they contain, such as sulfur.
9.2.3 They can differ in viscosity.

10 Crude oil is almost always refined before use. (Some is burned directly as boiler fuel.)
10.1 At different times, people have sought to obtain different products from crude oil.
10.1.1 Originally, people wanted kerosene from crude oil, to be used in lamps. Gasoline was a useless byproduct. With increased use of the automobile, a need arose to get more gasoline and less kerosene from the crude.
10.1.2 Changing seasons or market conditions may create a need for a refinery to alter the proportions of different

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products produced.

10.2 Many different processes are used in a refinery.

10.2.1 Distillation can be used to separate hydrocarbons with different boiling points.

10.2.2 Cracking is a process which breaks up large molecules into smaller ones.

10.2.3 Reforming is a process by which the shape of the molecule can be changed, for example from a long straight chain to a ring.

10.2.4 Alkylation is a process for changing very volatile hydrocarbons into ones that can be used in gasoline.

10.3 A refinery built to process crude from one field may not be able to process crude from another.

10.4 The refining process requires energy, and different products require different amounts of energy for their production. For example, it takes more energy to produce a gallon of gasoline than a gallon of diesel fuel.

11 Enhanced recovery is used to get more crude from an oil field than could be obtained by simple pumping.

11.1 About two-thirds of the oil in a field is still in the ground when pumping ceases to be effective.

11.2 Heat can be used to reduce the viscosity of oils to heavy to flow, for example by injecting steam.

11.3 Detergents can be injected to free the oil from the grains of rock.

11.5 To increase flow, rock surrounded a well can be fractured and the fractures held open by injected materials (proppants).

12 Natural gas is the most recently developed major fuel.

12.1 Knowledge of natural gas is thousands of years old, but very little use was made of it until the 1800s. For example, it was used in temples more than a thousand years ago, and in the early 1800's by people doing their laundry along western Pennsylvania rivers.

12.1.1 Natural gas is found with almost all oil, and in many places is found by itself.

12.1.2 For many years, gas was treated as a byproduct of oil production. In some other countries it is still vented or "flared," burned off because no way has been provided for taking it to market either as gas or as a product, like fertilizer, made from gas. In 1978, the 15 OPEC nations vented or flared an average of 50% of all the gas they extracted.

12.2 Transportation of gaseous fuels requires capital investment in pipeline networks.

12.2.1 Beginning in 1816, local pipeline distribution systems for gas were established in many American cities, distributing synthetic gas made locally from coal, and chiefly used for lighting.

12.2.2 Development of a long-distance pipeline system provided the means of getting natural gas from distant fields, especially Texas and Oklahoma, to market.

12.3 Natural gas is a mixture of different substances, but is chiefly methane (a molecule containing one carbon atom and four hydrogen atoms).

12.3.1 Raw gas from wells is processed to remove condensible components such as ethane, propane and butane.

12.3.2 Water, nitrogen, carbon dioxide, and other benign materials are removed. One of these, helium, is a valuable byproduct.

12.3.3 Toxic substances such as hydrogen sulfide and other sulfur compunds are removed.

12.3.4 Gas as delivered is a clean-burning fuel, producing no solid waste or particulates. (Oxides of nitrogen may be produced and, from some gas deposits, appreciable quantities of radon).

12.4 Natural gas may be stored.

12.4.1 A special need for storage is created because the demand for gas for home heating has a large winter peak, but a pipeline has a maximum capacity per month. Gas is delivered from the fields during the summer and stored for winter use.

12.4.2 Gas may be stored underground in depleted gas or oil fields.

12.4.3 To reduce bulk, natural gas can be stored as a liquid.

12.4.3.1 Some components of gas can be liquefied by pressure alone; they are sold as LPG (Liquified Petroleum Gas). Propane and butane are the chief such substances.

12.4.2.2 At room temperatures, methane cannot be liquefied by pressure alone. It must be cooled. At atmospheric pressure, methane liquifies at -259°F.

12.4.2.3 Energy is needed to liquefy the gas.

12.6 Tankers carrying liquefied natural gas are being used on a small scale to ship natural gas between continents.

12.6.1 If liquefied gas escaped, it would boil, and the cold vapor is expected to travel as a low-lying cloud that would be extremely flammable until it had been diluted to less than 5% gas by mixing with air.

12.6.2 Estimates of the distance the cloud might travel range from 1 to 50 miles, depending to a great extent on weather.

12.6.3 Consequently, great concern is being expressed over transporting fuel in this form, and especially regarding siting of terminals.

12.7 Reserves of natural gas have been declining; at present rates of consumption the supply is not expected to last more than a century.

12.7.1 A number of unconventional sources of gas are being investigated; these may significantly extend the supply. Examples of such sources include geopressurized methane, gas from tight sands, gas from coal seams, gas from Devonian shales, and gas hydrates.

12.7.2 Because synthetic fuel gases can be produced from coal and from renewable sources like biomass, and by dissassociation of water molecules by sunlight, and because transporting energy as chemical energy in a gas is efficient, the gas distribution network is likely to be useful even after natural gas is depleted.

13 The hydrocarbons obtainable from fossil fuels have many non-fuel uses.

13.1 Many useful substances can be separated from the fossil fuels: lubricants and solvents from petroleum; dyes and medicines from coal tar; carbon black by burning natural gas (now natural gas is too valuable to use for this purpose).

13.2 Chemists have discovered methods of making new substances, not present in the original fossil fuel, by rearranging the atoms in molecules and combining molecules. Examples include synthetic rubber, textile fibers such as polyesters, and plastics.

13.3 It is reasonable to suppose additional uses will be discovered; giving up those uses by using the fuel now is one of the opportunity costs of present-day consumption.

14 Differences in the properties of the fossil fuels help to explain why coal was the first to be developed and why consumption of oil and gas rapidly overtook that of coal.

14.1 The progress of technology and increasing capital investment have had differing effects on the extraction of the different fossil fuels.

14.1.1 Coal was successfully extracted with very primitive methods. Development of pumps increased the economically recoverable reserves. Development of mechanized mining, and especially of surface mining, has made extraction more efficient.

14.1.2 Although it is possible to drill oil and gas wells using primitive techniques (kick rigs, China circa 600 B.C.), the advent of rotary drilling made oil and gas extra very efficient from a net energy viewpoint.

14.1.3 With capital and present technology, oil and gas have been easier to extract than coal.

14.2 Gas can be burned with little or no processing before use; oil must be refined and coal too needs treatment.

14.2.1 Progress in refining and petrochemical technology has made crude oil ever more useful.

14.3 The progress of technology and increasing capital investment have had differing effects on the transportation of the different fossil fuels.

14.3.1 Coal can be transported by primitive means such as

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burlap bag; oil requires slightly more sophistication; gas even more.

14.3.2 Once pipelines are in place, it is much simpler to transport a quantity of gas or oil than the Btu equivalent quantity of coal.

14.4 As people became aware of the need to internalize environmental costs of fossil fuel use, gas enjoyed the advantage of being relatively clean-burning in simple equipment; oil less so; while coal is most difficult. Coal also produces considerable amounts of solid wastes.

14.5 Gas and oil are easily converted to work in cheap, lightweight internal combustion engines. Such advantages led to their supplanting the steam engine (which could burn coal) in most mobile applications.

14.6 Gas is more difficult to store than coal.

15 The eventual exhaustion of economically recoverable fossil fuels is certain.

15.1 Extraction from a mineral deposit often follows a bell-shaped curve, rising and then falling. In such cases an estimate of the lifetime of the resource can be made by matching production to date with the curve.

15.2 As a deposit nears exhaustion, it typically becomes more difficult to extract what remains.

15.3 Resource exhaustion can be delayed by the introduction of new recovery techniques.

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VI. ENERGY FROM NUCLEAR REACTIONS

1 Ordinary matter is composed of atoms.

1.1 Atoms consist of two parts: an outer cloud of electrons around an inner core called the nucleus (pl. nuclei). While the conventional diagrams are useful in illustrating this conception, students should not be given the idea that the atom is a miniature solar system.

1.2 The two parts of the atom are composed of particles.
- 1.2.1 The electron is a particle.
- 1.2.2 The nucleus is composed of particles called protons and other particles called neutrons.

1.3 Particles may have an electrical charge.
- 1.3.1 Protons have a positive charge.
- 1.3.2 Neutrons do not have a charge.
- 1.3.3 The nucleus of an atom is positively charged.
- 1.3.4 The electrons in an ordinary atom are negatively charged.
- 1.3.5 The magnitude of the charge of the electron is equal to that of the proton.
- 1.3.6 Because the number of negatively-charged electrons in the atom equals the number of positively-charged protons, the atom as a whole has no charge.

1.4 The chemical identity of an atom -- what element it is -- is determined by the number of protons in its nucleus (the atomic number), because this determines the number and arrangement of electrons.

1.5 The nuclei of two atoms with the same number of protons can have different numbers of neutrons. They are then atoms of different isotopes of the element. All elements have more than one isotope.

2 The nuclei of some isotopes are unstable. They change spontaneously, without any external influence.

3 When unstable nuclei change, they give off rays. Because of this, isotopes whose nuclei are unstable are called "radioactive isotopes," and the change is called "radioactive decay." All elements have at least one isotope that is radioactive.

3.1 Rays cause effects in the materials they strike, such as fluorescence or the exposure of photographic film.
- 3.1.1 We can use cloud chambers or photographic film to see the paths of some rays.
- 3.1.2 Some rays are bent by a magnetic field, which shows they have an electrical charge. Other rays are not bent.
- 3.1.3 Some rays pass through sheet metal, others are stopped by a piece of paper.

3.2 There are different kinds of rays.
  3.2.1 Alpha "rays" can be collected in a bottle. When we do this we find they are identical to the nucleus of the element helium, which consists of two protons and two neutrons, except for their kinetic energy.
  3.2.2 Alpha rays are easily stopped, but because of their great mass compared to beta rays, have more of an effect when they hit something.
  3.2.3 Beta rays consist of a fast-moving electron.
  3.2.4 Gamma rays are a form of electromagnetic radiation.

3.3 There are different types of radioactive decay. Each radioactive isotope will decay in only a few particular ways, sometimes only one.
  3.3.1 Some nuclei decay by emitting a negatively- charged electron (a beta particle) and changing a neutron to a proton. So the new nucleus will belong to an atom of the next element in the periodic table.
  3.3.2 Some nuclei decay by emitting an alpha particle. The new nucleus will have two less protons and two less neutrons.

4 When a nucleus decays, it usually turns into a nucleus of another element, because the number of protons in the nucleus is changed. The new element is called the daughter of. the original element. (The exception is the relatively uncommon decay by isomeric transition, in which the nucleus becomes a nucleus of another isotope of the same element.)
  4.1 In a nuclear reaction, charge is conserved. The products of the nuclear reaction will have the same number of charges of each sign as the atom which decayed.
  4.2 Some radioactive isotopes decay faster than others. How fast a radioactive isotope decays can be described by its half-life: the length of time it takes for half of any sample of the substance to change to another substance.

5 Bombarding a nucleus with alpha particles or neutrons can change it.
  5.1 Many stable isotopes can be transmuted into radioactive ones.
  5.2 Nuclei of one element can be changed into nuclei of another element.
  5.3 When the nuclei of certain isotopes are struck by a neutron, they may split into two new nuclei. This is called nuclear fission, and the new nuclei are called fission fragments.
    5.3.1 When a nucleus fissions, two or more new neutrons are thrown off at great speed.
    5.3.2 The new neutrons can cause certain other nuclei to fission, so the process may become self-perpetuating. It is called a chain reaction.
  5.4 Only one naturally-occurring isotope, uranium-235, can be made to fission by neutrons traveling at slow speeds. Isotopes with this property are called fissile isotopes.
    5.4.1 Very-fast-moving neutrons are needed to make the commonest isotope of uranium, U-238, fission.

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6 Energy is released when a nucleus fissions.

6.1 The fission fragments and leftover neutrons have less mass than the nucleus and neutron with which the reaction started. The missing mass has been converted to energy according to the relationship energy equals mass times the square of the speed of light.

6.2 About 80% of the energy given off by fission is in the kinetic energy of the fission fragments. This energy is quickly converted to heat through collisions between the fragments and surrounding molecules.

7 The energy obtained from nuclear power reactors comes from the fission of uranium-235 nuclei and other fissile nuclei. [Levine 1981; Martin 1980]

7.1 One way of controlling the rate of the reaction is to control the number of neutrons in flight at any one moment, so that just the desired number of fissions are caused.

7.1.1 The speed of the neutrons is important, because uranium-235 is hundreds of times more likely to fission if it is hit by a slow-moving neutron than if it is hit by a fast-moving one.

7.1.1.1 To slow down the neutrons, they are bounced off atoms in a substance that absorbs as few neutrons as possible. This substance is called a moderator.

7.1.2 During operation, a nuclear reactor is controlled by using substances that absorb neutrons.

7.1.2.1 Control rods made of substances that are very good neutron absorbers, like boron, can be inserted or withdrawn from the reactor's core.

7.2 The rate of the reaction is also controlled by how many fissile nuclei are present, and their spacing.

7.2.1 Uranium as mined ("natural uranium") consists of less than 1% fissile U-235; nearly all the rest is non-fissile U-238.

7.2.2 When ordinary water is used as a moderator, too few neutrons hit other U-235 nuclei to keep a reaction going in natural uranium.

7.2.3 To increase the chance that neutrons produced by fission will hit a U-235 nucleus, the percentage of U-235 is increased. This is called enrichment. Typically the fuel is enriched to about 3% U-235.

7.2.3.1 The gaseous diffusion enrichment process presently used consumes a very large amount of electricity, but facilities using less energy-intensive processes, like centrifuges, are being built.

7.3 Heat from fission is converted to electricity through a conventional turbine-generator set.

7.3.1 In a light water reactor, ordinary water is used both as the moderator and as the coolant, transferring the heat from the reactor vessel.

7.3.2 Some reactors use heat exchangers, so that the water

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circulating through the reactor vessel doesn't circulate through the turbine.

7.3.3 Reactors reject a greater proportion of the heat they produce to the environment than fossil-fuel fired power plants do, because they operate at a lower temperature. (See I.6.5.2) The highest temperature at which a reactor can operate is limited by the temperature at which the fuel rods will be structurally damaged, which is well below the temperatures reached by burning fossil fuels.

7.3.4 Additional cooling capacity, not part of the turbine loop, is provided for emergency use.

8 Fission fragments accumulate during the operation of the reactor.

8.1 Many fission fragments are themselves radioactive isotopes and decay into other substances, eventually into stable isotopes.

8.2 When the chain reaction in the reactor is stopped (for example by the use of the control rods) the decay of the fission fragments will continue to produce heat. So cooling must continue to be provided.

8.3 Some of the fission products in a reactor absorb neutrons and stop the reaction. So the fuel rods must be replaced when only about 2% of the fuel has fissioned.

8.3.3 Nuclear fuel can be reprocessed to separate unfissioned uranium-235 and plutonium produced by neutrons from other fission products.

9 Ionizing radiation, such as that from radioactive materials, is harmful to living things. [Lindenfeld 1980]

9.1 Different isotopes differ in their effects.

9.1.1 Radioactive isotopes differ in the type of radiation they produce, and different types of radiation differ in their effects. For example, alpha radiation, while not penetrating like gamma rays, causes more destruction within a cell. So, for example, inhalation of alpha emitters, causing them to be deposited on the surface of the lung, is very harmful.

9.1.2 Radioactive isotopes have different half-lives.

9.1.3 The physical nature of the form in which the radioactive isotope occurs affects its biological effect. For example, gases and fine particulates may be inhaled.

9.1.4 The chemical identity of the isotope affects its biological effect. Some isotopes become concentrated in particular organs of the body, for example, iodine in the thyroid gland, or are concentrated by passage through a food chain.

9.2 The more rapidly a tissue is growing, the more easily it can be damaged by radiation. So children and fetuses are particularly susceptible to harm -- as are fast-growing tumors, the basis of radiation therapy for cancer.

9.3 Radiation can damage the body. (somatic damage)

9.3.1 Large enough doses kill outright.

9.3.2 Smaller doses can lead to the development of cancer, usually years after the radiation was experienced. Unlike large doses, isolating the effect of low doses is very difficult statistically.

9.4 Radiation can cause genetic damage.

9.4.1 Radiation can cause changes in the DNA molecules in the cell that contain the code for the cell's reproduction.

9.4.2 If radiation alters the DNA of germ cells, mutations are produced. It is highly unlikely that any mutation will be beneficial.

9.5 Living things have always been exposed to natural background radiation, such as cosmic rays and radiation from the earth and building materials. This is the largest source of radiation exposure for most persons.

9.6 Human activities have increased our exposure to radiation.

9.6.1 Diagnostic and therapeutic use of x rays and radioactive isotopes is the major manmade source of exposure to radiation. One year's use of radiation in medical diagnosis at the present rate gives the human population an exposure equivalent to 70 days exposure to the natural background radiation.

9.6.2 Atomic bomb testing has produced worldwide fallout. Each year of such testing (averaged over the years 1951-1976) has committed the human population to the equivalent of 30 days exposure to the natural background radiation.

9.6.3 Various consumer products, like smoke alarms and some luminous watches, emit radiation. One year's exposure to such products is the equivalent of 3 day's exposure to the natural background radiation.

9.6.4 Operation of the nuclear fuel cycle adds to the exposure of the human population to radiation. One year's routine operation at the present global installed capacity commits the human population to an exposure equivalent to six-tenths of a day exposure to the natural background radiation.

10 Operation of the nuclear fuel cycle introduces additional radioactive substances into the environment.
(To provide some idea of the relative size of the contribution of different parts of the fuel cycle, the United Nations Scientific Committee on the Effects of Atomic Radiation's estimates of the dose commitment are given in man rads per megawatt (electric) per year.)

10.1 The mining of uranium ore has effects. (0.05 man rad per MW(e)y to the workers; small to public.)

10.1.1 The principal effect is the inhalation by miners of the gaseous daughters of the radioisotopes in the ore, which results in cases of lung cancer.

10.2 Uranium ore is processed (milled) to recover the uranium, enriched, and made into fuel rods. (0.15 man rad per MW(e)y for the workers; small for the public.)

10.2.1 Only about 1% of the ore is uranium; the rest is rejected as "tailings." Tailings are a form of low-level radioactive waste; they release small amounts of radon from the decay of the radium they contain.

10.3 The fuel assembly is left in the reactor about three years. (Workers' dose commitment is about 1 man rad per MW(e)y.)

10.3.1 During routine operation, a reactor releases small amounts of radioactive materials into the air (0.2 to 0.3 man rad per MW(e)y to the public). These include noble gases like krypton and xenon.

10.3.2 During routine operation, the reactor releases materials into the water. (Public dose commitment of about 0.03 to 0.06 man rad per MW(e)y.) This includes substances like the isotope of hydrogen, tritium.

10.3.2 During this time, some of the U-235 fissions, fission fragments accumulate, and the cladding around the fuel rod suffers radiation damage.

10.3.3 The fuel rod is removed and left in a pool of water for several months. During this time, the isotopes with short half-lives decay and the radioactivity of the rod is reduced by a factor of about 50. (Dose committment is very small compared to other items mentioned.)

10.4 Transportation of radioactive materials poses environmental hazards in the event of accidents or sabotage severe enough to breach the extremely strong shipping containers. (Under routine conditions, dose commitment is estimated at 0.003 man rad per MW(e)y.)

10.5 Used fuel elements can be reprocessed to recover unfissioned U-235 and "bred" fissile isotopes. (At present, this is not being done.) (Workers in previous reprocessing incurrred 1.2 man rad per MW(e)y.) (Global population dose commitment, 1.2 to 3.3 man rad per MW(e)y.)

10.5.1 This is potentially the most polluting step in the fuel cycle.

10.6 Radioactive wastes must be stored for long periods to keep them out of the environment.

10.6.1 The plan currently believed most satisfactory would be to embed the fission fragments in glass and store them in a geologically stable formation.

10.7 The physical quantity of wastes produced by the nuclear electric system is extremely small compared to coal plants producing the same amount of electricity.

10.8 Some materials put into the ecosphere by the nuclear fuel cycle are extremely long-lived, specifically uranium-238 (half-life, 4½ billion years) and iodine-129 (160 million years). As a result, even though the resulting exposure to the population is very small in any one year, the collective dose commitment over millions of years is large.

11 Release of radioactive material as a result of a reactor accident is a major concern.

11.1 A commercial nuclear reactor cannot explode like an atomic bomb; the uranium is not sufficiently enriched for it to do so.

11.2 A nuclear reactor that has been operating for a year has accumulated a large inventory of radioactive materials, mostly fission fragments. For these to escape the reactor vessel and redundant containment structures would have to be ruptured.

11.3 Containment might be breeched by external forces, such as a hit by a ballistic missile.

11.4 Containment might be breached if the reactor went "super-critical," i.e. if it was possible for the number of neutrons to increase indefinitely. In a light water reactor, physical factors, like the loss of moderation if the water boils in a PWR, make this almost impossible.

11.5 Containment might be breached if there was a loss-of-coolant accident.

11.5.1 The chief internal energy source available for breeching containment is the heat from the decay of the fission fragments themselves.

11.5.1.1 Even after the chain reaction has been stopped (by the insertion of the control rods or release of a neutron poison like boron into the reactor), heat will continue to be produced. This heat must be carried away by coolant to prevent melting of the fuel rods.

11.5.1.2 Several extra core cooling systems are built into the reactor for use if the main cooling system fails.

11.5.2 If heat is not carried away, the fuel rods will melt, releasing fission fragments into the coolant.

11.5.3 Reactions between the hot fuel rods and coolant could create enough pressure to breech the reactor vessel.

11.5.4 The melted fuel could melt through the bottom of the vessel, coming to rest 10-20 feet below the reactor.

11.6 No estimates of the chances or consequences of a reactor accident have been universally accepted.

11.6.1 The Rasmussen report estimated accidents were more likely, but of less consequence (less of the reactor inventory dispersed) than estimates made by earlier studies.

12 The amount of energy obtained from nuclear fission can be extended by use of reactors designed to convert non-fissile isotopes into fissile ones. Such a reactor is called a breeder reactor.

12.1 World reserves of uranium-235 may be exhausted within a century at present rates of consumption.

12.2 When a nucleus of uranium-238 absorbs a neutron it changes to uranium-239, which decays with a half-life of 23 seconds to neptunium-239, which decays with a half-life of 2 days to plutonium-239, which is fissile. This is the basis of one type of breeder reactor.

12.2.1 Because uranium as mined is more than 99% U-238, the use of breeder reactors would increase the amount of energy available from the uranium resource by a factor of almost 100.

12.2.2 Production of plutonium takes place in the fuel rods of light water reactors as well as breeder reactors; so there is plutonium in spent fuel rods. In fact, because the breeder burns more plutonium than the light water reactor does, the light water reactor produces a greater amount of plutonium.

12.3 An increased world inventory of plutonium is a matter of great concern.

12.3.1 While it is difficult to separate uranium-235 from natural uranium, it is relatively easy to separate plutonium because it has different chemical properties.

12.3.2 Plutonium has the property of forming very small particles which are long-lived intense alpha emitters.

12.3.3 The policing necessary to prevent misuse of plutonium might have undesireable social effects.

12.4 Another type of breeder reactor breeds uranium-233 from thorium-232. There is about 100 times more thorium in the world than uranium. The breeding gain would not be as great as with the uranium to plutonium cycle.

13 Energy may be obtainable from nuclear fusion, the nuclear reaction in which two small nuclei join to produce a larger one. [Fillo 1981]

13.1 This is the reaction that occurs in the sun and in hydrogen bombs.

13.2 Extremely high temperatures are required, so high that the reacting material cannot be allowed to touch its container.

13.3 To date, no design for a fusion reactor producing net power has been developed.

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VII. ENERGY FROM SOLAR TECHNOLOGIES

1 Solar radiation can be expected to be available at a roughly constant rate for millions of years to come (in contrast to our limited accumulation of ancient solar energy in the form of fossil fuels).

1.1 Averaged over the year, the energy arriving at the earth's surface on one day in the continental United States is about 1100 to 1600 Btu per square foot.

1.2 The amount of solar energy available in the sunniest and least sunny state (averaged over entire state's area, and on a per unit area basis) differs by a factor of about 2; i.e., though there is a real difference in the amount of solar radiation available in Arizona and Minnesota, it is not of the order of magnitude which would make solar heating technically impossible anywhere.

2 Mechanical energy can be obtained from the sun-driven atmospheric heat engine. See II.4 and II.5.

2.1 Mechanical energy can be obtained from falling water.

2.1.1 The power available at a site depends on the distance the water falls (the head) and the quantity of water falling in a given amount of time (the flow).

2.1.2 The use of hydropower entails risks, such as flooding if dams break and induced earthquakes, and creates environmental problems through fluctuations in water level or stream flow and destruction of habitat. Some large reservoirs have had an appreciable impact on climate.

2.1.3 Most sites suitable for large dams in the U.S. have been developed, but many small sites are available.

2.1.4 In time, all reservoirs fill with silt. This eliminates the energy storage capacity of the hydroelectric site, but as long as the river flows energy continues to be available from the head of water.

2.2 Energy can be obtained from the wind. [Gould n.d.]

2.2.1 Power output is proportional to the cube of wind speed, so determining the windiness of prospective sites is important. Also, wind speed increases with height above ground, hence towers.

2.2.2 Power output is proportional to the area swept out by the blades, i.e., to the square of their diameter. Very small machines (less than 25 kW peak power) thus are at an economic disadvantage compared to larger machines.

3 Fuels can be obtained by growing plants. (Biomass)

3.1 Plant material can be burned directly.

3.1.1 Biomass fuels are currently the major non-food energy source for much of the earth's population (estimated at about 20% of present world fuel consumption). In this country, biomass fuels from waste have long been significant in the lumber, paper, and sugar industries.

3.1.2 Heat can be obtained by burning fuelwood.

3.1.2.1 Ways of burning wood differ greatly in efficiency. Enclosed stoves are more efficient than open fireplaces. Use of some fireplaces results in a net loss of heat (see XII.4.5.1) Thermal mass evens heat output while permitting more complete combustion (compared to air-starved designs). Catalytic converters are available which greatly reduce air pollution.

3.1.2.2 Use of firewood carries with it risks (for example, fire and chain saw accidents, which increased in New England as fuel wood consumption rose) and environmental effects (air pollution by particulates, effect of wood harvesting on forests).

3.1.3 Production of fuel biomass could be increased by improved agricultural techniques, such as coppicing, selective breeding of existing crops (e.g. "super" trees) and introduction of new crops (some tropical plants produce hydrocarbon substitutes).

3.2 Liquid and gaseous fuels can be made from plant materials.

3.2.1 Through fermentation and other processes, alcohol can be made from sugars, starches, and even cellulose.

3.2.1.1 Ethyl alcohol can be mixed with gasoline to increase its octane rating. This takes the place of the higher octane components of gasoline, whose manufacture is energy-intensive. [Haase 1980]

3.2.2 Through anaerobic digestion, methane can be made from plant materials like crop wastes, manure and municipal sewage.

3.2.2.1 The liquid remaining after digestion is an excellent fertilizer, since escape of ammonia (which usually occurs in open composting) has been prevented.

3.2.3 Biomass can be reduced to gases and liquids by heating it in an oxygen-deficient environment. (pyrolysis)

4 Active solar systems can provide space or water heating.

4.1 Approximately 70% of the energy consumed directly in U.S. residences is consumed as low-temperature heat for water and space heating.

4.1.1 Solar energy is thermodynamically appropriate for this purpose, (see I.6.5.3) because the temperatures reached by solar collectors are a good match with those needed in the home.

4.2 A solar collector is used to absorb sunlight.

4.2.1 The direction the collector faces (the orientation) affects the amount of sunlight that will fall on each square meter of collector.

4.2.1.1 Maximum radiation is available if the collector faces south, unless particular times of day are regularly clear or cloudy.

4.2.1.2 Generally, maximum radiation is available

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if the collector is tilted the same number of degrees as the latitude. Add 15 degrees to the latitude if heat is needed primarily in the winter.

4.2.1.3 These rules only maximize heat gain. The collector will still work if other orientations are the only ones possible, and the difference in energy collected can be estimated mathematically.

4.2.2 The collector is designed to maximize absorption of radiation and minimize re-radiation. (see I.1.2)

4.2.2.1 Ideally, the "black" of the absorber plate is, is a good absorber of light emitted by an object at the temperature of the sun, but a poor emitter of radiation of the wavelengths emitted from an object the temperature of the absorber plate (i.e., it's black at visible wavelengths but not at thermal ones).

4.2.2.2 The glass covering is transparent at the wavelengths of sunlight but opaque to the wavelengths emitted by the absorption plate.

4.2.3 Heat loss from the collector by conduction and convection is minimized.

4.2.3.1 Loss by conduction is minimized by insulation under the absorber plate and around the side of the collection box. Sometimes double-glazing is used. The absorber plate is isolated from the case by supports which are poor thermal conductors.

4.2.3.2 Loss by convection is prevented by careful sealing of the case.

4.2.4 Collectors should not contain materials such as wood which will outgas or burn at the temperatures reached.

4.2.5 The larger the area of the collector, the more energy collected.

4.2.5.1 Because the collector expense increases almost linearly with increase in surface area, while the number of days the extra capacity would be needed decreases exponentially (four consecutive cloudy days are much less likely than three), it is a mistake to oversize a collector.

4.3 Heat is transferred from the collector by the flow of a fluid such as air, water, or some other liquid. Pumps or blowers are generally used to do this; hence the name active system.

4.3.1 To prevent the collector's cracking in a freezing climate, liquid in the collector must not be allowed to freeze. An antifreeze can be added to the water or a substance with a very low freezing point, like silcone oil, can be used instead of water. If such a substance is used, building codes require two partitions (a double-walled heat exchanger) between the antifreeze and drinking water. Automatic draindown systems can also be used.

4.4 Heat exchangers may be used to transfer the heat between the collecting fluid and storage and between storage and water or the building air.

4.5 Heat is stored by warming materials such as a rockbed or a tank of water.

4.5.1 Sometimes a storage medium is used which will freeze at a temperature a little above the desired temperature.

4.5.2 If the storage can be located above the collector, convection can be used to circulate the fluid instead of pumps or fans. (thermosiphoning).

5 Sunlight can be used to meet comfort needs through proper building design.

5.1 Different climates create different comfort needs and offer different possibilities for designing buildings to meet those needs.

5.1.1 Example: Desert climates often have great day to night temperature swings. Incorporating high thermal inertia into a house makes the warmth of the day available at night and night's coolness available during the day.

5.1.2 Example: In some climates, cold weather is also clear. In such climates the energy need for heat coincides very well with the availability of sunlight.

5.2 Orientation of a building affects its ability to use sunlight.

5.2.1 South-facing windows collect the most heat during the day. East and west-facing windows collect less heat as orientation from true south increases. North-facing windows provide light but lose heat.

5.2.2 Maximizing the area of the exterior walls exposed to the sun and minimizing shaded walls, increases the amount of radiant energy available. In a cold climate, a long narrow building should have its long dimension facing south.

5.3 Seasonal changes in the angle of sunlight (see II.3.3.2) can be matched to seasonal changes in the need for heat.

5.3.1 Overhangs can be used to admit light from the low winter sun but block high summer sun.

5.3.2 Deciduous trees or plants can be used on southern exposures to block summer sun but admit winter sun, (and similarly conifers can be planted on the side exposed to prevailing winter winds).

5.4 Building materials like concrete and stone can be used to store heat, for example as a ceramic tile floor exposed to the sun. Generally vertical surfaces (walls) will absorb more heat than horizontal surfaces (floors).

5.5. Open floor plans make it easier for warmed or cooled air to circulate.

6 Community cooperation is required for the most effective use of solar energy.
6.1 Local laws (in a few states, state laws) determine the extent to which a property owner can shade land to the north by construction or plantings.
6.2 The layout of a community (for example, the direction of the streets) is one of the factors that determines how efficiently sunlight can be used.
6.3 Building codes may prohibit innovative construction.

7 High temperatures can be reached by concentrating sunlight.
7.1 Lenses can be used to concentrate sunlight.
7.2 Mirrors may be used to concentrate sunlight.
7.2.1 A mirror shaped like a paraboloid will concentrate sunlight in a point, or if shaped like a trough with a parabolic cross section, in a line.
7.2.2 If it is to keep the sunlight concentrated on a point throughout the day, a concentrating collector must incorporate a tracking system, tilting the mirror to compensate for the apparent movement of the sun during the day.
7.2.3 A field of hundreds or thousands of mirrors can be used to concentrate light on a small area, for example on a boiler to supply steam to a turbine-generator set that produces electricity.

8 Energy can be obtained by direct conversion of light to electricity using photovoltaic cells.
8.1 Most solar cells consist of two slightly different layers of semiconductor; photons knock electrons across the boundary between the materials. This process has a maximum theoretical efficiency of around 22%; efficiencies of 17% have been reached in commercially-available cells.
8.1.1 The raw materials (silicates, e.g. sand) from which the most common type of cell, silicon cells, is made are obtained are extremely abundant, but a great deal of energy is needed to extract and refine the silicon to the necessary purity and grow the crystal. (Currently about 3-4 years of operation of the solar cell is needed to repay the energy needed to produce it.)
8.1.2 Silicon cells have a lifetime in the decades. The silicon itself never wears out, but the electrical connections may peel off the face of the chip.
8.1.3 The price of solar cells has fallen constantly since they were first introduced, from hundred of dollars per peak watt to about eight dollars per peak watt in 1980.
8.2 Although the monocrystalline silicon cell is the most familiar form of solar cell, other means of directly converting sunlight to electricity exist. Some involve less expensive forms of silicon; some other materials such as gallium arsenide; some

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other processes involving, for example, electrolytes. In all cases, what is being sought is the best balance of cost of production and efficiency of conversion.

8.3 Presently available roof area is sufficient to supply a significant part of present electrical demand using present technology. (Assuming use of 50% of existing flat and south-facing roof areas and a cell efficiency of 10%, photovoltaic collectors could provide 50% of electrical demand (in sunny areas).

8.3.1 In areas with abundant sunshine, there is a good match between peaks in the demand for electricity and availability of sunlight, since much of the peak electrical demand is due to airconditioning.

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VIII. ELECTRICITY AS AN ENERGY CARRIER

1 Electricity is not an energy source but a means of transmitting energy.

1.1 Energy sources, such as fuels, falling water, or fissioning nuclei, must be used to generate electricity.

1.1.1 Where electricity is generated in plants that burn fossil fuels, the cost of fuel is a major part of the cost of the electricity.

1.2 The value of electricity lies in the ease with which it can be converted to other forms of energy, such as motion, light, and heat. Its use in electronics is particularly significant.

2 Only part of the energy of the source can be converted to electricity. (see I.6)

2.1 Hydroelectric plants have very high efficiencies.

2.2 The efficiency of fossil-fuel fired commercial electrical generation plants has increased (from 3.6% in 1900, to 23% in 1925, to 34% in 1940, to approximately 38% by 1970).

2.2.1 The savings obtained by increasing efficiency were passed on to customers, resulting in a declining price per kilowatt-hour until about 1970.

2.2.2 Because the actual efficiency is nearing the theoretical maximum efficiency, further major increases in efficiency through engineering improvements in traditional technologies are considered unlikely.

2.3 The thermal efficiency of a power plant can be increased by making use of the heat rejected by the power plant. (cogeneration)

2.4 Adding air pollution control equipment, like scrubbers, has reduced the efficiency of power plants.

2.5 New methods of generating electricity may come into commercial prominence.

2.5.1. Some, like fuel cells, magnetohydrodynamic generation, combined-cycle and fluidized bed combustion convert traditional energy sources to electricity with higher efficiencies.

2.5.2 Some, like photovoltaics and windmills, tap energy sources that have not previously been major sources of electricity.

2.5.3 Many of the new technologies do not have the economies of scale typical of fossil-fuel fired generating stations, and so could be dispersed. This would reduce transmission losses, make cogeneration more feasible by placing potential users of waste heat nearer at hand, and lessen the chance of outages.

2.7 Energy is lost in transmission and distribution (for example, by conversion to heat due to the resistance of the cables); the amount depends on the distance and voltage, but a transmission system efficiency of 80%-90% is typical.

2.7.1 High voltages are used to reduce losses and increase the amount of power the cable can carry.

2.7.2 More efficient transmission techniques, like cryogenic systems and modern direct current systems, are being tested.

3 Electricity can only be stored by converting it to some other form; but it is difficult to do this economically.

3.1 Electrical energy is produced by conversion from some other form of energy at almost the instant it is used.

3.2 Batteries have been too expensive for utility use.

3.3 Electricity can be stored by pumping water uphill into reservoirs, and later discharging the water downhill through generating plants (pumped storage). Another system, similiar in principle, compresses air which is stored in an underground cavern.

3.4 Additional new methods of electrical storage, like flywheels, are being developed.

4 Changes in demand for electricity complicate the job of supplying it.

4.1 While in the past the demand for electricity had shown a steady and predictable growth (doubling every ten years except during the Great Depression), in the 1970s growth slowed and became less predictable.

4.1.1 Because it takes approximately 10 years to construct large power plants, utilities must accurately predict the demand for electricity ten years in advance.

4.2 Seasonal changes in the demand for electricity occur.

4.2.1 Increased use of air conditioners has resulted in electrical demand in the summer exceeding demand in the winter in areas where air conditioning is widely used.

4.3 Daily changes in demand for electricity occur.

4.3.1 Highest demand is typically in the afternoon.

4.4 The utility must provide enough generating capacity to meet peak demand.

4.5 The maximum amount of electricity called for at any instant during a period of time is called the peak load. The amount of electricity that is always needed, even when demand is least, is called the base load.

4.6 Base, intermediate, and peak loads are generated differently.

4.6.1 Since the base load is relatively constant, it can be met with generating plants that can't be started and stopped easily (such as coal and nuclear plants). Generally speaking, this type has the lowest operating cost per kilowatt-hour.

4.6.2 Peak load is met with plants that can be quickly brought on line, such as gas turbines. Such plants often use premium-priced fuels and have higher operating costs than the base load plants.

4.6.3 Costs can be minimized by providing as much of the power sold from base load as possible.

4.6.3.1 Electrical energy generated by the base load plant at night can be stored.

4.6.3.2 Loads can be managed in an attempt to switch them out of peak load hours. This can be done by pricing (time-of-day metering) or automatic shutdown of certain uses at peak hours, such as some industries or home water heaters.

5 At the present time, in most areas the cost of providing one more kilowatt-hour of electricity is generally greater than the average cost of a kilowatt-hour, because inflation has greatly increased the cost of new generating capacity, and because low-cost sources, such as large hydroelectric sites, have already been developed.
   5.1 Because conservation saves additional kilowatt-hours, saving is on the margin. The economic attractiveness of alternatives like home insulation and efficiency improvements by consumers should be measured in terms of the marginal and not the average price of the electricity saved.

6 When electrical energy (a form of energy rich in available work) is converted directly to heat (a form of energy with relatively little available work), thermodynamics suggests that there probably exists a different way of using that electrical energy which would provide more heat (perhaps a heat pump). Nevertheless, in some instances resistance heating may be most sensible economically and also save energy, due to the embodied energy used in making and installing, for example, a heat pump (example: an elderly lady who needs additional heat in her bedroom in an old house which will be razed on her death). Moral: examine each situation from first principles.

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IX. ECONOMIC AND FINANCIAL ASPECTS OF ENERGY USE

.1 Useful energy is scarce: there is not enough energy available to do everything everyone might want to do with it (if it were free). This has always been true and is not a result of the petroleum crisis. In these circumstances, how is energy allocated?

1.1 Because useful energy is scarce and everyone can't use it for everything he or she might want to, people have to decide what it's worth using energy for. They must choose between alternatives. [Leonard 1980]

1.2 Every such choice involves giving up alternatives, for example, other possible uses of the energy, other possible uses of the resources used to obtain the energy, or other uses of the labor used. (These foregone alternatives are called the opportunity costs of the choice.)

1.3 Prices in a marketplace provide one way of comparing alternatives in order to determine who will get how much energy.

1.3.1 At any particular price, buyers of energy will be willing to buy a particular quantity. This is called demand.

1.3.1.1 In general, the lower the price the more energy buyers will be willing to buy. For example, if the price of gasoline were ten cents a gallon, people would take trips they now forego, and buy big cars, so the number of gallons they purchased would be high. If gasoline were five dollars a gallon, they would carpool more, buy more fuel-efficient vehicles, and otherwise reduce the number of gallons bought.

1.3.1.2 Demand can be represented graphically as a curve on a graph of price against quantity, hence the term "demand curve".

1.3.2 At any particular price, sellers of energy will be willing to sell a particular amount of energy.

1.3.2.1 In general, the higher the price the greater the quantity sellers will be willing to sell. For example: at a high price per gallon gasoline producers will undertake tertiary recovery projects and drill more exploratory holes.

1.3.2.2 Supply can be represented graphically as a curve on a graph of price against quantity, hence the term supply curve.

1.3.3 In a free market -- one in which only the wishes of many competing individual buyers and sellers have an effect -- there is some price at which the quantity buyers want to buy equals the quantity sellers want to sell, and the selling price will tend toward this price. This price is referred to as the equilibrium, or market-clearing price.

1.3.3.1 If the price of the energy is higher than the equilibrium price, more energy will be offered for sale than buyers want to buy. In order to attract buyers, some of these sellers will reduce their prices.

1.3.3.2 If the price of energy is below the equilibrium price, some buyers will not be able to find energy to buy. Some of those buyers will raise their offering price in order to get energy.

1.3.4 Supply and demand curves can be quite flat or steeply sloping, reflecting a property called elasticity. An almost flat demand curve would mean that buyers want to buy almost the same amount at any price; this is called inelastic demand. The extent of consumer conservation recently has shown that the demand for energy is much more elastic than most people had supposed.

1.3.5 Price setting by supply and demand in a free market is the result of many individual decisions about the value of a good or service compared to other goods and services.

1.3.5.1 If anyone can control substantially all of the supply or demand for a good or service, he can control its price. This is called a monopoly (if supply is controlled) or a monopsony (demand is controlled).

1.3.5.2 Some people are not represented in the energy marketplace (for example, too poor, not yet born), and so their opinion of the value is not taken into account.

1.4 Over a period of time, supply and demand change, and when they do the equilibrium price will change also.

1.4.1 Over time, an individual's demand for energy can change. For example, imagine a consumer who moves closer to work, buys a more fuel-efficient car, insulates her house. As time passes and these steps are taken, that individual's demand curve changes slope. Changes in individual demand add up to a change in aggregate demand.

1.4.2 Over time, the supply curve for an energy source can change. For example: rising costs of extraction with depletion of a finite resource make suppliers willing to supply less at any given price; application of a new technology can make suppliers willing to supply more at an any given price.

1.5 Energy can be allocated by laws.

1.6 Energy can be allocated by social custom, e.g., the distribution of food energy by hunters in some traditional societies, or around our family tables.

1.7 The market for energy in the United States is, in general, not a free market. (The closest to it is probably the market for fuelwood.)

1.7.1 The prices of some suppliers, the utilities, are regulated.

1.7.2 Prices of some energy sources, like oil and gas, are or have been fixed by the government.

1.7.3 Suppliers have been subsidized in various ways by the government, for example oil tax laws, government-sponsored nuclear enrichment plants or hydroelectric projects.

1.7.4 At some times in the past, energy has been rationed (World War II) or allocated (recent crude oil allocations).

1.7.5 Competition has been restricted, for example by oil import quotas.

2 No way of getting or using energy is free; that is, there is always a cost.

2.1 Every way of supplying energy requires the use of scarce natural resources, scarce labor, and, with insignificant exceptions such as sunbathing, scarce capital resources.

2.2 In obtaining energy we give up the next-best use of these resources. This is called the opportunity cost or the alternative cost.

2.3 To find the true cost of energy, the energy used to obtain the energy must be costed on the same basis as the energy obtained.

3 The costs of energy supply and use are not always allocated to the same persons as benefits.

3.1 Not allocating costs to users encourages heedless consumption, for example, in an apartment where tenants do not pay electric utility bills.

3.2 Air pollution from an electrical generation plant represents a cost to old people with respiratory diseases, families with clean wash on the line, and so forth. The cost is not divided among the purchasers of the electricity generated by the plant. Such costs are called social costs (but note that all social costs are ultimately borne by individuals) or external costs (because sellers do not take external costs into account in setting their prices, in contrast to private or internal costs like the cost of fuel).

3.3.1 Use of air pollution control equipment reduces the cost to the old person by reducing his discomfort and medical bill, and increases the cost of electricity (because of the capital and operating costs of the control equipment). So it transfers costs to users.

3.4 There is a cost to allocating costs.
To use the example of the power plant again, the use of air pollution control devices is a way of allocating costs to the user: the costs of installing and operating the air pollution devices are paid by the users of the electricity when they pay their electric bills. It is even possible for the costs now borne by the users to exceed costs formerly borne by users and non-users (though in the case of the power plant, unlikely).

3.4.1 A point can be reached where the cost of allocating costs exceeds the benefits from doing so. To use the pollution control example again: it is much more difficult to remove the last 1% of pollutants than the first 10%. Since part of the cost to the users is passed on indirectly to non-users (money spent on the electric bill is not available for spending on other goods and services), a point can be reached where the cost to the non-user of the remaining pollution is less than the indirect costs incurred by allocation.

4 No way of saving energy is free; there is always a cost. The problem is to determine how far the benefits of saving the energy exceed the costs of doing so (if they do). (Sometimes the cost is trivial -- for example the labor and thought required to flick off a light switch on leaving a room -- but it exists.)

5 The return on investments in saving energy can be judged by life-cycle costing.

5.1 Purchase price is only one of the costs incurred in owning and using a consumer good like a car, house, or appliance.

5.2 Future energy costs can be reduced by purchasing more energy-efficient equipment. For example, replacing a gas guzzler with a fuel-efficient car avoids future gasoline purchases. Buying a more energy-efficient refrigerator avoids future purchases of electricity.

5.3 Often (not always) the more energy-efficient of two appliances will have a higher purchase price.

5.3.1 It may have cost more to make.

5.3.2 The higher cost may represent a discounting of the expected savings. For example, when the price of gasoline rose suddenly in 1979, some dealers raised the price of small fuel-efficient cars well above the sticker price at which they had been selling, and the cars still sold. Rebates were offered on larger cars, and the amount of the rebate approximated the price of the extra gasoline the large car would use during first ownership.

5.5 Some of the costs of owning and using a good are incurred in the present (such as the purchase price) and others in the future (such as the utility bills). Present costs cannot be compared directly with future.

5.5.1 Money in hand now is worth more than the same amount of money to be received in the future. (Even in the absence of inflation.)

5.5.2 The difference between the value of money now and its value in the future can be expressed as a rate. Call this the discount rate.

5.5.2.1 Different people have different personal discount rates, largely because of differing abilities to borrow. Because of this, life-cycle costing may show a conservation investment to be very attractive to a high income family but not attractive to a low-income family.

5.5.3 In order to compare present and future costs, we must convert each of these amounts to its value on one particular date, which is done by using a discount rate. Usually the date chosen is now, and the values are referred to as the present values.

5.5.4 We can find the lifecycle cost of a good by adding the present value of the estimated costs of owning and using the good over its useful life, including the opportunity cost and salvage value. Comparing the lifecycle costs of two comparable goods is a guide to whether a higher initial investment is worthwhile.

6 Resources tend to be invested in those projects which offer the greatest return.

6.1 Self-interest motivates energy suppliers, in choosing between alternative investments, to try to maximize return.

6.2 The higher the perceived risk, the greater the rate of return needed to attract investors.

6.3 In general, projects able to attract investment by offering a higher rate of return than alternatives can do so because they make more productive use of the invested resources.

6.4 Decisionmaking by economic analysis is effective in finding that use of resources which will lead to the greatest production of goods and services. It is not claimed to produce a distribution of those goods and services that people will regard as fair.

7 Energy is obtained from other countries by trade. [Brown 1978]

7.1 All trade is an exchange. To obtain oil from other countries, we must give them something they want.

7.1.1 Sometimes they don't want to trade for what we have to offer, but they do want something from another country who wants something from us.

7.1.2 Money is a way of facilitating such trades, just as it is within a country.

7.1.3 People accept money instead of goods in a trade because they believe they can trade the currency for goods and services they want.

7.2 Energy trade is one factor which affects the value of the dollar (or any other currency) relative to other currencies.

7.2.1 For a number of years, many oil-producing countries have asked to be paid in American dollars. Other oil-buying nations had to obtain dollars in order to buy oil.

7.3 If a country imports more than it exports, other things being equal the value of its currency will tend to decline. Imports will become more expensive, and its exports will look cheaper to buyers in other countries.

7.4 If the value of the dollar rises relative to the currency of another country, their goods look cheaper to us, so we will import more, and ours look more expensive to them, so we will be able to export less to them. And conversely.

7.5 The size of trade deficits caused by purchases of oil is creating a world-wide financial problem.

7.5.1 Some of the less-populated, less-industrialized oil exporting nations are earning more from their oil exports than they currently need to pay for imports of goods and services. They must find investments in other countries for this income.

7.4.2 Oil exporters must make a produce now or later decision. They can cut back production, saving the oil for future years and raising the current price (because demand would stay the same and supply would decrease), or they can seek investments that will increase in value at least as fast as the oil would if left in the ground.

7.4.3 The less-developed nations that do not have oil are particularly hard hit by oil price increases because they have few exports (especially of high-value manufactured goods) with which to balance their trade account.

8 Energy costs are part of the supplier's costs for all goods and services.

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X. ETHICAL ISSUES IN ENERGY USE

A different format has been used for this topic because it deals with questions of values, which each student must decide for him or herself. Since most ethical questions in energy use involve the effects of one's actions on other people, some generalizations on the interpersonal effects of energy supply and use are first presented, together with some list of examples which are not all-inclusive. These are followed by examples of questions of values which students might consider.

1 Any person's use of energy affects other people.

1.1 One's use of energy maybe helpful to others.
  1.1.1 Everyone uses energy in providing goods and services other people want.
  1.1.2 The use of energy sometimes contributes to the increase and spread of knowledge, which helps other people.

1.2 One's use of energy has environmental effects which affect other people.
  1.2.1 It exposes workers in energy supply to unhealthful conditions.
  1.2.2 It can affect the ability of the biosphere to sustain humanlife.

1.3 The use of energy affects the organization of society, and so affects individuals.
  1.3.1 It affects what sorts of jobs are available to others.
  1.3.2 It affects the spatial arrangement of communities.
  1.3.3 It affects the continuity of societies (e.g., Australian aborigines and uranium, boom towns of Wyoming and coal.)

1.4 One's use of energy affects the availability of energy for use by other people.
  1.4.1 The effect maybe felt through the price mechanism; that is, increasing demand tends to raise the price and puts energy from that source out of the reach of some users.
  1.4.2 The use of energy can deplete resources, leaving less for future generations.

1.5 The benefits and costs of energy use may be separated in time. For example, the costs of pollution are often left to be borne by future generations.

1.6 There is a range in how voluntary people's decisions to bear the costs of energy use are; on the one hand is the person who volunteers for hazardous work; on the other hand the

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people on the family farm downwind from a new generating plant.

2 Different groups are affected in different ways.

2.1 In our country, the poor spend a larger percentage of their income on energy than other groups do, yet their energy consumption per capita is smaller than that of higher income groups and so reductions in usage through conservation are more difficult.

2.2 Groups differ in their access to technologies, and that affects their use of energy.

Examples of Questions

Are our current activities in the field of energy fair to the other people who live in our communities and nation?

It is easy to get bogged down in considering only things we are doing and perhaps shouldn't (for example, what some describe as our profligate rate of consumption). However, it is equally important that students consider actions we are not taking and perhaps, for the benefit of others, should.

in terms of meeting the energy needs of others
(Are state mineral severence taxes, collected on fuels sold to other states, fair? Why or why not? Agree they have been found legal.)
in terms of the burden or costs placed on others
(Suppose it is legal to add a second story to your home that will shadow a neighbor's solar collector? Is it fair or not? Under what conditions?)
in terms of opportunities (like jobs) opened to others

Are our current activities in the field of energy fair to the people who are not yet born?

in terms of depletion of finite resources
in terms of pollution problems associated with energy use
in terms of a technological heritage (such as small-scale appropriate technologies? such as cheaper photovoltaic cells? such as breeder reactors? such as fusion reactors?)
in terms of a social heritage of an equitable means of distributing energy among the members of society? in terms of a social heritage of an efficient means of providing for society's need for energy?

Is there a conflict between equity, efficient production and use of energy, and stability, and if so how may conflicting needs be balanced?

Should any energy sources or uses be prohibited, and if so why? Who shall make such decisions and what is the source of their authority?

Should food like corn or land that could be used to produce it be used to produce fuel?

Are our current activities in the field of energy fair to people who live in other societies on our planet?

in terms of depletion of finite resources
(Should we encourage the less-populated oil-producing nations to sell their "national heritage" in order to invest the proceeds in the economies of the developed nations, or to preserve it for future generations of their citizens? [The wording is deliberately loaded to provoke students.])

in terms of pollution problems associated with energy use
(If it were shown that continued burning of coal would cause global climate changes, should one nation attempt to prevent another from using that energy source? [The question can be rephrased with petroleum, nuclear, etc.])

in terms of a responsibility to develop new technologies
(such as: small-scale "appropriate" technologies? such as less costly photovoltaic cells? such as breeder reactors? such as fusion reactors?)

7 Is there a conflict between freedom and interdependence?

Is dependence wrong? Is it wrong for one individual to depend on another? ...for one nation to depend on another? ... to be dependent on another? What is the difference, if any, between dependence and interdependence?

Does dependence create mutual obligations?
Assume one nation has had a long-term dependence on another for its energy supply, as many nations do depend on the Persian Gulf states. Is it ethical for the Persian Gulf state to cut off the supply of oil to the dependent state for a political purpose, knowing that this will produce economic chaos in the dependent country? In such a case, should the dependent country seek a violent remedy, i.e. seizure of the oil fields by military force? Do "oil as a political weapon" and "gun-boat diplomacy" differ in their rightness or wrongness? What if instead of oil it was "food as a political weapon"?

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XI. CONSERVATION OF ENERGY

(Shelter-related conservation and transportation conservation, the two biggest energy-users which individual citizens can control personally, are treated in separate sections XII and XIII respectively.)

1 Conservation means using less energy, but it does not necessarily mean doing without the benefits that energy use presently provides. Increases in efficiency provide the major means for achieving this. For example, a more efficient refrigerator can provide the same benefits to a family as a less efficient one, but will use less electricity.

2 Conserving energy benefits individuals and society as a whole.
   2.1 Fuel costs can be avoided.
   2.2 The rate at which energy prices increase will be less than it would be without conservation.
   2.3 The investment needed to save a certain amount of energy is often less than the investment that would be needed to provide that amount of energy.
   For example, in many areas $1000 invested in home insulation will save more energy than could be provided by $1000 spent on generating capacity and fuel, or on an active solar system.
   2.4 Conservation promotes stability.
      2.4.1 It reduces international tension over the distribution of resources.
      2.4.2 It makes our society less subject to shocks from sudden fluctuations in our energy supply.

3 All ways of conserving energy cost something.
   3.1 The question is the size of the net benefit
   3.2 Of the conservation measures that require investment, those that provide the earliest payback should be done first.

4 Energy is conserved on the margin, that is, energy that is saved is the one extra gallon of gasoline, the one more kilowatt-hour of electricity that would otherwise be needed, and the marginal cost is typically greater than the average cost.
   4.1 New capacity must be built at today's prices; old capacity was built at much lower prices.
   4.2 In general, the best dam sites, the shallowest oil, etc., is exploited first; the more you extract the more each additional unit costs to produce.

5 Energy may be saved by recycling materials. [Bowman 1978]
   5.1 It often takes less energy to reclaim a material than it does to produce the material from virgin resources.
   5.2 Municipal wastes may be used as an energy source.

6 Energy may be saved by using heat which is now rejected, such as (in the home) the heat in domestic wastewater or heat from clothes dryers. In industry, cogeneration, the use of heat rejected from engines or turbines being used to run electrical generators,

may be a large source of savings.

7 Energy may be saved by the wise choice of appliances.
   7.1 Appliances that use electricity to produce heat will generally be the biggest energy users.
   7.2 Frequently an appliance that is more energy-efficient than similiar models will have a higher purchase price, which may represent such additional manufacturing costs as more copper in the motor windings, extra insulation, or more sophisticated controls. Life cycle costing (see IX.4) may be used to determine whether the higher purchase price will be recouped through savings on utility bills over the life of the appliance.
   7.3 Information on energy efficiency of major appliances can be obtained from manufacturers' listings of EER and SEER ratings, legally required energy labels, consumer publications, and government agencies.

8 Energy can be saved by thrifty habits: recognizing when energy is being used to no purpose and avoiding it.

Selected References

Abelson, Philip H. 1974. Energy: Use Conservation and Supply. Washington, DC: Amer. Assn. for the Advancement of Science. See especially the section "People and Institutions." Selected articles from the magazine Science, a few of which now show their age.

Abelson, Philip H. and Allen L. Hammond, editors. 1978. Energy II: Use Conservation and Supply. Washington, DC: Amer. Assn. for the Advancement of Science. Articles from the magazine Science. See especially section 2.

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Annual Review of Energy. See reference on page 9.

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XII. SHELTER-RELATED CONSERVATION

1 Space heating uses more energy than any other activity in the typical household. About 40% of total residential energy use in the U.S. is for space heating.

2 The purpose of using energy for heating and cooling the home is to provide human comfort.

2.1 Degree-days are a unit used to measure the need the weather creates for heating. To find the heating degree-days for one day, first find the average of the highest temperature and the lowest temperatures reached on that day (in degrees Fahrenheit). This is called the mean temperature. Then subtract the mean temperature from 65°F. If the mean temperature is above 65°F, no heat is required and the number of degree-days is zero. To find the degree-days for a longer period, add the degree-days for the individual days.

2.2 Humidity interacts with temperature in determining human comfort.

2.2.1 More heat is needed to raise the temperature of moist air than dry air.

2.2.2 It takes energy to remove moisture from air.

2.3 Comfort depends on radiative heat transfer with room surfaces as well as ambient air temperature. A room with warm dark walls will feel comfortable at air temperatures much below those that would feel chilly if the walls were also cold.

2.4 Comfort needs donot require that a building be heated uniformly.

2.4.1 Older people and young children often need higher room temperatures.

2.4.2 Physical exercise reduces the need for heat.

2.4.3 Unused rooms need not be heated, except to prevent frozen water pipes or damage to special contents.

2.5 Clothing adjustments can substitute for increased heating or cooling.

3 Conduction can cause an unwanted loss of heat during the heating season or gain of heat while air conditioning is in use.

3.1 Some building materials are better thermal conductors than others. Building material that is used because it is a relatively poor conductor of heat is called insulation.

3.1.1 R-value is a unit used to measure the resistance of a building material to the flow of heat. The higher the R-value, the greater the resistance to the flow of heat. A substance with an R-value of one will permit one Btu to pass through one square foot in one hour when the difference between the temperatures on the two sides is one degree Fahrenheit.

3.1.1.1 The R-value for different thicknesses can be estimated by multiplying the thickness times the R-value for one inch. This is only an estimate, which becomes less reliable as thickness increases. For better information, consult the actual package markings.

3.1.1.2 To estimate the R-value of a wall or roof which contains layers of different materials, add the R-values of the different layers.

3.1.2 The U-value is the reciprocal of the R-value. The lower the U-value, the greater the resistance to the flow of heat through the material.

3.2 Properties besides the R-value must be considered in choosing an insulator. For example, some forms of insulation can cause corrosion of wiring conduit or plumbing. Some are a fire hazard and can only be used below ground. Some emit noxious gases.

3.3 The circulation of water vapor must be considered when insulation is installed.

3.3.1 The warm air in most residences contains enough water vapor that some of it will condense on surfaces as cold as the house's outside walls.

3.3.2 Water vapor that enters the insulation space within the walls reduces the insulating value of the insulation by making it soggy, and contributes to the rotting of the wood framing.

3.3.3 A waterproof vapor barrier, such as a sheet of polyethylene or aluminum foil, must be placed between the heated portion of the house and the insulation, to prevent condensation in the insulation.

3.4 Sheet glass is a poor thermal insulator compared to most building materials. A great part of the heat loss from a residence may be through closed windows.

3.4.1 Heat loss through windows may be reduced by putting insulation on the window.

3.4.1.1 Drawing heavy drapes at night reduces heat loss.

3.4.1.2 Thermal shades, insulating shutters, rigid insulation,and other devices can also be used to reduce heat loss.

3.4.1.3 Before insulating windows by methods that block the passage of light, the heat loss prevented should be compared with the heat gain prevented by blocking direct sunlight.

3.4.2 Heat loss through windows may be reduced by trapping dead air between the glass and additional layers of glass or plastic. These may be removable storm windows or double or triple-glazing.

3.5 Insulating ducts and pipes that carry heated air and hot water through unheated spaces can save energy.

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4 Infiltration of outside air causes an unwanted loss of heat during the heating season, or gain of heat while air conditioning is in use.

4.1 The rate at which inside air is exchanged for outside air depends on the size of the openings and the difference between the air pressure inside the house and the pressure outside.

4.2 The wind is the main cause of differences between the air pressure inside a building and the pressure on the other side of the wall. The stronger the wind, the greater the loss by infiltration. Wind exposure can be reduced by proper siting, by planting conifers on the windward side, and by earth-sheltering.

4.3 Some building materials, like brick, are porous and permit slow infiltration. The more porous a wall, the greater the infiltration loss. Porosity can be reduced by using sealers.

4.4 The longer and wider a crack, the more air can get in or out.

4.4.1 Caulking may be used to seal cracks. Caulking deteriorates and must be renewed at varying intervals (1 to 10 years) depending on the type of caulk used.

4.4.2 Weatherstripping is used to seal cracks around windows and doors.

4.5 Various deliberate openings in a building's envelope also permit the escape of heated or cooled air.

4.5.1 Open fireplaces exhaust warm interior air. This can be minimized by:

4.5.1.1 Keeping the damper closed when the fireplace is not in use.

4.5.1.2 Closing all doors in the room containing the fireplace, so that heated air cannot be drawn in from other rooms, and opening the window nearest the fireplace an inch or so to provide unheated air for combustion.

4.5.1.3 Using glass doors to restrict flow of inside air into the fireplace.

4.5.1.4 Feeding the fire with outside air through a special duct (with a damper).

4.5.2 Kitchen ventilators exhaust warmed interior air. In the heating season, kitchen ventilators should be used the least amount necessary to exhaust smoke and odors. If air-conditioning is in use, run the ventilator only as long as the air being exhausted is hotter than the outside air.

4.5.3 Bathroom ventilators exhaust warm interior air.

4.5.4 Clothes dryers exhaust heated air which may be saved in winter; but should be exhausted to the outside if air conditioning is being used. Good filtration is needed to prevent a health hazard from lint.

4.5.5 Heated air escapes through opened doors and the cracks around doors. Airlocks around entrances reduce the escape of heated air. Automatic door closers may also save energy.

4.6 Some exchange of inside and outside air must be provided in a tightly-sealed house, to prevent the accumulation of noxious fumes, radioactive decay products, and other pollutants.

4.6.1 An air-to-air heat exchanger can be used to recover heat from the air being exhausted (or cool incoming air).

5 Gain and loss of heat through radiation can be controlled.

5.1 Deciduous plants can be used to block sunlight in summer while admitting winter sunlight.

5.2 Darker roof and wall colors promote both absorption and radiation of heat. Light-colored roofs reduce summer heat gain.

5.3 Awnings or other shades can prevent entry of direct sunlight.

6 Ways of supplying heat to the home differ in efficacy.

It is better to use "efficacy" than "efficiency" in this context. An electric heat pump, for example, might have a Coefficient of Performance of 300%, indicating that it delivers three times as much energy in the form of heat than the wires deliver to it in the form of electricity. COP figures are a useful and usual way of comparing different heat pumps, and heat pumps with resistance heating. But they are a measure of efficacy and not of efficiency; the fact that energy cannot be created ensures that no device can have an efficiency of more than 100%.

6.1 The furnace and its firing rate should be sized to the job.

6.2 In forced air systems, energy can be lost from ducts.

6.2.1 Uninsulated ducts running through unheated areas waste heat.

6.2.2 Ducts can develop leaks which must be sealed with tape or caulking.

6.3 In some climates, heat pumps are a more economical form of heating. They are almost always more economical than electric resistance heating.

7 The way a heating system is used makes a difference.

7.1 Maintenance affects efficiency. For example:

7.1.1 Annual tuneups, for example of oil burners, save energy. The efficiency of the burner depends on the proper fuel/air mixture. If the burner is not correctly adjusted, incomplete combustion will result, wasting some of the energy in the fuel and creating other hazards as well.

7.1.2 Clogged filters require more energy to move the air. Filters must be replaced before they become clogged.

7.1.3 Coils of heat pumps and air conditioners, and radiators, must be kept clean. The purpose of the coils is to transfer heat between the fluid in the coils and the surrounding air; dirt acts as an insulator that retards heat flow.

7.2 Reducing the average thermostat setting saves energy.
7.3 Turning down the thermostat at night saves energy. Devices are sold which do this automatically.
7.4 Many heating systems can be adjusted so that different parts of the home receive only as much heat as is needed for the activities that take place there.

8 Air conditioning is a major use of energy in many homes. In the U.S. as a whole, it accounts for about 6% of total residential energy use. It is especially important in areas where it is the major cause of peak electrical demand.
8.1 The higher the thermostat setting, the less energy is used.
8.2 Filters must be replaced before they become clogged, to prevent a heavy load on the fan motors.
8.3 Reduce heating load.
8.3.1 Shade air conditioner coils.
8.3.2 Vent hot air, for example from dryers or stoves.
8.3.3 Save heat-producing tasks like cooking or ironing for night or cooler weather.
8.3.4 Prevent direct sunlight from entering the house.
8.4 Use ventilation instead of air conditioning where possible.
8.4.1 When the outside air is cool, use a whole house fan instead of an air conditioner.
8.4.2 Use house designs that take advantage of prevailing winds.
8.4.3 Use house designs that use natural convection in the interior.
8.5 Use day-night temperature fluctuations where possible.
8.5.1 Add thermal mass to the house and provide for night cooling (e.g., adobe walls with night ventilation, roof ponds with night re-radiation).
8.5.2 Use the thermal inertia of the earth itself (earth-sheltering, ventilation through buried pipes).

9 Water heating is the second largest use of energy in the average residence. It accounts for about 14-17% of total U.S. residential energy consumption.
9.1 Water heaters differ in efficiency, both between types (gas, electric, solar, heat pump, etc.) and within types. In choosing a water heater, initial purchase price and energy savings may be taken into account by using life-cycle costing (see IX.4).
9.2 Sediments that accumulate in the bottom of gas and oil-fired water heater tanks act as insulation that reduces the efficiency of the heater. Draining the tank flushes out this sediment.
9.3 Adding a blanket of additional insulation to gas water heaters will save fuel. (Don't close off the air supply at the bottom!)

9.4 It may pay to insulate hot water pipes that run through an uninsulated space.
9.5 Energy is saved by lowering the thermostat setting of the water heater. (But, don't do it if you are using an older model dishwasher that requires 140°F water.
9.6 Using less hot water is a way of reducing energy consumption.
   9.6.1 Cold or warm water wash cycles and cold rinse cycles are adequate for most laundry.
   9.6.2 Fix leaky faucets.
   9.6.3 Use flow restrictors in showers; take short showers instead of baths.
9.7 Waste heat, for example from air conditioners or used water, can be used to heat water.

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ASHRAE Handbook and Product Directory. 1977 Fundamentals. 1977. New York: American Society of Heating, Refrigerating, and Air-Conditioning Engineers.

Hand, A.J. Home Energy How-To. 1977. New York: Popular Science and Harper and Row. Part one is one of the better explanations of home conservation (part two, "Producing Energy," treats solar energy, windpower, and so forth.)

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XIII. TRANSPORTATION CONSERVATION

1 Transportation is a major use of energy.
About 25% of all energy consumed in the U.S. in 1979 was used for transportation.

1.1 Petroleum provides almost all the energy used for transportation in the United States.

1.2 In many households, gasoline purchases are the largest single energy purchase made in the household.

2 Means of transportation differ in the amount of energy required per unit transported: energy per ton-mile in the case of freight; energy per passenger-mile in the case of persons.

2.1 Besides direct fuel costs, in each form of transportation other costs will be incurred, some of which are indirect energy costs, some of which are not energy-related (e.g., people's time).

3 Changes in people's routines can reduce energy requirements for transportation. [Rubenking 1980b]

3.1 Combining trips saves energy. Not only is the same ground frequently retraced in multiple trips, but also it takes 20 minutes for the typical automobile to reach peak efficiency.

3.2 Sharing the ride (carpooling, shared shopping trips) saves energy.

3.3 A means of communication, like mail or the telephone, can sometimes be used to reduce the need for transportation.

3.4 Choosing a job near your home or a home near your job saves energy.

4 Automobile energy consumption can be reduced by more energy-efficient design.

4.1 Reducing the deadweight saves energy. Weight can be reduced by using new, lighter materials (e.g., plastic hoods, aluminum engine blocks), by eliminating features (e.g., power-operated windows).

4.2 Engines with better thermal efficiency are being developed.

4.2.1 Thermostatically-controlled fans speed engine warmup and reduce drag at crusing speeds.

4.3 Radial tires decrease energy loss to tire flexing, and can save on the order of ½mpg.

4.4 At highway speeds, most of the energy is used to overcome air resistance. Streamlining reduces gasoline consumption.

4.4.1 Adding roof-top luggage carriers or other accessories that disrupt the air flow will reduce fuel economy at cruising speeds.

4.5 Manual transmissions use less energy than automatic transmissions.

4.6 Indicators like vacuum gauges help the driver learn fuel-saving driving habits.

4.7 Some fuel-saving measures involve tradeoffs with safety and pollution control measures.

5 Automobile energy consumption can be reduced by more fuel-efficient driving techniques. There can be as much as a 30% difference in fuel consumption between a poor driver and one who is fuel-efficient. [North Dakota 1977, Reichert 1980, Rubenking 1980a]

5.1 Avoid idling.

5.1.1 ~~Warming up more than 20 seconds wastes gas. A car~~ that requires a longer warm-up needs a tune-up.

5.1.2 When a car is stopped for more than a minute, turning off the engine will save fuel (provided you know your car will restart.)

5.2 Sudden acceleration wastes gas.

5.2.1 Avoid jack rabbit starts.

5.2.2 Avoid habitual lane-changing.

5.2.3 Avoid racing the engine in neutral.

5.2.4 Don't repeatedly pump the accelerator when starting.

5.3 Brake as little as is consistent with safety.

5.3.1 Anticipate stops; let the engine do the braking.

5.4 Most cars get their best mileage at 35 mph. Miles per gallon will be about 20% better at 55mph than at 70 mph.

5.5 Don't overfill the tank; always have a gascap.

5.6 Get into high gear as quickly as possible.

5.6 If radio stations in your area broadcast traffic information, use them to avoid congestion.

6 Automobile energy consumption can be reduced by proper vehicle maintenance.

(To provide a picture of the relative importance of various problems, percentage reductions in gas mileage are given below. Because fuel efficiency depends on many factors, such as climate, the use of the car, the driver's technique, and so forth, these figures should only be taken as rough estimates, from reputable sources, that apply to some cars under some conditions.

6.1 Tune-ups can add 5% to gasoline mileage.

6.2 Underinflated tires can reduce gas mileage by 3 to 5%. Keep tires inflated to the highest pressure recommended by the tire manufacturer.

6.3 Remove unnecessary deadweight, like snow chains in the trunk in the summer. Adding 100 lbs to a subcompact will reduce mileage by 0.4%.

6.4 Change oil at recommended intervals. A multi-grade or synthetic oil may give better mileage.

6.5 Improper wheel alignment can reduce gasoline mileage by 2 to 3% (¼inch out).

6.6 Dragging brakes affect gasoline mileage.

6.7 Operation of the automatic choke affects gasoline mileage.

6.8 Fouled sparkplugs can reduce mileage by 3 to 7%, or 2 miles per gallon.

6.9 A broken thermostat or one set to open at too low a temperature reduces gas mileage by as much as 20%, since an engine is most efficient when warm.

7 Automobile energy use can be reduced by better traffic management by local and state agencies.

7.1 Idling time can be reduced, for example at stoplights by synchronizing traffic lights and allowing right turns on a red light, or moving more of the traffic on thruways.

7.2 Braking can be reduced by such measures as metered on-ramps on freeways, to maintain a steady flow of traffic.

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Weiers, Ronald M. 1980. Chilton's More Miles Per Gallon Guide, 2nd Edition. Radnor, PA: Chilton Book Company. The most comprehensive of the books of advice for car owners.

Automotive Fuel Economy PT-15. 1976. Warrendale, PA: Society of Automotive Engineers. The best of the papers on fuel economy published by the SAE between 1966 and 1976. Extensive bibliography.

Automotive Fuel Economy--Part 2 PT-18. 1979. Warrendale, PA: Society of Automotive Engineers. Extends the above work for the period 1976 to 1979.

CORRELATIONS

SOCIAL STUDIES

Is there a curriculum with which energy topics can be correlated?

Despite the appearance of great diversity and the fact that curriculum decisions are made at fifty state and thousands of local levels, there is considerable uniformity in the broad outlines of the social studies curriculum within the United States:

> While persons both in and out of the profession have maintained that social studies lacks uniformity and predictability, the data analyzed in SPAN indicates that this is not true. Information from the RTI survey, the Illinois case studies, and the Ohio State literature review points to a strong similarity of courses or topics taught at grade levels from K-12 across the nation. The impact of this similarity is a virtual nationwide curriculum which is held rather firmly in place by state laws, district requirements, textbook offerings, and tradition. The most typical sequence is shown in figure one.

figure one,
Dominant Social Studies Curriculum Organization Pattern

K - Self, school, community, home
1 - Families
2 - Neighborhoods
3 - Communities
4 - Regions, State History
5 - United States History
6 - World Cultures
7 - World Geography or History
8 - United States History
9 - Civics or World Cultures
10 - World History
11 - United States History
12 - United States Government

--(Superka, ref 405)

Should some course offerings receive priority?

Note that American History is by far the most dominant single offering, typically given at three different grade levels. At the high school level, 93% of the schools surveyed in a survey sponsored by the National Science Foundation offered American History and 81% required it of all students. The RTI survey states:

> Schools which include one or more of the grades 10-12 have their largest social studies enrollments in U.S. History (approximately 4 million), World History (approximately 2 million), and American Government (approximately 1.6 million). In each case, roughly one-third of the enrollment is in 10-12 schools, while the remainder is in schools which include grades 9-12. No other high school

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social studies course has an enrollment as high as one million, although several of the social science courses have enrollments in the 600,000-700,000 range.

Distribution by percent of all social studies classes in schools which include any of grades 7-12

American History	34%
Social Studies	18%
State History	7%
Civics	6%
World Geography	6%
Other	29%
	100%

Distribution by percent of all social studies classes in schools which include any of grades 10-12

American History	27%
World History	10%
Psychology	7%
American Culture, Cont. Issues	7%
U.S. Government	5%
Economics	5%
Other	38%
	100%

(Weiss, ref 406)

So American History seems in a class by itself among the social studies course offerings, whether one considers number of students enrolled, percentage of classes offered, the number of schools offering the subject, or the number of different grade levels at which students may be exposed to the subject. It would seem that because of this teacher training and supplementary materials development for American History will have a greater impact than similiar resources committed to other social studies course offerings.

The following section presents some sample objectives that might be considered for use at various grade levels in the typical sequence described previously. This list is far from exhaustive.

KINDERGARTEN & FIRST GRADE -- Families

Examples of Widely-Used [illegible]:

People at Home (King) [[illegible]]
Social Sciences: Concepts & Values (Brandwein) [Harcourt Brace]
Concepts and Inquiry Series: Our Country (Grade 1) [Allyn & Bacon]
***
You and Me (Grade 1), [Rand McNally]
Understanding People (King) [Laidlaw]

Examples of Energy-Related Objectives

The student recognizes instances of energy use in the home. (But, clearer insights into ways 4, 5, and 6-year-olds can conceive of energy are needed.)

The student can identify some energy sources entering his own home, such as food, gasoline, electricity, fuel oil, and natural gas.

The student recognizes that energy is being wasted in a few simple household examples, such as leaving on the lights or TV when there is no one in the room.

The student recognizes that his/her parents pay money for energy.

The student is aware of dangers involved in the use of heat and electric energy, and in the use of power-driven machinery.

Examples of Energy Curriculum Materials

4 Energy Conservation Activity Packet, K-2
132 The Energy We Use

1. The entries above the asterisks are those texts identified as most-used by the National Science Foundation survey in 1977, in order of popularity. Additional titles have been added (below the asterisks) to show the directions taken in more recent publications and by other major publishers.

SECOND GRADE--Neighborhoods

Examples of Widely-Used Texts
Families and Social Needs (King) [Laidlaw]
Social Sciences: Concepts and Values (Brandwein) [Harcourt Brace]
Concepts and Inquiry Series: Our Community [Allyn and Bacon]
***
Here We Are [Rand McNally]
Understanding Families (King) Laidlaw

Examples of Energy-Related Objectives

The student recognizes some uses of energy outside the home and recognizes that these uses benefit the student (such as street cleaning and street lighting).

The student recognizes that all forms of transportation require energy.

The student recognizes that a supply of energy is essential to the work done in a few occupations typical of the community.

Examples of Energy Curriculum Materials
4 Energy Conservation Activity Packet, K-2
117 Oklahoma Energy Awareness Education, K-3
17 . Community Workers and the Energy They Use

THIRD GRADE -- Communities

Examples of Widely-Used Texts

Communities and Social Needs (King) [Laidlaw]
Social Sciences: Concepts and Values (Brandwein) [Harcourt]
Concepts and Inquiry Series
***
Exploring Communities [McGraw-Hill]
Exploring Our World: Communities [Follett]
Understanding Communities (King) [Laidlaw]
Our Land [Rand McNally]

Examples of Energy-Related Objectives

The student recognizes some objects in the community were made to provide members of the community with energy. This would include the functions of such infrastructure as electric lines, gasoline stations, and in a larger perspective the existence of systems like the electrical system (generating station, transmission lines, etc.).

The student recognizes that some people in the community have jobs relating to supplying the community with energy. In other words, the meter-reader, fuel oil dealer, and solar installer can be a community helpers too.

The student can identify most of the energy sources used in the community, and can identify the geographical source of the petroleum used, and the fuels (or hydropower) used to generate electricity.

The student recognizes the role of energy in such community functions as transportation of food and people.

Examples of Energy Curriculum Materials

5 Energy Conservation Activity Packet, Grade 3 17 Community Workers and the Energy They Use
128 Energy and Transportation
163 Energy Use in Homes and Stores
164 Schools Can Conserve, Too
165 Transportation: The Energy Eater

FOURTH GRADE -- Regions

Examples of Widely-Used Texts

Exploring Our World: Regions (Gross et al) [Follett]
Social Sciences: Concepts and Values (Brandwein) [Harcourt]
Regions and Social Needs (King) [Laidlaw]
Contemporary Social Science Curriculum (Anderson) [Silver Burdett]
Man and His World Series
Concepts and Inquiry series: Agriculture: People and the Land, and Industry: People and the Machine [Allyn and Bacon]
Tiegs-Adams series
***
Studying Cultures [McGraw-Hill]
Understanding Regions of the Earth (King) [Laidlaw]
Where on Earth? [Rand McNally]

Examples of Energy-Related Objectives

The student recognizes that the energy resources of regions differ, and can describe the chief energy resources of two different regions.

The student describes the role of energy in transportation within a region and between regions.

The student relates the occupations within a region to the energy resources available to the people.

The student can give examples of the role of energy in providing organic and inorganic raw materials.

Examples of Energy Curriculum Materials

86 Networks: How Energy Links People, Goods, and Services

FOURTH GRADE -- State History

Texts

Texts for this subject naturally vary from state to state. Examples of such texts include Exploring Our State: Wisconsin [Follett], Ohio: Geography, History, Government, (Second Edition) [Laidlaw], and A Panorama of Florida and A Panorama of West Virginia (Jalamap Publications).

Examples of Energy-Related Objectives

The student describes the sequence in which the sources of energy used by the people who inhabited the area where he/she lives have changed in the course of time. [Here is a clear example of the opportunity and necessity for local groups to develop classroom materials on energy. In many states, much of the historical spadework has already been done, typically by state energy offices, and is available to educators. For examples of such sources (which are not themselves classroom materials) see Kuntz, ref 604; Itami, ref 602, Fang, ref 601.]

The student describes the energy supply and use position of the state in which he/she lives. (Again, because the energy flows in states do differ greatly, local development is essential. For a graphic display of the differences in energy use and supply from state to state, see Kidman, ref 703. Ref 3 provides a useful model although not at the proper grade level.)

The student can describe the role of energy in one industry or other economic activity which has been important in the development of the region.

The student contrasts the energy situation of his/her state with that of another state or country.

The student describes how the climate of the state has affected its people's use of energy.

The student uses historical data (1973, 1978 newspapers) and knowledge of the way the state uses energy to predict the effects a petroleum shortage would have on the state, and proposes solutions the problems created.

The student describes the events leading to the passage of a state or local law or ordinance involving energy use or supply.

Examples of Energy Curriculum Materials

86 Networks: How Energy Links People, Goods, and Services

FIFTH GRADE -- United States History

Examples of Widely-Used Texts

Exploring Our World: the Americas (Gross et al) [Follett]
Social Sciences: Concepts and Values (Brandwein) [Harcourt]
The Social Studies and Our Country (King) [Laidlaw]
Contemporary Social Science Curriculum (Anderson)
Man and His world series
Concepts & Inquiry series [Allyn and Bacon]
***
Understanding the United States [McGraw-Hill]
Understanding Our Country (King) [Laidlaw]
Across America [Rand McNally]
The Making of Our America [Allyn and Bacon]

Examples of Energy-Related Objectives

The student describes ways early Americans depended on wood as a fuel.

The student describes how colonial Americans used animate energy and contrasts it with the use of energy today.

The student relates changes in the nation's transportation system to changes in our use of energy.

The student relates urbanization to changes in the sources of energy available to families.

Examples of Energy Curriculum Materials

SIXTH GRADE -- World Cultures

Examples of Widely-Used Texts

Exploring series [Follett]
Social Sciences: Concepts & Values (Brandwein) [Harcourt]
Understanding the World (King) [Laidlaw]
Contemporary Social Science Program (Anderson)
Man and his World series
Concepts & Inquiry series: The Age of Western Expansion, New World and Eurasian Cultures, The Challenge of Change, The Interaction of Cultures.
Tiegs-Adams series
***
Investigating Societies [McGraw-Hill]
The World--Then and Now [Rand McNally]
Cultures of the World [Allyn and Bacon]

Examples of Energy-Related Objectives

The student recognizes that cultures may differ in the sources of energy they use.

The student recognizes that the level of per capita energy consumption varies greatly from culture to culture.

The student recognizes that some uses of energy are socially determined.

The student recognizes that energy use and supply may be influenced both by the physical environment (such as the presence of fuel deposits, vegetation, climate), and by human factors such as cultural tradition and education.

The student describes an instance in which one culture has acquired a new energy source or way of using energy from another culture.

The student relates an instance when a new energy-use technology had a major impact on a society.

Examples of Energy Curriculum Materials

48 Energy and World Cultures
95 Bringing Energy to the People: Ghana and the U.S.
96 Two Energy Gulfs
120 Energy Management Center Intermediate Program

SEVENTH GRADE — World Geography

Examples of Widely-Used Texts

Our World Today series [Allyn & Bacon]
World Geography (Backler) [SRA]
World Geography Today (Israel) [Holt]
World Views [Rand McNally]
(Land and People. A World Geography. Intended for the 9th grade.)

Examples of Energy-Related Objectives

The student recognizes that the earth's mineral energy resources are not evenly distributed, and can locate the major resources. (Ref 14)

The student recognizes that a variety of climates exist, which creates differing needs for energy.

The student describes the role of energy in world trade.

Examples of Energy Curriculum Materials

95 Bringing Energy to the People: [illegible]ana and the U.S.
96 Two Energy Gulfs
106 Energy Activities for Junior Hig[illegible] Social Studies

SEVENTH GRADE -- World History

Examples of Widely-Used Texts

***

A World History (Linder et al) [SRA]
Human Heritage: A World History [Merrill]

Examples of Energy-Related Objectives

The student recognizes the brevity of the period of human use of fossil fuels in comparision with the length of human existence.

The student recognizes that exponential rates of growth cannot be sustained.

The student describes the innovations in the use of energy during the Bronze Age.

The student describes the innovations in the use of energy during the Industrial Revolution in England.

The student describes ways in which our society's use of energy differs from that of all previous societies.

The student describes an example of the impact of an energy-related technological development on a society.

The student describes the role of petroleum in Middle Eastern politics in the Twentieth Century.

Examples of Energy Curriculum Materials

48 Energy and World Cultures

EIGHTH GRADE--United States History

Examples of Widely-Used Texts

This is America's Story (Wilder) [Houghton Mifflin]
America: Its People and Values (Wood et al) [Harcourt]
***
The American Adventure [Allyn & Bacon]
The Impact of our Past (Weisberger) [McGraw-Hill]
Freedom's Trail (Bartlett et al) [Houghton Mifflin]
The Free and the Brave (Groff) [Rand McNally]
America Is [Merrill]
Discovering Our Past: A History of the U.S. (Bowes et al) [SRA]
Faces of America: A History of the U.S. (Smith et al) [Harper and Row]
America! America! [Scott Foresman]
American History (Garraty) [Harcourt Brace]

Examples of Energy-Related Objectives

The student can date each of the three U.S. energy transitions.

The student can describe, giving dates, the United States changing role as a petroleum exporter and importer.

Examples of Energy Curriculum Materials

20 Energy Transitions in United States History
24 Energy, Engines, and the Industrial Revolution
40 Energy in American History
49 Energy and American History
169 Energy, Food, and You

NINTH GRADE -- Civics

Examples of Widely-Used Texts

American Civics (Hartley)
***
Civics for Today (Branson et al) [Houghton Mifflin]
Governing Your Life: Citizenship and Civics (Dublin et al) [SRA]
Civics for Americans (Patrick) [Scott, Foresman]
Civics (Ball et al) [Follett]

Examples of Energy-Related Objectives

The student recognizes that laws affect sources and uses of energy.

The student can describe the rationale and some problems of sun rights ordinances and the process by which such a measure is debated and enacted.

Examples of Energy Curriculum Materials

25 Transportation and the City
33 Western Coal: Boom or Bust?
133 How a Bill Becomes a Law to Conserve Energy

NINTH GRADE -- World Cultures

Examples of Widely-Used Texts

***

The Human Experience, World Culture Studies (Weitzman et al) [Houghton Mifflin]
People, Places, and Change: An Introduction to World Culture (Berry et al) [Holt]
People and Cultures (Garbarino) [Rand McNally]
Global Insights: People and Cultures [Rand McNally]

Examples of Energy-Related Objectives

The student compares sources and uses of energy in an ancient and modern culture.

The student compares how access to energy sources is determined in two contrasting cultures.

The student compares the incentives to capital accumulation in two contrasting cultures.

Examples of Energy Curriculum Materials

21 Energy in the Global Marketplace
48 Energy and World Cultures

TENTH GRADE--World History

Examples of Widely-Used Texts

***

Unfinished Journey (Perry) [Houghton Mifflin]
History and Life, The World and Its People [Scott Foresman]

Examples of Energy-Related Objectives

The student describes the changing uses of energy in the ancient Middle East.

The student describes how the attempt to obtain resources has been a source of conflict in the twentieth century.

The student describes how the Industrial Revolution changed the availability of power.

The student describes in broad outlines the historical relationship between per capita energy consumption and human well-being and capital accumulation.

Examples of Energy Curriculum Materials

21 Energy in the Global Marketplace
24 Energy, Engines, and the Industrial Revolution

ELEVENTH GRADE -- United States History

Examples of Widely-Used Texts
Rise of the American Nation (Todd) [Harcourt Brace]
History of a Free People (Bragdon)
American History (Abramowitz) [Follett]
***
These United States (Sheraton et al) [Houghton Mifflin]
The American Experience (Madgic et al) [Addison-Wesley]
The United States: A History of the Republic [Prentice-Hall]
The Americans: The History of a People and of a Nation (Jordan et al) [SRA]
We Americans (Banks) [Allyn and Bacon]
Modern American History: The Search for Identity (Wilte) [Harper and Row]

Examples of Energy-Related Objectives

The student describes each of the three energy transitions in U.S. History, suggests causes for each of them and suggests some of the impacts each of them had.

The student gives a chronological account of the role of the United States in world energy trade, and suggests some effects our energy trade may have had on our relations with other nations.

The student gives an historical account of the rise of the automobile and its impact on life in the United States in the period 1900-1973.

The student compares the impact of electrification on the farm and in the city, providing dates.

The student describes the changing use of energy on the farm in the period 1800-1980, and describes its impact on American society at large.

The student compares wood consumption in America and Europe in the period 1750-1850, and suggests economic reasons for the differences.

Examples of Energy Curriculum Materials
19 Agriculture, Energy and Society -

TWELFTH GRADE -- United States Government

Examples of Widely-Used Texts
Magruder's American Government (McClenaghan) [Allyn and Bacon]
***
American Government (Kownslar et al) [McGraw-Hill]
American Government (Schick et al) [Houghton Mifflin]
United States Government: the People Decide (Hale et al) [SRA]
American Government: Comparing Political Experiences (Gillespie et al) [Prentice-Hall]
American Government (Rosencranz) [Holt]
American Government Today (Lewinski) [Scott, Foresman].

Examples of Energy-Related Objectives

The student describes the process by which a bill about energy becomes a law.

The student describes the process by which regulatory agencies carry out laws related to energy.

The student describes some ways energy may affect our relation with other governments.

Examples of Energy Curriculum Materials
16 Energy and Society
27 U.S. Energy Policy: Which Direction?
133 How a Bill Becomes a Law to Conserve Energy

SCIENCE

Is there a curriculum pattern in science with which energy can be integrated?

At the K-6 levels, there appears to be considerable national diversity in the content taught at any one of the elementary grades. In part, this may be a heritage of the science curriculum projects of the 1960's and 70's, which placed a strong emphasis on science as process rather than as a body of facts. Nevertheless, though there is nothing like the year-by-year pattern of themes encountered in the social studies, if one considers only the topics introduced and not the grade level at which they are approached there is considerable uniformity of scope nationwide. This is especially evident if only programs prepared by commercial publishers are considered, since the elementary curriculum projects were less inhibited about introducing new topics.

In any case, different programs often treat any given topic at different grade levels. As measured by the content of leading texts (an appropriate method because it has frequently been observed that elementary science teaching is highly text-oriented), the range does not appear to exceed three grade levels. The sample correlation offered below reflects one common scope and sequence.

At the junior high and high school levels, course content is much more clearly defined.

In considering the practicality of additional treatment of energy in the science curriculum, a few additional facts may be pertinent:

Proprietary surveys by commercial publishers have shown that as a group science teachers have been much more interested in introducing energy-related topics into their classes than social studies teachers have been.

The average number of minutes elementary teachers spend on science each day is decreasing.

Eighty per cent of the elementary schools have no budget set-aside for science materials; eighty-four per cent have none for science equipment. (Weiss, ref 406)

Should some course offerings receive priority?

It is clear that more students take biology than anything else:

Distribution of all Science Classes in schools having grades 7-9.

General Science	30%
Earth Science	25%
Life Science	16%
Physical Science	15%
Biology	6%
Other	8%

In the grade levels 10-12, the following pattern was found:

Biology	40%
Chemistry	19%
Physics	15%
Advanced Biology	5%
Other	21%

(Weiss, table 28, page 63)

In addition, elementary teachers tend to emphasize biological topics over physical science topics, reflecting their training and, often, a fear of or distaste for the physical sciences. These considerations confirm the usefulness of developing life-science-oriented energy materials for infusion at the elementary level. On the other hand (as there is no escaping the relevance of the underlying physics), they may also reveal the need to develop inservicing methods which would teach elementary teachers very basic thermodynamics, and which would make them comfortable with related classroom activities.

KINDERGARTEN & FIRST GRADE

Examples of Widely-Used Texts
Concepts in Science (Brandwein) [Harcourt]
Science: Understanding Your Environment (Mallinson) [Silver Burdett]
New Laidlaw Science Program (Smith)
Heath Science Series (Schneider)
***
Accent on Science [Merrill]
Heath Science
Holt Elementary Science
Ginn Elementary Science

Examples of Energy-Related Objectives

The student identifies light, heat and motion as different forms of energy.

The student recognizes that energy is needed to make something move.

The student recognizes that the flow of heat energy sometimes causes changes in states of matter.

The student is aware that all living things require energy.

The student recognizes that food provides energy.

The student recognizes that the sun is the source of all daylight.

Examples of Energy Curriculum Materials
1 Energy: A Multimedia Kit for Teachers
35 Energy and Conservation Education Activities for the Classroom, Level 1-3.
132 The Energy We Use

ERIC

SECOND GRADE

Examples of Widely-Used Texts
Concepts in Science (Brandwein) [Harcourt]
Science: Understanding Your Environment (Mallinson) [Silver Burdett]
New Laidlaw Science Program (Smith)
Heath Science Series (Schneider)
***
Accent on Science [Merrill]
Heath Science
Holt Elementary Science
Ginn Elementary Science

Examples of Energy-Related Objectives

The student recognizes that energy can change from one form to another.

The student recognizes that energy can be stored.

The student can name some common fuels, such as gasoline, wood, coal, and natural gas.

The student recognizes that fuels are a store of energy.

The student is aware that switches control a flow of electricity, and that appliance markings such as "low med high" represent increasing levels of energy consumption.

The student is aware of how at last one activity related to energy supply or use contributes to air or water pollution, and can describe one means of pollution abatement.

The student can read a thermometer.

Examples of Energy Curriculum Materials
17 Community Workers and the Energy They Use
35 Energy and Conservation Education Activities for the Classroom, Level 1-3.

ERIC

THIRD GRADE

Examples of Widely-Used Texts

Concepts in Science (Brandwein)
Science: Understanding Your Environment (Mallinson) [Silver Burdett]
New Laidlaw Science Program (Smith)
Heath Science Series (Schneider)
***
Accent on Science [Merrill]
Heath Science
Holt Elementary Science
Ginn Elementary Science

Examples of Energy-Related Objectives

The student recognizes that the earth is warmed by sunlight.

The student identifies some manmade devices that can change energy from one form to another.

The student recognizes that all life activities involve energy.

The student recognizes that plants require light energy.

The student is aware that ordinary matter is made of atoms which have structure.

Examples of Energy Curriculum Materials

5 Energy Conservation Activity Packet, Grade 3
128 Energy and Transportation

ERIC

FOURTH GRADE

Examples of Widely-Used Texts
Concepts in Science (Brandwein) [Harcourt]
Science: Understanding Your Environment (Mallinson) [Silver Burdett]
New Laidlaw Science Program (Smith)
Today's Basic Science Series (Navarra)
***
Accent on Science [Merrill]
Heath Science
Holt Elementary Science
Ginn Elementary Science

Examples of Energy-Related Objectives

The student describes the kinetic theory of heat, mentioning molecular motion.

The student recognizes that materials are not used up in natural cycles.

Examples of Energy Curriculum Materials

6 Energy Conservation Activity Packet, Grade 4
45 Energy and Conservation Education Activities for the Classroom, Level 4-6
113 Chemical Energy
115 Electrical Energy
116 Solar Energy

FIFTH GRADE

Examples of Widely-Used Texts
Concepts in Science (Brandwein) [Harcourt]
Science: Understanding Your Environment (Mallinson) [Silver Burdett]
New Laidlaw Science Program (Smith)
Today's Basic Science Series (Navarra)
***
Accent on Science [Merrill]
Heath Science
Holt Elementary Science
Ginn Elementary Science

Examples of Energy-Related Objectives

The student describes the relation between force and work.

The student describes the photosynthesis-respiration cycle.

The student describes the loss of energy as it is passed along a food chain.

The student describes how various techniques of residential heat control, such as insulation, double-glazing, and storm windows work, and describes their relative effectiveness in terms of energy savings.

The student can describe how heat is transferred by conduction, convection, and radiation.

Examples of Energy Curriculum Materials

7	Energy Conservation Activity Packet, Grade 5
51	Energy-Environment Double-E Project, 5-6
59	Wind Energy
113	Chemical Energy
115	Electrical Energy
116	Solar Energy
120	Energy Management Center Intermediate Program

SIXTH GRADE

Examples of Widely-Used Texts
Concepts in Science (Brandwein) [Harcourt]
Science: Understanding Your Environment (Mallinson et al) [Silver Burdett]
New Laidlaw Science Program (Smith)
Today's Basic Science Series (Navarra)
***
Accent on Science [Merrill]
Heath Science
Holt Elementary Science
Ginn Elementary Science

Examples of Energy-Related Objectives

The student can describe the role of magnetism in the operation of electric motors.

The student can distinguish between power and energy.

The student recognizes that the use of a simple machine does not alter the total amount of energy used.

The student recognizes that some chemical reactions release energy.

The student is aware that nuclear reactions involve changes in the nucleus of atoms.

The student attributes the production of light by stars to a nuclear reaction.

The student can describe the process of radioactive decay.

The student can describe the use of half-lives to describe rate of decay.

The student can describe the nature and some effects of radiation.

The student can describe the process of nuclear fission.

The student can describe the role of energy in communications and data processing.

The student can read an electric meter.

(continued next page)

ERIC

Examples of Energy Curriculum Materials

LIFE SCIENCE (7th to 9th grade)

Examples of Widely-Used Texts

***

Life: A Biological Science [Harcourt]
Focus on Life Science [Merrill]
Life Science (Richardson) [Silver Burdett]
Addison-Wesley Life Science (Barr et al)
Prentice-Hall Life Science (Webster et al) [Prentice-Hall]
Holt Life Science (Ramsey et al) [Holt]
Interaction of Man and the Biosphere (Abraham et al) [Rand Mcnally]
Exploring the Living World: Pathways in Life Science [Globe]

Examples of Energy-Related Objectives

The student can describe the flow of energy in a community.

The student can describe the flow of energy in the ecosphere.

Examples of Energy Curriculum Materials

19 Agriculture, Energy and Society
168 Energy, Food, and You
169 Energy Flows through a Food Chain

PHYSICAL SCIENCE (7th to 9th Grade)

Examples of Widely-Used Texts

Energy: A Physical Science [Harcourt]
Focus on Physical Science [Merrill]
Physical Science (Schneidervent) [Silver Burdett]
Ideas and Investigations in Science (Dolmatz et al) [Prentice-Hall]
Holt Physical Science (Ramsey et al) [Holt]
Modern Physical Science (Tracy) [Holt]
Interaction of Matter and Energy (Abraham et al) [Rand McNally]
Introductory Physical Science [Prentice-Hall]
Prentice-Hall Physical Science [Prentice-Hall]

Examples of Energy-Related Objectives

The student understands measurements of energy consumption (for example, the wattage of consumer appliances), and can convert measurements from one system of units to another, and of one form of energy to another.

The student distinguishes between power and energy.

The student can calculate the efficiency of an energy conversion.

The student distinguishes between potential and kinetic energy.

The student is familiar with an electrical circuit.

Examples of Energy Curriculum Materials

24 Energy, Engines, and the Industrial Revolution
60. Solar Energy
131 Energy Systems: Present, Future
150 Activities. Junior High Science
159 Energy and Order

ERIC

EARTH SCIENCE (7th to 10th grade)

Examples of Widely-Used Texts
Focus on Earth Science (Bishop et al) [Merrill]
Modern Earth Science (Ramsey) [Holt]
***
Matter: An Earth Science [Harcourt Brace]
Earth Science (Brown) [Silver Burdett]
Ideas and Investigations in Earth Science (Bernstein et al) [Prentice-Hall]
Holt Earth Science (Ramsey) [Holt]
Interaction of Earth and Time (Abraham) [Rand McNally]
Prentice-Hall Earth Science [Prentice-Hall]
Exploring the Earth, Sea and Sky: Pathways in Earth Science [Globe]

Examples of Widely-Used Texts
The student can describe the manner in which solar energy drives various natural cycles, including its role in the formation and deposit of sediments.

The student can account for the slow rate of accumulation of fossil fuels by reference to the manner of their formation.

The student recognizes the inevitability of uncertainties in estimates of the resource base.

The student can describe the relation between the price offered for a resource and the reserves available.

Examples of Energy Curriculum Materials
3 Energy from Start to Finish (Texas only)
13 Oil Shale: The Reluctant Energy Source
39 Oil Refineries: What Do We Get from a Barrel of Oil?
148 Activities. Earth Science

ERIC

BIOLOGY (10th through 12th)

Examples of Widely-Used Texts

Modern Biology (Otto) [Holt]
Biological Science: An Ecological Approach (BSCS Green)
Biological Science: An Inquiry into Life (BSCS Yellow) [Harcourt]
Biology: Introduction to Life (Nason) [Addison-Wesley]
Biology: Living Systems (Oram) [Merrill]
Experiences in Biology (Bauer et al) [Laidlaw]
Macmillan Biology (Creager et al) [Macmillan]
Scott, Foresman Biology [Scott Foresman]

Examples of Energy-Related Objectives

The student describes the process of photosynthesis in terms of recycling of materials and a chain of energy conversions.

The student describes the flow of energy through a plant and a higher animal.

The student describes some impacts of human energy use on natural cycles.

The student describes the flow of energy in a community, using the terms producer, secondary consumer, and decomposer correctly.

The student compares the photosynthetic efficiency of different communities.

Examples of Energy Curriculum Materials

19 Agriculture, Energy and Society
61 Energy Use in Nebraska Agriculture
146 Activities. Biology.
168 Energy, Food, and You
169 Energy Flow through a Food Chain

ERIC

CHEMISTRY (10th through 12th grade)

Examples of Widely-Used Texts

Modern Chemistry (Metcalfe) [Holt]
***
Chemistry: A Modern Course [Merrill]
Chemistry: Experimental Foundations [Prentice-Hall]

Examples of Energy-Related Objectives

The student can trace the role of the element carbon through energy flows in the economy.

The student can relate the energy requirements for the smelting and refining of metals to their chemical properties.

The student can relate trace impurities in various coals to the environmental effects of burning them.

The student can describe the operation of a fuel cell.

The student can apply the laws of thermodynamics to a chemical reaction.

Examples of Energy Curriculum Materials

62 Gasohol
147 Activities. Chemistry and Physics

ERIC

PHYSICS (10th through 12th grade)

Examples of Widely-Used Texts
College Physics (Schaum)
Modern Physics (Williams)
The Project Physics (Rutherford)[Holt]
Physics: Principles and Problems [Merrill]

Most of the physics course of study concerns energy. The objectives below includes only less-taught items which may have short range practical implications in improving our energy situation, and technological applications.

Examples of Energy-Related Objectives

The student describes the Carnot cycle.

The student compares various energy sources in terms of available work.

The student computes and accounts for the efficiency of various heating plants.

The student explains differences in the operation of two types of windmill using physical principles.

The student uses the gas laws to specify requirements for a device to measure the energy in a flow of natural gas.

The student designs a solar collector, predicts its performance, builds the collector and compares performance against predication.

Examples of Energy Curriculum Materials

9,32,37,55,99,104,109,171 Modules from the American Association of Physics Teachers "Issue-Oriented" series. Consider only for gifted and advanced placement

147 Activities. Chemistry and Physics

159 Energy and Order.

170 Physical Laws of Electric Power Generation

Special Learners

In addition to being correlated to existing curricula, energy education must be matched to students' needs. To achieve this, local adaptation is required, as it is for any subject. No single program of energy education can be optimal, unadapted, for all students in a country as diverse as the United States. Ordinarily, the necessary adaptation is the responsibility of local curriculum specialists and classroom teachers.

However, for some groups of learners adaptation at the national or regional level might be more sensible. These are the students whose special problems, such as blindness, make the use of most materials unsatisfactory. Though such groups are only a small fraction of the student population in any one school district, the number of individuals in the nation as a whole is considerable.

Such groups include the visually and hearing impaired. An excellent example of what can be done to make energy education accessible to such students is the material developed by the Science Activities for the Visually Impaired program at the Lawrence Hall of Science, Berkeley, California (ref 141).

A second group requiring special attention in the development of programs are the educable mentally retarded. An example of materials for this group would be the Energy and You unit from the Topeka, KS Public Schools (Kellogg, ref 89).

BIBLIOGRAPHIES

1. CURRICULUM MATERIALS

This section lists publications written for the classroom teacher that describe units, lessons, or activities intended for classroom use, as well as textbooks.

The energy data used in some of these publications is out of date, but the educational design may still be of interest to curriculum specialists.

The materials listed vary greatly in quality and disinterestedness. There is no escaping the need for the curriculum specialist to acquire a background in the subject matter prior to making recommendations for adoptions.

1. Alabama Power Company. No date. Energy: A Multimedia Kit for Teachers. 116pp, of which 53 are spirit masters. Intended for grades K-3.

2. Allen, Rodney F. and David E. LaHart, editors. 1977. Sample Energy Conservation Education Activities for Elementary School Students. Tallahassee, FL: Florida State University. Prepared in cooperation with the Palm Beach County Board of Public Instruction. ERIC order number ED 147 217. 59pp. Intended for grades K-6.

3. Anderson, Jay Earl Jr. 1977. Energy Resources of Texas Curriculum Materials. Unit One: Energy from Start to Finish. Austin, TX: Bureau of Economic Geology, University of Texas at Austin. 130pp.

4. Bakke, Ruth, coordinator. 1977. Energy Conservation Activity Packet, K-2. Des Moines, IA: Iowa Energy Policy Council. $2.00 Produced by the Iowa Energy Policy Council in cooperation with the Iowa Department of Public Instruction. 55pp plus 3 posters and a 20pp teacher's bibliography. Intended for grades K-2. This series (see the following four entries) has been widely adapted and reissued by other states.

5. Bakke, Ruth, coordinator. 1977(?). Energy Conservation Activity Packet, Grade 3. Des Moines, IA: Iowa Energy Policy Council. $2.50 See above. 53pp plus 20pp teacher's bibliography.

6. Bakke, Ruth, coordinator. 1977(?). Energy Conservation Activity Packet, Grade 4. Des Moines, IA: Iowa Energy Policy Council. $2.50 See above. 67pp plus 7pp bibliography for grades 4-6 plus 20pp teacher's bibliography.

7. Bakke, Ruth, coordinator. 1977(?). Energy Conservation Activity Packet, Grade 5. Des Moines, IA: Iowa Energy Policy Council. $2.50 See above. 56pp plus 7pp bibliography for grades 4-6 plus 20pp teacher's bibliography.

8. Bakke, Ruth, coordinator. 1977(?). Energy Conservation Activity Packet, Grade 6. Des Moines, IA: Iowa Energy Policy Council. $2.50 See above. 63pp plus 7pp bibliography for grades 4-6 plus 20pp teacher's bibliography.

9. Bason, Frank C. 1981. Energy and Solar Heating (draft). Stony Brook, NY: American Association of Physics Teachers. One of the "Issue-Oriented Modules" coordinated by the AAPT. 58pp. Intended for college undergraduates, but could be used with a gifted twelfth grade physics student.

10. Battelle Center for Improved Education in cooperation with the Ohio Dept. of Energy. 1975. Energy. A Teacher's Introduction to Energy and Energy Conservation, Elementary Edition. Columbus, OH: Ohio Department of Education. 86pp. Intended for grades K-6.

11. Battelle Center for Improved Education in cooperation with the Ohio Dept. of Energy. 1975. Energy. A Teacher's Introduction to Energy and Energy Conservation, Secondary Edition. Columbus, OH: Ohio Department of Education. 90pp. Intended for grades 7-12.

12. Beckenhauer, Don. 1980. "Economics and Energy." From Basic Teaching Units (BTU's) on Energy, volume 1, Gary A. Lay and Donald McCurdy, editors. Lincoln, NE: Nebraska Energy Office. 18pp. Intended for grades 11 & 12, economics.

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14. Bernoff, Robert and Joshua Bernoff. No date. Energy in Our Society. Philadelphia, PA: Philadelphia Electric Company. Intended for grades 9-12.

15. Biglan, Barbara. 1979. Energy Generation: Sources and Consequences. Pittsburgh, PA: University of Pittsburgh. Curriculum Module I of the Urban Environmental Education Project. Mimeographed.

16. Biological Sciences Curriculum Study. 1977. Energy and Society. Investigations in Decision Making. Northbrook, IL: Hubbard. 115pp student text; 35mm slides; 7 photo study cards; 8mm film loop; "Energy Game." Intended for grades 11 & 12.

17. Bloch, Lenore, Chris Hatch, Olivia Swinton, et al. 1977. Community Workers and the Energy They Use. EDM-1030. Oak Ridge, TN: DOE Technical Information Center. A Project for an Energy-Enriched Curriculum unit. 80pp. Intended for grade 2.

18. Bowman, Mary Lynne and Herbert L. Coon. 1978. Recycling Activities for the Classroom. Columbus, OH: ERIC Information and Analysis Center for Science, Mathematics, and Environmental Education. $4.95. ERIC order number ED 159 075.

19. Brock, Phyllis, John Day, Gloria Hill, Andrew Pogan, et al. Revised by Emmet Wright and Robert Snyder. 1978. Agriculture, Energy, and Society. EDM-1034. Oak Ridge, TN: DOE Technical Information Center. A Project for an Energy-Enriched Curriculum unit. 59pp teacher's manual plus 48pp student guide. Intended for grades 10-12.

20. Brown, Evelyn, Arthur Goldman, Bette Johnson, et al. 1979. Energy Transitions in United States History. HCP/U 3841-0004. Oak Ridge, TN: DOE Technical Information Center. A Project for an Energy-Enriched Curriculum unit. 60pp teacher's manual plus 57pp student guide. Intended for grades 8 & 9.

21. Brown, Evelyn, John Day, Arthur Goldman, Kenneth P. Weeden et al. 1978. Energy in the Global Marketplace. HCP/U 3941-0007. Oak Ridge, TN: DOE Technical Information Center. A Project for an Energy-Enriched Curriculum unit. 39pp teacher's manual plus 11pp student guide. Intended for grades 9-11.

22. Brown, Evelyn, Lois Lutes, Charles Durr, et al. 1978. Mathematics in Energy. HCP/U 3841-02. Oak Ridge, TN: DOE Technical Information Center. A Project for an Energy-Enriched Curriculum unit. 54pp teacher's manual plus 56pp student guide. Intended for grades 8 & 9.

23. Chevron USA. No date. Energy Learning Center. San Francisco, CA: Chevron USA. Intended for grade 6.

24. Childs, Barbara, Arthur Goldman, Bette Johnson, Leon Scipio, et al. 1977. Energy, Engines, and the Industrial Revolution. EDM-1032. Oak Ridge, TN: DOE Technical Information Center. A Project for an Energy-Enriched Curriculum unit. 37pp teacher's manual plus 41pp student guide. Intended for grades 8 & 9.

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26. Christensen, John W. 1981. Energy, Resources, and Environment. Dubuque, IA: Kendall/Hunt. $12.95. 256pp. Intended for senior high and college.

27. Christensen, John W., Robert Snyder, John Day, Kenneth P. Weeden et al. 1980. U.S. Energy Policy: Which Direction? DOE/CA/3841-T1. Oak Ridge, TN: DOE Technical Information Center. A Project for an Energy-Enriched Curriculum unit. 61pp teacher's manual plus 134pp student guide. Intended for grades 11 & 12.

28. Communications and Education Group, division of the Mazer Corporation. Energy Adventure. Chicago, IL: Amoco Educational Services. A program of the Energy Education Division, Oak Ridge Associated Universities. 28pp teacher's manual plus 7 spirit masters, 10pp of 'exhibits,' and a 4pp supplement on energy and economics.

29. Coon, Herbert L. and Michaele Y. Alexander, editors. 1976. Energy Investigations for the Classroom. Columbus, OH: ERIC Information Analysis Center for Science, Mathematics, and Environmental Education. ERIC order number ED 130 833 (2 fiche). 148pp.

30. Coon, Herbert L. and Mary Bowman. 1978. Energy Activities for the Classroom: Volume II. Columbus, OH: ERIC Information Analysis Center for Science, Mathematics, and Environmental Education. $3.00. ERIC order number ED 173 072 (2 fiche). 165pp.

31. Davis, W. Douglas. 1979. Solar Energy Laboratory Program. 96pp manual plus 48pp teacher's guide.

32. Davitian, Harry. 1981. Windpower (draft). Stony Brook, NY: American Association of Physics Teachers. One of the "Issue-Oriented Modules" coordinated by the AAPT. 61pp. Intended for college undergraduates, but could be used with a gifted twelfth grade physics student.

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34. Department of Energy, Mines, and Resources (Canada). 1979. Energy Management for the Future. Ottawa, Ontario: Office of Energy Conservation.

35. Department of Industrial Education, Texas A & M University. 1977. ENCORE: Energy Conservation Resources for Education. College Station, TX: Texas A & M University. ERIC order number ED 164 287. 463pp.

36. Dille, Nancy, editor. 1978. Teaching about Energy Awareness: 33 Activities. Denver, CO: Center for Teaching International Relations. $12.95. 168pp. Intended for grades 5-12.

37. Duff, G.F.D. 1982. Energy From Tides. Stony Brook, NY: American Association of Physics Teachers. One of the "Issue-Oriented Modules" coordinated by the AAPT. Intended for college undergraduates, but could be used with a gifted twelfth-grade physics student.

38. EDU/PR. 1978. Your Energy World, Energy Overview, Unit One. Washington, DC: U.S. Department of Energy. 6 spirit masters. See U.S. Dept. of Energy for 3 additional units in this series. Intended for grades 4-6.

39. Emry, Randy. 1980. "Oil Refineries: What Do We Get from a Barrel of Oil?" From Basic Teaching Units (BTU's) on Energy, volume 3. Lincoln, NE: Nebraska Energy Office. 12pp. Intended for grades 9-12 science.

40. Energex Energy Education Programs. 1981. Energy in American History. Lakewood, CA: Energex Energy Education Programs. 64pp student booklet plus 36pp teacher's guide. Intended for grade 8.

41. Energex Energy Education Programs. 1978. Power Quiz. Lakewood, CA: Energex Energy Education Programs. 36pp student booklet plus 38pp teacher's guide. Intended for grade 5.

42. Energex Energy Education Programs. 1978. Captain Power. Lakewood, CA: Energex Energy Education Programs. 9pp of student materials plus 38pp teacher's guide. Intended for grade 2.

43. Energex Energy Education Programs. 1981. Energy Crunch. Lakewood, CA: Energex Energy Education Programs. 51pp student booklet plus 45pp teacher's guide. Intended for grade 8 science.

44. Energy and Man's Environment. 1977. Energy and Conservation Education Activities for the Classroom. Level 1-3. Portland, OR: Energy and Man's Environment. $24.00. Intended for grades 1-3.

45. Energy and Man's Environment. 1977. Energy and Conservation Education Activities for the Classroom. Level 4-6. Portland, OR: Energy and Man's Environment. $24.00. Intended for grades 4-6.

46. Energy and Man's Environment. 1977. Energy and Conservation Education Activities for the Classroom. Level 7-9. Portland, OR: Energy and Man's Environment. $24.00. Intended for grades 7-9.

47. Energy and Man's Environment. 1977. Energy and Conservation Education Activities for the Classroom. Level 10-12. Portland, OR: Energy and Man's Environment. $24.00. Intended for grades 10-12.

48. Energy Education Curriculum Project. 1980. An Energy Curriculum for the Middle Grades. Unit I: Energy and World Cultures. Indianapolis, IN: Indiana Energy Group, Dept. of Commerce; and Division of Curriculum, Dept. of Public Instruction. ERIC order number ED 185 554. 229pp. Intended for grades 6-8.

49. Energy Education Curriculum Project. 1980. An Energy Curriculum for the Middle Grades. Unit II: Energy and American History. Indianapolis, IN: Indiana Energy Group, Dept. of Commerce; and Division of Curriculum, Dept. of Public Instruction. ERIC order number ED 187 555. 174pp. Intended for grades 6-8.

50. Energy 80. 1981. Energy 80. Los Angeles, CA: Enterprise for Education. 32pp student booklet plus 384pp teacher's manual. Intended for grades 7-9.

51. Energy-Environment Double E Project. 1980 (revision). Energy-Environment Double E Project, 5-6. Tulsa, OK: Tulsa Public Schools. 254pp. Intended for grades 5 & 6.

52. Energy-Environment Double E Project. 1980. Energy-Environment Double E Project, 7-9. Tulsa, OK: Tulsa Public Schools. 256pp. Intended for grades 7-9.

53. Energy-Environment Double E Project. 1981 (revision). Energy-Environment Double E Project, 10-12. Tulsa, OK: Tulsa Public Schools. 259pp. Intended for grades 10-12.

54. Filiu, Tom and Lisa Lively. The Best of Energy Book. Volumes I and II. Cleveland, OH: Modern Curriculum Press. Compiled by the Colorado State University Extension Service in cooperation with the Denver Public Schools. Each book $8.55. Volume I, 135pp, intended for grades K-3; volume II, 160pp, intended for grades 4-6.

55. Fillo, J.A. 1981. Introduction to Nuclear Fusion Power and the Design of Fusion Reactors (draft). Stony Brook, NY: American Association of Physics Teachers. One of the "Issue-Oriented Modules" coordinated by the AAPT. 54pp. Intended for college undergraduates, but could be used with a gifted twelfth grade physics student.

56. Frank, Helmut J., John J. Schanz, Jr., and John S. Morton. 1975. The Economics of the Energy Problem. New York, NY: Joint Council on Economic Education. 20pp.

57. Freiberg, Jerry L. 1980. "Solar Energy Use in Food Preparation and Preservation." From Basic Teaching Units (BTU's) on Energy, volume 2. Lincoln, NE: Nebraska Energy Office. 50pp. Intended for 7-12 social studies, home economics, and science.

58. Gandy, Sharon S. No date. The Energy Crisis. Fort Myers, FL: Lee County Environmental Education Program. 20pp.

59. Gould, Mauri, director. No date. Wind Energy. DOE/IR-0037. Oak Ridge, TN: DOE Technical Information Center. One of the "Science Activities in Energy Series" developed at the American Museum for Science and Energy. 26pp.

60. Gould, Mauri, director. No date. Solar Energy II. EDM-1054. Oak Ridge, TN: DOE Technical Information Center. Part of the "Science Activities in Energy Series" developed by the American Musuem of Science and Industry. 12 activities on separate sheets of paper. Intended for grades 7-12.

61. Gray, Darrol, Dennis Gray, and Jerry Beach. 1980. "Energy Uses in Nebraska Agriculture." From Basic Teaching Units (BTU's) on Energy, volume 1, Gary A. Lay and Donald McCurdy, editors. Lincoln, NE: Nebraska Energy Office. 40pp. Intended for grades 9-12, social studies, science, and vocational agriculture.

62. Haase, Don, R. Stephan Skinner, and Ronald G. Crampton. 1980. "Gasohol." From Basic Teaching Units (BTU's) on Energy, volume 1, Gary A. Lay and Donald McCurdy, editors. Lincoln, NE: Nebraska Energy Office. 58pp. For laboratory supplement, see Kinzer, Edward. Intended for grades 7-12, chemistry or biology.

63. Hahn, Ruth. 1980. "The History of United States Energy." From Basic Teaching Units (BTU's) on Energy, volume 2. Lincoln, NE: Nebraska Energy Office. 25pp. Intended for K-12.

64. Hahn, Ruth. 1980. "The National Energy Policy." From Basic Teaching Units (BTU's) on Energy, volume 2. Lincoln, NE: Nebraska Energy Office. 40pp. Intended for grades 9-12, social studies.

65. Hahn, Ruth, and Robert Harper. 1980. "Fueling Around Could Be Hazardous to your Health." From Basic Teaching Units (BTU's) on Energy, volume 1, Gary A. Lay and Donald McCurdy, editors. Lincoln, NE: Nebraska Energy Office. 25pp. Intended for grades 7-12.

66. Harder, Alma Jean and Carolyn Clark Newsom. 1975. The Energy Situation. A Two-Week Self-Contained Unit for the Secondary School. Dover, DE: Del Mod System. ERIC order number ED 119 992. Intended for grades 7-12.

67. Heimler, Charles H. and Jack Price. 1977. Electrical and Nuclear Energy (Focus on Science Series). Columbus, OH: Charles E. Merrill Publishing Co.

68. Hirschmann, Rich and Frances Rohrich. 1980. "The U.S. and OPEC: Where Do We Go from Here?" From Basic Teaching Units (BTU's) on Energy, volume 3. Lincoln, NE: Nebraska Energy Office. 31pp. Intended for grades 8-9, social science.

69. Hodges, Laurent. 1980. Thermodynamic Efficiencies and Thermal Pollution (draft). Stony Brook, NY: American Association of Physics Teachers. One of the "Issue-Oriented Modules" coordinated by the AAPT. 34pp. Intended for college undergraduates, but could be used with a gifted twelfth grade physics student.

70. Horvitz, Cathy. 1979. Energetics. Davis, CA: Soft Aware Associates, Inc. $15.95. Game and workbook. Intended for grade 2 up.

71. Hughes, Judi. No date. The Energy Crisis, the Dictionary as a Resource. Fort Myers, FL: Lee County Environmental Education Program.

72. Illinois State Office of Education. 1977. Environmental Education, Values for the Future: Energy. Grades 6-8. Springfield, IL: Illinois State Office of Education. ERIC order number ED 149 987. 47pp.

73. Illinois State Office of Education. 1977. Environmental Education, Values for the Future: Energy. Grades 9-12. Springfield, IL: Illinois State Office of Education. ERIC order number 149 994. 58pp.

74. Individualized Science Instructional System (ISIS). 1977. Housepower. Lexington, MA: Ginn and Company.

75. Individualized Science Instructional System (ISIS). 1977, October (draft). Sharing the Earth. Lexington, MA: Ginn and Company.

76. Innovative Communications. 1979. Aunt Energina's Almanac and Book of Fun. Walnut Creek, CA: Innovative Communications. 16pp student booklet plus 48pp teacher's guide. Also available in Spanish (1980) with additional 16pp teacher's guide supplement. Teacher training tape also available. Intended for grades 3 & 4.

77. Innovative Communications. 1981. Electric Gnus Special Energy Issue. Walnut Creek, CA: Innovative Communications. 16pp student booklet plus 48pp teacher's guide. Teacher training tape also available. Intended for grades 7-9.

78. Innovative Communications. 1981. Magic Quiz. Walnut Creek, CA: Innovative Communications. 32pp teacher booklet which includes reproducible activity sheets. Intended for grades 4-6.

79. Innovative Communications. 1981. What Makes Things Go? Walnut Creek, CA: Innovative Communications. Coloring sheets and accompanying 70 frame filmstrip. Intended for grades K-2.

80. Innovative Communications. 1981. Politics of Energy. Walnut Creek, CA: Innovative Communications. Kit, use of Apple computer optional. Intended for grades 9-12, government.

81. Innovative Communications. 1982. Aunt Energina's Poster and Poster Pad activity Sheets. Walnut Creek, CA: Innovative Communications. Intended for grades 1-6.

82. Innovative Communications. 1982. Golden Moments in Radio. Walnut Creek, CA: Innovative Communications. Six worksheets plus tape cassette. Intended for grades 7-9.

83. Iowa State Department of Public Instruction. 1974. Energy Materials. Des Moines, IA: State Department of Public Instruction. ERIC order number ED 121 569. 127pp.

84. Jamason, Barry W., director. No date. Living Within our Means: Energy and Scarcity. Environmental Education Instructional Activities K-6. Albany, NY: State Department of Education. 86pp. Specific grade levels are suggested for each activity.

85. Jamason, Barry W., director. No date. Living Within Our Means: Energy and Scarcity. Environmental Education Instructional Activities 7-12. Albany, NY: State Department of Education. 106pp. Specific grade levels and subject areas are suggested for each activity.

86. Johnson, Bette, Olivia Swinton, et al. 1978. Networks: How Energy Links People, Goods, and Services. HCP/U 3941-0005. Oak Ridge, TN; DOE Technical Information Center. A Project for an

Energy-Enriched Curriculum unit. 66pp teacher's manual plus 32pp student guide. Intended for grades 4 & 5.

87. Johnson, Bob, Paul Fletcher and Phil Frank. 1980. The Adventures of Aunt Energina and Her Energy Agents. Walnut Creek, CA: Innovative Communications. 32pp student booklet plus 48pp teacher's guide. Teacher training tape also available. Intended for grades 4-6.

88. Jorgensen, Eric, Trout Black, and Mary Hallesy. 1978. Manure to Meadow to Milkshake. Los Altos Hills, CA: Hidden Villa Environmental Project. $4.95. 130pp. Intended for grades K-6.

89. Kellog, C.L., Thad Whiteaker, Don Coffey, and Barbara Stanley. No date. Energy and You. Topeka, KS: Topeka Public Schools. Intended for the educable mentally retarded in grades 7-9.

90. Kennedy, Dianne J. 1980. "Coal: Fuel of the Past, Hope of the Future." From Basic Teaching Units (BTU's) on Energy, volume 2. Lincoln, NE: Nebraska Energy Office. 42pp. Intended for grades 9-12, science or social studies.

91. Kentucky State Department of Education. 1978. Energy Conservation Activities for the Classroom K-12. Frankfort, KY: State Department of Education. Produced in cooperation with the Kentucky Department of Energy. ERIC order number ED 161 727 (3 fiche). 244pp. Intended for grades K-12.

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93. Lampert, Seymour, Kathleen M. Wulf, and Gilbert Yanow. 1979. A Solar Energy Curriculum for Elementary Schools. Pasadena, CA: Jet Propulsion Laboratory and Univ. of Southern California. 332pp. Intended for grades K-6.

94. Lehigh Energy Education Advisory Council. 1981. Energy Conservation in our Homes -- or, How I'm Going to Help Save Energy by Starting with Me. Allentown, PA: Pennsylvania Power and Light Co. Intended for grade 5.

95. Lendsey, Jacquelyn L., Bette Johnson, Olivia Swinton, et al. 1978. Bringing Energy to the People: Ghana and the U.S. HCP/U 3841-0006. Oak Ridge, TN: DOE Technical Information Center. A Project for an Energy-Enriched Curriculum unit. 29pp teacher's manual plus 20pp student guide. Intended for grades 6 & 7.

96. Lendsey, Jacqueline L., Arthur Goldman, Chris Hatch, et al. 1979. Two Energy Gulfs. HCP/U 3941-03. Oak Ridge, TN: DOE Technical Information Center. A Project for an Energy-Enriched Curriculum unit. 47pp teacher's manual plus 44pp student guide. Intended for grades 6 & 7.

97. Leonard, Kenneth E., Robert Reinke, Donald Wentworth, George Whitney, and Jonathan C. Deming. 1980 revision. Energy Trade-offs in the Marketplace. Seattle, WA: Washington State Council on Economic Education & Washington Supt. of Public Instruction Office. 159pp.

98. Levine, Melvin M. 1981 (2nd draft). Fission Reactors. Stony Brook, NY: American Association of Physics Teachers. One of the "Issue-Oriented Modules" coordinated by the AAPT. 41pp. Intended for college undergraduates, but could be used with a gifted twelfth grade physics student.

99. Lindenfeld, Peter. 1980. Radioactive Radiations and their Biological Effects (draft). Stony Brook, NY: American Association of Physics Teachers. One of the "Issue-Oriented Modules" coordinated by the AAPT. 58pp, plus a 26pp supplement "A Summary of Some Properties of Nuclei, Nuclear Radiation, and Reactors." Intended for college undergraduates, but could be used with a gifted twelfth grade physics student.

100. Linder, Richard. 1980. "Petroleum in an Age of Scarcity." From Basic Teaching Units (BTU's) on Energy, volume 1, Gary A. Lay and Donald McCurdy, editors. Lincoln, NE: Nebraska Energy Office.

101. Martin, R. Doug. 1980. "Energy from the Atom." From Basie Teaching Units (BTU's) on Energy, volume 2. Lincoln, NE: Nebraska Energy Office. 25pp. Intended for grades 9-12 science or social studies.

102. Masonbrink, John, R. Doug Martin, and Robert Starr. 1980. "Energy Conservation in the Home." From Basic Teaching Units (BTU's) on Energy, volume 1, Gary A. Lay and Donald McCurdy, editors. Lincoln, NE: Nebraska Energy Office. 43pp. Intended for grades 7-12 science or social science.

103. McGill, Patrick. "Future Energy Technologies." From Basic Teaching Units (BTU's) on Energy, volume 1, Gary A. Lay and Donald McCurdy, editors. Lincoln, NE: Nebraska Energy Office. 30pp.

104. McDaniels, David K. 1982. Solar Thermal Electricity. One of the "Issue-Oriented Modules" coordinated by the AAPT. Intended for college undergraduates, but could be used with a gifted twelfth grade physics student.

105. Melcher, Joan. 1980. Connections. Butte, MT: National Center for Appropriate Technology. $6.00 Intended for grades 5 & 6.

106. Minnesota State Energy Agency. 1977. Energy Activities for Junior High Social Studies. St Paul, MN: Minnesota State Energy Agency. ERIC order number ED 151 297. Intended for grades 7-9 social studies.

107. National Coordinating Center for Curriculum Development. 1978. Electrical Energy Use in the Home. Revised Draft. Stony Brook, NY:

State University of New York. 69pp teacher's guide plus 30pp student materials.

108. Nelson, Greg E. 1980. "Hydroelectric Power: Energy from Falling Water." From Basic Teaching Units (BTU's) on Energy, volume 3. Lincoln, NE: Nebraska Energy Office. 25pp. Intended for grades 9-12, social studies.

109. Nguyen, V. Thanh. 1979. Geothermal Energy: Resource and Utilization (draft). Stony Brook, NY: American Association of Physics Teachers. One of the "Issue-Oriented Modules" coordinated by the AAPT. 44pp. Intended for college undergraduates, but could be used with a gifted twelfth grade physics student.

110. Nickish, Marge Hill. 1981. Energy: Nebraska Home Economics Energy Management Guide. Lincoln, NE: Nebraska Energy Management Office. $12.00. Intended for grades 7-12 home economics.

111. North Dakota Department of Public Instruction. 1977(?). Driver Education Energy Conservation Curriculum. Bismarck, ND: Department of Public Instruction.

112. Nous, Albert P. 1979. Energy Conservation: What Are the Options? Pittsburgh, PA: University of Pittsburgh. Curriculum Module II of the Urban Environmental Education Project.

113. Oak Ridge Associated Universities. 1977. Chemical Energy. EDM-1054. Oak Ridge, TN: DOE Technical Information Center. Part of the "Science Activities in Energy Series." Developed with the assistance of the Lawrence Hall of Science, U.C. Berkeley. 15 activities, each on a separate sheet of paper. Intended for grades 4-6.

114. Oak Ridge Associated Universities. 1978. Conservation. Oak Ridge, TN: DOE Technical Information Center. Part of the "Science Activities in Energy Series." Developed with the assistance of the Lawrence Hall of Science, U.C. Berkeley. 14 activities, each on a separate sheet of paper. Intended for grades 4-6.

115. Oak Ridge Associated Universities. 1977. Electrical Energy. Oak Ridge, TN: DOE Technical Information Center. Part of the "Science Activities in Energy Series." Developed with the assistance of the Lawrence Hall of Science, U.C. Berkeley. 16 activities, each on a separate sheet of paper. Intended for grades 4-6.

116. Oak Ridge Associated Universities. No date. Solar Energy. EDM-837. Oak Ridge, TN: DOE Technical Information Center. Part of the "Science Activities in Energy series, this one developed with the assistance of the Lawrence Hall of Science, Berkeley. See also Gould, Mauri. 12 activities, each on a separate sheet of paper. Intended for grades 4-6.

117. Oklahoma State Department of Education. 1977. Oklahoma Energy Awareness Education, Energy Education Activities, Grades K-3.

Oklahoma City, OK: Oklahoma State Department of Education. ERIC order number ED 153 819. 176pp.

118. Oklahoma State Department of Education. 1977. Oklahoma Energy Awareness Education, Energy Education Activities, Grades 4-12. Oklahoma City, OK: Oklahoma State Department of Education. ERIC order number ED 153 820. 220pp.

119. Oxenhorn, John M. 1979. Energy and Our Future. New York, NY: Globe Book Co. 224pp plus teacher's guide. Intended for grades 9-12.

120. Pasco County Schools Energy Management Center. 1976. Energy Management Center Intermediate Program. Port Richey, FL: Pasco County Schools Energy Management Center. Consists of three basic publications, "Let's Learn about Energy," 54pp; "Nature's Energy," 63pp; and "Man and Energy," 52pp, each $0.90, with Teachers manual ($8.25) and ancillary material. For related teacher training material, see under this author in the Inservice section. Intended for grades 4-6.

121. Pennsylvania Department of Education. 1975. The Environmental Impact of Electrical Power Generation: Nuclear and Fossil. Washington, DC: U.S. Gov't Printing Office. 266pp text (ERDA-69), $3.05; 20pp teacher's manual (ERDA-70), $1.20.

122. Pennsylvania Department of Education. 1977. Pennsylvania's Energy Curriculum for the Middle Grades. Harrisburg, PA: Pennsylvania Department of Education. Intended for grades 6-9.

123. Peterson, Gaylord. 1980. "No Energy." From Basic Teaching Units (BTU's) on Energy, volume I, Gary A. Lay and Donald McCurdy, editors. Lincoln, NE: Nebraska Energy Office. 24pp. Intended for grades 8 & 9.

124. Philadelphia Electric Company and the Pennsylvania Energy Education Advisory Council. No date. Our World of Energy: An Interdisciplinary Curriculum Program for Elementary Schools. Philadelphia, PA: Philadelphia Electric Company. Intended for grades K-6.

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128. Project for an Energy-Enriched Curriculum. 1978. Energy and Transportation. HCP/U 3841-001. Oak Ridge, TN: DOE Technical Information Center. 76pp. Intended for grade 3.

129. Project for an Energy-Enriched Curriculum. 1980. The Energy Dome. DOE/CA/06083-03. Oak Ridge, TN: DOE Technical Information Center.

130. Project for an Energy-Enriched Curriculum. 1980. The Energy Future Today. DOE/CA/06083-01. Oak Ridge, TN: DOE Technical Information Center. Intended for grades 7-9 social studies.

131. Project for an Energy-Enriched Curriculum. 1980. Energy Systems -- Present, Future. DOE/CA/06083-03. Oak Ridge, TN: DOE Technical Information Center. Intended for grades 7-9 science.

132. Project for an Energy-Enriched Curriculum. 1977. The Energy We Use. HCP/U 3841-08. Oak Ridge, TN: DOE Technical Information Center. 42pp. Intended for grades 1 & 2.

133. Project for an Energy-Enriched Curriculum. 1977. How a Bill Becomes a Law to Conserve Energy. HCP/U 3841-10. Oak Ridge, TN: DOE Technical Information Center. 59pp teacher's manual plus 54pp student guide. Intended for grades 10-12.

134. Project for an Energy-Enriched Curriculum. 1980. How We Make Energy Work. DOE/CA/06083-02. Oak Ridge, TN: DOE Technical Information Center. Intended for grades 4-6, science.

135. Public Service Co. of Colorado et al. 1981. Energy Management Strategies for Home Economics Teachers. Denver, CO: Public Service Co. of Colorado. Produced with the cooperation of the Colorado State Board for Community Colleges and Occupational Education and Energy and Man's Environment.

136. Reichert, Robert. 1980. "A Project to Obtain Data on Motor Vehicle Fuel Economy over Short Distances." From Basic Teaching Units (BTU's) on Energy, volume 3. Lincoln, NE: Nebraska Energy Office. 11pp. Intended for senior high physics and chemistry, and auto shop.

137. Reifdorph, Tom, et al. 1978. Industrial Arts Manual to the Construction of Miniaturized Alternative Energy Source Equipment. Port Richey, FL: Pasco County Schools Energy Management Center. $12.00. 45pp plus blueprints. Intended for grades 7-12.

138. Roeder, Allen A. and James A. Woodland. 1980. "Solar Energy in the Home." From Basic Teaching Units (BTU's) on Energy, volume

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