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ABSTRACT

This is the teacher's guide to accompany the student guide which together comprise one of five computer-oriented environmental/energy education units. This unit explores U.S. energy consumption; is applicable to Mathematics, Social Studies, and Ecology or Science Studies with Mathematics background; and is intended for use in grades 9 through 14. The unit is divided into five sections each dealing with a main issue such as: (1) growth in energy demand; (2) problems converting and distributing energy; (3) new energy sources; and (4) transportation and energy consumption. Each section is concluded with a set of exercises with which a computer may be used. This teacher's guide gives an introduction to the unit, unit goals and objectives, answers to exercises, and an annotated bibliography. (MR)

COMPUTER TECHNOLOGY PROGRAM
ENVIRONMENTAL EDUCATION UNITS

A Computer Oriented Problem Solving Unit

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CCCCC   OOO   N   N   SSSSS   U   U   M   M   EEEEE
C   C  O   O  NN  N  S       U   U   MM MM   E
C   C  O   O  N N N  S       U   U   M M M   E
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C      O   O  N N N      S   U   U   M   M   E
C   C  O   O  N  NN      S   U   U   M   M   E
CCCCC   OOO   N   N   SSSSS   UUU    M   M   EEEEE
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TEACHER GUIDE

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Prospective users of this manual are urged to first run the sample simulation program provided in order to determine any needed or desirable adjustments prior to use.

September 1975

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INTRODUCTION TO THE UNIT

Unit Description

Subject Areas: Math, Social Studies and Advanced Ecology (with mathematics background)

Topic: U.S. Energy Consumption

Abstract: This mathematically-based unit introduces students to some basic issues concerned with U.S. energy consumption, including growth in energy demand, problems of converting and distributing energy, new energy sources, and the serious question of transportation and consumption. It provides definitions and comparisons among energy measures such as BTU's, Kcal, Hp, kw and so forth at the outset so that the figures involved in energy consumption issues can be grasped meaningfully. Based primarily on figures and their comparisons and projections, the unit provides students with a realistic quantitative understanding of the present energy consumption problems, the need for solutions, and possible directions from which solutions may come.

The unit is divided into five logical sections, each dealing with a main issue and concluding with a set of exercises in which students manipulate and interpret figures to discover their significance for the energy problem and society, present and future. Several short computer problem solving and simulation programs are provided within the text which students use to help solve problems given in the exercises. Students are guided toward a concrete grasp of such facts as: bicycling is the most efficient method of transportation ever invented, and at the present rate of growth our power consumption will triple by the year 2000.

Grade Level: 9-14

Computer Language: BASIC

Program Names: CONV PROG, EXPO GRO, RES DEPL, NAT'L POWR, ECO MODEL

Goals and Objectives

The intent of this unit is, by no means, to train engineers or technicians to cope with problems arising from the energy crisis. Rather, the intent is to modify awareness, change attitudes, and provide perspective to the problems springing from change attitudes, and provide perspective to the problems springing from the energy question. At the beginning of this unit, most students will have absolutely no feel for the relation between activities occurring around them and demands on power and energy supplies necessary to sustain those activities. By the end of the unit, students should be keenly aware of the connection between energy supplies and consumption patterns.

It is also intended that the student should acquire (mostly on his or her own) an understanding of the need for global solutions to energy problems which tend to arise from nationalistic bases. This is most important and flies in the face of natural feelings of patriotism and national pride. Nevertheless the concept of "lifeboat earth" is one which we must all pay more and more attention to. In effect, when the ship goes down, we all go together regardless of nationality.

The computer is used to ease the burden of computations and to develop models which otherwise could not be treated. The exercises should be considered typical and should be expanded to meet the particular needs of each group using the material. Almost every topic can be the starting point for open ended investigations which will lead far past the range of the topics discussed. If at all possible encourage this type of activity as it is in the true spirit of education, and promotes in-depth involvement with a most important problem rather than the usual peripheral treatment.

ANSWERS TO EXERCISES

Exercises on Power and Energy, pages 7-9

1. a. 150 Kcal x 3.969 = 595.4 BTU
   b. 150 Kcal x 0.010 = 1.50 Human hours
   c. 300 Kcal/hr x 1.559E-3 = 0.4677 Hp

2. a. Assuming 24 hours:

$$\frac{821 \text{ Kcal}}{24 \text{ hr}} = 33.83 \text{ Kcal/hr}$$

33.83 Kcal/hr x 1.163E-3 = 0.0393 kw
33.83 Kcal/hr x 1.559E-3 = 0.0527 Hp

   b. Assuming 0.0001 sec (?) or 2.778E-8 hr:

$$\frac{812 \text{ Kcal}}{2.778\text{E-8 hr}} = 2.923\text{E10 Kcal/hr}$$

2.923E10 Kcal/hr x 1.163E-3 = 3.399E7 kw
2.923E10 Kcal/hr x 1.559E-3 = 4.556E7 Hp

   c. The power ratio = $\frac{4.556\text{E7}}{0.0527}$ = 8.64E8

   Taking the uncertainties in the assumptions into account, the true power ratio is probably in the range 1E7 to 1E9 which is certainly dramatic compared to the energy ratio of 0.5.

3. a. 2E7 Humans x 5.198E-6 = 104.0 Jets
   b. 2E7 Humans x 7.206E-5 = 1,441 Barrels of Oil per hour
   c. 2E7 Humans x 0.1560 = 3.120E6 Hp

4. a. 5 x 20,500 BTU/hr = 102,500 BTU/hr

   102,500 BTU/hr x 3.929E-4 = 40.27 Hp

   b. 5 x 3,400 BTU/hr = 17,000 BTU/hr

   17,000 BTU/hr x 3.929E-4 = 6.68 Hp

5. a. 1.150E6 kw x 1.303E-4 = 150 Tons Coal/hr
3,596 Tons Coal/day

b. 1.150E6 kw x 6.194E-4 = 712 Barrels Oil/hr
= 17,100 Barrels Oil/day

c. 1.150E6 kw x 4.470E-5 = 51.4 Jets

d. 1.150E6 kw x 6.707E-3 = 7,713 Cars

e. Not all the energy of the coal is converted to electricity. The efficiency is

$$\frac{3,596}{10,570} \times 100 = 34\%$$

6. a. Perhaps 10% of the cars are running on the average.
92.7E6 x 0.10 = 9.27E6 cars

b. 9.27E6 cars x 9.241E-2 = 856,600 Barrels of Oil/hr

c. 9.27E6 cars x 1.942E-2 x 2 = 360,000 Tons Coal/hr

7. $$\frac{22.5E12}{365 \times 24} = 2.568E9 \text{ cu ft Gas/hr}$$

a. 2.568E9 cu ft Gas/hr x 0.3077 = 7.903E8 kw

b. 2.568E9 cu ft Gas/hr x 1.375E-5 = 35,310 Jets

c. $$\frac{7.903E8 \text{ kw}}{1E6 \text{ kw}} = 790 \text{ power plants.}$$

Exercises on Energy Consumption and Supply, pages 17-19

1. Use the computer program to derive the following information:

Growth (percent)	Number Periods to Double (rule of 72)	Factor
2	36	2.04
4	18	2.02
6	12	2.01
8	9	2.00
10	7.2	1.99
12	6.0	1.97
14	5.1	1.95
16	4.5	1.95
18	4.0	1.94
20	3.6	1.93

The rule is most accurate for growth rates around 8%, but still gives good results over the range 2 to 20%.

2. On the 64th square there will be 1.84467E19 grains of wheat. The total wheat is twice this or 3.68934E19 grains.

(Extra Credit: A grain has a volume of $\pi (.02)^2(0.25)/4 = 7.85E-5$ cubic inches 4.545E-8 cubic feet. Thus the total volume of wheat is about 1.68E12 cubic feet. If we assume a cubic shaped bin, each side of the bin would be 11,880 feet or about 2.25 miles. Thats a lot of wheat no matter how you measure it.)

3. The program can be used to develop the following information.

	Reserves	Consumption	Growth	Years Left
Oil	455	15	3.9	21
	1000	15	3.9	34
	200	15	3.9	11
	455	15	2	24
	455	15	6	18
	455	15	8	17
	455	15	0	31
	455	15	-2	47
	455	15	-3	80
	455	15	-3.25	129
	455	15	-3.50	Very Long

	Reserves	Consumption	Growth	Years Left
Coal	5000	2	4.1	116
	2000	2	4.1	94
	8000	2	4.1	128
	5000	2	6	87
	5000	2	8	69
	5000	2	10	58
	5000	2	0	2501
	5000	2	-2	Very Long
Natural Gas	1140	30	4.7	23
	2000	30	4.7	31
	500	30	4.7	13
	1140	30	2	29
	1140	30	6	21
	1140	30	8	19
	1140	30	0	39
	1140	30	-2	71
	1140	30	-4	Very Long

4. Use reserves of 455 billion barrels and present consumption of 15 billion barrels per year. Use program in Fig. 6 as modified to get data.

Decrement	Years Remaining
0.1	22
0.2	23
0.5	40
0.51	50
0.511	56
0.520	Very Long

Optional for Programmers

5. a.

```
100 DEF FNA(D)=(2-.434294*LOG(D))/.301205
110 PRINT
120 LET D=100
130 PRINT "D","N"
140 PRINT
150 PRINT D,FNA(D)
160 LET D=D/10
170 IF D>1.E-08 THEN 150
180 END
```

RUN

D	N
100	7.12394E-06
10	3.32
1	6.64
.1	9.95999
.01	13.28
.001	16.60
.0001	19.92
.00001	23.24
.000001	26.56
1.00000E-07	29.88

b. At 10%, N = 3.32 doubling periods.

c. Doubling period = 72/4 = 18 years.

Years = 18 x 3.32 = 59.76 years.

c. At 0.1%, N = 9.96 doubling periods.

Years = 18 x 9.96 = 179.3 years.

Exercises on Energy Conversion and Distribution, pages 27-28

1. Anything that could be done without electricity should be done. This includes cooking, heating, refrigeration, all of which can be run by oil or natural gas. The problem is that fossil fuels are in short supply and are going to get shorter.

2. The automobile has an efficiency of perhaps 25%. We can generate electricity from oil or natural gas with an efficiency of 41%. If the electric car had a high efficiency we might gain in overall energy consumption. If pollution free sources of electricity other than fossil fuels could be found, electric cars would be a big advantage.

3. A significant number of families do without clothes dryers and air conditioners, and all families could do so. A great deal of energy could be saved if air conditioning were cut out, and clothes dryers were run by natural gas.

4. The table shows clearly the economic potential in terms of natural resources. Quite apart from any political considerations involved, Russia, among all the developed nations of the world, is in a enviable position as far as resources are concerned.

5. If each bomb had a thermal life time of 1 year, we could capture thermal energy at the rate of

$$\frac{5E9}{365 \times 24} = 5.708E5 \text{ kw.}$$

Converting 50% to electricity the result is about 0.3 million kw per bomb per year. If a high capacity power plant puts out 1 million kw we would need 3 bombs per year per plant. If the 1970 power needs of the country were thus supplied we would need about 2100/0.3 = 7000 bombs per year which strains the imagination.

6. The main benefit would be to electrify all transportation. The other result would be a dramatic increase in the quality of the environment. Possibly controlled hydrogen fusion will be able to furnish such a supply of electricity.

7. Since natural gas furnaces are very efficient, we would gain in overall efficiency.

8. If we shift to coal the figure of $60 per capita would certainly go up. At $60 per capita, probably not too much concern is paid to the cost of air pollution. At $600 per capita there certainly would be a great deal of concern. Water pollution and trash pollution is going to be more and more expensive.

9. The French have been burning trash in Paris for the past 50 years as a source of electricity and heat for space heating. The energy content of trash is about 1/3 that of a good grade of coal. Considering the enormous amounts of trash that is generated by our society this would appear to be a high priority item for all major cities.

Exercises on Energy Flow in Our Society, pages 34-37

1. A typical print out is shown below. The point is that about the only segment of the society where much can be done if we insist on consuming the large amounts of energy is in transportation. A great deal certainly needs to be done in transportation.

```
INPUT PRESENT EFFICIENCIES (%)
    HOUSEHOLD & COMMERICAL?80
    TRANSPORTATION?25
    INDUSTRIAL?78

INPUT ANNUAL DECREASE IN WASTE (%)
    HOUSEHOLD & COMMERCIAL?1
    TRANSPORTATION?4
    INDUSTRIAL?1
HOW MANY YEARS?10
```

YEAR	HOUSEHOLD & COMMERCIAL	EFFICIENCY TRANSPORTATION	INDUSTRIAL
1	80	25	78
2	80.2	28.	78.22
3	80.398	30.88	78.4378
4	80.594	33.6448	78.6534
5	80.7881	36.299	78.8669
6	80.9802	38.847	79.0782
7	81.1704	41.2932	79.2874
8	81.3587	43.6414	79.4946
9	81.5451	45.8958	79.6996
10	81.7296	48.06	79.9026

2. a. Use program in Fig. 5 and explore. Answer is

$$R = 4.13\%$$

b. Rule of 72: 72/4.13 = 17.4 year doubling time.

c. 1980: 96.8E15 BTU
1990: 145.1E15 BTU

3. a. The greatest opportunity for savings occur where the growth rate is the greatest. Clothes drying, refrigeration, and air conditioning seem the best bets.

b. It is roughly the same. Therefore space heating is growing proportional to the overall growth in consumption. However, this is about twice the rate of growth in population. This could mean more people are housed better in 1968 than in 1960.

c. One way to do this is place a progressive tax on air conditioners, clothes dryers, and large refrigeration systems. This could also be done by having a sliding charge for electricity, paying much more as larger quantities are consumed. Somehow the increasing spiral of consumption has to be broken.

4. Commercial rates of growth are behind the overall rate except for: cooking (due to McDonalds, Shakey's Pizza, and so forth), air conditioning, and "other." It is clear that the savings would have to be achieved in "other," what ever that is.

5. The growth in fuel consumption is almost exactly the same as the overall growth rate. However, the raw materials rate of growth is almost zero. This would seem to imply that transportation equipment and facilities are not being replaced, which if true, implies bad news about railroads, bus lines, etc. In 1974 reports have begun to come out about large sections of rail bed that are no longer safe to use, and which have been responsible for several passenger train accidents.

6. a. $10 = 150 \times \frac{\text{miles}}{\text{gal}}$

$$\frac{\text{gal}}{\text{mile}} = \frac{150}{10} = 15 \text{ gal/mile}$$

b. Daily: 2 x 7000 miles x 15 gal/mile = 210,000 gal/day
Yearly: 365 x 210,000 gal/day = 76.65 million gal/year

c. 100 Aircraft: 7665 million gal/year = 182 million barrels per year.

The question is, is the expenditure of this quantity of energy justified by the return in transportation speed for the number of passengers served? The answer is generally felt to be NO. A separate and controversial question is the possible disastrous effects upon the ionosphere in particular, and the environment in general.

7. a. 40 trains per hour.
   40 x 6 x 72 = 17,280 passengers per hour.

   b. With the assumptions in the text, a lane in a highway could carry no more than 3,000 passengers per hour, and the railroad about 15,000 passengers per hour.

   c. Either BART or a railroad can carry about 5 times the number of passengers per hour than the lane on a highway. However, systems like BART are very expensive. (We note that in the fall of 1974 BART was several years behind schedule, was way over budget, had not operated in transbay service, and had not utilized computer control.) Possibly a better alternative would be to spend significantly smaller amounts of money to develop existing rail facilities.

8. If we looked at the energy requirements, probably something like the following could be organized.

5 blocks:	Walk (better for you anyway!)
5 miles:	~~Motorcycle (Bicycle would be much better)~~
50 miles:	Bus or Train
2,000 miles:	Jet

Forget about the automobile!

9. 0.1 Hp x 2.02E-2 = 0.002 gal gas/hr

$$PE = \frac{1 \times 15}{0.002} = 7,500$$

Even if due to efficiency, only 1/3 the energy of the gasoline is converted to work the PE is still 2,500 or 20 times that of the very efficient bus. All studies point to the same fact. The bicycle is the most efficient means of transportation ever devised. In addition, our health problems would decrease if riding a bicycle provided regular exercise. Whether the U.S. society could be sold on the bicycle for all 0 to 10 mile trips is not clear.

Exercises on Computer Models and Energy, pages 43-44

1. Use program in Fig. 7 to generate the following information.

Year	Power (billions of kw)	Power Ratio
1970	2.04	1.00
1980	2.86	1.40
1990	4.00	1.96
2000	5.60	2.75

a. This exercise shows clearer than anything else why conditions must change. If we are having trouble with energy at the present power level, what will society do at almost three times the power level in 2000?

Optional

2. Modify the program in Exercise 1 as follows:

```
342  Let R1 + R1 - 0.1
```

This will produce results:

Year	Power (billions of kw)	Power Ratio
1970	2.04	1.00
1980	2.73	1.34
1990	3.32	1.63
2000	3.65	1.79

Clearly, getting the population under control makes a big improvement. However, more is needed.

3. Program in Exercise 2 modified with

```
344  Let R2 = R2 - 0.06,
```

will result in:

Year	Power (billions of of kw)	Power Ratio
1970	2.04	1.00
1980	2.66	1.30
1990	2.96	1.45
2000	2.81	1.38

Notice that the power ratio has started to decrease by the year 2000. Now all that remains is to find a way to implement the assumptions in the model into policy, stick with them, and we might get control.

Optional

4. This is an open ended investigation. Students should carefully consider their assumptions and try to sort out those which present viable alternatives to the hazardous present courses of action.

5. Run the program in Fig. 8. The answer is 0.051 kg or 51 grams/square meter per day. This happens to be a value very well correlated with actual measurements. Students should plot the new biomass versus hours to see how plants respond in a daily rhythm.

6. Cut solar input to 25 Kcal/day. The result is -0.009 kg or -9 grams/square meter per day. Along with other reasons this exercise points out why you can't grow things well at high latitudes.

7. If the respiration factor is changed to 1E-4 the system is almost exactly balanced. If the biomass is decreased, it starts moving back towards the balanced value. The same thing happens if the biomass is increased. In other words, the system is stable. Left alone it will seek out and find a balanced condition.

8. 50 g/meter^2/day x 120 days x 4047 meter^2

   = 2.428E7 grams
   = 53484 pounds
   = 27 tons.

   The actual crop yield should be less than this due to the biomass produced which is not food. As an example, in the Santa Clara Valley of California, a yield of 5 tons per acre is considered average for varietal grapes. This is certainly consistant with the model predictions. You should be able to get similar correlations with other crops in your own vicinity.

ANNOTATED BIBLIOGRAPHY

General references pertinent to the energy crisis are given below. The list contains those works which have proven to be the greatest value to the author, and is not intended to be exhaustive by any means. The works are listed in the order of estimated value to the material at hand.

1. A Scientific American Book, Energy and Power, W. H. Freeman and Company, San Francisco, 1971.

   This book should be read cover to cover by anyone seriously interested in the energy crisis. Never has such a wide ranging and penetrating look at energy been assembled in one book. Must reading for student and faculty alike.

2. Meadows, Donella H., et al. The Limits to Growth, A Potomac Associates Book, Signet Books, New York, 1972.

   This modest book has stirred up a whirlwind. It is indeed rare to see such violent reaction, both pro and con to a single book. The National Observer reviewer stated:

   > Mark this book. It may be as important to mankind as the Council of Nicacea and Martin Luther's 95 Theses. It is a revolutionary new way of looking at man and society.

   This book describes the results of computer runs of the world model generated by the Club of Rome. All the indications point to cataclysmic events within the next half century.

3. Cole, H.S.D., et al. Models of Doom, A Critique of the Limits to Growth, Universe Books, New York, 1973.

   This book contains a number of essays in answer to The Limits to Growth done by a group based at the University of Sussex, England. The critique is scholarly and well thought out. At the end of the book is a Reply to Sussex by the authors of The Limits to Growth. It is rare that a book can stir up this type of critique.

4. Priest, Joseph. Problems of Our Physical Environment, Energy, Transportation, Pollution, Addison Wesley, Reading, 1973.

This is a textbook suitable for general education science courses. Very good general reference.

5. Odum, Howard T. Environment, Power and Society, Wiley Interscience, New York, 1971.

Unique in its treatment of the energetics of very unusual systems such as: politics, religion, economics, ecosystems, etc.

6. Rocks, Lawrence, and Runyon, Richard P. The Energy Crisis, Crown Publishers, New York, 1972.

Good general reference and suitable for a one term course on energy and power.

7. Beckman, Eco-Hysterics and the Technophobes, The Golem Press, Boulder, 1973.

The author of this book disagrees most strongly with most of the ideas developed in this unit. It is interesting reading and provides a provocative look at the other side of the issues. Very well written and most convincing.