KILOWATT COUNTER

by

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of the

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FOREWORD

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We present KILOWATT COUNTER to you as tool for making informed decisions regarding our individual buying habits, energy consumption and conservation, and environmental responsibility. Many of these decisions are very personal in nature. Others are far removed, determined by somebody else, and often without our immediate knowledge or input. Even though the decisions may be far removed, we are all called upon to review them or at least approve their continued results.

One simply can't make these decisions regarding energy without basic, comprehendable, and deliberate knowledge of the facts. KILOWATT COUNTER gives us the facts on energy and outlines the decisions that must be made. It clearly and succinctly introduces us to the world of energy decision making.

KILOWATT COUNTER defines exactly what energy is, how it is used, measured, conserved, wasted, and revered by individuals and society. In addition, it honestly explains the potentials of alternative sources of energy. In an easy to comprehend manner, KILOWATT COUNTER presents the trends and realities of using nuclear versus organic, solar, wind and other alternative energy resources.

KILOWATT COUNTER is a consciousness raising tool that should be read by everyone. Hopefully, by reading KILOWATT COUNTER, you will be able to determine the future by making informed decisions regarding energy, its uses, and abuses.

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TABLE OF CONTENTS

CHAPTER ONE

CHAPTER TWO

CHAPTER THREE

CHAPTER FOUR

APPENDIX

Introduction

Did you know that:

* The energy value of the food crops we eat in the United States is about equal to the energy we burn in our tractors alone.
* Sixty percent of private automobile trips in urban areas are less than 2½ miles and carry only one passenger.
* The glowing filament of an ordinary 100 watt bulb produces 19 times more heat than light.
* It takes eight times more energy to push a vehicle through the air at 60 miles per hour than at 30 miles per hour.

Ours is an age when energy has suddenly become a precious commodity. International economics, local building codes and individual transportation decisions are all beginning to take the cost of energy into account. As we enter an energy conscious era we will be increasingly bombarded with new words and concepts. Efficiency ratings will be listed on our air conditioners, not just their gross power consumption. Net energy will become an even more common term Energy accounting systems, based on units of energy rather than units of money, are already being designed by several state governments and private researchers.

Yet the average person remains bewildered by the sudden turn of events. We seem to be on the outside looking in. Some of us blame the whole thing on inefficient government, or corporate shenanigans. Others simply hide their heads in the sand and hope the problems will go away. Even for those of us who are honestly trying to understand what is going on and what we can do about it, it seems like such a complicated topic.

For instance, there are so many terms used when we discuss energy. Physicists find it convenient to use electron volts, ergs and joules. Biologists and nutritionists think in terms of calories. Engineers deal in British Thermal Units and watt hours. Since the atomic bomb explosion we often hear of energy release being measured in tons of TNT. How does an individual make his or her way through this maze?

Even in those institutions which are supposed to teach us about the world around us, our schools and universities, the problem exists. The light energy in our classrooms is measured in kilowatt-hours. The heat energy in our school buildings is measured in BTUs. The energy that heats our bodies so we can walk to school is measured in calories. How do we relate the one to the other? How do we measure the efficiency of various alternatives? How do we know when we are conserving energy and when we are using even more?

One way for us to know more is to have a handy tool which can give us a basic grasp of energy definitions and a preliminary knowledge of energy arithmetic. In this booklet there are listings of energy useage of various appliances and of various sectors in our society, conversion tables to permit us to switch from one unit to another, and simple problems that anyone can do. This is designed as an introduction to the subject, not as a definitive work. But you will find that one doesn't need a Ph.D. in physics to understand the world around us. The math is simple; nothing is more complicated than addition, subtraction, multiplication and division.

Many of the decisions affecting energy usage are individual ones. Will we use more heat or put insulation in the house? Will we buy raw potatoes or pre-cooked french fries? Will we drive to work or take the train or bus? Many are social decisions, but individuals can participate in the decision-making process.

But no one can participate in our coming national debate on energy or even make individual decisions, without basic information about energy, its different forms of measurement, and the average usage in various activities. The Kilowatt Counter can simplify energy arithmetic while educating us to a new awareness of our place in the natural world. Just as Calorie Counters made their way into our grocery stores, pockets, and kitchens when our waistlines expanded too much, Kilowatt Counters and energy arithmetic will become portable educational tools to trim the fat off from our national energy diet.

CHAPTER ONE

What Is Energy?

Everyone has a feeling for what energy is because the term is used so often, but really it's not something you can put your finger on, because it's not a real thing. You don't measure energy itself, but what happens when an energy change takes place. A change in energy gives physical results which we can measure such as heat, light or motion.

Forms of Energy

Energy takes many forms and it's the changing from one form to another that we are interested in. A lump of coal, for example, has energy "stored" in it in the form of chemical energy. If we burn the piece of coal, the stored chemical energy is released as thermal (heat) energy. If the thermal energy of the burning coal is used to heat water and drive a steam turbine, it is converted to mechanical energy. If the steam turbine is used to turn an electrical generator, the mechanical energy is converted to electrical energy.

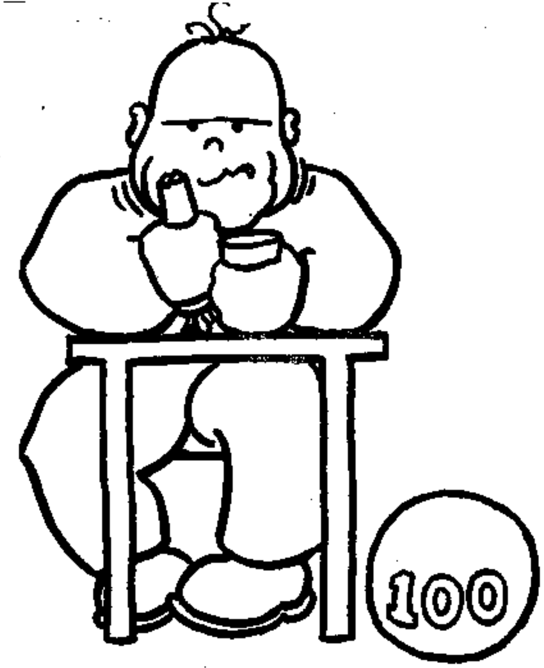
Conservation of Energy

Although energy can be changed from one form to another, the amount of available energy cannot be increased. If 100 units of mechanical energy are used in turning the steam turbine, the most we can expect from the electrical generator would be 100 units of electrical energy. In fact we will find something less than 100 units of energy coming from the generator-perhaps 80 units, for example. The other 20 units of evergy were converted to heat energy due to friction in the moving mechanical parts of the turbine and generators. In physics, this is called the Law of Conservation of Energy. In everyday language, it means you don't get something for nothing. It is called a "law" because no one has yet come across a case where the conservation of energy principle didn't apply. It explains why no one has succeeded in building a perpetual motion machine, although some people still try.

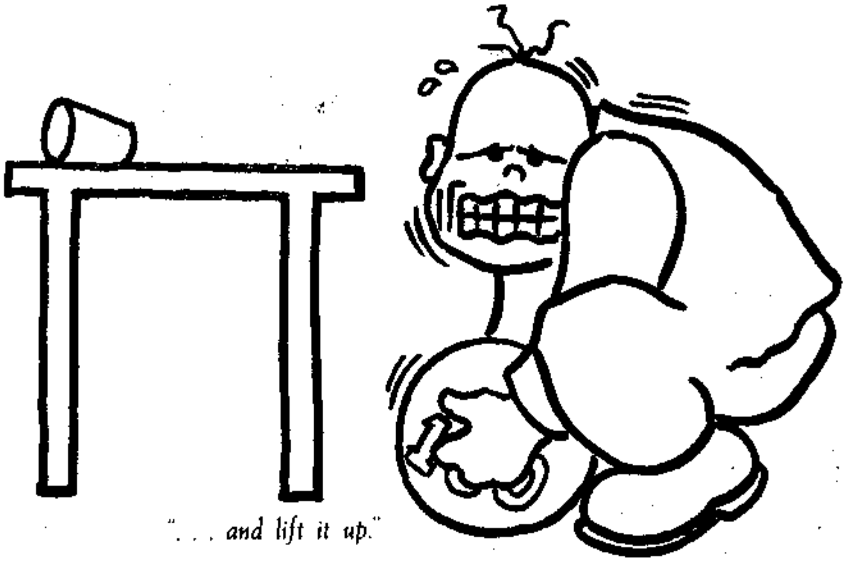
Potential Energy

If you have a weight on the floor and want to move it up to a table, some energy will have to be expended. You could put a stick of dynamite under it and blow it up onto the table. You could pull it up with a powerful electromagnet. Or you could expend a little chemical (food) energy yourself and lift it up.

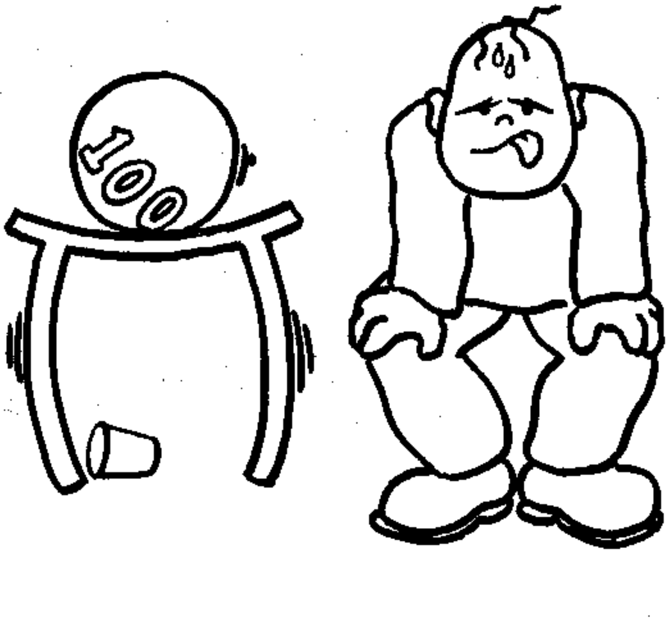
Where does this energy go to? Well, it's "in" the object on the table or more precisely, it's "in" the



"or you could expend a little chemical (food) energy yourself. . ."



". . . and lift it up."



situation of the object being on the table rather than on the floor. You have the potential of getting the energy "back" by letting the weight fall to the floor. This is what is meant when we refer to Potential Energy.

Energy Units

There are many different units used in measuring energy. Some units are associated with the different forms of energy -- like British Thermal Units (BTU's) for heat or foot-pounds (ft-lb) for mechanical energy. Some units are used in measuring different ranges of energylike electron-volts on the atomic scale and kilowatt-hours on the industrial scale to measure electrical energy. There are also differences in units because of the different systems of measure -- specifically the British system and the metric systems of measure.

Different units for different energy forms were defined at a time when these different forms were being studied separately, and one may often be more convenient than another. We should at least know how to convert those units back and forth.

Different units for different ranges also have the advantage of great convenience. It would be silly to measure the energy of a chemical reaction in kilowatt hours. The number would be too tiny. It would be just as silly to measure the output of a giant powerplant in electronvolts. The number would be too large. Certainly,you could do either of those things. But would it help you, any more than it would be useful to measure the length of your block with a six inch ruler, or the thickness of a hair with a yardstick?

The third kind of difference, the different measurements systems which different countries use, is rapidly coming to an end. The United States, England, and a few other countries, use the British system, using inches, ounces, pounds, and Fahrenheit temperature. We all have experience in how difficult these systems are to use. There are 12 inches in a foot, three feet in a yard. Does anyone know how many yards there are in a mile? The metric system is much simpler. Everything is based on some power of ten. Thus one hundred centimeters make a meter (which is a little over a yard), 1,000 meters make a kilometer, and so on . Conversions to metric units are good to know not only because, once mastered, they are easier to work with, but because they will be the standard measuring system throughout the world in a very few years. Some U.S. industries are already being converted to metric.

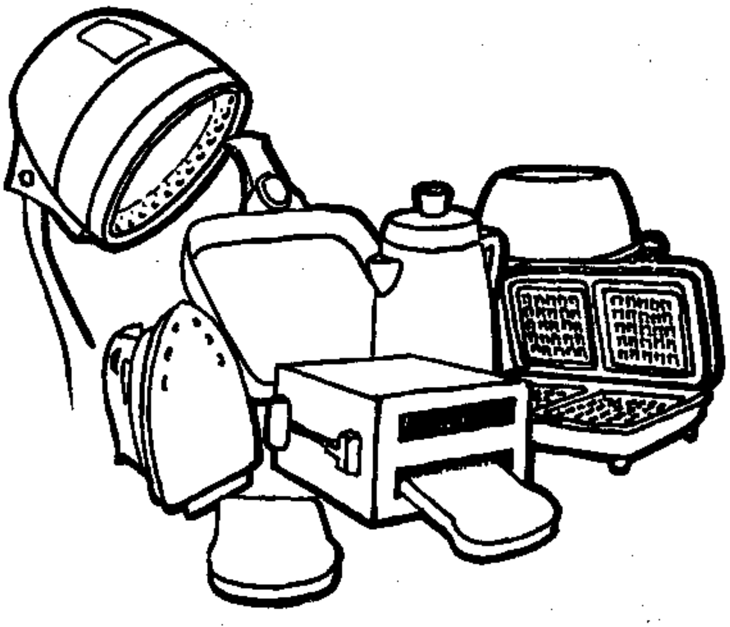
In the following examples of the physical meaning of energy units, both British and metric units will be explained. Conversions from one energy unit to another will be shown in Table 1.

After we have explained the units we'll give you some sample problems to help you understand how these strange words and light arithmetic can help you to know how much energy you are using.

Heat Units

Thermal energy may be measured in British Thermal Units (BTUs). A BTU is the amount of energy needed to raise the temperature of one pound of water one degree Fahrenheit. For example, a pound of coal "contains" about 13,000 BTUs of chemical energy. This means that the coal has the potential of heating 13,000 pounds of water 1 F° (or 260 pounds of water 50F°), a change of thermal energy.

The metric heat unit is the Calorie (cal. or c.). A calorie is the amount of energy needed to raise the temperature of one gram of water one degree Centigrade. The calorie is most commonly used as a measure of food energy. Actually, the unit usually used with food energy values is the kilocalorie (1000 calories or kcal.). The kilocalorie is generally written as Calorie (with a capital C) or Cal. If you convert Fahrenheit to centigrade degrees and pounds to grams, you would find that 1 BTU = ¼ Cal.



ENERGY CONVERSION:
ELECTRICAL TO THERMAL

ENERGY CONVERSION: ELECTRICAL TO MECHANICAL

Mechanical Units

Mechanical energy may be measured in foot-pounds (ft-lbs). A foot-pound is the amount of energy needed to lift a one pound object one foot off the earth.

The metric mechanical unit is called the joule (J) and is the energy needed to raise a one kilogram object one meter off of the earth. If you convert foot-pounds to Joules, you will find that 1 ft-lb = 1.4 J.

Another unit of mechanical energy is the horsepower-hour (hp-hr). One horse-power-hour is the equivalent of 33,000 ft-lbs of work per minute (one horsepower) done for one hour.

Electrical Units

Electrical energy is measured in watt-hours. A watt is the product of the voltage (volts) times the amperes (amps) in an electrical circuit. A volt is the measure of the "pressure" in an electrical circuit. An ampere is the measure of the current (flowing electrical charge) in a circuit. A voltage of 1 volt and a current of one amp applied to a circuit for one hour would use one watt-hour of electrical energy. A killowatt-hour (kw-h) is 1,000 watt-hours. The kilowatt-hour is the unit most often used when measuring electrical consumption in homes and factories.

Power

It is often convenient to know not only the amount of energy involved in an energy change but also the rate at which the change occurs. The term used to indicate the rate of energy change is called power. All power units indicate energy per unit time.

For example, it is incorrect to say that a machine uses 200 watts of energy per month; the watt is a unit of power. We must know how often the machine is used, as well as its power consumption, in order to know how many watt-hours of energy are consumed. Similarly, a person might have sufficient energy in calories to move 5000 pounds of stones if there is no time limit. But this person might not have enough power to do this in one hour.

So, the units of power that correspond to the energy units that we just reviewed are:

Power Unit	Energy Unit
BTU per hour (BTU/hr).	BTU
Cal. per second (Cal./sec.) . .	Cal.
Foot-pound per second (ft-lb/sec.)	ft-lb
Joule per second (Joule/sec) .	Joule
Horsepower (hp)	hp-hr
Kilowatt (kw)	kwh

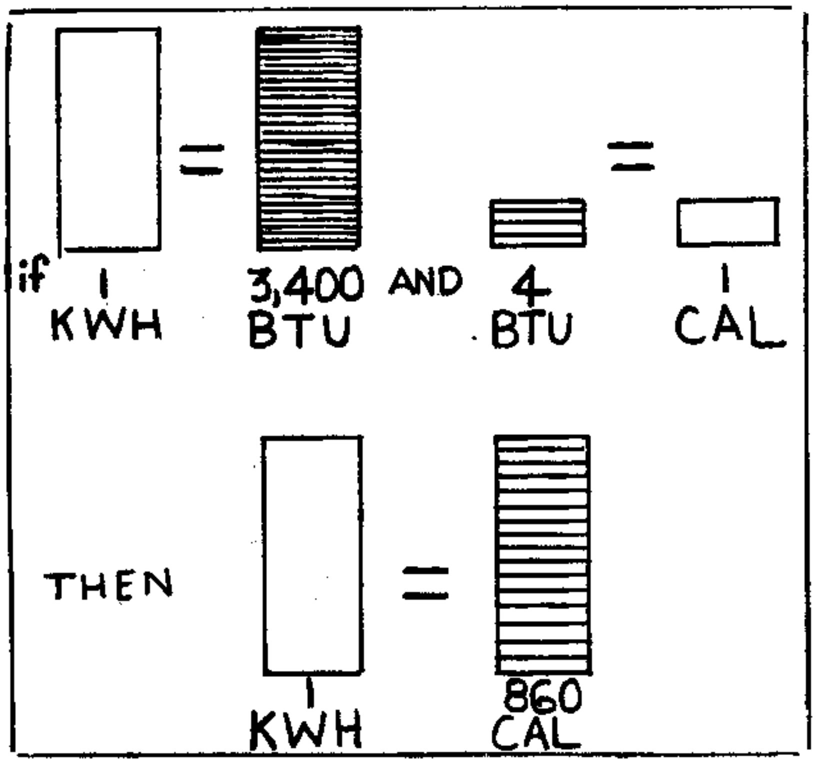
Converting Between Units

It is often necessary to convert from one type of unit to another, or just to know the relative size of a unit. Table 1 is an energy conversion chart showing how to convert from one type of unit to another. The chart also applies to power units.

TABLE 1

ENERGY UNIT CONVERSION CHART

From	To BTU	CAL.	FT-LB	JOULES	HP-HR	Kwh.
BTU	-	¼	778	1,055	.00039	.00029
CAL	4	-	3,090	4,200	.00156	.0012
Ft-lb	.0013	.00032	-	1.4	5.0×10^{-7}	3.8×10^{-7}
Joules	.00095	.00024	0.74	-	3.7×10^{-7}	2.8×10^{-7}
Hp-hr	2,500	640	2,000,000	2,700,000	-	0.75
Kwh	3,400	860	2,700,000	3,600,000	1.3	-



Notice the following conversions in Table 1.

$$1 \text{ kwh} = 1.3 \text{ hp-hr}$$
$$= 3400 \text{ BTU}$$
$$= 860 \text{ Cal}$$
$$= 2.7 \times 10^6 \text{ ft-lbs}^*$$

We can understand how these conversions work a little better by spreading them out. For example:

if 1 kwh = 3400 BTU

and 1 Cal = 4 BTU

then $1 \text{ kwh} = 3400 \text{ BTU} \times \frac{1}{4}\frac{\text{Cal}}{\text{BTU}} = 860 \text{ Cal}$

Similarly:

if 1 kwh = 1.3 hp-hr

and 1 HP = 33,000 ft-lb/min

so $1 \text{ kwh} = 1.3 \text{ hp-} \times \frac{33{,}000 \text{ ft-lb/min}}{1 \text{ hp}} \times \frac{60 \text{ min}}{1 \text{ hr}} = 2.7 \times 10^6 \text{ ft-lbs}$

Notice that units in the denominator (bottom of a fraction) cancel out units in the numerator (top of a fraction). When dividing, first invert the fraction you are dividing by:

$$\frac{3}{4} \div \frac{5}{8} = \frac{3}{4} \times \frac{8}{5}$$

Laying out your problems in this way not only helps make clear how the conversions work, but also provides an easy way of checking your work and making sure you finish with the correct units.

Energy Conversion Problems

Problem: Suppose, on an average day, you eat 2,500 Cal worth of food. How many BTUs of energy does that food represent?

Answer: Since 1 Cal = 4 BTU then $2{,}500 \text{ Cal.} \times \frac{4 \text{ BTU}}{1 \text{ kcal}} = 10{,}000$ BTU.

Problem: You consume the above amount of food energy over a 24-hour period. How many watts of power are you using on the average?

Answer: 1 Cal = 1.2 watt-hrs, or, 1 Cal/hr = 1.2 watts. Every hour you eat $\frac{2500 \text{ Cal}}{1 \text{ day}} \times \frac{1 \text{ day}}{24 \text{ hrs}} = 104$ Cal/hr. So we multiply $\frac{1.2 \text{ watts}}{1 \text{ Cal/hr}} \times 104 \text{ Cal/hr} = 124.8$ watts.

Now that you feel comfortable with the simple conversions, try the following:

Problem: How many kilowatt-hours of energy are there in a gallon of gasoline?

Answer: A gallon of gasoline contains about 132,000 BTUs of energy. In scientific notation, 132,000 equals 1.32×10^5. In order to find out how many kwh this represents, we multiply 1.32×10^5 by 2.9×10^{-4} (from TAble 1.) This gives us $(1.32 \times 10^5) \times 2.9 \times 10^{-4} = 38.3$ kwh per gallon of gas.

The average household uses about 8,700 kwh of energy per month to support itself. How many gallons of gasoline is this equivalent to?

Problem: Your car gets 11 miles per gallon in city driving. What is its energy consumption, in kwh per mile?

Answer: At 11 mpg, 11 miles takes 38.3 kwh equivalent energy so 1 mile uses $\frac{38.3 \text{ kwh}}{\text{gal}} \times \frac{1 \text{ gal}}{11 \text{ mi}} =$ 3.49 kwh/mile.

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*Don't let this kind of number scare you. Called "scientific notation," it's just a convenient way of representing very large or very small numbers without using a lot of space. The number above and to the right of the 10 (called the "power" of 10, or the exponent) indicates how many times to multiply the first number (called the mantissa) by 10. If the exponent is negative, it tells how many times to divide by 10. Turn to page 32 for examples of how to work with these numbers.

Problem: How many kwh do you use on a 10 minute trip across town at an average speed of 20 mph with a mileage of 11 mpg?

Answer: (20 miles/hr) x 10 $\frac{\text{min}}{} \times \frac{1\ \text{hr}}{60\ \text{min.}}$ = 3.3 miles are travelled

In 10 minutes then 3.49 kwh/miles 3 miles = 115 kwh

Problem: What does it cost to leave one 100 watt light bulb on in the house for 8 hours a day, for the entire year, with electricity costing 5¢/kwh?

Answer: 100 watts x 8 hours = 00 watt-hrs = .8 kwh. 5¢/kwh x kwh - 0¢. If one light bulb is kept on for the entire year, 8 hours a day, it will cost 365 x 40¢ = $14.60.

SURVEYING YOUR HOME

Time out for a look at your own home. Table 2 shows figures for average appliance consumption in the United States. But averages are averages. They vary with the individual and the region and the appliance. Anytime you can, try to get information directly from your own home about the amount of energy you use. There are various ways to do this.

Look at your monthly electric bill. It will tell you how many kilowatt hours you used during the last month. If you burn one 60 watt light bulb for one hour, as you know from the previous examples, you have used 60 watt-hours. If you burn 10 such bulbs you have used 600 watt-hours or .6 kwh of energy.

You can have an appliance which has a very high wattage, like a microwave oven, but which works so fast that it uses very little energy to accomplish its job. Or you might have the 60 watt light bulb, which if left on many hours can begin to lift that electric bill.

Go around the house to see where most of the kilowatt hours you used last month come from. How do you figure it out? Find the wattage of various appliances (it's usually stamped on the back or bottom of the unit). If the wattage is not available, find the amperage. If you multiply the amperage by the voltage (which on regular house current is 110, but can be 220, for an electric water heater or washing machine or electric stove), you get the wattage. So, for example, if it says on the back of your radio that it uses ½ amp. we multiply 110x½@55 watts. Do this for those appliances used most during the day, like the refrigerator, electric clock, lights, or radio and television. Multiply each wattage by the number of hours the appliance is on, and add those figures for the daily energy consumption. Then multiply by 30 and compare this monthly total with your electric bill. You will probably find that all these appliances represent only a small portion of your total electricity use. Look at figures 1, 2, and 3. Figure 1 shows the average energy requirement of an all-electric house and what percentage of that is used for various functions. Figure 2 shows the percentages for an electric house which utilizes a heat pump,* and figure 3 illustrates the needs for a house with gas furnace, hot water and dryer.

Let's look at one of the major energy users right now, using our newfound skills in energy arithmetic. Air conditioners give off cooling air. This is measured in BTUs per hour of cooling capacity. In order to do this they use electricity, measured in kw. The energy efficiency rating (EER) of an air conditioner can be measured by the following formula:

$$\text{EER} = \frac{\text{Energy out in BTU}}{\text{Energy in kw-hr}}$$

Air conditioners have EERs ranging from about 4.7 to 12.2. The higher the number, the more cooling you are getting out per kwh of electricity you put in. The State of Massachusetts now requires EER to be listed on all air conditioners sold in the state, and many other states are expected to follow suit.

Problem: Your air conditioner gives you 10,000 BTU of cooling capacity, and uses 1,000 watts. What is its EER?

Answer: $\text{EER} = \frac{\text{Energy out}}{\text{Energy in}}$ - $\frac{10{,}000}{1{,}000} = 10$

Problem: You need to choose between two air conditioners, one rated at 10,000 BTU and drawing 2,100 watts; the other rated the same but drawing 880 watts. Which do you choose?**

Answer: Air conditioner A has an EER of $\frac{10{,}000}{2{,}000} = 4.8$.

Air conditioner B has an EER of $\frac{10{,}000}{880} = 11.4$.

Problem: Using the two air conditioners cited in problem 2, what is the difference in cost to run the two over a year in Washington, D.C., where the average room air conditioner operates 800 hours per year?

Answer: Assuming the cost of electricity to be 5c per kwh, then air conditioner A would use 800 x 2.1 kw = 1680 kwh. Then 1680 kwh x .05 = $84.00. Air conditioner B would use 800 x 0.88 kw = 704 kwh. Then 704 kwh x .05 = $35.20.**

Using the same two air conditioners again, and assuming that each would last about 7 years (and wouldn't require major repairs), what would be the difference in lifetime costs between the two units, if A costs $200 and B costs $300?

Unit A

EER = 4.8	
Purchase	$200.00
Cost per year, $84.00	
x 7 years	588.00
Total 7 year cost	$788.00
Cost per year (total divided by 7)	$112.57

Unit B

EER = 11.4	
Purchase	$300.00
Cost per year, $35.20	
x 7 years	246.00
Total 7 year cost	$546.40
Cost per year (total divided by 7)	$ 78.06

So while B cost $100 more to buy, it saves over $200 over its lifetime, due to lower operating costs. Now look at your own air conditioner and figure out its EER, and its lifetime cost.

The EER is especially useful for air conditioners. For most other items, "efficiency" is more useful,

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*See footnote page 19.

**We might add that usually the cheaper and lower efficiency air conditioners are also those which have no thermostat control. That means that there is no way to cut these off when the room reaches the desired temperature. They run continuously using much more energy than ones with a cut-off device, and also shortening the life span of the machine itself.

TABLE 2

ANNUAL ENERGY REQUIREMENTS OF ELECTRIC HOUSEHOLD APPLIANCES

	average wattage	est. kwh consumed annually
Health & beauty		
Germicidal lamp	20	141
Hair Dryer	381	14
Heat Lamp (infared)	250	13
Shaver	14	1.8
Sun Lamp	279	16
Tooth brush	7	0.5
Vibrator	40	2
home entertainment		
Radio	71	86
Radio/Record player	109	109
Television		
black & white tube type	160	350
solid state	55	120
color - tube type	300	660
solid state	200	440
housewares		
Clock	2	17
Floor Polisher	305	15
Sewing Machine	75	11
Vacuum Cleaner	630	46
Food preparation		
Blender	386	15
Broiler	1,436	100
Carving Knife	92	8
Coffee Maker	894	106
Deep Fryer	1,448	83
Dishwasher	1,201	363
Egg Cooker	516	14
Frying Pan	1,196	186
Hot plate	1,257	90
Mixer	127	13
Oven, microwave (only)	1,450	190
Range with oven	12,200	1,175
with self-cleaning oven	12,200	1,205
Roaster	1,333	205
Sandwich Grill	1,161	33
Toaster	1,146	39
Trash Compactor	400	50
Waffle Iron	1,116	22
Waste Disposer	445	30

	average wattage	est. kwh consumed annually
food preservation		
Freezer (15 cu ft)	341	1,195
Freezer (Frostless 15 cu ft)	440	1,761
Refrigerator (12 cu ft)	241	728
Refrigerator (Frostless 12 cu ft)	321	1,217
Refrigerator/Freezer (14 cu ft)	326	1,137
(Frostless 14 cu ft)	615	1,829
laundry		
Clothes Dryer	4,856	993
Iron (hand)	1,008	144
Washing Machine (automatic)	512	103
Washing Machine (non-automatic)	286	76
Water Heater	2,475	4,219
(quick-recovery)	4,474	4,811
comfort conditioning		
Air cleaner	50	216
Air conditioner (room)	1,566	1,389
Bed Covering	177	147
Dehumidifier	257	377
Fan (attic)	370	291
Fan (circulating)	88	43
Fan (rollaway)	171	138
Fan (window)	200	170
Heater (portable)	1,322	176
Heating Pad	65	10
Humidifier	177	163

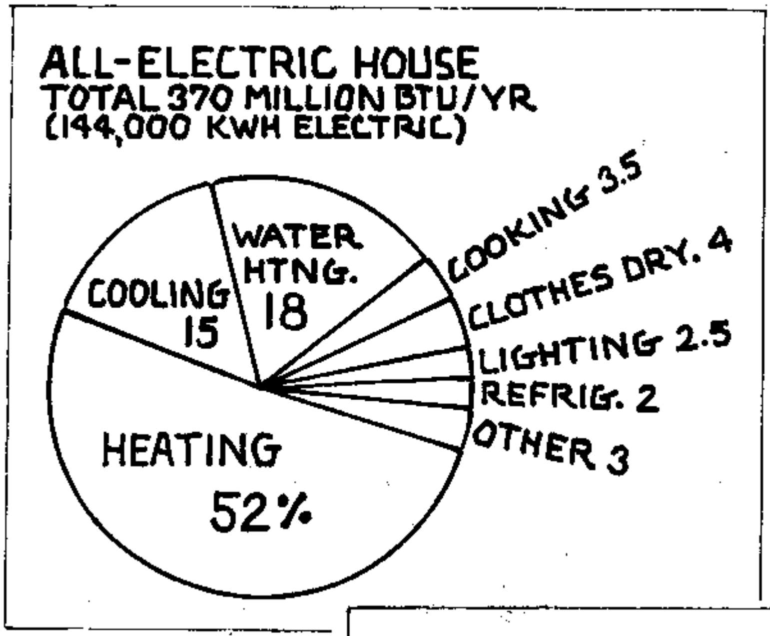
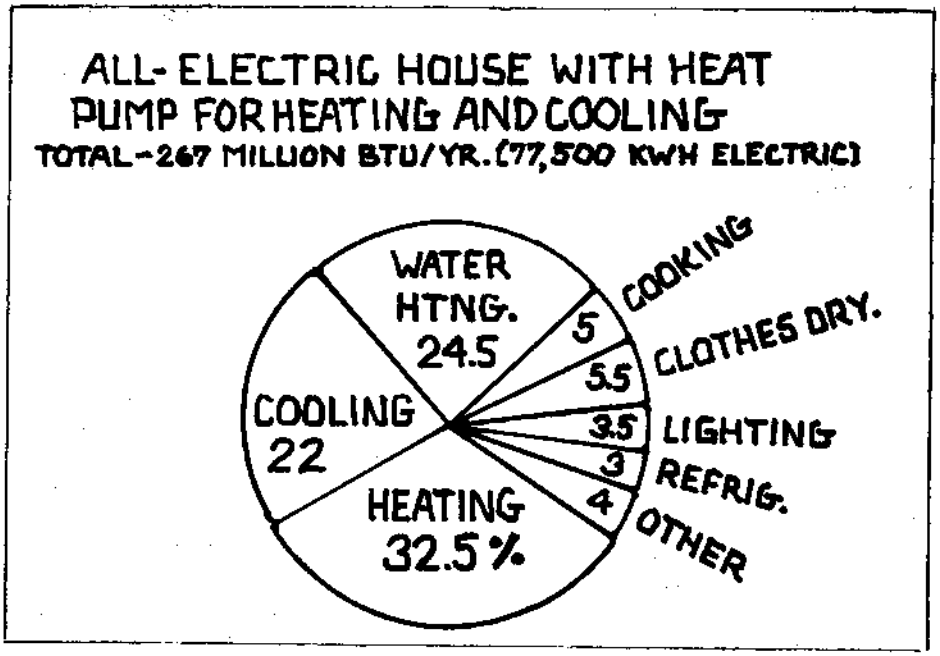


Fig. 1 All Electric House Energy Requirements

Fig. 2 All Electric House with Heat Pump Energy Requirements



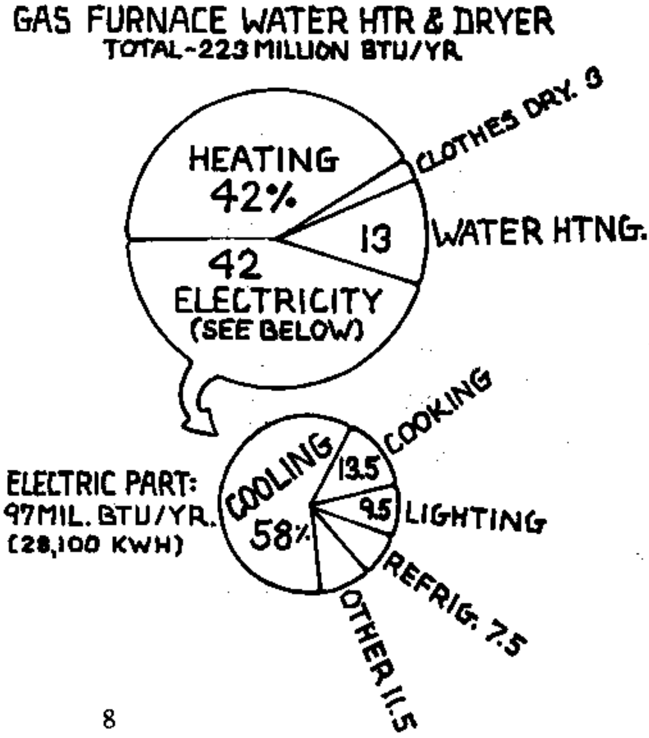
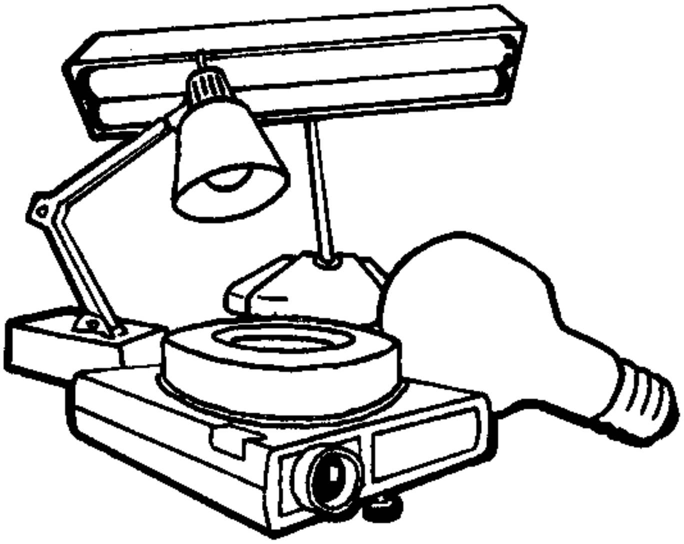


Fig. 3 House with Gas Furnace, Hot Water, and Dryer Energy Requirements



ENERGY CONVERSION: ELECTRICAL TO RADIANT

and is found much like EER:

$$\text{Efficiency} = \frac{\text{Energy out}}{\text{Energy in}} \times 100\%$$

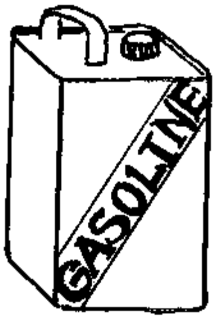
Note that in this case "energy out" and "energy in" must be in the same units.*

The next time you shop for an appliance or a car, compare efficiency, or EER, and lifetime cost before you buy.

Your electric bill is not the only energy bill you get each month. There is also the gas and/or oil bill. The gas bill will tell you how many cubic feet of gas were used. A cubic foot of natural gas contains about 1,000 BTUs of energy. Multiply this figure by the number of cubic feet on the bill to estimate how much energy you used for heating your house, or in cooking or water heating. In some areas, gas use is listed in "therms." A therm is 100,000 BTU.

Look over your oil bill. It will give gallons purchased. The energy content of a gallon of heating oil is around 120,000 BTU. Multiply the number of gallons by this figure to estimate how much energy was used in heating the house.

Of course, it doesn't make sense to look at your energy bills without doing something to conserve energy in the future. We have listed several energy conservation references at the end of this booklet. Here is something to consider: according to recent studies, "if approximately half the money needed for a proposed nuclear power plant was spent giving insulation to the homes it would serve, the energy saved each year would exceed that generated by the proposed plant,which then would not have to be built." (CoEvolution Quarterly, Summer, 1975)



Let's leave the house and venture out to the garage to find the family car. How many miles per gallon does your car get? You can rely on government studies, or manufacturers' statistics, but as with any such figures they are only general, averaging out millions of cars or based on test runs. You can get a rough idea about the efficiency of your car by filling up your gas tank to full. Record your odometer reading and then record it again in a week, or whenever you need gas. Fill up the tank to the top once again. Divide the number of gallons used by the number of miles traveled. For example, say you drive 100 miles and need 5 gallons to refill your tank. This gives you 20 miles per gallon. The miles per gallon will vary depending on whether you're driving in the city or on the open highway. Do the computation a number of times and take the average. Now get those government or manufacturers' figures and see how you compare. It might be time for a tune-up.

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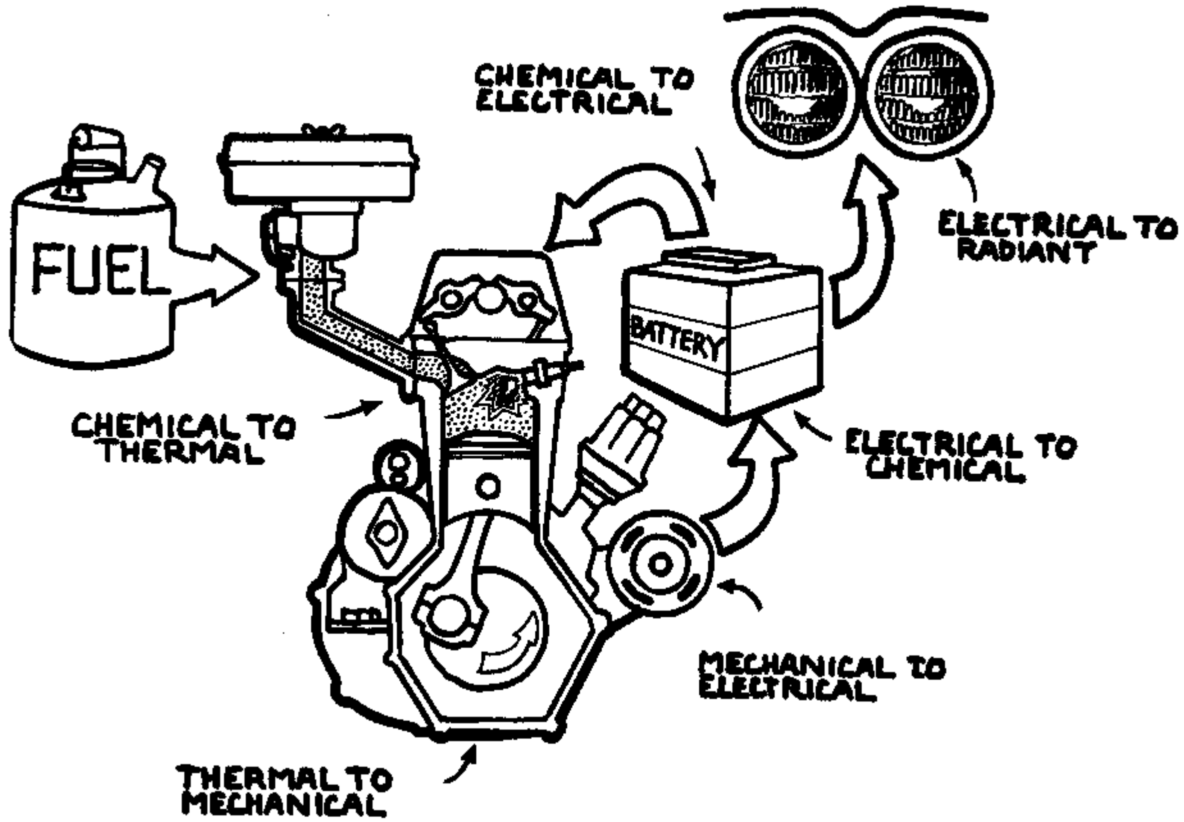
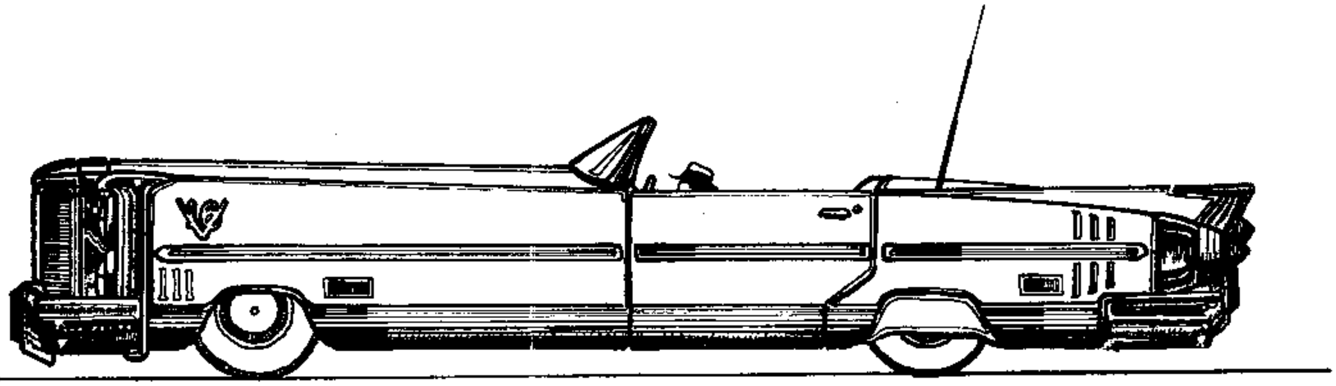
* You might have noticed that the efficiency of the air conditioners in the above examples -- if you convert kwh to BTU, or vice versa --- is over 100%. How can that be? See the footnote on page 19 for a brief discussion of heat pumps.



THE AUTOMOBILE: A SYSTEM OF ENERGY CONVERSIONS



<u>Problem:</u> Five friends decide to take a car pool to work, instead of driving separately. Driving alone each would travel an average of 15 miles per day, with an average gas consumption of 16 miles per gallon. Car pooling, the average route is 17 miles per day (longer to pick them up and let them off) with the average gas consumption of 15 mpg (because a larger car is used). How much gas and energy, in kwh, is saved? What was the energy cost per person of getting to work, alone and pooling, calculation for one year, five days a week, with six weeks off (230 days)?

<u>Answer:</u> Driving alone: 15 miles per day x 230 days/yr = 3,450 mi/yr. With a mileage of 16 mpg, we get 3,450/16 = 215.6 gal/yr per person or 5 x 215.6 = 1,078 gal/yr for all 5 people. The energy used is 215.6 gal/yr x 38.3 kwh/gal = 8,257 kwh/yr per person or 5 x 8,257 = 41,287 kwh/yr for all 5 people.

Car pooling: 17 miles per day x 230 days/yr = 3,910 miles/yr. At 15 mpg, we get 3,910/15 = 260.7 gal/yr for all 5 people or 260.7/5 = 52.1 gal/yr/person. The energy used is 260.7 gal/yr x 38.3 kwh/gal = 9,985 kwh/yr for all 5 people or 9,985/5 = 1,997 kwh/yr/person.

The overall savings in gallons of gas and in kilowatts of energy are then:

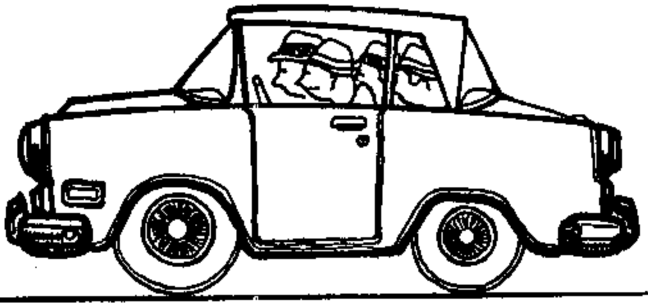
Gas Used Energy Used

	Gas Used	Energy Used
Driving Alone:	1,078 gal/yr	41,287 kwh/yr
Car pooling:	261 gal/yr	9,985 kwh/yr
Savings:	817 gal/yr	31,302 kwh/yr

The savings in gallons of gas and kilowatts of energy per person are:

	Gas Used	Energy Used
Driving alone:	216 gal/yr	8,257 kwh/yr
Car pooling:	52 gal/yr	1,997 kwh/yr
Savings:	164 gal/yr	6,260 kwh/yr

At 60c a gallon, that's a savings of $98.40 per year per person, not counting operating costs on the other autos. (It costs, according to the AAA, 23.2c per mile to own and operate a full-size U.S. car in a "high cost" area, and 16.4c per mile in a "low cost area.)



CHAPTER 2
SOCIETY AND ENERGY

Now that we've begun your survey of the private use of energy, let's pull back for a wider view of the national picture, where millions of people, and thousands of industries and government units are making similar decisions. Even though we may not always be able to have direct influence over these decisions, we can have indirect influence, through our choice of lifestyles and consumption of various goods.

In order to do that, we need to know which sectors of our society are energy intensive (are heavy users of energy), and what our relationship to energy and its sources have been.

Some of the charts on the following pages may seem to be a jungle of information. But take your time, and see if you can find the answers to these questions.

Figure 4 shows the flow of energy in the United States. The left side of the chart shows sources of energy to the U.S. system. The right side shows ultimate uses. The width of each band is proportional to the amount of energy used in that activity. What can you learn from the chart? What fuel source is the greatest contributor to our energy use? What percentage of our oil was imported in 1970? (Though it's not shown on this chart, find out how much is imported today, and compare the two figures.) What percentage of our energy is used to generate electricity? Which use of energy is least efficient (produces the most waste and the least work)? Which is most efficient?

Figure 5 displays society's energy use in a different format. What does it tell you? Which sector of the economy uses the most energy? Within each sector, which are the most energy intensive uses?

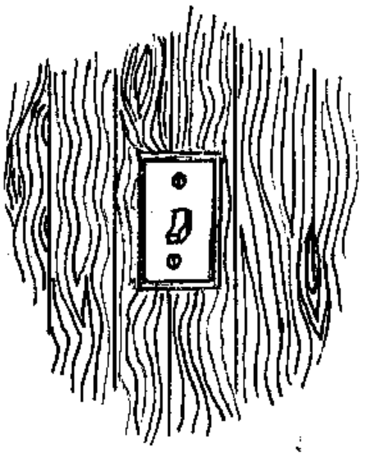


Figure 6 shows the change in U.S. fuel consumption from 1850 up to the present. The use of which energy source has been growing most rapidly? Compare the use of coal and oil in 1950 with the use of the same two fuels in 1975. The dotted line represents U.S. population growth. What can you say about energy use and population?

Table 3 shows efficiencies of different forms of transportation. This gives us a way to compare the energy efficiency of different forms of transportation, with the efficiency expressed as passenger-miles per gallon, as BTU per passenger-mile (for passenger transport), and BTU per ton-mile (for freight). From the information in the table, which is the most efficient form of transportation? The least efficient? Notice that most of these forms are not fully utilized. Automobiles, for example, usually carry only one or two people per trip. How would their energy efficiency change if they were more fully utilized? Compare your answers with the car pool problem in Chapter One.

Walking, is very energy efficient. Bicycling uses less energy and can carry a person both farther and faster than walking. Motorized transport can carry us farther and faster still, but at a higher energy cost. So energy use is not the only factor; but combined with a sense of what we really need for a given trip, it can help us to make the wisest choice.

TABLE 3
EFFICIENCY OF MODES OF PASSENGER TRANSPORT

Mode	Cruise Power (H.P.)	Speed (mph)	Seat Capacity (no.)	Occupancy Assumed (%)	Transportation efficiency (Pass. mile per gal.)	Transportation efficiency (BTUs per pass. mile)*
Rail						
Fast train **	2,400	100	360	55	133	980
Commuter train†	4,000	40	1,000	50	100	1,300
Cross-country train	2,400	60	360	55	80	1,600
10-car subway train††	4,000	30	1,000	50	75	1,700
Road						
Large bus	200	50	43	58	125	1,000
Automobile (sedan)	50	67	4	25-50	16-32	8,100-4,100
Bicycle		6-10				180
Walking		3.5				800
Air						
747-jet	60,000	500	360	55	22	5,900
707-jet	28,000	500	136	62	21	6,200
STOL‡ plane (4-prop)	10,000	200	99	55	18	7,200
SST (US)	240,000	1,500	250	60	13.7	9,500
Helicopter (3 engine)	12,000	150	78	58	7.5	17,300

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* Conversion obtained with 130,000 BTUs per gallon

** 3-car, self-propelled, bi-directional double-deck, 67 tons per car

† 10-car train with 2 diesel locomotives, 950 tons gross weight

†† New N.Y. subway train at heavy, non-rush hour traffic

‡Short-take-off-and-landing (see "Aircraft in the Balance," Environment, December, 1971)

Source: Rice, R.A., ASME, 70 WA/ENER-8, November 1970, Table 12

Table 3 - From System Energy as a Factor in Considering Future Transportation, paper no. 70-WA/Ener-8, by Richard A. Rice, presented at the 1970 American Society of Mechanical Engineers Winter Annual Meeting, Nov. 29-3, NY, NY. Used by permission.

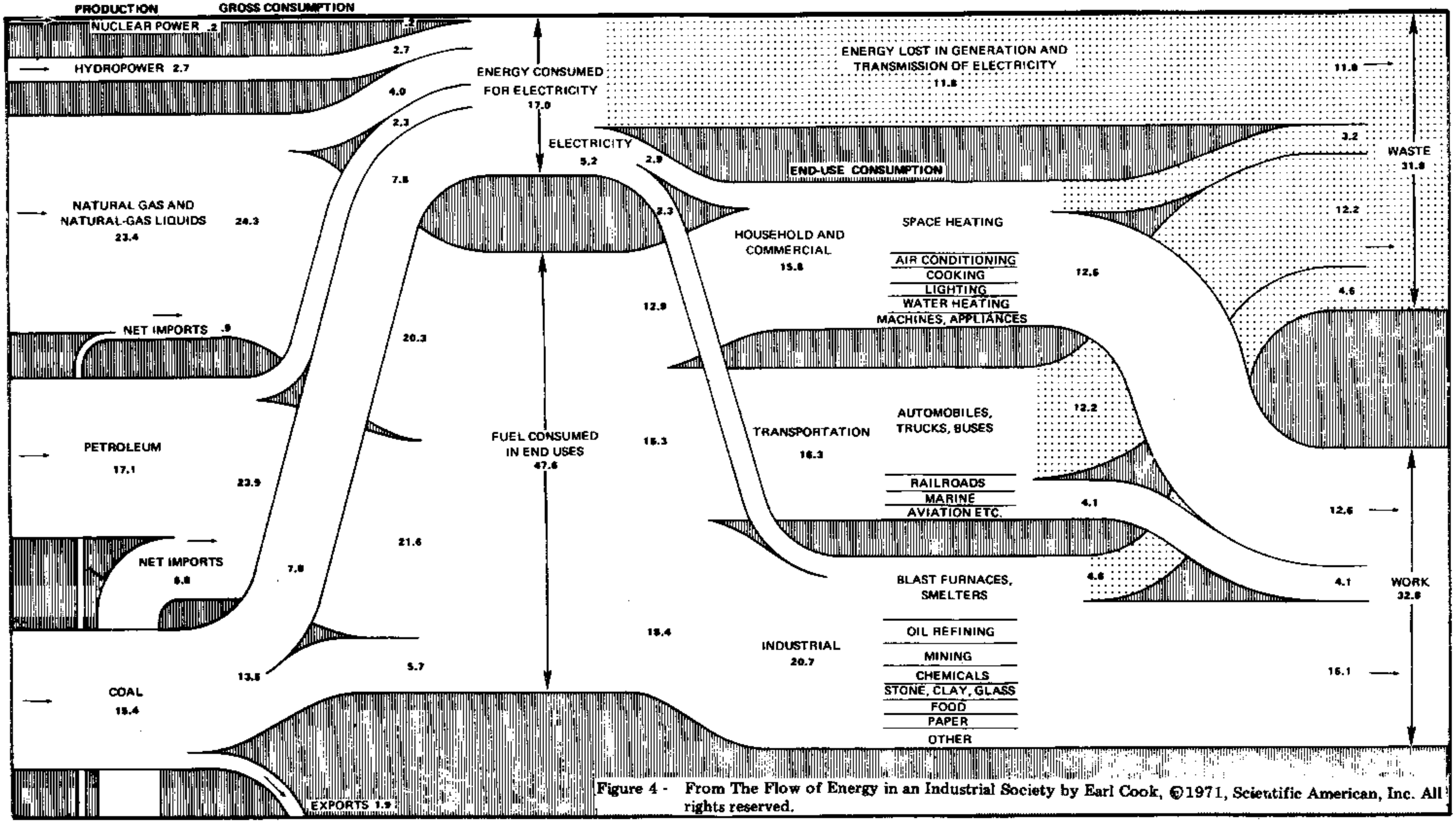

Figure 4 - From The Flow of Energy in an Industrial Society by Earl Cook, ©1971, Scientific American, Inc. All rights reserved.

FLOW OF ENERGY through the U.S. system in 1970 is traced from production of energy commodities (left) to the ultimate conversion of energy into work for various industrial end products and waste heat (right). Total consumption of energy in 1970 was 64.6 x 10^{15} British thermal units. (Adding nonenergy uses of fossil fuels, primarily for petrochemicals, would raise the total to 68.8 x 10^{15} B.t.u.) The overall efficiency of the system was about 51 percent. Some of the fossil-fuel energy is consumed directly and some is converted to generate electricity. The efficiency of electrical generation and transmission is taken to be about 31 percent, based on the ratio of utility electricity purchased in 1970 to the gross energy input for generation in that year. Efficiency of direct fuel use in transportation is taken as 25 percent, of fuel use in other applications as 75 percent.

Fig. 4 The Flow of Energy in the U.S. System

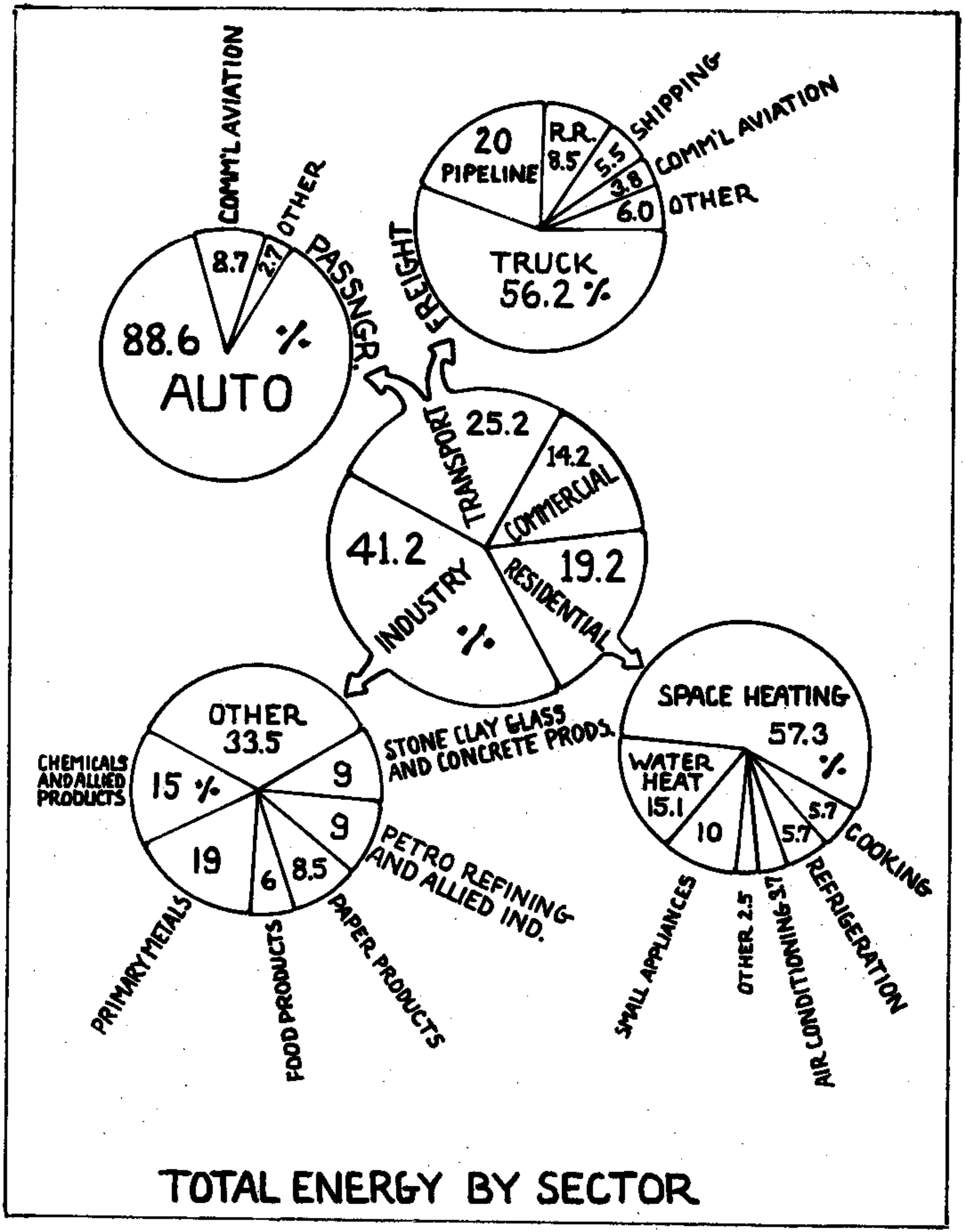

Fig. 5 Total Energy Use By Sector

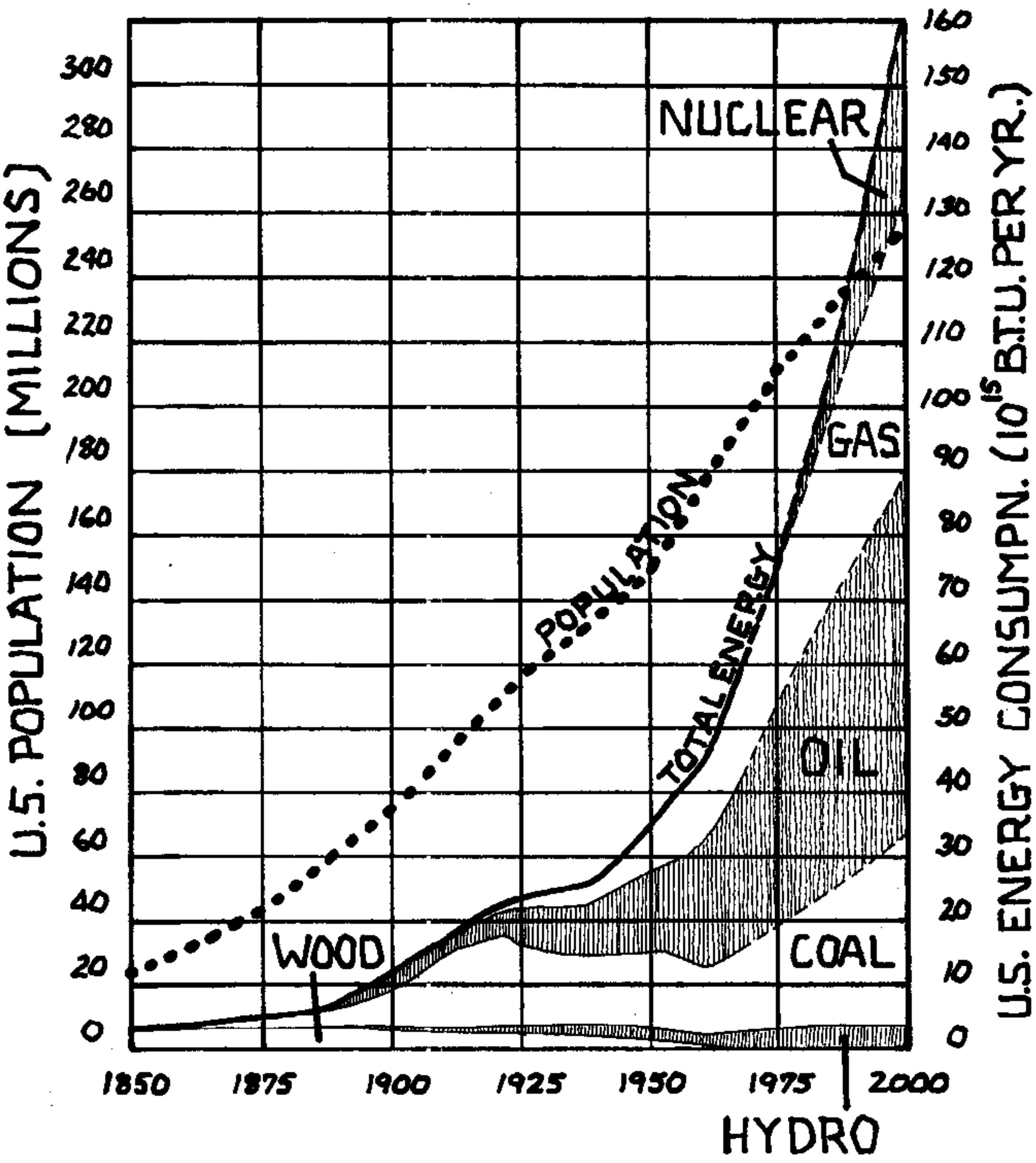

Fig. 6 U.S. Fuel Consumption

Figure 6 - From The Flow of Energy in an Industrial Society, by Earl Cook, and Energy and Power, by Chauncey Starr. © 1971 by Scientific American, Inc. All rights reserved.

FOSSIL FUELS

Fossil fuel - that is coal, oil and natural gas - are compressed or concentrated fossilized remains of plants and animals. Fossil fuels are a very concentrated form of energy, because the processes of millions of years and millions of tons of pressure have packaged a great amount of energy in a small amount of space. A gallon of gasoline, for example, contains about 132,000 BTU, over one million BTU per cubic foot. If we were to rely on the sun directly for our energy, we would need hundreds of square feet of collectors to harvest a "gallon's worth" in an hour. Using the sun indirectly, we could burn wood, but wood contains only about 100,000 BTU per cubic foot. It is understandable, then, why fossil fuels have become such a popular and convenient energy source, and why we have built our way of life on these concentrated forms of energy.

However, people are now recognizing that, as useful as these fuels are, their supply is limited. These fuels are not renewable, meaning that the fuel we take from the ground in one year can only be replaced by nature after hundreds of thousands of years have gone by. Sunlight, on the other hand, is a renewable resource; it is a dilute form of energy, but comes to us day after day. It can be used, but it can't be used up.

The analogy which is often used is income energy versus energy capital You can draw more than your dividends, that is, if you draw from your fixed capital, you will, after some amount of time, run out of money.

Just how limited our supplies of fossil fuels are is a matter of some dispute. We hear people talk of reserves, proven reserves, undiscovered reserves, likely future discoveries, and so on. It is possible that more fossil fuel reserves will be discovered in the coming years, but though our "capital" will then be large, it will still be finite. To make this point more clear, let's look at some projections of life expectancies of each major fossil fuel.

RESOURCE DEPLETION

If we use the known reserves, as of 1970, and assume that the world will continue to use the same amount of energy each year, then the life expectancies for each fossil fuel (found by dividing the total reserves* by consumption per year) are:

Coal	2,300 years
Oil	31 years
Natural gas	38 years

This is a picture of a static world. In fact, our consumption of energy, and fossil fuels, is currently rising. If we assume that consumption will continue to increase as it has in the past, then the life expectancy figures change:

Coal	111 years
Oil	20 years
Natural gas	22 years

This, of course, assumes that we don't discover new sources of fossil fuels. It is surprising, though, how little the life expectancy figures change even if we assume tremendous increases in known reserves. If we project five times current known reserves then the life expectancies become:

Coal	150 years
Oil	50 years
Natural gas	49 years

If we assume that we will find 100 times the known reserves, the figures look like this:

Coal	223 years
Oil	123 years
Natural gas	110 years

EXPONENTIAL GROWTH

The reason that the resource life expectancies grow so little compared to the reserves is that the use of these products is growing exponentially. Exponential growth is like compound interest at the bank. The growth of use (or interest) is computed for the previous consumption (or deposit). It is then added to the old consumption to give the new consumption (or balance), which is the basis for the next calculation..

For linear growth, as for simple interest, the increment is always calculated from the first consumption (balance), and so remains constant. In exponential growth, the increment itself is growing. In other words, if use in year one is 100 units, and use is growing by 5% per year, use for the second year would be 105 units (100 + (.05x100) or (1.05 x 100). For year three, the use is a little over 110 units (1.05 + (.05 x 105). For the first few years, this change does not seem important, but by the end of the 10th year, the demand will grow to 163 units per year (vs 145 units at linear growth and the yearly increase in demand will rise to 8 rather than 5 units) and for year 31, it is 432 (vs 250) units per year. The total units used in the 30 years of our example is 7,076 units, or an average of about 236 units per year.

You can figure out roughly how long it takes the use to double with this approximate formula:

$$\text{Doubling time (years)} = \frac{70 \text{ years}}{\% \text{ annual increase}}$$

Thus, in our example above, use doubled after 70/5 = 14 years. If the use of coal rises at 4% per year, it will double in 70/4 = 17½ years This doubling is very potent, for as time goes on, and consumption grows, we are doubling a larger and larger number. Doubling 1,000 to 2,000 produces a very different change from doubling 10 to 20. Or look at it another way: The next time we double our energy consumption, we will be using more energy in that doubling period (10 to 20 years, depending on the rate) than has been used in the whole of human history.

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*These numbers change frequently, as reserve estimates are revised - for instance, in June 1975 the U.S. Geological Service reduced estimates of U.S. oil and natural gas reserves by 80% -- so they are not offered as strictly accurate (as if reserve estimates ever could be). So while these numbers, from the "Limits to Growth" study of 1968, are somewhat dated, the trend of resource depletion, and the impact of exponential growth, are with us all the same; the numbers may shift slightly (and the example will explain why only slightly), but what is crucial is an understanding of the pattern.

Part of this increase in energy consumption, of course, has been because of our steadily growing population. But, if you look back at figure 6, you'll see that energy use has been growing much more quickly than population -- that is, per capita energy use is growing too. It is these combination of factors, rising population and growing per capita consumption, that are driving our energy needs steadily upward, both in the U.S. and around the world. From what you've learned, do you think this trend should continue? What strategies could you propose for slowing it?

The numbers above are only rough estimates, but they can give you a good idea of what we face in the future, not just with fossil fuels, but with all our mineral resources. (The numbers may shift up or down, but the pattern is the same). We can see that although we have huge reserves of coal, this does not guarantee us an infinite resource life expectancy if world consumption continues to rise as it has in the past. Furthermore, these figures do not take into account the economics of mining this coal. As more coal is mined and it becomes deeper or more spread out, the costs in obtaining it go up. So the estimates of economically recoverable coal vary widely (see footnote, P16).

we can put together some of the things we have learned and come to further conclusions. Over 55% of our petroleum now goes into transportation. If, in 30 years, we have very little oil available, we might want to switch to electric vehicles, with electricity generated from coal. This would mean a huge increase in our use of coal, and a faster depletion of coal reserves. If cars and trucks had been shifted to electricity in 1970, we would have needed to almost have doubled our electricity production in this country. What effect would this have on the life expectancy of coal reserves?

Running out of fuel does not necessarily mean running dry. Clearly, long before supplies of any resource are exhausted the price of that resource will go way up. This does not mean only that it will be more expensive to run our cars. Energy is an increasingly important part of every commodity we buy, from radios to potato chips. A rise in energy prices can very quickly ripple through the rest of the economy, as we learned after the Arab oil boycott of 1973.

The tables below present two ways of looking at the "costs" in the production of many of our basic materials. Table 4 shows the amount of fuel and electricity costs as a percentage of the total costs for various materials. Table 5 shows the energy content in BTU per million tons of various materials ("energy content" meaning the amount of energy needed to process and manufacture the material).

We can see that some ways of building might be more efficient, in terms of energy, than others. Of course, there are certain characteristics of each material that makes it peculiarly applicable to different work. Steel has a great structural strength. Aluminum is lighters. Plastic is not easily recyclable, and so forth. But besides building, this chart can help us see something else. Our soda and beer containers are now increasingly a combination of steel and aluminum, or aluminum alone, and use about four times the energy that returnable glass bottles do.

TABLE 4

Fuel and Electricity Purchases As Percentage of Total Materials Costs

Steel	8.5%
Petroleum refining	2.9
Cement & hydraulic industry	43.0
Plastic materials & synthetics	6.3
Building paper and paperboard mills	16.2
Industrial chemicals	14.8
Glass	14.5
Structural clay products	21.2

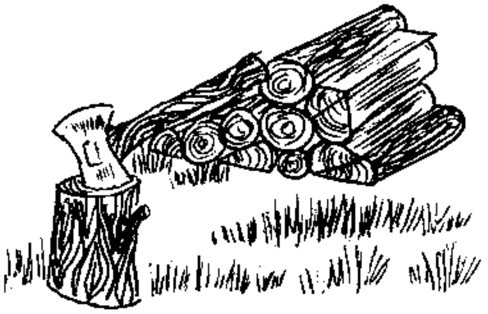
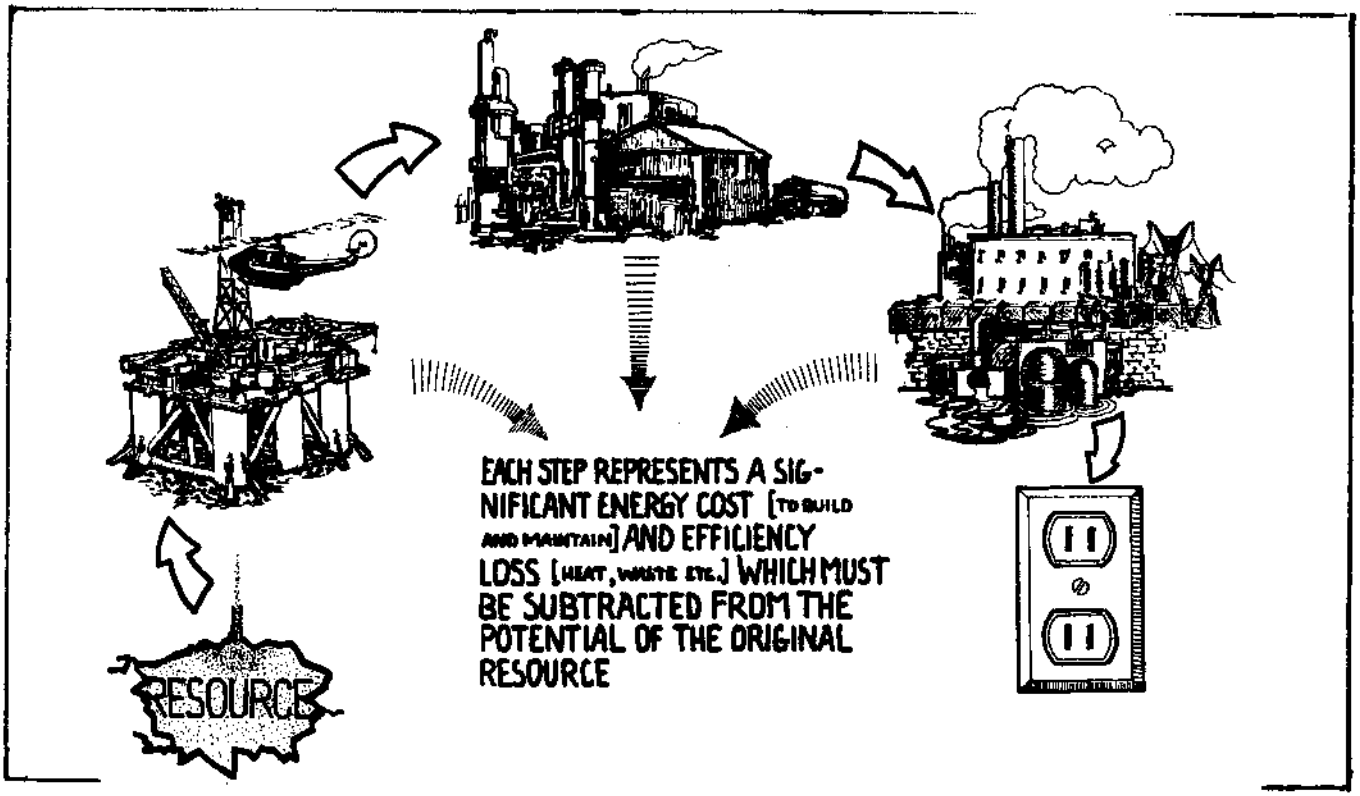


TABLE 5

BTU Content of Materials

Material	Energy content BTU x 10^6/ton
Carbon Steel:	
cold-rolled	52.7
wire	61.1
pipe	52.6
forged	76.0
Alloy Steel:	
cold-rolled	55.3
wire	63.7
pipe	55.2
forged	78.6
Stainless Steel	
Cold-rolled	78.8
wire	87.2
pipe	78.7
forged	102.1
Steel Casting	46.7
Iron Casting	25.0
Aluminum rolled, forged, cast	75.0
Copper:	
rolled	128.0
wire	106.2
cast	124.5
Zinc	
Rolled	79.2
cast	87.7
Nickel	374.7
Tin	469.3
Lead	31.1
Hard and Soft Woods	.3
Paperboard	36.4
Paper	40.6
Flat Glass	18.1
Crushed Stone	.1
Cement	12.4
Brick	6.9
Polystyrene	22.6×10^3



NET ENERGY

But energy doesn't just cost us money. It costs us energy as well. The amount of energy resources we really have is the amount stored in the ground minus the amount of energy it takes to bring energy to its final use. Just as we could understand the difference between energy capital and energy income through the example of the bank, above, an example from everyday experience might make this concept of net energy more clear:

Let's say you have a job right now which pays you $2.50 per hour, and which is located in your neighborhood, within walking distance. You are offered another job which pays $4.00 an hour, but which is located 20 miles away. The total amount of your paycheck (not counting tax deductions, health insurance, etc.) is $100 a week for the first job and $160 a week for the second. What is the difference in your net income? At first glance you might say $60. But let's see why this isn't correct.

If you drive the 40 miles round trip each day, that's 200 miles per week. At 15 miles per gallon, about average for a medium sized car, you would use about 13 gallons per week. If gasoline costs 60¢ a gallon (in which case, you're lucky), that would be $7.80 a week. Now you must add to that the depreciation (decline in value from wear, tear, and aging) on your car, the maintenance and insurance costs you must pay, and so on. Recent figures put this cost at about 12½¢ a mile for a medium sized car. That adds $25 to your weekly operating costs. Parking could add another $10 or so per week, but even without that expense, we see that the $32.80 per week expense of your car reduces the $60 per week increase in your net income to $27.20.

Just as there are hidden costs in operating a car, there are hidden costs in using energy. When we switch on a light, we are signalling the end of a long process which has included mining coal, processing it, transporting it to generating plants, converting it to electricity, transmitting the electricity to our homes, and cleaning up (or absorbing) the environmental impact of each of these steps. Each of these steps takes energy. If it takes us 50 BTUs of input to get an additional 100 BTUs, of output, we have really gained only 50 BTUs, not 100. If it ever takes us 100 BTUs of input to get an additional 100 BTUs of out put, we may as well give up, for we have gained nothing.

This concept of net energy is crucial to understanding our energy future, because, as our energy supplies decrease, it becomes increasingly difficult to get them out of the ground. We must drill deeper, or drill in places which are inconvenient, like offshore, or in the arctic. We must mine coal deeper under the ground, or spend more energy and money reclaiming surface land after strip mining it. In other words, in the future, we will have to spend more and more energy to get the same amount of energy back.

EFFICIENCY AND WASTE HEAT

We discussed efficiency earlier in this booklet, with the examples about air conditioners. We explained that the efficiency of an appliance, too, or process was the amount of useful energy we get out compared to the amount of energy we put in. Think of this as if you were buying a product. You want to know that you are getting the best buy for your dollar. How much convenience, satisfaction, or joy are you getting back for the dollar you spend? Are you getting your money's worth? Well, the question is the same with energy. Are we getting our "energy's" worth?

As a simple example of what we mean by efficiency, let's compare what happens when we use a gas versus an electric water heater. First we trace the path of energy from original source to useful work. Natural gas is discovered in and pumped from the ground, and transported by pipeline to our homes, where it is used to heat water. Electricity is not a fuel, but is produced in generating plants, usually by burning fossil fuel (or by using falling water or nuclear power). In this process, coal is discovered, mined, processed, transported, and converted to electricity, and the electricity transmitted over wire to our homes. The different levels of efficiency which are involved in these two processes are shown in Table 6.

Table 6 shows the estimated fuel efficiencies for various fuels. The delivered efficiency takes into account the average losses in the transporting, mining, processing, etc. of the fuel. The utilization efficiency shows the efficiency when the fuel is actually used for heat. The overall or ultimate - efficiency is the product of the delivered times (x) the utilization efficiency.

Notice that the efficiency of electricity in heating water is almost 100%, far greater than that of natural gas. In other words, once we get electricity into our homes, it is more efficient than gas. But we can also see that we waste a lot of energy from the coal field to the water heater. The overall efficiency (found by treating the component efficiencies as decimals - 56% = 0.56, etc. - and multiplying them all) of using electricity for water heating is only 17%, while for natural gas it is 40%.

Heat pumps can have apparent efficiencies of over 100% because 1) most of the work is done by "natural" energies that are not accounted for in the efficiency equation, and 2) the efficiency of the delivered electricity (about 17%) is usually omitted as well (The effect of inclusion of this second point is shown in table 6.) Also remember that building the system has energy costs too, which must be considered when assessing its overall energy efficiency. Thus, even though the heat pump is very efficient at the home, the heat pump using fossil-fuel generated electricity uses one-third more primary energy than central oil heat. Resistance electric heating, we can see from Table 6, uses more than twice as much primary energy as the heat pump.

PROBLEMS

If electricity costs 5¢/kwh, and oil 50¢/gal (138,000 BTU/gal), what would it cost to provide 100,000 BTU of <u>usable</u> heat, by central oil heating and by central heat pump heating?*

To find how much energy you must <u>purchase</u> to get the <u>usable</u> energy you need, divide the energy needed by the <u>utilization</u> efficiency.

<u>OIL</u>

$$\frac{100{,}000 \text{ BTU}}{.63} = 158{,}730 \text{ BTU}$$

This amount of energy would be supplied by:

$$\frac{158{,}730 \text{ BTU}}{138{,}000 \text{ BTU/gal}} = 1.15 \text{ gal oil}$$

At 50¢/gal, that would cost 1.15 gal x $0.50/gal = $0.575

<u>HEAT PUMP</u>

$$\frac{100{,}000 \text{ BTU}}{2.26} = 44{,}194 \text{ BTU}$$

From the conversion table, 34,000 BTU = 1 kwh, so 44,194 BTU =

$$\frac{44{,}194 \text{ BTU}}{3400 \text{ BTU/kwh}} = \text{about } 13 \text{ kwh}$$

At 5¢/kwh, that would cost 13 kwh x $0.05/kwh = $0.65

This example compared the <u>utilization</u> efficiency of two alternatives. Let's compare the overall efficiency, to see how much primary energy it took to get that 100,000 BTU of usable heat. In this example, we'll divide by ultimate efficiency.

<u>OIL</u>

$$\frac{100{,}000 \text{ BTU}}{.51} = 196{,}078 \text{ BTU}$$

<u>HEAT PUMP</u>

$$\frac{100{,}000 \text{ BTU}}{.384} = 260{,}416 \text{ BTU}$$

Just as it is inefficient to use electricity to produce heat, it is also inefficient to use gas to produce light. There are four million gas lamps in the United States, each using 20 times more energy than its electric equivalent, the 25 watt bulb. The national gas savings that could be realized by replacing gas lamps with electric bulbs would heat over 600,000 homes annually.

What happens to the energy that doesn't reach us as useful work? Directly (like exhaust going up a smokestack) or indirectly (like the friction losses in an engine), it is dissipated as heat, into the air, a body of water, or the ground.

An important law of energy is that energy cannot be created or destroyed, but only changed in form. If we release 100 BTUs of energy from coal we end up with 100 BTUs of energy, but might have 70 BTUs go off as waste heat and only 30 consumed in useful work. The less efficient our use of energy is, the greater the amount that goes off as waste heat.

For example, the waste heat released over the Los Angeles basin in 1970 amounted to about 5% of the total solar energy absorbed at the ground. This level of heat release is already affecting the local climate. Waste heat released over the Boston-Washington metropolitan corridor in the early 1970's was also in the neighborhood of 5% of incoming solar energy. "For a limited area of highly concentrated energy use like Manhattan Island, waste heat already <u>exceeds</u> incoming solar energy by a sizeable margin." (from <u>Inadverdent Climate Modification</u>, Massachusetts Institue of Technology, 1971)

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*A heat pump is a device that uses electricity not as a primary source of energy for heating (or cooling), but as a control mechanism to effectively use energies in the local environment, and to transfer energy from one part of the environment to another.

Thus, somewhat simplified, a heat pump responsible for heating a home in the winter might circulate a fluid through coils outside the house -- often, though not necessarily, underground -- where the fluid would pick up heat (even if it's cold outside, the fluid can still pick up heat, though at reduced efficiency, in effect making the outside environment a tiny bit colder); the fluid then gives up that heat when circulated through the house itself. The outside environment parallels the hotter back of the refrigerator. The dynamics of the cycle are the same, though the "useful" point is different. In each case, you have to supply energy to drive the pump (and of course, to construct the system), but not to produce the heat as with direct resistance heating.

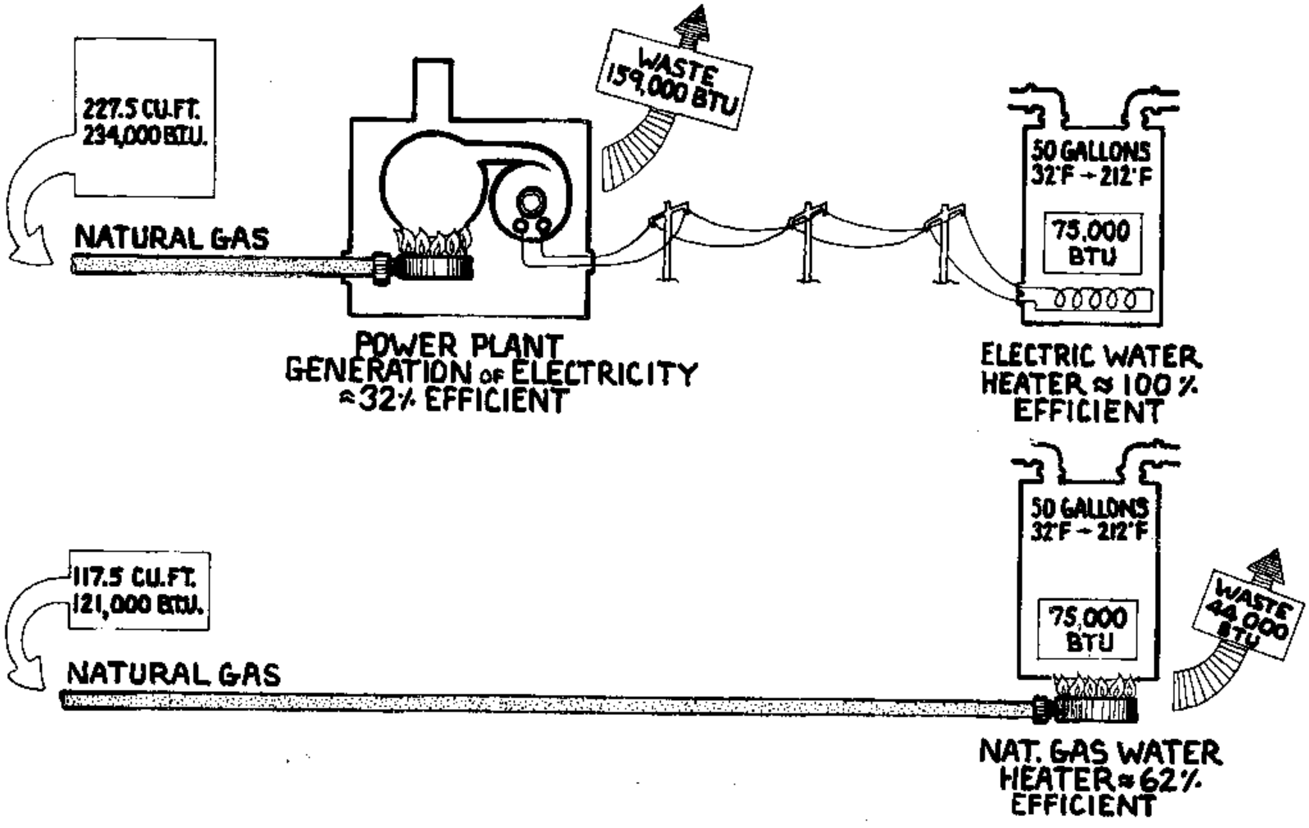
An air conditioner is a common type of "heat" pump, using the same principle for cooling. A fluid travelling through coils picks up heat from the air that passes through the machine into the room, turning to a gas in the process. When compressed, it returns to the liquid state, giving up its heat to the outside environment, which in turn becomes a little bit warmer. (An interesting project might be to calculate how much a large number of air conditioners in a city might heat the outside air, thus increasing people's needs for air conditioners.) Air conditioners are so effective at cooling the incoming air that the air often has to be partially reheated to a comfortable level.

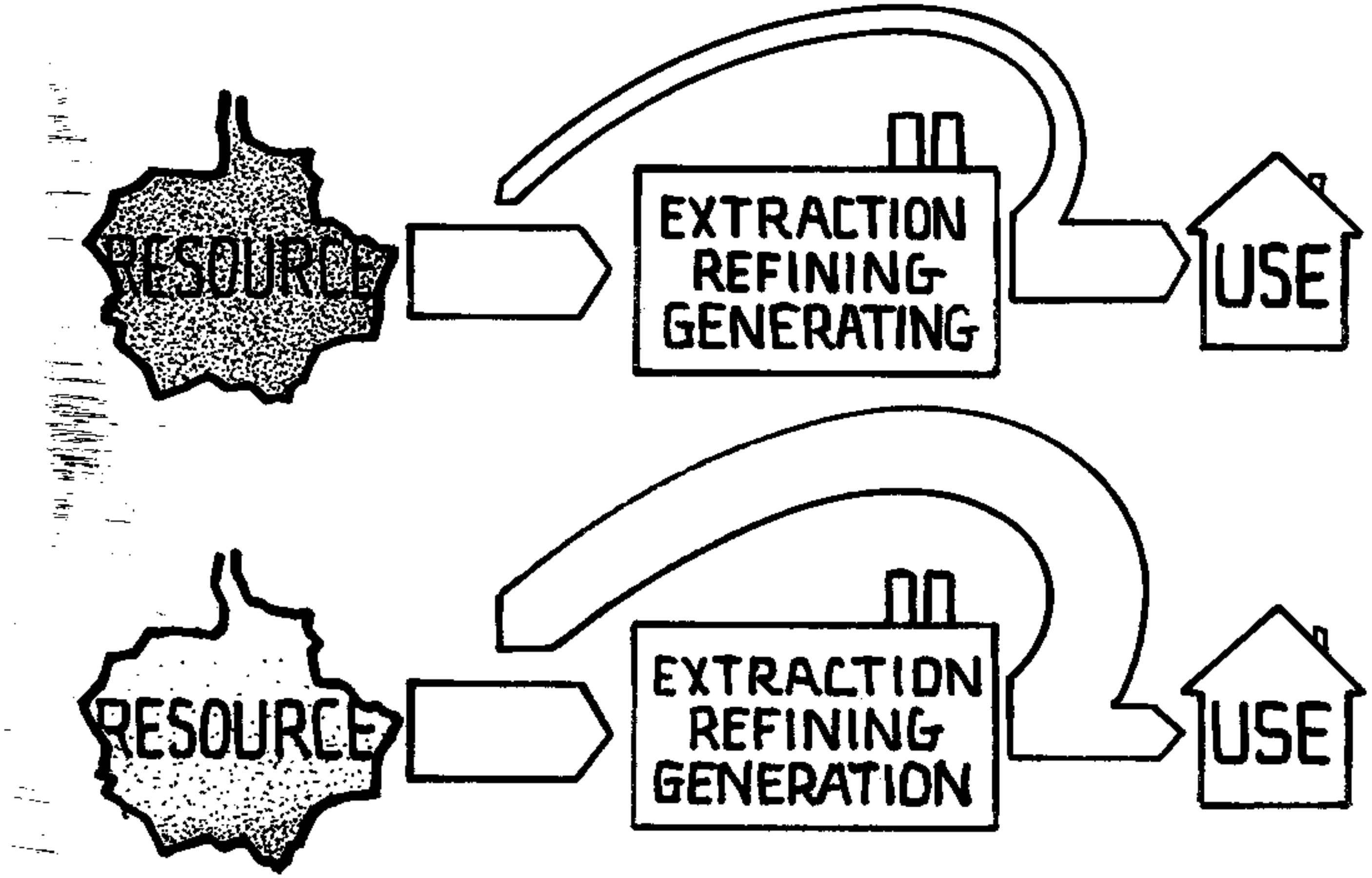
TABLE 6

ESTIMATED ULTIMATE FUEL EFFICIENCY:

(in percent)

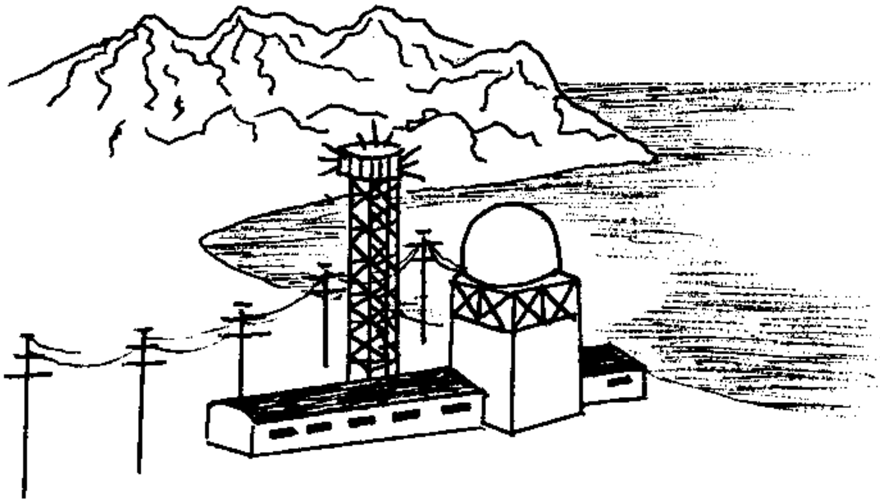
Fuel and use	Delivered efficiency	x	Utilization efficiency	=	Ultimate efficiency
Coal (bituminous):					
Central heating, hand fired	93.0	x	45.0	=	41.8
Central heating, stoker fired	93.0	x	55.0	=	51.1
Water heating, pot stove	93.0	x	14.5	=	13.5
Oil:					
Central heating	81.0	x	63.0	=	51.0
Water heating, 100 gallons per day	81.0	x	50.4	=	40.8
Natural gas:					
Central heating	93.0	x	75.0	=	69.7
Water heating, 100 gallons per day	93.0	x	63.7	=	59.2
Electricity:					
Central heating, resistance	17.0	x	95.0	=	16.1
Central heating, heat pump	17.0	x	226.0	=	38.4
Water heating, 100 gallons per day	17.0	x	92.2	=	15.6





AS ENERGY RESOURCES BECOME SCARCER AND HARDER TO REACH, INCREASING AMOUNTS OF ENERGY MUST BE USED TO GET THEM OUT OF THE GROUND.

Waste heat can cause environmental problems if it is concentrated in one area, as for example, when the effluent (heated cooling water) of a powerplant raises the temperature of a river, affecting fish life in the river. Large cities put out so much waste heat that they can change weather patterns. Waste heat can be reduced, through more efficient technologies, so less is released in the first place, and through total utility systems, where the waste heat is used, not surprisingly, for heat. There are already cities in Europe that are heated by the waste heat from their electrical generating plants, including Vasteras, Sweden (population 120,000), parts of Paris, and other French and German cities. With tightening environmental regulations and rising energy costs making waste too expensive, we can expect to see more of these kinds of ideas implemented. But while waste heat can be reduced, it cannot be eliminated. And even if our waste heat produced per BTU of energy used shrinks, our total energy consumption is rising so rapidly that total waste heat will rise as well. In fact, according to Dr. William E. Heronemus of the University of Massachusetts, the amount of cooling water needed by U.S. powerplants "will exceed our total U.S. ground water runoff in about 1995." Then what?



NUCLEAR ENERGY

Nuclear energy is such a controversy these days that we couldn't possibly be conclusive about it in this limited space. But it may be helpful if we explain some of the questions that have been raised about nuclear energy.

Uranium is subject to the same patterns of depletion we discussed above with fossil fuels. To meet this problem, scientists have been trying to develop the "breeder reactor," which is supposed to produce more fuel than it consumes. Although it has been given major priority as a national energy strategy, the breeder is definitely controversial. It actually takes a long period of time before such a reactor would produce more fuel than it consumes. Also, the fuel produced is Plutonium 239, which is extremely toxic if released in even small amounts to the environment. The Plutonium could also be used in making bombs. Finally, the breeder reactor is more likely to speed up its reaction if the coolant, liquid sodium, is lost than with a regular (water cooled) reactor, In either case, the result could be a "melt-down" of the reactor core and release of radioactivity.

A major problem with all nuclear reactors remains that of storing the resulting radioactive waste. The tanks at the sites where these wastes are stored must be kept leak free, and must be cooled for hundreds of years in the future. Any failure due to mechanical means or direct sabotage could be disastrous. There are also problems of logistics and safety in transporting these radioactive materials around the country (current projections call for 1,000 nuclear plants in the U.S. by the year 2000).

Despite these problems, there is a strong impetus at the national level to continue to develop nuclear power. With fossil fuel prices rising, there is great pressure to develop any source of energy which will keep the sophisticated industrial system we have going at the pace it has for the last 30 years. Clearly, though, any solutions developed to deal with the problems of nuclear power will have their own energy costs, which will have to be included in the net energy accounting of nuclear alternatives. Already there are some people who suggest that the net yield from nuclear energy (including the decades of development costs and the centuries or more of waste storage) may be very close to zero.

Fusion is another long range nuclear alternative. Unlike fission, where a heavy element (like uranium) is split into two lighter ones, fusion works by joining, or fusing, two light elements into one: for example, two atoms of hydrogen into one atom of helium. Both processes can release enormous amounts of energy; fusion is what powers hydrogen bombs and the sun. But scientists have not yet learned to produce controlled fusion reactions, so no one can be sure when, if ever, fusion will become a practical energy alternative. Also, while the fusion process is, unlike fission, basically non-polluting (though recently some writers have questioned that assumption), both it and fission produce great amounts of waste heat (see Efficiency and Waste Heat, above). In fact, a fission based generating plant will put a 60% greater heat load on cooling waters than a fossil plan of equivalent size.

CHAPTER THREE
ALTERNATIVE SOURCES OF ENERGY

So far, we have been looking at the fossil fuels for our examples. Fossil fuel reserves have been built up over millions of years as plant matter decays and is compressed. Green plants use the sun's light to store energy by the process of photosynthesis. The sun is the source of all our food energy. If we eat animals, we are eating a creature which had previously gotten its energy from plants, or other animals which get their energy from plants.

If we burn our crops, like wood, corn, or wheat, we will get energy that can be used to generate electricity or run machines or heat our homes. We can distill alcohol from various grains and use this in our automobile engines. But all this takes a lot more work to produce the same amount of energy as we get from our fossil fuels. You can easily understand why this is so by realizing that the plants which form the basis of our fossil fuels are compressed together over millenia to give us the concentrated forms of energy we use today.

While our fossil fuel resources are non-renewable, there are other sources of energy which are 'renewable'. That is, they are continuous, and when we take a part of that energy and convert it into useful work we do not reduce the amount that is available the next day. We can use the sun's light for heating our homes, for instance, by capturing the heat on our roofs and bringing it into our houses. No matter how much of the sun's heat we use in this manner, we are not going to use up the sun.

Renewable forms of energy come directly or indirectly from the sun. We have already mentioned that green plant energy, produced by photosynthesis, needs the sun's rays for the chemical reaction to occur. The sun also evaporates water from the earth and carries it into the atmosphere where it forms clouds and then rains down, falling on mountains and hills to form rivers which can be used to power waterwheels or hydroelectric plants. The sun heats up the atmosphere itself to different degrees in different places, causing winds to blow throughout the world, and that wind can be used to blow sailboats or turn windmills. Our oceans themselves are possible producers of huge amounts of energy. The top of the ocean is subjected to the sun's heat, but that same heat cannot penetrate far beneath the surface. The difference in temperature between the surface and the lower layers can be used to produce useful energy. Tides are produced by the gravitational attraction of the moon, and to a lesser degree, the sun, and can also be used to generate power.

We will describe three forms of solar energy in this chapter, and do some energy arithmetic with each. We are going to look at solar energy for heating our homes and producing electricity; wind energy for windmills; energy from solid wastes and organic matter.

SOLAR ENERGY

A solar collector is typically a sealed box with a bottom of blackened metal and a cover of glass, or other transparent material, separated by an air space.

A solar collector mounted on the roof of a building or elsewhere can be used to capture some of the sun's energy by heating air or water flowing through the collector unit. The heated air or water is then sent to a heat storage tank where the heat can be evenly distributed to the building, or stored for use at times of little or no sunlight.

The amount of solar energy which falls on a specific surface is called insolation. Table 7 gives the amount of insolation falling on a square foot of horizontal surface in different locations in the U.S.

Problem: Energy from sunlight falls on the earth at the average rate of 63 watts/ft^2/minute. If heat from the sun could be efficiently converted into work, what horsepower would be available from an area 16 feet by 8 feet exposed to the sun?

Answer: The area is 16x8 = 108 square feet. From Table 1, we know that there are 746 watts in one horsepower. The amount of energy falling on the surface above is therefore 63 x 108 = 6,804 watts or approximately 9 HP.

Problem: What is the total solar energy falling on a 4 ft. x 8 ft. solar collector in Nashville, Tennessee, in June?

Answer: From table 7, insolation in Nashville in June is 1,934 BTU/ft^2/day x 30 days = 58,020 BTU/ft^2. Panel area is 4 ft. x 8 ft. = 32 ft^2. Total energy, then is: 58,020 BTU/ft^2 x 32 ft^2 = 1,856,640 BTU.

Question: If a house in Washington, D.C, with a 1,200 ft^2 roof surface requires 100,000,000 BTU (10^8) for winter heating (October - March), what per centage of that heating load could be supplied by the sun, assuming overall solar collector and storage efficiency of 40%?

Answer: From Table 7, we know the daily insolation for the months in question:

TABLE 7

October	1,035 BTU/ft^2/day X	31 days/mo =	32,085 BTU/ft^2/mo
November	745	30	22,350
December	539	31	16,709
January	568	31	17,608
February	738	28	20,664
March	1,225	31	37,975
			147,391 BTU/ft^2 for 6 mos.

Roof surface is 1,200 ft^2.
So, 147,391 BTU X 1,200 = 176,749,200 BTU fall on that roof.

If the solar system is 40% efficient, the 176,749.200 BTU x .4 = 70,699,680, or about 70,000,000 BTU is available as house heat, which is 70% of the heat load.

The remaining 30,000,000 BTU would have to be supplied by a backup heating system. Or, the heating needs could be reduced by such energy conservation measures as better insulation and lowering thermostats.

TABLE 7

Daily Average Solar Insolation (BTU/ft^2/day)
Received on A Flat Surface for Various U.S. Cities

CITY	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual
Santa Maria, Cal	1070	1380	1882	2251	2506	2399	2428	2369	1945	1594	1114	867	1817
Grand Lake, Colo.	790	1144	1624	2030	2177	2362	2236	1989	1720	1328	863	613	1373
Miami, Fla.	1100	1284	1535	1756	1852	1771	1749	1716	1528	1351	1232	1085	1497
Griffin, Ga	1063	1107	1181	2103	2288	2273	2170	2066	1546	1358	1044	738	1578
Twin Falls, Idaho	613	827	1269	1705	2184	2303	2280	1985	1646	1255	738	450	1438
New Orleans, La.	756	915	1207	1487	1500	1697	1491	1439	1402	1258	952	804	1250
Caribou, Maine	531	745	1192	1697	1771	1983	2015	1690	1343	937	450	391	1227
Boston, Mass	454	745	1085	1328	1661	1823	1690	1582	1184	937	502	406	1110
E. Lansing, Mich. (low)	384	649	945	1284	1395	1638	1653	1432	1048	819	380	343	998
St. Cloud, Minn	627	878	1461	1734	2070	2066	2118	1667	1343	1048	646	561	1352
Glasgow, Mont	576	900	1146	1852	2362	2494	2435	2011	1395	900	642	450	1455
Lincoln, Neb.	686	930	1247	1576	1852	2052	2122	1775	1506	1114	771	613	1354
Las Vegas, Nev	963	1292	1956	2111	2362	2771	2539	2332	2044	1483	1166	845	1822
Seabrook, N.J.	686	908	1321	1668	1897	2007	1838	1771	1336	1052	771	535	1316
Albuquerque, N.M	1133	1354	1834	2236	2494	2749	2502	2299	2018	1712	1284	1085	1802
New York, N.Y.	450	705	956	1339	1572	1646	1620	1351	1166	897	546	395	1054
Hatteras, N.C.	941	1063	1550	2103	2229	2266	2229	2125	1587	1269	1015	756	1594
Cleveland, Ohio	373	675	1030	1550	2140	2214	2192	1934	1705	1041	487	406	1312
Stillwater, Okla	923	1004	1520	1801	1838	2196	1889	1937	1565	1255	900	775	1467
Toronto, Ont	351	605	1084	1317	1668	1926	1756	1627	1144	797	399	347	1078
Medford, Ore.	391	768	1232	2107	2790	2590	2804	2494	1553	1063	550	362	1575
State College, Pa	506	642	1015	1428	1572	1845	1889	1683	1321	915	605	424	1154
Newport, R.I.	583	845	1196	1535	1786	1963	1860	1683	1358	1092	668	524	1238
Charleston, S.C.	923	1232	1664	2059	2288	2166	1989	1945	1509	1203	1139	786	1575
Nashville, Tenn	524	753	1089	1557	1838	1934	1867	1668	1439	1125	779	465	1253
El Paso, Tex. (high)	1328	1546	2125	2524	2716	2731	2531	2435	2403	1786	1428	1207	2037
Seattle, Wash	229	328	1033	1823	1867	2286	2170	1753	1235	627	325	229	1160
Washington, D.C.	568	738	1225	1513	1716	1867	1808	1631	1373	1035	745	539	1234
Madison, Wis.	539	797	1166	1498	1727	1904	1993	1609	1321	959	557	443	1218

TABLE 8

Annual House Heat and Water Heat Loads for a Well-Insulated House of 1500 ft^2

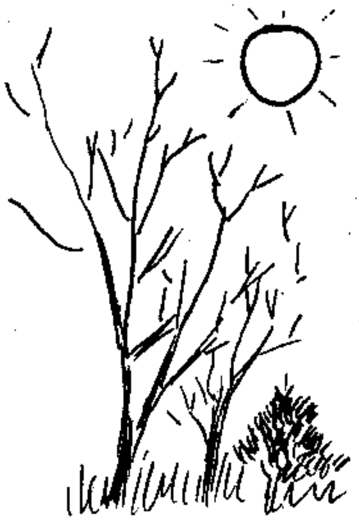
Locality	Latitude	Annual House Heat (Therms)	Annual Water Heat (Therms)
Albuquerque, N.M.	35.0	1238.80°	306.36
Atlanta, Ga.	33.8	976.17°	308.15
Blue Hill, Mass.	42.0	1693.91°	319.10
Central, Mass	42.5	1685.75°	320.17
Charleston, S.C.	32.8	690.55°	302.28
Columbia, Mo.	38.9	1193.89°	313.23
Columbus, Ohio	39.9	1403.75°	315.09
El Paso, Texas	31.8	890.69°	300.51
Fresno, Calif.	36.6	1064.69°	309.22
Ft. Worth, Texas	32.8	688.82°	302.28
Grand Junction, Colo.	39.1	1267.89°	313.66
Ithaca, N.Y.	42.5	1512.47°	320.17
Lander, Wyo.	42.9	1746.74°	320.96
Los Angeles, Calif.	34.0	922.35°	304.50
Madison, Wis.	43.1	1600.21°	321.32
Medford, Ore.	42.2	1591.45°	319.46
Nashville, Tenn.	36.1	976.17°	308.15
N.Y. City and Long Island	41.8	1342.03°	318.74
Phoenix, Ariz.	33.5	677.08°	303.43
Rapid City, S.D.	44.0	1544.71°	322.75
Rhode Island	41.7	1621.60°	318.38

Table 8 shows the annual house heat and water heat requirements for a well insulated house of 1,500 square feet for various locations. How much energy did it take to heat your house last winter, or to heat an average house in your area? What percentage of that heat could be supplied by a 40% efficient solar system which would fit on your roof?

Sunlight can also be used to produce electricity directly. The instrument which makes this possible is called a photovoltaic cell, which means a device which can use photons, or light, to produce volts, or electrical pressure. The photovoltaic cell is made out of a number of different types of materials, but the most common is the silicon cell, and we will use the terms silicon solar cell and photovoltaic cell interchangeably.

The solar cell works by using the sun's energy to push electrons out of their bonds into a current which can then be used like any electric current. The cells are small wafers, a few thousandths of an inch thick and about three inches indiameter. They are linked together to increase the amount of electrical output available.

It is important to note that the cells cannot convert all the available sunlight into electricity. Their efficiency is about 15% currently, although there are new advances that might raise this to about 18 to 20%. Their cost is about $17.00 per watt of peak power*, which makes them too expensive for general use at this time. Their cost will come down dramatically in the next decade.



Problem: If you could convert the energy considered in the second problem above to electricity, at total system efficiency**, of 10%, how many kwh of electricity would be available this month?

<u>Answer:</u> 1,856,640 X .1 = 185,664 BTU.

From the conversion table, we know that 1 kwh = 3,400 BTU.

$$\text{So} \frac{185,664 \text{ BTU}}{3,400 \text{ BTU/kwh}} = 54.6 \text{ kwh}$$

per month per 4 ft by 8 ft panel.

Problem: How many square feet of solar cells (assuming 10% total efficiency) will you need to run your color television (assuming adequate storage facilities, and using the 63 w/ft^2 average insolation figure?

Answer: By looking back to the appliance list in the first chapter we find that a color television, using solid state equipment, uses 200 watts. Since 63 watts is falling per square foot, operating at 10% efficiency, solar cells would produce 6.3 watts per square foot. Therefore we need about 31.75 ft^2 (200 / 6.3) of solar cells to run your color television.

WIND ENERGY

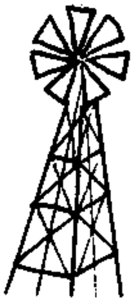
Another indirect form of solar energy is wind. One of the best ways to use wind productively is to have it turn the blades of a windmill. These blades then rotate a shaft which can turn a pump or a generator which produces electricity. Windmills have been used for centuries, primarily to drive pumps, grain mills, or other mechanical devices. Suddenly, with the current energy crisis, wind is becoming a topic for serious consideration as a supplementary power source.

How much energy is there in the wind? The available power in kilowatts for different windspeeds and size windmills is shown in Table 9. The figures for the table are based on the formula:

$P(\text{power}) = (2.5 \times 10^{-6}) AV^3$.

"A" stands for the area in square feet swept by the windmill blades (A= r^2) and "V" is the velocity of the wind in miles per hour.

Notice that the power increases directly as the area of the wind mill blades (and therefore as the square of the diameter) and that it increases as the cube of the wind velocity. In other words, every time you double the wind speed, the power available to the windmill increases by a factor of 8. This explains why wind power as a source of energy is much more attractive in the Plains States, where average wind speeds are often 6 miles per hour or less.



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*A peak power rating is the amount of power that would be generated in direct sunlight at noon of a bright day at 77° F. Average power, which takes into account cloudy and rainy days, as well as times the sun is not shining, is about 1/5 peak power. Thus, a solar array which generates 1 kilowatt of peak power will provide continuous power of 200 watts , provided there is adequate storage capacity.

**Electricity from solar cells is direct current, and for many household appliances it must be converted to alternating current. Since neither the device which does this (called an inverter), nor the storage system (usually batteries) is 100% efficient, the total system efficiency is less than the efficiency of the individual solar cells.

Problem: If the average wind speed where you live is 15 m.p.h. what is the maximum amount of energy you could capture with a 10 foot diameter windmill?

Answer: From Table 9, the maximum power available from the wind for a 10 foot diameter windmill at 15 mph is 0.666 kilowatts. The average wind speed is determined by taking into account the times when there is little or no wind as well as the times when the wind blows in strong gusts, and taking the average. There are 8,760 hours in a year, so an estimate of the annual energy available in this case would be: 0.666 Kw x 8,760 hr/yr = 5,834 Kwh/yr. Assuming that the electrical generator used to convert this energy to electricity was 80% efficient and that the batteries used to store the electricity were 80% efficient, the actual amount of usable energy would be: 0.8 X 0.8 X 5,835 = 3,734 kwh/yr, or 311 kilowatt hours per month. This would be enough electrical energy to supply a home with energy for lighting and small appliances, but not for electric water heating or electric stove cooking.

SOLID WASTES AND ORGANIC MATTER

There is another source of energy which we usually overlook. This is the area of wastes. What is a "waste" anyway? It is something which we have already used once and don't want to use again. The tons of garbage we throw away each day is waste. So are the millions of pounds of wrapping paper, bags, and so on which we dispose of each year. So is the human waste product, the human manure which we flush to sewage treatment plants. But by another definition, waste is just material we have not yet learned to use.

All these "wastes" can produce energy. Each little bit can only produce a small amount, but taken together they can produce significant amounts of energy. Table 10 gives the amount of available waste resources in the U.S. Remember that one barrel of oil contains about 6 X 10^6 BTUs.

The conclusions of this chart should not be taken to mean that all of these "wastes" can or should be converted to electrical energy or heat. In many instances, it would be better to compost the wastes such as urban garbage for use as fertilizer. Also, these figures reflect the wastes resulting from the high

TABLE 9

Windpower in Kilowatts, for Various Wind Speeds and Different Diameter Wind Blades

Wind Speed	Windmill Diameter (Feet)					
(mph)	10	15	20	25	50	100
5	0.0247	0.0556	0.0987	0.154	0.61	2.47
10	0.197	0.455	0.790	1.23	4.94	19.8
15	0.666	1.50	2.67	4.16	16.8	66.6
20	1.58	3.55	6.32	9.87	39.5	158.0
25	3.09	6.94	12.3	19.3	78.1	308.5
30	5.33	12.0	21.3	33.3	133.4	533.1

TABLE 10

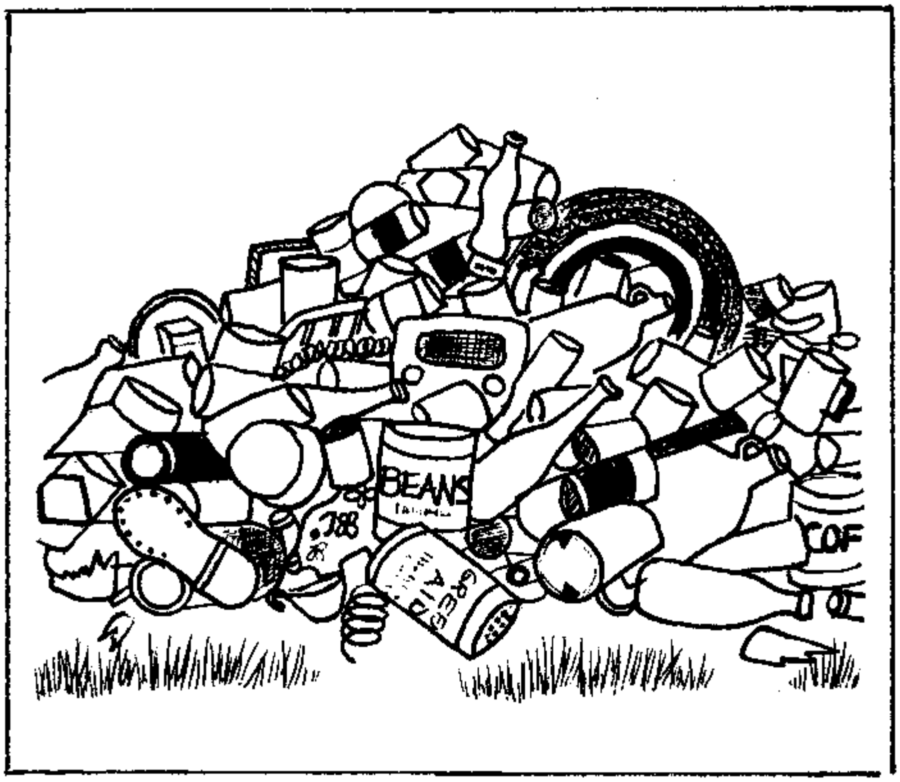
Estimate of Available Organic Wastes

SOURCE		Total organic wastes generated	Total organic solids
Manure	Millions tons/yr	200	26.0
Urban refuse	"	129	71.0
Logging and wood manufacture residues	"	55	5.0
Manufacture - Agricultural crops and food wastes	"	390	22.6
Industrial wastes	"	44	5.2
Municipal sewage solids	"	12	1.5
Misc. organic wastes	"	50	5.0
TOTAL	"	880	136.3
Net oil potential* million barrels		1098	170

"170 million barrels would provide half the residual fuel oil currently obtained from domestic sources and would reduce imports of this fuel accordingly."

from "Energy Potential from Organic Wastes; A Review of the Quantities and Sources," by Larry L. Anderson, Bureau of Mines, U.S. Department of the Interior.

*energy equivalent of these 'wastes' expressed as barrels of oil (N6 x 10^6 BTU)



energy technologies which are used today. Thus it might be better not to generate these wastes to begin with. As the cost of energy goes up, these "wastes" will naturally be cut down, e.g., as the cost of plastic goes up, so does the cost of food packaged in plastic containers

The generation of methane gas from farm animal manure has received much interest. It is attractive because the sludge left over after the manure is "digested" in a special tank makes good fertilizer. Again, however, the most economical applications coincide where there are large concentrations of animals. These large concentrations, such as in feedlots and large dairy operations, while efficient as single units, are basically high energy factories made possible by the availability of cheap energy for transportation costs, fertilizer, manufacturing equipment, etc.

Why haven't we seen much use of solar, wind, and other renewable energy sources until now? Basically, this is because fossil fuels have been so inexpensive -- the fuel itself was cheap and the user did not have to pay for environmental costs. Furthermore, the government has subsidized the energy industries through many tax breaks for the coal and oil interests, as well as heavy development subsidies for nuclear power. For example, in 1975, the Federal Government spent $1.5 billion on nuclear research, as compared to $38 million on solar research. In 1976, the figures are $1.7 billion on nuclear and $85 million on solar research. It's an improvement over 1973 (when $481 million was spent on nuclear research and only $4 million on solar) -- better, but still a very major gap.

Furthermore, we have long been geared to a fast growth, high-energy-use economy. The alternative energy sources of solar and wind power do not lend themselves as easily to this economy. This is because the equipment for utilizing alternative energy sources generally has a higher "first cost" than fossil fuel equipment and, in a fast growth economy, low initial cost is needed to create a mass market. A gas or oil furnace can be built for a few hundred dollars whereas an equivalent solar heating system may cost a few thousand dollars. Of course the fossil fuel furnace will cost a few hundred dollars to operate every year and the solar system will cost very little to operate. To make the alternative energy sources more "competitive" in our economy where consumption gives a plus in the Gross National Product but energy savings are ignored, some people are exploring various means to equalize the situation. For example: removing the depletion allowance tax breaks for fossil fuels; tax deductions or low interest loans for solar and low energy use housing; increased insulation requirements for FHA housing; etc. Undoubtedly, the renewable energy source industries will become more competitive in time, as fossil fuel costs go up and mass production of basic solar panels lower the costs of such devices. However, the renewable energy sources will probably never allow us to use energy as has been done in the last thirty years. They have their built-in feed-back which tells us much sooner than that of fossil fuels that we are using energy too quickly. This is because the renewable sources represent what energy is available right now from the sun or wind, whereas fossil fuels represent energy which has been stored for millions of years. This does not mean that we will have to chuck all of our technological capability and return to the stone age. What it certainly *does* mean is that the level of consumption of goods and resources, particularly that of more non-essential consumer goods, will be declining from the all-time peak which has been reached in the U.S.

From now until the end of the century we will probably see a gradual-but definite-trend from a petroleum-based society to a society with increased reliance on the more abundant coal resources, particularly for industrial applications. Energy conservation measures in our public policy decisions and in our personal lives will become increasingly important. The renewable energy sources will become more widely accepted, particularly for the heating and cooling of buildings. The biggest "if" in the future is how nuclear energy will develop, with all its technological and cost problems. You can help determine this future of ours by your choices and actions, and by becoming more aware of energy and what it is and what it means to our lives. We hope that this pamphlet will help you in that direction.

CHAPTER FOUR
TESTING YOUR ENERGY AWARENESS

If you have been doing the problems in this booklet, and spinning off problems of your own, by now you probably have a good idea of what a kilowatt is, what our total energy consumption patterns are, and how to figure out the energy consumption of various activities.

Below we present 36 multiple choice questions concerning energy and society. The answers to some of the questions may surprise you. We hope that at least they will get you thinking about this new, and permanent, area of America's attention. After you've tested yourself, turn to the back of the booklet where the answers are given, with explanations where they are needed.

1. What percentage of the total gas used in cooking is used by the pilot light?
   a. 5%
   b. 30%
   c. 60%
2. How long would a 100 watt bulb burn on the energy needed to manufacture one aluminum soft-drink can?
   a. under 10 minutes
   b. 5 hours
   c. over 20 hours
3. How much energy stored in crude petroleum is lost in the series of processes between the oil well and a moving car?
   a. 20%
   b. 60%
   c. 90%
4. How much of the energy stored in coal which is burned in a power plant can be delivered to the customer's home as electricity?
   a. 1/3
   b. 2/3
   c. all of it
5. The total amount of electricity used by all small appliances, including radios, toasters, clocks, shavers, and so forth, is what percentage of the total amount of electricity used in our homes?
   a. 10%
   b. 30%
   c. 75%
6. The amount of energy used in the manufacturing, distribution, and operation of automobiles in this country makes up what percentage of total energy use?
   a. 16%
   b. 30%
   c. 2%
7. The United States, with 6% of the world's population, consumes what percentage of the world's available energy each year?
   a. 10%
   b. 20%
   c. 30%
8. The average North American family uses how many times more energy than the average South American family?
   a. 5 times more
   b. about the same
   c. 100 times more
9. What percentage of commuters use a private automobile for transportation to and from work?
   a. 25%
   b. 50%
   c. 95%
10. How much energy does it take to supply processed vegetables rather than natural vegetables?
    a. same amount
    b. twice as much
    c. three times as much
11. What percentage of our petroleum is used for making synthetic fabrics, plastics, and medicines?
    a. 50%
    b. 10%
    c. 1%

12. Which is a more energy efficient mode of transportation: walking or riding a bicycle?

13. True of false: The energy consumed in all sectors of the economy to put a glass of milk on the kitchen table is equivalent to that contained in a half a glass of diesel fuel.

14. How many years did it take nature to make a pound of coal?

a. 100 years
b. 1,000 years
c. 1,000,000 years

15. Over the lifetime of a refrigerator, what percentage of its total costs, including those of buying it, maintaining it, and operating it are due to energy costs?

a. 10%
b. 25%
c. 60%

16. Of the solar energy coming to the earth, on the average, what percentage is used by plants to produce food energy for animals?

a. 50%
b. 20%
c. 1%

17. A returnable bottle is reused how many times?

a. two times
b. six times
c. fifteen times

18. If the underdeveloped parts of the world were to consume as much energy per person as North Americans do today, the worldwide level of energy consumption would be roughly how many times its present figure?

a. five times
b. ten times
c. fifteen times.

19. While beverage consumption rose 1.6 times between 1958 and 1970, beverage <u>container</u> consumption rose how many times during the same period?

a. the same
b. twice as much
c.almost three times as much

20. In the United States, what percentage of our energy comes from non-renewal fossil fuel reserves?

a. 50%
b. 75%
c. 98%

21. What percentage of energy do we get as visible light from an ordinary 100 Watt incandescent light bulb?

a. 90%
b. 35%
c. 5%

22. What percentage of energy do we get as visible light from a typical fluorescent lamp?

a. 90%
b. 40%
c. 20%

23. What percentage of total U.S. energy consumption is used in food processing?

a. 1%
b. 4%
c. 15%

24. What percentage of total U.S. energy consumption is used in all food related activities?

a. 2%
b. 10%
c. 16%

25. One ton of average municipal solid waste contains the energy content of:

a. 1/3 ton of coal
b. 1/2 ton of coal
c. one ton of coal

26. True or false: The yields per acre of farms using heavy machinery are higher than those using labor-intensive farming.

27. What percentage of the energy it takes to manufacture an aluminum can does it take to recycle it?
    a. 3%
    b. 15%
    c. 50%

28. To grow, process, and deliver food to the consumer takes how much energy compared to the food energy we get from eating the food?
    a. the same amount
    b. one-half the amount
    c. ten times the amount

29. In Japan, a rice farm takes about 90 horsepower hours per acre for cultivation and harvesting. In a comparable United States rice farm, how many horsepower hours are used?
    a. 45
    b. 200
    c. 1,500

30. Between 1946 and 1968, the population of the United States grew by about 40%. In that same period, how much did electric power consumption increase?
    a. same as population growth
    b. twice as much as population growth
    c. over five times as much as population growth

31. If in 1980 one-half of the cars on American roads were to have an average fuel economy of 22 miles per gallon (compared to today's average of 14 miles per gallon), the annual fuel savings would be which figure, assuming the same number of cars for both years?
    a. 17 thousand gallons
    b. 17 million gallons
    c. 17 billion gallons

32. If the average home used electric space heating, what percentage will that be of its total electric bill?
    a. 10%
    b. 25%
    c. 40%

33. If we use energy equivalents of Calories expended and BTUs in a gallon of gasoline, how many miles does a bicyclist get per gallon?
    a. 15 mpg
    b. 400 mpg
    c. 1,100 mpg

34. True or false: The beverage industry used enough energy in the manufacturing of throw-away containers in 1970 to have supplied the total 1970 electrical needs for Washington, D.C., Pittsburg, San Francisco, and Boston for about five months.

35. Optimum insulation of your house can save what percentage of your heating bills?
    a. 5%
    b. 20%
    c. 40%

36. A three-degree reduction in your temperature setting for your home heating furnace saves how much fuel?
    a. 3%
    b. 10%
    c. 50%

Answers begin on page 33.

SCIENTIFIC NOTATION

If a number is written as 2×10^3, then the 2 is called the mantissa and the 3 is called the exponent. As we learned in Chapter One, (see footnote, page 4), the exponent indicates how many times to multiply (or divide, if it is negative) by 10.

So,

$$2 \text{ X } 10^3 = 2 \text{ X } 10 \text{ X } 10 \text{ X } 10 \quad \text{three times}$$
$$= 2 \text{ X } 1000 \quad \text{three zeroes}$$
$$= 2000$$

$$6.8 \times 10^4 = 6.8 \times 10 \times 10 \times 10 \times 10 \quad \text{four times}$$
$$= 6.8 \times 10{,}000 \quad \text{four zeroes}$$
$$= 68{,}000$$

$$3 \times 10^{-2} = 3 \text{ divided by } 10 \times 10 \quad \text{two times}$$
$$= \frac{3}{100} \quad \text{two zeroes}$$

One advantage of scientific notation is that it makes multiplying and dividing large and small numbers very easy. The simple rule is: First, multiply (or divide) the mantissa*, as usual. Then, to multiply, add the exponents.

So,

$$10^2 \times 10^6 = 10^{(2+6)} = 10^8$$
$$10^3 \times 10^{-4} = 10^{(3-4)} = 10^{-1}$$
$$(2 \times 10^3) \times (8 \times 10^6) = (2 \times 8) \times (10^3 \times 10^6) = 16 \times 10^{(3+6)} = 16 \times 10^{(3+6)} = 16 \times 10^9$$

To divide, subtract the exponent of the number you are dividing by from the exponent of the other.

$$\frac{10^5}{10^2} = 10^{(5-2)} = 10^3 \quad (100{,}000/100 = 1{,}000)$$
$$\frac{6 \times 10^2}{3 \times 10^6} = \frac{6}{3} \times \frac{10^2}{10^6} = 2 \times 10^{(2-6)} = 2 \times 10^{-4} \quad (2/10{,}000)$$

If the exponent of the number you are dividing by is negative, change its sign and ADD it to the exponent of the top number.

$$\frac{9 \times 10^2}{3 \times 10^{-3}} = \frac{9}{3} \times \frac{10^2}{10^{-3}} = 3 \times \underset{\text{change sign}}{10^{(2+3)}} = 3 \times 10^5 \quad (300{,}000)$$

Multiplying by 10 moves the decimal point to the right, the same number of spaces as the power of 10. Dividing (or multiplying by a number with a negative exponent) moves the decimal point to the left.

$$2.6 \times 10^3 = 2600 \qquad\qquad 3.1 \times 10^{-2} = .031$$

---

*if none is shown, the mantissa equals 1; e.g., $10^5 = 1 \times 10^5$.

ANSWERS TO THE ENERGY AWARENESS QUIZ

1. 50%. The pilot light is always on even though you use the stove only a few times a day. There are, on the market, inexpensive devices which light the stove burners by making a spark, thus eliminating the need for a pilot light going all the time.

2. c. Over 20 hours. It takes 2.25 KWH to manufacture an aluminum can, so the exact answer is 22.5 hours.

3. Over ninety per cent of the energy in the gas line from crude petroleum is lost in making your car move. The efficiencies of the most important steps where energy is lost are:

producing the crude oil -- 96%
refining -- 87%
gasoline transportation -- 97%
engine efficiency -- 29%
rolling efficiency -- 30%

To get the total efficiency of the system, we multiply the six factors together, and get 7%.

4. Similar to the problem above, there are losses when the coal is burned in the power plant to produce electricity; there are losses in transmitting the electricity to your home, and there are losses in getting the coal from the ground to the power plant. The answer to this question is (a) 1/3.

5. a. 10%. The biggest users in our homes are air conditioners, electric water heaters, and electric space heating. Refrigerators and freezers are fairly large users also. The many gadgets that we have are not such big users, but they take energy to make them.

6. a. 16%. Automobiles not only burn a large portion of the petroleum we use in this country, but they also use significant portions of our steel, rubber, and aluminum.

7. c. 30%. If there were a village of 100 people, and only 6 of them were using resources which could be used for thirty, how long do you think that situation would be permitted to exist?

8. c. 100 times more.

9. c. 95%, and this is still increasing.

10. c. three times as much.

11. c. 1%. Almost all of our petroleum is burned in power plants and in our cars, trucks, and busses.

12. Riding a bicycle. The reason is that the gears and pedals give you much more "pull" for the amount of energy you are expending.

13. True. This includes the petroleum that was used in the tractor which plowed the field to grow the food for the cows. It includes the pesticides which are petroleum based. It includes the fertilizer needed to raise the food. It includes the milking machines, the trucks which transport the milk, the pasteurization and homogenization machines, the refrigeration facilities needed both in transportation and in your local store.

14. c. 1,000,000 years

15. c. 60%. Increasingly, people will become interested in knowing what the total cost of an appliance is, not just the buying price of it. The energy prices are increasing and many of our common appliances will cost far more to operate than to buy.

16. c. 1%. Most solar energy doesn't even get through the atmosphere. It is reflected. The little which does come through can be used to produce food energy in plants only in certain wave lengths.

17. c. about 15 times

18. c. fifteen times

19. c. almost three times as much.

20. c. 98%.

21. c. 5%. The rest of the energy comes out as heat. That is why an incandescent bulb is so hot to touch. It is a very inefficient way to get light.

22. c. 20%. A fluorescent lamp is four times more efficient than an incandescent bulb.

23. b. 4%

24. c. 16%

25. b. 1/2 ton of coal.

26. False. Labor intensive farming produces just as much per acre as machine intensive farming. Our acre yield increases have come about mostly as a result of hybrid crops and increased fertilization.

27. a. 3%

28. c. ten times the amount. See the answer to number 13.

29. c. 1,500.

30. c. over five times as much as population growth. Each person, therefore, was using more electricity.

31. c. 17 billion gallons.

32. c. 40%.

33. c1,100mpg. A non-athletic person of about 150 lbs. can manage to leisurely maintain a speed of 11 mph on a 30 pound 10-speed for an extended period of time. This person will need to add about 1500 Calories to his diet for each five hours he cycles, or about 300 Calories per hour. One gallon of gasoline equals about 30,000 Calories. Therefore, a bicyclist can travel 100 hours (30,000/300) on one "gallon". 100 hrs/gal x 11 mi/hr = 1,100 miles per gallon.

34. True. Producing 60 million throwaway containers a year uses the energy equivalent of 2 billion gallons of gasoline, enough to heat 2.5 million homes per year.

35. c. 40%. This includes 6 inches of insulation in the roof, three inches in the walls, storm windows, and window and door weatherstripping.

36. b. 10%.

FOR FURTHER READING

A few books you might find useful for further reading include:

Save Energy: Save Money, by Eugene and Sandra Eccli, 1974. Free, from the National Center for Community Action, Network Services: Energy, 1711 Connecticut Avenue NW, Washington, DC 20009. Simple, thorough, extremely practical handbook on energy conservation in the home.

Energy Primer, ed. by Richard Merrill,et al. Portola Institute, 1974. $4.50 from your local bookstore, or Whole Earth Truck Store, 558 Santa Cruz Ave, Menlo Park, CA. Subtitle "Solar, Water, Wind, and Biofuels", this book presents comprehensive discussion of these renewable energy resources, including design factors, data tables, lots of illustrations, access information, and outstanding bibliographies. Good treatment, also, of the energetics, the ecology of agriculture, and integrated systems.

Energy, by Bruce Chalmers, Academic Press, NY, 1964. A textbook approach to the physics of energy.

Energy for Survival, by Wilson Clark, Anchor, NY, 1975, $4.95. "Encyclopedic" is how this book is always described, and it is. The authorative treatment of our energy situation, with major attention to renewable energy resources.

Environment, Power, and Society, by Howard T. Odum, Wiley, NY, 1971. Heavier reading than the above, this is nonetheless an important book. A study of how systems – natural, mechanical, social -- are organized by the energy flows concept and energetics as an analytical tool. Odum is largely responsible for the development of the "net energy" concept.

Tips for Energy Savers, Free from the Federal Energy Administration in Washington, D.C.

The Consumers – A Citizens Guide to Resources Conservation, by Albert J. Fritsch, Praeger Publishers, NY, $3.50.

CREDITS

Figure 1 - From various sources (see esp. Patterns of Energy Consumption in the US, Office of Science and Technology, Jan. 1972)

Figure 2 - From various sources (see esp. Patterns of Energy Consumption in the US, Office of Science and Technology, Jan. 1972)

Figure 3 - From various sources (see esp. Patterns of Energy Consumption in the US, Office of Science and Technology, Jan. 1972)

Figure 4 - From The Flow of Energy in an Industrial Society, by Earl Cook, ©1971, Scientific American, Inc. All rights reserved.

Figure 5 - Patterns of Energy Consumption in the United States, US Office of Science and Technology, Jan. 1972

Figure 6 - From Flow of Energy in an Industrial Society, by Earl Cook, and Energy and Power, by Chauncey Starr. ©1971 by Scientific American, Inc., All rights reserved.

Table 2 - Electric Energy Association, 90 Park Avenue, New York, N.Y. 10016

Table 3 - From System Energy as a Factor in Considering Future Transportation, paper no. 70-WA/Ener-8, by Richard A. Rice, presented at the 1970 American Society of Mechanical Engineers Winter Annual Meeting, Nov. 29-3, NY, NY. Used by Permission.

Table 4 - Transition, Office of Energy Research and Planning, Office of the Governor, Oregon, 1974

Table 5 - Transition, Office of Energy Research and Planning, Office of the Governor, Oregon, 1974

Table 6 - From The Council on Environmental Quality, Executive Office Building, Washington, D.C. 20506

Table 7 - Speyer, E. 1959 Optimum Storage of Heat with a Solar House. In: Solar Energy Journal: 3-4

Table 8 - Heating and Ventilating Reference Data, April 1954 (ASHRAE)

Table 10- From Energy Potential from Organic Wastes; a Review of the Quantities and Sources, by Larry A. Anderson, Bureau of Mines, U.S. Dept. of the Interior.

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THE INSTITUTE FOR LOCAL SELF-RELIANCE is a non-profit, tax exempt research and educational organization based in Washington, DC. It explores the possibilities of urban communities becoming productive, increasingly self-reliant systems-raising their own food, generating their own energy, utilizing their "wastes", controlling their economies, and directing their own affairs. The Institute investigates the technological, economic, and legal tools needed to make those possibilities real.

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Perspectives on Urban Agriculture, (reprint) 2 pp Overview discussion of some current issues facing the growth of urban food production efforts: potential impact, short and long term security questions, air pollution contamination of crops, and others.	.25

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