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ABSTRACT

This notebook provides vocational agricultural teachers with 10 detailed lesson plans on the major topic of energy management in agriculture. The lesson plans present information about energy and the need to manage it wisely, using a problem-solving approach. Each lesson plan follows this format: lesson topic, lesson performance objectives, materials needed, the situation, introduction to lesson, presentation of lesson (the problem and possible solutions to the problem), student application (suggested exercises), evaluation suggestions and instruments, and a listing of references. Appendixes provide handouts and transparency masters. The ten lesson plans are (1) An Overview of the Energy Situation for Ohio Agriculture, (2) Framework for Evaluating Costs and Benefits of Alternative Energy Systems, (3) Electrical Energy Management for the Home and Business, (4) Using Solar Energy as a Renewable Energy Resource at Home or on the Farm, (5) Using Wood as a Renewable Energy Source, (6) Energy Management with Maintenance and Operation of Tractors, (7) Reducing Energy Costs in Producing Corn, (8) Energy Management in Livestock Production, (9) Energy Management in the Greenhouse with Engineering and Cultural Practices, and (10) Inventory of Energy Use. (YLB)

ENERGY MANAGEMENT LESSON PLANS
FOR
VOCATIONAL AGRICULTURE INSTRUCTORS

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CONTENTS

(Each Lesson Plan is page-numbered separately, 1 to the end.)

INTRODUCTION

The age of an abundant supply of inexpensive energy for the United States is past. All of us, as consumers, now find it necessary to make important decisions concerning the use of energy in all phases of our life: at home, at work, and at play. Producing food takes 17 percent of the nation's total energy; of that, 75 percent is supplied by those vanishing fuels, oil and natural gas. To have sufficient energy from fossil fuels to produce food now and in the future, energy conservation must be practiced by all segments of our society. In the operation of feeding the people of the United States and the world, there is at present no alternative to modern mechanized agriculture with fossil fuel energy inputs.

Agricultural educators must, by virture of their job role, take the lead in helping their clientele face the energy problem. Agriculturalists of today, beginning with the high school student, need to take a hard look at energy and food production and what the agricultural sector must do to curtail their energy usage.

Most teachers of vocational agriculture have in their school files bulletins, magazine articles, and other technical publications concerning the nation's energy situation. However, because of lack of time on the part of the instructor, or for other reasons, this material often does not get processed into an appropriate lesson plan, but remains unused in the files.

Purpose of Notebook

The major purpose of this energy management notebook is to provide vocational agriculture teachers detailed lesson plans suitable for classroom instruction. These lessons can be taught with a minimum of preparation time. Facts about energy and the need to manage it wisely cannot be effectively taught as facts per se. The facts need to be related to management decisions that must be made by the home dweller, farmer/producer, and/or agri-business person. Within this notebook, the teacher will find ten lesson plans on the major topic of energy management in agriculture; these plans present the information using the problem solving approach. This approach to teaching provides a real situation to enable the student to better understand how to conserve energy. It also provides some possible alternatives that are feasible for the production and processing of agricultural products today.

An Appeal to the Teacher

As a teacher of vocational agriculture, you can, by using these lesson plans, take an active part in helping our country do something about the energy situation. You can show your students the value of wise energy management and the importance of energy conservation. Now that energy supplies are rapidly dwindling, it is essential that some behavioral changes occur in our society. Citizens must adopt an Energy Conservation Ethic. As a teacher, you have the opportunity to make clear to your students, both teenagers and adults, that such an ethic is founded on a data-based realization that many of the raw materials on which current living standards rely will not be available much longer. You can help your students become acutely aware of the difference between essential needs and nonessential desires, and of specific activities in energy management that can be followed by themselves and their families. You can help them develop an Energy Conservation Ethic not unlike that of our puritan ancestors' "work ethic." This Energy Conservation Ethic will help them continually think in terms of wise and efficient uses of resources when developing, buying, or consuming those resources.

How to Use the Book

Handouts, overheads, application suggestions, and evaluation means are all provided in each lesson plan. The plans are written so that a teacher can effectively teach energy management principles and techniques by simply following the outline provided in the lesson plan. It is our hope that the materials provided will stimulate you, the teacher, to utilize the problem-solving approach in the classroom and provide students with the information they need to make decisions on their energy usage.

L.E. Hedges

L.E. Miller

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I. Lesson Topic:

AN OVERVIEW OF THE ENERGY SITUATION FOR OHIO AGRICULTURE

by

MIKE SHERTZER

II. **Lesson Performance Objectives**

At the end of this lesson, the student will be able to:

1. Define the term *energy*.
2. List the energy sources available for agriculture today.
3. List the two largest energy consumption sectors in Ohio and in the United States.
4. Determine where energy waste is significant in Ohio and how it can be reduced.
5. List alternative energy resources for reducing the energy shortage.
6. Develop a written plan for meeting present and future energy needs of the students in their individual agricultural situations.

III. **Materials Needed**

Box of matches (100 count)
1 Pint of water in *Pyrex* glass
1 Candle
1 Electric hotplate
Sunflower and soybean seeds
1 Empty, dry gasoline can

IV. **The Situation**

We must realize that there is an energy crisis (or energy shortage, however you wish to state it.) Agriculture is not immune to this energy crisis. Even though oil is presently available and gasoline prices continually rise and fall, there continues to be a long-term (and often a short-term) energy problem.

Due to the shortage at times of certain fuels and low market prices for farm products, all agriculture must conserve energy. There is a need to reduce the amount of energy consumed by farm production methods to save dollar costs and insure a supply of energy for the future. However, these conservation efforts cannot reduce income or productivity if agriculture is to meet the needs of a growing population and to protect itself as an industry.

As agriculturalists, we need to take a closer look at the present energy situation. A self-analysis of our present energy shortage may result in improved energy conservation and the development of new energy sources. Seven to eight calories of fossil fuel are needed to produce one calorie of food. A shortage of energy results in the shortage of food production. When reviewing the energy crisis, we need to consider the effects of a shortage of energy sources.

V. **Introduction to Lesson**

1. Tell the class that you want to boil a glass of water to make a cup of coffee.
2. Take a wooden match, light it, and place it under a glass of water till the flame barely touches the glass. Continue until the match burns out.

Observation and Question: "This demonstration illustrates energy in the form of heat, one match being equal to one BTU. The water did not reach the boiling point before the match burned out. What can we do to heat the water to the desired temperature?"

Possible Student Answers:

1. Use more matches.
2. Use an alternative heat source such as a candle or an electric burner.

Question: "Which is the least expensive method of energy to use to accomplish this task?"

Answer: "We need to work the example to find out." (Write example on chalkboard.) "We know that a BTU is defined as the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit. If we boil one pound of water (16 ounces or two 8-ounce coffee cupfuls) from 62°F to 212°F, we have raised the temperature 150° (F) or, according to our definition of a BTU, the equivalent of 150 BTU's.

MATCHES: One match equals one BTU.
One hundred matches equals 100 BTU's (one box).
One hundred fifty matches (1½ boxes) are required to boil the water.
*At $0.89/box, the total cost for two cups of (coffee) water is $1.34.
Thus it costs $0.67 ($1.34÷2) to heat *one* cup of coffee water.
Not very efficient cost or time use.

CANDLES: One candle equals 100 BTU's (approximately, depending on size and type).
1½ candles equals 150 BTU's.
At $1.29 per candle, the total cost to heat two cups of water is $1.94 ($1.29 x 1½).
½ candle will be left over.
The cost to heat one cup of (coffee) water is $0.97 ($1.94÷2).
Not very efficient cost or time use either.

HOT PLATE: 500-watt hot plate (from Sears, Roebuck & Co.) costing $18.00.
**Takes 12½ minutes to heat one pound of water at 62°F to boiling.
At 500 watts/hour, 12½ minutes of hot plate operation takes about 104 watts.

$$\frac{500 \text{ watts/hour}}{60 \text{ minutes/hour}} \times 12\tfrac{1}{2} \text{ minutes} = 104.1 \text{ watts}$$

104 watts = 0.104 kilowatts (unit by which electricity is sold).
At $0.06/kwh, total electrical usage cost is $0.006.
Depreciating the hot plate over three years equals $0.016/day

$$\frac{\$\,18.00}{365 \times 3} = \$0.016$$

Hot plate plus electrical usage equals $0.022 for two cups of water.
Thus, one cup of (coffee) water costs $0.011 ($0.022÷2).
Very efficient cost and time use.

Question: "Which of the three is the most efficient energy source for boiling the water?

Answer: (Let students arrive at the answer) "Hot plate."

Teacher follows student answer with the remark, "Let's apply this idea to *student's* pickup truck."

Question: "If *student's* tank is nearly empty, what are the alternatives for refueling the truck?"

Possible Student Answer: "Buy more gasoline."

*Any local prices for matches, candles, hot plate, and Kwh can be used.

**The teacher can either time how long it takes the water to boil, or determine how many seconds it takes to raise the temperature one degree F.

Example:

5 seconds to increase the temperature one degree F
In one minute, 12 degrees rise in temperature

$$\frac{150 \text{ degrees F}}{12 \text{ degrees F}} = 12\tfrac{1}{2} \text{ minutes}$$

Question: "There is a gasoline shortage. What should he/she do?"

Possible Student Answer: "Use gasohol."

Question: "Gasohol is 90% gasoline. Also it is too expensive, and there are not enough gasohol stations around to obtain it very often. Could we possibly use other energy alternatives like soybean or sunflower oil?"

Answer: Yes, but these sources are not yet fully developed as alternate fuels. Much more research needs to be done.

Question: "Note that in all cases *student* is using up some type of energy. What alternative can you suggest to keep energy use to a minimum?"

Possible Student Answers:

1. Drive less. 2. Sell truck. 3. Buy a moped.

Question: "What impact can this situation have on *you*?"

Possible Student Answer: "Possibly none of us will be able to buy gasoline or diesel fuel for our pickup trucks within 10 to 20 years, or before we reach 30 years of age."

VI. Presentation of Lesson

1. "Since we have been doing considerable talking about energy, and before we do any more, perhaps we should make sure we all understand the scientific definition of it."
   (Write the following on the chalkboard):

   Energy = ability to do work

   Unit of energy = ***BTU*** (British Thermal Unit), the amount of heat required to raise the temperature of 1 pound of water 1 degree F

2. "Let's look at what kind of *energy shortage* we really have. If we were to sit down to an 'energy meal,' our plate would be divided as follows:"
   (Distribute Figure 1, the handout or overhead entitled, *U.S. Energy Budget*, in the Appendix. Make the following points to the students):

   A. "What we really have is a liquid fuel energy shortage.

   • The gross energy consumption by fuel in Ohio, the 5th largest industrial state, is as follows:" (Distribute Figure 2, *Gross Energy Consumption by Fuel, 1980* as a handout or use overhead.)

   • "Compare Ohio and the U.S.A. as to consumption of various fuels. Ohio depends heavily on coal. Ninety-seven percent of the electricity in Ohio is produced from coal. The eastern part of the U.S.A. uses oil and the southern part uses natural gas for producing electricity.

   • Note that fossil fuel is the source of 99.4% of our energy." (Write on the board the following):

   coal — 42.7%

   oil — 31.6%

   gas — 25.1%

   other — 0.6% (mostly nuclear and hydro-electric)

   B. "Let's look at energy use in Ohio agriculture." (Write on board):

gasoline	19.0%	electric	7.8%
diesel	15.6%	fuel oil	0.4%
natural gas	49.8%	coal	0.1%
LP gas	7.3%		

(Source: Rask and Ott, *Energy Use in Ohio Agriculture*, OSU Dept. of Ag. Econ. & Rural Sociol.)

C. Ask the question, "How long will fossil fuels last?"
Provide students with the following figures on the board:

oil	40 to 70 years
gas	over 70 years
coal	250 to 300 years

D. "Realizing we have a liquid fuel shortage, let's go back to student's pickup truck. What can he or she do or what can the U.S.A. do to solve the problem?"

Possible student answers:

1. Use alternative liquid fuels
2. Conserve what we have
   - Use less
   - Make substitutions

3. ***The Problem.*** The problem is presented by placing the following question on the chalkboard:

"What production practices can ________ utilize that will save energy on the farm without giving up income or productivity?"

Possible student answers:

1. Reduce tillage.
2. Keep equipment in good maintenance.
3. Use high quality seed and livestock.
4. Use alternative energy sources (wind, sun, hand labor).
5. Replace equipment with better fuel economy equipment.
6. Recycle energy (e.g., use waste oil to heat shop).
7. Exercise better energy management.

(Refer to Figure 3, handout or overhead entitled, *1981 Energy Status Report of Ohio.*)

Make the following conclusion from the students' answers:

"It seems that most of the suggestions you made involve the last one, *Exercise better energy management.* This report of energy consumed in Ohio suggests that over half of it is wasted. In other words, Ohioans could enjoy the same standards on half the energy they are presently using."

Review the report with students. Assign the worksheet entitled *Energy Management on the Farm* to take home overnight and complete. Go over the findings of the students on the worksheets the next class day. Much discussion can be included here on energy alternatives. How far and to what depth this discussion will be carried depends on the amount of time you as the instructor want to spend. Before proceeding you may review the previous material either orally or with a quiz.

Question to be put on chalkboard (note that by using the chalkboard we are saving energy compared to using an overhead projector or slide projector, or running a handout):

"Student has completed a preliminary analysis of energy use on his/her farm and has even listed some suggestions for alternative energy sources. How can student determine where to reduce energy waste most effectively on his/her farm?"

Possible student answers:

1. Look at those areas that use the most energy.
2. Check to see if motors and engines are matched to the job they are to do.
3. Consider the most expensive energy users.

"If Ohio or the United States is to reduce energy usage, they must do an analysis similar to *student's* ."

(Now refer to Figure 4, the handout or overhead entitled, "*Gross Energy Consumption by Sector, 1980.*)

Question: Which areas of energy consumption in Ohio and the United States use the most energy?"

Have students:

1. Compare the energy consumption of Ohio with that of the whole United States.
2. Note that the industrial sector is the largest energy consumer. Transportation is the second largest.

Question: "Let's take **transportation use** for an example. We realize that transportation is a major energy user in Ohio and the U.S.A. We can therefore assume that reducing transportation on *student's* farm will also reduce energy use. How can *student* reduce his/her transportation energy usage?"

Possible student answers:

1. Eliminate unnecessary trips.
2. Buy most items at one place.
3. Car or truck pool.
4. Keep cars, trucks well maintained.

Question: "Will one individual trying to save energy make any difference in overall reduction of energy use? Is it worth the effort?"

Points to ponder:

"Many times we think of the energy shortage only in terms of short supplies of gasoline and heating oil. But energy shortages will change our way of life, our standard of living, and things we now take for granted."

One or both of the following questions may be proposed to the class to finish up the unit. General discussion can be held or the class may be divided into assigned pro and con positions so that a debate can be conducted. Again, how far this is carried out depends on the time allowed.

Write the following questions on the board:

Question: "The United States has 6% of the world population, but consumes 1/3 of all the oil produced. Half of this oil is imported. As just one country on this earth, do we have the right to use that much oil? Or are we 'hoggish' and wasteful?"

Question: " 'The projected need for energy in the year 1990 will be at the same level as 1980. Industrial, commercial, residential, and utility use will increase, but this can be offset by a reduction in transportation usage.' Do you agree or disagree?"

VII. Student Application

The following are some suggestions where the class or the individual students can apply, in a practical way, what they have learned.

1. The class can develop an energy saving plan for the school farm. They can carry out the plan and record the amount of energy saved using their plan over the previous year's energy use.
2. Have each student keep an energy diary on his or her energy use. Then make a cut of 1/3 in that energy use and evaluate the results. For example, keep a 2-week diary on gasoline used in the student's truck or car. Reduce the amount used by 1/3; then have the student drive 2 weeks on that amount of fuel and compare the difference with the previous amount.
3. Require each student in the class to have energy management as one of his or her home improvement projects. The student can set goals to attain in the agreement, plan costs in the budget, and list everything done at home to reduce energy usage. These activities can be checked during student visitations by the instructor so that parent cooperation and one-on-one instruction by the teacher will help each individual student to meet his or her goals.
4. Encourage energy savings to reduce costs when calculating budgets of production projects. List in a diary or on the evaluation page of record books any energy saving measures taken.

VIII. Evaluation

The evaluation procedure can be any one or a combination of the following:

1. Written objective exam
2. Written subjective position paper on how energy usage can be reduced (personal, farm, or general agriculture)
3. Oral presentation with a speech, panel discussion, or debate
4. Student visitations to check home improvement projects dealing with energy management. The instructor can also check practices used with production projects to reduce energy usage.

ENERGY MANAGEMENT ON THE FARM

NAME ____________________

1. List the number of energy users on your farm.
   a. electric motors ______
   b. electric power tools ______
   c. light bulbs ______
   d. gasoline engines ______
   e. diesel engines ______
   f. grain dryers ______
   g. heating systems ______

2. As you can see from the above survey, most of your energy comes from electricity or liquid fuels. List some alternative energy sources right on your farm that you could tap to do some of the same jobs that you listed above.

	Energy Source	Used for	Extra Equipment Needed
Example:	*wind*	*pump water*	*windmill*

3. You can see that some types of energy sources do certain jobs better than others. Should you concentrate on one energy source or use several to run your total farming operation? Explain your answer.

4. List five (5) ways you could reduce your total energy use on your farm today.

QUIZ ON ENERGY MANAGEMENT

NAME ____________________

1. Energy is the ability to do ____________________.

2. BTU is a term used to measure the amount of ____________ required to do a job.

3. List three (3) advantages to the farmer of producing energy from his/her crop residues.

____

____

____

4. The type of energy the U.S. is short of is ____________________.

5. Two ways to solve the energy shortage are:

____

____

6. TRUE OR FALSE (circle one): We have enough oil to last only 60 years.

7. TRUE OR FALSE (circle one): It is the job of the government and scientists to solve our energy problem for us.

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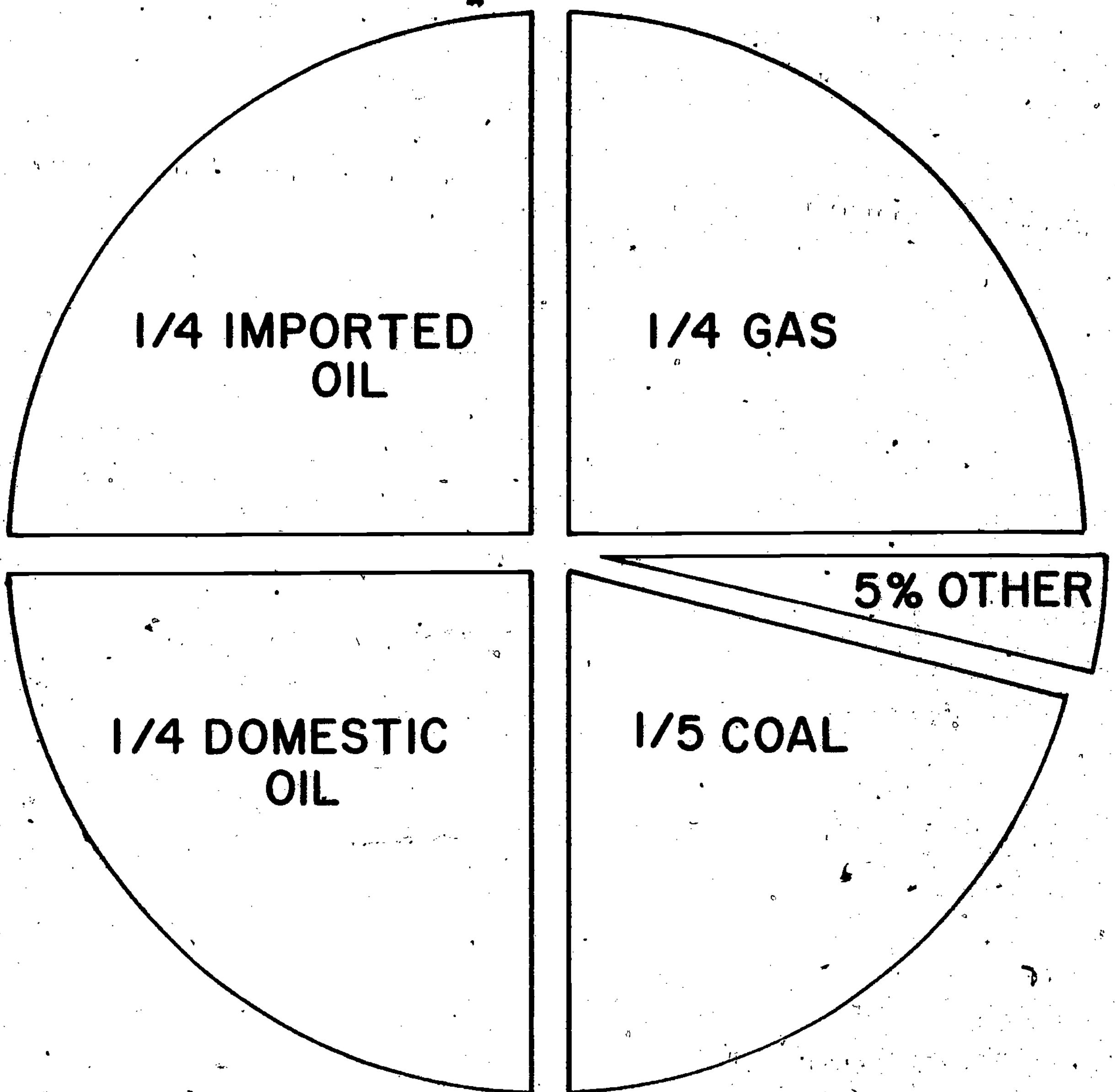


FIGURE 1.

U.S. ENERGY BUDGET

(Source: Rask, Norman, *Energy Policy Illustrations*, 1978)

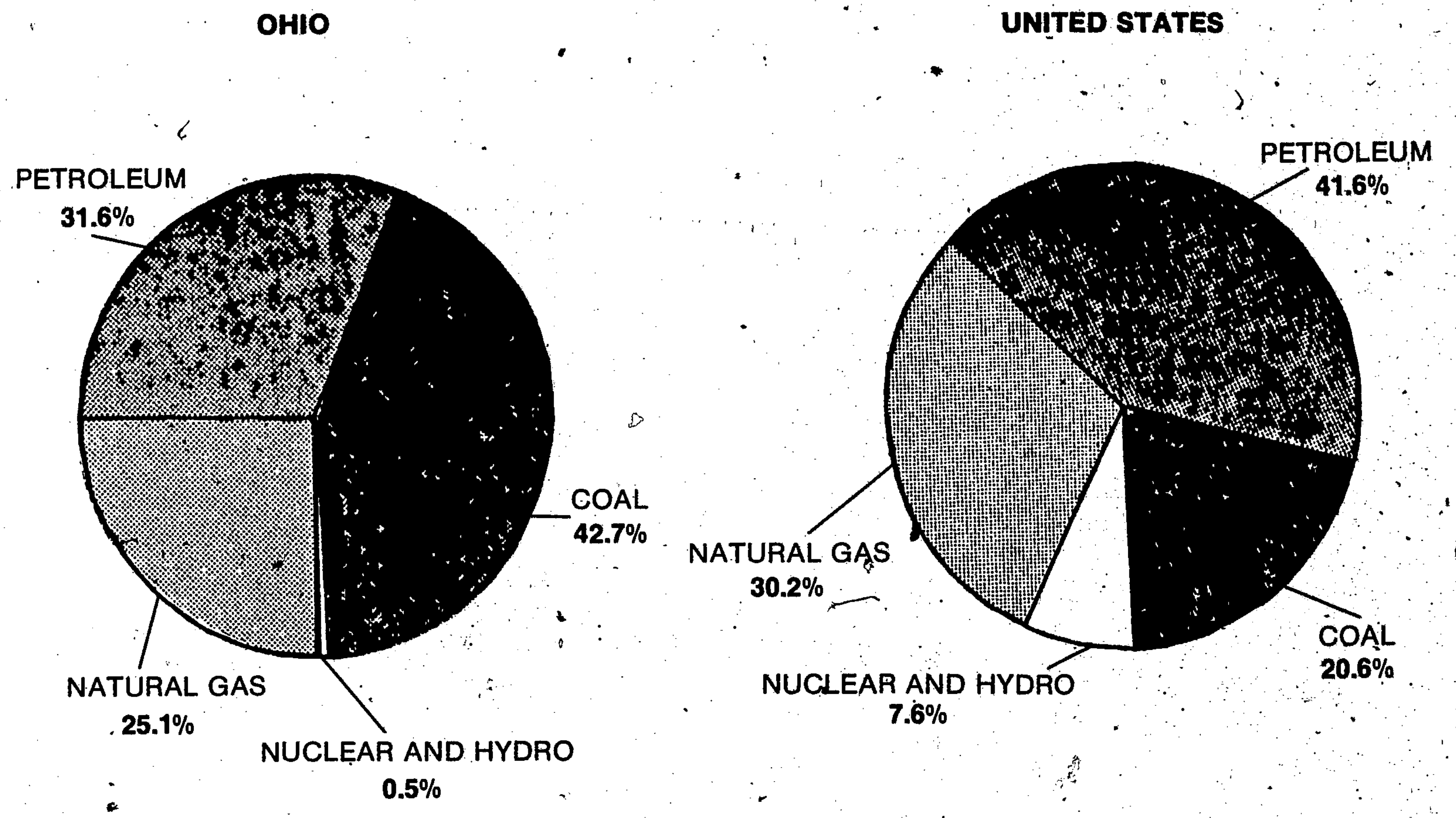


Figure 2. Gross Energy Consumption by Fuel, 1980.

Source: *Monthly Energy Review, April 1981*, U.S. Department of Energy and Ohio Department of Energy.

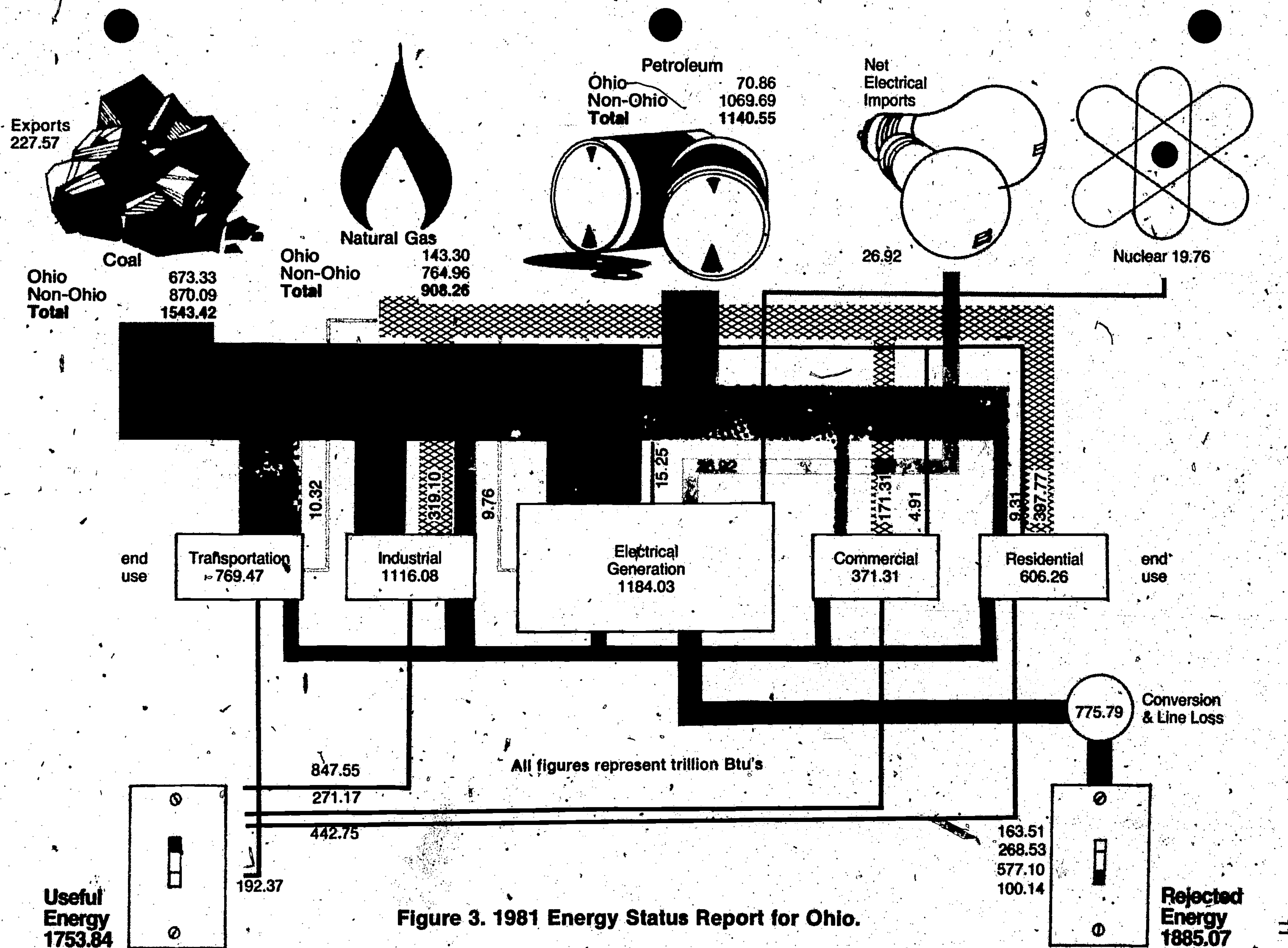


Figure 3. 1981 Energy Status Report for Ohio.

Source: Ohio Department of Energy, 30 East Broad Street, Columbus, OH

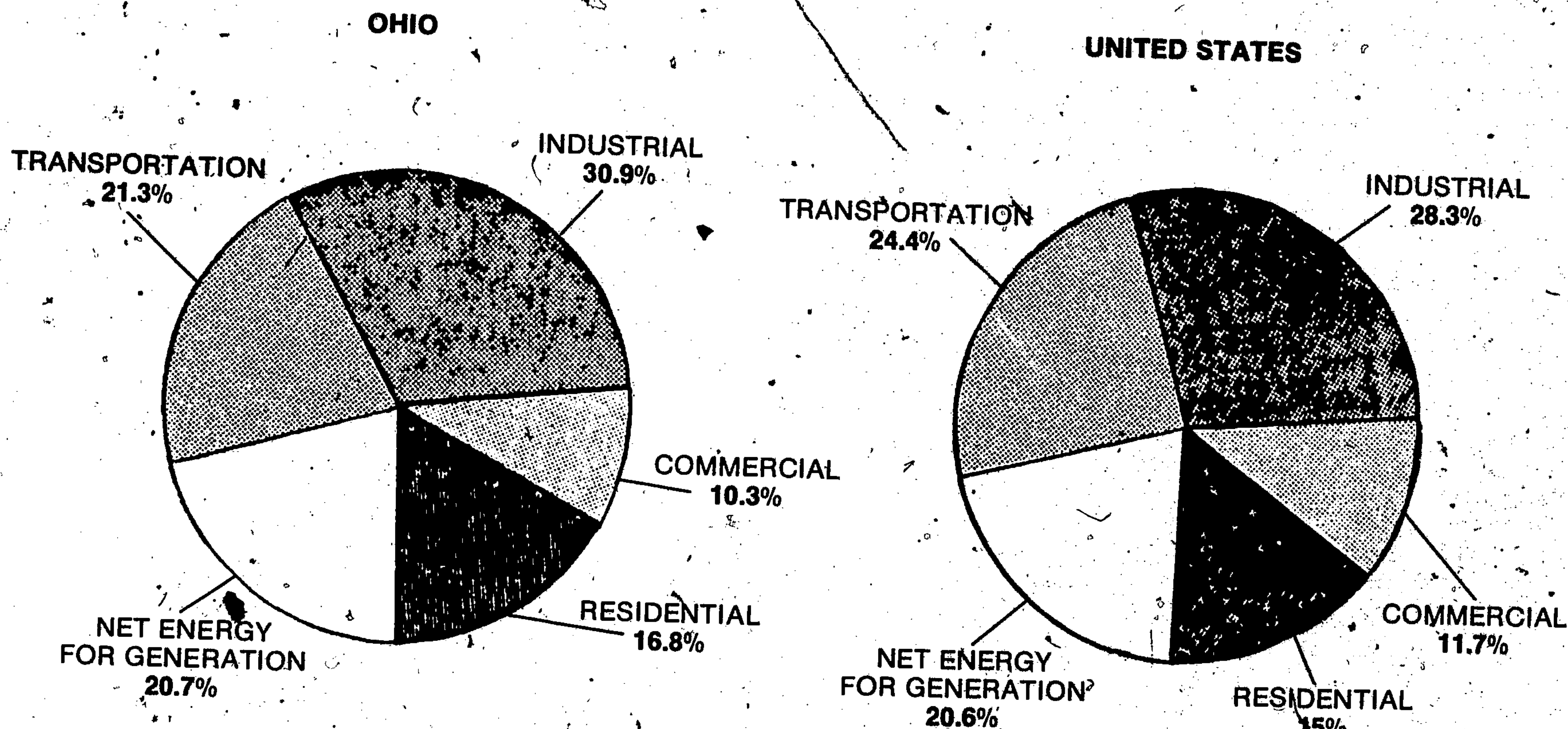


Figure 4. Gross Energy Consumption by Sector, 1980

Source: *Monthly Energy Review, April 1981*, U.S. Department of Energy and Ohio Department of Energy

I. Lesson Topic: FRAMEWORK FOR EVALUATING COSTS AND BENEFITS OF ALTERNATIVE ENERGY SYSTEMS

by

JOHN MILLER

II. Lesson Performance Objectives

At the end of this unit, the student will be able to:

1. Calculate, using the TI59 calculator or by written math, the costs and benefits of various energy sources such as fuel oil, natural gas, hardwoods, electricity, coal, liquid propane, softwoods, and a heat pump.

2. Perform long-range planning for his/her needs by calculating cost-effectiveness of energy resources.

3. Make various energy management decisions based on cost-effectiveness determination.

III. Materials Needed

1. A well-lighted classroom

2. Adequate chalk board or flip chart space for illustrating lesson points

3. At least one flat surface such as a table for use with the programmable calculator (TI59)

4. A Texas Instrument 59 (TI59) programmable calculator. More than one would be desirable in order to keep the lesson flowing smoothly. Programs should already be in place when lesson is begun.

5. Handout: *Fuel Cost Comparison* (a TI59 program, NRAES 5.46, courtesy of the North Regional Agricultural Extension Service)

6. Handout: *Comparing Heating Fuel Costs* (Extension Bulletin FS-12, courtesy of the North Regional Agricultural Extension Service)

IV. The Situation

One method a farmer can use to reduce the costs of production is to reduce the use of energy required in the production of products. This saving of energy will also help our nation to become more self-sufficient in energy resources. Many alternative sources of energy are available to the farmer for use in the production process. Not all are suitable in form or in cost. This lesson, therefore, provides a framework for evaluating costs and benefits of alternative energy sources and systems.

V. Introducing the Lesson

In preparing to teach this lesson, it would be desirable for the teacher to put the program on a magnetic card, ready for installation in case electricity to the programmed TI59 calculator is accidently cut off. An adequate extension cord should be available in order that the calculator(s) can be placed in the center of class activity. In this way, attention can be directed to the screen or to the tape if a print cradle is used. The teacher should program the TI59 calculator before class begins and check out the results from previous practice sessions.

The teacher should have students obtain prices for the various fuels prior to the start of class. This assignment may be given at previous class sessions in order to build interest in this lesson.

If a student in the class or someone else in the community (whom the students know and respect) plans to change or build new or remodel with the choice of fuel as one of the decisions to be made, this situation should be used to give meaning to this lesson for the student. This lesson implies the need for a decision on the part of a student regarding the type of fuel he/she should use for a specific purpose.

VI. The Problem Situation

Problem Statement: "Our friend, _student or other citizen_, is considering a different heating system for his/her _home, shop, barn, etc._. He/She would like to use the least expensive fuel possible that will still provide sufficient heat. What kind of fuel(s) might _student_ use to heat the selected area?" (Teacher places that question on the chalkboard under the label *Problem.*)

Possible student responses to be listed on chalkboard:

- natural gas
- propane gas
- fuel oil
- wood
- electricity
- coal
- heat pump
- (other)

Question: "Where do these fuels come from? What is their basic source?"

Natural gas - mostly from Southern United States' gas and oil wells
Propane gas - a by-product of the refining of oil
Fuel oil - from crude oil pumped from Southern United States
Wood - local farm wood lots
Electricity - generated locally from coal, oil or uranium
Coal - mines in Eastern United States
Heat pump - powered by electricity. (If students are unfamiliar with a heat pump, the teacher may use **handout #1,** *Comparing Heating Fuel Costs,* NRAES Extension Bulletin FS-12.)

Question: "Can the student (or other citizen) obtain these fuels?"

Possible student answers:

- Depends on locality
- Some, but not all of them
- Yes, wood if he/she owns woodlot

Question: "What heating equipment does _student_ now have?"

Possible student answers:

- A coal furnace
- "I don't know. I've never been to _student's_ home."
- It makes no difference what he/she has now if a new heating system is going to be installed.

Question: "Do any of these fuels require any special skills in their handling?"

Possible student answers:

- Some do; some don't.
- Some fuels are fed automatically. The operator doesn't need any skill other than setting a thermostat.

Teacher: "Let's make a list of any special skills needed in handling these fuels."(On chalkboard:)

Natural gas — usually automatic. Lighting pilot may be difficult for some people. Once installation is operating correctly, little adjustment is necessary.

Propane gas— much like natural gas. Changing or filling storage tanks must be learned.

Fuel oil — usually automatic. Lighting pilot may be difficult for some people. System must be watched for development of dirty burners.

Wood — fire box must be refilled regularly and ashes removed. Must be regulated with change in outside weather. Watch for formation of creosote and soot.

Electricity — usually automatic. Change of heat bulbs needed periodically. Heating elements must be kept free of dust and cobwebs.

Coal — much like wood. Longer lasting fire than wood. Less danger of creosote and soot in pipes and chimney.

Heat pump — usually automatic. Must be kept very clean to be efficient.

Question: "Do these fuels contain different amounts of heat?"

Possible student answers:

- Probably
- How do we compare electricity and wood?
- Let's burn some of them and see.

Teacher: "Let's take a look at this **handout #2**, *Fuel Cost Comparison*, specifically the paragraph labelled, 'Assumptions'."

Question: "Will the information in this paragraph affect your choice of fuel?"

Possible student answers:

- Yes. Now we see some differences.
- No. It says something about BTU and efficiency, but I don't understand what that means.
- Yes. I would pick the fuel with the highest efficiency.

Question: "Your answers indicate that we need to get a better understanding of some new terms. What is meant by the letters **BTU**?"

(Again refer the students to **handout #1**, *Comparing Heating Fuel Costs*, for the definition.)

Question: "What is meant by the term *efficiency*?" (Refer the students again to **handout #1** - page 3, Table 1.)

Teacher: "In order that we might have the information about the various fuels in a form that is easy for us to see and evaluate, let's put on the chalkboard the necessary information about the fuels we've studied." (Teacher begins the development of a chart on the chalkboard similar to the chart on page 4. The amount of BTU's per unit of fuel, the efficiency of the fuel, can be obtained from *Fuel Cost Comparison*, **handout #2** - page 1. The students will have obtained the cost per unit of each fuel prior to the lesson.)

Question: "Now we need to compare the various fuels as to cost per heat unit or BTU. What would be a quick way to do the calculations?"

Possible student answers:

- Use a calculator.
- Use a computer.

Teacher: "We do have a calculator available that will help us do the calculations very quickly. Who would like to be the first one to operate it? OK, here's how it is operated." (Prior to class, the teacher will have performed the following operations: 1) turned the calculator on; 2) entered the program, either from a magnetic card or by punching in the 155 steps from **handout #2** - page 2, *Fuel Cost Comparison*; and 3) pressed R/S to enter the assumed stove efficiencies.)

The first steps for the student are:

1) Press A on the calculator keyboard.
2) Enter the fuel cost in dollars per unit (or in the case of electricity, cents per KWH).
3) Press the appropriate key listed to find cost per million BTU's. Remember to press "2nd" for B, C, D, and E.

(The teacher may alternate students while determining costs with the use of the TI59.)

Note: The teacher may also have some students simultaneously doing paper calculations by using the following reasoning:

Example: Natural gas: 100 cubic feet gives 100,000 BTUs at 75% efficiency. This will provide 75,000 BTUs.
It will take 1,000,000 divided by 75,000 equalling 13.33 hundred cubic feet of gas to furnish the one million BTU's at 75% efficiency. Therefore, 13.33 times cost per hundred cubic feet ($0.42) equals $5.60 worth of gas to furnish one million BTU's of heat.

As students put fuel cost comparisons on the chalkboard, the teacher could have other students compare costs among fuels with **handout #1**, *Comparing Heating Fuel Costs*. The teacher will need to explain to the students how the chart on page 1 is used.

Make the point that fuel prices will change. In like manner, then, the cost per million BTU's will change, too.

Students now have a method of comparing fuel costs, using *heat units* (BTUs), *cost* (per unit sold - gallons, cubic feet, etc.), and *efficiency* (depending upon the heating device used to burn the fuel).

VII. Solution to the Problem

The teacher should place on the chalkboard the solution or conclusion to the student's problem:

"At today's prices, __*student*__ should use __*selected fuel*__ to heat his/her selected area."

SAMPLE CHART OF VARIOUS FUEL COSTS AND BTU VALUES

Fuel	Unit	Efficiency	Cost of Fuel	Cost per Million BTU
Natural gas	100,000 BTU/100 cu. ft.	75%	$ 0.42*	$ 4.00
Fuel oil	140,000 BTU/gallon	75%	1.30*	12.38
Hard woods	24,000,000 BTU/cord	50%	100.00	8.33
Soft woods	15,000,000 BTU/cord	50%	70.00	9.33
L.P. gas	93,000 BTU/gallon	75%	0.70*	10.04
Electricity	3,412 BTU/KWH	100%	0.04	11.72
Coal	12,500 BTU/pound	60%	90.00	6.00
Heat pump			0.04	21.10

*These costs reflect regulated fuel prices. Deregulation may double or triple the costs over the expected life of the alternate systems being compared.

Question: "What else should be considered?"

Possible student responses:

- Cost of installation
- Availability of fuel
- Will it do the job?

For example, "Heat for baby pigs needs to be directed and constant. In contrast a farm shop does not have to be evenly or continuously heated."

Questions: "Could ___*student*___ use two heat sources, such as a wood stove for space heating and a radiant heater for a specific space — a space such as for baby pigs or a work area?"

"Could ___*student*___ use heat wasted otherwise? Heat from a cooling compressor could be retained in a milk or egg room. Could that be a consideration?"

"Does the heat source ___*student*___ has chosen involve more work to operate than he/she should be doing?"

Answer: "Some heat sources need to be maintained periodically and fuel obtained for them. Refueling, cleaning or adjusting may be needed."

Questions: "Would a person hired by the owner as a substitute worker during vacation be able to operate the heating devices?"

"Would a new system save money?"

Answer: Use **handout #1** - page 3, Table 1, to see how saving energy could possibly help pay for a different system.

VIII. Application

"Now, let's see how well you can apply the principles you have learned so far to the following situation:

Suppose you're going to remodel your chicken house to put hogs in it.

Question: What fuel(s) would you use?

Question: Why would you use that fuel (those fuels)? (Three reasons, please).

Question: What does that fuel (those fuels) cost per million BTU's? (Please show all calculations)."

IX. Evaluation

QUIZ

NAME ____________________

Directions: If the statement is true, circle the letter "T." If the statement is false, circle the letter "F."

T F 1. Wood is a less efficient fuel because much of its heat is lost by soot and hot air going up the chimney.

T F 2. Electricity is more efficient because it can operate in a closed room with no loss up the chimney.

T F 3. There is the same amount of heat (BTU's) in a gallon of fuel oil and a gallon of propane gas.

T F 4. It takes no special ability to clean the burner of an oil stove.

T F 5. Fuel costs will always be the same, so this comparison of fuel cost will always remain the same.

Directions: Fill in the blank with the correct word or words to complete the statement.

6. The fuel source located closest to my home is ____________.
7. To truly compare fuel costs, one must compare the usable amount of heat in a million ________ at the cost of each fuel in the quantity by which it is sold.

Directions: Complete the following problem, showing all of your calculations.

Using the "fuel cost comparison," at $0.50 per 100 cu. ft. for natural gas, figure the following:

8. the number of BTU's per 100 cu. ft. ____________
9. the percent efficiency of natural gas ________
10. the cost of one million BTU's of natural gas ____________

REFERENCES CONSULTED

Parsons, R.A., *Fuel Cost Comparison*. Northeast Regional Agricultural Engineering Service, Cooperative Extension Services of the Northeast Land Grant Universities and the United States Department of Agriculture, Bulletin 5.46.

Stipanuk, D.M., *Comparing Heating Fuel Costs*. Northeast Regional Agricultural Engineering Service, Cooperative Extension Services of the Northeast Land Grant Universities and the United States Department of Agriculture, Bulletin FS-12, Revised June 1981.

HANDOUT #1 - page 1

FS-12

Comparing Heating Fuel Costs

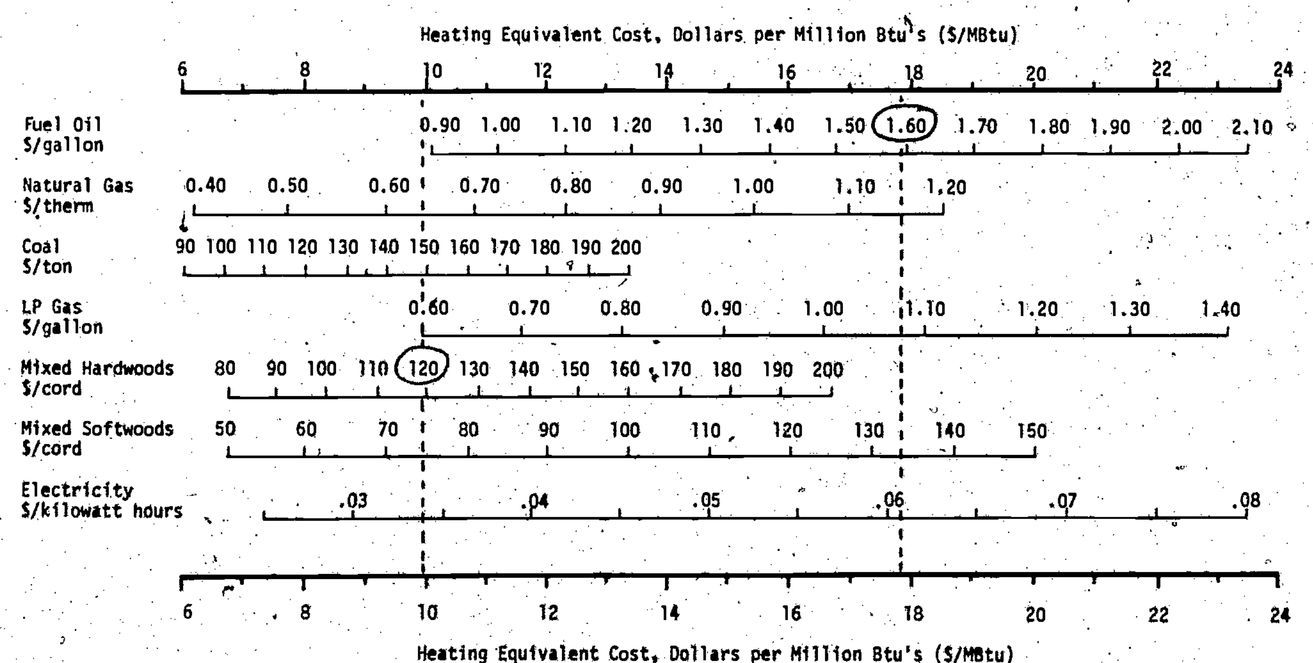
The costs of various forms of energy are evaluated in different ways, making comparisons difficult. The following chart will enable you to compare the cost of various heating fuels on the basis of their heating equivalent as expressed in dollars per million British thermal units[1] ($/MBtu). To use the chart, read across the fuel price columns to the Heating Equivalent column to determine the price per MBtu.

For example, if a source of mixed hardwood is available at $120/cord, the equivalent fuel cost is approximately $10.00/MBtu. Fuel oil at $1.60/gallon has an equivalent fuel cost of $17.80/MBtu.

If you are considering switching fuels, remember the cost of the heater. A good quality wood stove and new chimney costs a thousand dollars or more. Heat pumps cost several thousand dollars. It may require many years of fuel savings to pay for a new installation. Insulation or improving the efficiency of the existing heating system may be a better investment.

[1]One Btu = The amount of energy required to raise a pound of water 1° Fahrenheit.

Fuel Cost Comparison



ASSUMPTIONS

Natural Gas - Therm = 100,000 Btu = approx. 100 cu ft. 65% Efficiency. $/MBtu = 15.38 × $/Therm

Fuel Oil - 138,000 Btu/gallon. 65% Efficiency. $/MBtu = 11.15 × $/gallon

LP Gas - 93,000 Btu/gallon. 65% Efficiency. $/MBtu = 16.54 × $/gallon

Electricity - 3412 Btu/kwh. 100% Efficiency. $/MBtu = 293 × $/kwh

Mixed Hardwoods - 24 MBtu/cord. 50% Efficiency (Airtight stove). $/MBtu = $/cord ÷ 12

Mixed Softwoods - 15 MBtu/cord. 50% Efficiency. $/MBtu = $/cord ÷ 7.5

Coal - 12,500 Btu/lb. 80% Efficiency. $/MBtu = $/ton ÷ 15

COOPERATIVE EXTENSION

Northeast Regional Agricultural Engineering Service

HANDOUT #1 - page 2

Fuel Price Information

Most electricity or natural gas is sold on a block pricing structure. A typical rate schedule might be, the first 12 kwh of electricity costs $3.00, the next 12-300 kwh costs 6¢ per kwh, the next 300-1200 cost 4¢ per kwh. etc. To calculate heating costs, use the price for the highest level of monthly consumption. For example, you would use the 4¢ per kwh value if you consumed between 300 and 1200 kwh per month in an area with the price structure mentioned above.

Some electric utility companies have a seasonal rate, so energy costs more at one time of the year than another. Areas with a high air conditioning load may have higher summer rates, while areas with a large electrical heating demand may have higher winter rates. Also several electric utilities offer lower off-peak rates at night because this is a low electrical demand period. Some electric heaters are now available to take advantage of these low rates by storing electrical energy at night by heating a ceramic material to a very high temperature. Then during the day the electrical heaters are switched off and the stored energy is used for heating.

Typical prices for electricity range from 4¢ to 12¢ per kwh. Natural gas prices range from 40¢ to 70¢ per therm. Contact your local utility to obtain the most current rates for the heating season. Prices for LP gas and fuel oil are available from local dealers. However, LP and fuel oil prices are somewhat seasonal; try to obtain prices during the heating season.

Heat Pumps

A heat pump is similar to a central air-conditioning unit. It either extracts heat from outside air for winter space heating, or removes heat from the air in the house for space cooling in the summer. A heat pump is most cost effective when both winter heating and summer cooling is needed.

Because the heat pump extracts heat from outside air it provides more heat per kilowatt hour than an electrical resistance heater. However, heat pumps work less efficiently as outside temperatures drop. Some heat pumps turn on supplemental resistance heaters to supply the heat required when the heat pump efficiency drops. Other heat pumps rely on a backup furnace fired by gas or oil to provide space heating when the outside air temperatures drop below about 20°F.

In most of the Northeast, heat pumps operate with an efficiency or Seasonal Performance Factor (SPF) of 1.8 to 2. The Seasonal Performance Factor is the total amount of heat energy delivery by the heat pump divided by the annual electrical energy used by the heat pump. In cold areas the SPF will be lower; in warm areas it will be higher. Heat pump dealers generally have detailed information regarding the SPF expected for heat pumps in various parts of the country.

You can use the fuel chart to determine the cost of heat supplied by a heat pump. First divide the price of electricity by 1.8 or 2 (or by the SPF of your heat pump in your area) and then use this effective price of electricity in the chart. Remember, this is the fuel cost only. A complete analysis should include the additional initial cost (if any) of the heat pump over that of the alternative heating system.

Wood or Coal as Fuels

The wood and coal heating values on the fuel cost chart are for good airtight stoves or furnaces—the only devices which efficiently deliver the heat from wood and coal.

If you have a non-airtight stove and want to calculate the cost of wood or coal as a heating fuel, multiply the fuel cost in $/MBtu for wood or coal shown on the fuel chart by 2. Example: Mixed hardwood at $100/full cord has a fuel cost equivalent of $8.33/MBtu in an airtight stove. In a non-airtight stove its heating equivalent would be $16.66/MBtu.

Which Fuel?

For much of the Northeast, the price of natural gas, coal and wood are close enough that there is little significant difference in their Heating Equivalent Cost. Fuel oil may be slightly less expensive than LP gas in some areas and more expensive in others. Electricity may be relatively inexpensive compared to fuel oil in areas offering off-peak rates. In areas around New York City and other locations where oil is used as a fuel for electricity production the price of electricity is substantially higher than other fuels.

Heat pump systems may have lower fuel cost than many alternatives. However, heat pumps may have substantially higher capital costs than heating systems using other fuels. In areas that use air conditioning, heat pumps have additional advantages since they can both heat and cool.

High Efficiency Heaters

The fuel cost comparison table uses efficiencies typical of furnaces and boilers found in most older homes. Many new furnaces and boilers have efficiency values significantly higher. In addition, improvements can be made in existing heating systems to improve their efficiencies. Among these improvements are flue dampers, electrical ignitions, outside combustion air and the installation of new burners.

Use Table 1 to help evaluate the value of replacing an existing furnace or boiler with a more efficient one. For example, calculate the fuel savings achieved by replacing an old oil furnace with an assumed 65% efficiency with one that has a seasonal heating efficiency of 80%. The example home annually uses 1000 gallons of oil that costs $1.60 per gallon for an annual cost of $1.60 × 1000 = $1600. Table 1 shows that an efficiency improvement to 80% will lower the annual heating bill by 19%. The annual fuel savings is then 0.19 × 1600 = $304.

Table 1. Percent Reduction in Fuel Use for Improved Heating System Efficiency.

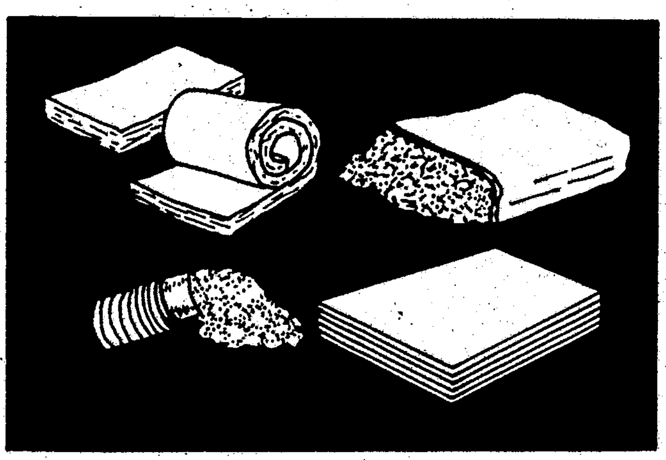
New Heating System Seasonal Heating Efficiency[1]	Percent Reduction in Annual Heating Fuel Usage[2]
70%	7
75%	13
80%	19
85%	24
90%	28
95%	32

[1] Energy delivered to dwelling: Energy Input to Heating System.
[2] Current system assumed to be 65% Efficient.

Added Insulation

An alternative way to lower heating costs is to add insulation. The fuel savings from additional insulation depend on the:

- amount of existing insulation
- amount of insulation to be added
- current cost of heating fuel.



The following steps may be used to calculate the value of fuel saved by increasing insulation. As an example of this calculation look at a single story, 1500 square foot home in Hanover, NH. It has 6 inches of fiberglass insulation in the attic with an equivalent R value, or resistance to heat loss, of about 19. The house uses oil for heating at a cost of $1.60 per gallon. Calculate how much can be saved by adding 6" of insulation (R-19) as follows:

Step 1. Find the heating degree days for the area from the heating degree day map. Hanover, NH has 7500 heating degree days.

Step 2. Calculate the heat loss through the existing insulation by the following equation:

$$\text{Rate of Heat Loss} = Q = \frac{1}{R} \times A \times HDD \times 24$$

where R = R value of insulation
A = area of insulated surface
HDD = heating degree days

The heat loss for the existing ceiling (R-19) is about:

$$Q = \frac{1}{19} \times 1500 \times 7500 \times 24$$

= 14.2 million Btu's.

Step 3. Find the new total R value by adding the R value of the new insulation to the existing insulation R value.

New R = 19 + 19 = 38

Step 4. Calculate the newly insulated ceiling heat loss.

$$Q = \frac{1}{38} \times 1500 \times 7500 \times 24$$

= 7.1 million Btu's

Step 5. Find the fuel heating equivalent from the fuel cost comparison chart.

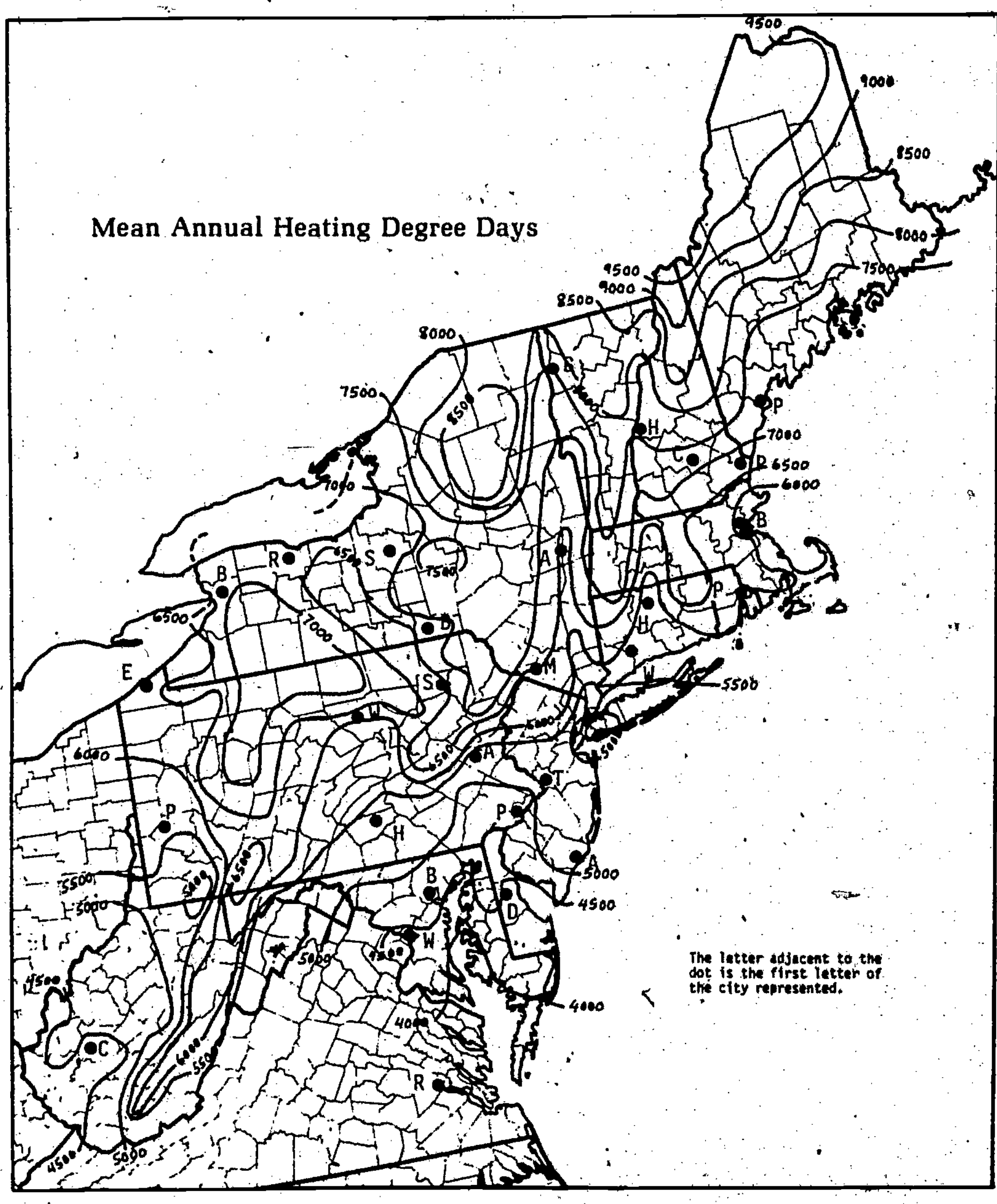
Fuel oil costing $1.60 per gallon is equivalent to $17.80 per million BTu's.

Step 6. Calculate the annual savings. Subtract the new heat loss from the old heat loss and multiply by the fuel heating equivalent.

Fuel cost savings = (14.2 - 7.1) × $17.80 = $126

So, an additional 6" of insulation will lower annual fuel cost by $126 in this example. As fuel costs increase, the savings will increase each year.

HANDOUT #1 - page 4



Written by D.M. Stipanuk, Cornell University

The Northeast Regional Agricultural Engineering Service is an activity of the Cooperative Extension Services of the Northeast Land Grant Universities and the United States Department of Agriculture.

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FS-12

Cooperative Extension Provides Equal Program and Employment Opportunities

Revision June '81 — 30M

Fuel Cost Comparison

R.A. Parsons

This program first calculates the cost per million Btu (MBtu) for a given fuel and then compares that cost to several other fuels.

1. Enter program
   a. Turn on calculator and enter program card side 1.
   b. Press R/S to enter assumed stove efficiencies.

2. Find cost per MBtu for a specific fuel
   a. Press A
   b. Enter fuel cost in $ per unit sold (¢/Kwh for electricity).
   c. Press the appropriate fuel key listed below to find cost/MBtu.

Fuel	Sales unit	Press	Example	Display Fuel cost $/MBtu
Fuel oil	gallon	B		
Natural gas	therm	C		
Mixed hardwoods	cord	D	$100	8.33
Electricity	Kwh	E		
Coal	ton	B'		
Liq. propane	gal	C'		
Mixed softwoods	cord	D'		
Heat pump	Kwh	E'		

3. Find equivalent cost per sales unit of other fuels
   a. Press the appropriate fuel key or keys listed above.
   Example. Press B and 0.87 is displayed. Thus fuel oil costing $0.87 per gallon is equal in heating value to wood costing $100 per cord that is burned in an efficient wood stove. If E is pressed, 2.84 is displayed; or $100 hardwood is equal to electrical heat that costs 2.84¢ per kilowatt hour (kwh).

To change the programmed heating efficiencies enter your assumed efficiency as a decimal. Then

Press	To change
STO 02	fuel oil heating efficiency
STO 03	natural gas & LPG
STO 04	hard or soft wood efficiency
STO 05	coal
STO 06	heat pump seasonal performance coefficient

Assumptions:

Natural Gas - Therm = 100,000 Btu
- 100 cu ft
75% Efficiency

Fuel Oil - 140000 Btu/gallon
75% Efficiency

Mixed Hardwoods - 24 MBtu/cord
50% Efficiency

Mixed Softwoods - 15 MBtu/cord
50% Efficiency

LP Gas - 93,000 Btu/gallon
75% Efficiency

Electricity - 3412 Btu/kwh
100% Efficiency

Coal - 12,500 Btu/lb
60% Efficiency

Heat pump seasonal performance coefficient - 1.8

HANDOUT #2 - page 2

NRAES 5.46

Fuel Cost Comparison

LRN

Step	Code	Key
000	93	.
001	07	7
002	05	5
003	42	STO
004	02	02
005	42	STO
006	03	03
007	93	.
008	05	5
009	42	STO
010	04	04
011	93	.
012	06	6
013	42	STO
014	05	05
015	01	1
016	93	.
017	08	8
018	42	STO
019	06	06
020	58	FIX
021	02	2
022	91	R/S
023	76	LBL
024	11	A
025	86	STF
026	01	1
027	91	R/S
028	76	LBL
029	12	B
030	42	STO
031	01	01
032	53	(
033	43	RCL
034	02	02
035	65	×
036	93	.
037	01	1
038	04	4
039	54	)
040	76	LBL
041	44	SUM
042	87	IFF
043	01	1
044	00	0
045	51	51
046	65	×
047	43	RCL
048	00	00
049	95	=
050	91	R/S
051	55	÷
052	43	RCL
053	01	01
054	95	=
055	35	1/X
056	42	STO
057	00	00
058	22	INV
059	86	STF
060	01	1
061	91	R/S
062	76	LBL
063	13	C
064	42	STO
065	01	01
066	53	(
067	43	RCL
068	03	03
069	65	×
070	93	.
071	01	1
072	54	)
073	61	GTO
074	44	SUM
075	76	LBL
076	14	D
077	42	STO
078	01	01
079	53	(
080	43	RCL
081	04	04
082	65	×
083	02	2
084	04	4
085	54	)
086	61	GTO
087	44	SUM
088	76	LBL
089	15	E
090	42	STO
091	01	01
092	93	.
093	03	3
094	04	4
095	01	1
096	02	2
097	61	GTO
098	44	SUM
099	76	LBL
100	17	B'
101	42	STO
102	01	01
103	53	(
104	43	RCL
105	05	05
106	65	×
107	02	2
108	05	5
109	54	)
110	61	GTO
111	44	SUM
112	76	LBL
113	18	C'
114	42	STO
115	01	01
116	53	(
117	43	RCL
118	03	03
119	65	×
120	93	.
121	00	0
122	09	9
123	03	3
124	54	)
125	61	GTO
126	44	SUM
127	76	LBL
128	19	D'
129	42	STO
130	01	01
131	53	(
132	43	RCL
133	04	04
134	65	×
135	01	1
136	05	5
137	54	)
138	61	GTO
139	44	SUM
140	76	LBL
141	10	E'
142	42	STO
143	01	01
144	53	(
145	93	.
146	03	3
147	04	4
148	01	1
149	02	2
150	55	÷
151	43	RCL
152	06	06
153	54	)
154	61	GTO
155	44	SUM

LRN

Press 1 2nd Write
Insert mag card.

(Permission granted to use TI-59 program)

I. Lesson Topic: **ELECTRICAL ENERGY MANAGEMENT FOR THE HOME AND BUSINESS**

by

DON OVERMYER

II. Lesson Objectives

At the conclusion of this lesson, the student will be able to:

1. Identify practices which will result in using less electrical energy.
2. Identify practices which can be eliminated, resulting in the use of less electrical energy.
3. Develop a priority list of electrical loads in the home or business, the use of which will lower the monthly demand load.

III. The Situation

The supply of certain fossil fuels, such as oil, is rapidly decreasing. The demand for electrical energy is increasing. Most of our electricity is produced by burning fossil fuels. The cost of these fuels is increasing, putting a strain on many family budgets. Families and individuals are seeking ways to reduce the use of electricity, thereby conserving fossil fuel and at the same time reducing the amount of money paid out in electric bills.

IV. Introduction to Lesson

To emphasize the need for energy conservation, ask the students how much energy is used now as compared to ten years ago. List the answers on the board. After discussing why the amounts are different, use the film strip/cassette entitled, "Doubling Time." (The set is available for loan from the Cooperative Extension Service. Check with your county agent.)

Emphasize to the students that we do have limited supplies of fossil fuel. Eventually, some other energy source must be developed to replace fossil fuel. In order to "buy time" to develop alternate fuels, we must conserve what fuels are now available. In the production of electricity, the utility companies throughout the United States use the following *energy* mix: **hydro, 40%; coal, 17%; nuclear, 8%; and oil, 35%.**

Since this lesson deals with electrical energy, try to limit the discussion to electricity. Using the chalkboard to record student answers, ask the following:

Question: "Why must we conserve energy?" The information given may be helpful as a contribution to the discussion.

Possible Student Answers:

1. There is a shortage of oil.
2. Producing electrical energy is costly.
3. Electric companies' billing methods make it worthwhile for the consumer.

To bring the lesson discussion "closer to home," state that *Jill* (a student) and her family of four have decided to figure out how to reduce electric costs and still get economical use from the electrical energy needed to maintain a comfortable household living standard. Place on the chalkboard the following:

V. Problem Statement: "What can *Jill* and her family do to reduce electrical usage and costs and still maintain a comfortable living standard? Is it possible?"

VI. Solution to Problem; Presentation of Lesson

Ask the question, "What are some things ___*Jill*___ and her family will need to know in order to make this decision?"

Possible Student Questions in Response:

1. In what ways can ___*Jill*___ and her family reduce electrical usage in the home and in the farm business?
2. Will their electric company provide any assistance in determining the most efficient ways to use electricity?
3. Does their electric company charge different rates for different amounts of electricity used?
4. Is there some electronic device that ___*Jill*___ and her family could use to keep them from using so much electricity?

These "possible student questions" ___*Jill*___ will need to know can be answered with the teaching of 1) how electric companies calculate the electric bill; 2) why it is expensive for both the consumer and the company to have production capacity available to produce all the electrical energy people want whenever they want it; 3) how families can save money by scheduling appliance use over a 24-hour period; and 4) how electric devices are available to help control or schedule major electrical appliances. The following dialogue may be conducted with the students as a means of teaching the lesson content.

Question: "How do electric companies calculate electric bills?"

Answer: Electric companies charge customers for the number of "kilowatt hours" used. One *kilowatt-hour* is a measurement of electrical power at the rate of 1000 watts per hour. For example, an appliance such as an iron is rated at so *many* watts, say 1000 watts. If that iron is used for one hour, it "used" 1000 watts or one kilowatt-hour of electricity. Finding the number of kilowatts used by an appliance can be done in one of the following ways: 1) Each appliance has a watt listing. This figure is the total watts which the appliance will use in one hour's time. 2) On motors, the name plate may not list watts, but may list horsepower. To convert horsepower to watts, multiply the rated horsepower by 1000 watts. The answer will equal the total watts used by the motor in one hour of operation.

___*Jill's*___ house has a meter located near the place where the electric wires enter the house. This meter has either four or five dials. (At this point, the teacher could take the class to the school's electric meter to show them what a meter looks like and how it is read. Space will not permit the teaching of that skill in this lesson plan.) The teacher will need to explain that a meter (most companies use a load meter) measures two things: the number of kilowatt-hours used during the month, and the "load" or greatest number of kilowatts in use for a half-hour period during the month.

Time should now be taken to explain to the class the method of calculating the monthly bill and the role the highest half-hour demand plays in the final cost of the electric bill. The following examples assume an average of 1,000 kilowatt-hours usage per month.

Methods of billing:

- ***Straight rate,*** based on kilowatt-hours used
- ***Demand meter,*** based partially on period of highest use

Let's look at a number of examples, each one based on ___*Jill's*___ average use of 1,000 kilowatt-hours per month.

Example 1: In this example, we use no demand meter and do not take into account the periods of highest demand for electricity. The electric company uses a rate schedule similar to the one which follows:

Rate Schedule		Bill Calculation
First 50 kilowatt-hours cost 9.60¢/kw-hr.		$ 4.800
Next 80 kilowatt-hours cost 7.33¢/kw-hr.		5.864
Next 320 kilowatt-hours cost 3.79¢/kw-hr.		12.128
Next 350 kilowatt-hours cost 3.12¢/kw-hr.		10.920
Next 200 kilowatt-hours cost 2.92¢/kw-hr.		5.840
1000 kilowatt-hours used	**Total Cost:**	$ 39.552

(Fuel cost is 1.0556¢ per kilowatt-hour regardless of load meter or no load meter.)

Example 2. In this example we use a demand meter which registers the largest flow of electricity occurring during any one-half-hour time period within the billing period. In this example, we will use a demand peak (block base) of 25 kilowatt-hours. We multiply 25 kilowatt-hours by 125 (a constant figure) which equals 3,125 kilowatt-hours and is greater than 1000 kilowatt-hours. In this case, no money would be saved. One must use more than 3,125 kilowatt-hours to save money.

Example 3: In this example, using a demand meter and a peak demand of 7 kilowatt-hours, we discover the following rate schedule. (Note the change found in the rate schedule. 7 multiplied by 125 equals 875, which is less than 1000. Difference is 125 kilowatt hours). This indicates a possible financial savings. The rate will remain the same for the first 875 kilowatt-hours used, with a special rate for the remaining 125 kilowatt-hours.

Rate Schedule		Bill Calculation
50 kilowatt-hours at 9.60¢/kw-hr.		$ 4.800
80 kilowatt-hours at 7.33¢/kw-hr.		5.864
320 kilowatt-hours at 3.79¢/kw-hr.		12.128
(800 kilowatt-hour block basis)		
350 kilowatt-hours at 3.12¢/kw-hr.		10.920
75 kilowatt-hours at 2.92¢/kw-hr.		2.190
(875 kilowatt-hour block basis)		
Balance of 125 kilowatt-hours at 0.62¢/kw-hr.		0.775
	Total Cost:	$ 36.677

This situation (Example 3) results in a savings of $2.88.

Question: "What does this tell you about demand billing?"

Answer: This shows that as the peak demand lowers, the total electric bill will be lower when using the same quantity of electricity. If we lower our peak demand during any one half-hour block of time, we can also lower our bill, while using the same or slightly more kilowatt-hours. In other words, consumers should "balance" their electrical use during the day and the month. Savings can be realized by balancing the load demand.

Question: "In what ways can ___*Jill*___ and her family keep the peak demand for electric power at a lower level?"

Possible student answers:

1. Make sure that several large appliances are not in operation at the same time.
2. Discontinue the use of some appliances, motors, etc.
3. Develop a priority list of electric appliances that need to be on at specific times, such as electric stove, hot water heater, water pump, milking machine, motors that operate livestock feeding mechanisms, etc.

At this point, the teacher can assist the students in developing a concept of load management by scheduling appliance use. A procedure for developing a priority schedule is as follows:

- Inventory the major appliances, motors, heaters, etc., that are used on a frequent basis, and those that are used on a seasonal basis.
- Develop a priority list as if the power available were limited and you had to pick and choose from these items. At the same time indicate the most common hours of highest use. The priority list could look like the following:

Required Load		**Manageable Load**
milker vacuum pump	MOST NEEDED	silo unloader
milk cooler	↓	gutter cleaner
doors	↓	feeders
exhaust fans	↓	grain dryer
hot water	LEAST NEEDED	household items

Students may want to make a priority list of only household items. Examine the priority list, while considering the following questions:

1. Can the normal periods of use for these appliances, etc., be altered?
2. What changes in normal lifestyle might result for the family?
3. Can some items be eliminated or reduced?

At this time ask for some answers to these questions from the students. To help the students with their answers, display a transparency of Table 1 (or give information as a handout).

After allowing students to discuss a variety of possible ideas, have each student develop a possible priority list for his or her home, using the data from the above-mentioned transparency or handout. ___*Jill*___ should be developing her list along with the rest of the class. Allow about 10 minutes for this activity.

After the students complete their priority lists, have them think about the question, "What can be done to assure that no high energy user is operating while another high energy user is in operation?" At this time, the teacher could teach about devices that turn items on and off, either by manual control or automatic control.

Ask the students to name familiar devices which control the operation of appliances, motors, fans, etc. Devices mentioned may be switches, fuses, circuit breakers, photo-electric cells, clock timers, etc.The diagrams in the Appendix (Figures 1 - 7) may be useful in explaining the various methods that can be used to control electrical loads.

LOAD CONTROL AND MANAGEMENT

The basic idea of load management is to keep the peak demand for electric power at a lower level.

Table 1. Electric Energy Consumption of Appliances

Appliance	Average Wattage	Estimated KWH Consumed Annually
Oven, microwave (only)	1,450	190
Range (regular oven)	12,200	1,175
Range (self-cleaning oven)	12,200	1,205
Toaster	1,146	39
Freezer (15 cu. ft.)	341	1,195
Refrigerator (frostless, 12 cu. ft.)	321	1,217
Clothes dryer	4,856	993
Iron (hand)	1,008	144
Washing machine (automatic)	512	103
Water heater (standard)	2,475	4,210
Air conditioner (room)	1,566	1,389
Hair dryer	381	14
Heat lamp (infrared)	250	13
Radio	71	86
Radio/record player	109	109
Television (color; solid state)	200	400
Clock	2	17
Vacuum cleaner	630	46

(***Source:*** Hansen, *Energy Conservation: Wise Use of Appliances,* WRAES 62. For additional information concerning electrical energy consumption of appliances and the approximate cost of operation, see **handout #1** in the Appendix.)

During the evening hours there is an increased demand for electric power due to cooking, washing, or drying clothes, extra hot water needed for washing or showers, heating or cooling, etc. This increased demand causes the power companies to increase power generation. The power companies must have the facilities for meeting these demand periods. The increased power generation facilities result in a higher net electric bill.

If a means of controlling peak demand in the home were instituted, the power generation facilities could be smaller and the net result could be a lower electric bill.

Some companies have a method of monitoring individual home peak power consumption. If the "demand limit" is exceeded during the month, a higher rate is paid during that month.

Listed in this paper are various methods for controlling the peak demand. (See Figures 1-7 in the Appendix.)

VII. Application

Now that students have an idea of various electronic control devices, have them refer back to their priority list. Have them determine if electronic control devices can be used to solve some of the scheduling problems which they encountered in their home situation.

VIII. Evaluation

QUIZ: ELECTRICAL ENERGY MANAGEMENT

NAME ____________________

Directions: Give short answers for the following. Use complete sentences where appropriate.

1. List four sources of energy used to generate electricity.
2. Give two main reasons for conserving our use of electricity.
3. What is the major reason most households and businesses are using more electricity now than 20 years ago?
4. Give the advantages of the "demand" meter over the "straight" meter.
5. List two ways that a family can reduce its "peak demand" for electrical power.
6. List three ways that one can reduce the amount of electricity used in heating home or business.
7. Explain the term "EER" (Energy Efficient Ratio).
8. List three ways to reduce the amount of electricity used to heat water.
9. Give an example of how to reduce the use of electricity when cooking a meal.
10. List two adjustments in your lighting system which will reduce the amount of electricity used.
11. Using the given list of electrical appliances, prioritize it, starting with the one most needed.

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APPENDIX

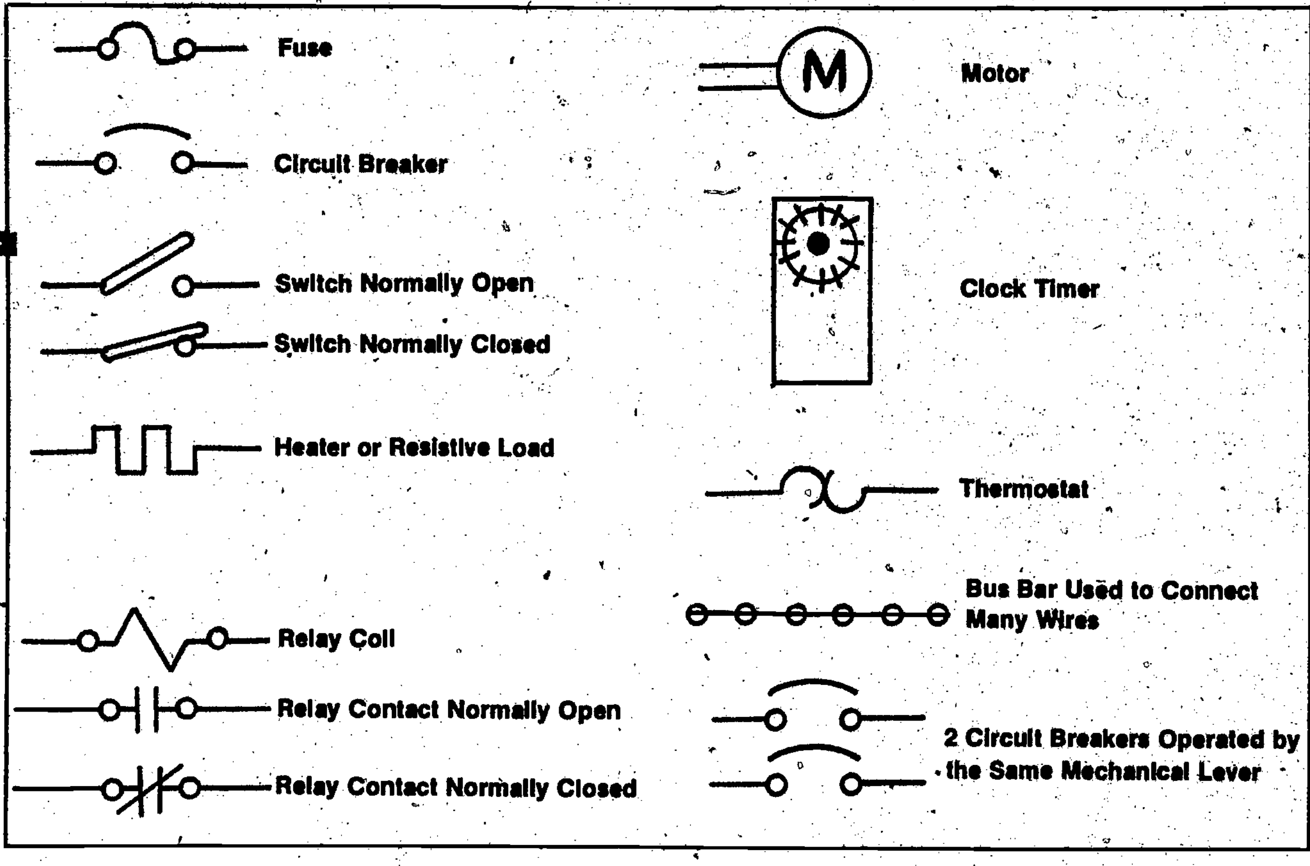


FIGURE 1. Devices for controlling peak demands.

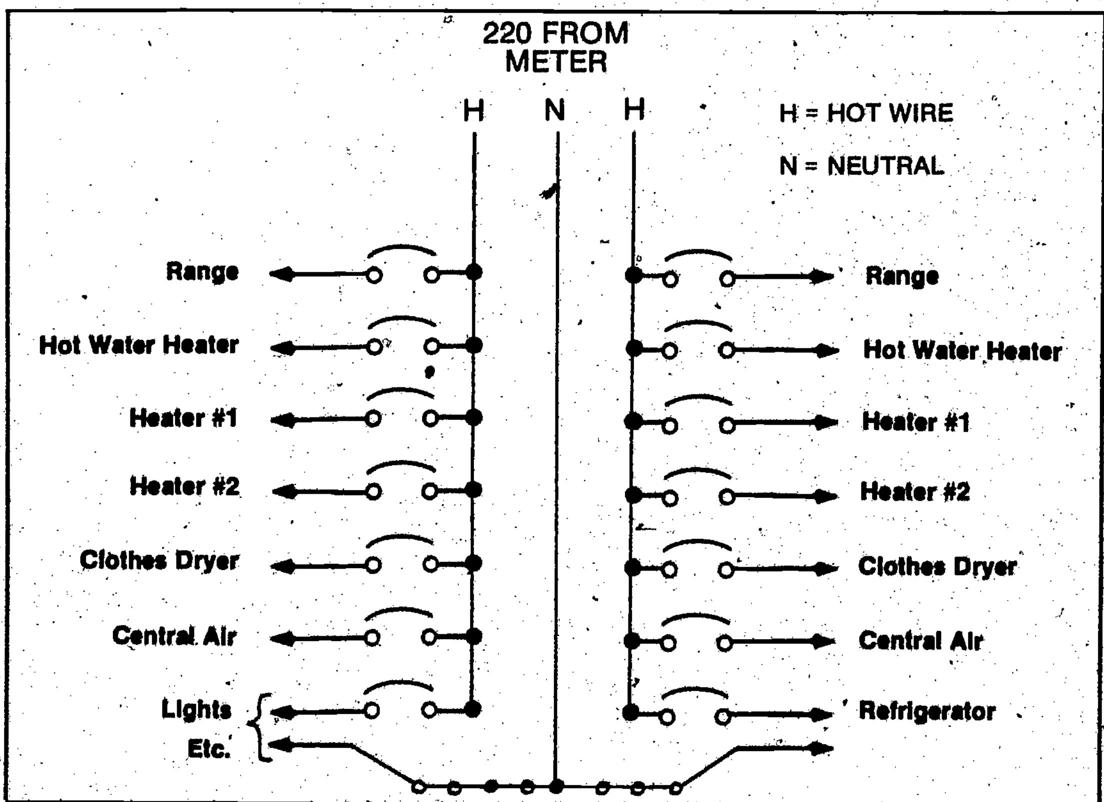
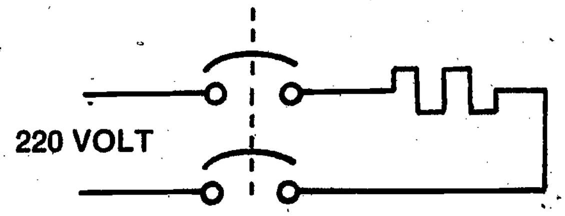


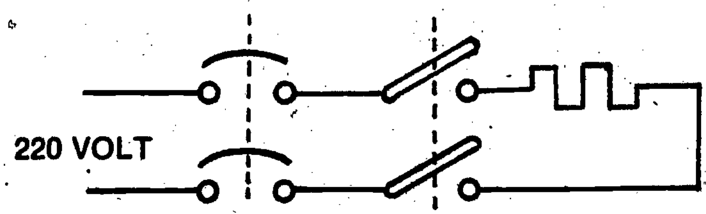
FIGURE 2. One type of home distribution panel with loads shown.

(*Note:* All loads with the exception of lights and refrigerator are shown wired for 220-volt operation. Lights and refrigerator are wired for 110-volt operation.)

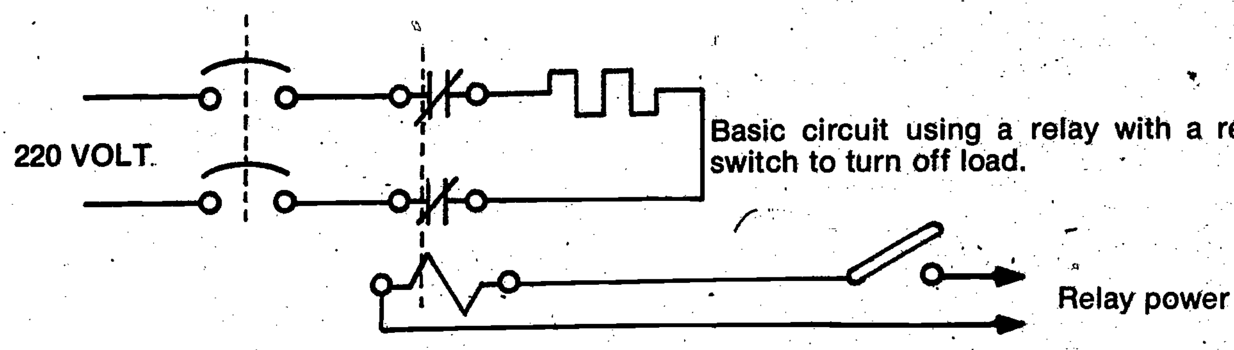
(***Source*** of Figures 1-7: M.J. Sciarini, Department of Agricultural Engineering, OARDC, Wooster, Ohio)



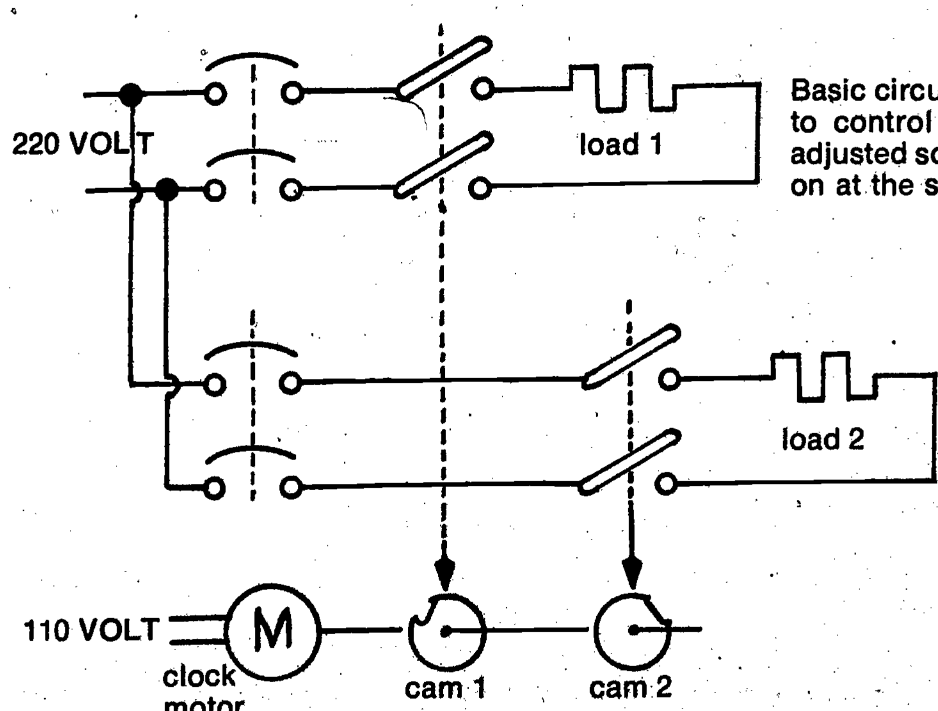
Basic circuit using circuit breaker to turn off load.



Basic circuit using a switch to turn off load.

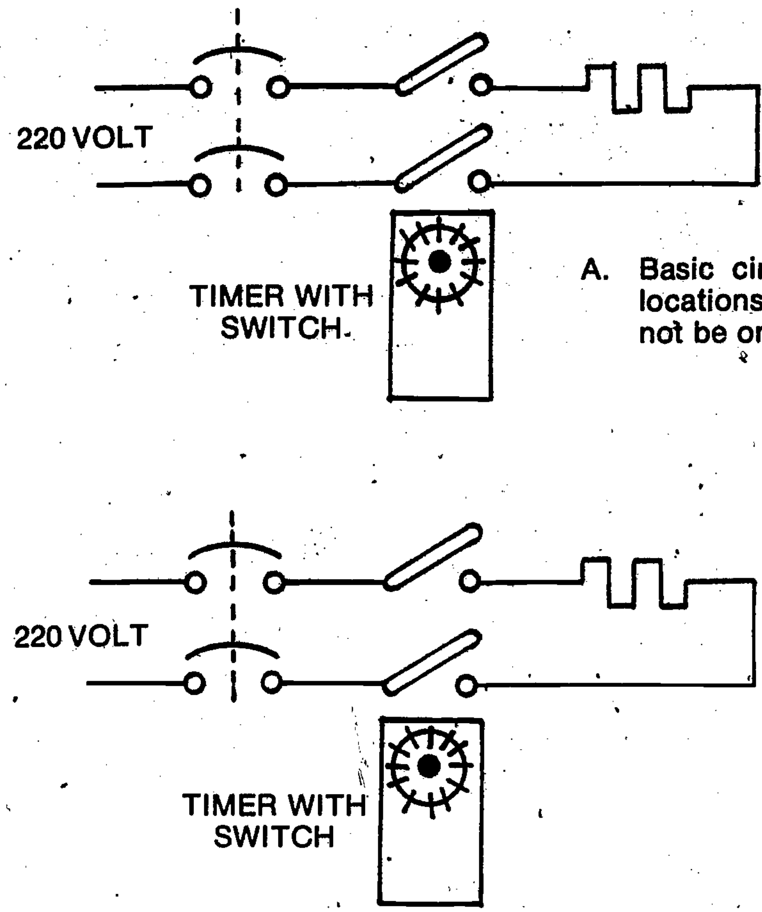


Basic circuit using a relay with a remote switch to turn off load.

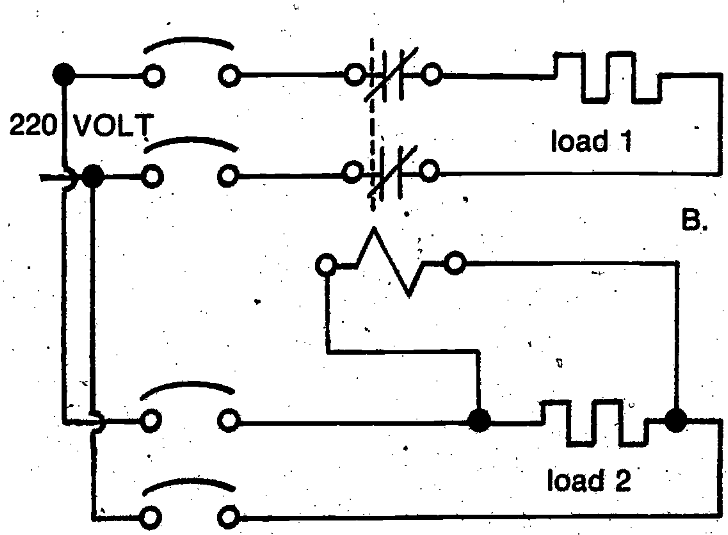


Basic circuit using a cam type switch to control the loads. The switch is adjusted so that both loads will not be on at the same time.

FIGURE 3. Basic circuits and switches used.



A. Basic circuit for controlling loads at different locations. Timers are set so that both loads will not be on the same time.



B. Basic circuit that uses a relay, activated by load 2 to control load 1.

Load 2 has the highest priority.

FIGURE 4. More basic circuits for controlling loads

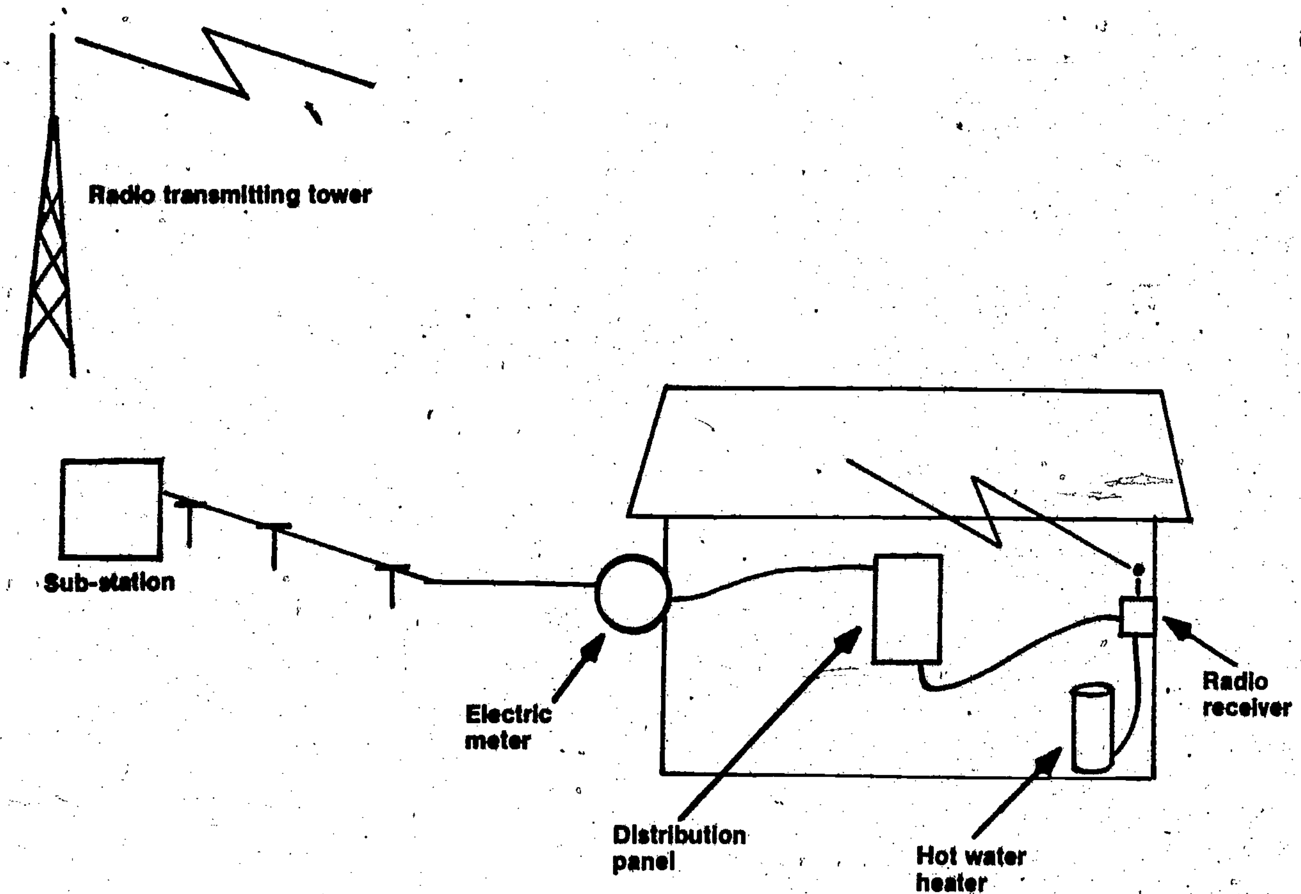


FIGURE 5.

Basic circuit using radio signal. Signal is transmitted by the power company to turn off hot water during peak load period.

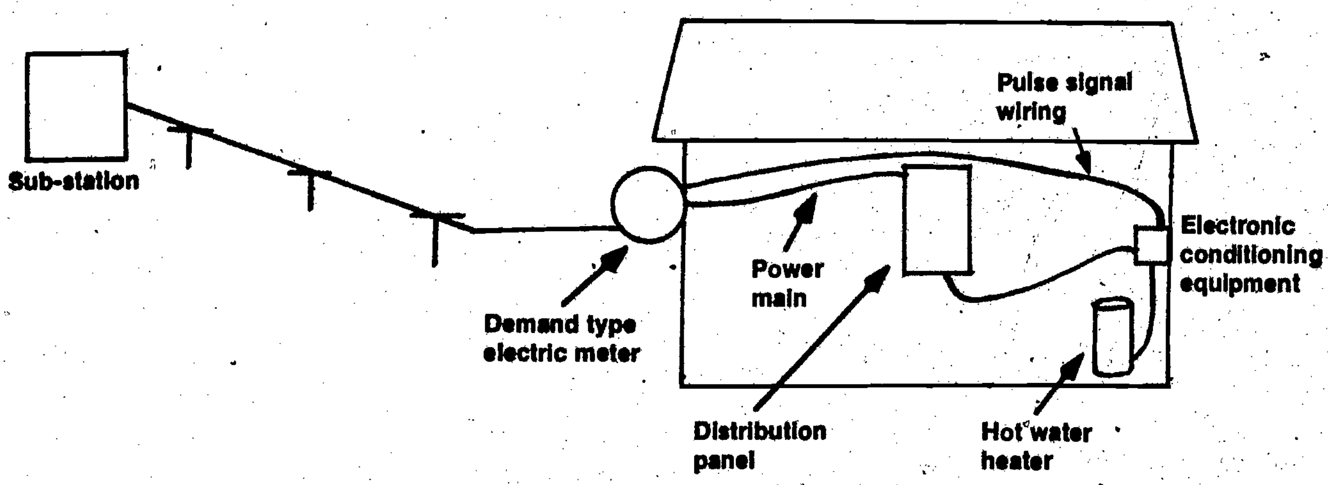


FIGURE 6.

Basic circuit using a demand-type electric meter. This meter indicates and controls electrical power usage. As the power usage increases, a pulse signal output increases and therefore is used to control electrical loads via electronic conditioning equipment.

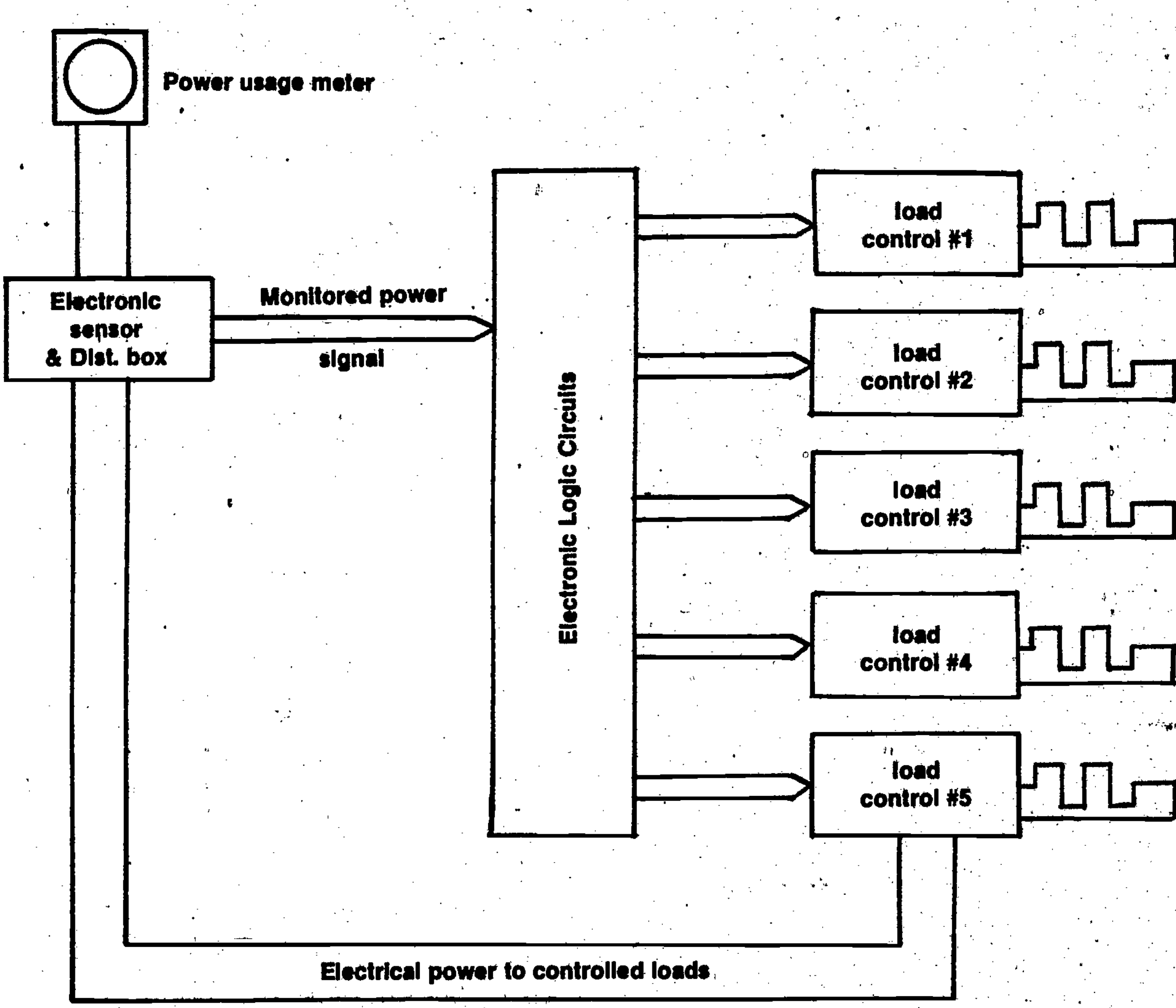


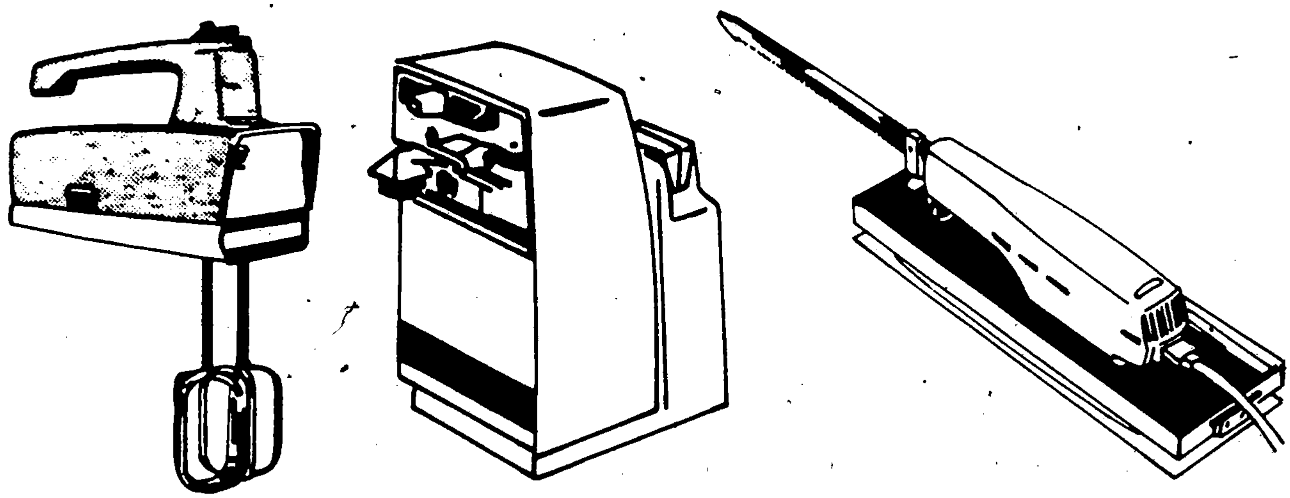
FIGURE 7.

Block diagram of one type of electronic load control and management system. The power consumed is monitored continuously and analyzed by the electronic logic circuits. The electronic logic circuits then determine which load is to be "turned off," and which load is to be "turned on."

The net result is to keep the power consumption below the demand limit.

Small Appliances

Saving energy in small ways



Many of the energy use decisions you make do not involve a great deal of energy—such as warming a single roll in the oven or tossing one pair of jeans in the washer—but these acts count up as money spent. Every time you decide to "buy" some energy, it costs you.

In this fact sheet we're talking about spending energy on small appliances. Most cost less than a nickel or so for each hour of use. But in a family where many members are often deciding to buy energy for appliances for everything from drying their hair to brushing their teeth, those decisions may be costing more than you think. Remember, the physical size of the appliance does not give any idea of how much energy it consumes. A large clock has a wattage rating of two, a small hair dryer, 1,000.

Operation

If not operated carefully, small appliances can waste energy and money. Here are some tips for prudent use:

- A faulty appliance will not work efficiently and can waste energy. Repair or replace it promptly.
- Items like electric radios are low wattage appliances, and their use doesn't contribute very much to your electric bill. Similarly, appliances that are used for brief periods, like electric mixers, carving knives, tooth brushes and small tools, have little effect on your bill.
- Using small kitchen appliances can save energy in preparing meals. Toasters, waffle irons, electric grills and skillets, egg cookers, bean pots, fondue cookers, popcorn poppers, electric coffee pots and bottle warmers usually require less energy than the range when used correctly. As with the range, it is important to turn them off immediately after use.
- During operation, keep portable cooking appliances out of drafts that reduce their efficiencies.
- Use your portable appliances that can double as serving dishes to cut down on dishes to be washed.
- Cook several foods at one time in your electric skillet to reduce cooking load and number of dishes.
- Many blower-type hair dryers require as much power as an electric toaster and for longer periods. Consider toweling and avoid overdrying.
- Be sure the TV, radio and stereo are off when no one is watching or listening. Color sets (solid state) consume 300 percent more energy then black and white sets. Instant-on TV sets use electricity 24 hours a day keeping components heated and ready for operation. Unplug these when they will not be used for a long time.
- Solid-state television sets, radios and stereos require less energy than conventional sets.
- Electric blankets allow furnace thermostats to be set lower at night than usual but should be turned off when not in use, or the gains will be quickly offset.
- Oil household cleaning devices as recommended in the use and care manual to maintain maximum efficiency. These manuals may also give additional tips on conserving energy while using the device.
- When vacuuming, empty or replace the dust bag frequently. A full bag reduces the suction and increases vacuuming time.

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HANDOUT #1 - page 2

Cost of Operation

This table is based on average wattages of appliances and an average kilowatt hour cost. To understand the "hourly cost" column, remember .045 is 4.5 cents and .0045 is less than 1 cent.

This cost of operation table is based on one hour's usage. To determine the cost, simply multiply the hourly cost by the number of hours on, or the fraction of hours on.

Appliance	Typical Wattage	Hourly "on" time	kWh Used	Hourly Cost based on $.045
Air Cleaner	50	1 hr	.05	.0023
*Blanket	175	½ hr	.09	.0041
Blender	300	1 hr	.30	.0135
Can Opener	100	1 hr	.10	.0045
Carving Knife	90	1 hr	.09	.0041
Clock	2	1 hr	.002	.0001
*Coffee Maker				
Brew Cycle	890	¼ hr	.22	.0099
Hold Cycle	50	1 hr	.05	.0023
Dehumidifier	260	1 hr	.26	.0117
Disposer	445	1 hr	.45	.0203
Egg Cooker	520	1 hr	.52	.0234
Fan				
Attic	370	1 hr	.37	.0167
Circulating	90	1 hr	.09	.0041
Furnace (⅓ horse power)	300	1 hr	.30	.0135
Rollaway	170	1 hr	.17	.0077
Window	200	1 hr	.20	.0090
Floor Polisher	300	1 hr	.30	.0135
*Fry Pan	1200	½ hr	.60	.0270
Hair Dryer, Blower	1000	1 hr	1.00	.0450
Heat Lamp	250	1 hr	.25	.0113
Humidifier	175	1 hr	.18	.0081
*Iron	1100	½ hr	.55	.0248
Mixer				
Hand	125	1 hr	.13	.0059
Stand	150	1 hr	.15	.0068
Radio	70	1 hr	.07	.0032
Radio/Record Player	110	1 hr	.11	.0050
Septic Tank Aerator (⅓ horse power)	300	1 hr	.30	.0135
Sewing Machine	75	1 hr	.08	.0036
Shaver	15	1 hr	.02	.0009
Slow Cooker				
Hi setting	150	1 hr	.15	.0068
Lo setting	75	1 hr	.08	.0036
Sunlamp	280	1 hr	.28	.0126
Television				
Black/White				
Solid State	45	1 hr	.05	.0023
Tube	100	1 hr	.10	.0045
Color				
Solid State	145	1 hr	.15	.0068
Tube	240	1 hr	.24	.0108
Toaster	1150	1 hr	1.15	.0518
*Toaster oven	1500	¼ hr	.38	.0171
Trash Compactor	400	1 hr	.40	.0180
Vacuum Cleaner	630	1 hr	.63	.0284
*Waffle Baker	1200	½ hr	.60	.0270

*Designates thermostatically controlled appliances.

Some appliances such as a clock, fan or washing machine use electricity the entire time they are turned on. Other appliances such as an oven, iron or frypan cycle on and off. Estimates of "on" time are based on the time the heat element is "on" and will be less than the actual time the appliance switch is on.

From publications of the Arizona Public Service Co., Columbus and Southern Ohio Electric Company and the University of Rhode Island, prepared by Fern Hunt, professor, home management and housing, The Ohio State University.

I. Lesson Topic:

USING SOLAR ENERGY AS A RENEWABLE ENERGY RESOURCE AT HOME OR ON THE FARM

by

BARBARA MALPIEDI and BOB BENDER

II. Lesson Objectives

The student will be able to:

1. List at least three advantages and three disadvantages of using solar energy.
2. Outline how a basic solar energy heating system operates (as given in the notes).
3. Name several factors which affect the economics of a solar energy system.
4. Given data and a blank graph, chart the typical daily solar radiation for all months of the year, applicable to Wooster, Ohio (OARDC) or Columbus, Cleveland, or other specified locations.
5. List media for heat transfer and materials for heat storage that may be used with solar energy systems.
6. Differentiate between passive and active solar energy systems by listing major characteristics of each.
7. Contribute to a class brainstorming session, citing several uses for solar energy systems.

III. Materials Needed

1. Three boxes 1' square with glass pane cover: one is unpainted, one is painted black inside, and one is painted black and insulated
2. Three thermometers
3. Overhead projector and transparencies
4. Handouts
5. Graph paper

IV. The Situation

Vocational agricultural students studying renewable energy resources have identified solar energy as one of these sources. Most of the students will probably use solar energy on their farms or in their homes. The lesson introduces them to some of the principles and practical uses of solar energy.

V. Introduction to the Lesson (Interest Approach)

"We have identified solar energy as a renewable energy source that may be used in your homes or on your farms. In order to demonstrate some of the general energy requirements and the nature of solar energy, three different boxes or 'solar collectors' have been placed outside." (It should be a sunny, cool day.) "The thermometer located inside each box gives us a temperature reading of the amount of heat in that box. This gives us an idea of how much solar energy was absorbed into that box. As you observe the boxes, answer the following questions:

1. Which box has the highest interior temperature?

   — the black box with insulation

2. What is different about this box that may be contributing to the higher temperature?

   — it is painted black

   — it is insulated

3. What advantages are there in producing heat with solar energy over producing heat from burning wood or using gas, oil, or electricity?

   — energy is free

   — solar energy is non-polluting

Let's return to the classroom and expand upon some of these ideas."

VI. Problem Statements/Questions to be Answered

"The three boxes are primitive means of capturing solar energy. What questions do you have about solar heating and solar energy?"

Draw possible responses:

1. What other advantages and disadvantages are there in using solar energy?
2. How do solar energy systems work?
3. What is required so that solar energy systems can be used at home or on the farm?
4. What are the different types of solar systems used for heating?
5. What are the practical applications for solar energy systems?

Deal with one question at a time:

A. ***"What other advantages and disadvantages are there in using solar energy?"***

Lecture/Discussion:

1. What **advantages** did we observe from the demonstration boxes outside? Solar energy is:

   - free energy (that is, the energy itself, not the system)
   - non-polluting

   Other advantages are that it is:

   - non-political (whereas oil and gas imports are 'political')
   - non-destructive
   - non-exhaustive (relatively speaking)
   - fixed cost system

2. What **disadvantages** are there?

   Lead question: "Is the sun radiation always the same?" (Show transparency or make reference to Figure 1, "Hourly clear day radiation.")

   — No, radiation levels differ night and day as well as on cloudy days and seasonally.

   Question 2: "Do we receive all the sun's radiation that is originally displaced into the atmosphere?" (Refer to Figure 1 again.) — No.

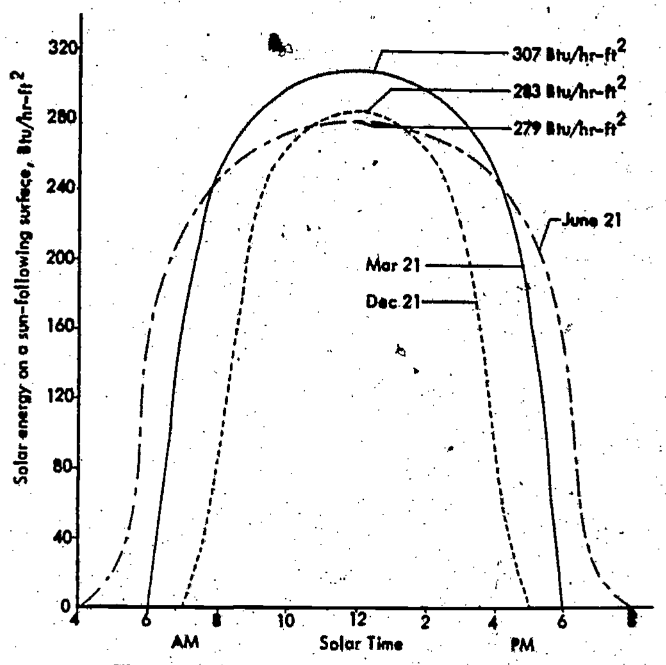

***Figure 1.* Hourly clear day radiation.**
(Source: MWPS-22, *Low Temperature & Solar Grain Drying Handbook*)

Question 3: "The energy itself is free; however, what costs will be involved?"

- equipment costs
- panels
- pumps, etc.
- heat transfer and storage media
- depending on the system, a high initial investment (partly due to lack of mass production)
- maintenance

Have students list in their notes all advantages and disadvantages discussed.

At this stage of the lesson, or perhaps even earlier, the teacher should show slides, pictures, or diagrams of several solar systems such as solar water, glass windows in a house, grain drying, livestock buildings, and maybe photovoltaic. For each system mention type of collector, storage (if any), transfer medium, and controls. This activity will give students a feel for the material before they are exposed to a large number of details.

B. ***"How do solar energy systems work?"***

Lecture /Discussion:

1. *Lead question:* "What was used in the experiment outside to capture the sun's radiation?"

— a black box

"So we have a **collector** absorbing radiation."

Question 2: "What do you think was one reason for covering and insulating the box?"

— to keep the warm air inside

Question 3: "When the sun goes down, the interior air temperature of the box drops. What could we put in the box to hold the heat?"

- water (efficient storage - 62.4 Btu/ft³ °F)
- rock (20-25 Btu/ft³ °F)
- phase change materials (pcm) - several salt hydrates. Will store 5,000 to 10,000 Btu/ft³ at their melting point. Most expensive.

"So we also have a **storage place** for the solar heat."

Question 4. "Suppose we wanted to use that solar energy to heat an adjacent building. How could we transfer the heat inside the box?"

— Connect the building and collector with an insulated pipe allowing the heat to flow from collector to building. This usually requires a fan.

"So now we are using air in the connection pipe as a **transfer medium** to distribute the heat to the point of use. Water and other liquids may also be used as transfer media. (Passive systems usually do not require a transfer medium. However, if the medium is needed, the system is called *Passive Hybrid Design.*)

Note: In most active solar systems the storage is separated from the collector. For example, the collector may be on the roof and the storage will be in an insulated container inside the building.

Question 5:" What else should the system include so that we can maintain the temperature desired?"

— controls (differential thermostat to turn fan or pump on and off)

"Now we also have manual or automatic **controls** to monitor and regulate our system."

Question 6:"For those days when there are low amounts of solar radiation, what else should the system include?"

— an auxiliary heater

"We also have a dependable heat source for times when no solar energy is available."

Summary of How Solar Energy Systems Work

1. Radiation is absorbed by collector, converting it to heat.
2. Solar heat is transferred by air or liquid to storage or end use.
3. Operation is monitored or controlled.
4. Auxiliary heater is available as a back-up.

C. ***"What is required so that solar energy systems can be used at home or on the farm?"***

Lecture/Discussion:

Lead question: "What were the characteristics *outside* of the solar collector box that had the highest *interior* temperature?"

- painted black
- glass cover
- well insulated

"These would be a few requirements."

"Let's make a list of requirements that include those three." (You may need to expand the students' list.)

1. Need good absorbers - dark surfaces are best.

2. Energy must be absorbed to be converted to heat.
3. Other than absorption, solar energy must be transmitted through or reflected from surfaces to increase energy collection.
4. Building must be well insulated to reduce total heat needs.
5. House or building heating load must be computed so that amount of energy required is known. Consider fuel bills (for existing house).
6. A back-up heat source. (Solar system should account for 25-75%.)
7. Heat transportation medium - water, air, other non-freezing liquids.
8. Heat storage - water, rock, phase change materials (pcm).
9. Collectors must be positioned so that system is most efficient.
   - location, no shade from 9 a.m. to 3 p.m.
   - orientation, optimum due south (deviate 30° east or west of due south and obtain 90% of available solar energy)
   - tilt, maximum absorption perpendicular to sun's rays (tilt angle usually 30° - 60° above horizontal)
10. The region – climate, degree days, solar radiation — must be evaluated to determine if system would be suitable.

D. *"What are the different types of solar systems used for heating?"*

"There are two basic types: Passive and Active."
(Show transparency of Table 1, or refer to reference, "Considering Solar Heat," EFS-106, pages 2 and 3.)

***Table 1.* Typical Characteristics of Solar Systems**

PASSIVE	ACTIVE
1. No moving parts. A passive system relies on natural movement or else uses the solar where it is collected.	1. Has mechanical parts. May include pumps or fans to actively move heated liquid or air from collectors to storage and from storage to use area.
2. Massive materials for heat storage	2. More conventional construction
3. Collector and storage are part of the structure.	3. Collector and storage may be added to an existing structure.
4. Windows concentrated on south side of building or house	4. Collector on south side of building or house or apart from house
5. Generally less expensive	5. Generally more expensive
6. Generally less temperature control	6. Generally better temperature control

(**Note:** With the many available types and designs of solar systems for home and farm use, there are many exceptions to the above characteristics. The teacher should not get too concerned with labeling a system *active* or *passive*.)

E. *"What are the practical applications for solar energy systems?"*

Brainstorming:

"Think of all the places where we use traditional energy sources for heat. We are going to brainstorm and try to come up with all possible ways we can use solar energy. Here are the rules:

1. Only one person speaks at a time.
2. There will be no discussion or debate on items given.
3. Every idea is to be written down.

After the brainstorming, we will evaluate the list to determine which ideas might work the best for our situations considering the information we've studied.

How can we use solar energy?"

(A possible list; you may need to write a few items first to get the group started.)

- dehydrate fruits and vegetables
- distill seawater to obtain fresh water for greenhouses
- heat pools for culturing fish
- process cheese
- cure tobacco
- pasteurize fruit juices
- heat turkey houses
- heat greenhouses

(Source: *Energy Research for the Farm*, USDA)

- heat soil
- heat homes
- dry grain
- heat livestock buildings
- heat water in a milking parlor
- heat chick brooder
- extract honey from combs
- heat broiler houses
- heat farrowing houses

etc.

With additional reference materials, students may wish to select one or more of the suggested uses for solar energy and design a plan to implement the system in their own homes or on their farms. One possibility may be home heating.

VII. Applying the Lesson to the Home or Farm

In most communities served by vocational agriculture departments, there will be a family of a student (in high school or young and/or adult farmer class) who is seriously considering the use of solar energy. The family could be considering this for several reasons, the primary one being that of saving money. A second reason, would be conserving fossil fuels.

The teacher of vocational agriculture will find that a lesson on the use of solar energy will be more meaningful to all the students if the vo-ag class can assist that member's family in making the necessary correct decisions regarding the proposed use of solar energy. If a class member's situation cannot be used, perhaps within the school community you can find another person whose situation can be used as a class problem.

The lesson could therefore logically revolve around that member's problem or decisions to be made. For example, assume that the family has decided on the possibility of using solar heat for their home. This lesson is based on that decision.

Following a brief explanation of the member's situation for which solar energy is being considered, the teacher should place on the chalkboard the following question as the problem statement:

Question: "What procedures should ___*student*___ follow in determining whether or not a solar heating system will save the family heating expense?"

Permit the students to offer various ideas as to procedures to follow. Some possible suggestions are:

1. Hire an architect

2. Talk to people who have solar heating systems.
3. Read all the information easily available on solar heating.
4. Visit a business that sells solar heating systems.
5. Use research data from colleges or research centers.
6. Use a reliable method to calculate whether or not solar heating is economical for them.

(*Note:* A family should use several of the above in reaching a decision.)

This portion of the lesson is developed around suggestion #6: Use a reliable method to calculate whether or not solar energy is feasible for a specific situation - in this case, heating a house. The system referred to is a *Solar Worksheet* (Table 2) developed by Randall Reeder, Extension Agricultural Engineer, the Ohio Cooperative Extension Service. He explains this worksheet in the Cooperative Extension Bulletin EFS-106, *Considering Solar Heat*. (This bulletin is included in the Appendix.) In order for the *Solar Worksheet* to be used, certain mathematical calculations must be made concerning the yearly cost of the consumer's fuel for heating, annual interest costs for money borrowed to purchase a solar unit, and others. Also, certain questions must be answered by the consumer and certain decisions must be made. These questions/decisions include the following:

***Table 2.* Solar Worksheet**

Here's a worksheet that can help you compare solar system cost to conventional fuel. Your answers will give you an idea of whether you can save money by installing a solar system this year. Questions one through 9 compare expected fuel savings to interest cost.

Questions 10 through 16 will help you determine how big the solar system must be. Note that this worksheet does not consider depreciation and maintenance costs. It does not account for rising fuel prices either. If you want to estimate these factors, you might assume annual depreciation and maintenance costs at 5 percent to 10 percent of the first cost of the system and add that to your answer of question eight. What if fuel prices double or triple? Recalculate questions three and four with these higher prices and compare to answer eight to see how this might affect your decision.

1. What will the proposed solar system do? (Heat house? heat domestic hot water? heat livestock building? dry grain? other?)
2. What is your present heating system? (gas, fuel oil, LP-gas, electric resistance, electric heat pump, other?)
3. How much does your conventional fuel cost per year? $__________
4. How much do you expect to save with solar? $__________
5. How much will the solar system cost? $__________
6. Considering tax credits, what will be the net cost of the solar system? $__________
7. What interest rate would you have to pay to borrow the money? __________percent.
8. Calculate your annual interest cost. (Multiply answer No. 6 times answer No. 7. $__________
9. Is answer No. 4 more than answer No. 8? (If "no," the solar system probably will not be economical for you at this time. If "yes," go on to the next question.)
10. Does the solar system include heat storage? (In water, rock, salt or other.)
11. How much heat will the solar system collect on an average winter day? __________Btu (Probably between 400 and 500 Btu per square foot of collector surface.)
12. How much heat will the solar system collect throughout the heating season? __________Btu sq. ft. per season. (May average as high as 750 Btu per day sq. ft. if used all year such as for domestic water heating.)
13. How many units of conventional fuel will that amount save per year? __________(Use the table below. For example, if a solar water heater collects 270,000 Btu/sq. ft. per season, that is equivalent to about 80 kilowatt hours of electricity, i.e. 270,000 ÷ 3,413: or about 3.7 gallons of LP-gas, i.e. 270,000 ÷ 73,600.)

Fuel	Selling Unit	Available Heat Per Selling Unit (Btu)
Natural gas	100 cubic feet	80,000
LP-Gas	gallon	73,600
No. 2 oil	gallon	98,000
Electricity	KWHR	3,413
Coal	ton	16.25 million
Wood	cord	17.9 million

14. How much money will that save per year? $__________per square foot. (Multiply answer No. 13 by the present unit price of fuel.)
15. How many square feet of solar collector are needed to save desired amount? __________ square feet (Divide answer No. 4 by answer No. 14.)
16. Is that size reasonable for your application?
17. Are there better ways to save energy instead of investing in solar? Consider insulation, lower thermostat setting, reduced ventilation rates, caulking cracks to minimize infiltration, changing management routine, installing more efficient conventional system. (Even with solar you will want to adopt appropriate energy-saving practices.

1. How much heat will the solar system collect on an average winter day?
2. How much heat will the solar system collect throughout the heating season?
3. How many units of conventional fuel will that amount save per year?
4. How much money will that save per year?
5. How many square feet of solar collector are needed to save that desired amount?
6. Is that size reasonable for your application?

Much valuable student learning can take place as this lesson is taught, since the lesson revolves around the *Solar Worksheet* and the worksheet requires the consumer/student to possess or locate certain basic information about solar energy. As the teaching of the use of the worksheet moves along, the content of the lesson is taught via the questions to be answered and the decisions to be made.

Procedure for Using the *Solar Worksheet*:

1. The worksheet could be presented as the "best" simple procedure for student to use in determining the feasibility of solar heat for the house.

2. The worksheet could be handed out to each student and time taken to get acquainted with it. Study of it will indicate the need for information about the problem situation (by selected students) not readily available. Note that questions 1 ~~through 9~~ compare expected fuel savings to interest cost. Questions 10 through 16 will help determine how big the solar energy system must be.

   With the help of the class, identify those questions that require student to ask his/her parents for the needed information. These questions are 3, 4, and 5, if the family has already done some price checking, and perhaps 7. The other questions in the worksheet can be answered by the class if you, the teacher, are adequately prepared for the lesson.

   Questions 4 and 5 apply where a salesperson is selling a specific solar system and is providing accurate performance data. But normally you must use some information from questions 11 to 15 to arrive at a total system cost or verify the claimed performance.

   As an opening class exercise the teacher may want to assume an answer for question 4 (say $400), then skip to questions 11 to 15 to size the system. Next, the teacher could contact a local solar salesperson or contractor to answer question 5, then proceed through question 9.

3. The class can proceed to answer any worksheet questions they can while waiting for student to bring information from home. Questions 11, 12, and 13 can be taught, not only in connection with the worksheet calculations, but as basic information concerning solar energy that can be used in making other decisions by the students and their families.

4. To answer the worksheet questions not dependent on information from the student, proceed with *question 5*. It may be practical to obtain prices from a local dealer. Or one could record the actual cost of a system already installed in a home in the community.

   Question 6: Information on tax credits is found in the reference bulletin, page 4, first column. Federal tax credits permit homeowners a 40% credit (maximum claim of $4,000). Ohio gives an added 10 percent tax credit to businesses and property owners who install solar systems.

   Question 7: Local interest rates should be used for money borrowed to purchase solar heating systems.

   Question 11: Information concerning the amount of heat the solar system will collect on an average winter day is found in the same bulletin, page 2, second column. More specific information concerning average total daily radiation measured in BTU/day-ft.², is found in Table 3.

***Table 3.* Average Total Daily Radiation, BTU/day-ft²**
(Collector Tilt Angle 55°)

Month	Columbus	Cleveland	Lincoln, NE	Dodge City, KS
Jan	800	750	1512	1910
Feb	1000	900	1585	1885
Mar	1300	1200	1657	1961
Apr	1400	1400	1530	1910
May	1400	1500	1499	1710
June	1600	1600	1500	1784
July	1500	1500	1501	1772
Aug	1500	1600	1608	1859
Sept	1500	1500	1618	1922
Oct	1400	1300	1688	1922
Nov	950	850	1354	1849
Dec	800	700	1390	1815

(Source: MWPS-22, *Low Temperature and Solar Grain Drying*, and Randall Reeder, OSU.)

The 400 to 500 BTU/ft² can be calculated as follows for Columbus:

November	950
December	800
January	800
February	1,000
March	1,300
	4,850

4,850 divided by 5 = 970 BTU/ft². This is the average daily amount of solar energy falling on a solar system near Columbus, Ohio.

If the system generates at 50% efficiency, then the collection by the system would be 970 x 50%, or 485 BTU/ft² per day.

If April's collection is added to the other figures, the average would be about 520 BTU/ft² per day during the heating season.

Now back to the *Solar Worksheet* questions:

Question 12: "How much heat will the solar system collect throughout the heating season?" (In BTUs per square foot per season: ________)

Total the number of days in the months of November, December, January, February, and March: 151

Multiply 151 days times the average number of BTU's collected per square foot per day during the heating season:

151 x 485 = 73,00 BTU's/sq. ft./season

Question 13: "How many units of conventional fuel will that amount save per year?"

Assume that the family presently has electric heat. 73,000 divided by 3,413 = 21.4 kilowatt hours of electricity. After question 13 is answered, use that information to determine the answers to questions 14, 15, and 16. (21.4 x 5¢/kwh = $1.07, or 375 ft.^{2} to save $400/year).

If you, as the teacher, wish to spend additional class time concerning energy saving methods in the home, question 17 provides a guide as to methods to study.

To give students a better "feel" for solar economics, assign research of a number of different situations such as solar water heater (12 months), comparing Ohio to Kansas, comparing fuels using current costs, etc.

Students should quickly understand that there is no single answer on solar systems. Many variables affect the economics of solar energy.

At some time during this lesson point out that the *Solar Worksheet* is a quick and easy way of **estimating solar economics.** Various other factors such as life of the system, maintenance, anticipated fuel inflation, and tax considerations are also important in the final decision.

VIII. Application

After the class completes its initial use of the *Solar Worksheet* in assisting *student or family* with the decision-making process, the other students could use the worksheet to compare solar system cost to conventional fuel for their homes. (Other student activities are listed in the Appendix.)

IX. Student Evaluation

SOLAR ENERGY QUIZ

Date ______________ NAME ________________________________

Score ______________

Part I. TRUE OR FALSE: Read the statement carefully. If it is completely true, write TRUE in the blank preceding the question. If any part of the statement is false, write FALSE in the blank and **correct** the statement. (50 points— 10 each)

________ 1. Solar energy systems make use of all the radiation emitted by the sun.

________ 2. Solar energy is a non-polluting, non-political, free, renewable energy source.

________ 3. Maximum radiation absorption is attained when the solar panels or collectors are perpendicular to the sun's rays.

________ 4. Solar energy may be stored in water, air, or oil.

________ 5. A passive solar heating system's structure, collector and storage are all one unit.

Part II. COMPLETION: List the appropriate responses or complete the following diagrams and graphs. (50 points)

1. List 3 advantages and 3 disadvantages of using solar power.

Advantages

a. ________________________________

b. ________________________________

c. ________________________________

Disadvantages

a.

b. ________________________________

c. ________________________________

2. Outline the five steps in the operation of a basic solar energy system.

a. ________________________________

b. ________________________________

c. ________________________________

d. ________________________________

e. ________________________________

3. Using graph paper supplied by your instructor, draw a graph plotting solar radiation for all months of the year from the Wooster, Ohio, data given:

Months of the Year	Mean Solar Radiation - BTU per sq. ft. per DA - hundreds
January	600
February	875
March	1,075
April	1,375
May	1,700
June	1,950
July	1,900
August	1,700
September	1,300
October	1,000
November	550
December	440

4. Describe the probable importance of solar energy to the homeowner ten years from now.

5. Draw a simple diagram showing how a basic **active** solar energy heating system works.

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APPENDIX

STUDENT ACTIVITIES RELATED TO ENERGY MANAGEMENT

SOLAR

1. Make a solar still.
2. Construct 3 boxes 1' square with glass pane cover. Leave one plain, paint one black inside, paint the third one black and insulate it. Set the boxes outside on a cold sunny day and record the temperature in each box.
3. Take a field trip to a solar-assisted house.
4. Form a debate team (pro and con) on solar energy.
5. Make a solar collector with copper tubing and window glass.
6. Develop a list of jobs at home which could be done with solar energy.
7. Have the student calculate the roof space of the southern exposure (or western exposure) on his/her family's house where it is undivided by gables, etc. This is done to calculate how large and how heavy a solar collector would or could be installed.
8. Have the students call various solar energy dealers to get price estimates for solar installation for different house sizes.
9. Take a field trip to a solar collector site in use.
10. Prepare a scrap book of solar energy ideas being used by farmers who have received coverage in farm magazines or newspapers.
11. Attend Farm Science Review and make sure class attention is given to solar pond.
12. Have students bring in solar powered model engine (available at solar energy dealers).
13. Have students study and report on solar energy-using livestock confinement buildings, grain drying systems, etc., currently in use and available.
14. Have students contact area weather stations to determine amount of solar energy available for collection daily over a year's time.
15. Identify various ways to conserve energy by using solar power.
16. Identify the advantages and disadvantages of solar energy.
17. Identify some of the places solar energy may be used.
18. Have student collect data on days-time of sunlight in a certain month.
19. Have student calculate the size of pond needed at given efficiency to obtain number of Btu's.
20. Make a bulletin board or school trophy case display depicting solar energy as a useful and creative alternate energy source.
21. Set up a mock solar pond model complete with brine solution.
22. Calculate the amount of solar pond surface for the house floor surface.
23. Design a heat retaining system for a greenhouse using the portable solar heater.
24. Visit the OARDC greenhouse that is solar heated. Discuss the advantages and disadvantages.

Student Activities *(continued)*

25. Visit dealer of solar drying equipment.
26. Identify various ways to conserve energy by using solar power.
27. Identify the advantages and disadvantages of solar energy in crop production.
28. Identify some of the places solar energy may be used in crop production.
29. Locate a farmer using solar energy in a livestock building. Questions should be asked as to reasons for going to solar energy, costs, savings, etc.

Ohio Cooperative Extension Service

Considering Solar Heat

For The Ohio Home and Farm

by Randall Reeder
Extension agricultural engineer

Can you afford solar?

Well, it depends. Don't pull out your hair at our straddle-the-fence attitude. But you should not make a snap decision on a solar investment of several thousand dollars. It may take a few minutes to plod through this fact sheet, but the bankroll you save may be your own.

Here are some questions you should answer before plunging into a solar committment:

- How much will the solar system cost?
- How much energy do I hope or expect to save?
- How much solar energy can I collect?
- How many days per year will I need solar energy?
- Am I talking about passive or active solar systems?
- How can I reduce total energy needs?

You will undoubtedly think of more questions. Coming up with the right questions is almost as important as finding the right answers. Often it is something you never thought of that wreaks havoc with your plans.

Now we will attempt to help you answer some of these questions. We will also raise other questions for you to ask your solar supplier or contractor.

Cost

The cost of a new American-made mid-size car won't vary much regardless of the manufacturer or dealer. But solar systems are different. You can spend less than $1,000 or more than $5,000 for a solar system that will provide 100,000 Btu on an average Ohio winter day. That's enough to heat a small, well-insulated house.

Solar system prices are often compared on a dollars per square foot of collector basis. Some simple systems consisting primarily of a low cost collector may cost only $1 per square foot. Systems with heat storage, fans or pumps and controls will usually cost at least $10 to $40. Some have a total cost upwards of $100 per square foot. You can't afford an expensive system if a cheaper one will do the job.

Note that system efficiencies must be considered in comparing systems. Efficiency depends on the quality of the design, construction and installation of the solar system and also how the solar heat is used. Although you might expect more expensive systems to have the highest efficiencies, that is not always the case. A low cost solar grain dryer may operate at 50 to 75 percent efficiency but an expensive industrial solar system with curved concentrating collectors to produce steam may deliver only 25 percent of the available solar.

Adding a solar system to an existing building is more expensive than including it in new construction. A few architects are designing solar homes that cost about the same as conventional houses.

You'll need the same furnace with solar as without it. A week with no sunshine and temperatures near zero means your old heater will have to supply all the heat. It's true that many solar-heated homes have smaller heaters, but that's only because the structures are better insulated and sealed to reduce total heat needs.

First things first

With or without solar, reducing the total heat requirements for a building is the first consideration. Insulation, storm windows, caulk and weather stripping are essential for any heated building before considering solar. These conservation measures slash fuel bills and can cut the size and cost of the conventional heating system and solar system. (Several Cooperative Extension Service fact sheets are available with detailed information.)

Installing a high efficiency heating system is a good step. Most old oil and gas furnaces waste 20 to 40 percent of the fuel consumed. Replacement with a new model may be economical.

An electric heat pump may be a good alternative to electric resistance heat. Ordinary electric heat is 100 percent efficient but heat pumps do even better. It's not magic. Heat pumps use electrical energy to take additional heat from outside air or ground water. Although heat pumps cost more and require some maintenance, they can cut heating costs because they operate more efficiently, giving you more heat for each unit of fuel you buy.

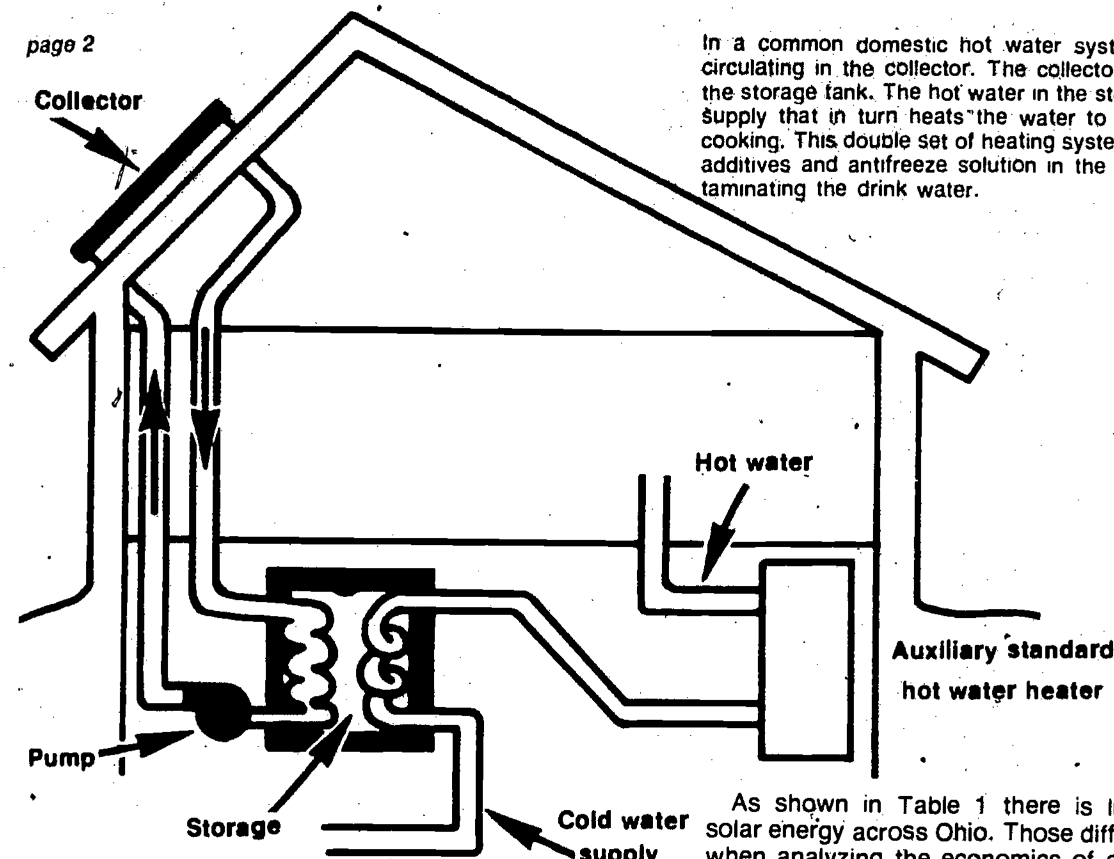
The air-to-air heat pump will save about a third, compared with electric resistance heat in Ohio. The water-to-air heat pump (using ground water at a constant 55 to 60 degrees pumped from a well) will save about two-thirds. If resistance heat costs $600 per winter, an air-to-air heat pump should warm your house for about $400 and a water-type for about $200.

Saving fuel with solar

How much fuel you can save with solar depends on how much you use or expect to use in a new building.

Solar systems with heat storage can probably save 50 percent to 75 percent of fuel needs, but trying to squeeze more from a solar system will not be economical in Ohio.

Solar systems without storage can save energy only during daylight hours, and most active solar systems will collect energy only when the sun shines bright enough to raise collector temperatures to at least 80° to 100°F. A daily average of 3¼ hours of sunshine in winter means the savings cannot exceed about 15 percent if heat requirements are constant over 24 hours. Systems that can use difuse, "low



In a common domestic hot water system, the sun heats water circulating in the collector. The collector then delivers its heat to the storage tank. The hot water in the storage tank heats a second supply that in turn heats the water to be used for washing and cooking. This double set of heating systems prevents anti-corrosive additives and antifreeze solution in the solar collectors from contaminating the drink water.

temperature." solar energy (such as a solar preheater for ventilation air) can save a little more. Later we'll help you calculate your fuel savings and system size.

How much solar?

How much collectable solar energy falls on your solar system is determined by where the system is and the direction it faces. Unfortunately for Ohioans, the best geographic site for a solar heating system is west of Columbus about 1,500 miles: Colorado. Rocky Mountain winters are cold so they need solar heat, and the sun shines about 70 percent of the possible time. Ohio winters are cold too, but the sun shines only about 40 percent of the daylight hours from November through March (Table 1). Only a few states get less sunshine than Ohio.

We point out these facts not to discourage you from considering solar but rather to emphasize the care required to make an economical solar purchase in Ohio. Besides having less solar available, energy costs (especially electricity) are often lower here than in many states.

Table 1

Average Percent Possible Sunshine

City	Nov.	Dec.	Jan.	Feb.	Mar.	Winter Avg.	Yr. Avg.
Cincinnati	44	38	41	45	51	44	57
Cleveland	31	26	32	37	44	34	52
Columbus	38	30	37	41	44	38	53

Source: U.S. National Oceanic & Atmospheric Administration.

Compare to these approximate winter averages:

- Phoenix....80%
- Denver....70%
- Wichita....60%
- Concord, N.H....50%
- Portland, Ore....30%

As shown in Table 1 there is little variation in annual solar energy across Ohio. Those differences are insignificant when analyzing the economics of a solar system.

On an average winter day in Ohio, a solar system operating at 50 percent efficiency should collect about 400 to 450 Btu/ft.². This assumes the collector faces south at an ideal tilt angle of 40° to 60° above horizontal.

Turning the collectors away from due south up to 30° east or west is acceptable, reducing the solar energy only about 10 percent. Collectors facing due west or east lose 40 percent. Collectors facing north collect only moss. A tilt angle of 20° reduces collectable solar about 20 percent. A south-facing wall collector loses 25 percent, but this may be the best choice because installation costs are often lower.

Solar 365 Days

About two-thirds of the solar energy available in Ohio comes from May to September when we don't want to heat our houses. Unfortunately, we have no economical way to store solar energy for six months.

Although it may or may not be economical to heat a house with solar energy, applications that take maximum advantage of summer solar are better. For instance, the best use of solar energy for some people might be for heating water. Why? Because you need hot water 365 days a year, and you use about the same amount every day.

Passive and active solar

The fundamental solar information presented here applies to both passive and active systems. The basic difference between the two is in how heat is moved from where it's collected to where it's used.

In active systems a pump or fan "actively" moves heated liquid or air. A passive system relies on natural movement or uses the solar where it's collected. Passive systems are usually built-in as part of a new structure. Temperature control is not as precise as in active systems. For instance, a south-facing living room in a passive solar house may be "too hot" while a room on the north side is "too cold." An active system will generally keep the whole house as comfortable as a central heating system.

A south-facing window is a simple passive collector, but it does not necessarily give a net energy gain. According to a U.S. Dept. of Energy study, a window has to be triple-pane glass or be insulated at night (insulating curtains or shutters) to provide a significant heat gain in Ohio. A double-pane glass without night insulation will lose almost as much energy as it collects, and a single-pane window is an energy waster.

Buyer beware

The solar industry is relatively new. Many small businesses have been started and many large established firms have added solar systems to their product line. Many of these people in the solar industry are competent and honest but several are not. Check out the reputation of suppliers and builders. Don't believe everything you read or hear. Advertisements and product literature often mislead the public by including half-truths and results from non-standard "tests". Even articles and booklets from neutral sources such as government agencies and universitites may not tell you all you need to know to make a sound decision.

Be alert to "package deals" that make a solar system seem better than it really is. For example, let's assume you have a large, drafty, frame house with a $1,500-a-year heating bill. A contractor offers you a solar system guaranteed to save 80 percent of your heating cost for only $12,000. As a special bonus he will blow four inches of insulation into your walls, 12 inches in the attic, and install storm windows and doors absolutely free!

"Well, now, that sounds pretty good," you figure, "For $12,000 I'll save $1,200 a year, a 10-year payback. And if fuel prices double again, that solar system could pay off in only five years."

But wait. Suppose you pay someone $3,000 for the insulation and storm windows. That alone would probably save $1,000 per year. Now how much is the solar worth?

Here's another quick example.

The ad says, "Buy a solar heater for your swimming pool, and we'll give you an insulating pool blanket of clear plastic." Fact is, if you buy the blanket you probably won't need the solar system.

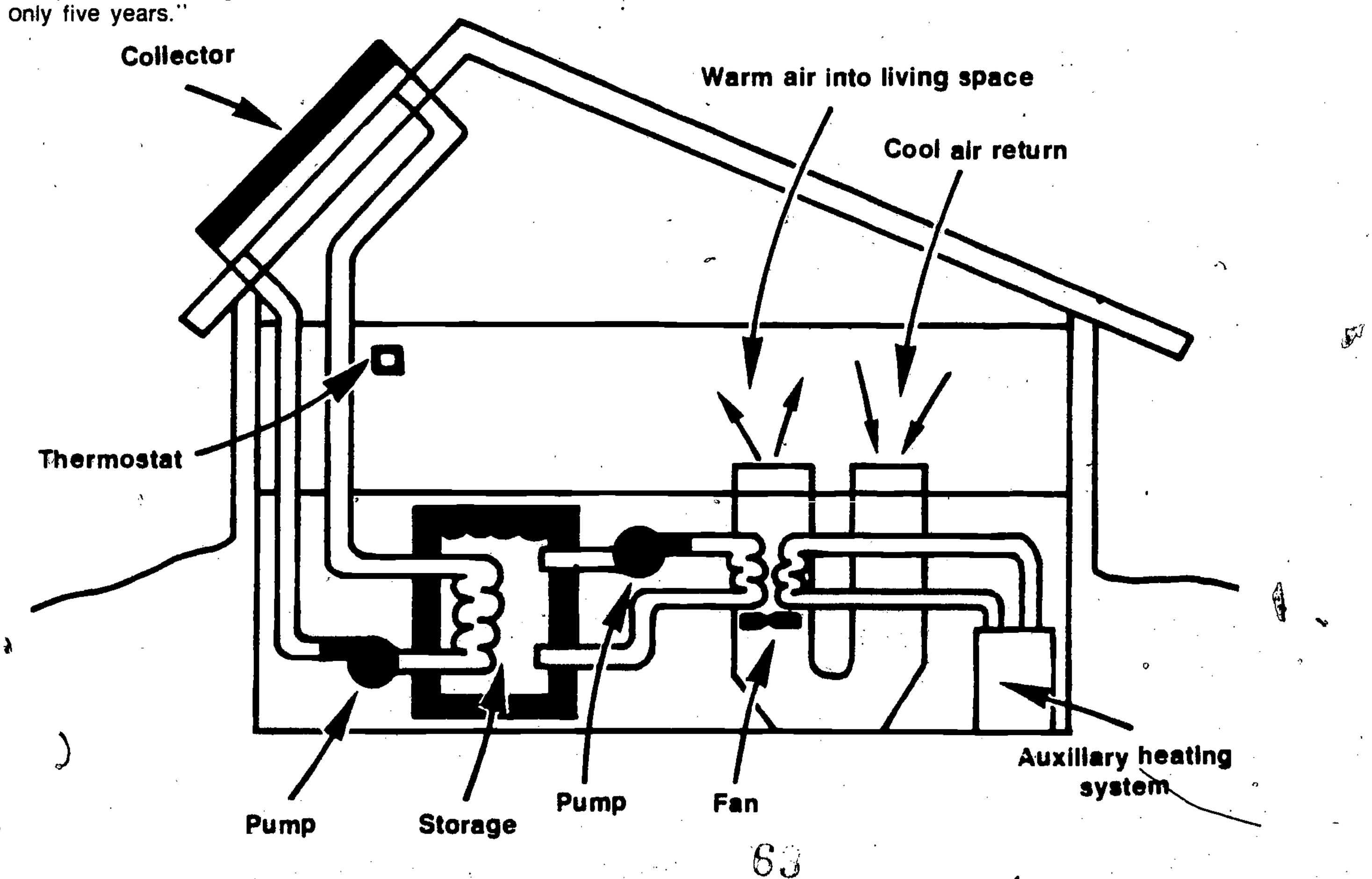
With any "solar package" analyze the parts separately so you can give credit where credit is due.

Beware of salespersons claiming a solar system will increase in value as it gets older. Parts wear out or break. Advances in technology may make the system obsolete, and potential buyers may be unwilling to pay more for a house with an out-of-date system. To be safe, figure no more than a 20-year useful life for a solar installation, adding at least 5 percent of your investment to each year's operating and interest costs.

Solar air conditioning

Although solar energy can be used to cool air, most systems are too inefficient to be economical in Ohio. Solar air conditioning has a low priority because we use much more energy in space heating and water heating.

An active heating system may be a liquid subsystem that uses water with antifreeze and anti-corrosion additives as the way to move heat from roof-top collectors into the storage or living area. An air subsystem uses air rather than water as the heat transfer medium.



Solar Tax Credits

Tax credits can significantly reduce the net cost of a solar system. A homeowner can get back 40 percent of the cost of the solar system (up to a maximum of $4,000) when filing his federal income tax form. Businesses, including farmers, get a 15 percent credit for solar investments with no maximum limit.

In addition, Ohio gives a 10 percent tax credit to businesses and property owners who install solar systems or ground water heat pumps. Together the tax credits can cut the cost of a solar system 50 percent for a home installation and 25 percent for a farm or business.

Solar worksheet

Here's a worksheet that can help you compare solar system cost to conventional fuel. Your answers will give you an idea of whether you can save money by installing a solar system this year. Questions one through 9 compare expected fuel savings to interest cost.

Questions 10 through 16 will help you determine how big the solar system must be. Note that this worksheet does not consider depreciation and maintenance costs. It does not account for rising fuel prices either. If you want to estimate these factors, you might assume annual depreciation and maintenance costs at 5 percent to 10 percent of the first cost of the system and add that to your answer of question eight. What if fuel prices double or triple? Recalculate questions three and four with these higher prices and compare to answer eight to see how this might affect your decision.

Solar Worksheet

1. What will the proposed solar system do? (Heat house? heat domestic hot water? heat livestock building? dry grain? other?)
2. What is your present heating system? (gas, fuel oil, LP-gas, electric resistance, electric heat pump, other?)
3. How much does your conventional fuel cost per year? $__________
4. How much do you expect to save with solar? $__________
5. How much will the solar system cost? $__________
6. Considering tax credits, what will be the net cost of the solar system? $__________
7. What interest rate would you have to pay to borrow the money? __________percent.
8. Calculate your annual interest cost. (Multiply answer No. 6 times answer No. 7. $__________
9. Is answer No. 4 more than answer No. 8? (If "no," the solar system probably will not be economical for you at this time. If "yes," go on to the next question.)
10. Does the solar system include heat storage? (In water, rock, salt or other.)
11. How much heat will the solar system collect on an average winter day? __________Btu (Probably between 400 and 500 Btu per square foot of collector surface.)
12. How much heat will the solar system collect throughout the heating season? __________Btu sq. ft. per season. (May average as high as 750 Btu per day sq. ft. if used all year such as for domestic water heating.)
13. How many units of conventional fuel will that amount save per year?__________(Use the table below. For example, if a solar water heater collects 270,000 Btu/sq. ft. per season, that is equivalent to about 80 kilowatt hours of electricity, i.e. 270,000 ÷ 3,413; or about 3.7 gallons of LP-gas, i.e. 270.000 ÷ 73,600.)

Fuel	Available Heat Selling Unit	Per Selling Unit (Btu)
Natural gas	100 cubic feet	80,000
LP-Gas	gallon	73.600
No. 2 oil	gallon	98.000
Electricity	KWHR	3,413
Coal	ton	16.25 million
Wood	cord	17.9 million

14. How much money will that save per year? $__________per square foot. (Multiply answer No. 13 by the present unit price of fuel.)
15. How many square feet of solar collector are needed to save desired amount?__________ square feet. (Divide answer No. 4 by answer No. 14.)
16. Is that size reasonable for your application?
17. Are there better ways to save energy instead of investing in solar? Consider insulation, lower thermostat setting, reduced ventilation rates, caulking cracks to minimize infiltration, changing management routine, installing more efficient conventional system. (Even with solar you will want to adopt appropriate energy-saving practices.

Issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914 in cooperation with the U.S. Department of Agriculture, George R. Gist, Acting Director of Cooperative Extension Service, The Ohio State University.

I. **Lesson Topic:** **USING WOOD AS A RENEWABLE ENERGY SOURCE**

by

BARBARA MALPIEDI

II. Lesson Objectives

The student will be able to:

1. Identify and list major uses of land in the U.S.A. and state the percentage of land used by forests according to the land use diagram.
2. List and/or recite reasons why wood is a renewable energy source based on the definition of *renewable energy sources*.
3. Using notes and reference materials, outline at least four (4) ways in which wood is used as an energy source.
4. Calculate the estimated timber volume of a woodlot, given sample plot data.
5. Define *standard cord* in terms of dimensions and cubic foot volume.
6. Calculate the number of standard cords in a stack of wood, given data dimensions.
7. As indicated on class handouts, list the qualities and characteristics of firewood that is suitable for burning.
8. Outline a management plan for a woodlot that will be used as a source for firewood.
9. With environmental considerations in mind, recite and/or list possible solutions to given problems as a result of Timber Harvest.

III. Materials Needed

1. Overhead projector/transparencies
2. Numerous handouts
3. Chainsaws, axes, wedges, safety equipment, fuel, if firewood project is included
4. Tree identification references
5. Supplemental heating system references

IV. The Situation

Vocational agriculture students have identified wood as one of the renewable energy sources. The following lesson will review with students the various uses of wood as a fuel source, the management and wise use of home wood resources, the practicality of wood as a home heating source, and the utilization of wood stoves and fireplaces. It should be impressed upon students that wood is only a renewable energy source as long as wood resources are wisely managed. Also the success of wood as an energy source lies in the hands of researchers and wood technologists who will be responsible for finding the key to the efficient production and use of our wood resources.

V. Introduction (Interest Approach)

GROUP DISCUSSION

Lead question: "How is land used in the U.S.A.?"

Student responses: Farming - cropland
pasture or grazing

Residential - urban homes

Industry and business

Recreation

Some land isn't usable - deserts (or limited surface use)

"In terms of millions of acres, try to guess how many acres in the U.S.A. are covered in some form by forests."

(Take several guesses.)

"Here is the total picture of major land uses in the U.S.A." (Show Figure 1 as a transparency.) "How many million acres are in some way forested?"

— 732 million acres

"Imagine how many trees that would be in 732 million acres! Imagine how much wood this could mean for potential energy supplies. Is wood a renewable energy source?"

— Yes.

"Why?"

— Wood is a renewable energy source because it can be managed so that the supply is continuous. New trees can be grown to replace those cut down to meet energy needs.

"Since we have identified wood as a renewable energy source, what questions do you have about using wood as an energy source?"

Possible questions/responses:

1. How is wood being used as an energy source?
2. How do we best manage wood resources at home or on the farm so that wood is always available for use?
3. How practical is heating our homes with wood?

"During the lesson we'll try to answer these questions as well as any others that come up."

VI. Solutions to Questions

Question 1: "How is wood being used as an energy source?" *(Write question on chalkboard)*

Possible student answers:

1. as firewood
2. as a source for methane gas production
3. as waste wood for generation of electricity in forest products industry and some municipal power plants

As Firewood

"Back in the 1800's wood supplied 80-90% of the country's energy needs. If we were to use the *same* amount of firewood as our ancestors did, our wood resources would be quickly depleted. However, we still can use wood for a portion of our heating energy needs. Many of you students have woodlots that, if managed correctly, could provide both timber *and* wood for heating purposes. Let's spend some time learning more about the use of wood as a renewable energy source, especially for heating purposes. At a later date, perhaps we will find time to study other uses of wood as an energy source."

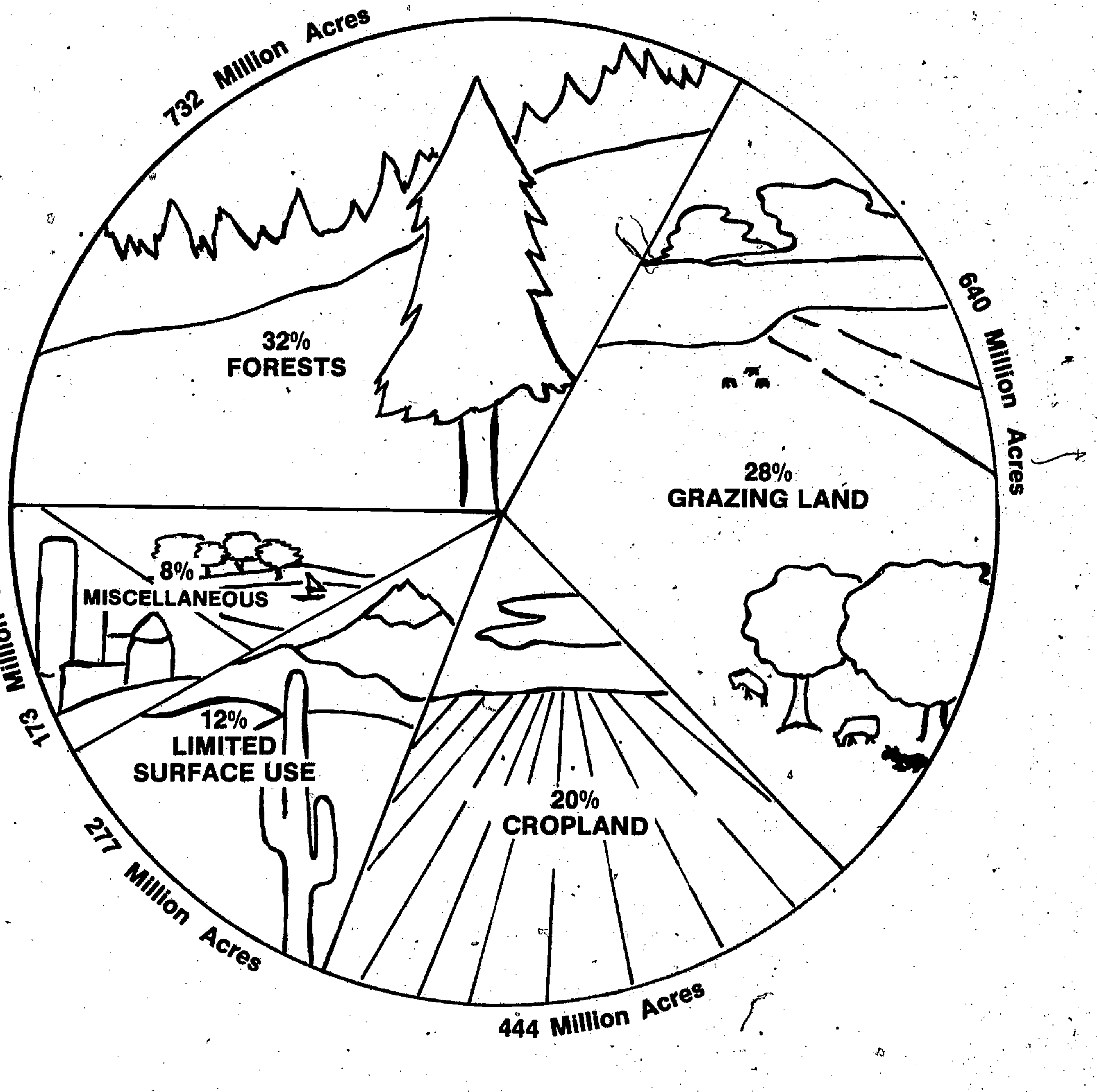


***Figure 1.* Major uses of land in the U.S.A.**

Source: *Harvesting Wood Products.* Vocational Instructional Services, Ag. Ed., Texas A & M University, College Station, TX, August 1976.

Question 2: *(Write question on chalkboard)*

"How do we best manage wood resources at home or on the farm so that wood is always available for use as an alternate energy source?"

A. *Introduction:*

Total above-ground wood, bark, and foliage on U.S. commercial land is equivalent to some 20 to 30 billion tons. The material is 80% wood, 12% bark and 8% foliage. Stump and roots add perhaps another 4 to 6 billion tons, but add little potential for use. Annually timber removal amounts to about 340 million tons of wood, bark, and foliage. Of this, approximately 145 million tons remain in the forest as unused logging residue. From your previous reading, how does the Forest Service plan to manage their forests?"

1. Evaluate their total resources.
2. Find several uses for the product.
3. Select trees or develop a tree removal plan that will also enhance the value and longevity of the forest.
4. Replant fast growing or high quality species of trees.
5. Manage the forests so that soil and wildlife are not jeopardized.

"You will want to do some of the same things in your home woodlots or in other woodlots where you are permitted to remove timber."

B. *Solution:*

"In developing a management plan for our home woodlot, what would be some management decisions that we would probably need to make?"

Possible student answers:

1. Which trees should we select for firewood that would make the best fire?
2. Which trees should we leave in the woodlot?
3.

C. *Question:* "Is one tree better than another? (Show Tables 1 and 2 as transparencies or give each student a copy.) "Select good firewood species from Tables 1 and 2 based on the given wood characteristics and qualities."

1. "Put checkmarks on the two tables by ten (10) tree species that would be better than others for firewood."

***Table 1.* Characteristics of woods for fireplace use**

Species	Ease of Starting	Coaling Qualities	Sparks	Fragrance	Heating Class (I best)
Apple	Poor	Excellent	Few	Excellent	II
Ash	Fair	Good	Few	Slight	II
Beech	Poor	Good	Few	Slight	I
Birch (White)	Good	Good	Moderate	Slight	II
Cedar	Excellent	Poor	Many	Good	III
Cherry	Poor	Excellent	Few	Excellent	II
Elm	Fair	Good	Very few	Fair	II
Hemlock	Good	Low	Many	Good	III
Hickory	Fair	Excellent	Moderate	Slight	I
Locust (Black)	Poor	Excellent	Very few	Slight	I
Maple (Sugar)	Poor	Excellent	Few	Good	I
Oak (Red)	Poor	Excellent	Few	Fair	I
Pine (White)	Excellent	Poor	Moderate	Good	III

(Source: *Supplemental Heat*, OSU Cooperative Extension Service Bulletin FS-21)

Table 2. **Energy equivalents of a cord of different kinds of wood**

A Cord of Air-Dry Wood equals		Tons of Coal	Gallons of Fuel Oil	Therms of Natural Gas	Kilowatt Hours of Electricity
Hickory, Hop Hornbeam (Ironwood), Black Locust, White Oak, Apple	=	0.9	146	174	3800
Beech, Sugar Maple, Red Oak, Yellow Birch, White Ash	=	0.8	133	160	3500
Gray and Paper Birch, Black Walnut, Black Cherry, Red Maple, Tamarack (Larch), Pitch Pine	=	0.7	114	136	3000
American Elm, Black and Green Ash, Sweet Gum, Silver and Bigleaf Maple, Red Cedar, Red Pine	=	0.6	103	123	2700
Poplar, Cottonwood, Black Willow, Aspen, Butternut, Hemlock, Spruce	=	0.5	86	102	2200
Basswood, White Pine, Balsam Fir, White Cedar	=	0.4	73	87	1900

Assumptions —

Wood: 1 cord = 128 cubic feet wood and air or 80 cubic feet of solid wood at 20% moisture content. Net or low heating value of one pound of dry wood is 7,950 Btu. Efficiency of the burning unit is 50%.

Coal: Heating value is 12,500 Btu per pound. Efficiency of the burning unit is 60%.

Fuel Oil: Heating value is 138,000 Btu per gallon burned at an efficiency of 65%.

Natural gas: One therm = 100,000 Btu = 100 cu. ft. Efficiency of burning is 75%.

Electricity: One KWH = 3,412 Btu. Efficiency is 100%.

Example

A cord of American elm is equal to 103 gallons of oil. If oil is 80¢ a gallon, you can pay up to about $82 for a cord. If the wood costs more, then oil is the best buy. The elm is also equal to 12,300 cu. ft. of natural gas. If gas is $3 a thousand cu. ft., you can pay up to about $37 for a cord. It is also equal to 2,700 Kwh of electricity. If your electric heat costs 4¢ per Kwh, then you can pay up to $108 for a cord of American elm.

Remember — The volume of one standard cord of wood is 128 cu. ft. You must use this measurement to make a fair cost comparison to your present fuel.

(Source: *Wood-burning Stoves*, OSU Cooperative Extension Bulletin L-309)

2. "Circle the names of the checkmarked trees that you have in your own woodlot." (Some students may not know what trees are available in their woodlots or in timber available for cutting. A good learning activity may include going to a woodlot and practicing tree identification. Golden Guide, *Trees of North America*, and USDA Forest Service, *Important Trees of Eastern Forests*, are excellent reference guides.)

D. *Question:* "What would be the consequences if you cut only high quality, mature trees from your woodlot?"

1. A lot of smaller quality trees would remain.

2. Numbers of dead or disease-damaged trees would increase.

Now students will probably ask the question: "Which trees *should* we cut?"

Answer: "Quality firewood can be obtained from even the most poorly formed or worst-looking trees in the woodlot. Picture some forest industry operations that remove quality logs from the forest and leave all the forest residue lying on the ground. Now we see a need for management plans to use *all* forms of wood for energy. You can improve the value of your woodlot while gathering firewood if you apply a few Timber Stand Improvement techniques." Before starting on the specific techniques, ask:

E. *Question:* "How much wood is in a cord?" Answer by sharing Figure 2 with the students.

Timber Stand Improvement Techniques

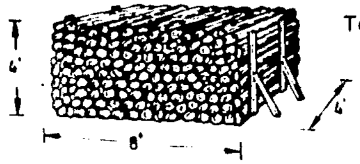
1. "A typical woodlot has a sustaining yield of about ½ cord per acre per year. To obtain the most value, cut those trees that will give more room for the growth of the best trees in the woodlot.

2. Remove crooked, forked, dead, top-spreading and crowded trees to decrease tree competition and increase stand quality (see Figure 3). (Many of these trees will be good firewood species.)

3. Use as much of the tree as possible for firewood and even firewood kindling.

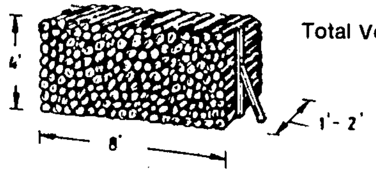
4. Set up an acre or plot rotation so that each year you improve the quality of another part of the woodlot by cutting from only those plots.

Standard Cord



Total Volume = 128 cu. ft.

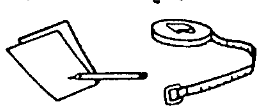
Face or Short Cord

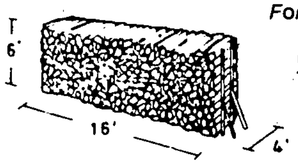


Total Volume = 32 to 64 cu. ft.

A pick-up truck with a bed 4 feet wide, 8 feet long and 19 inches deep will hold about a 16-inch face cord. That is 1/3 of a standard cord. A dump truck may hold up to 4 standard cords. After you stack the wood, you can measure it for the purpose of making the fuel cost comparison.

To calculate the number of cords in a stack of wood, multiply the pile's height by its length and then by stick length (all in feet), then divide by 128.





For example:

$$\frac{6 \times 16 \times 4}{128} = 3 \text{ Standard Cords}$$

***Figure 2.* Measurement units of a cord of wood.**

(Source: *Wood-burning Stoves*, OSU Cooperative Extension Service Bulletin L-309)

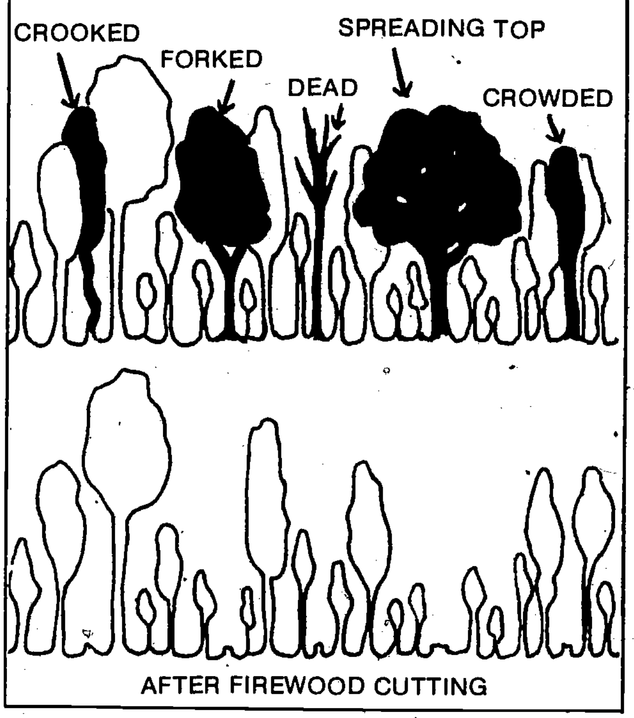


***Figure 3.* Improve the value of your woodlot while gathering firewood.**

(Source: Ohio Forestry Service)

5. Establish a reforestation program for your woodlot; replant any cleared areas with seedlings. (Contact your service forester or county extension agent for assistance.)

6. Woodlot or forestry operations can have some devastating impacts on the environment. Some of these are listed in Table 3. Try to suggest ways in which these problems can be minimized so that we don't upset the ecological system of the forest." (Table 3 could be put on a transparency.)

***Table 3.* Timber harvest-caused problems and solutions.**

Problems as a Result of Timber Harvest	**Possible Solutions** *(students generate answers)*
Den trees, animal homes, and habitat destroyed	Leave a few den trees. Construct artificial nesting boxes; build brush piles. Cut in sections and allow understory regrowth.
Erosion due to barren soil and tree removal	Develop access roads for travel. Leave some harvesting residue. Replant trees.
Falling trees damaging standing trees resulting in disease and insect infestation	Direct the fall of the trees into more open space. Remove severely damaged trees. Prune, if possible.

F. *Suggested Teacher Activity*

Select an area of the school land lab or have the service forester set up a timber stand improvement project for the class in the community with an area tree farmer. Demonstrate chainsaw use and safety; help students develop skills in timber removal. Often an arrangement can be made so that class members are "paid" for their work or can take a percentage of the firewood cut for their own club or FFA sales.

Question 3. "How practical is heating our homes with wood?" *(Write question on chalkboard)*

Lecture/Discussion:

1. "We have already studied the amount of energy in BTU's that can be derived from wood of different species of trees. How does this compare to other heat sources?"

   (Again show Table 2 as a transparency or use it as a handout. Help students make conclusions from this table.)

   - Electric heater is 100% efficient;* however, it does not have the available heat per million BTU's that wood has. Also it is more than three times as expensive.
   - Oil and coal heaters are less efficient than this particular type of wood stove (air-tight). Both are more expensive than wood.
   - Gas is more efficient than wood, but is more expensive. (This expense probably will continue to increase.)

2. "Some of you have electrically heated homes. Let's evaluate one home owner's heating costs with and without a wood stove as supplemental heat." (Show transparency of Table 4.)

*The actual **generation** of electricity — the conversion of fuel to electrical energy — is less than 50 percent efficient in even the most modern plants.

***Table 4.* Comparison of heating costs with and without a wood stove** as supplemental heat for a three month period, 1976 and 1977**

	1976 (Without Stove)			1977 (With Stove)		
Month	**Kilowatt Hours Used**	**Cost per KWH**	**Total Cost**	**Kilowatt Hours Used**	**Cost per KWH**	**Total Cost**
October 14 to November 11	4492	0.0247	$ 111.06	1668	0.043	$ 72.51
November 11 to December 13	6687	0.0250	$167.18	3139	0.040	$126.35
December 13 to January 13	9399	0.0258	$241.06	4196	0.031	$132.99

ADDITIONAL KILOWATTS REQUIRED WHEN STOVE NOT IN USE

Date	**Time Period**	**Temperature**	**KWH Used**	**Kilowatts Used per Hour**
January 21 to January 23	53 hours	High 16°	198	3.73 KW per hour (stove on)
January 23 to January 24	19 hours	High 30°	241	12.68 KW per hour (stove not in use)
January 24 to January 25	24 hours	High 36°	114	4.75 KW per hour (stove on)

**Lowell E. Hedges residence, 3960 LaRue-Prospect Road S., Prospect, Ohio 43342

"How much money is saved in one season or three-month period?"

111.06	167.18	241.06	
- 72.51	- 126.35	- 132.99	
38.55 +	40.83 +	108.07	= $187.45

"We are making the following assumptions (based on information from *American Forest Magazine*, "Wood Heat: Participating Energy," October, 1978):

- You have access to your own wood.
- You and another person cut it because you can use it in your home and because you enjoy being outdoors getting the exercise.
- You use 4½ cords per season.
- The wood is a supplemental heat source for your electric home.
- The savings in electrical heat costs are projected over two years since you supplied two years' worth of wood heat source in one season's cutting budget.
- You can assign a monetary value to the wood cut as income for your labor."

3. "Let's compare costs and savings." (Write the information from Table 5 on the board.)

Table 5. Comparison of firewood costs and electrical heat savings.

Firewood Costs		**Electrical Heat Savings**	
Chainsaw (initial investment)	$ 350.00	2 seasons: $187.45 x 2 =	$ 374.90
Bar and chain oil, gas and mix	125.00	9 cords/$50/cord/2 seasons	450.00
Axe	18.00		
Splitting maul (self-made)	0		
Two wedges	12.00		
Own time 60-70 hours	0		
	$ 505.00		$ 824.90

4. *Conclusion to Problem:* Savings over two years = $319.90. Next two years will continue to show savings by eliminating investment costs.

"We did not consider the cost of the wood stove or its installation, nor did we make a charge ($5.00/hour average) for our labor used in cutting the wood. Figuring those costs in, it would be a few years before actual savings was realized. But you see, just the savings in electrical heating costs alone will allow the system to pay for itself soon."

VII. Application: Student Activities Related to Energy Management

WOOD

1. Have a representative from a wood stove company make a presentation.
2. Survey residents in the area that burn wood and ask what they estimate they are saving by burning wood.
3. Have students make charts showing the heat value of wood compared to fuel oil, LP gas, and natural gas.
4. Cut a certain volume of green wood and weigh and measure it. Leave in shop or building for 8-12 weeks; then weigh and measure it again.
5. Arrange trip to local businesses to find out the types of stoves that are available in the area. Compare prices.
6. Burn different types of wood fuels to study their characteristics and heat output.
7. Do survey of all students in classes or grades in high school. Find out number with air-tight, Franklin-type stoves and those with fireplaces.
8. Find out and prepare chart on prices being paid for wood in the area.
9. Have each student take measurements of his or her own home. Suggest appropriate size wood burner for each home.
10. Keep a daily record of energy (natural gas, LP gas, oil, electric) used compared to wood used.
11. Identify some of the safety practices to follow when using a wood stove.
12. Compute BTU ratings of various types of wood.
13. View a model wood burner to identify parts, discuss draft controls, etc.
14. Have resource person give chainsaw safety talk and demonstrate operation.
15. Supervised study
    a. Each student develops a list of safety rules when using a wood stove or fireplace.
    b. Each student develops a list of directions for a stove's operation and maintenance.
16. Calculate the amount of money you could save by cutting your own firewood.
17. Construct a solar dryer for seasoning green wood.
18. Visit a woodlot and have students identify trees.
19. Contract a Timber Stand Improvement project with the Service Forester as a source of firewood for FFA sales and as an opportunity to have students practice safe chainsaw operations and timber removal techniques.

VIII. Student Evaluation

HEATING WITH WOOD QUIZ

Date ______________ NAME ______________________________

Score ______________

Completion: Fill in the blanks to complete the statements or calculate the answers to given problems. (100 points)

1. Forests account for about ________% of all the major uses of land in the U.S.A.
2. Wood is considered a renewable energy resource because:

   ____

   ____
3. List three (3) examples of how wood is being used as a renewable energy resource other than as a source for home heating.

   a. ____

   b. ____

   c. ____
4. Given the following data, estimate the number of trees that would be good firewood sources:

   Plot 1: 1000 sq. ft., 18 trees — *Woodlot size:* 2 acres

   Plot 2: 1000 sq. ft., 14 trees — 43,560 sq. ft. = 1 acre

   Plot 3: 1000 sq. ft., 12 trees — ____________ trees in woodlot
5. Calculate the number of standard cords of firewood cut. Firewood stack is 21 feet long, 8 feet high, and 4 feet deep.
   128 cu. ft. = 1 standard cord

   ____________ cords
6. List the characteristics or quality of wood that makes certain species of wood better than others to use as fuel for heating.

   a. ____

   b. ____

   c. ____
7. Briefly outline a management plan for removing firewood from your woodlot. Start with assessing your resources and end with consideration of the environment. (Use a separate sheet of paper.)
8. List three (3) ways to minimize the environmental impact upon the woodlot ecosystem from which you are removing firewood.

   a. ____

   b. ____

   c. ____

***Teacher Note* to Problem 4:**

Result: Average 44 ÷ 3 = 14 trees/1000 sq. ft.
43,560 ÷ 1000 = 43.56
14 x 43.56 = 609.84 x 2 acres = 1219.68 trees

***Teacher Note* to Problem 5:**

Result: $\frac{21' \times 8' \times 4'}{128 \text{ cu. ft.}} = \frac{672}{128} =$ 5.25 cords

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I. Lesson Topic: **ENERGY MANAGEMENT WITH MAINTENANCE AND OPERATION OF TRACTORS**

by

RAY CLEVENGER

Part 1: Reducing Energy Cost on the Farm by Proper Tractor Operation

Part 2: Reducing Energy Cost on the Farm Through Proper Tractor Maintenance

II. Lesson Performance Objectives

At the end of this lesson the student will be able to:

Part 1

1. Identify and list 5 operational procedures which, if used, will reduce fuel consumption.
2. Identify and list causes of increased wheel slippage.
3. Calculate percent tire slip.
4. Calculate tire slippage and adjust tractor weighting as needed.
5. Calculate the horsepower needed in a tractor.
6. Calculate and match machine size to tractor horsepower.
7. Identify and list factors affecting horsepower requirements of the tractor.

Part 2

8. Identify and list the common maintenance items causing reduced fuel efficiency.
9. Determine typical fuel savings which result from proper maintenance.
10. Perform (optional) the required maintenance for a gasoline engine to increase its fuel efficiency: ignition timing, point care, spark plug cleaning, replacement and adjustment, service of air cleaners, carburetor adjustments, valve tappett adjustment, and cooling system maintenance.
11. Service a diesel fuel system, properly bleed the line, service the air cleaner, and maintain cooling system.
12. Evaluate the performance of available power units on the basis of fuel efficiency.
13. Evaluate the result of overfueling a diesel.

III. Materials Needed

1. Transportation for field trips to farms, implement dealers, and student homes
2. Sample weights for tractors or access to weights
3. Handouts referred to in the lesson
4. Basic tractor maintenance tools and equipment

IV. The Situation

With the liquid fuel supply at times becoming more restricted and the cost per unit increasing, it is becoming increasingly important for farmers to take steps to get the most work possible from each unit of fuel. Studies have revealed that proper engine maintenance can reduce fuel use on the average by 15% and proper tractor operational procedures could reduce this amount by at least another 20%. This is an extremely significant energy savings and one that can no longer be ignored.

V. Introduction to Lesson

As an interest approach to this lesson, introduce the following type of situation. A similar situation can be drawn from your own students' agricultural experience programs.

> _Jim_ and _Joe_ both have a soybean project for which they fall plowed a field. They equally divided the field in which very little difference exists in soil type. Because they were to pay Dad for the fuel used, they carefully recorded the amounts used for each job. They were amazed at the results: _Jim_'s fuel usage for the same job was nearly 20% less than _Joe_'s. The only variable was the operator. Also, in comparing fuel consumption with tractor test data (Nebraska tractor tests) they found they were consuming over 20% more of what they should be to get the job done. (*Any terminology new to the students should be explained at this point.*)

Question: What causes differences in fuel consumption and lower-than-expected fuel efficiency?

Possible Student Answers:

- Difference in the way each drives (operational procedure)
- Improper matching of power and equipment
- Wheel slippage
- Poor engine maintenance
- Improper equipment adjustment or maintenance

No one wants higher-than-necessary fuel cost. Therefore, "How can operational procedures be changed to reduce fuel usage?" and "How can original fuel efficiency be regained?"

PART I. REDUCING ENERGY COST ON THE FARM BY PROPER TRACTOR OPERATION

VI. Problem Statements (Place on chalkboard)

A. ***How can _student_ operate his/her tractor differently to save fuel?***

(Present transparency and/or distribute **handout #1**, found in the Appendix. **Handout #2**, Bulletin L-306, may also be distributed at this time. Conclusions should be reached from the data presented.)

Student should operate his/her tractor near rated load. Engines operate most efficiently at near (80%) rated load.* (The instructor may wish to have the students write on page 24 their conclusions reached from the graphs presented in **handout #2.**)

B. ***What procedures should _student_ follow in matching power and equipment?***

Using **handout #3** entitled *Matching Horsepower Needs - Tractor Size and Machine Size*, evaluate the student's situation in terms of matching tractor and equipment. A field trip to a student's home to measure field equipment size, etc., may be of value and add practical experience to solution of the problem. Reference to Nebraska tractor data in **handout #4** would help determine actual drawbar power of the tractor. (Remember that the tests are conducted on concrete.) Also, these data show that the maximum HP/hr./gal. was achieved at near rated load on drawbar performance.

* Be sure to define *rated load* and any other new terms as you move through the lesson.

Refer to the following procedures when using **handout #3**.

Suggested Procedure for Using Handout #3, AM 17-72 worksheet:

Explain the worksheet, relating its use to evaluation of whether the tractor is being loaded to an efficient level (approx. 80%). Also note that draft per foot of implement is for average conditions. More exact draft measurements can be made by use of special hitches. (Refer to specific equipment draft or *FMO Machine Management*, 1975, Deere and Company, page 46.) However, because of varying field conditions, the use of averages in most cases will be quite adequate.

Complete the problems in **handout #3** (right column).

Answers are:

A (2) Horsepower
B (3) Reserve horsepower
C (4) Speed, MPH
D (1) Implement width
E (5) Total draft

1. 52.3 HP
2. 85 dbHP
3. 46.7 dbHP (250 pounds/foot was used for draft. Once the total draft of 3500 pounds is determined, refer to formula in problem no. 2 to determine dbHP.)
4. 5.64 feet (67.76 inches)
   4 (4.2) 16-inch bottoms
   5 (4.8) 14-inch bottoms

After working and explaining the above problems, solve the following student problem or a similar one for a specific student's situation.

Student's Situation and Problem — #1

"Student A and Student B have a 100 dbHP tractor. How much plow width should they be using if plowing is done at 5 mph?"

$$\text{Implement width (feet)} = \frac{375 \times \text{dbHP}}{\text{MPH} \times \text{draft per foot} \times 1.25} = \frac{375 \times 100}{5 \times 850 \times 1.25} = \frac{37500}{5312.5} = 7.06 \text{ feet}$$

Question: "How many 16-inch bottoms should they be pulling for good fuel efficiency?"

$$\frac{16 \text{ inches}}{12 \text{ inches}} = 1.3 \text{ feet} \qquad \frac{7.06}{1.3 \text{ ft.}} = 5.4 \text{ bottoms (or a 6-16" bottom plow)}$$

Question: "What are some plowing factors that would increase plowing draft and reduce fuel efficiency?"

- improper plow adjustment
- depth of plowing too great
- poor condition of plow parts (points, shears, etc.)
- improper use of draft control and/or hitching arrangement

(The teacher may wish to refer back to these points later to introduce a unit on plows and plowing.)

Student's Situation and Problem — #2

"Student has been using an 18-foot disc at about 5 MPH. Is the 100 dbHP tractor being used at near rated load? How near?"

Compute the draft for the 18-foot disc.

18-foot width x 280 pounds per foot = total draft of 5040 pounds

Formula: $\text{dbHP} = \dfrac{\text{MPH x total pounds of draft x 1.25}}{375} =$

$$\frac{5 \times 5040 \times 1.25}{375} = \frac{31500}{375} = 84 \text{ dbHP}$$

Answer: "No, the tractor is not being loaded heavily enough for best fuel efficiency."

Conclusion to problem (of inadequate loading):

1. Use a combination of machines to load the tractor to its rated capacity.

   Question: ***(Example)*** "Could ________ pull an 18-foot spike-tooth harrow behind the disc at the same rate of speed?"

   180# draft of harrow + 280# draft for disc = 460 lb./foot of width (draft)

   460# per foot x 18 ft. width = 8280# total draft

   $$\text{dbHP required} = \frac{\text{5 MPH x 8280\# draft x 1.25 reserve power}}{375} = 138 \text{ dbHP}$$

   Answer: "No, not at that speed."

   Question: "What effect would slowing to 3½ MPH have on dbHP required?"

   $$\text{dbHP} = \frac{3.5 \times 8280 \times 1.25}{375} = \frac{36225}{375} = 96.6 \text{ dbHP}$$

   Point to be Made: Speed as well as implement draft directly affect dbHP requirements. **Remember:** Speed should be determined by equipment. Most machines have a recommended speed for best performance.

2. Trade for a disc of the proper size.

   Question: ***(Example)*** "What size disc should *student* have for his/her 100 dbHP tractor?"

   $$\text{Implement width (ft)} = \frac{375 \times \text{dbHP}}{\text{MPH x draft per ft. x 1.25}} =$$

   $$\frac{375 \times 100}{5 \times 280 \times 1.25} = \frac{37500}{1750} = 21.4 \text{ feet}$$

   It should be pointed out that not all discs have the same draft characteristics because of design, angles of set, shape, and blade condition.

Summary of Approved Practices Resulting from Class Activities

1. "*Student* should use a combination of machines to load the tractor to its rated capacity when possible."

   Performing a job that is not needed to improve crop yield is a major energy waste. For instance, if adding a drag behind the disc is not needed to prepare the seed bed properly, the solution to reduced fuel cost is to eliminate use of the drag. Consideration for savings would be given to operating at a higher gear and reducing throttle if not operating at near rated load.

2. "*Student* should shift up and throttle back on light loads."

(This applies more to larger tractors under light loads.) When performing jobs requiring less than full power output (50%), reducing engine speed will improve fuel efficiency. Providing one does not lug the engine, transmission efficiency is improved by shifting up to a higher gear.

Refer to **handout #5**, Table A, entitled "600 hrs/year Fuel Use and Cost." Point out to the students that the difference between Tests C and D was that in Test D the tractor was operated in a higher gear at a reduced throttle setting. This resulted in a fuel use reduction of 778 gallons of diesel or 732 gallons of gasoline. Thus, large tractors pulling light loads can save 22.4 to 28.3% in fuel consumption by changing to a gear or two higher and then throttling back the engine to maintain the same ground speed. Also significant is the cost comparison and the 569 gallons of liquid fuel saved by diesel vs. gasoline. Use of a diesel engine as shown in Test C, working at 50% load, would reduce fuel consumption by 16%.

3. "_Student_ should shut the engine off under no-load situations."

Don't let the engine idle for long periods of time. Illinois studies showed tractors idling for more than 12% of the hours of operation were using more than ½ gallon of fuel per hour.

C. ***What procedures should _student_ follow in adding weight to the tractor to increase safety and reduce slippage?***

The following information may be used to reach a conclusion on this question.

Question #1: "Where does the tractor fuel go?" (Write the following on the chalkboard.)

Of each 100 gallons of fuel put in the tractor:

- 20-25 gallons are lost through the radiator
- 25-35 gallons are lost through the exhaust
- 10-15 gallons are lost as miscellaneous heat; so only —
- 10-35 gallons are used to produce engine output, but of this amount another:
  - — 2-6 gallons are lost in power transmission
  - — 5-16 gallons are lost in wheel slippage and rolling resistance.

(Source: Samuel G. Huber, Agricultural Engineering Department, OSU)

Therefore, only 5-20 gallons of each 100 gallons put in the tank produce drawbar horsepower (dbHP). (It should be noted that the difference in fuel losses is the result of procedures and engine maintenance, the latter point covered in more detail later in this lesson.)

The greatest loss of engine power occurs at the traction wheels. In typical field use, 20% to more-than-60% of the engine power is lost at the wheels. This loss is within the control of the tractor operator.

Question #2: "What percent slip is _student_ getting in the field?"

Procedure for determining percent slippage:

Using _student's_ tractor and tillage equipment, determine present slip in the field. (Use a chalk mark on the tire to help in counting wheel revolutions.) With the tractor and equipment operating in the field at normal operational speed, mark the distance travelled under load in 10 wheel revolutions. Then have the tractor with no load travel the same distance; carefully count the number of revolutions. The percent slip can then be determined as follows:

% slip = 10 x (10 minus revolutions with no load)

Example:

= 10 x (10 - 8.5 revolutions with no load) = 10 x 1.5 = 15%

After running the check and calculating the % slip, the following should be related to the students.

The amount of horsepower loss (15% in above calculations) due to wheel slippage and rolling resistance is determined primarily by the kind of soil surface, tire pressure, tire size, weight on the tire, and drawbar draft. (See **handout #4.**) As the amount of weight on traction wheel is increased, wheel slip decreases and rolling resistance increases (See **handout #2**, Figure 1). Thus there is an optimum weight at which the sum of the slip and resistance is minimal. Wheel slip is the best indicator of wheel HP loss. There is an optimum amount of slip for each kind of traction surface.

Question #3: "What percent slip is optimum for __*student*__ ?"

Refer to **handout #2**, Figure 2 for these conclusions:

firm soil conditions	8-11%
tilled soil conditions	11-14%
soft soil conditions	14-17%

Question #4: "How can __*student*__ obtain optimum slip?"

By matching the load to a properly weighted tractor.

Question #5 "How much ballast (weight) should __*student*__ add?"

Handout #2 can supply the correct information. The following sample problems may serve as a guide in solving the above question.

__*Student*__'s 100 PTOHP tractor pulling a disc on tilled soil at 5 MPH would require 120 pounds per PTOHP or 12,000 pounds on the rear wheels.

__*Student*__'s unballasted rear wheel weight of the 100 PTOHP tractor is 8,450 pounds. Therefore, 12,000 pounds of needed weight minus 8,450 equals 3,550 pounds additional weight needed. The tractor weight may be obtained by weighing the tractor, checking in the operator's manual, or using tractor test data (Nebraska usually prints total weights only).

Question #6: "How much of this weight could be added by liquid ballast?"

Refer to **handout #2**, Tables 1 and 2. Each one of __*student*__'s 18.4 - 38 tires would hold 1,113 pounds of liquid weight, or 2,226 pounds total. When discing, etc., __*student*__ usually uses duals, which will add 1,324 additional pounds, even though they are not fluid filled. Using single tires (8 ply), __*student*__ would be at maximum safe tire weights at 20 psi of air in the tires. By using duals he would have a margin of safety.

Question #7: "How much front end weight should __*student*__ add?" (for safety and balance)

Thumb Rule:

- Towed implement -front weight should be about 33% of rear weight.
- Semi-mounted implement - front weight should be about 40% of the rear weight.
- Mounted implement - front weight should be about 50% of the rear weight.

Solution:

1. __*Student*__'s tractor rear weight was 12,000 pounds. 12,000 pounds x 0.3 for towed implement equals 3,600 pounds. The tractor's unballasted front end is 3,870 pounds, which is adequate. However, if using mounted equipment, calculate 12,000 x 5 = 6,000 pounds. 6,000 - 3,870 = 2,130 pounds of additional weight needed. This figure emphasizes safety and weight transfer even though fully mounted equipment would not likely be used on tilled soils.
2. __*Student*__'s front tires are 11.00 - 16 (6 ply). With 28 psi, what carrying capacity do they have? (Refer to **handout #2**, Table 2.) 2 x 2,520 pounds for each tire = 5,040 pounds total. This would be

less than the desired 6,000 pounds needed for mounted equipment. In using semi-mounted equipment, the following would be true: 12,000-pound tractor's rear weight x 0.40 = 4,800 pounds recommended on the front. 4,800 minus 3,780 pounds (weight of tractor front) equals 1,020 pounds added weight needed. ***Note:*** Semi-mounted and fully-mounted implements require less added weight to the rear wheels because of weight transfer (see **handout #2**, Figure 5), thus reducing front-weighting figures in the above problem.

Question: "What procedure should <u>student</u> use to determine the proper weighting of a four-wheel-drive tractor? Why are the procedures different than for a two-wheel-drive tractor?"

A guide to the weighting of 4-wheel-drive tractors is given in Table 1. About 60% of the tractor's weight should be on the front wheels and 40% on the rear.

***Table 1.* Optimum Total Weight for 4-wheel-drive Tractors**

SPEED MPH	TOTAL WEIGHT IN POUNDS/PTOHP
4	140
5	115
6	95
7	80

Example: Versatile 835 in accordance with Nebraska test data has a maximum PTOHP of 198.

At 5 MPH total weight should be 115 x 198 = 22,770 pounds. Because this unit weighed 24,280 pounds without ballast, no additional weight is needed at this speed. It should be noted that at a slower speed of 4 MPH an addition of 3,440 pounds is needed (2,064 pounds on the front and 1,376 pounds on the rear).

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The following information is for teacher reference and may be used as needed. (***Source:*** *Fundamentals of Machine Operation, Tillage,* Deere & Company)

For a quick measurement of wheel-slippage in the field, mark a spot on the ground and a chalk mark on the rear tractor tire. Then drive the tractor under load with the implement in its normal operating mode. Count 10 complete rotations of the rear tire and place another mark on the ground. Repeat the trip without the implement and again count the wheel rotation between the two marks. Estimate the fraction of the last rotation as nearly as possible.

Check the number of rotations counted on the second trip. Using Table 2, determine the percentage of wheel slippage.

***Table 2.* Rear-wheel Slippage Chart**

Rotations	Rear-wheel Slippage Percent	What to Do
10	0	Remove ballast
9½	5	
9	10	Proper ballast
8½	15	
8	20	Add ballast
7½	25	
7	30	

If less than 8½ rotations are counted, add weight. If more than 9 rotations are counted, remove weight from the rear wheels.

If measuring tire-slippage by counting wheel rotations is not possible, one can get an approximate indication by examining the tire-tread pattern produced when pulling under load (see Figure 1).

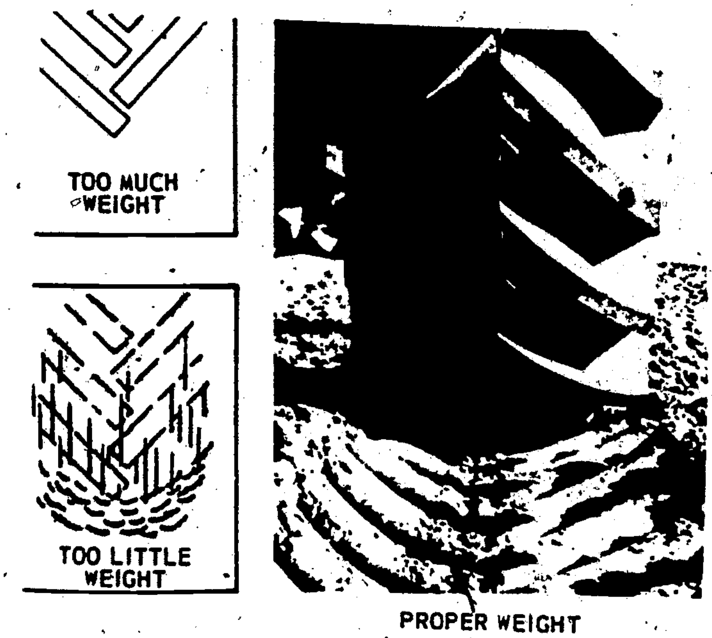


Figure 1. **The tire "footprint" is a rough guide to wheel slip.**

When **too much weight** is used, the tire track will be sharp and distinct. This does not allow for engine flexibility. Thus power needed to move is increased and dbHP is reduced.

When tires have **too little weight**, they lose traction. Tread marks are wiped out and forward progress slows.

When tires have **proper weight**, a small amount of slippage occurs. The soil between the cleats is shifted but the pattern is visible. 15% slip is barely visible. If slip can be seen, slippage probably exceeds 15%; correct immediately.

Adding weight: Adding weight of 100 pounds to the rear tires increases db pull according to the surface conditions as follows: concrete, 66 lb.; dry clay, 55 lb.; sandy loam, 50 lb.; dry sand, 36 lb.; and green alfalfa, 36 lb. Keep in mind that draft is usually much less in sand than clay, but that any extra weight greatly increases rolling resistance in loose soils. Regardless of weight added, db pull could be zero under adverse surface conditions.

Cast-Iron vs. Liquid Ballast

Cast Iron: Easy to install and remove, no special equipment or service, not lost if tire is damaged or serviced, higher initial cost, may not be enough weight, and may increase tractor width.

Liquid: Readily available, lower initial cost, excellent weight distribution, no change in tractor width, 30% heavier than water and will not freeze, is lost with tire or valve damage, not easy to remove and re-install, requires special handling and installation equipment, and slightly reduces bruise resistance of the tire (at 75% recommended fill).

Flotation: In soft, loose soil, increasing wheel diameter and width is more effective in increasing db pull than adding weight, partly because of reduced rolling resistance and better flotation. Adding duals doubles the contact area between tires and soil, but does not increase traction. Equally weighted single and dual wheels of the same size will pull almost the same load in good soil conditions. Duals increase flotation and with added weight improve traction in adverse conditions. Duals increase stability, improve performance in land preparation, are cost effective, and permit work under a wider range of conditions. They have the disadvantages of possibly overloading axles, bearings, and gears; making tractor handling more difficult; and being difficult to install and remove. These disadvantages also create safety hazards.

PART II. REDUCING ENERGY COST ON THE FARM THROUGH PROPER TRACTOR MAINTENANCE

VI. Problem Statement: ***"How can*** *student* ***improve the fuel efficiency of his/her tractor engine?"***

Answer: Proper maintenance and engine tune-up

It is estimated that U.S. farmers use about 4 billion gallons of gasoline each year. Studies have shown that this fuel consumption could be **reduced by nearly 15%** if the tractor engine is properly maintained or tuned up. In addition to this fuel savings, there would be an 11% increase in available horsepower. This savings in fuel for the entire nation could amount to 600,000 gallons per year. At a cost of $________ per gallon this fuel savings nationally represents over $________; also the fuel saved could be used to produce crops on 15% more land.

Question: "What gasoline engine components most commonly cause increased fuel consumption and loss of power?".

Answer: The value of proper adjustment of the gasoline engine is documented by many studies such as the following completed by agricultural engineers from Kansas State. A brief summary of their work reveals the following:

1. ***Ignition timing*** was off on 52% of the tractors tested. By correcting this the HP increased 5.3% and fuel consumption decreased 5.3%.
2. ***Spark plugs*** were replaced with new plugs on 90% of the tractors. HP increased 5.6% and fuel consumption decreased 6.1%. Where the tractors misfired under load with their old plugs, new plugs resulted in a 21.5% increase in power and a 14.2% decrease in fuel consumption.
3. ***Air cleaner*** servicing was required on 10% of the tractors. This resulted in a 7.6% increase in HP and an 11.4% decrease in fuel consumption.
4. ***Carburetor adjustments*** were made on 72% of the tractors: 46% had too rich a mixture and 26% had too lean a mixture. A 9.5% reduction in fuel was obtained when correcting the over-rich mixture with no change in HP output. Correcting the lean mixture increased HP 2.9% while increasing fuel consumption by 1.4%.
5. ***Governor adjustments*** were needed on 80% of the tractors. The no-load speed was too high on 32% of the tractors while full-load speed was too low on 62%. Simple repairs and adjustments corrected only 20%. This resulted in a 9.1% increase in HP and a reduction of 4.8% in fuel usage. The remaining 60% of the tractors required parts replacements before adjustments.

The overall result of the above adjustments and replacements was an average increase in HP of 11.1% with a reduction in fuel consumption of 14.4%.

Service Recommendations: (The following are very minimal. The teacher may wish to expand the details of each recommendation.) Review the operator's manual. Keep a service use record. Record fuel intake at each filling, as well as oil used between changes and during changes. Record hour meter reading and date when the next service is required. Many farmers use tractors about 500 hours/year with heavy work in the spring and again in the fall. Thus, an engine tune-up after about 250 hours could be done in January or February and again in August or September. This would assure maximum power with minimum fuel use during heavy-use periods. Well equipped shops can perform excellent tune-up work. Tractors can be hooked to a dynamometer and their output measured before and after service.

Compare performance with original ratings. Governor and valve clearance adjustments can be performed. Whether you perform the tune-up (sometimes less expensive) or a dealer does it (sometimes more expensive), the main point to remember is that regular tune-ups are essential for maximum HP and minimum fuel usage.

Review the following student situation including fuel consumption records as an example.

Question: "How does *student's* fuel consumption compare to average energy requirements for the various jobs or to the Nebraska tractor test data?"

Compare the following data with the information given in **handout #5**, Table C.

Sample Problem:

Situation: *John* uses a J.D. 5020 diesel. His records show that he used 90 gallons of fuel to plow 30 acres. The 30 acres required about 12 hours to plow.

Question: "How much fuel did *John* use per acre for plowing?" 90 divided by 30 equals 3 gallons/acre.

Question: "How does this compare with typical fuel consumption per acre?" (Refer again to **handout #5**, Table C.)

Plow 8 inches deep — 1.68 gallons/acre for diesel.

Conclusion: "*John's* fuel consumption is higher than expected for his medium to heavy soils."

Probable reasons:

- poor engine performance
- poor operator efficiency

"Let's review the reasons for poor engine performance and poor efficiency." (Hold brief discussion).

Question: "How many gallons and dollars could be saved by improving engine performance and operator efficiency?"

Using **handout #6**, compare *John's* situation with Nebraska test data, taking into consideration field efficiencies. (Explain meaning of the new term, *field efficiency.)*

Sample Problem: Using the same situation as above, compare with Nebraska test data in **handout #6.**

Situation: *Beth*'s 5020, according to Nebraska test (performed on concrete), develops 100.36 dbHP at 75% load traveling 5.64 MPH. The tractor uses 7.712 gallons of fuel per hour and develops 13.01 HP hours/gallon. She usually travels at 5½ MPH with 5-16" plows. 90 gallons of fuel in 12 hours results in a fuel consumption of 7½ gallons/hour, which appears good compared to the 7.7 gallons per hour of the Nebraska test.

Question: "Why does her fuel consumption per hour seem to be OK, but her fuel consumption per acre much too high?" (Refer to previous problem.)

Points to consider: Nebraska test is done on concrete with 100% field efficiency. (If formula is discussed, do it carefully and with adequate explanation of terms and figures.)

Beth's **theoretical** field capacity is:

$$TFC = \frac{5\frac{1}{2} \text{ MPH} \times 6.67 \text{ ft. wide}}{8.25} = 4.4 \text{ acres per hour}$$

However, her **effective** field capacity is: $$EFC = \frac{30 \text{ acres}}{12 \text{ hours}} = 2.5 \text{ acres per hour}$$

for a **field efficiency** of $$FE = \frac{EFC}{TFC} = \frac{2.5}{4.3} = 57\%$$

Question: "What is a typical field efficiency for plowing?" (Refer to Table 3.)

Table 3. Field Efficiency Table

OPERATION	FIELD EFFICIENCY, PERCENT
Tillage	
Moldboard Plow	75-85%
Disk Harrow, Disk Plow	77-90%
Field Cultivator	75-85%
Spring-Tooth or Spike-Tooth Harrow	65-80%
Cultivation	
Row Crop	65-80%
Rotary Hoe	75-85%
Seeding	
Corn Planter	
1. Corn Only	60-75%
2. With Fertilizer and/or Pesticide Attachment	45-65%
Grain Drill	65-80%
Broadcast	65-70%

OPERATION	FIELD EFFICIENCY, PERCENT
Harvesting	
Mower	75-85%
Rake	65-90%
Baler	65-80%
Loose Hay Stacking Wagon	65-80%
Forage Harvester	50-70%
Combine	60-75%
Corn Picker	55-70%
Cotton Picker	60-75%
Swather	70-85%
Miscellaneous	
Sprayer	55-65%

(**Source:** *Machinery Management*, John Deere & Company)

Conclusion: "Beth's field efficiency is too low. What contributes to poor field efficiency?"

- equipment failure
- wasted time on turns
- odd shaped fields
- operator distractions, breaks, etc.
- bottlenecks in the total operation

When her fuel usage/hour is put on the basis of a normal field efficiency of about 80%, she should have done 3.4 acres per hour or completed the job in 8.8 hours.

Calculations (optional):

4.3 acres/hour (theoretical) x 0.8 (efficiency) ≐ 3.4 acres per hour

30 acres divided by 3.4 acres per hour = 8.8 hours

90 gallons fuel divided by 8.8 hours = 10 gal./hr. or approximately 10 hphrs./gal.

Use of a Lab Test

Run a lab test on a student's tractor using a dynamometer in the school shop or a nearby dealer shop to evaluate fuel consumption in terms of horsepower hours per gallon, etc. Compare lab test results to Nebraska test data. At this point the instructor may wish to have the students perform maintenance on multi-cylinder engines. Emphasis should be on the six areas most commonly identified as causing poor fuel efficiency: ignition timing, spark plugs, air cleaners, valve tappett clearance, carburetor adjustment, and governors.

This lesson outline does not include specific details of preventive maintenance. *Preventive Maintenance* (Deere and Company) or its equal would provide the needed reference material in addition to operator's manuals for the teaching of a farm power unit.

Most farm tractors are diesel. The significant factors affecting their fuel efficiency are the same with the nozzles, fuel pump, and fuel filter maintenance replacing the spark plug and distributor.

The overfueling of diesel tractors (explain) is much too common today. An Illinois survey revealed two-thirds of the diesel units were overfueled. This practice, considered a quick and easy method of increasing diesel power, has an adverse effect on both engine life and fuel economy.

Overfueling is not only quite inefficient, but also very damaging (explain how) to a diesel engine. Here is a good summary of the situation. Diesel engine power is never set for the maximum (explain why). The horsepower of a diesel engine increases nearly in proportion to fuel rate up to a certain point. However, beyond that point HP increases very little for large increases in fuel delivery.

In one particular engine a fuel consumption of 0.435 lb./HPhr was required up to 78 HP. To raise the HP 5% more (4 HP) requires three times more fuel per HPhr. Most of this excess fuel goes to waste in the form of heat or smoke and wasted money.

The extra heat creates great thermal stress in engine parts. This is similar to the high temperatures and pressures during detonation in spark-ignition engines. But perhaps the most damaging aspect of overfueling diesels is the formation of soot during combustion. Much of this soot leaves the engine as dense black smoke, but plenty is also left in the engine to be carried into the piston ring grooves and into the crankcase oil.

Shop dynamometers are often used to check out engine performance. They are an excellent method of making sure that optimum performance is obtained. The direct horsepower reading dial on the dynamometer is accurate only for standard PTO. It will tend to read too low if rated PTO rpm is exceeded, and too high if the tractor is operating below rated rpm for standard PTO. When the tractor must be run at less than rated rpm to achieve standard PTO, refer to the tractor test for correct hp at standard PTO or others.

SUMMARY — ENERGY MANAGEMENT FOR FARM TRACTOR OPERATORS

Consider:

. . . Most of the energy used on farms for crop production is used by tractors.

. . . The adoption of minimum tillage practices reduces labor, machine time, and fuel costs.

. . . Proper selection of tractor size and matching of implement size maximize efficient use of fuel — a tractor working at full load requires only 1/3 more fuel than when working at half load.

. . . Diesel powered tractors consume less fuel than gasoline powered tractors of the same horsepower rating.

Remember:

. . . Proper maintenance, tune-up and lubrication procedures extend tractor life, reduce down time, decrease fuel consumption and thus cut operating costs.

Potential for Energy Savings

■ Indicates little or no investment required

	Potential Energy Saving	We Should Investigate Check (✓)
■ Select the proper tractor size to fit the farming operation	5-30%	
■ Size the equipment to match the tractor	up to 25%	
■ Practice minimum tillage where practical to reduce trips across the field	up to 25%	
■ Follow regular maintenance and tune-up procedures	6-20%	
■ Merge small fields into large fields to take advantage of longer rows and less turning	5-15%	

Summary *(continued)*

	Potential Energy Saving	We Should Investigate Check (√)
■ Keep all implements lubricated and properly adjusted	5-15%	
■ Use tractor weights to distribute load for minimum wheel slippage	5-10%	
■ Replace faulty radiator thermostats	up to 25%	
■ Keep tillage tools sharp and properly aligned	5-25%	
■ Avoid excessive idling and engine warm-up time	5-25%	
■ Remove tractor wheel weights when not needed	5-10%	

Source: *Managing Energy on the Farm*, Syracuse, New York: Agway, Inc.

ANSWER KEY
to Unit Test which follows on page 14

Section 1	*Section 2*	*Section 3*	*Section 4*	*Section 5*
1. c	11. D	16. F	26. F	36. 100
2. c	12. I	17. T	27. T	37. 4.76 (5 bottoms)
3. a	13. I	18. F	28. F	38. 180
4. c	14. I	19. F	29. F	39. 20
5. c	15. D	20. T	30. A	40. 4500
6. a		21. T	31. F	
7. b		22. F	32. T	
8. c		23. T	33. F	
9. b		24. T	34. T	
10. a		25. T	35. T	

VII. Evaluation

UNIT TEST ON ENERGY MANAGEMENT IN THE OPERATION OF TRACTORS

NAME ____________________

GRADE ____________________

Section 1. Multiple Choice: Select the best answer to the following. Write the letter of your choice on the line to the left of the statement.

____ 1. Proper engine maintenance and operation could reduce fuel consumption on the average by as much as —

a. 15% b. 20% c. 35% d. 50%

____ 2. Engines operate most efficiently at a rated load of —

a. 60% b. 70% c. 80% d. 90%

____ 3. To achieve increased fuel efficiency when operating on job requiring less than full power (50%) —

a. Engine speed should be reduced and a higher gear selected.
b. Engine speed should be increased and a higher gear selected.
c. Engine speed should be increased and a lower gear selected.
d. Engine speed should be reduced and a lower gear selected.

____ 4. An idled gasoline engine will consume fuel at about —

a. 1/10 gal./hr. b. 1/4 gal./hr. c. 1/2 gal/hr. d. 3/4 gal./hr.

____ 5. Which of the following soil conditions would permit the highest % optimum slip?

a. firm b. tilled c. soft d. medium

____ 6. For towed implements the tractor front should be weighted —

a. 33% of rear weight b. 40% of rear weight c. 50% of rear weight d. 60% of rear weight

____ 7. Studies revealed the greatest saving in fuel was found after —

a. correction of timing
b. spark plug replacement
c. servicing the air cleaner
d. carburetor adjustment

____ 8. Overfueling a diesel will —

a. increase HP per gallon
b. decrease engine heating
c. reduce fuel efficiency
d. have no effect on fuel use

____ 9. Increasing tractor speed —

a. increases slippage
b. increases power requirement
c. reduces traction
d. reduces slippage

____ 10. Which requires the most rear wheel weight per PTOHP?

a. towed implements b. semi-mounted c. fully mounted d. integrated

UNIT TEST on Energy Management in the Operation of Tractors - page 2

Section 2. Fill in the Blank: Answer the following as to their effect on dbHP requirement by selecting one for each blank: **(I)** increases dbHP requirement; **(D)** decreases dbHP requirement; **(0)** has little or no effect on dbHP requirement.

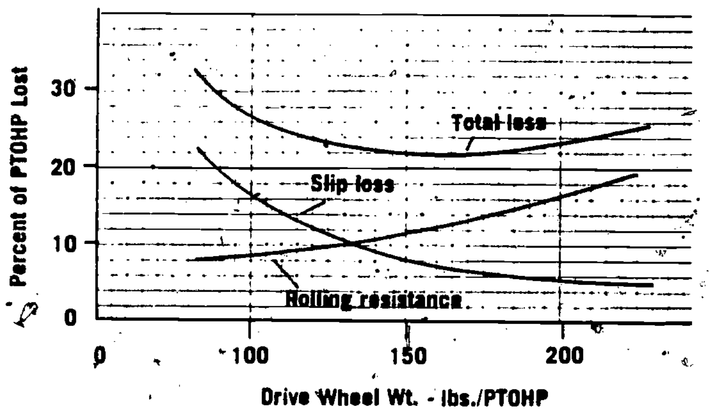
____ 11. Adding of duals in soft loose soil
____ 12. Adding additional implement width
____ 13. Increasing speed
____ 14. A loose soil surface
____ 15. A firm soil surface

Section 3. True or False: Place the letter "T" on the line to the left of the statement if it is true; "F" if it is false.

____ 16. Theoretical field capacity remains constant regardless of speed.
____ 17. Field efficiency is never 100%.
____ 18. Doubling implement width will double the effective field capacity.
____ 19. A square shaped field would have a higher field efficiency than a long narrow field of equal size.
____ 20. Usually 25% reserve horsepower is adequate.
____ 21. Overfueling a diesel engine is a highly inefficient method of increasing horsepower.
____ 22. Most farm tractors should be tuned-up every 500 hours.
____ 23. As wheel slippage is reduced, rolling resistance increases.
____ 24. Duals without additional weighting reduce traction.
____ 25. Duals increase flotation and reduce rolling resistance.

Section 4. True, False, or Indeterminate: Answer the following statements based on the data provided by marking "T" if the statement is true, "F" if the statement is false, or "A" if the truth or falsehood of the statement can not be determined from the data given.

Typical Power Losses at the Drive Wheel



____ 26. Rolling resistance decreases with additional weight.
____ 27. Slippage decreases with additional weight.
____ 28. Total PTOHP loss decreases with each unit of additional weight.
____ 29. Zero slippage is desirable for minimizing PTOHP loss.
____ 30. Best fuel efficiency is achieved at 130 lb. of drive wheel weight/PTOHP.
____ 31. Total loss of PTOHP is least at a point where rolling resistance is the lowest.
____ 32. As slippage decreases rolling resistance increases.
____ 33. Rolling resistance decreases as slippage is reduced.
____ 34. Minimum PTOHP is achieved at approximately 8½% slip.
____ 35. Rolling resistance is of equal concern to wheel slipping in minimizing HP loss.

UNIT TEST on Energy Management in the Operation of Tractors – page 3

Section 5. Problems: Complete the following problems. SHOW ALL WORK!

36. How large a tractor (dbHP) is required to operate a 20-foot disc with a 300 pound-per-foot draft at a speed of 5 MPH? ____________

$$\text{dbHP} = \frac{\text{MPH x total draft x 1.25}}{375}$$

37. A 90 dbHP tractor would be properly matched to how many 16-inch plow bottoms? (850 lb. draft/foot of width.) Plowing is done at 5 MPH. ____________

$$\underset{\text{(feet)}}{\text{Implement width}} = \frac{\text{375 x dbHP}}{\text{MPH x draft/ft. x 1.25}}$$

38. What fuel savings would result by increasing the fuel efficiency of a power unit by 15% if the tractor is used 400 hours a year and is presently averaging 3 gallons of fuel per hour? ____________ gallons saved

39. The distance traveled by a tractor under load in 10 revolutions was marked. This same tractor under no load traveled the same distance in 8 revolutions. What is the percent slip? ____________

40. A 100 PTOHP tractor pulling a towed implement 4.4 MPH on tilled soil requires 130 lb. of weight on the rear wheels/PTOHP. The unballasted rear weight of the tractor is 8500 lb. How much additional weight should be added to the rear of the tractor? ____________

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APPENDIX

HANDOUT #1 - page 1

Cooperative Extension Service

AGRICULTURAL ENGINEERING

Farm Machinery No. 11
April 1974

COLLEGE OF AGRICULTURE AND HOME ECONOMICS OF THE
OHIO STATE UNIVERSITY AND THE UNITED STATES
DEPARTMENT OF AGRICULTURE COOPERATING

TRACTOR OPERATION TIPS FOR SAVING FUEL

The quantity of tractor fuel required to perform a specific amount of work depends largely upon how you operate the tractor. Drawbar load, engine speed, gear used, amount of turning, and amount of engine idle time can cause the quantity of fuel used to vary by more than thirty percent. Such a variation occurs because: (1) engine efficiency changes with engine speed and load, and (2) the efficiency of the power transmission system changes with speed of travel, gear used and the load.

Throttle back--shift up

Use a large enough machine or combination of machines to provide either a drawbar and/or a P.T.O. load large enough to load the engine to its rated capacity. Under these conditions fuel efficiency will be nearly maximum and the work will get done more quickly.

Some jobs will not require the full power output of the engine. In fact, studies indicate that on the average a tractor is loaded to only 50% of its rated capacity. When pulling such loads, reducing the engine speed will improve fuel efficiency. Nebraska Test data shows that tractors operating at 50 percent load used 20 percent less fuel at reduced engine speed than was used on the same load at full engine speed. Many diesel engines are more efficient in the use of fuel at 50 percent load with reduced engine speed, than at 100 percent load with full engine speed. For this reason, it will probably require less fuel to use a large diesel tractor at reduced engine speed on light loads than to use a smaller size tractor at full engine speed.

Fig. 1 was drawn from test data for a 50 HP diesel tractor. Each of the curves represents a line of constant engine RPM. You will note that for each RPM line the fuel efficiency increases as the HP output increases up to about 80% of the maximum HP produced at that engine speed.

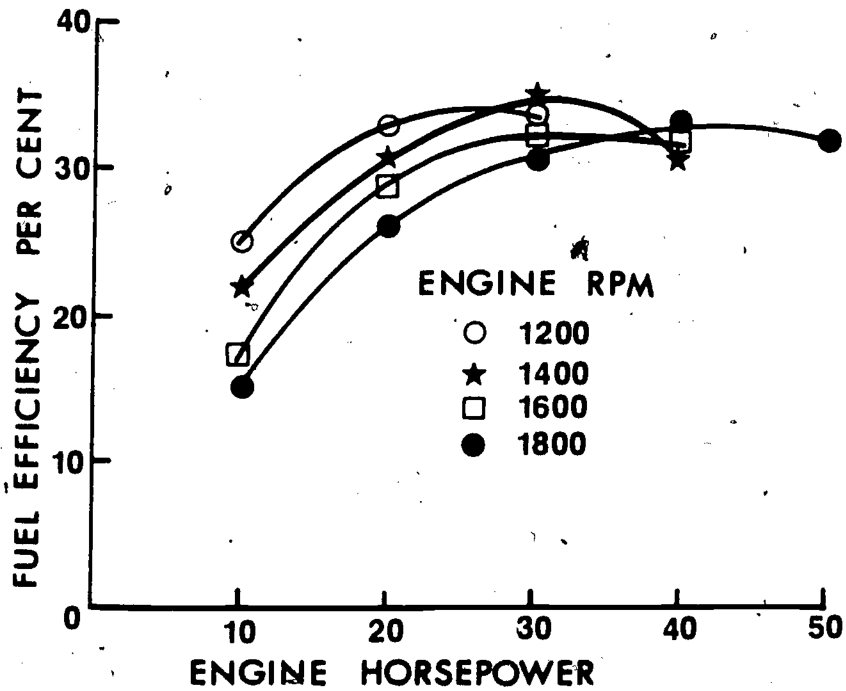

FIG 1. THE EFFECT OF ENGINE RPM AND HP OUTPUT UPON THE FUEL EFFICIENCY OF A DIESEL TRACTOR

HANDOUT #1 - page 2

Increasing the power output still more reduces the fuel efficiency. At part loads, for example 20 HP, the fuel efficiency improves as the RPM is reduced. The engine should not be "lugged". Best fuel efficiency for any RPM occurs at a power output which is slightly less than the maximum which could be developed at that engine speed. For this particular tractor, best fuel efficiency was obtained at 30 HP and an engine RPM of 1400.

Select the gear which provides the desired speed of forward travel at the reduced engine speed. On tractors having a wide range of forward gears, it is possible to have engine speeds which give nearly optimum engine fuel efficiency at the desired speed of travel.

Horsepower lost in the transmission gears, at a given speed of travel, is less in the higher speed gears. Therefore, transmission efficiency will be improved by shifting up to the higher gear.

Shut the engine off

Don't let the engine idle for long periods of time. An Illinois study showed that tractors idled for more than 12 percent of the total hours of operation. An idling engine may use more than 1/2 gallon of fuel per hour.

How much fuel can you save?

The amount of fuel saved by following the suggestions will depend upon your present operating practices. The savings can exceed 20 percent if you have been following the practice of operating the engine at nearly full throttle on all light loads.

Summary

- Try to operate the tractor near rated load (rated engine RPM at full hand throttle) at all times.
- Use combinations of machines to load the tractor to its rated capacity.
- On light load -- shift up and throttle back.
- Shut the engine off under no load situations.

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L-306

Proper Weighting of Farm Tractors Saves Fuel

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9/79—20M

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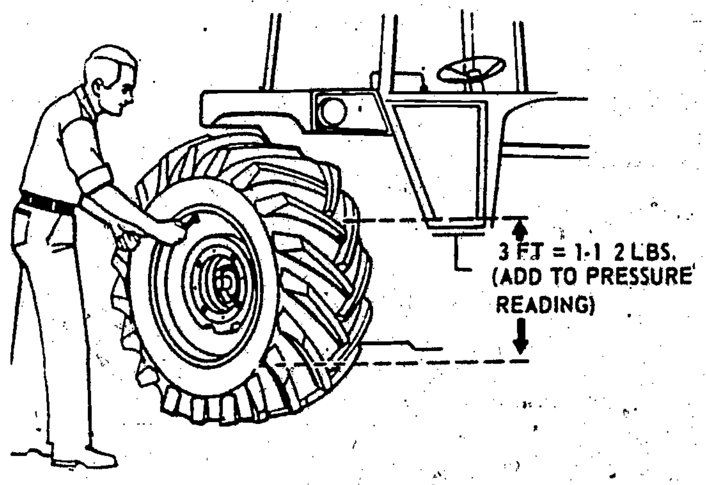


With liquid ballasted tires, check inflation pressure as shown here.

It makes sense to use tractors so that work may be done using as little fuel as possible. The greatest loss of engine power occurs at the traction wheels. In typical field use, 20 to more than 60 percent of the engine power may be lost at the wheels because of wheel slip and wheel rolling resistance. The amount of these losses is, to some degree, within the control of the tractor operator.

Wheel Slip and Rolling Resistance Losses

The amount of HP loss due to wheel slip and rolling resistance is determined primarily by the kind of soil surface, tire inflation pressure, tire size, the amount of weight on the tire, as determined by weighting, and the drawbar load. As the amount of weight on the traction wheel is increased, wheel slip decreases and the rolling resistance increases (Fig. 1). With a small amount of weight on the wheel, slip losses become quite high. If a large amount of weight is placed on the wheel to reduce slip, rolling resistance losses become high. Thus, there is an optimum amount of weight at which the sum of the slip and rolling resistance is minimal. Wheel losses will be greater than necessary if the correct weight is not placed on the wheel. Wheel slip is the best indicator of wheel HP loss. There is an optimum amount of wheel slip for each kind of traction surface.

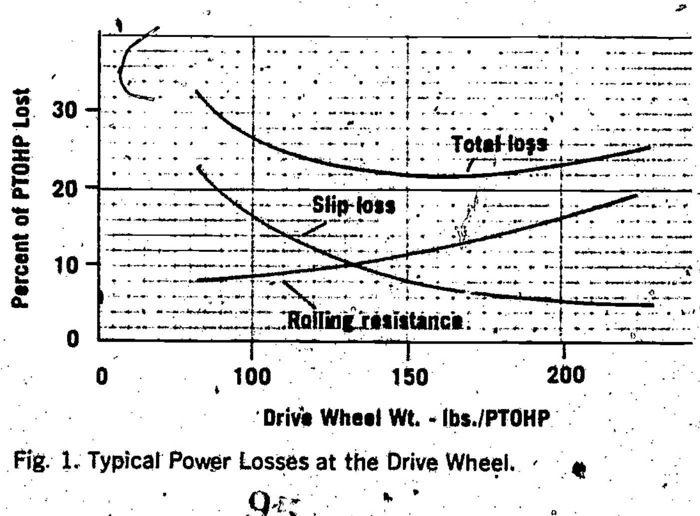


Fig. 1. Typical Power Losses at the Drive Wheel.

HANDOUT #2 - page 2

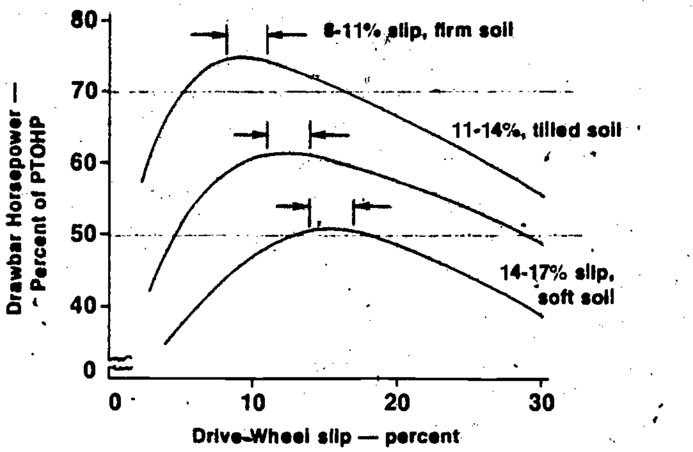


Fig. 2. Optimum Drive Wheel Slip For Different Field Conditions.

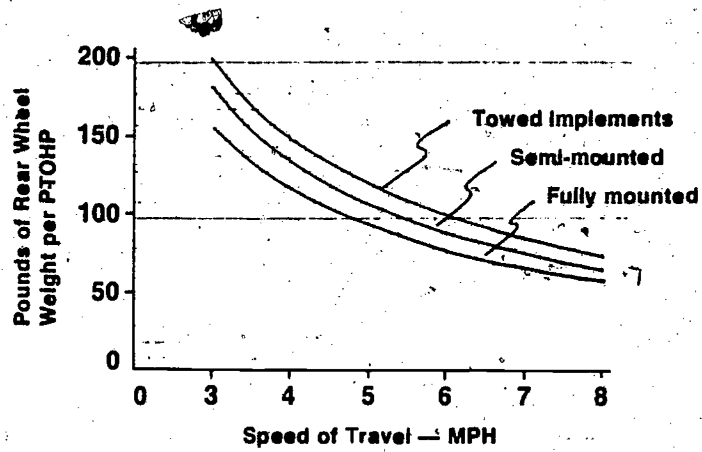


Fig. 3. Recommended Rear Wheel Weight — 2-Wheel Drive, Firm Soil, Such as Alfalfa or Brome Grass Sod, 12% Slip.

What Is Optimum Slip?

The change in drawbar HP with wheel slip for firm, tilled and soft soil is shown in Fig. 2. The drawbar HP is expressed as a percent of power take off horse power (PTOHP). When operating on firm soil at optimum slip (about 9 percent) the drawbar HP will be about 75 percent of the maximum PTOHP. When operating on tilled and soft soils, the maximum drawbar HP will be about 60 and 50 percent of PTOHP, respectively. Optimum percent slip for tilled and soft soil is about 11 and 14 percent, respectively. Nearly maximum drawbar HP is obtained over a fairly wide range of wheel slips, as indicated on the graphs.

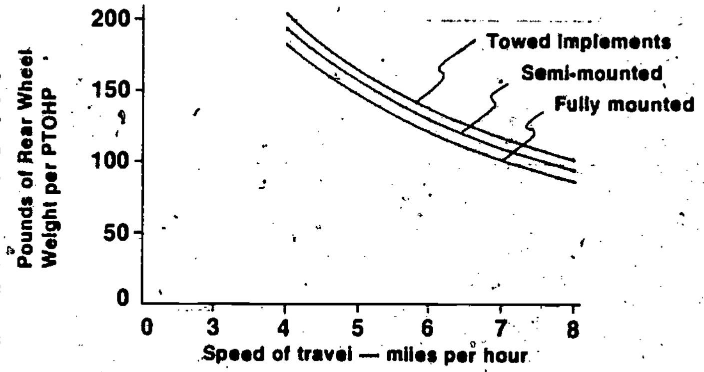


Fig. 4. Recommended Rear Wheel Weight for 2-Wheel Drive Tractors Operating on Soft Soil, Such as Newly Plowed Ground or Sand, 16% Slip.

WEIGHTING 2-WHEEL DRIVE TRACTORS

How Can Optimum Slip Be Obtained?

Figures 3, 4 and 5 are guides for determining the optimum drive wheel weight for firm, soft and tilled soil, respectively. Suppose you have a tractor rated at 100 PTOHP and you will be pulling a semi-mounted plow at 5 MPH on firm soil. From Fig. 3, you can see that about 107 pounds of rear wheel weight is required for each PTOHP. The total rear wheel weight should be 10,700 pounds (100 PTOHP x 107 lbs/PTOHP).

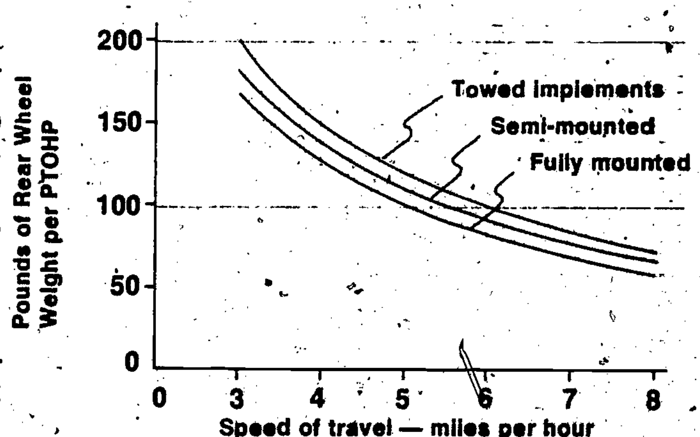


Fig. 5. Recommended Rear Wheel Weight for 2-Wheel Drive Tractors Operating on a Tilled Soil Such as Plowed Ground Disked Once, 14% Slip.

How Much Ballast Should Be Added?

Find the unballasted rear wheel weight of the tractor either from manufacturer's literature or by weighing the rear wheels of the tractor. If this weight is less than the optimum weight needed, the difference must be made up by adding weight.

For example, the unballasted rear wheel weight of the 100 PTOHP tractor is 8450 pounds. The amount of weight to be added is 2250 pounds (10,700 lbs. — 8450 lbs. = 2250 lbs.). Weight may be added either as liquid ballast, cast iron weights, or a combination of both.

The tractor has single 18.4-38 tires. From Table 1, each tire will hold 1113 pounds of 3.5 pounds calcium chloride per gallon of water solution. The two tires will hold 2226 pounds of liquid ballast. This is about the weight needed. You should probably use liquid ballast rather than cast iron wheel weights because liquid costs much less. When filled with fluid the rear wheel weight will be about 10,700 pounds.

Be Certain That the Tires Are Not Overloaded

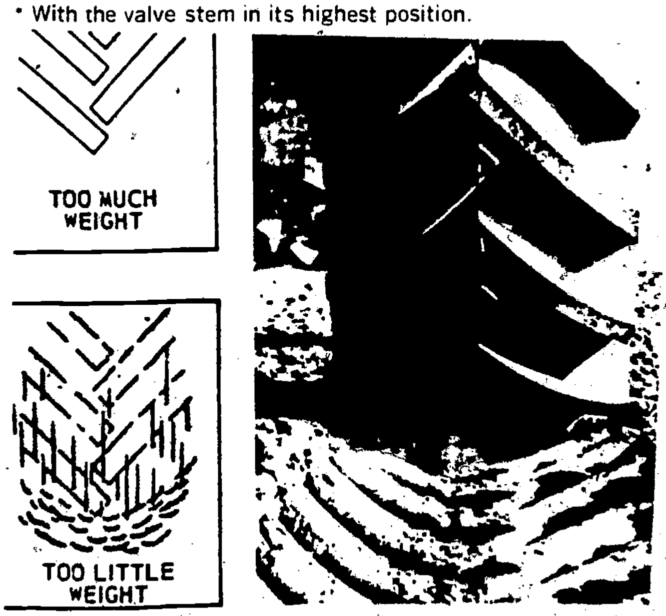
Too much weight on the tires will reduce tire life. The weight on a single tire should not exceed the load capacity given in Table 1. For example, the total rear end weight is to be 10,700 on two 18.4-38 10 ply tires. Each tire must carry 5350 pounds. From Table 1 an 18.4-38 tire will carry 5250 pounds at 16 pounds per square inch (p.s.i.) inflation pressure and 6980 pounds at 26 p.s.i. The carrying capacity of the tire is adequate at any pressure between 18 and 26 p.s.i.

HANDOUT #2 - page 3

Table 1: Tractor Drive Wheel Tires, Inflation Pressure, Load Capacities, and Pounds of Liquid Ballast

Tire Size	Use	Ply Rating	Tire Load Capacity-Pounds: Minimum Pressure p.s.i.	Maximum Load at Min. p.s.i	Maximum Pressure p.s.i.	Maximum Load at Max. p.s.i	Liquid Ballast 3½ lb. Calcium Chloride/Gal. Water *(stem level fill) pounds
14.9-28	Single	6	14	2880	20	3550	
	Single	8	14	2890	26	4140	545
15.5-38	Single	6	14	3160	20	3890	663
	Dual	6	12	2540	20	3420	
16.9-24	Single	6	16	3540	18	3800	616
16.9-28	Single	6	16	3780	18	4050	699
16.9-30	Single	6	16	3900	18	4180	746
16.9-38	single	6	16	4380	18	4700	912
	Dual	6	12	3260	18	4160	
18.4-28	Single	6	16	4530	16	4530	852
18.4-30	Single	6	16	4680	16	4680	912
18.4-34	Single	6	16	4970	16	4970	1007
	Single	8	16	4970	20	5660	
	Dual	6	12	3690	16	4360	
	Dual	8	12	3690	20	4970	
18.4-38	Single	6	16	5250	16	5250	1113
	Single	8	16	5250	20	5990	
	Single	10	16	5250	26	6980	
	Dual	6	12	3910	16	4620	
	Dual	8	12	3910	20	5260	
	Dual	10	12	3910	26	6140	
20.8-34	Single	8	16	6010	18	6440	1291
	Dual	8	12	4470	18	5670	
20.8-38	Single	8	16	6360	18	6820	1421
	Single	10	16	6360	22	7670	
	Dual	8	12	4730	18	6000	
	Dual	10	12	4730	22	6750	
23.1-26	Single	8	16	6280	16	6280	1291
23.1-30	Single	8	16	6700	16	6700	1457
	Dual	8	12	4980	16	5890	
23.1-34	Single	8	16	7110	16	7110	1610
	Dual	8	12	5290	16	6260	
24.5-32	Single	10	18	8180	20	8700	1729
28L-26	Single	10	18	7800	18	7800	
	Dual	10	12	5410	18	6860	
30.5L-32	Single	12	18	9770	20	10390	
	Dual	12	12	6780	20	9140	

* With the valve stem in its highest position.



...e "footprint" is a rough guide to wheel slip.

If the total weight on the tire exceeds the tire carrying capacity, then you must either use a tire with more load capacity or use dual tires. You will note from Table 1 that the load capacity of a tire is less when used as a dual than when used as a single tire.

On firm surfaces, dual tires offer little advantage over singles except for load carrying capacity. On soft soils dual tires have a decided advantage over singles due to less rolling resistance.

Front End Weight

Front end weight should be sufficient to keep the front wheels on the ground at all times. However, there is no advantage in having too much weight on the front wheels. With towed implements, front wheel weight should be about one-third of the rear weight. With mounted and semi-mounted implements the front weight should be about 50 and 40 percent, respectively, of the rear weight.

The tractor used in our example required 10,700 pounds of rear wheel weight when pulling a semi-mounted plow. It should have approximately 4280 pounds on the front wheels (10,700 x 0.4 = 4280). The

HANDOUT #2 - page 4

Table 2: Tractor Steering Wheel Tires, Inflation Pressures and Load Capacities

Tire Size	Ply Rating	Tire Load Limits at Various Cold Inflation Pressures, lbs. 24 p.s.i.	28 p.s.i.	32 p.s.i.	36 p.s.i.	40 p.s.i.	44 p.s.i.	48 p.s.i.	52 p.s.i.	56 p.s.i.
4.00—12SL	4	330	370	400	430	470	490	520	550(4)	
5.00—15SL	4	540	600	660	710	760	810(4)			
5.50—16SL	4	660	740	810	870	940(4)				
6.00—14SL	4,6	680	760	830	900(4)	960	1030	1080	1140(6)	
6.00—16SL	4,6	760	840	920	1000(4)	1070	1140	1200	1260(6)	
6.50—16SL	4,6	850	950	1040	1130(4)	1210	1280	1360(6)		
7.50—16SL	4,6,8	1100	1220	1340(4)	1450	1550	1650(6)	1740	1830	1920(8)
7.50—18SL	4,6	1190	1330	1450(4)	1570	1680	1790(6)			
7.50—20SL	6	1280	1430	1560	1690	1810	1930(6)			
9.00—10SL	4	1100	1230(4)							
10.00—16SL	6,8	1750	1950	2130(6)	2310	2470	2630(8)			
11.00—16SL	6,8	2070	2300	2520(6)	2720	2920(8)				
		Low Section Height Tires								
7.5L—15SL	6,8	1060	1180	1290	1390	1490	1590(6)	1680	1770	1850(8)
9.5L—15SL	6	1290	1440	1580	1700(6)					
11L—15SL	6	1570	1740	1910(6)						
14L—16.1SL	6	2560	2850(6)							

Note: Figures in parentheses denote ply rating for which loads and inflations are maximum.

unballasted front end weight is 3870 pounds. Approximately 410 pounds of ballast should be added to the front of the tractor.

The front tires are 11.00-16, 6 ply with a carrying capacity of 2520 pounds each at 28 pounds per square inch pressure (Table 2). (2 x 2520 = 5040). The front tires have adequate carrying capacity. So ballast can be added to obtain the desired weight on the front end.

WEIGHTING 4-WHEEL DRIVE TRACTORS

A guide for weighting of 4-wheel drive tractors is given in Table 3. Note that the table gives total tractor weight per PTOHP. About 60 percent of the tractor weight should be on the front wheels and 40 percent on the rear.

Table 3. Optimum Total Weight for 4-Wheel Drive Tractors

Speed MPH	Total Weight Pounds per PTOHP
4	140
5	115
6	95
7	80

Checking Performance In the Field

The procedure suggested for weighting of tractors serves as a guide and weight may have to be adjusted for your conditions. You can tell whether the drive wheels are properly weighted by measuring drive wheel slip under field conditions. To measure wheel slip:

1. Place a mark on one of the rear tires.
2. Position a starting stake at a convenient point in the field where you are to operate.
3. With the tractor under load drive past the starting stake at the normal speed of travel. Note the position of the mark on the tire at the time the rear axle passes the stake. (A helper makes it easier.)
4. Travel a distance of 10 wheel revolutions. Place a finish stake at this point.
5. Raise the tool out of the ground and travel the same distance with no load. Count the wheel revolutions.
6. Calculate percent slip from the formula: % slip = 10 x (10 minus wheel revolutions without load)

For example: You drive 10 wheel revolutions under load. The tractor travels the same distance in 8.5 wheel revolutions with no load.

% slip = 10 x (10 - 8.5)
= 10 x 1.5
= 15%

Measure wheel slip to check the proper weighting.

HANDOUT #2 - page 5

Table 4 may be helpful in determining slip.

Table 4: Determining Percent Wheel Slip

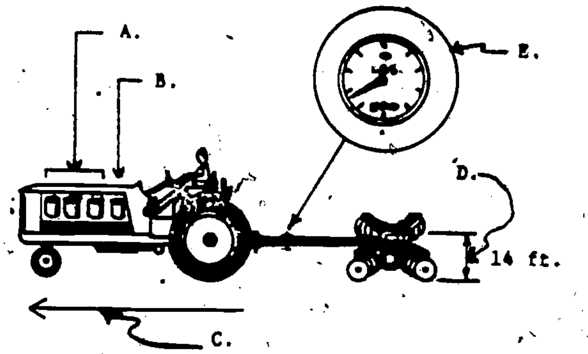
Wheel Revolutions No Load	Percent Slip
9.5	5
9	10
8.5	15
8	20
7.5	25

If slip is greater than the optimum shown in Fig. 2, add more weight to the drive wheels. If slip is less than optimum, remove weight. Too much drive wheel weight may overload and shorten the life of the power transmission of the tractor. Wheel slip protects the power transmission from overloading when operating in the lower gears. If full engine horsepower is used below four miles per hour, you may have too much weight on the drive wheels. Check the tractor instruction manual for wheel weight recommendations.

HANDOUT #3

DEPARTMENT OF AGRICULTURAL ENGINEERING
IOWA STATE UNIVERSITY
AM 17-72

MATCHING HORSEPOWER NEEDS - TRACTOR SIZE AND MACHINE SIZE



Operation Teaches (Ability to.........
(Understanding of...

1. U. A method of determining horsepower needed in a tractor.
2. U. A method of matching machine size to tractor horsepower.
3. A. Identify factors affecting horsepower requirements of a tractor.
4. A. Find the tractor size needed for a field operation.
5. A. Find the largest machine size suited to a tractor.

Machine	Draft per foot width	Speed in MPH
Moldboard plow	850 lbs.	3.3-5.0
Disk, stalk ground	250	3.7-4.7
Disk, tilled ground	280	3.5-6.0
Spike tooth harrow	180	3.5-7.2
Row crop cultivator	150	2.0-5.7
Field chop, green forage	800	3.3-4.6
Hay or straw	200	3.3-4.6
Row crops	1250	3.0-4.5
Corn picking	650	2.5-3.5

Evaluation Score Sheet

Item	Points Possible	Points Earned
1. Definitions	5	______
2. Problem 1	15	______
3. Problem 2	15	______
4. Problem 3.	30	______
5. Problem 4	30	______
6. Attitude and work habits	5	______
Total	100	______

Name ______________________________

Date ____________________ Grade __________

Definition Matching

A. ____________________ 1. Implement width
B. ____________________ 2. Horsepower
C. ____________________ 3. Reserve horsepower
D. ____________________ 4. Speed, MPH
E. ____________________ 5. Total draft

Horsepower Need Determination

$$HP = \frac{\text{miles per hour x total pounds draft}}{375}$$

1. Problem: What horsepower is required to pull a disc at 5 MPH? The disc has a total draft of 3920 pounds.

$$HP = \frac{\_\_\_ \text{ MPH x } \_\_\_ \text{ lb. draft}}{375} = \_\_\_ \text{ HP}$$

Draw Bar Tractor Horsepower (dbHP)

Tractor draw bar horsepower needs are equal to the maximum draft load plus 25% to 30% for reserv power.

$$dbHP = \frac{\text{MPH x total lbs. draft x 1.25 reserve}}{375}$$

2. Problem: How powerful a tractor is needed to pull a plow at 5 MPH? The plow has a total draft of 5100 lbs.

$$dbHP = \frac{\_\_\_ \text{ MPH x } \_\_\_ \text{ lb. T. draft x 1.25}}{375} = \_\_\_ \text{ dbHP}$$

Tractor Power Needed, Draft Per Foot Implement

Total implement draft = implement width x draft per foot.

3. Problem: What size tractor is needed to pull a 14 foot disk at 4 MPH. Disk draft for stalk ground (Use table for draft per foot). ______

___ ft. wide x ___ lbs. per ft. = ___ T. draft

Implement Sized to Tractor

$$\text{Impl. width} = \frac{375 \text{ x dbHP}}{\text{MPH speed x draft of 1 ft. x 1.25}} = \text{ft. width}$$

4. Problem: What size plow can a tractor with 80 draw bar HP pull at 5 MPH?

$$\text{Width} = \frac{375 \text{ x } \_\_\_ \text{ dbHP}}{\_\_\_ \text{ MPH x } \_\_\_ \text{ draft per ft. x 1.25}} = \_\_\_ \text{ft}$$

Number of 16" bottoms ______________

Number of 14" bottoms ______________

Developed by Hilbert J. Hoof

HANDOUT #4

WHERE DOES THE HORSEPOWER GO?

Farm tractors are generally rated according to the maximum observed power-take-off horsepower. Therefore, when you say you are buying a 100 HP tractor, you mean that it has 100 horsepower available at the PTO shaft. However, this is not 100 HP available at the drawbar. Some of the power is lost in the power transmission system. There is also loss due to drive wheel slippage. In addition, power is required to move the tractor alone. It is not advisable to load a tractor to its maximum power, so an allowance must be made for a power reserve.

If 100 HP is available at the PTO shaft, about 96 HP will be available to the rear axle.

It is standard practice to provide a power reserve of 20% of the 96 HP. This reduces the power available to 78 HP.

Wheel slip is a direct loss of power. Ten percent slip is a 10% loss of power. Unfortunately, wheel slip cannot be eliminated because it is necessary to develop drawbar pull. Even though it cannot be eliminated, there is an optimum amount of slip for a specific soil condition. Optimum slip is about 8 percent for a firm traction surface such as sod; about 11% for tilled soil; and about 15% for soft or sandy surface.

Power required to move the tractor on level ground will be about 6.4% of the PTO HP on firm soil, 13% on tilled soil, and 22.2% on soft or sandy soil.

The figures are summarized in Table I.

Table I. Power Available at the Tractor Drawbar

	Soil Condition		
	Firm	Tilled	Soft
Max. PTO HP (Nebraska Test)	100.0	100.0	100.0
HP available at driving axle (96% of PTO HP)	96.0	96.0	96.0
Less deduction for power reserve (20%)	-19.2	-19.2	-19.2
Usable HP at driving axle	76.8	76.8	76.8
Less deduction for wheel slip	- 6.1	- 8.5	-11.5
	70.7	68.3	65.3
Less deduction for power to move tractor	- 6.4	-13.0	-22.2
Drawbar HP available for implement	64.3	55.3	43.1

(*Source:* Samuel G. Huber, Agricultural Engineering Department, The Ohio State University, Columbus, Ohio, August 1976)

HANDOUT #5

Table A 600 hrs/year Fuel Use and Cost

Test	Average Load	Annual Fuel Requirement Diesel (gal)	Gas (gal)	Annual Estimated Fuel Cost (1) Diesel @ 52¢ gal	Gas @ 63.5¢ gal
A	100%	3644	4378	$1895	$2780
B	75%	3268	3947	$1674	$2507
C	50%	2746	3269	$1428	$2076
*D	50%	1968	2537	$1024	$1611

Table B 1200 hrs/year Fuel Use and Cost

Test	Average Load	Annual Fuel Requirement Diesel (gal)	Gas (gal)	Annual Estimated Fuel Cost (1) Diesel @ 52¢ gal	Gas @ 63.5¢ gal
A	100%	7288	8756	$3790	$5560
B	75%	6536	7894	$3347	$5013
C	50%	5492	6538	$2856	$4152
*D	50%	3936	5074	$2047	$3222

*Test D was at the same HP load as Test C, but Test D was a gear or two higher in the transmission and at a reduced throttle setting.

(1) Tax refund for off-road use would be subtracted.

The gallons of fuel used to plow or disc an acre are nearly constant regardless of the size of implement or tractor used. Table C gives the average PTO horsepower hours and gallons of fuel needed per acre for various tillage operations.

Attaining greater operating hours per tractor yearly has little or no significant effect on energy consumption but may be an important factor in total investment required and related tractor costs.

Using the above tractor model as an example, appreciable savings in annual fuel savings can be realized by choosing a diesel engine over a gasoline engine.

Example 1. Selection of a diesel engine for the tractor shown in Test C above and working at 50% load, would reduce fuel consumption by 16% and reduce fuel costs by 31%—$1296/year saving (Table B).

Example 2. Large tractors pulling light loads can save 22.4% to 28.3% in fuel consumption by changing to a gear or two higher and throttling back the engine to maintain the same ground speed. The comparison of tests C and D above shows diesel, $809 saving/year; gasoline, $930 saving/year (Table B).

Example 3. If the tractors described in examples one and two are compared, it can be seen that the diesel tractor saves 16.7% in gallons of fuel used, and with diesel fuel selling for 52¢/gal and gasoline selling for 63.5¢/gal, the diesel model costs $3.06/hr. for fuel to operate, and the gasoline tractor costs $4.48/hr. This is a 31.7% saving in favor of the diesel model.

Changing badly fouled plugs can decrease fuel use by 6%. $216 saving per year.

Properly adjusted carburetors can lower fuel usage by 9½%. $342 saving per year.

Fuel consumption increases by approximately 25% when the engine is operating at 100°F rather than 160°-180°F $150 saving per year.

Table C

Operation	PTO HP-Hrs. Per Acre	Gals./Acre Diesel	Gasoline
Plow 8 in. deep	24.4	1.68	2.16
Heavy offset disc	13.8	0.95	1.22
Chisel plow	16.0	1.10	1.41
Tandem disc (unplowed)	6.0	0.45	0.58
Tandem disc (plowed)	11.0	0.76	0.98
Cultivate row crops	6.0	0.45	0.58
Planting row crops	6.7	0.50	0.64
Grain drill	4.7	0.35	0.45

*Part of data prepared by Wendell Bowers, Oklahoma State University Extension Engineer.

Example 1. (See top line in Table C above) An 85.45HP diesel tractor has the potential to plow approximately 3.5 acres/hr. (85.45HP ÷ 24.4HP-hrs/acre = 3.5 acres/hr.). This value, multiplied by the gallons of fuel required per acre (1.68) for plowing, gives a value for gallons per hour (3.5 x 1.68 = 5.88 gals/hr.).

Example 2. The same model tractor, except gasoline powered, is rated at 79.73 HP and has the potential to plow approximately 3.27 acres/hr. 3.27 x 2.16 = 7.06 gals/hr.

Managing Energy

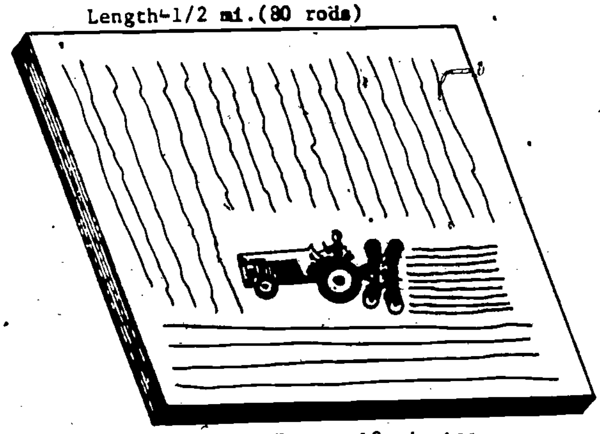
(Source: *Managing Energy on the Farm.* Syracuse, New York 13221: Agway Inc., P.O. Box 4933)

HANDOUT #6

DEPARTMENT OF AGRICULTURAL ENGINEERING
IOWA STATE UNIVERSITY
AM 16-72

MACHINE ACREAGE CAPACITY

Length–1/2 mi.(80 rods)



Time - 10 minutes

Operation Teaches (Ability to.........
(Understanding of...)

1. U. Theoretical field capacity of a machine.
2. U. Effective field capacity of a machine.
3. U. Field efficiency of machine use.
4. A. Determine field travel speed in miles per hour.
5. A. Determine theoretical field capacity of an implement.
6. A. Determine effective field capacity of an implement.
7. A. Determine field efficiency of an implement.

Range in Field Efficiency for Common Machines

Moldboard plow	75-80%	Corn plan only	60-75%
Disk harrow	77-90%	Corn plan plus	45-65%
Field cultivator	75-85%	Combine	60-75%
Spring, spike harrow	65-76%	Corn picker	55-70%
		Swather	70-85%
Row cultivation	68-85%	Sprayer	55-85%
Rotary hoe	80-88%		

Evaluation Score Sheet

Item	Points Possible	Points Earned
1. Field travel speed	18	_____
2. Theoretical field capacity	18	_____
3. Effective field capacity	18	_____
4. Field efficiency	18	_____
5. Plan machine work capacity	18	_____
6. Attitude and work habits	10	_____
Total	100	_____

Developed by Hilbert J. Hoof

Field Travel Speed (MPH) Determination

A 14 ft. tandem disc is pulled across a field 1/2 mile long (80 rods) in ten minutes. What is the ground speed in MPH? (1 mile = 5280 ft.; 1 rod = 16.5 ft.)

$$MPH = \frac{\text{ft. traveled}}{\text{Min. x 88}} = \frac{\_\_\_\text{ ft.}}{\_\_\_\text{ x 88}} = \_\_\_\_$$

Theoretical Field Capacity of a Machine (TF Cap.)

$$\text{TF Cap.} = \frac{\text{MPH x implement width in feet}}{8.25} = \text{A/hr.}$$

Problem: 14 ft. tandem disc is drawn at 4.5 MPH. Find the TF Cap. in A/hr.

$$\text{TF Cap.} = \frac{\_\_\_\text{ MPH x }\_\_\_\text{ ft. wide}}{8.25} = \_\_\_\_\text{ A/hr.}$$

Effective Field Capacity (EF Cap.)

$$\text{EF Cap.} = \frac{\text{acres covered or worked}}{\text{hours of time used}} = \text{A/hr.}$$

Problem: A 14 ft. tandem disc is used to till 38 acres in 10 hours. Find the EF Cap. in A/hr.

$$\text{EF Cap.} = \frac{\_\_\_\text{ acres}}{\_\_\_\text{ hours required}} = \_\_\_\_\text{ A/hr.}$$

Field Efficiency (Field Eff.)

$$\text{Field eff.} = \frac{\text{EF Cap.}}{\text{TF Cap.}} \times 100$$

Problem: Find the field eff. of discing when the theoretical field capacity is 6.6 acres and the effective field capacity is 3.8 acres.

$$\text{Field eff.} = \frac{\text{EF Cap. }\_\_\_\text{ A/hr.}}{\text{TF Cap. }\_\_\_\text{ A.hr.}} = \_\_\_\_ \times 100 = \_\_\_\%$$

Machinery Use Planning

EF Cap. = TF Cap. x field eff. = Acres per hour

Problem: Find the acres of corn that can be planted with a 4-36" row planter being drawn at 3 MPH. The field eff. expected is 60%.

$$\text{TF Cap.} = \frac{\_\_\_\text{ MPH x }\_\_\_\text{ ft. wide}}{8.25} = \_\_\_\_\text{ A/hr.}$$

EF Cap. = ____ TF Cap. x ____ field eff. = ____A/hr

Name ______________________________

Date ____________________ Grade ________

I. **Lesson Topic:** **REDUCING ENERGY COSTS IN PRODUCING CORN**

by

LOWELL E. HEDGES

II. Lesson Performance Objectives

At the end of this lesson, the student will be able to:

1. Identify or list specific practices which will result in drier corn at harvest time.
2. Determine specific moisture requirements for safe storage of corn over a given length of time.
3. Compute the cost (losses) occurring from over-drying of corn in terms of bushels not marketed plus wasted energy.
4. List the advantages of delayed harvest of corn to permit dry-down in the field.
5. Select a tillage system that will reduce energy requirements without adversely affecting income from corn production.
6. Select the most efficient corn drying method for his/her operation.
7. Select a high-yielding hybrid that will be fast-drying in the field.
8. Select a planting date that will permit optimum field drying of corn.
9. Select a fertilization and crop rotation program that will make maximum use of nitrogen fertilizer.
10. List reasons why adequate field drainage will aid in faster field drying of corn.

III. Materials Needed

1. Literature from locally patronized seed corn companies that pertains to seed corn varieties
2. References listed in bibliography
3. Transportation available so that class can visit nearby farmers who utilize the improved practices discussed in this lesson
4. Samples of phosphorus, potash, and nitrogen fertilizers

IV. The Situation

Due to the shortage of some fuels used in corn production, the low market price of corn, and the increased concern to reduce the amount of energy consumed in the production of agricultural crops, it has become necessary to decide what areas can be improved in our corn production program to provide for the conservation of energy. It is important to conserve energy, but it is also important not to decrease crop yields or income to the farmer.

The production of corn requires the largest quantity of energy of any Midwest crop. This energy is utilized in various forms, such as gasoline, diesel fuel, fertilizer, herbicides, and fuels for drying. As energy costs rise and the availability of energy becomes less certain, farmers are looking for ways to reduce their energy needs and still maintain income.

V. Introduction to Lesson

1. As an interest approach to the lesson, ask the students the question, "What Midwestern U.S. crop requires the largest quantity of energy to produce?" In answering the question after the students have given their suggested crops, show a transparency of the two graphs shown in Figure 1. These graphs indicate that corn requires the most energy to produce.

2. To further impress upon the students the amount of energy required to produce corn, show them another transparency with the following information: (Ted Glenn, *Energy Conservation in Corn Production and Drying*)

   The sum total of all these energy inputs can equal as much as the heat equivalent of 80 gallons of diesel fuel per acre.

   Typical usage is in the neighborhood of 50-60 gallons of fuel per acre.

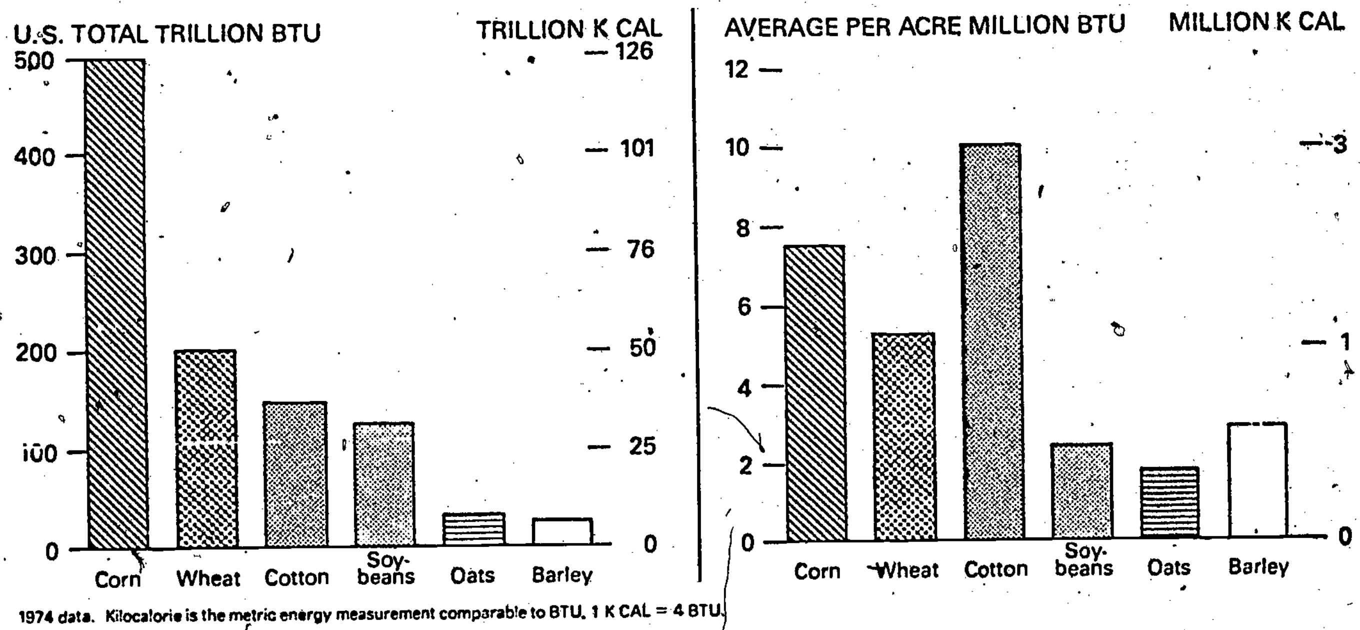


***Figure 1.* Energy use by crops**— U.S. total and average per acre. (Source: Agricultural Handbook No. 551, USDA, Nov. 1978)

A typical breakdown for harvesting 26-28 percent moisture corn in Ohio is as follows:

- 50 percent fertilizers and pesticides (80 percent of this is in the nitrogen fertilizers)
- 35-40 percent drying requirements
- 10-15 percent field operations

3. At this point in the lesson, students can be helped to understand something about energy costs. Rapidly changing energy costs plus the need to conserve energy in the form of fossil fuels make no longer economical or advisable many practices previously used in producing corn. A student who has a corn project for a supervised occupational experience program can be selected for assistance by the class in determining practices that can be used to reduce energy costs in producing corn.

VI. Problem for Class

The following problem, or decision to be made, can be placed on the chalkboard.

"What production practices can ___student___ utilize to save energy in producing corn without sacrificing either yield or income?"

1. Possible student answers:

   a. Use fast-drying, high-yielding hybrids to reduce amount of artificial drying required.
   b. Plant early to permit more drying in the field.
   c. Provide adequate drainage so that corn can be planted early.
   d. Use reduced tillage systems where suited in order to reduce amount of fuel used in field work.
   e. Manage more efficient drying systems.

The second transparency can be referred to again to assist the students in determining some *specific* energy-reducing production practices. If students say, "Reduce artificial drying time," the teacher can build on that suggestion and expand it to specifics. At this point, student answers as to suggested practices need not be very specific.

2. Depending on the time available for the teaching of this problem, or decision, the teacher may teach one or all of the practices mentioned previously to reduce energy amounts and costs in producing corn. The remainder of this lesson plan consists of strategies and content for the teaching of all these practices.

3. A possible alternative follow-up statement the teacher could make after putting the problem on the chalkboard is: "Let's look again at the main production areas in which energy is used in producing corn. What are these three main areas? *(Expected answer: fertilizers and pesticides, drying requirements, and field operations.)* To help us in our thinking concerning energy-saving production practices, let's take each area and list some specific practices that could save energy."

   With student help, the teacher selects the following practices to be listed on the chalkboard:

   a. Fertilizers and pesticides:
      - Supply sufficient nutrients.
      - Use nitrification inhibitors or slowly available forms of nitrogen fertilizer.
      - Use crop rotation, including legumes.

   b. Drying requirements:
      - Harvest at lower moisture, thus requiring less artificial drying.
      - Use more energy-efficient drying methods.
      - Don't over-dry.
      - Select faster-drying, high-yielding hybrids.

   c. Field Operations:
      - Plant early.
      - Provide adequate drainage.
      - Use reduced tillage systems where suited.

4. At this point, the teacher may make a statement such as, "Let's take each of these possible energy-saving production practices and determine if ______ *student* ______ can use the practices, and how he/she should put the practices into use." The teacher then arbitrarily selects the order for teaching the practices. The factor of seasonality should be considered when selecting the order in which the practices are to be taught.

A. SELECTING A PLANTING DATE

Problem Statement: "When should ______ *student* ______ plant corn in order to obtain optimum yield plus reduced energy requirements?"

In getting students interested in determining the ideal planting date for ______ *student* ______, the teacher could ask the question, "What are the benefits of early planting of corn?" Or, "How does early planting of corn affect energy requirements?" In answering the first question, the teacher may present the following information for consideration by the students:

a. Planting early provides the corn crop with more Growing Degree Days faster; thus the crop is more likely to mature before frost. As a result, grain can be left longer in the field to permit natural drying. This in turn yields a saving in fuel normally used for artificial drying.

b. Vegetative growth is completed and pollination initiated prior to the period of greatest moisture stress in July.

c. Grain filling occurs during the period when solar radiation is high, so there is greater accumulation of dry matter in the grain. This results in a higher yield.

d. Earlier planting leads to an earlier harvest in the fall. This allows time for fall plowing and application of lime and fertilizer.

Students now see some of the advantages of early planting. They should be receptive to doing supervised study to determine the best date for the planting of corn. The teacher may proceed with a comment like this: "Now that we can see some of the advantages of early planting, we need to find out what would be the best date for ___student___ to select for planting corn. To help us in our decision-making, let's study these research data supplied by the Cooperative Extension Service. Can you tell from this information what might be an ideal planting date?"

The teacher should present the students with the following chart (Table 1) as a printed handout or transparency.

Table 1. **Effect of planting date on yield and moisture content of corn** grown at Columbus, Ohio (9-year average)

Planting Date	Bu/A @ 15.5% Moisture	Moisture (%)
March 20-30	176	19.3
March 31-April 8	183	19.3
April 9-15	177	19.3
April 16-22	176	20.2
April 23-29	175	20.8
April 30-May 7	173	23.7
May 8-14	163	24.9
May 15-21	155	——
May 22-27	152	28.2
May 28-June 4	138	35.0
June 5-23	91	40.0

(Source: *1978-79 Agronomy Guide*, Bulletin 472)

In helping students use this information to determine the best "early planting date," the teacher may ask the following questions: "Do you see one particular planting date that gives the highest yield?" Students will probably answer, "April 8th." The teacher may then ask if weather in their area at that time of year usually permits the planting of corn. The class will probably indicate that the weather usually is too cold and the soil too wet to permit planting. The teacher could then ask, "Can you find a particular date for corn planting after which yields show a sharp decline and the moisture content rises?" The chart indicates that corn yields decline sharply after a May 7th planting date (at Columbus, Ohio).

At this point, the teacher should also help the students understand the correlation between early planting, higher yield, *and* lower moisture content of the corn. The lower moisture content at harvest would result in less drying time for safe storage, thus saving energy.

In order to help students determine the best planting date for their location, the teacher should provide this thumb rule: "Corn may be planted one day earlier for every 10 miles south of Wooster." (Eckert, Bulletin 645)

To arrive at a decision for ___student___, the teacher should ask the class, "Considering that we are ________ miles (south or north) of Wooster, what would be the best corn planting date for ___student___?" The students can now do the calculations. When they have completed the calculations, and agreed upon a date, the teacher should write on the chalkboard, "Conclusion: We recommend that ___student___ should plant corn on ___date___ in order to obtain maximum yield and reduced energy requirements for drying the corn."

If time permits, the teacher may want to continue the discussion of early planting of corn to include consideration of ways in which a corn producer can increase chances of planting on time. Procedures that can be done include:

a. Have all materials and equipment ready before the planting season.
b. Switch to larger equipment to permit grower to cover more ground in less time.
c. Work fields as soil moisture conditions allow them to be worked, performing at least some operations on well-drained areas while poorly drained ones are drying.
d. Consider drainage improvements and possible modification of tillage operations.

B. SELECTING A VARIETY OF CORN

Problem statement: "What variety of corn should ____student____ select that will mature early, thus permitting more drying time in the field?"

The teacher may begin with the decision-making process on variety selection, by asking the question, "What factors should we consider (or what characteristics should we look for) in a corn variety that will help us conserve energy?" The teacher should aid the students in eventually arriving at the factors of (a) maturity length, (b) the relationship between grain moisture and yield, and (c) standability. The teacher also should impress upon the students the importance of choosing a hybrid on the basis of its proven performance in the student's particular area.

Before specific varieties are compared using a "Possibilities-Factors" approach to lesson planning and teaching, the teacher should help the students understand more fully the benefits of planting a variety of corn which will mature in a reasonable period of time. Reasons include:

a. Danger of frost is reduced if the crop has already matured; there is less chance of ending up with a field of wet corn which will require much energy for drying.

b. If the crop matures early in the fall, the grower can take advantage of free drying energy provided by the sun. The mature crop can be left in the field for a period of time.

One more point should be made before developing on the chalk-board the Possibilities-Factors Chart that students will use to select an appropriate early maturing corn variety. The teacher should assist the students in understanding that **Growing Degree Days** (GDD) seems to be the most accurate method available today for measuring corn maturity. In other words, this information about a variety can be used for the factor of maturity length. The grower should choose hybrids whose GDD requirements are within the GDD expectations for that particular area. Many seed corn companies willingly provide information on GDD requirements of their hybrids.

The teacher should now construct on the chalkboard the framework of the Possibilities-Factors Chart (Table 2).

Table 2. **Possibilities - Factors Chart**

POSSIBILITIES	FACTORS		
Varieties	**Maturity Length in GDD**	**Relation between Moisture & Yield**	**Standability**
1.			
2.			
3.			
(etc.)			

Varieties to consider as possible selections should come from students' experience and knowledge, or from the teacher's knowledge of community practices. Another source of variety choices could be the publication entitled, "Ohio Corn Performance Test." (Agronomy Department Series 215)

An obvious factor to consider in choosing a corn variety for a particular location in the state is the GDD expectation for that location. Figure 2 provides that information. (Eckert, Bulletin 645)

Figure 2 can also be used to show students that the longer planting must be delayed because of location, the sharper will be the drop in available GDD's. To make full use of the solar radiation available, the producer should choose hybrids which fit the GDD expectations of his/her location, and should plant early in the season.

Table 3 can help students locate specific sites throughout the state and figure the GDD's of five dates in May.

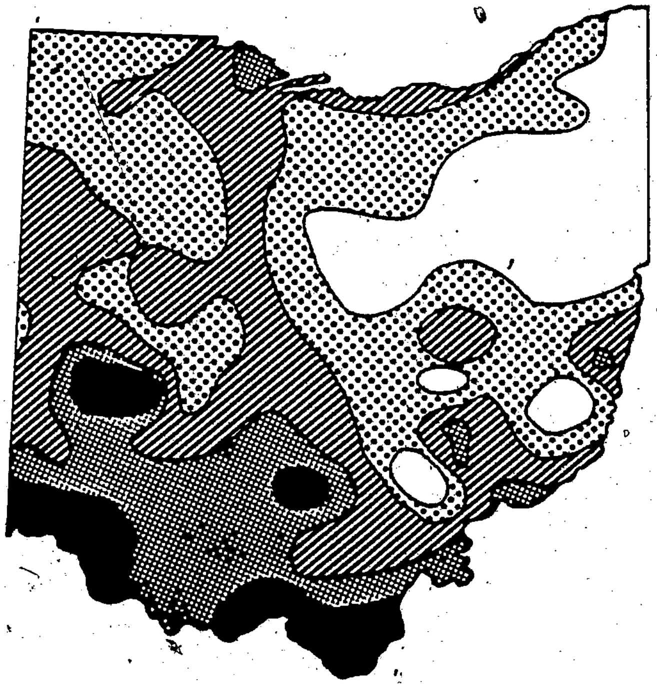


Figure 2. Expected GDD accumulation from May 8 to average date of 10 percent chance of frost: *white* — less than 2,400; *dots* — 2,400-2,600, *diagonals* — 2,600-2,800, *cross-hatch* — 2,800-3,000, *black* — more than 3,000.

The students should now list on the chalkboard possible corn varieties for consideration, along with the information about each variety — the factors to consider.

When students are satisfied that enough varieties have been listed for consideration, the teacher should lead the students through the reasoning process of selecting the variety or varieties which has/have "most of the best" characteristics. When a conclusion has been reached, the teacher should write on the chalkboard, "Conclusion: We recommend that *student* plant *selected variety or varieties* to make possible early planting, which results in more drying time in the field and thus conserves energy without adversely affecting yield and income."

Additional information for this problem or decision can be found in the publication, *Growing Drier Corn for the Conservation of Energy*, Bulletin 645, Donald J. Eckert, Dept. of Agronomy, Cooperative Extension Service, The Ohio State University (1978).

Table 3. Growing-degree days (GDD) accumulated at various sites in Ohio from several dates in May through the 10%-frost date in the fall.

	GDD from May to 10 percent chance-of-frost				
Station Name	**May 1**	**May 8**	**May 15**	**May 22**	**May 29**
Akron-Canton Airport	2324	2250	2176	2102	2028
Arsenal. Ravenna	2185	2112	2040	1967	1894
Ashland	2650	2570	2489	2408	2327
Athens	2763	2663	2563	2463	2363
Barnesville	2391	2311	2231	2152	2072
Bellefontaine	2779	2691	2603	2514	2426
Bowling Green	2805	2718	2630	2542	2454
Bucyrus	2525	2444	2363	2282	2201
Cadiz	2820	2731	2642	2553	2464
Caldwell	2814	2718	2621	2524	2427
Cambridge	2676	2582	2488	2395	2301
Canfield	2277	2208	2138	2069	2000
Carpenter	2791	2691	2590	2489	2388
Celina	2782	2687	2592	2497	2401
Centerburg	2501	2416	2331	2246	2161
Chardon	2434	2366	2298	2230	2162
Charles Mill Dam	2245	2176	2106	2037	1968
Chillicothe	3158	3049	2940	2831	2722
Chilo	3099	2994	2890	2785	2681
Chippewa Lake	2389	2313	2237	2161	2085
Cincinnati-Abbe	3391	3283	3175	3067	2959
Circleville	3023	2917	2811	2704	2598
Columbus-OSU	2777	2683	2590	2496	2403
Coshocton	2787	2691	2596	2500	2404
Dayton	3237	3125	3014	2903	2792
Defiance	2570	2489	2408	2327	2248
Delaware	2726	2537	2547	2457	2367
Dennison	2491	2405	2319	2233	2147
Dorset	1977	1915	1852	1790	1728
Eaton	2769	2678	2588	2497	2407
Elyria	2682	2603	2524	2445	2368
Fernbank Dam	3324	3215	3107	2998	2889
Findlay	2598	2518	2437	2357	2276
Franklin	2896	2796	2696	2596	2496
Fredericktown	2372	2293	2213	2134	2054
Fremont	2828	2741	2655	2568	2481
Gallipolis	3160	[illegible]	2931	2818	2701
Geneva	2525	2460	2395	2330	2265
Greenville	2707	2621	2535	2449	2365
Hamilton	3132	3024	2915	2807	2698
Hillsboro	2931	2835	2738	2642	2546
Hiram	2460	2409	2338	2267	2196
Hoytville	2623	2535	2447	2359	2272
Ironton	3359	3240	3121	3002	2884
Irwin	2574	2487	2400	2313	2226
Jackson	2739	2638	2536	2434	2332
Kenton	2604	2523	2443	2362	2281
Lancaster	2750	2654	2557	2461	2364
Lima	2706	2617	2529	2441	2353
London	2755	2665	2576	2487	2398
Marietta	2918	2818	2719	2619	2520
Marion	2721	2629	2538	2447	2356
Marysville	2630	2545	2460	2375	2291
McConnelsville	2898	2805	2712	2618	2525
Millersburg	2528	2444	2360	2276	2192
Millport	2182	2111	2041	1971	1901
Mineral Ridge	2513	2433	2354	2274	2194
Montpelier	2664	2580	2495	2411	2327
Napoleon	2692	2610	2528	2446	2365
NC-Substation	2510	2427	2344	2261	2179
Newark	2636	2545	2455	2365	2275
New Lexington	2595	2504	2412	2321	2229
Norwalk	2569	2490	2411	2332	2254
Oberlin	2618	2539	2459	2380	2301
Painesville	2642	2575	2509	2442	2376
Pandora	2518	2435	2351	2268	2185
Paulding	2651	2567	2484	2400	2317
Peebles	2898	2795	2691	2587	2483
Philo	2885	2784	2682	2581	2480
Plymouth	2569	2491	2412	2333	2254
Portsmouth	3476	3353	3231	3109	2987
Put-in-Bay	3087	3013	2939	2865	2791
Sandusky	3030	2946	2863	2779	2696
S. Charleston.	2617	2505	2394	2283	2172
Senecaville Dam	2497	2408	2319	2229	2140
Sidney	2653	2567	2481	2395	2308
Springfield	3103	3002	2900	2799	2697
Steubenville	2837	2747	2657	2567	2477
Tiffin	2762	2675	2587	2500	2412
Tom Jenkins Dam	2150	2072	1994	1916	1838
Upper Sandusky	2721	2632	2543	2453	2364
Urbana	2622	2535	2449	2362	2276
Van Wert	2778	2688	2598	2509	2419
Warren	2559	2479	2398	2318	2237
Washington CH	2909	2812	2716	2619	2523
Wauseon	2516	2439	2362	2285	2208
Waverly	2917	2811	2706	2600	2495
Wilmington	2958	2858	2754	2653	2551
Wooster	2350	2277	2205	2132	2059
Xenia	2893	2794	2695	2596	2496
Zanesville	2351	2266	2181	2096	2011

Source: *Ohio Report* 61:1 (3-4)

C. PROVIDING ADEQUATE DRAINAGE

This lesson is not intended to develop in the student the skills, attitudes, and understanding required to select and implement an appropriate drainage system for a specific farm. However, the student should be helped to understand the effect of drainage on the number of days available for field operations. The student should recognize that excess water can delay early crop growth and ultimately reduce crop yields. Improved drainage can significantly increase the number of days available for field work, thus making possible early planting.

To help the students understand how improved drainage can result in energy savings plus higher yields, the teacher may present the following table as either a printed handout or transparency for overhead projection. This information may be preceded by the question, "What effect does drainage have on days available for field work?"

***Table 4.* Days available for field work** between March 21 and May 1.

Soil Drainage	Average per Year	80% of Years
Poor	9 days	4+ days
Poor, with drainage improvement	12	7+
Moderately well-drained	12	7+
Well-drained	14	10+

(Source: *Timely Field Operations for Corn and Soybeans in Ohio,* Bulletin 605)

D. REDUCING TILLAGE

The adoption of a reduced tillage system may also be useful in achieving early planting, which in turn results in more drying time available in the field and, therefore, higher yields. The teacher can present the information in Table 5 below to emphasize that reduced tillage operations can substantially reduce the time required to establish a corn crop. Such reductions can make possible substantial fuel savings.

The presentation of this information can be preceded by the question, "What effect does tillage have upon the time required to establish a crop and the quantity of fuel required for tillage?" The teacher should make certain that students understand that the no-till system requires the least time and fuel, but may not be applicable in every situation represented by the class. The teacher may desire to teach a separate lesson on tillage systems to enable the students to learn how to reduce tillage requirements for corn production.

***Table 5.* Time and fuel required** to establish 100 acres of corn using four different tillage systems.

Tillage System	Hr./100 Acre	A /hr.	Gal. Fuel/100 A
Plow-Disk-Plant	80.0	1.25	315
Chisel-Plant	50.0	2.00	155
Disk-Plant	38.3	3.61	110
No-till	25.0	4.00	40

(Source: Agronomy Department Mimeograph - *Selecting a Tillage System)*

E. OBTAINING LOWER MOISTURE CONTENT AT HARVEST TIME

Problem Statement: "How dry should __*student's*__ corn be before he/she starts to harvest it?"

As an interest approach to this decision, the teacher may first want to get the students thinking about the advantages of growing drier corn. The following question can be used to help students see the need to be concerned about the moisture of corn at harvest time: "What are the advantages, if any, of growing drier corn?"

To get student participation started, the teacher can use the following table to point out to the students certain conclusions from research.

Table 6.* Dollars per acre received from corn after drying.

Yield (bu/A) No. 2 Corn	Grain Moisture at Harvest						
	20	22.5	25	27.5	30	32.5	35
	dollars/acre						
100	190	187	183	177	171	162	153
105	200	196	192	186	180	171	161
110	209	205	201	195	188	179	169
115	219	215	210	204	197	187	176
120	228	224	220	213	205	195	184
125	238	233	229	222	214	203	192
130	247	243	238	231	222	211	199
135	257	252	247	239	231	219	207
140	266	261	256	248	240	227	215
145	276	271	265	257	248	236	222
150	285	280	274	266	257	244	230
155	295	289	284	275	265	252	238
160	304	299	293	284	274	260	245
165	314	308	302	293	282	268	253
170	323	317	311	301	291	276	261
175	333	327	320	310	299	284	268
180	342	336	329	319	308	292	276
185	352	345	339	328	317	300	284
190	361	355	348	337	325	309	291

*Based on cash price of $2 per bushel of No. 2 corn, and average shrinkage rates and drying charges of elevators in Wayne County, Ohio. (Eckert, Bulletin 645)

Conclusions:

1. At any yield, the return decreases as moisture content increases.
2. The penalty for wet corn increases with increasing moisture content at a specific yield and also between specific moistures with increasing yield.
3. A 10 bushel/acre decrease in yield is compensated for if moisture is reduced 2.5 to 10 percent, depending on specific yield. (For example, 150 bushels of corn at 25 percent moisture are worth just as much as 160 bushels at 30 percent.)

Additional facts that may help students understand the advantages of growing drier corn are: (Eckert, Bulletin 645):

1. As grain moisture content increases, the grain tends to shell out more imperfectly, especially at moisture levels above 25 percent. The portion of the kernel left in the cob is lost, thus reducing yield.
2. Quality of grain decreases as it is harvested at higher moisture content. Crackage, as well as the amount of foreign material, increases and results in a price penalty for the grain.
3. Wet grain is less convenient to handle than is drier grain. With wet grain the grower must handle more weight and additional volume. This costs more time, effort and money. Drier corn reduces these costs.

Rather than the teacher's giving the above information directly to the students, they should be encouraged to obtain the information themselves through supervised study. The teacher should have available enough copies of the reference *Growing Drier Corn for the Conservation of Energy.*

After the students understand the advantages of growing drier corn, the teacher should help the class arrive at a correct calculation of the appropriate moisture level at which to begin harvesting.

Research indicates that harvesting corn at 25 percent moisture or below can save the producer time and money. Students can be helped to arrive at this figure by being shown the following research conclusions/results: (Eckert, Bulletin 645)

1. Kernel crackage increased three-fold as grain moisture at harvest was raised from 25 to 30 percent.
2. Imperfect shelling becomes pronounced at moisture levels above 25 percent.
3. Fifty-six pounds of corn at 15.5 percent moisture (one No. 2 bushel) contain 4.5 lb. additional water when wet to 30 rather than 25 percent moisture. Assuming a three-hundred-acre farm producing 100 bushels of corn per acre, the grower must handle an extra 67.5 tons of material (all excess water) if harvesting is done at 30 rather than 25 percent moisture. Since corn expands as it becomes wetter, the grower must also handle an additional volume (approximately 2,000 bushels of material).

The teacher should now place on the chalkboard the conclusion or solution to the problem. "Conclusion: *student* should begin harvesting corn at 25 percent or less moisture content in order to save money at the elevator, as well as time and energy."

F. AVOID OVERDRYING OF CORN

Problem Statement: "If *student* has to dry corn artificially, what practices can we recommend?"

Introduction:
The teacher needs to help students understand the implications to the grower of drying corn artificially . Practices should be followed that will use the least amount of energy possible to dry the corn to the recommended storage moisture for a specific situation. The teacher needs to help students understand that a grower can conserve energy in two ways: 1) avoiding overdrying (drying grain only to provide safe storage for the required time to be stored), and 2) managing drying systems efficiently.

As an interest approach to this problem area, the teacher may want to assist the students in understanding how overdrying occurs. The math calculations could be presented for determining the cost (and energy wasted) when corn is overdried. This question may be placed on the chalkboard and then answered: "How costly would it be for *student* to overdry his/her corn?"

Sample calculations to use are as follows:

Question: How much weight and bushel loss do we have when drying 10,000 bushels of No. 2 corn at 15.5% moisture down to 14.5% moisture?

Question: What is the dollar loss?

1. **No. 2 corn consists of 0.155 pounds of water**/(lb. dry grain + lb. water)
2. Therefore, **to find total weight of 10,000 bu. corn at 15.5% moisture:**

W_1 = weight of water = 0.155 x 10,000 bu. x 56 lb./bu.	=	86,800#	= W_1
G = weight of dry grain = 0.845 x 10,000 bu. x 56 lb./bu.	=	473,200#	= G
Total weight of 10,000 bu. (T_1)	=	560,000#	= T_1

3. **To find total weight after drying to 14.5% (T_2):**

T_2 = weight of water (W_2) in 14.5% moisture corn + weight of grain (G) or $T_2 = W_2 + G$

Solving for W_2:

$$0.145 = \frac{W_2}{G + W_2} = 0.145\,(G + W_2) = W_2$$

$$W_2 = 0.145\,G + 145\,W_2$$

$$0.855\,W_2 = 0.145G, \text{ or } W_2 = \frac{0.145}{0.855} = \frac{0.145}{0.855}(473{,}200) = 80{,}250$$ lb. water in 14.5% corn moisture

Total weight of grain at 14.5%

$T_2 = W_2$ (80,250) + (G) 473,200 *or* T_2 = 553,450#

T_1 (560,000) minus T_2 (553,560) = 6,550 pounds weight loss

4. 6,550 lb. divided by 56 lb./bu. = 117 bu. @ $2.50/bu. = $292.50 **marketable weight loss**

5. **Fuel cost:**

W_1 = 86,800
W_2 = 80,250

6,550# water removed x 2300 BTU/lb. water x $\frac{\text{gal. L.P.}}{91{,}500\text{ BTU}} \times \frac{\$0.60}{\text{gal. LP}}$ =

energy cost of overdrying = $98.79

6. **Total cost of overdrying** 10,000 bushels of corn (from 15.5% moisture to 14.5% moisture):

$292.50 + $98.79 = $391.29

Table 7 below can also be used to draw students' attention to the fact that overdrying reduces bushels to be sold as well as increasing cost by wasting fuel. (Glenn, OARDC, Feb. 1980)

***Table 7.* Overdrying costs you money.**

% Moisture	Extra Cost of Drying	Shrink Cost	Total Cost/Bushel
14	1.70 cents/bu.	4.4 cents/bu.	6.1 cents/bu.
13	3.16	7.2	10.3
12	6.00	12.0	18.0

Following the interest approach, the teacher can ask the question, "What practices can *student* use to improve grain drying efficiency?"

One decision a grower needs to make is how dry the corn should be for his/her particular storage situation. The students could be given the problem statement, "How dry should *student* get the corn for his/her situation?"

The students will need to know *student's* situation. This can be done during a field trip to the farm. When the situation is known, the students can refer to the tables which follow (handout or transparency) for the recommended safe storage moisture content for corn for *student's* situation.

Place on the chalkboard:

Example:

Dale M's situation:

(a) Lives near Findlay, Ohio
(b) Wants to start harvesting about October 15
(c) Length of storage period for his corn: up to June 1

Table 8. **Estimated safe* storage duration,** based on worst-year weather data during 1962-72, for various starting dates of corn storage at Springfield, Ohio.

Starting Date for Storage	For Grain Moisture (Wet Basis) 20%	19%	18%	17%	16%	15%
	Safe Until					
October 1	Oct. 20	Oct. 25	Nov. 11	Feb. 9	Apr. 30	July 23
October 15	Nov. 16	Nov. 26	Feb. 7	Apr. 7	May 11	July 30
November 1	Jan. 22	Feb. 27	Apr. 1	Apr. 25	May 21	Aug. 7
November 15	Mar. 15	Mar. 30	Apr. 11	Apr. 30	May 26	Aug. 10
December 1	Mar. 25	Apr. 6	Apr. 15	May 8	May 31	Aug. 16

*For estimated less than 0.5% deterioration
(Source: Glenn, *Energy Conservation in Crop Production and Drying, OARDC*)

Table 9. **Estimated safe* storage duration,** based on worst-year weather data during 1962-72, for various starting dates of corn storage at **Findlay, Ohio.**

Starting Date for Storage	For Grain Moisture (Wet Basis) 20%	19%	18%	17%	16%	15%
	Safe Until					
October 1	Oct. 23	Oct. 28	Nov. 17	March 11	May 13	Aug. 2
October 15	Nov. 16	Dec. 22	Mar. 1	Apr. 21	May 23	Aug. 10
November 1	Mar. 1	Apr. 3	Apr. 17	May 8	June 4	Aug. 23
November 15	Mar. 31	Apr. 12	Apr. 27	May 12	June 8	Aug. 26
December 1	Apr. 5	Apr. 16	May 3	May 17	June 11	Aug. 27

*For estimated less than 0.5% deterioration
(Source: Glenn, OARDC)

Using Table 9 for Findlay, the students, with the help of the teacher, will identify 16 percent as the moisture content corn should be dried to.

The teacher should write on the chalkboard the following: "Conclusion: Dale should dry his corn to 16 percent moisture in order to have safe storage to June 1."

***Table 10.* Estimated safe* storage duration**, based on worst-year weather data during 1962-72, for various starting dates of corn storage at Wooster, Ohio.

Starting Date for Storage	For Grain Moisture (Wet Basis) 20%	19%	18%	17%	16%	15%
	Safe Until					
October 1	Oct. 26	Oct. 31	Dec. 9	March 16	May 20	Aug. 25
October 15	Nov. 28	Dec. 26	Mar. 1	Apr. 21	May 31	Sept. 2
November 1	Mar. 3	Apr. 2	Apr. 16	May 9	June 7	Sept. 7
November 15	Mar. 31	Apr. 9	Apr. 25	May 16	June 13	Sept. 10
December 1	Apr. 8	Apr. 16	May 3	May 20	June 15	Sept. 12

*For estimated less than 0.5% deterioration
(Source: Glenn, OARDC)

After this decision has been made, the teacher may want to assist the students in identifying not only Dale's present drying system, but other drying systems available for use in the community.

Drying systems identified will probably be (a) High-temperature drying, (b) Low-temperature drying, (c) Combination drying, and (d) Batch-in-bin drying.

Students need assistance in identifying energy-saving measures for each system. The teacher can list on the chalkboard the name of each system and then help the students identify how each system can be operated more efficiently.

For example;

a. High-temperature Drying

Description of system: (Refer to Figure 3. Give to students as a handout for their notebook. Review printed description as well as the drawing.)

Operating procedures to reduce energy requirements:

- Eliminate rapid cooling in the dryer.

The students need to understand why this procedure is recommended. Either through handouts or supervised study using references, students should learn the following:

High temperature drying with rapid cooling produces non-uniform temperature and moisture profiles within the kernel, resulting in stress-cracking and a considerably more fragile or less stable product during handling and storage. A solution to this problem is to eliminate rapid cooling in the dryer. This is the first step in the "dryeration process" which produces better quality corn while increasing efficiency.

With dryeration (Figure 3), corn is discharged from the dryer still carrying some excess moisture (usually 1 to 3 percent) at temperatures of at least 120 to 140° F. The corn is immediately transferred to a separate cooling bin. Here, steaming in its own vapor, it is held without mechanical cooling for a tempering period. The corn is then cooled slowly to remove the 1 to 3 percent excess moisture before it is transferred, dry and cool, to storage or load out.

Comparing results for dryeration where corn is removed hot from the dryer at 17.5% moisture to figures for conventional high-temperature drying (from 28 down to 15 percent moisture content), the dryeration energy saving is 16 percent, while there is a 70 percent increase in capacity of the

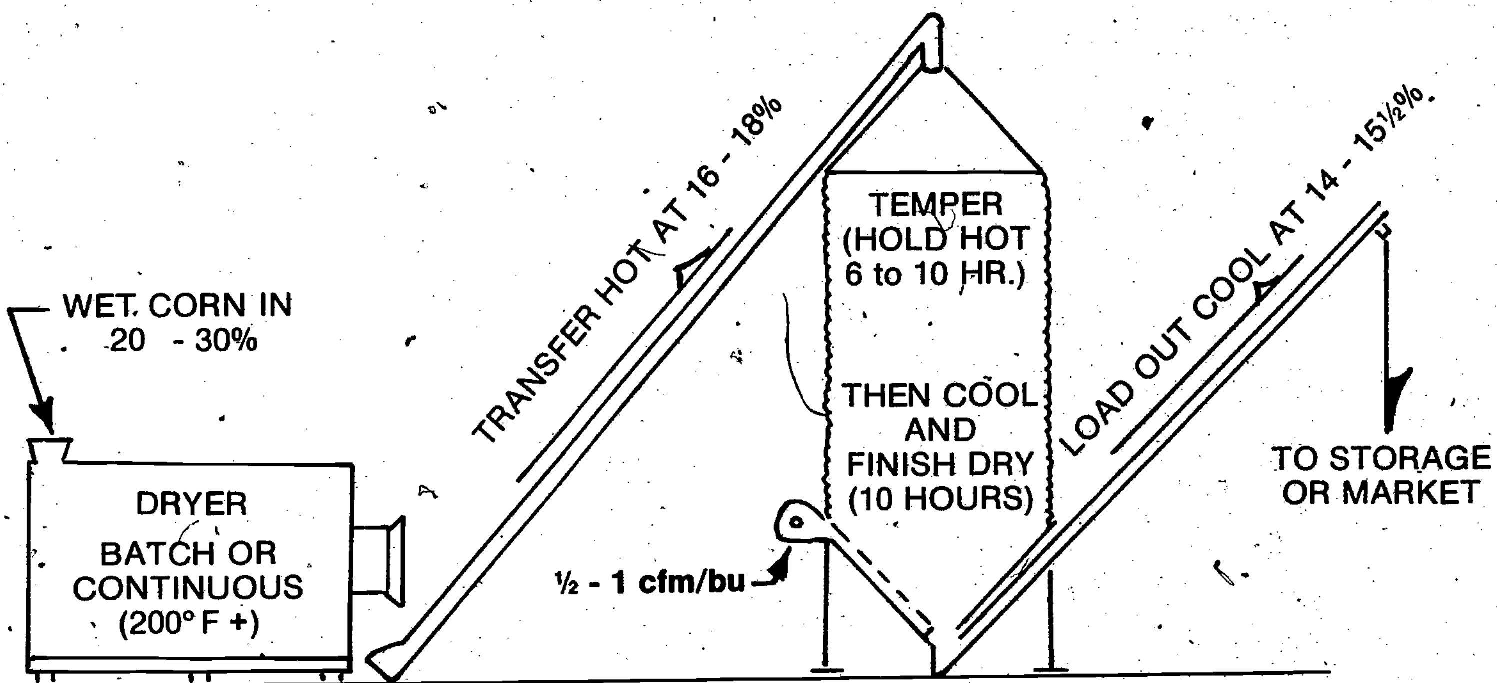


Figure 3. **Schematic flow diagram of the dryeration process (hot-temperature drying).** Wet corn is placed in the dryer from a holding bin or transport vehicle. After drying, corn is transferred hot to the dryeration cooling bin. Corn is accumulated without cooling for approximately 4 to 10 hours for tempering, then cooled slowly. Slow cooling takes about 10 hours and reduces moisture about 2 percent. Grain is unloaded cool and dry. (Reference: Purdue Extension Bulletin AE-72; Source: Glenn et al., *More Efficient Corn Drying Systems*, OARDC)

high-temperature dryer due to the reduced amount of drying and elimination of the cooling cycle or section.

The teacher will need to "lead" the students through the drying steps to ensure that they understand where and how the energy savings occur.

b. Low-temperature Drying

Description of system: This method uses natural (unheated) air or only slightly heated air. To reduce energy consumption in low-temperature drying, natural air should be used whenever possible. However, a small amount of heat is generally needed to dry below 16 percent during average northern Ohio weather conditions in November.

Operating procedures to reduce energy requirements:

- Keep grain depths as shallow as practical. Use large-diameter bins.

The students need to understand why this procedure is recommended. Either through handouts or supervised study using references, students should learn the following:

Computer simulation results for low-temperature drying have been developed at OARDC for various depths of corn. Using 16 feet as compared to 20 feet of corn results in an energy savings of 16 percent, while using 12 feet results in an additional 12 percent savings, or a total of 28 percent energy savings over the 20-foot depth. These results were generated for drying from 20 percent down to 15 percent moisture content, with 1 cfm per bushel and a 3° F (electric heat) temperature rise above average October ambient air in Ohio. The increased energy required for drying in deeper beds is due to the additional airflow (fan) power required to overcome the larger resistance of the deeper bed.

c. Combination Drying

Description of system: (Refer to Figure 4)

Operating procedures to reduce energy requirements:

- Dry corn to 19-23 percent moisture in high-temperature dryer; then move corn to the low-temperature system where corn is subjected to in-bin drying to complete the process.

Low temperature should generally not be used to dry corn above 25 percent moisture. This is especially true in September and October, when higher ambient air temperatures speed up the deterioration and spoilage rate of particularly the top layers of an in-bin system. To handle this situation, combination drying systems have come into use. Low-temperature drying takes advantage of the drying potential in natural air, while combination drying can recover some of the heat imparted to the grain during the high-temperature phase. Results on energy savings and capacity in combination drying are similar to those in dryeration — only greater. When coming out of a high temperature dryer at 20.5 percent moisture (instead of 17.5 percent as in dryeration), the increased energy savings and high-temperature dryer capacity are double those for the dryeration process. These results suggest a possible alternative to farmers who now have high-temperature batch or continuous-flow dryers are looking for increased capacity with improved efficiency and better quality.

d. Batch-in-bin Drying

Description of system: Placing batches of grain in a bin, drying the grain, and moving it to permanent storage.

Operating procedures to reduce energy requirements:

- Use grain stirring devices.

These systems are generally efficient users of heat energy because the drying air when passed through 4 to 6 feet of grain picks up practically all the moisture it is capable of carrying. Also, the depths used are generally optimum in terms of airflow delivered and drying capacity; greater depths tend to reduce or choke-off the air delivered for a given size fan and motor.

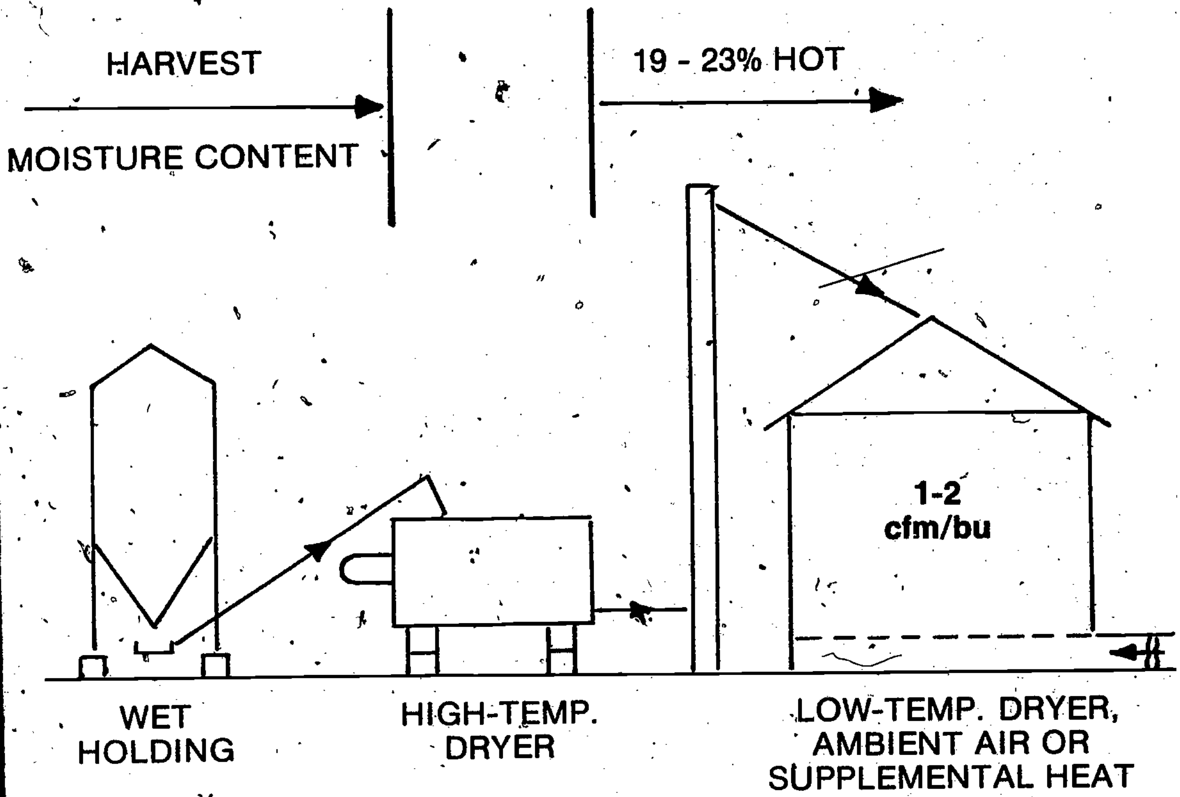


Figure 4. **Schematic diagram of a combination high-temperature, low-temperature grain drying system.**
(Reference: G. Shove, ASAE Paper No. NA78-305; Source: Glenn et al., OARDC)

To provide a more uniform moisture content throughout the batch, grain stirring devices can be operated, preferably after drying is finished. These devices help obtain the highest possible drying efficiency. Energy-saving procedures such as dryeration or combination drying can also be applied to the hot grain leaving batch-in-bin dryers.

Note: Assistance in determining any needed changes in corn dryer management can be obtained by using the *Computer Simulation* form, page 18.

G. SUPPLYING SUFFICIENT NUTRIENTS

Problem Statement: "What fertilization program should *student* use for corn?"

Interest Approach: Before the class gets involved in determining a fertilization program for *student's* corn, the teacher may want to assist the students in limiting conclusions for this problem statement. The program should result specifically in reduced grain moisture at harvest, plus increased standability. Other fertilization lessons can speak to other aspects of corn fertilization.

Adequate phosphorus seems particularly important to ensure decreased moisture at harvest. Potassium is needed to reduce the incidence of rotted stalks and lodging in corn caused by adverse effects of nitrogen. The teacher should correlate the fertilizer program requirements (phosphorus for reduced moisture at harvest; potassium for greater standability) with production practices previously taught: 1) use of early-maturing corn to permit in-field drying; 2) leaving the early-maturing crop in the field longer to take advantage of free solar drying. Adequate phosphorus and potassium are needed if the above two practices are to succeed.

The teacher can use Table 11 to help the students understand that increasing phosphorus fertilization not only increases corn yield but also decreases the moisture content of the grain at harvest. Adequate phosphorus tends to hasten the maturity of the crop.

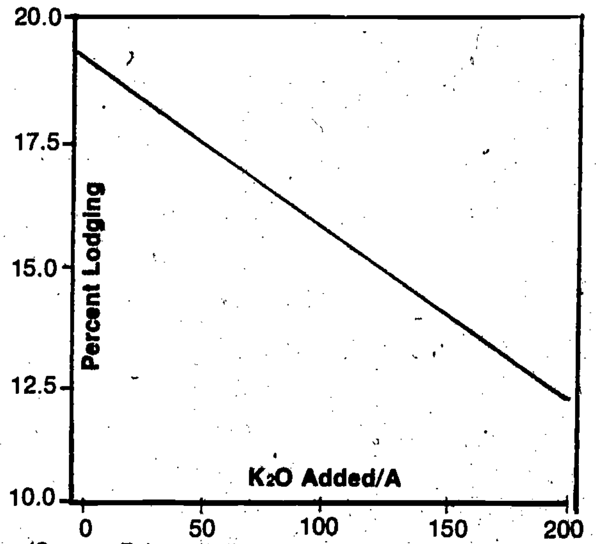
The effects of added potassium on stalk lodging of corn can be taught by using the information in Figure 5. The addition of potassium fertilizer significantly reduces the incidence of rotted stalks and lodging in corn, thus counteracting the adverse effects of high rates of nitrogen.

***Table 11.* Effect of phosphorus fertilization** on yield and moisture content of corn grown at Wooster, Ohio.

Bray P_1 Test (lb./A)	P_2O_5 (lb./A)	Yield (Bu./A)	% Moisture
		1976	
16	0	140	30.6
16	20	149	29.0
16	40	163	28.1
16	80	165	27.6
16	120	167	26.9
		1977	
12	0	150	23.4
13	20	166	22.9
14	40	175	22.8
19	80	183	21.5
18	120	191	21.4

(Reference: J.W. Johnson; Source: Eckert, Bulletin 645)

***Figure 5.* Effect of added potassium on stalk lodging of corn receiving 350 lb. N/A.**



(Source: Eckert, Bulletin 645)

COMPUTER SIMULATION to Improve Corn Dryer Management

Describe your present system and any possible changes you are considering. Then answer the questions that follow. This will allow a computer analysis of your present and future energy usage and drying costs.

Describe your present system (i.e. hi-temp portable column type, low-temp electric heat, batch-in-bin, etc.)

____

____

Describe the system changes you would like to consider. (Refer to the articles entitled "More Efficient Corn Drying Systems" or "Cut Corn Drying Costs" for possible alternatives.)

____

____

____

Answer these questions for use in the computer analysis.

Fan power source: Electricity _____, Gas or Diesel Engine _____

Heat source: Propane _____, Electricity _____, None _____, Other _____

Fuel costs: Fan power ¢/kWh _____, ¢/gal. _____

Heat source ¢/kWh _____, ¢/gal. _____

Fan powered by _______ hp or air flow _______ cfm/bu. _______

Bin diameter(s): _______ ft; Grain depth(s): _______ ft.

Or for high-temperature column-type dryers,

Drying section grain volume: _______ bu.; Column width: _______ in.

Drying air temperature(s): _______ °F

Grain moistures: Harvested at _____%, Out of dryer _____%

Drying in: Sept. _____, Oct. _____, Nov. _____, Other _______

Total bushels dried _______

Your **name, address,** and **phone number** ____________________

____

____

Return to: Dr. Ted L. Glenn
Agricultural Engineering Department
Ohio Agricultural Research and Development Center
Wooster, Ohio 44691 (Ph. 216-264-1021)

2/22/80

VII. Student Application

The teacher should assist the students in applying in their occupational experience programs the selected improved practices studied in this lesson.

VIII. Student Evaluation

Directions: *The following questions require short answers. You do not need to use complete sentences.*

1. In our discussion of production practices that _student_ could use to save energy, we listed five. Please describe them below.

   a. ____________________
   b. ____________________
   c. ____________________
   d. ____________________
   e. ____________________

2. Considering our location, the best corn planting date for _student_ would be ________

3. Corn planted close to this date acquires more Growing Degree Days faster and thus is more likely to mature before frost. Describe how this situation saves the corn producer in energy costs.

4. Describe how early planting results in a higher yield of corn.

5. Describe how early planting of corn benefits the producer in regards to seed bed preparation for the next crop season.

6. When a corn grower is in the process of making a decision as to which variety of corn to select, he/she considers certain factors or characteristics about corn varieties. Please list those factors or characteristics that we discussed in class.

7. List at least 2 corn varieties selected by the class during our discussion.

8. In a few sentences, explain the effect that field drainage has on days available for field work.

9. Describe the process by which reduced tillage brings about a higher yield of corn.

10. In a few sentences, describe the advantages, if any, of growing drier corn.

11. During our class discussion, we recommended that _student_ should begin harvesting corn at a certain moisture content. Please give the moisture content recommendation.

    ____

12. During our class discussion, we determined that there are two primary practices a corn grower can use to conserve energy when drying corn artificially. Please name those two practices.

13. One conclusion we reached in our class discussion was the recommended moisture content to which Dale should dry his corn in order to have safe storage to June 1. What is that recommended moisture level? ____________

14. What procedures would you recommend that *student* follow in order to prevent rapid cooling of grain when using a high temperature drying system?

15. Describe how increasing phosphorus fertilization of corn affects energy consumption in corn production.

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I. Lesson Topic: **ENERGY MANAGEMENT IN LIVESTOCK PRODUCTION**

by

DENNIS RIETHMAN

II. Lesson Performance Objectives

At the end of this lesson, the student will be able to:

1. Determine the amount of fuel needed to raise a crop for one year on his/her farm.
2. Determine the amount of fuel needed to raise livestock for one year on his/her farm.
3. Select areas which may be wasting fuel during the production of the crop and/or livestock.
4. Determine the amount of heat lost through a wall.
5. Determine the fuel cost at a certain heat loss rate.
6. Determine the fuel use for buildings on the farmstead.
7. Explain the purposes of ventilation.
8. Determine what information is needed to size a ventilation system.
9. Determine the proper size fan needed for a specific ventilation system.
10. Determine the ventilation inlet size.

III. Materials Needed

1. Overhead projector
2. Examples of different types of insulation; (power companies are a good source for these examples)
3. Transportation for field trips

IV. The Situation

Energy management means getting the maximum output from the least energy input to get the job done. Reducing energy units used for each output unit produced saves money and energy.

Only 3 percent of the energy used in the U.S.A is required to keep farms in operation. This may be a small amount, but energy has become an increasingly expensive resource. Farmers must learn to cope with this the same way they deal with other problems that arise on the farm.

The following sections on energy management in livestock production are divided into four different problems of concern. Each section can be used as written or adjusted to fit the local situation. The four problems presented are:

1. Estimating Farm Fuel Requirements
2. Determining the Value of Insulation
3. Determining Ventilation and Heating Needs
4. Recapturing Heat Losses in a Dairy Operation

It is important that we study energy management and conservation in livestock production so that we can 1) save money and increase profits, 2) raise healthier livestock, 3) conserve our natural resources, and 4) become better farm managers. To improve energy efficiency in livestock production, we need to look at three areas of energy usage:

1. ventilation
2. insulation
3. recapturing heat loss

Improper ventilation, lack of insulation, and heat loss through cooling of milk all result in an energy loss in livestock production.

CONCERN 1: ESTIMATING FARM FUEL REQUIREMENTS

V. Introduction to Lesson

The United States is presently facing an energy supply problem. Even though an estimate of only 3 percent of the energy consumed in the United States is used for production of agricultural products, producers should use farm fuels efficiently. If gas rationing becomes a necessity because of reduced supplies, the producer must be able to adjust to this and be able to distinguish or determine how much fuel will be needed for crop and livestock operations.

VI. The Problem

Present the following problem situation to the students on a handout or overhead:

> _John_ and his father farm 375 crop acres. This past year they planted 20 acres in wheat, 20 acres in hay to be baled, 85 acres in soybeans, and 250 acres in corn. Fifty acres of the corn was used to fill their silos for feeding steers and the remaining 200 acres of corn, which yielded 150 bushels per acre, was dried under good conditions with a propane operated drying system. All field operations were performed with diesel tractors and combine, under conventional methods of field preparation and harvesting.
>
> The livestock on the farm consists of 60,000 laying hens and 100 feeder cattle finished for market. The cattle are finished on a feedlot with a bunk feeder and bedding is provided in the housing area. The poultry house contains a manure handling system comparable to a liquid manure system for a swine confinement finishing barn. All livestock production and manure removal operations are performed with diesel tractors.

Ask the students the following question; this is the **problem statement**:
"_John_ wants to be prepared for any fuel shortage which may occur and would like to evaluate the fuel usage on his farm. What is _John's_ fuel usage in a one-year period?"
Discuss _John's_ situation and farming operation.

VII. Solution to Problem

Distribute to the class **handout #1** in the Appendix, *Estimating Farm Fuel Requirements for Crop Production and Livestock Operations*. Point out to the students the major types of information in the publication. Explain that the information is to be used to help find the solution to _John's_ problem.

Work through _John's_ problem with the students. The completed problem on the board should look like the following (see Table 1):

Table 1. **Estimating fuel requirements for crop production and livestock operations**

CROPS

Total Acres: 375

Crop	Acres of Each Crop	Gallons Fuel Needed per Acre	Total Gallons Fuel Needed
Wheat	20	3.00	60.0
Hay	20	8.65	173.0
Soybeans	85	6.50	552.5
Corn	200	6.85	1370.0
Corn Silage	50	8.65	432.5
		Total:	2588 gallons *(diesel)*

Fuel Needed to Dry Corn:

30,000 bushels ÷ 6 bu./gal. propane = 5,000 gallons

TOTAL CROP FUEL REQUIREMENT: **7,588 gallons** *(LP gas)*

LIVESTOCK

Production:

Number of Animals	Gallons Fuel (per Animal)	Gallons Fuel Needed
100 Feeder Steers	1.3	130 *(diesel)*
60,000 Layers	5.4/100 birds	3240
	TOTAL FUEL USE FOR PRODUCTION:	**3370 gallons** *(diesel)*

Manure Removal and Hauling:

Type of System	Gallons Fuel (per Animal)	Gallons Fuel Needed
Feedlot with Bedding in Housing Area	1.6	160
Liquid Manure System	0.3/100 birds	180

TOTAL FUEL USED FOR MANURE HANDLING:	340 gallons
TOTAL DIESEL FUEL USED FOR LIVESTOCK:	3710 gallons
TOTAL DIESEL FUEL USED FOR OPERATION:	6298 gallons
TOTAL LP GAS USED FOR OPERATION:	7588 gallons

Evaluate with the class the amount of fuel used in *John's* operation. Draw some conclusions as to where *John* might be able to reduce his fuel usage.

Areas of possible fuel reduction:

- In the need for drying corn.

- In his conventional method of tillage and ground preparation. (No-till not only reduces fuel cost but permits use of a smaller tractor.)
- In his corn drying methods. (Low-temperature drying can eliminate LP gas use while substituting some electricity to run the drying fans.)

VIII. Application

Following are some suggestions to the student or the class for applying what they have learned:

1. Divide the class into five groups and have each group work together to determine the energy requirements for raising different species of livestock, e.g., dairy, beef, swine, sheep, and poultry. Present each group with a case situation for the different animal species. (The teacher may want to use the enclosed sample situations along with **handout #2,** the *Farm Fuel Estimate Worksheet.*) Once completed, develop a chart on the board and compare the results from each group.
2. Have each student determine the fuel usage for his/her particular farming operation.

   (***Note:*** It is important for students to understand the difference between fuels. Power or heat per gallon and cost per gallon differ, so which fuel one uses will influence the cost.)

IX. Evaluation

The teacher may choose to use one of the following five case situations as a quiz on this lesson section or problem.

CASE SITUATION #1:

SWINE FARM OPERATION

Estimate the fuel requirements for this operation. On a separate sheet of paper list five areas in which the owners of this operation might be able to reduce their fuel usage.

This swine operation consists of 40 sows and 950 pigs finished to market weight. The sows are housed and fed on a lot except during farrowing. The pigs are housed in a finishing house with liquid manure collection. All production and manure handling operations are performed with diesel tractors.

The cropping system consists of 475 crop acres: — 215 acres of no-till corn, 135 acres of soybeans, 80 acres of wheat (no plowing), and 45 acres of hay (3 cuttings, self-propelled cut). The corn is stored in a high-moisture storage facility. All operations for the cropping system are performed with diesel tractors and combine, except the hay which is harvested with gasoline tractors.

CASE SITUATION #2:

SHEEP FARM OPERATION

Estimate the fuel requirements for this operation. On a separate sheet of paper list five areas in which the owners of this operation might be able to reduce their fuel usage.

This sheep operation consists of 525 feeder lambs finished to market. The feeder lambs are raised in a feedlot, with bedding in the housing area similar to that in a beef feedlot. All production operations are performed with gasoline tractors, while the manure handling operations are performed with diesel tractors.

The cropping system consists of 475 crop acres: — 220 acres of corn using plowing with minimum tillage planting; 60 acres of no-till corn silage; 50 acres of dry cured, baled hay; 25 acres of wheat (no plowing); 100 acres of soybeans; and 20 acres of dry chopped haylage. The corn (130 bushels/acre yield) is dried in a propane-type dryer under favorable conditions. All field work for the crops is performed with diesel tractors and combine.

CASE SITUATION #3:

POULTRY FARM OPERATION

Estimate the fuel requirements for this operation. On a separate sheet of paper list five areas in which the owners of this operation might be able to reduce their fuel usage.

This poultry operation consists of 30,000 pullets and 90,000 laying hens. The chicken housing has a manure handling system similar to a liquid manure system for swine. All production operations are automated and therefore use only half the gasoline estimate. The manure removal operations are performed with diesel tractors.

The cropping system consists of 475 crop acres: — 125 acres of corn raised under conventional methods and 90 acres of no-till corn, 135 acres of soybeans, 80 acres of wheat (no plowing) and 45 acres of hay (3 cuttings, self-propelled cut). The corn is stored in a high-moisture storage facility. All cropping operations are performed with diesel tractors and combine.

CASE SITUATION #4:

BEEF FARM OPERATION

Estimate the fuel requirements for this operation. On a separate sheet of paper list five areas in which the owners of this operation might be able to reduce their fuel usage.

This beef farm consists of 50 beef cows and 20 replacement heifers. The operation also finishes out for market 225 steers yearly. The operation has a beef feedlot with bedding used in the housing area. All of the production and manure removal operations are performed with gasoline tractors.

The cropping system consists of 475 crop acres: — 220 acres of no-till corn; 60 acres of corn silage planted and harvested under conventional methods; 50 acres of dry cured, baled hay; 25 acres of wheat (no plowing); 100 acres of soybeans; and 20 acres of dry chopped haylage. The corn (120 bushels/acre yield) is dried in a propane-type dryer under favorable conditions. All field work for the crops is performed with diesel tractors and combine.

CASE SITUATION #5:

DAIRY FARM OPERATION

Estimate the fuel requirements for this operation. On a separate sheet of paper list five areas in which the owners of this operation might be able to reduce their fuel usage.

This dairy farm consists of 80 milking cows (producing 12,000 lb. of milk per cow yearly) and 50 replacement heifers. The milk cows are housed in an area having liquid manure collection, and the replacement heifers are housed in a dairy lot with bedding in the housing area. The production and manure handling systems for the dairy cows are performed with diesel tractors. The production and manure handling systems for the heifers are performed with gasoline tractors.

The cropping system consists of 475 crop acres with 220 acres of corn planted under conventional methods; 60 acres of corn silage; 50 acres of dry cured, baled hay; 25 acres of wheat (no plowing); 100 acres of soybeans; and 20 acres of dry chopped haylage. The corn (112 bushels/acre yield) is dried in a propane-type dryer under good conditions. All field work for the crops is performed with diesel tractors and combine.

CONCERN 2: DETERMINING THE VALUE OF INSULATION

V. Introduction to Lesson

To reduce fuel costs of heating in home or farm buildings with the use of insulation, a person must estimate the fuel being used presently and then compare that figure to the fuel used (or saved) if insulation is added. The problem then arises as to how this estimate of fuel used can be determined.

VI. The Problem

Discuss *John's* situation with the class and lead discussion to how heat loss is determined (see Figure 1).

John has a 24-foot wide, 36-foot long, and 8-foot high farrowing house heated with fuel oil. The farrowing house has no insulation in its walls or ceiling. The ceiling is ½ inch plywood and the walls are ½ inch plywood plus steel siding. *John* would like to know his present fuel loss and how much fuel he could save by adding insulation to the walls and ceiling of his farrowing house.

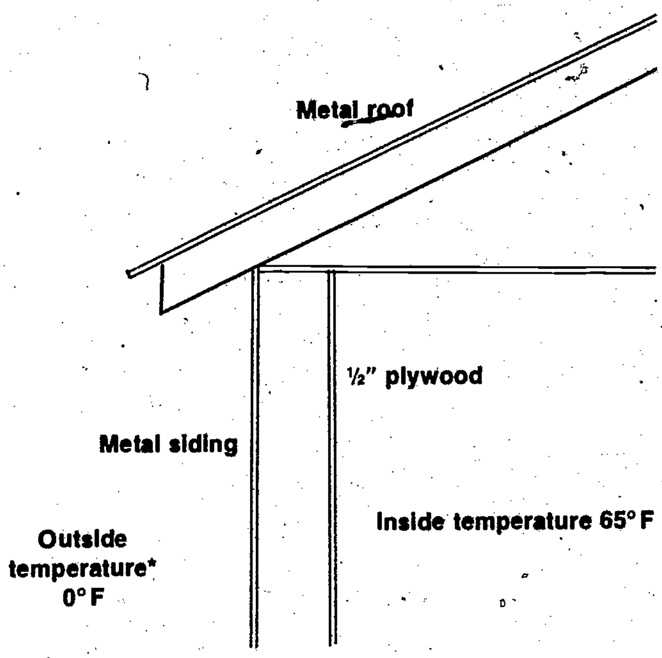

***Figure 1.* Sketch of farrowing house**

*Design temperature for sizing the heater. Average temperature ≈ 30° F
(The symbol ≈ means "is roughly equivalent to.")

Problem Statement: (Place the following question on the chalkboard)

"Is it economically feasible for *John* to add insulation to the walls and ceiling of his swine farrowing house?"

VII. Solution to the Problem

Distribute to the class **handout #3**, *House Insulation Types and Values*. Discuss heat flow with the class and explain the meaning of Thermal Resistance or "R" values.

A. Determine the heat flow through the walls and ceiling of *John's* farrowing house by developing a chart on the board with the class. The chart should look like the following:

Step 1. **Building Dimensions (ft)** / **Surface Area (ft²)** / **R Values**

Building Dimensions (ft)		Surface Area (ft²)		R Values	
Length	36′	Ceiling area	864	Ceiling	0.62 (½″ plywood)
Width	24′	Wall area	960	Walls	1.23 (½″ plywood and steel siding)
Wall height	8′				

Step 2. **Change in Temperature**

	Minimum	Average
Outside temperature	0° F	30° F
Desired inside temperature	65° F	65° F
Temperature change	65° F	35° F

Step 3. **Heat Loss from Building**

Use formula:

$$\frac{\textbf{Change in Temperature x Area}}{\textbf{R Value}}$$

Step 4.

	Minimum	Average
Ceiling:	$\frac{65° F \times 864 \text{ ft}^2}{0.62}$ = 90,580 BTU/hr.	$\frac{35° F \times 864 \text{ ft}^2}{0.62}$ = 48,774 BTU/hr.
Walls:	$\frac{65° F \times 960 \text{ ft}^2}{1.23}$ = 50,732 BTU/hr.	$\frac{35° F \times 960 \text{ ft}^2}{1.23}$ = 27,317 BTU/hr.
Total Loss	= 141,312 BTU/hr.*	76,091 BTU/hr.

Step 5. 76,091 BTU/hr. x 24 hours x c. 200 days = 365 million BTU/year as annual total.

B. Determine the heat flow through the building if 4″ of fiberglass (blanket/batt) insulation were added to the ceiling and walls. With help from the class develop on the board another chart like the previous one. The "R" value for the fiberglass is found in **handout #3**, *House Insulation Types and Values.*

Step 1.

Building Dimensions (ft)		Surface Area (ft²)		R Values	
Length	36′	Ceiling area	864	Ceiling	0.62 + 14** = 14.62
Width	24′	Wall area	960	Walls	1.23 + 14** = 15.23
Wall height	8′				

*Heater needs to be this size to handle conducted heat loss.

**14 = 4″ X 3.5R/inch

Step 2. **Change in Temperature**

Outside temperature	0° F
Inside temperature	65° F
Temperature change	65° F

Step 3. **Heat Loss from Building**

Use formula:

$$\frac{\textbf{Change in Temperature x Area}}{\textbf{R Value}}$$

Step 4.

	Minimum		Average
Ceiling:	$\frac{65° F \times 864 \text{ ft}^2}{14.62}$	= 3841 BTU/hr.	2068 BTU/hr.
Walls:	$\frac{65° F \times 960 \text{ ft}^2}{15.23}$	= 4097 BTU/hr.	2206 BTU/hr.
	Total Loss	= 7938 BTU/hr.	4274 BTU/hr. or 20.5 million BTU per year

C. Compare the difference in heat loss between the insulated and the uninsulated building.

365 million BTU/yr. — Uninsulated building

20.5 million BTU/yr. — Insulated building (with 4" of fiberglass in ceiling and walls)

345 million BTU/yr. — Difference (saved)

(Note that if the insulation were doubled to 8" (R ≈ 30), the savings is increased to only about 355 million BTU.)

D. Determine the **amount of fuel saved** by adding insulation to the building.

Calculations: At typical efficiencies,

Fuel oil ≈ 100,000 BTU/gallon
LP gas ≈ 75,000 BTU/gallon

Therefore, 3450 gallons fuel oil saved (345 million BTU ÷ 100,000 BTU)

OR 4600 gallons LP gas saved (345 million BTU ÷ 75,000 BTU)

E. Determine the amount of money saved by adding insulation to the building.

(Fuel oil cost is calculated at $1.20/gal.)
3450 gallons saved x $1.20/gal. = $4,140.00 saved (using fuel oil)

(LP gas cost is calculated at 75¢/gal.)
4600 gallons saved x 75¢/gal. = $3,450.00 saved (using LP gas)

F. *Conclusion:* After working the problem with the students, discuss the dollars saved by adding insulation and whether adding insulation will pay for itself.

4" Fiberglass Batt Insulation (Cost 13½¢/ft²)

1824 ft² insulation needed.
x 0.135
$ 246.24 Cost of the insulation

Over $3,000 saved from fuel

Will the insulation pay for itself?

Conclusion (on chalkboard): ____

____

(*Note:* An extra 4" of insulation would cost about $250 and would save about $100 per year.)

While assisting the class to reach a conclusion to this problem, the teacher should point out that no farmer would attempt to heat an uninsulated building to 65° F. The real decision is how much insulation to use. Usually the wall cavity should be filled. The ceiling should probably have 6" to 12" insulation in a building heated all winter.

VIII. Application

Have the students work a problem relating to their home situation on the following worksheet. If the students don't have a suitable home situation to use, then give them the sample problem to work.

SAMPLE PROBLEM: **Determining the Value of Insulation**

An area dairy farmer has a 24-foot wide and 46-foot long calf barn with 8-foot high walls. The ceiling is made of a sheathing-type insulation board and the walls are 8-inch concrete block. Also, there are six 18 x 24-inch single glass windows in the building. The inside temperature of the building is kept at 55° F with a fuel oil heater. The average outside temperature during the winter months is 15° F.

This farmer can purchase enough rigid glass fiber insulation to put 3 inches in the ceiling of the building at a cost of $0.15 per square foot. To add 3 inches of insulation to the walls he would use loose fill wood fiber inside the concrete blocks. This would require 15 bags of wood fiber insulation at $18.00 per bag.

1. Determine this farmer's heat loss in the calf barn without insulation.
2. Determine this farmer's heat loss in the calf barn with insulation added.
3. Compare the difference in heat loss between the insulated and uninsulated building.
4. Determine the amount of **fuel saved** by adding insulation to the building. (Use **handout #4,** *Heat Loss Worksheet* with **handout #5,** *Estimated Fuel Used,* page 25.)
5. Fuel oil costs this farmer $1.21 per gallon. Determine the amount of money saved on the cost of fuel by adding insulation to the building.
6. Will adding insulation to the calf barn pay for itself for this farmer? (Explain)

IX. Student Evaluation

TEST: DETERMINING THE VALUE OF INSULATION

NAME ______________________

You have a 32-foot wide and 80-foot long pig nursery with 8-foot high walls. The ceiling in the building is a sheathing type insulation board and the walls are ½-inch wood siding on the outside and aluminum siding with foil backed insulation board on the inside. There are eight 24-inch by 24-inch single glass windows in the building. The inside temperature of the building is kept at 75° F with a fuel oil heater. The average outside temperature during the winter months is 15° F.

Four inches of blanket-type mineral fiber insulation (R = 3.7 per inch) will cost $0.38 per square foot and could be put in the ceiling. Loose fill-type cellulose could be blown into the walls, adding 3½ inches of insulation. This would take 35 bags of insulation at $17.50 per bag.

1. Determine the heat loss in the pig nursery at the present time (without insulation).

   ____________ BTU/hr.

2. Determine the heat loss of the pig nursery if insulation were added.

   ____________ BTU/hr.

3. Compare the difference in heat loss between the insulated and uninsulated building.

   ____________ BTU/hr. saved

4. Determine the amount of **fuel saved** by adding insulation to the pig nursery. (Use the chart below)

   ____________ gallons saved

Component Areas		*Gallons Oil Used/100 sq. ft.*
Ceiling: No insulation	R = 2.06	48.0
+4" insulation	R = 16.86	8.2
Wall: No insulation	R = 3.77	32.0
+3½" insulation	R = 16.72	7.5
Window: Single glass	R = 0.91	140.0

5. Fuel oil costs $1.08 per gallon. Determine the amount of money saved on fuel by adding insulation to the building.

   $ ____________

6. Will adding insulation to the building pay for itself? Explain.

CONCERN 3: DETERMINING VENTILATION AND HEATING NEEDS

V. Introduction to Lesson

Ventilation is very important in livestock production. It is needed at all times in confinement livestock housing. A properly designed and operated ventilation system can result in substantial savings in livestock production costs because of increased animal performance and lower heating—cooling costs. Since energy use is directly related to the operation of a ventilation system, livestock producers should use properly sized equipment and manage it efficiently to conserve energy and to minimize expenses.

To prepare the class for assisting *John* in making decisions about ventilating his farrowing house, the teacher may present the following four questions to the class. These questions should help develop in the students an interest in values of adequate ventilation in livestock buildings.

Question 1: Why is ventilation needed? What is the purpose of ventilation?

Possible student answers:

1. Provide oxygen
2. Remove moisture
3. Remove odors
4. Prevent heat buildup; cool animals
5. Dilute air-borne disease organisms

Question 2: How can ventilation be accomplished?

Possible student answers:

1. Mechanical means - fans and thermostats and slot inlets
2. Natural means - using the least amount of energy, but limited to certain operations

Question 3. How can we save energy with mechanical ventilation?

Possible student answers:

1. Make sure you have the right size of fan for the building.
2. Make sure the fan and louvers work right. (Clean *at least* once a year.)
3. Make sure the fan controls work right.

Question 4. What factors will determine or affect the size of fan to put in a building for ventilation?

Possible student answers:

1. Size of the building
2. Number and size or age of animals in the building
3. Temperature needed in the building.
4. Design of the building (solid vs. slatted floors)
5. Type of animal in the building

VI. The Problem

Present the following situation to the students:

"___John___ wants to ventilate his swine farrowing house but still save energy and keep his costs down. He wants you to help him in determining the correct size fan to install in his farrowing house for ventilation." (Teacher writes problem statement on chalkboard: *"What size of fan should ___John___ obtain for his farrowing house?"*) "What would you ask ___John___ about his farrowing house to help him make a decision?"

1. How big is the building?
2. Does the building have any insulation?
3. How many sows will you keep in the farrowing house?
4. What temperature do you want inside the building during the winter?
5. What temperature do you want inside the building during the summer?
6. What type of flooring do you have in the building?
7. Do you have any heaters in the building? What type?

Answers to the questions asked of ___John___:

The farrowing house is 35 feet long by 20 feet wide. The building is well insulated and will hold 14 sows and their litters. He expects the building to be kept at 70° F during the winter and at about the same temperature as outside during the summer. He has a partly slotted floor and unvented radiant-type heaters.

Distribute to the students **handout #6**, the worksheet on *Determining Fan Size*, and **handout #7** on Environmental Control Systems. Work through the problem with the students and determine what size of fan ___John___ needs in his farrowing house. It would be best to make a transparency of the worksheet so students can see where the numbers are to be located in the worksheet.

Conclusion: After working through the problem, discuss with the students different options ___John___ might have in selecting the right fans. Also discuss and review with the students what guidelines they used to select that fan size.

VII. Application

Have each student work through a problem relating to his/her home situation. For some students this may not be possible. Therefore, give them a class situation or have them work with a student who has a swine enterprise.

VIII. Student Evaluation

On the *Determining Fan Size Worksheet* have the students work through the following problem and give their recommendations.

An area farmer has a 40-foot long and 15-foot wide pig nursery with a fully slotted floor and a vented-type heating system. The nursery will hold 85 pigs. It is to be kept at a temperature of 75° F year around. Determine *your* recommendation on fan size to install in the pig nursery.

Using Handout #6

Dr. Randall Reeder, Department of Agricultural Engineering, OSU, offers the following advice concerning the use of the worksheet, *Determining Fan Size*. This worksheet (pages 26-27) can be very confusing. The teacher should be careful not to make the problem harder than it really is. The students should understand that getting the small, constant-running minimum rate fan is critical to energy conservation. The next step can be a variable speed fan. OSU's recommendation is to avoid using a variable speed fan to provide the *minimum* rate. Adjustment is too difficult and these fans generally do not ventilate dependably at less than ¼ of maximum rate. A variable speed fan is fine for the "middle range" fan. The summer rate is not a precise number. For example, in farrowing, the recommendation ranges from about 250 to 500 cfm, depending on whom you talk to. The fact is that a fan at the high rate would keep a building only 1 to 3 degrees cooler than one at the lower rate. Up to one-half of the hot weather rate can be accomplished with **circulation** fans rather than exhaust fans.

The teacher should spend some time on size and location of inlets. Fans can be placed almost anywhere, but the size and placement of inlets is critical for good uniform ventilation for all parts of a building. (Air should not have to move more than **75 feet** from any inlet to an exhaust fan.)

The teacher should calculate energy lost through winter ventilation for comparison with previous calculations. Reeder suggests using three months (December through February) with an average temperature of about 25°F. For farrowing, compare 20, 40, and 80 cfm, and perhaps 10 cfm. Use this equation:

$$Q = \frac{\text{cfm} \times 60 \times \Delta T}{50\ \text{ft}^3/\text{Btu}/^\circ\text{F}}$$

Q = __________ Btu/hr.

Then multiply 24 (hours) x 90 (days) to get Q = __________ Btu/winter. The total Q for the rates 300, 600, 1200, and 150 cfm is 35 million, 70 million, 140 million, and 17.5 million Btu, respectively. Note that dropping the ventilation rate from about 80 cfm down to 20 cfm saves about 100 million Btu (140-35). That is a difference of about 1000 gallons of fuel oil. The high ventilation rate was common a few years ago. Note that cutting the rate from 20 to 10 cfm saves only 17 million Btu.

Students should understand that in a well insulated, properly ventilated building, the ventilation heat loss will usually account for 50 to 75 percent of the heat loss. Note also that most of that heat loss may be supplied by the animals at no cost to the owner.

CONCERN 4: REDUCING WATER HEATING COST IN THE MILKHOUSE

V. Introduction to Lesson

1. Increases in energy costs over the past years have increased the need for energy efficient management for dairy operators.

2. A practical area in a dairy operation in which to try to improve energy efficiency is the use of hot water. Dairy operations require large amounts of hot water and the cost of electricity to heat the water is continuing to increase.

VI. The Problem

___*John*___ is currently milking 70 dairy cows which produce approximately 3,000 pounds of milk each day. ___*John*___ has a relatively modern four-on-a-side milking parlor with a prep stall on each side. He also has an automatic washing bulk tank. ___*John's*___ problem is that his hot water costs are very high. He has heard of dairy heat exchangers for heating water and would like to know if it is economically feasible to install one in his dairy system.

Problem Statement (to be placed on the chalkboard):

"Is it feasible for _John_ to install a dairy heat exchanger?"*

VII. Solution to Problem

1. Explain to the class what heat exchangers are, and what types are available. Use **handout #8**, Figure 1, *Dairy Farm Heat Exchangers for Heating Water*. Check with local dairy supply services on available materials (for example, Surge, De Laval).
2. Present _John's_ situation to the class.
3. Distribute **handout #8**, *Dairy Farm Heat Exchangers for Heating Water* (NRAES, Cornell University).
4. Have the class read through the section "Expected Savings" (page 1).
5. Using Table 1 in the handout, determine _John's_ daily hot water use.

Example:

Washing Operation	Hot Water Volume
Bulk tank	50 gallons
Pipeline	75 gallons
Prep. stalls	35 gallons
Parlor floor	40 gallons
Milkhouse floor	10 gallons
TOTAL	200 gallons/day

6. Using Table 2 and Table 3 in the handout, determine the savings _John_ can expect by installing a heat exchanger. (***Note:*** Adjust fuel prices in tables to current prices.)

COMPLETE CONDENSING HEAT EXCHANGER

Table 2: 3,000# milk — 260 gallons of 140°F water produced daily

Electricity savings - approximately $834.00 @ 4¢/kwh

ADD-ON HEAT EXCHANGER

Table 3: 3,000# milk — 124 gallons of 125°F water produced daily

Electricity savings - approximately $333.00 @ 4¢/kwh

7. Discuss with the class the results of the findings from the tables.
   - Should _John_ install a heat exchanger?
   - Which type would be better for his dairy operation?

***Note:** Nearly every farmer with a pipeline system can justify a heat exchanger.

VIII. Application

Have all students work through the same procedure for their dairy operation or a dairy farm they are familiar with. If this is not possible, give each student a case situation to determine the feasibility of a heat exchanger.

IX. Student Evaluation

Write a case situation on the board and have each student determine the feasibility of a heat exchanger for a dairy system. Have the students explain in a short paragraph their decision and reasons supporting their decision.

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Miller, Roger A., *Reducing Fuel Costs in House Heating with Insulation*. Columbus, Ohio: Cooperative Extension Service Bulletin L-266, The Ohio State University

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HANDOUT #1- page 1

ESTIMATING FARM FUEL REQUIREMENTS for Crop Production and Livestock Operations

Federal energy experts estimate that 3 to 4 percent of the energy consumed in the United States is required by American agriculture to produce the nation's food and fiber. With the energy supply problems facing our country, every producer should use farm fuels efficiently and be able to adjust to possible reduced supplies.

If shortages become critical, you may be required to apply for a fuel allotment. While you may have all of your gas tickets from the past crop season, would you be able to distinguish what fuel had been used for which crop and how much might have gone to provide mechanization for your livestock operations?

How to Estimate Your Farm Fuel Requirements

By using the Iowa fuel use tables and good judgment, you can estimate the gallons of gasoline, diesel fuel or LP gas you will need to grow your next crop and maintain your livestock program.

Here's an example of how you can use the Iowa fuel use tables for next year's crop planning. Consider a 480-acre Corn Belt farm. The operator plans to plant 240 acres of corn, 160 acres of soybeans and wants to raise 800 market hogs. The field crop operations are performed *mostly* with his diesel-engine tractors and combines; the livestock chore jobs are done with a gasoline-burning tractor.

From the table, 6.85 gallons of diesel fuel are needed to grow an acre of corn; 6.5 gallons of diesel fuel will produce an acre of soybeans. So,

Corn—6.85 gal/a x 240a planned = 1,644 gallons diesel fuel
Soybeans—6.50 gal/a x 160a planned = 1,040 gallons diesel fuel

Estimated Annual Requirement = 2,684 gallons diesel fuel

Estimates of Fuel Burned for Crop and Livestock Production Operations Under Average Conditions

Crop Production

Cropping system	Gasoline	Diesel fuel	LP gas
Corn—conventional methods	9.5	6.85	11.4
Corn—plowing with minimum tillage planting	7.5	5.40	9.0
Corn—no plowing, minimum tillage planting	6.0	4.30	7.2
Corn harvested and stored as whole-plant silage			
Conventional methods	12.0	8.65	14.4
Plowing with minimum tillage	10.0	7.20	12.0
No plowing, minimum tillage	8.5	6.10	10.2
Soybeans—conventional methods	9.0	6.50	10.8
Small grains—oats, barley, rye, wheat	4.25	3.00	5.1
Small grains—with plowing	6.50	4.70	7.8
Hay—dry cured, 3 cuttings, baled	12.0	8.65	14.4
Haylage—3 cuttings or dry chopped	18.0	13.00	21.6
Using combined type cutting with self-propelled cut, crush, windrow			
Hay—3 cuttings	7.2	5.20	8.6
Haylage—3 cuttings	13.2	9.50	15.8

(Gallons per acre)

Corn drying—with favorable drying conditions—1 gal. propane will dry 7 bu. corn
—with good drying conditions—1 gal. propane will dry 6 bu. corn
—with unfavorable drying conditions—1 gal. propane will dry 5 bu. corn

Reviewed for reprinting by Erdal Ozkan, Extension agricultural engineer.

Cooperative Extension Service
Iowa State University
Ames, Iowa 50011

Pm-587 | Reprinted | July 1980

Livestock Production
(Includes all fuel used to remove feed from storage, process and deliver to feeders)

		Gallons per animal or 100 birds		
Animal	**Feeding period**	**Gasoline**	**Diesel fuel**	**LP gas**
Swine	Raise 1 pig to market including feeding of sow and boar	0.40	0.30	0.50
Dairy	Cow milking 9,000 lbs. milk/year	1.00	0.75	1.20
	Cow milking 12,000 lbs. milk/year	1.35	1.00	1.60
	Heifer—1 year	0.40	0.30	0.50
Beef	Steers—grown from 400 to 1,200 lbs.	1.80	1.30	2.15
	Heavy steers—grown from 700 to 1,200 lbs.	1.00	0.75	1.20
	Heifers—grown from 400 to 850 lbs.	1.35	1.00	1.60
	Yearlings—grown from 650 to 1,200 lbs.	1.75	1.25	2.10
	Cows—winter and raise calf to 400 lbs.	0.90	0.65	1.10
Sheep	Lambs—native, from birth to market	0.60	0.45	0.70
	Feeder lambs—50 lbs. to market	0.125	0.10	0.15
Poultry	Raise 100 broilers from birth to market	0.75	0.55	0.90
	Raise 100 pullets from birth to laying	2.70	1.95	3.25
	Layers for 1 year—100 birds	7.50	5.40	9.00
	Raise 100 turkeys from birth to market	7.50	5.40	9.00

Manure Removal and Hauling

	Gallons of fuel used per animal produced		
	Gasoline	**Diesel fuel**	**LP gas**
Cleaning beef feedlots with bedding used in housing— Per animal marketed	2.25	1.60	2.70
Cleaning beef feedlots, no bedding used in housing; for feedlots holding up to 1,000 cattle at one time— Per animal marketed	1.25	0.90	1.50
Cleaning beef feedlots without housing, 1,000 to 4,999 cattle on feed at one time— Per animal marketed	0.50	0.35	0.60
Cleaning beef feedlots, without housing, over 5,000 cattle on feed at one time— Per animal marketed	0.40	0.30	0.50
Cleaning dairy lots with bedding used in housing (includes scraping lots) per year— For each milk cow in herd	6.75	4.85	8.10
Cleaning dairy buildings with liquid manure collection, storage and hauling— For each milk cow in herd	9.00	6.50	10.80
Cleaning swine confinement finishing barns with liquid manure system, haul and spread— Per pig raised to market	0.40	0.30	0.50
Cleaning swine finishing barns and lots; may be bedded— Per pig raised to market	0.30	0.22	0.35
Cleaning sow housing, per year (includes cleaning farrowing house)	2.60	1.90	3.10

The table indicates that 0.4 gallon of gasoline is needed to raise a market pig. It takes 0.4 gallon of gasoline to keep the liquid manure hauled from the confinement finishing house and field spread.

Growing market pigs—0.4 gal. x 800 head = 320 gallons of gasoline

Cleaning finishing building—0.4 gal. x 800 head = 320 gallons of gasoline

Estimated Annual Requirement = 640 gallons of gasoline

The amount of LP gas (propane is the most popular dryer fuel) needed to dry shelled corn can be estimated. The operator in the example planned to dry 20,000 bushels of corn. With good drying weather, 1 gallon of propane will dry 6 bushels of corn.

$$\frac{20{,}000 \text{ bushels}}{6 \text{ bu./gal.}} = 3{,}333 \text{ gallons of LP gas}$$

Now comes the judgment part of the fuel use estimates. The long-range weather forecast for his area predicts that the planting season will be "above normal" for rainfall and with "near normal" daytime temperatures.

With those conditions, a farmer needs to anticipate more fuel for planting, so should add 10 percent to the diesel fuel estimate. Adding 268 gallons to 2,684 gives 2,952 gallons of diesel fuel needed to grow the corn and soybean crops. He would not need to increase the gasoline required to raise 800 market pigs because a pig grown in confinement is not greatly affected by the weather.

If he used both diesel fuel and gasoline-burning tractors to grow the crops, he must adjust his estimates. In one example, suppose that about half of each type of fuel was used to produce corn. This means that he grew *120 acres of corn using all diesel fuel* and *120 acres using only gasoline.* So:

Corn—6.85 gal/a x 120a planted = 822 gallons of diesel fuel

Corn—9.5 gal/a x 120a planted = 1,140 gallons of gasoline

Total 240a planted

The amount of fuel burned between Jan. 1 and Dec. 31 to produce an acre of any crop might vary in different parts of Iowa or the Corn Belt due to many unforeseen conditions beyond the producer's control.

These figures provide estimates of fuel required to do jobs under typical Iowa conditions. In any given year, fuel consumption on a particular farm may be either larger or less than the values given in the tables.

Basis for Fuel Use Estimates in Crop Production

The system used to develop the fuel use estimates was to, first, list the various field operations required to produce an acre of crop beginning with land preparation and continuing through planting and harvest into storage; then to determine the horsepower hours required for each operation and, finally, to divide the horsepower hours by the typical number of horsepower hours per gallon of gasoline to get the estimates on a gallons-per-acre basis.

The fuel consumption estimates for field operations are based on studies by the Iowa State University agricultural engineering research group. Crop production studies were conducted by James C. Frisby, formerly assistant manager, University Farm Services. All field operations were time-and-motion studies to determine typical rates of travel with various sizes of field machines, field operating efficiencies and tractor-implement size relations versus timeliness.

Fuel consumption rates by the various tractors and self-propelled implements are based on a 10-year summary of Nebraska Tractor Test data for tractors operating at 50 and 75 percent of maximum load both on power take-off and drawbar. An Illinois study disclosed that tractors operate at approximately 55 percent of maximum load while performing field work.

When determining fuel consumption rates for the various operations, the 50 to 75 percent of maximum load figures were interpolated to match field speed and type of load based on experience with farm operations. The fuel consumption rates for minimum tillage operations were evaluated in the preparation of a master's thesis by Allan J. Wald, now farming in North Dakota.

The fuel consumption estimates for the production of corn, soybeans, small grain, hay and silage have been checked against actual fuel consumption records by many Iowa farmers at the time field representatives of the Iowa Department of Revenue, Motor Vehicle Fuel Tax Division, responsible for checking refunding of gasoline taxes, audited their fuel consumption records. The Motor Vehicle Fuel Tax Division reports a close correlation between our research-based figures and actual farm performance.

Fuel Use in Livestock Enterprises

Livestock production—particularly finishing beef, cow-calf herds, market hogs and dairy—are important livestock enterprises throughout the Corn Belt. Estimates given are based on amount of fuel needed to grind, mix, haul and deliver to the bunk the feed required to grow an animal from birth to market in the case of swine or beef cattle.

Fuel used to feed a dairy cow through 1 year's production, including the dry period, is on an annual basis. Estimates for poultry are based on amount of fuel used in the production of 100 birds.

Tons of feed required to finish meat animals and poultry and to maintain dairy cows in production were obtained from the department of animal science at Iowa State University. These figures are based on many years of research in nutrition and production of livestock.

One of the large chore jobs with livestock is the cleaning and maintenance of buildings and lots and the handling of liquid manure from confinement livestock systems. Waste production volumes used in manure removal and hauling estimates for all farm livestock havé been well established by research people working in environmental quality. Allowances were made for a system where large amounts of bedding are being used.

Limitations

These estimates of fuel used in field crop and livestock production are based on the most reliable experimental data available and are tempered by practical experience.

The estimates given in this report are typical considering soil, field, crop and weather conditions; but the values might be adjusted 10 percent up or down providing good judgment is exercised by the farm operator.

Some of the estimates in this publication are used by courtesy Iowa Department of Revenue, Motor Vehicle Fuel Tax Division, and **Farm Journal**.

File: Engineering 3-2

Cooperative Extension Service, Iowa State University of Science and Technology and the United States Department of Agriculture cooperating. Charles E. Donhowe, director, Ames, Iowa. Distributed in furtherance of the Acts of Congress of May 8 and June 30, 1914.

HANDOUT #2

FARM FUEL ESTIMATE WORKSHEET

CROPS

Total Acres: ________________

Type of Crop	Acres of Each Crop	Gallons Fuel Needed/Acre	Gallons Gas Needed/Acre	Total Gallons Fuel Needed	Total Gallons Gas Needed
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					

Total: ____________ gal. fuel ____________ gal. gas

FUEL NEEDED TO DRY CORN:

________ bushels corn ÷ ________ bu./gal. propane = ____________ gal.

TOTAL CROP FUEL REQUIREMENT: ____________ gal.

LIVESTOCK

Production

Number of Animals	Gallons of Fuel/Animal	Gallons of Gas/Animal	Gallons of Fuel Needed	Gallons of Gas Needed
1.				
2.				
3.				
4.				
5.				
6.				

TOTAL FUEL FOR PRODUCTION: ____________ gal. fuel ____________ gal. gas

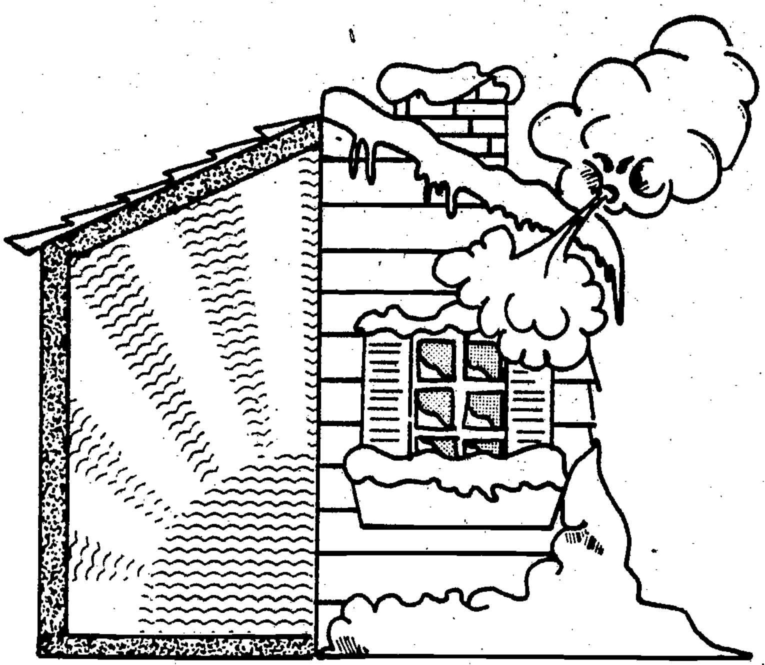
Manure Removal and Hauling

Type of System	Gallons of Fuel/Animal	Gallons of Gas/Animal	Gallons of Fuel Needed	Gallons of Gas Needed
1.				
2.				
3.				
4.				

TOTAL FUEL USED FOR MANURE HANDLING: ____________ gal. fuel ____________ gal. gas

TOTAL FUEL USED FOR LIVESTOCK: ____________ gal. fuel ____________ gal. gas

TOTAL FUEL USED FOR FARM OPERATION: ____________ gal. fuel ____________ gal. gas



House Insulation types & values

All building materials have some insulation value, but, the term "insulation" generally refers to products designed primarily for this purpose. Insulation helps keep heat in the building during cold weather and helps keep heat out in hot weather.

There is no ideal or perfect insulation which is the best for all applications. For example, some materials may be well suited for insulating walls or ceilings in new construction but could not be used for insulating existing buildings. The various forms of insulation are rigid, blanket, batt, foamed-in-place and loose fill.

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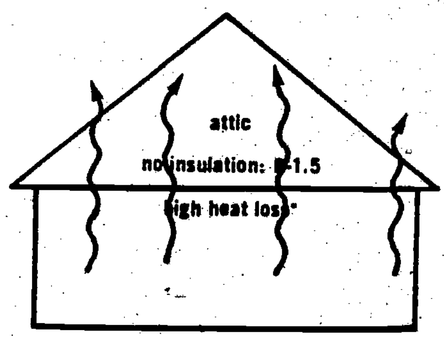
Thermal Resistance

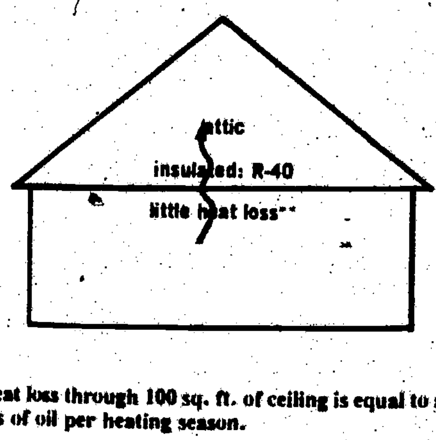
The insulating value of various materials can be compared by their thermal resistance which is commonly called "R" value. The "R" value indicates the ability of the material to resist the transfer or passage of heat. The higher the "R" value, the better the insulation. Published "R" values may be for a one inch thickness of material, or for the total thickness of a material. The "R" values are added together to get the total insulation value. For example: 6 inches of vermiculite @ R 2.2 per inch = 13.2; 6 inches of cellulose @ R 3.7 per inch = 22.2. The total R of 22.2 provides a greater resistance to the passage of heat than the R of 13.2.

Adding insulation to a house will increase the resistance to heat flow and reduce the fuel used per season.

Note the examples below.



*The approximate heat loss through 100 sq. ft. of ceiling is equal to about 61 gallons of oil per average heating season.



**The heat loss through 100 sq. ft. of ceiling is equal to about 3 gallons of oil per heating season.

Insulation Values

The "R" values given for the basic types of insulation in this publication are approximate or within range. The exact "R" value can vary due to a difference in the temperature, density and material structure. Some materials will have a difference in the rating when used in the wall as compared to use in the ceiling. The "R" values are indicated by the manufacturer, usually on the product or package.

Material	R Per Inch Thickness*
Loose Fill (blown and poured)	
Mineral fiber (rock, slag or glass)	3.0-3.3
Cellulose (milled paper or wood pulp)	3.7
Wood fiber, softwoods	3.3
Perlite, expanded	2.7
Vermiculite, expanded	2.3
Blanket and Batt	
Mineral fiber (rock, slag or glass)	3.0-3.7
Rigid (boards and slabs)	
Mineral fiberboard, wet felted, acoustical tile	2.7
Mineral fiber with resin binder	3.5
Glass fiber, organic bonded	4.0
** Expanded polystyrene, molded beads	3.6
Expanded polystyrene, extruded plain	4.0
Expanded polystyrene, extruded (R-12)	5.0
Expanded polyurethane (R-11)	6.3
Foam (foamed-in-place)	4.5-5.0

Building Materials	**R Per Unit**
Aluminum & Steel siding	.61
Aluminim & Steel siding plus 3/8-inch insulation board, foil backed	2.96
Wood siding, 1/2-inch, bevel, lapped	.81
Plywood, 1/2-inch	.62
Sheathing, 25/32-inch insulation board	2.06
Concrete block, 8-inch, sand & gravel	1.11
Concrete cast in place, 8 inches	.64
Brick, common, 4-inch	.80
Brick, face, 4 inch	.44
Windows (air to air)	
Single glass	.91
Plastic sheet; 0.125 thick	.94
Insulated glass;	
double with ½" air space	2.04
triple with ½" air space	3.23
Single glass plus storm	2.00

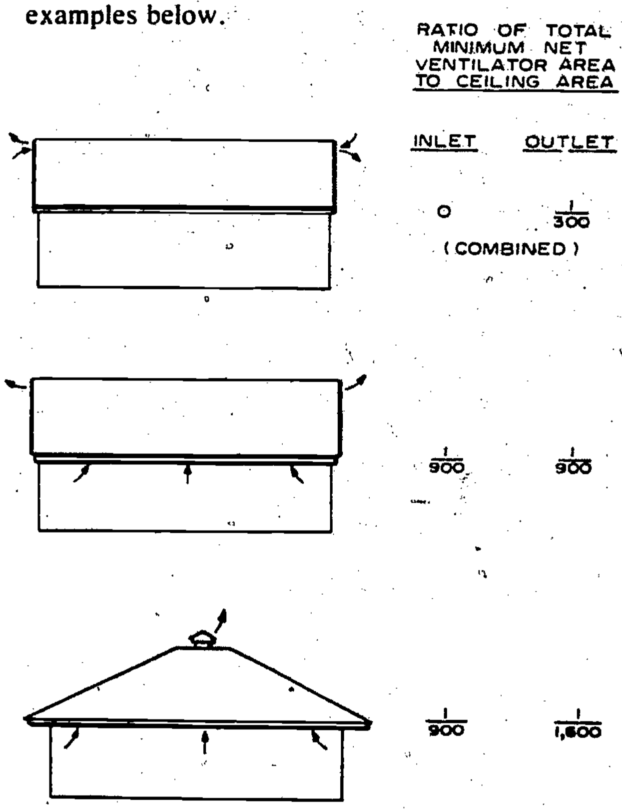
*ASHRAE Handbook of Fundamentals.
**The poly foam boards or slabs should not be left exposed to occupied areas.

Vapor Barrier

Insulation is available with or without a vapor barrier. In new construction, insulation with the vapor barrier attached is commonly used. But, a separate vapor barrier of plastic film can be placed between the insulation and the inside wall, floor or ceiling material.

In existing houses, the exterior walls that have had insulation added can be provided with a good vapor barrier on the interior wall surface with two coats of aluminum paint, over which decorative paint or wall paper can be added. Vinyl wall coverings, or two coats of enamel paint, can also serve as a vapor barrier. Also the installation of vents in the exterior wall surface will let the wall breathe. Moisture that gets inside the wall can exit through the vents. This also helps reduce the possibility of paint peeling.

The ceiling of an existing house will not need a vapor barrier if the attic is well ventilated. Note examples below.



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Issued in furtherance of Cooperative Extension work, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture, Roy M. Kottman, Director of the Cooperative Extension Service, The Ohio State University.

By Roger A. Miller
Extension Agricultural Engineer

HANDOUT #4

HEAT LOSS WORKSHEET

Building Dimension (ft)		*Surface Area (ft²)*		*R Values*	*Insulated*	*Uninsulated**
Length	______	Ceiling	______	Ceiling	______	______
Width	______	Windows	______	Windows	______	______
Height	______	Doors	______	Doors	______	______
		Walls	______	Walls	______	______

Change in Temperature	
Outside Temperature	______ °F
Inside Temperature	______ °F
Temperature Change	______ °F

*Heat Loss from Building***

	(Insulated)	*(Uninsulated)*
Ceiling	______ BTU/hr.	______ BTU/hr.
Windows	______ BTU/hr.	______ BTU/hr.
Doors	______ BTU/hr.	______ BTU/hr.
Walls	______ BTU/hr.	______ BTU/hr.
Total Loss	______ BTU/hr.	______ BTU/hr.

Difference ______ BTU/**hour** saved

Difference ______ BTU/**year** saved

FUEL USED

Area (ft²)		*Uninsulated*			*Insulated*	
Ceiling	______	______	gal./100 ft² =	______	______ gal./100 ft.² =	______
Windows	______	______	gal./100 ft² =	______	______ gal./100 ft.² =	______
Doors	______	______	gal./100 ft.² =	______	______ gal./100 ft.² =	______
Walls	______	______	gal./100 ft² =	______	______ gal./100 ft.² =	______
			Total Fuel Used	______ gallons		______ gallons

Difference ______ **gallons** saved

*For this worksheet, the teacher may prefer to start with *some* insulation, perhaps R = 10.

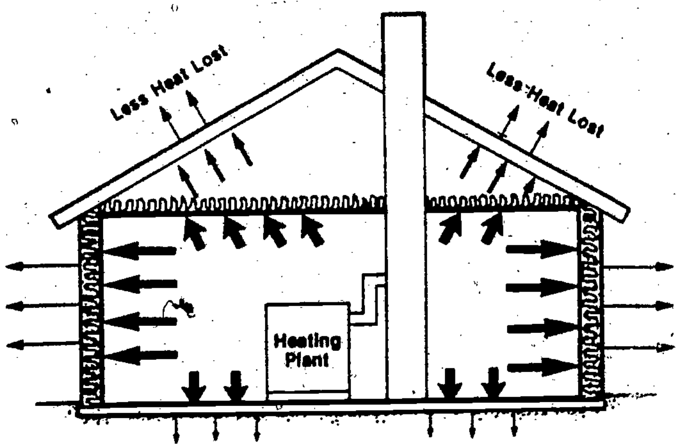
** Change — $\frac{\text{temp. x area}}{\text{R value}}$

Note: The teacher should emphasize the **gallons or dollars used** as well as that saved. Put it into production terms such as in farrowing; the fuel cost is $______ per pig weaned. Perhaps compare with feed costs or profit margin.

HANDOUT #5- pages 1 and 4

L - 266

Reducing Fuel Costs in House Heating with Insulation



This publication can be used to indicate the approximate savings in fuel obtained by the use of insulation. The table contains heat loss values for the component areas of a house. This heat loss by conduction is expressed in gallons of oil and based on 5660 degree days, an average heating season in central Ohio. For northern Ohio add 15% and for southern Ohio reduce 15%. Oil & gas heating units are assumed 75% efficient and electric resistance heating at 100%. Examples of how to estimate fuel savings are on the back.

Cooperative Extension Service
The Ohio State University

By Roger A. Miller,
Extension Agricultural Engineer

HOW TO ESTIMATE FUEL SAVINGS

Example 1

Ceiling area of house is 1400 sq.ft. with 3" of insulation
Consider adding 6 more inches.

From table:	3 inches	10.8	gallons of oil/100 sq.ft.
	9 inches	- 3.96	
	Save	6.84	

$\frac{6.84 \text{ gallons}}{100 \text{ sq.ft.}} \times 1400 \text{ sq.ft.} = 95.76$ gallons of oil saved per season

Example 2

House has 12 windows with total area of 160 sq.ft.
Consider adding storm windows.

From table:	single glass	139.1
	single glass plus storm	- 68.8
	Save	70.3

$\frac{70.3 \text{ gallons}}{100 \text{ sq.ft.}} \times 160 \text{ sq.ft.} = 112.5$ gallons of oil saved per season

Example 3

Wall area of house is 1107 sq.ft. (total area less windows and doors)
Consider filling wall cavity.

From table:	wall no insulation	25.3
	3½" insulation	- 7.77
	Save	17.53

$\frac{17.53 \text{ gallons}}{100 \text{ sq.ft.}} \times 1107 \text{ sq.ft.} = 194$ gallons of oil saved per season

For Your House

1. measure to get sq.ft. of component area
2. determine amount of insulation
3. select values from table.
4. follow examples

9/77—30M

Issued in furtherance of Cooperative Extension work, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture, Roy M. Kottman, Director of the Cooperative Extension Service, The Ohio State University.

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ESTIMATED FUEL USED (a) (f)

Component Areas		Gallons of oil used for 100 sq.ft. (e)	
Ceiling: No insulation	R= 1.54	61.2	
+ 3" insulation	R=11.44(b)	10.8	
+ 6" insulation	R=21.34	5.78	
+ 9" insulation	R=31.24	3.96	
+12" insulation	R=41.14	3.01	To convert gallons of oil to other fuels:
Wall: No insulation	R= 5.11	25.3	
+ 3½" insulation	R=16.66(b)	7.77	oil × 1.52 = gal of L.P. gas
+ 5½" insulation	R=23.26	5.56	
+ 3½" insulation (foam)	R=20.86(c)	6.20	oil × 140 = cu.ft of Nat. gas
Window: Single Glass	R= .93	139.1	oil × 30.77 = Kwh of electricity
Insulating glass-double. ½ space or single glass plus storm;	R= 1.88	68.8	
Insulated glass-triple. ½ space;	R= 2.92	44.3	
Floor: Over vented crawl space;	R= 3	15.4	
+ 3½" insulation	R=14.55(b)	4.7	
+ 6" insulation	R=22.8	3.0	
Crawl Space Wall: Crawl space not vented. Wall	R= 1.96	47	
+3½" insulation on wall.	R=11.55(b)	8	
Basement: No insulation at 50°F		11.78(d)	
No insulation at 70°F		21.64	
+ storm windows, 2" insulation on walls~~(b)~~		12.71	
Door: 1¾" Wood;	R= 3.02	8.5 gallons for one door	
+ storm	R= 4.08	6.5 gallons for one door plus storm	

(a) During average heating season for central Ohio dwelling, 5660 degree days; for northern Ohio add 15% — for southern Ohio reduce 15%.
(b) Insulation resistance value used is 3.3 per inch.
(c) Foam-in-place resistance value used is 4.5 per inch.
(d) For basement estimates, use area of basement floor only!
(e) Oil and gas units at 75% efficiency; electric at 100%.
(f) The values in this table are based on the energy estimating methods of the American Society of Heating, Refrigerating Air-Conditioning Engineers, Inc.

For Insulation Resistance (R) values of various materials, refer to Cooperative Extension Service Leaflet 255.

DETERMINING FAN SIZE WORKSHEET

Step A. Building Information

1. Size (width and length) 35' x 20' *
2. Type of facility (farrowing, nursery) farrowing
3. Floor type partly slotted
4. Number of animals 14 sows

Step B. Recommended Ventilation Rates (Table 1, Handout #7) **and Space Heating Rates** (Table 2, Handout #7) **per Animal Unit**

1. Moisture control ventilation rate (cfm) 21 (17 + 4)
2. Odor control ventilation rate (cfm) 35
3. Mild weather ventilation rate (cfm) 80
4. Hot weather ventilation rate (cfm) 325

Step C. Total Recommended Ventilation and Heating Rates

1. Moisture control rate x no. of animals: 21 x 14 = 294 cfm
2. Odor control rate x no. of animals: 35 x 14 = 490 cfm
3. Mild weather rate x no. of animals: 80 x 14 = 1120 cfm
4. Hot weather rate x no. of animals: 325 x 14 = 4550 cfm

* The handwritten figures given on the worksheet are the correct calculations for the student-evaluation problem on page 12. When reproducing a blank worksheet for the students, the teacher will need to block out the handwritten figures.

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Determining Fan Size Worksheet *(continued):*

	a **Total Recommended Ventilation Rate** (from Step C)	b **Additional cfm Needed** (columns a - d from previous line)	c **Fan Size for Additional cfm Needed** (Table 4)	d **Total Fan Capacity** (sum of fan sizes - column c)
1. Moisture Control	294	(always left blank for determining fan size for moisture control)	(minimum rate for line 1 only) 2, 150 cfm fans, constant running	300
2. Odor Control	490	(490 - 300 =) 190	14" variable speed* fan set with minimum speed of 200 cfm	(does not apply)**
3. Mild Weather	1120	(does not apply)**	same 14" variable speed fan has 1600 cfm capacity	(1600 + 300 =) 1900
4. Hot Weather	4550	(4550 - 1900 =) 2650	18"- 3000 cfm or 16"- 2400 cfm fan might be enough	(3000 + 1900 =) 4900

*This variable speed fan provides both the odor control rate and mild weather rate. Fan should have manual switch so the farmer can turn this fan on only when he/she is working in the building in winter. In mild weather the fan would stay on with speed controlled by thermostat.

Variable speed fan eliminates need for this calculation. **Note: Students should get experience in calculating constant speed fan sizes as well as variable speed fan sizes as done in this sample problem. Both experiences are needed.

WORKSHEET FOR SIZING LIVESTOCK HOUSING ENVIRONMENTAL CONTROL SYSTEMS

A mechanically-ventilated confinement livestock building must have *properly-sized* fans, furnaces and slot air inlets if it is to operate satisfactorily. This worksheet was developed to help producers and builders calculate the capacities and dimensions of equipment needed for specific livestock buildings. It should be used in conjunction with Purdue Extension Publication AE-96, "Environmental Control for Confinement Livestock Housing," which deals with the principles and design of commonly-used environmental control systems.

This worksheet leads you through a step-by-step procedure for calculating the needs of an *exhaust* ventilation system, by far the type most commonly used today. For design information on *positive* and *combination positive/negative* ventilations systems, consult publication AE-96.

An example situation is presented to illustrate the types of calculations involved and how they are 'worked.' Be sure you understand where the various input figures come from, why they were used and how the answers were arrived at before applying the worksheet to your particular building. Some of the input data needed for the calculations are provided in Tables 1-4 which follow. At the end of the worksheet is a brief summary and information on sources of related publications and computer programs.

Table 1. Recommended Per-Head Ventilation Rate for Confinement Swine and Dairy.

	Cold weather rates						
	For moisture control on—			Added for	For	Mild	Hot
Type of animal or facility	Fully slotted	Partly slotted	Solid floor	unvented heaters*	odor control	weather rates	weather rates
	cubic feet per minute						
Swine							
Sow and litter	10	17	20	4	35	80	325
Pre-nursery pig (12-30 lbs.)	1	1.6	2	0.5	3.5	10	25
Nursery pig (30-75 lbs.)	1.5	2.5	3	0.5	5	15	35
Growing pig (75-150 lbs.)	3.5	5.5	7	1.0	10	24	75
Finishing hog (150-220 lbs.)	5	8	10	—	18	35	120
Gestation sow (325 lbs.)	6	10	12	1.0	20	40	150
Boar (400 lbs.)	7	12	14	2.8	24	50	180
Dairy							
Cow	16.5	28	33	—	50	130	600
Calf	5	8.5	10	2	16	25	150
Milk rooms (total cfm)	—	—	8	—	—	25	50
Parlors (total cfm)	—	—	8	—	—	25	100

* Increase the fully-slotted, partly-slotted and solid floor moisture control rates by these amounts if unvented heaters are used.

Table 2. Likely Supplemental Space Heat Requirements per Animal Unit for Confinement Swine and Dairy Calves.*

Animal unit	Inside temp.	Supplemental heat: Slotted floor	Supplemental heat: Solid floor**
		BTU/hr.	
Sow and litter	60°F	—	3500
	70°F	3000	
	80°F	4000	
Pre-nursery pig (12-30 lbs.)	80°F	350	—
Nursery pig (30-75 lbs.)	65°F	—	450
	75°F	350	
Growing pig (75-150 lbs.)	60°F	600	
Gestation sow and boar	60°F	500	
Dairy calf	70°F	1000	1000

* Sized for the odor control ventilation rate in a moderately well-insulated building. Additional creep heat will be needed for young animals in farrowing and nursery; size creep heaters at about half the space heat needs shown.

** Solid floor scraped and bedded periodically.

Table 3. Temperature Optimums and Ranges for Confinement Swine and Dairy Animals.

Type of animal	Temperature: Optimum	Temperature: Range
Swine		
Lactating sow	60°F	50- 70°F
Litter, newborn	95°F	90-100°F
Litter, 3 weeks	75°F	70- 80°F
Pre-nursery pigs (12-30 lbs.)	80°F	75- 85°F
Nursery pigs (30-75 lbs.)	75°F	70- 80°F
Growing/finishing hogs	60°F	50- 70°F
Gestation sow and boar	60°F	50- 70°F
Dairy		
Cows	50°F	45- 70°F
Calves	70°F	45- 80°F

Table 4. Speeds and Capacities of Various Size Commercial Ventilation Fans.

Diameter in inches	Horsepower	Speed in rpm	Capacity in cfm*
Single- and multiple-speed fans			
7	1/20 (2-speed)	1550	30
		3000	150
8	1/20 (2-speed)	1550	80
		3000	450
10	1/6 (2-speed)	1550	375
		3000	950
10	1/28	3000	600
12	1/6	1725	1000
14	1/4	1725	1600
16	1/4	1725	2400
18	1/4	1725	3000
20	1/3	1725	3200
24	1/2	770	5000
30	1/2	600	8000
36	3/4	545	11,000
48	1	525	18,000

Variable speed fans		Max. rpm	Min. cfm	Max. cfm
12	1/10	1700	250	850**
14	1/8	1750	110	1600
16	1/3	1725	850	2250
18	1/3	1600	500	3500
24	1/3	1050	800	4500
36	1/2	800	600	8000

* All single-speed capacities shown are at 1/8 or 1/10 inch water pressure.

** Maximum cfm is at 1/12 inch water pressure.

Agricultural Energy Management

Dairy Farm Heat Exchangers for Heating Water

R. A. Peterson, New York State Electric and Gas Corp., Binghamton, NY
R. K. Koelsch, Cornell University, Ithaca, NY

Milk cooling and water heating may consume up to 40% of the electric energy used on modern dairy farms. You can save energy and cut the cost of heating water in a dairy operation by more than half by installing a heat exchanger to recover the heat now being lost to the air from the milk refrigeration system.

Heat is available from a milk tank refrigeration unit from two sources. One is the heat that is removed from the milk to cool it from about 90°F to 40°F or below. The second is from the electrical energy used to run the compressor. Most of this heat is contained in the hot gas which comes from the compressor.

Types

There are two ways to recover this heat. One is to add a heat exchanger between the compressor and the existing air-cooled condenser, along with a water storage tank and a circulating pump. Figure 1a shows a schematic of such an installation. A pump circulates water from the water storage tank through the heat exchanger when the compressor runs and the temperature in the heat exchanger is above the temperature of the water in the storage tank. The conventional water heater is thus supplied with water in the 100°F to 140°F range rather than cold water (50°F) from the well.

The second type of exchanger is a special water-cooled condenser unit instead of the typical air-cooled condenser (Figure 1b). It would normally be considered when installing a new system or replacing an old, worn out unit. One design variation incorporates the heat exchanger into the storage tank. Because hot water rises to the top of the tank, two different temperatures of water can be removed at different levels of the tank (Figure 1c). The hottest water at the top of the tank is about 140°F. Water removed from a tap at the center of the tank is lukewarm, and is often used for washing udders and general cleanup. This heat exchanger is available as either an add-on or complete condensing unit.

A water-cooled condenser recovers more heat than an add-on unit because all heat from the refrigerant is transferred to the water and an add-on unit may still lose some heat through the condenser. An add-on exchanger may recover as much as 70% or as little as 15% of the milk heat depending on the compressor head pressure setting and the time of water use. Dairies with normal water use patterns can expect to recover at least 40% of the milk heat from a properly adjusted add-on heat exchanger.

Expected Savings

You must know 1) your hot water use, and 2) the amount of milk cooled daily before you can estimate the potential savings of a heat exchanger. About 2 to 3 gallons of warm to hot water per cow per day is used by many dairies. Some use less than one gallon per cow per day which suggests it is possible to save even more by figuring ways to cut hot water use. Use Table 1 to estimate water use.

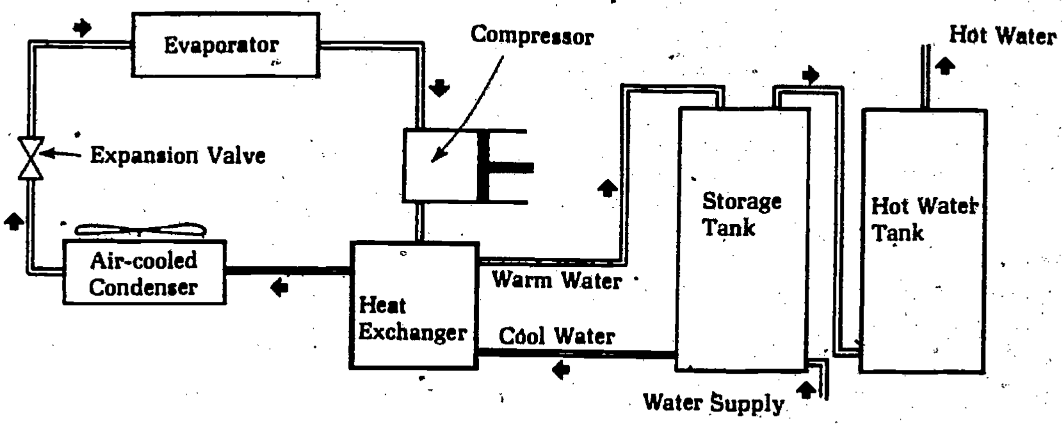
Table 1. **Volume of milkhouse and parlor wastes.**

Washing Operation	Water Volume
Bulk Tank	
Automatic	50-60 gal/wash
Manual	30-40 gal/wash
Pipeline	
In parlor	75-125 gal/wash
(Volume increase for long lines in a large stanchion barn)	
Pail milkers	30-40 gal/ wash
Miscellaneous equipment	50 gal/day
Cow prep.	gal/wash per cow:
Automatic	1-4 1/2
Estimated Average	2
Manual	1/4 - 1/2
Parlor Floor	40-75 gal/day
Milkhouse Floor	10-20 gal/day
Toilet	5 gal/flush

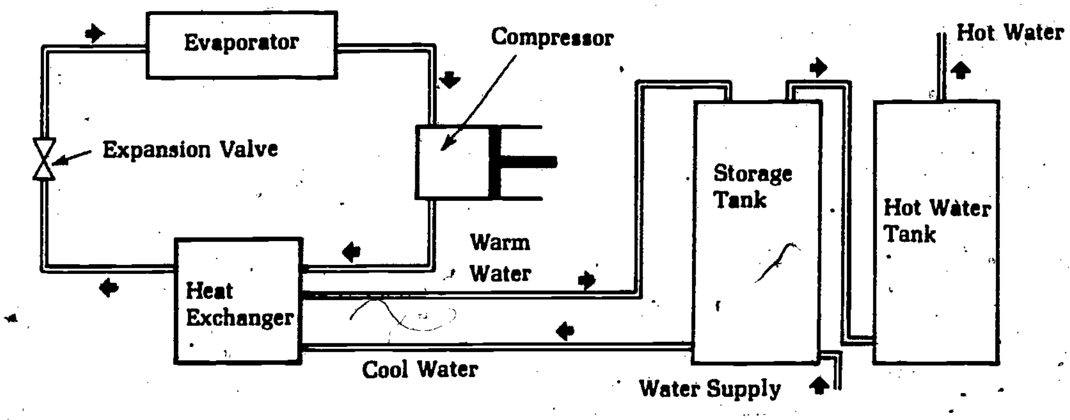
HANDOUT #8- page 2

Figure 1. **Types of Heat Exchangers**

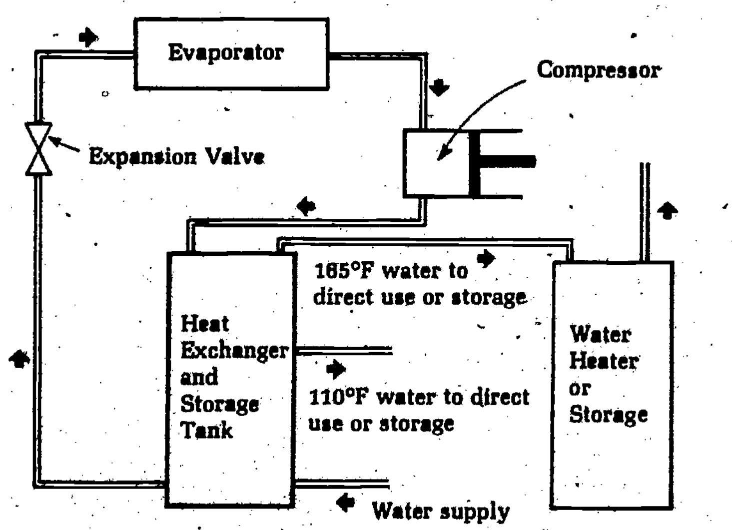
a. Add-on Heat Exchanger retains present Air-cooled condenser.



b. Complete Condensing Heat Exchanger eliminates Air-cooled Condenser



c. Complete Condensing Heat Exchanger Producing Two Different Water Temperatures



HANDOUT #8- page 3

Table 2 and Table 3 list the expected annual value of the hot water produced by both types of heat exchangers.

Table 2. Expected Savings and Hot Water produced by a Complete Condensing Heat Exchanger that recovers 90% of Heat from Refrigerant Gases.

Daily Milk Production (pounds)	140°F Water Produced Daily (gallons)	Annual Fuel Cost Savings*, dollars		
		Electricity at 4¢/KWH	Fuel Oil at 50¢/gal	LP Gas at 50¢/gal
1000	8	278	113	170
2000	174	556	225	340
3000	260	834	339	510
4000	346	1112	452	681
5000	432	1390	565	851
6000	520	1669	668	1020
7000	606	1946	790	1190
8000	693	2225	904	1360

*Savings based on using 100% of the hot water produced. This will not be possible in most dairy operations.

Table 3. Expected Savings and Hot Water produced by an Add-on Heat Exchanger that recovers 40% of Heat in Refrigerant Gases.

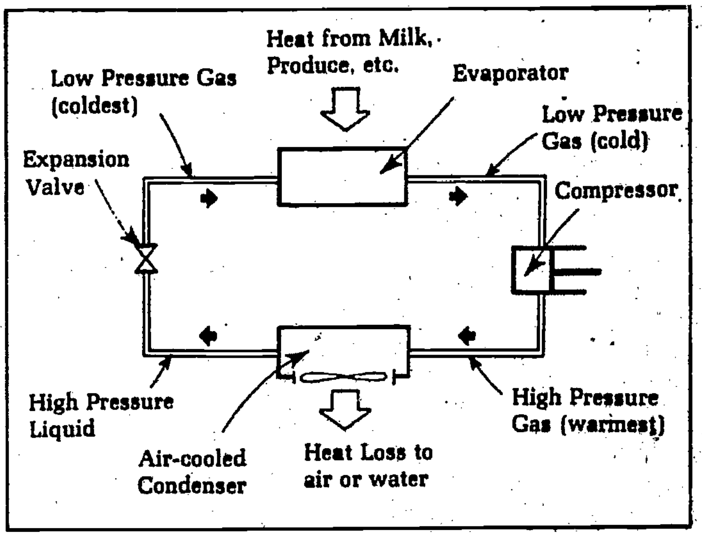
Daily Milk Production (pounds)	125°F Water Produced Daily (gallons)	Annual Fuel Cost Savings*, dollars		
		Electricity at 4¢/KWH	Fuel Oil at 50¢/gal	LP Gas at 50¢/gal
1000	42	111	45	68
2000	84	222	90	136
3000	124	333	136	204
4000	167	445	181	272
5000	208	556	226	340
6000	249	667	271	408
7000	291	779	316	476
8000	334	890	361	594

For example, consider an 80 cow dairy that produces 4000 pounds of milk a day and uses 2 gallons of hot water per cow per day (160 gallons/day). All the hot water from an add-on exchanger can be used, so electric savings are $445 per year. A complete condensing heat exchanger should produce 346 gallons of 140°F water per day. This dairy can only use about half that amount, so the electric savings is still about $500 per year, not the $1112 listed in Table 2. It is very important to have some idea of the quantity of hot water used daily to get a reasonable idea of cost savings.

Heating Water - How Hot?

Most mechanical refrigeration systems, no matter what application, are similar. All have an evaporator, compressor, condenser, and expansion valve (Figure 2). To remove heat from a medium such as air or milk, liquid refrigerant at low pressure passes through an evaporator. The refrigerant boils or evaporates in the evaporator, and in the process, absorbs heat from the medium being cooled. The refrigerant vapor then passes to the compressor. The compressor, powered by an electric motor, is the major energy input to the refrigeration system. In a compressed state, the hot vapor flows through the condenser and gives up heat easily as it changes from a gas to liquid. Still at high pressure, the liquid refrigerant flows through an expansion valve where its pressure is reduced, and continues back to the evaporator.

Figure 2. **Typical Refrigeration System**



A heat exchanger can heat water to almost any desired temperature, but the compressor often operates at higher than normal design pressure to heat water above 120° to 140°F. When the head pressure of the compressor is increased the electrical demand also increases and refrigeration efficiency and cooling capacity drops. For these reasons, be sure the head pressure is not altered when an add-on heat exchanger is installed. In general, the head pressure switch controlling fans on the air-cooled condenser should be set between 150 and 190 psia for a R-12 system and between 250 and 300 psia for a R-22 system.

Currently marketed complete condensing heat exchangers frequently operate at higher head pressures than a conventional air-cooled condenser. Upon installation, you may notice it slows milk cooling and increases electrical consumption slightly. These effects normally are not serious unless the present refrigeration system barely cools milk within the required time limit. If this situation exists, ask the heat exchanger supplier how to alter the temperature or pressure switch setting to allow water to bleed off at lower temperatures. This change would allow the refrigeration system to operate at more normal head pressures.

Compressor life might also be reduced if head pressures remain excessively high. At present, however, there is little concern by compressor manufacturers that the head pressure settings used by currently available complete condensing heat exchangers will significantly reduce the lifetime of the compressor.

Well Water Coolers

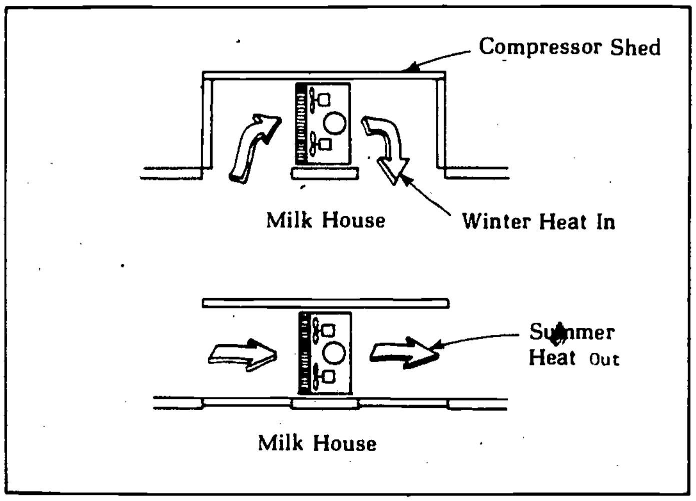
Some dairies install in-line milk coolers that use well water as a coolant. This equipment is used (1) where water is abundant and inexpensive and (2) to boost the cooling capacity of an existing refrigeration system. The tempered water may be used for stock watering or parlor flushing.

In a few cases it may pay to install a heat exchanger together with a well water in-line cooler. Make a careful study of water use before installing both units, though. Often a heat exchanger will pay for itself long before a well water in-line cooler will.

Space Heating

Heat from an air-cooled condenser may be used to heat the milk room. Various arrangements (Figure 2) are possible to change from summer ventilation to winter heat utilization. On dairies with more than 100 cows, it may also be worthwhile to heat the milking parlor or nearby rooms with hot water collected by a heat exchanger. The application of space heating is best suited to complete condensing units. Hot water is circulated from the top of a storage tank by a thermostatically controlled pump through a unit heater and returns to the bottom of the tank. Most designs connect the space heating equipment directly to the potable hot water storage tank.

Figure 2. **Compressor Arrangement to change from Winter Milk House Heating to Summer Ventilation.**



Sizing units

Generally, the size of the heat exchanger is dictated by the size of the refrigeration unit. Follow the recommendations of both heat exchanger and compressor manufacturers regarding heat exchanger selection.

Some manufacturers of heat exchangers provide storage tanks as part of the package. If a storage tank is not provided by the manufacturer a rule of thumb suggests the tank should hold enough water to supply all the hot water needs for one milking. This size will provide adequate hot water, yet still be empty after cleanup. A fresh charge of tap water in the storage tank will then be ready to cool the refrigerant during the next milking; an important step to maintaining refrigeration efficiency.

Installation

Water quality is very important to the successful operation of a heat exchanger. For this reason, the water should be analyzed and results discussed with potential heat exchanger suppliers before purchase. Some heat exchanger suppliers provide this service.

Install the heat exchangers in an area that will not freeze. Avoid long plumbing runs by installing the unit as close as possible to the compressor and water heater. Insulate all hot water lines. Follow manufacturer's installation recommendations.

Maintenance

Clean periodically to remove any scale or other deposits. The frequency of cleaning depends on water conditions, so make provisions for cleaning when installing. Follow the manufacturer's maintenance instructions.

NRAES FS-18
Apr 79, 30M

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Cooperative Extension Provides Equal Program and Employment Opportunities

I. **Lesson Topic:**

ENERGY MANAGEMENT IN THE GREENHOUSE WITH ENGINEERING AND CULTURAL PRACTICES

by

LARAE WATKINS

II. **Lesson Performance Objectives**

At the end of this lesson, the student will be able to:

1. Describe the need for energy conservation practices in the greenhouse.
2. List and compare the ways a greenhouse operator can alter the structure of a greenhouse to conserve energy.
3. List growing practices that a greenhouse operator can implement to conserve energy.

III. **Materials Needed**

Handout - Fuel Cost Trends
Pictures of greenhouse modifications
Handout - Suggested Methods of Double Poly Covering
Handout - Operation of a Polystyrene Pellet Insulated Greenhouse
Handout - A Track-type Thermal Blanket
Handout - Air-inflated Plastic Tubes for an Energy Screen
Handout - Experimental Greenhouse with North Wall Insulation
Pictures of inflated tubes
Pictures of insulated sidewalls, gable ends, and sills
Pictures of floor and bench heating systems
Handout - Chart on Methods of Fuel Savings in the Greenhouse
Handout - Energy Wasting Practices in the Greenhouse
Shirt box and dozen circular objects, such as paper cups
Handout - Plant Spacing Arrangements on Benches
Test - Energy Management in the Greenhouse

IV. **The Situation**

The ability to control a closed environment is the basis for the production horticulture industry. The amount of fuel needed to maintain a specific environment is, in itself, staggering. As fuel costs rise, the importance of limiting this staggering amount of fuel becomes very pronounced.
Energy conservation is almost mandatory and making large production changes has become quite common. Greenhouse growers and researchers are continually trying to find new methods, structures or gimmicks to limit the amount of fuel needed to run a greenhouse. Keeping up with new energy conserving technology is absolutely necessary if a greenhouse grower is not to be forced out of the business by the rising fuel costs. All greenhouse employees need to be aware of this technology and what they can and should do to help lower greenhouse operation costs and possibly save their jobs.

V. **Introduction to Lesson**

A. Select a student who drove to school. Ask him or her how much the gasoline cost the last time the tank was filled. Discuss the cost of fuel; have students imagine using a gasoline-powered generator to heat a room or a small greenhouse. How much would that cost, even for just one week?

B. Discuss the types of fuel available to a greenhouse operator (e.g., natural gas, #2 oil, coal, propane). Ask:

"What fuels are available?" (*List on board.*) Then ask: "What are their relative costs?"

C. Give the students **handout #1**, *Fuel Cost Trends*. Have the students try to identify which line goes with which type of fuel. Discuss the graph, emphasizing the following points:

1. The units are 100,000 BTU's. A grower with 20,000 ft.^{2} often uses 20,000 of these units in a year's time.
2. One therm unit of gas = 100,000 BTU's.
3. In 1982, gas is the most economical; propane is the most expensive. 1986 projection: coal is the most economical, propane is the most expensive; **none** of them are inexpensive.

D. If the students need more convincing as to the high cost of energy (fuel), have them figure the cost of using each type of energy source in a 20,000 ft^2 greenhouse for one year, using 1982 and/or 1986 figures from the chart. For example (*place on chalkboard*):

20,000 units of energy

1 unit of energy = 100,000 BTU's

Cost of gas, 1982 = $ 0.36/100,000 BTU's

20,000 x $0.36 = $10,000 (have students calculate this cost)

Cost of propane, 1986 = $1.75/100,000 BTU's

20,000 x $1.75 = $35,000

Question: **"If a grower can't control the price of fuel and needs to cut fuel costs, what can he or she do?"**

VI. Problem Statement *(Write on chalkboard)*:

Question: "What can ___student or operator___ do to lower greenhouse fuel costs?"

Possible Student Answers:

1. Change to cheaper fuel
2. Get out of the greenhouse business
3. Use less fuel
4.

Discuss each answer:

1. Temporary solution: accept fact that all prices are rising.
2. Defeatist's way out: if everyone left the business, then . . .
3. Good idea, but what questions still need answering before we can use less fuel? (List answers to this question on the board.)

Possible student answers (or the *questions to be answered):*

1. How can the greenhouse itself be changed in order to use less fuel?
2. What cultural practices can be followed to use less fuel?

VII. Solution to Problem

Question: **"How can the greenhouse itself be changed in order to use less fuel?"**

1. Ask student to compile a list of potential energy-saving structural changes on the board. Add to the list anything from the list below that is missing.

2. Take each modification and explain what it is and how it works. The following outline can be used as a model for student notes, written on the board or shown on a transparency. Prepare slides in advance, or at least have pictures of each type of greenhouse modification. Samples, pictures and diagrams can often be obtained through wholesalers or company sales people.

   A. DOUBLE-INFLATED POLYETHYLENE OVER GLASS

   Two layers of plastic are stretched over part or all of a glass house and air is forced between the layers. (Use **handout #2,** *Suggested Methods of Double Poly Covering.*) Briefly discuss each method shown, emphasizing construction details.

   B. POLYSTYRENE PELLET INSULATION

   At night a layer of polystyrene beads is forced between two layers of polyethylene that cover the greenhouse. During the day the beads are pumped out and stored in a separate facility. (Use **handout #3** or display on a transparency, *Operation of A Polystyrene Pellet Insulated Greenhouse.*)

   C. THERMAL BLANKETS/CURTAINS

   A blanket of polyethylene or fabric is pulled over the benches, plants and heating lines to limit the space which must be heated. The blanket is pulled at sunset and removed at sunrise. Blanket may be clear, opaque or reflective.

   Variations of this system include pulling a blanket from gutter to gutter in a range and putting up a permanent gutter-to-gutter poly sheet. (Give the students **handout #4**, *A Track-type Thermal Blanket*, plus pictures or examples.)

   D. INFLATED TUBE CEILING

   Rows of air-inflated polyethylene tubes (tube touching tube) are placed from gutter to gutter. Tubes may be permanent or pulled each night. (Use **handout #5** or display pictures or examples.)

   E. INSULATION OF SIDEWALLS/GABLE ENDS/SILLS

   Board, spray-on foam, plastic, or other insulation is applied to the sidewalls, sills, gutters and/or north gable ends. Light loss is minimal, especially when aluminum reflecting material is used. (Use **handout #6** or display pictures or examples.)

   F. FLOOR AND BENCH HEATING (using warm water at 100° F)

   These systems involve heating only the immediate area around the plants. Series of hot water-carrying tubing are used. Pots are placed directly on the warm floor, bench or tubing.

   These systems have seen limited use so far because: (1) systems must be designed for each grower; (2) mostly potted plants have been used; (3) systems must be used with other heating and conservation techniques. (Display pictures or examples.)

3. ***Group Activity:*** Divide the class into groups of 2-4 students. Have each group do a little research on each structural energy-saving method and find out:

   1. percentage of fuel savings
   2. cost
   3. advantages
   4. disadvantages

   Information will be presented to the class by one member of the group and placed on a chart on the board or an overhead. A sample chart follows.

SAMPLE CHART WITH POSSIBLE ANSWERS

Method	Fuel Savings	Cost	Advantages	Disadvantages
DOUBLE POLY	40 - 60%	45 - 60¢/ft² plus 10-30¢/ft²/2 years	- good savings - quality plants obtained if cultural practices are altered - higher CO_2 levels possible - no water seepage or dripping through slipped glass	- reduced light intensity - must be replaced every 2 years - CO_2 generator should be added
POLYSTYRENE PELLETS	60 - 90%	\$0.50 - 1.50/ft² (equipment) \$0.60/ft³ (pellets)	- excellent savings potential - no daytime light reduction	- snow load - static cling of pellets - moisture in pellets (freezing between polyethylene layers) - still experimental
THERMAL BLANKETS/ CURTAINS	20 - 60%	\$0.16 - 0.42/ft² (curtain) \$0.50 - 2.00/ft² (installed)	- good savings - no reduction in light intensity (besides spot shade) - relatively low cost	- not adaptable to all greenhouses - dripping - increased relative humidity - spot shade from pulled back curtain
INFLATED TUBES	35 - 50%	\$0.25 - 0.50/ft²	- fast and easy installation - cheap - good savings	- snow load - reduced light intensity - must be replaced every 2-3 years
INSULATED PERIMETERS	10% or more depending on surface area insulated	\$0.50 - 1.00/ft²	- relatively inexpensive - easy to do - adaptable to all greenhouses	- limited light loss - structure must be strong enough to hold the insulation
FLOOR AND BENCH HEATING (Biotherm)	up to 40%	varies with the greenhouse	- excellent savings - can improve production	- limited use - snow load - not easily adaptable to all greenhouses

References for Group Activities (see page 10 for complete references)

1. Badger and Poole
2. *Grower Talks*, Volume 46 (1)
3. Perry and Robertson
4. Short and Bauerle
5. Short and Huizing

VIII. Solution to Problem:

Question: **"What cultural practices can be followed to use less fuel?"**

1. Hand out the "wasted energy" picture to the students (**handout #7**). Discuss the picture briefly; point out one or two "energy wasters." As an individual, in-class assignment, have students list as many energy-wasting problems as they can find. (There are at least 9.) For each problem, students are to list at least 1 solution or answer (preferably 2 or 3) to the energy-wasting problem. Five major energy-wasting categories and a few potential solutions are given in Table 1.

***Table 1.* Energy Wasters and Possible Solutions**

Energy Wasters	Possible Solutions
1. Energy-wasteful growing practices are used for example, plants are overwatered and too much lighting is used.	a. Don't water plants more than necessary. b. Remove unneeded light bulbs.
2. Equipment is left on when not needed; for example, empty refrigeration unit is left on.	a. Turn off empty refrigeration units. b. Turn off full refrigeration units on cool nights.
3. Pipes, ventilation louvers, and other equipment are not well maintained.	a. Repair pipes so they don't leak. b. Repair ventilation louvers so heated air doesn't escape. c. Caulk cracks around doors.
4. Pots, cans, bottles, water, and cardboard are not recycled.	a. Set up a recycling program for metal, glass, and paper products. b. Reuse pots. c. Collect run-off water.
5. Delivery practices are inefficient.	a. Send out only trucks that are carrying full loads. b. Drive to save energy - smoothly, without sudden starts and stops.

Source: "Energy Efficiency for Tomorrow's Greenhouse Workers," *American Institute for Research*, January, 1982.

2. When assignments are completed, have students report on each picture and the solutions they suggested. Use "Energy Saver" sections of "Energy Efficiency for Tomorrow's Greenhouse Workers" as guidelines for discussion. Point out that many of these things are common sense, good growing practices.

3. ***Special Assignment:*** Have student(s) develop a list of items that should be checked regularly to keep a greenhouse running energy-efficiently. Have copies made and present them to the class.

4. Pose the following **problem** to the students:

   You are the head grower/manager for a small potted plant production greenhouse. The owner of the greenhouse, a very stingy man, insists that the utility bill for the greenhouse operation is too high. As grower/manager, you have caulked all the doors, fixed all the broken vents and glass, and turned down or off all the equipment you can. The owner, who will not finance any structural changes, says, "Cut the bills!" or he'll get another manager. What can you do?

   After a few minutes, when you have made sure everyone understands the problem, start soliciting answers from students. List the answers on the board.

   Possible student answers (which should be discussed):

   1. ***Change to Alternative Cool Crops*** - 15-40% savings

      - Crops are grown at lower temperatures, so less heating is necessary.
      - The crop must be one that the public will buy.

      Special assignment: Have student(s) write reports on different **cool crops** and present the information to the class.

   2. ***Close Down Business for Part of the Winter*** — 0-50% savings

      Many problems:

      - No production or income
      - Hard to re-enter the market each year
      - Must drain all water lines
      - Must provide for snow removal from the unheated greenhouse

   3. ***Change the Space Utilization*** — 10-50% savings

      Spacing. (Have on hand a shirt box and about a dozen circular objects such as paper cups. They can be used to visualize the additional number of plants that can be grown when staggered spacing is used.) (Display or distribute copies of **handout #8**, *Spacing Arrangements.*)

      - Use vertical space
        - — Grow shade-tolerant plants *under* the benches.
        - — Fill up overhead space with hanging baskets.
      - Rearrange benches to get more usable bench space per ft^2 of greenhouse.
        - — Floating aisle
        - — Peninsular benches

      Special assignment: Have student(s) research the "floating aisle" bench and explain what it is, how it works, and why it is important to the class.

   4. ***Grow Improved Cultivars*** — 5-40% savings

      Breeders are trying to breed popular plants for the ability to tolerate cooler growing temperatures, shorter cropping time, and more productivity.

5. ***Harvest Crops Prior to Full Maturity*** — 0-20% savings

   Reduce cropping time. For example, mums or carnations can be bud harvested.

6. ***Reduce Crop and Marketing Loss***

   If less of the product is lost to disease, insects or mishandling, the increased productivity and resulting profit will make the utility bill look smaller.

IX. Application

A. *Group Activity*. Divide the class into groups of 4 or 5 students. Give each group a section of, or if possible, an entire greenhouse to conduct an energy audit on. Groups are to look for energy-wasting problems or practices, formulate plausible solutions, and, when possible, implement the solution. Groups will submit three reports:

   1. Report on the problems that they found.
   2. Report on the solutions that they recommended for each problem.
   3. Report on how the solution was implemented (what materials were used, what results were obtained, etc.)

   When the groups have completed their solutions, each group will be assigned a second (check-up) energy audit.

B. *Wrap-up*. Each group will present its three reports to the whole class. The group that did the check-up on the area will then make comments on the job that was done, pointing out anything that was missed and giving suggestions. (If a local grower is willing, energy audits and possible solutions could be formulated for his/her range, instead of, or in addition to, the school's range.)

C. *Optional Activity*. Take a field trip to a local greenhouse which may have employed some of the energy conserving methods that were studied. Be sure the following questions are answered:

   1. Is conserving energy important in this greenhouse? Why?
   2. What has the grower done to conserve energy?
   3. What will the grower be doing in the future? Are there any major structural changes planned?

X. Evaluation

TEST: ENERGY MANAGEMENT IN THE GREENHOUSE

NAME ____________________

I. Matching: Match the greenhouse energy waste practices with possible solutions by placing the number of the correct solution in front of each energy waste practice in the first column.

___ empty refrigeration unit left on	1. water only when necessary
___ dirty pots sitting around	2. wash and reuse pots
___ broken louver	3. turn off unused equipment
___ plants overwatered	4. fix leaky plumbing
___ half full delivery truck	5. repair and caulk doors
___ hot rod delivery truck driver	6. fire the driver
___ leaking pipes	7. dispatch only full delivery trucks
___ loose door hinge	8. repair louvers
	9. remove unneeded light bulbs

II. Multiple Choice: Circle the one best answer for each statement from the list of items below each statement.

1. Fuel(s) used to heat greenhouses include:

   a. natural gas
   b. #2 oil
   c. propane
   d. all of the above

2. Which of the following are methods of fuel conservation which may be used for greenhouse modification? (1) polystyrene pellet insulation; (2) thermal blanket/curtain; (3) air-inflated tubes; (4) styrofoam over entire greenhouse.

   a. 2, 3, 4
   b. 1, 3, 4
   c. 1, 2, 3
   d. 1, 2, 4

3. The biotherm method (floor and bench heating system) of fuel conservation in a greenhouse saves up to 40% in fuel. The disadvantages of this system are:

   a. limited light loss and need for replacement every 2 years
   b. limited use and snow load
   c. reduced light intensity and increased relative humidity

4. The most expensive fuel for greenhouse boilers is:

   a. gas
   b. #2 oil
   c. propane
   d. none of the above

5. The double inflated polyethylene-over-glass method of fuel conservation for a greenhouse consists of:

   a. a blanket which is pulled out at sunset and removed at sunrise
   b. polystyrene beads forced between two layers of polyethylene which cover the greenhouse
   c. two layers of polyethylene plastic stretched over glass with air forced between the layers

Test: Energy Management in the Greenhouse *(continued)*

6. When either permanent or removable air-filled polyethylene tubes are placed from gutter to gutter, the conservation method is known as:

   a. Biotherm (floor & bench heating)
   b. Insulation
   c. Air inflated tubes
   d. Thermal blanket

III. Identification: Write in the blank the correct name for the structural change described on the right.

1. ______________________ Pots placed directly on tubing filled with hot water
2. ______________________ Forced air between two layers of plastic
3. ______________________ Rows of air inflated tubing
4. ______________________ Polystyrene beads forced between two layers of plastic
5. ______________________ Fabric pulled on a track over the plants and benches
6. ______________________ Spray-on foam applied to sills and side walls

IV. Problem: A greenhouse needs 30,000 units of energy per year to operate. How much would the energy bill be if the owner uses:

a. gas (at $0.36/100,000 BTU's)?

b. coal (at $0.48/100,000 BTU's)?

KEY

Section I:

3
2
8
1
7
6
4
5

Section II:

1. d
2. c
3. b
4. c
5. c
6. c

Section III:

1. Biotherm (floor and bench heating)
2. Double inflated polyethylene
3. Air inflated tubes
4. Polystyrene pellet insulation
5. Thermal blankets/curtains
6. Insulated sidewalls/gable ends/sills

Section IV:

gas - $10,800.00
coal - $14,400.00

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McBain, S.L., "Energy Efficiency for Tomorrow's Greenhouse Workers," *American Institute for Research*, January 1982

Perry, David B., and Jerry L. Robertson. *An Economic Evaluation of Energy Conservation Investments for Greenhouses*. Wooster, Ohio: Ohio Agricultural Research and Development Center Bulletin 1114, January 1980

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Poole, Hugh A., and Priscilla A. Gresser. *An Annotated Bibliography of Greenhouse Energy Conservation and Management*. Wooster, Ohio: Ohio Agricultural Research and Development Center Research Circular 262, October 1980

Short, Ted H., and William C. Bauerle. "Energy Conservation and Plant Growth by Using Double Plastic on Glass Greenhouses." Wooster, Ohio: *OARDC Journal* article #157-77, 1978

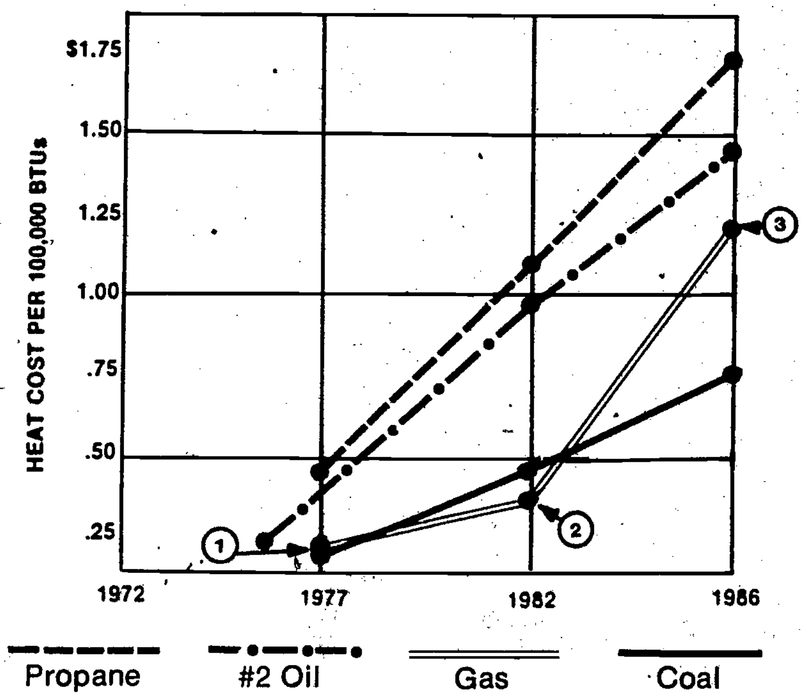
Short, Ted H., and Jon Huizing. *The Development of a Movable Energy Screen for Greenhouses Using Air Inflated Plastic Tubes*, Bulletin 629, Ohio Florists' Association. Research from OARDC, Wooster, Ohio and National Institute of Agricultural Engineering in Holland, March 1982

APPENDIX

HANDOUT #1

FUEL COST TRENDS

Expressed in comparable heat units (100,000 BTUs)



Gas (1) 1977 — 21c per therm
(2) 1982 — 36c per therm
(3) 1986 — $1.15 per therm

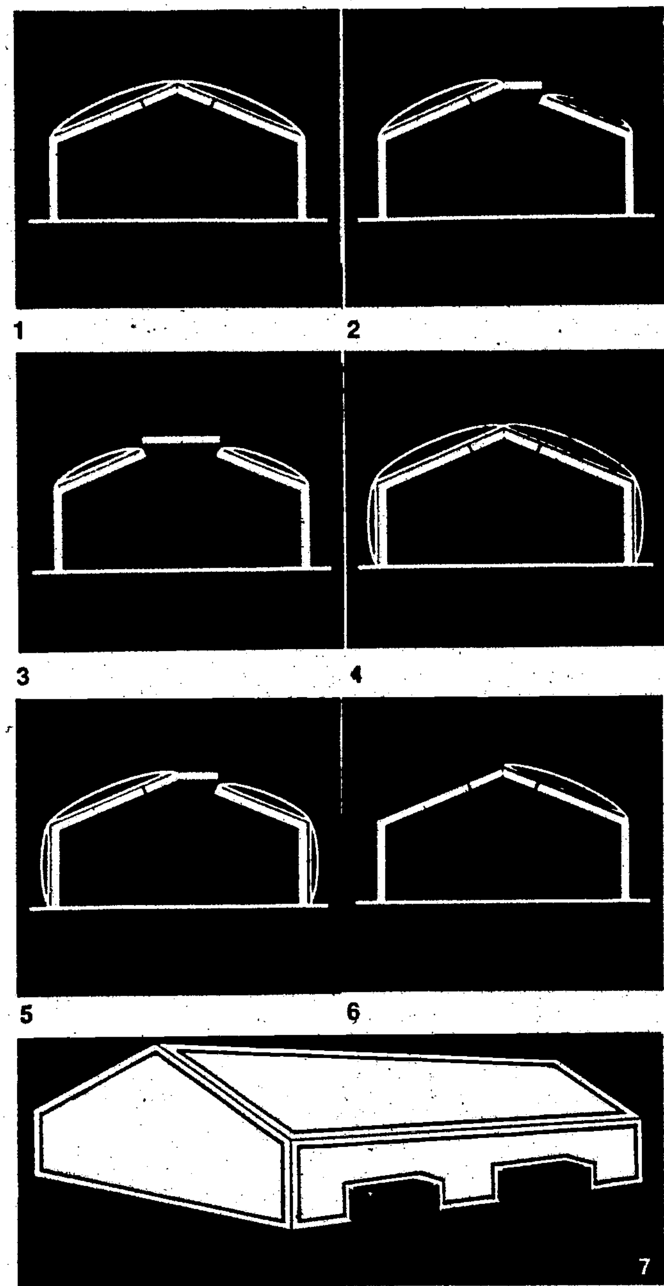
1986 figures for coal and oil are 1982 plus 10% per year inflation. (Our best guess!) For gas it is GROWER TALKS estimate. All figures are approximations.

Canada growers price for gas is 65% of the energy equivalent for oil — by government mandate.

Source: *Grower Talks*, May 1982

HANDOUT #2

Suggested Methods of Double Poly Covering



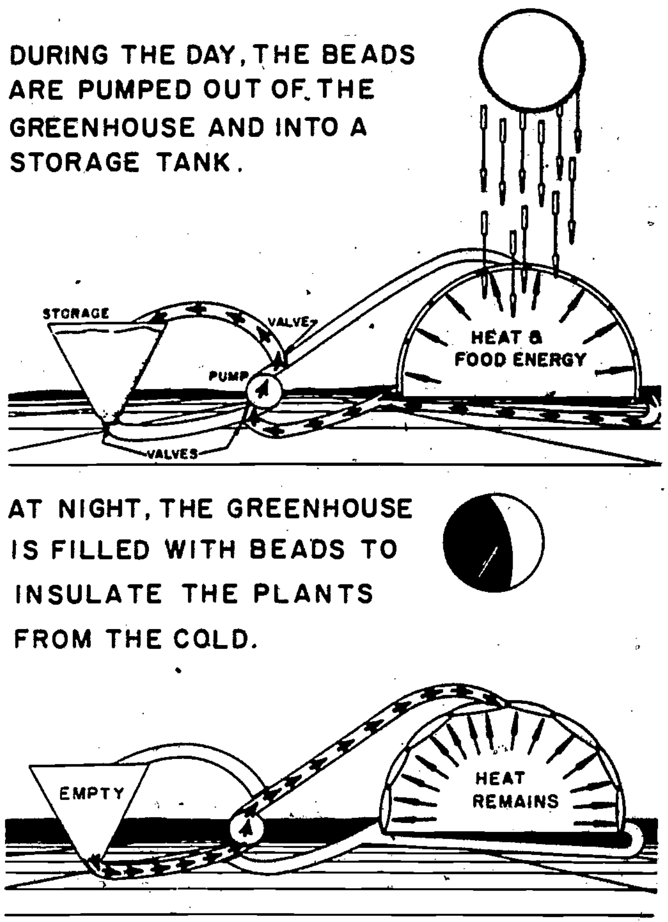
Suggested methods of double poly covering:
1. Over the top—eave to eave.
2. Up to the vent.
3. Both vents open.
4. Sill to ridge with one bubble.
5. Sill to vent with one bubble.
6. Separate bubbles on the roofs.
7. Work around vents, fan boxes and doors. You can also cover ends.

Some growers prefer to use separate wall bubbles over side vents of Aspen pad areas which can be removed when warm weather approaches. Monsanto Plastics & Resins Co. photo

Source: Badger and Poole, *Conserving Energy in Ohio Greenhouses*, Cooperative Extension Bulletin 651, November 1979

HANDOUT #3

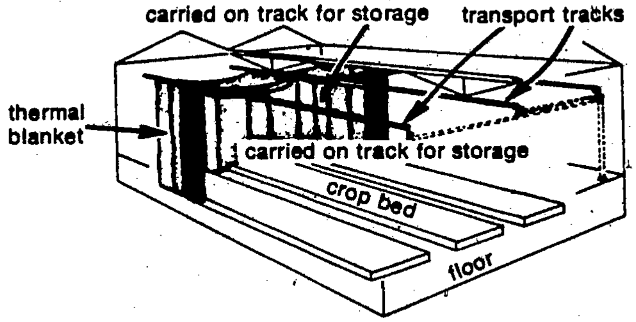
Operation of a Polystyrene Pellet Insulated Greenhouse



Source: Badger and Poole, *Conserving Energy in Ohio Greenhouses*, Cooperative Extension Bulletin 651, November 1979

HANDOUT # 4

Track-type Thermal Blanket



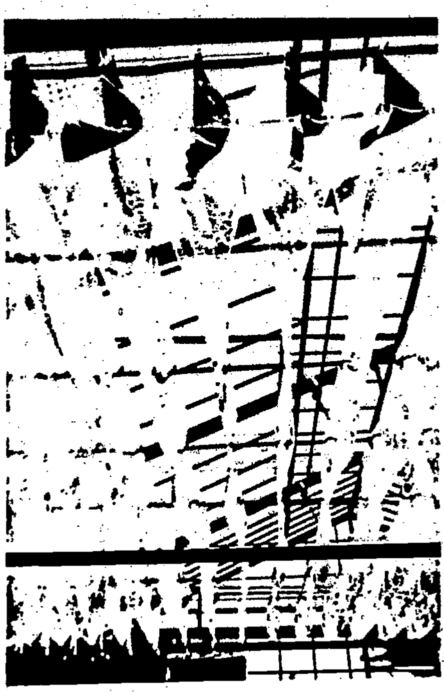
Pennsylvania State University photo

A track-type thermal blanket. Note side and end curtains.

Source: Badger and Poole, *Conserving Energy in Ohio Greenhouses*, Cooperative Extension Bulletin 651, November 1979

HANDOUT #5

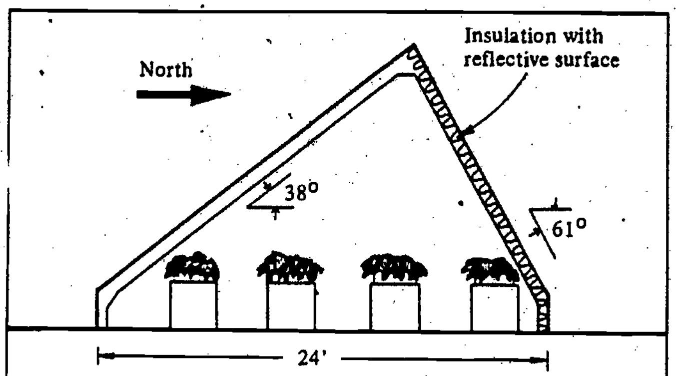
Air-inflated Plastic Tubes for an Energy Screen



Source: Short and Huizing, *The Development of a Movable Energy Screen for Greenhouses Using Air-inflated Plastic Tubes*, Bulletin 629, Ohio Florists' Association, March 1982

HANDOUT #6

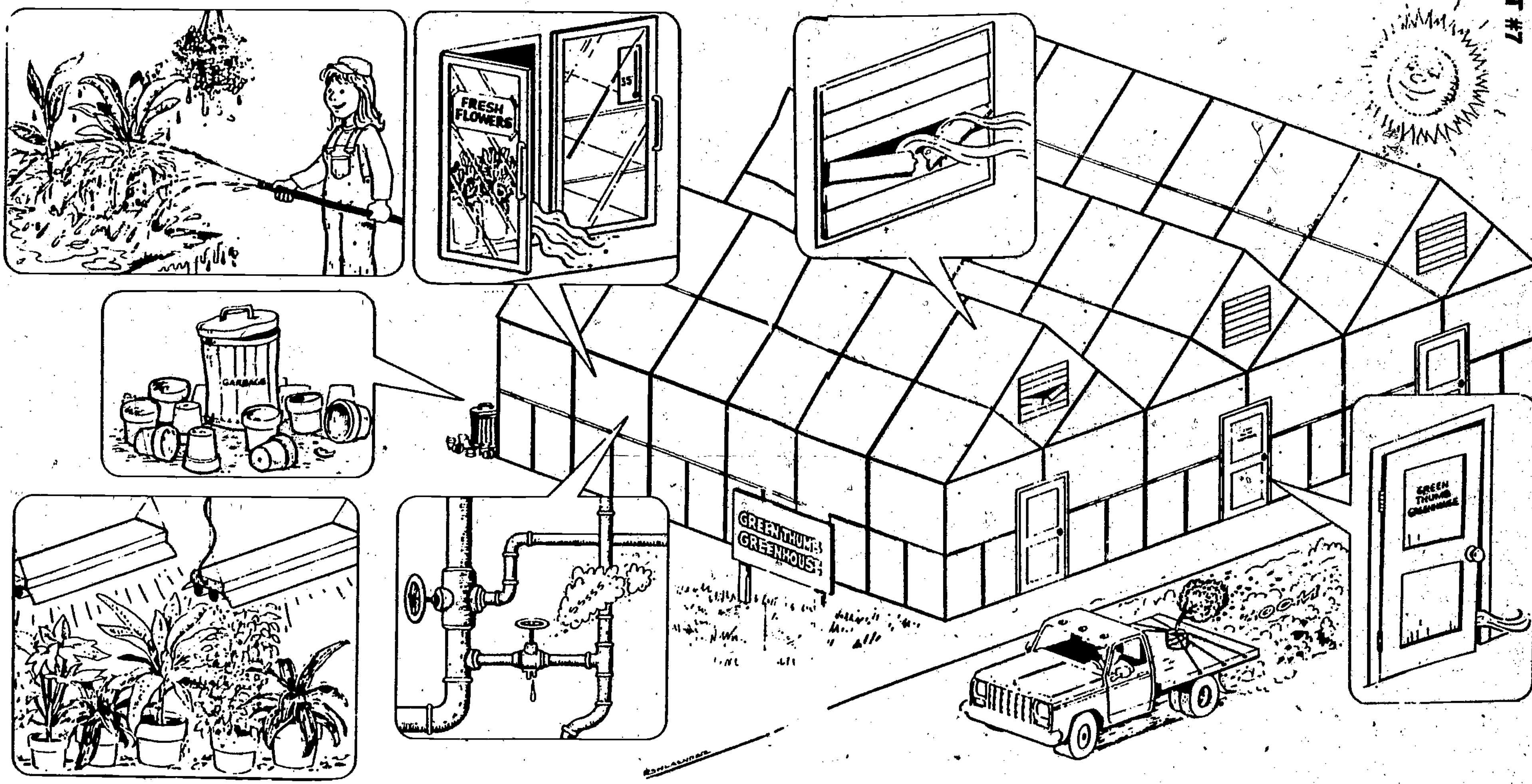
Experimental Greenhouse with North Wall Insulation



Experimental greenhouse with north wall insulation

Source: Blom et al., *Energy Conservation in Ontario Greenhouses*, Ministry of Agriculture and Food Publ. 65, 1978.

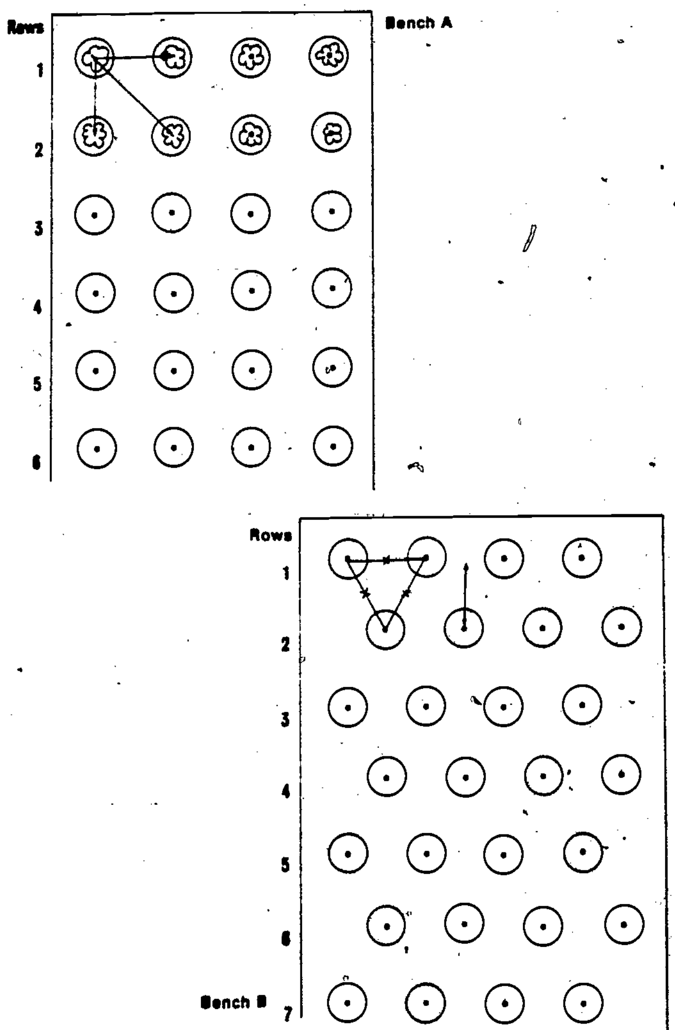
Energy Wasting Practices in the Greenhouse



Source: McBain, "Energy Efficiency for Tomorrow's Greenhouse Workers," *American Institute for Research*, January 1982

HANDOUT #8

Plant Spacing Arrangements on Benches



Spacing arrangements for standard and staggered systems with a common spacing distance. Note that approximately 15 percent more rows and plants can be placed on Bench B (staggered) than on Bench A (standard).

Source: Poole and Badger, *Management Practices to Conserve Energy in Ohio Greenhouses*, Cooperative Extension Service Bulletin 668, July 1980

I. **Lesson Topic:** **INVENTORY OF ENERGY USE**

by

LOWELL E. HEDGES

II. **Lesson Performance Objectives**

At the end of this lesson, the student will be able to:

1. Determine the amount of heat loss in the home.
2. Determine effective methods of preventing heat loss in the home.
3. Determine estimated cost and potential dollar savings for various energy conservation activities.
4. Identify those behaviors, activities and practices which he/she is willing to change in order to set new priorities to better manage and conserve energy.
5. Conduct an inventory of energy usage in the home and business.
6. Conduct an inventory of energy usage for recreational and pleasure activities.
7. Compare his/her energy usage practices with those of a like student in another school, state, and/or national culture.

III. **Materials Needed**

1. Transportation available so that the class can visit nearby homes, farms and/or businesses that utilize the improved practices discussed in the lesson.
2. Access to names of students of other nationalities/cultures with whom they might correspond.

IV. **The Situation**

Energy management means getting the maximum output for the least energy input to get the job done. Achieving a reduction in energy units used for each output unit produced saves money and energy. The preceding nine lessons have attempted to show the students how to do just that. These nine lesson plans have considered the following major steps as ways to approach and to think about energy management in agriculture:

1. ***Cutting out waste***

The lesson plan on tractor maintenance and operation helped the student use tractors effectively, size them to the job to be done, and maintain and operate them for maximum efficiency. The livestock management lesson plan showed reasons why buildings need to be properly insulated and ventilated for efficient energy use and also for livestock and owner health. Effective energy management in greenhouse operation was also stressed in a lesson plan. Many practices taught in these lessons can bring about immediate and significant savings in energy. They require commitment and determination. Some require little or no investment.

2. ***Changing methods***

Some lesson plans concentrate attention on how the job is done, such as the use of the tractor and equipment, how field work is done, how farm buildings and homes are used and heated. All result in getting more done with the same or less energy input. The lesson, *Framework for Evaluating Costs and Benefits of Alternative Energy Systems*, should enable students to learn to make wise energy use decisions.

3. ***Improvement***

Some lessons specifically direct our attention to methods of getting more out of the energy we use. Using waste heat in a dairy operation is one example. Using diesel engines in tractors is another. Decisions such as the interior arranging of tables in a greenhouse cannot be overlooked. And, of course, conserving what we have through reducing heat loss with better insulation is high on the list of energy management priorities.

4. ***New Approaches***

As the potential in steps 1, 2, and 3 is taught in certain lessons, new approaches to energy management can be encouraged so that further energy savings not readily visible can be brought to light. The potential of new field working and cropping practices, alternate sources of heat for the home and business, such as solar energy or wind power, priority use of electrical appliances and equipment in the home and business — all of these approaches to energy management can be available to your students through careful study, imagination, a pioneering spirit, and flexibility. The challenge is yours, the teacher's, to bring this all about.

V. Introduction

This lesson is designed to help the student take an analytical look at energy usage in his/her overall lifestyle. Emphasis will be given to areas concerning the home, other buildings, recreation, i.e., energy usage in the student's culture. An attempt will also be made to assist the teacher in exposing students to energy management practices in other cultures.

The teacher might use the following statement/question as a means of getting the students to consider energy use and conservation beyond what the first nine lessons covered. "Our study of energy and its use up to now has concentrated primarily on specific uses of energy such as electricity and wood; specific conservation practices in our use of tractors, corn production, livestock production, building use; and in other phases of our agricultural business. In what other areas of our lives are there possibilities for more efficient energy use?"

Possible student answers

1. Individual and family living style
2. Our overall energy use as compared to that of other countries.
3. Development of a master plan of energy use for our families at home, at work and at play
4.

At this point in the lesson, the teacher should have students select the sequence in which the above suggested areas will be studied, or else the teacher may arbitrarily select the order that will best fit into the overall activity schedule of the vo-ag program.

VI. Statement of the Problem

The areas of additional study suggested by the students can be easily handled as **problems to be solved** by the student and his/her family, or as **decisions to be made** concerning efficient energy use by the individual and the family.

As was done in the other lesson plans, the teacher may want to use a specific student's situation for the class to analyze and to make specific recommendations. Following that action, each student could then analyze his/her own situation and make specific recommendations that fit that particular situation.

The additional areas of study suggested by the students could be rephrased as follows in order to make them read as problems to be solved or decisions to be made:

A. "What additional behaviors, activities and practices can __*student*__ and his/her family change that will enable them to better manage and conserve energy?"

B. "What procedures should __*student*__ follow in developing a master plan of energy use for himself/herself and his/her family at home, at work and at play?"

C. "What procedures should __student__ follow in comparing energy use and management in his/her lifestyle and culture with that of another culture?"

VII. Solution to the Problem/Conclusion to the Decision

PROBLEM A

A. *Question:* "What additional behaviors, activities, and practices can __student__ and his/her family change that will enable them to better manage and conserve energy?" (The problem should be written on the chalkboard with students' suggestions beneath.)

Possible student answers

- Their recreational and leisure time activities
- The way they use their home
- Little practices like cutting down on the use of plastic that is made of petroleum and the time spent watching television

B. After the students have completed their suggestions, the teacher might want to use the following transition statement as a lead-in to the next class activity. "When using energy or in our attempts to conserve energy, we must take into account our economic, practical, and self-esteem values, and even our moral, aesthetic and spiritual values. By examining personal values, individuals can determine what energy-conserving habits and possessions in their lifestyle are to be maintained and which can be deleted or altered in order to manage and use energy more efficiently."

At this point, the teacher could distribute **handout #1**, *Energy Ethic*. Discussion could be held on what activities are most important to the individual. The students can then individually complete Columns A and B in the exercise. Further discussion could be held concerning which items the students could do without and thus help conserve energy. Column C could then be completed. Here students have an opportunity to decide which activities can be eliminated in a severe energy crisis.

C. Another exercise that students can complete is **handout #2**, which provides them an additional opportunity to analyze their lifestyles. Questions at the end of the exercise provide excellent guidelines for class discussion on adjusting individual lifestyles to use less energy.

D. **Handouts #3 and #4** offer a way for students to look closely at their common leisure-time activities and provide a means of making wise decisions in reducing high energy-consuming leisure-time activities. Meaningful discussions can be held during this exercise as students share their value systems.

PROBLEM B

A. *Question:* "What procedures should __student__ follow in developing a master plan of energy use for himself/herself and his/her family at home, at work, and at play?" (The problem should be written on the chalkboard with students' suggestions written underneath.)

Possible student answers

- Make an inventory of the family's energy usage.
- Make a list of energy conservation activities the family can follow.
- Write up an agreement for the family to follow in implementing energy-saving practices.
-

B. **Handout #5** can be used by the student to determine what energy management activities/practices are presently being followed by him/her and his/her family. The checklist is constructed so that it can also be used to indicate future energy conservation practices that an individual or a family plan to follow.

C. As part of the master plan for energy conservation, the family can conduct a **home energy analysis** to determine the heat loss in the home plus estimated cost and potential dollar savings for various conservation activities. **Handout #6**, a questionnaire developed by the Ohio Department of Energy, can be used to make this analysis. The completed questionnaire can then be sent to the Department of Energy for the computer analysis. Some County Agricultural Extension Agents can also process the questionnaire.

D. By the time students have been taught the ten lessons on energy management, they should be ready for and capable of developing a master energy management plan for their home, farm, or business and for their family and themselves.

A review of the *Energy Management Checklist*, **handout #5**, should enable the student and his/her family to select those energy management activities that still can be put into action. Give the students **handout #7**. This Master Plan provides a means to identify the activity; to indicate if further help is needed to implement this activity, and, if needed, who will provide it; and estimated yearly savings in dollars if that energy management activity is used. The Master Plan also provides for the recording of the key person in the family or business who is responsible for taking the initiative in putting the energy management activity into use.

PROBLEM C

A. *Question:* "What procedures should student follow in comparing energy use and management in his/her life-style and culture with that of another culture?" (The problem should be written on the chalkboard with students' suggestions written underneath.)

Possible student answers:

- Correspond with a pen pal in another country.
- Study how farming is done in a developing country and compare (with our farming) the amounts of energy used to produce a unit of food.
- Do an in-depth study of world-wide energy use and conservation.
-

B. Establishing a pen pal relationship with a foreign student/family for the purpose of obtaining new insights into energy management can be a novel and rewarding experience. Many European and Scandinavian countries were practicing energy conservation in all aspects of their life-styles long before the United States became aware of the "energy problem." Through correspondence with a pen pal in Norway, for example, a student can learn unique ways in which the Norwegian family wisely manages energy usage in their life-style. Assistance in locating pen pals can be found by writing to **World Pen Pals**, 1690 Como Avenue, St.Paul, Minnesota, 55108. Initial participation cost is $1.00 per individual.

C. To become aware of what other cultures around the world have been doing and plan to do as to energy conservation would be of value to our students in their consideration of energy use and conservation in our culture. This cross-cultural study should include developed as well as developing countries. How do these cultures differ from our own in energy use, percent of energy imported, energy consumption per capita, and percentage of world energy consumption versus percentage of the world population? Also, our students should benefit from comparing the flow of energy in modern, highly mechanized, fossil fuel agriculture with that flow in a non-fossil fuel, simpler form of agriculture that is found in most of the developing countries.

Handout #8 contains charts comparing the flow of energy in two agricultural societies, specifically the "slash and burn" (gardening) agricultural system and the modern fossil fuel-based agricultural system. Advantages and disadvantages in terms of energy use and productivity are obvious discussion points for this exercise. Ten discussion questions are included in **handout #8**.

D. One approach that a teacher might use in teaching this section is to solicit questions from students concerning energy use and conservation in other cultures as compared to those in our culture. The following are some possible questions students might ask, along with answers. **References** for the questions are included in the Appendix (pages 33-37).

1. If the United States made a serious commitment to energy conservation, how much less energy could it consume and still maintain an enjoyable standard of living?

   — 30 to 40 percent less (Reference #1)

2. In the debate concerning energy conservation, there are several theories as to the best way to reduce energy usage. What are the various theories and what are the specific beliefs?

   a. *Free market proponents.* They argue that price alone should determine the extent and definition of conservation. They believe swift deregulation of energy markets, for one thing, is the way to realize energy conservation.

   b. *Non-deregulation group.* These people would reluctantly go along with deregulation, but argue that it is not a sufficient condition for optimal energy use. The "free" market has failed to reflect full social costs from such externalties as oil spills, air pollution, and congestion from automobiles, balance of payment deficits, and the potential disruptive economic and national security costs of an oil embargo. They also believe in the need for higher taxes on energy, particularly gasoline.

   c. *"Windfall profits" group.* These people are concerned with the "windfall profits" or economic rents from higher energy prices accruing to a limited number of large producers. Regulation of energy prices for this reason makes conservation less attractive. On the other hand, lower income consumers bear relatively more of the burden of higher energy prices. Many feel that they should be protected or compensated. (***Source:*** Reference #1)

3. What percent of the world's population resides in the United States? What percent of the oil consumed in the world each day is consumed by the United States?

   — 6% of the population; 1/3 of the oil. (Reference #1)

4. What proportion of the oil used by the United States is imported?

   — About 1/2. (Reference #1).

5. How does the energy consumption of the American people compare with that of other countries?

   — West Germany consumed about 3/4 as much energy as the U.S. and France approximately 1/2 as much energy for each dollar of gross domestic product in 1976. (Other comparisons can be found in Table 1, Reference #1.)

6. In the United States, how much of the total amount of oil used is consumed by the transportation sector? How much by the private auto?

   — Transportation uses about 1/4 of the energy consumed, and 1/2 of the oil. The private auto uses over half of the transport sector's energy. (Reference #1)

7. What are some other major use areas of energy in the United States?

   - Residential sector = 20 percent, with 2/3 for space and water heating, plus 1/4 lost due to air infiltration in the house.
   - Production agriculture = 2.8 percent of total energy use.
   - Processing, marketing/distribution, input manufacture and food preparation = 13.2 percent. (Reference #1)

8. How dependent is agriculture on the liquid fuels?

   — Oil and natural gas provide about 85 percent of energy use in the food and fiber system, and over 90 percent of energy use in agricultural production. (Reference #1)

9. What happens to price incentives for conservation when energy prices are controlled either because of windfall profits or because of concern for lower income consumers?

   — Price incentives are reduced. (Reference #1)

10. If number 9 above is true, how then do we achieve more energy conservation?

    — More reliance must be placed on voluntary patriotic or involuntary schemes for rationing or curtailing energy use. (Reference #1)

11. Do price controls on energy sources affect future generations?

    — Price controls clearly work against future generations. (Reference #1)

12. How does the energy consumption per capita of heavily populated countries compare with Western European countries and the United States?

    — In comparing kilograms of coal equivalent per capita, Bangladesh records 28 per capita, United Kingdom 5265, and the United States 10,999. (Reference #2)

13. Why is modern agriculture energy intensive?

    — Because of mechanization and the petroleum base of many agricultural chemicals currently used to increase crop yields and net returns. (Reference #3)

14. How does a subsistence diet compare with an affluent diet in terms of food or fuel needs?

    — Subsistence diet = 400 lb. of grain and 0.2 acres. Affluent diet = 1600 lb. of grain and 19 acres. (Reference #3)

VIII. **Evaluation**

QUIZ: INVENTORY OF ENERGY USE

NAME ____________________

1. List five possessions and five activities which are of real importance to you. For each of the ten things listed, explain in a sentence why it is so important to you.

2. List four factors which would cause you to change your life-style so that you would use less energy.

3. List five changes you would be willing to make in your life-style to conserve energy. List five conditions of your life-style which you would resist changing even with a real energy shortage or very high cost of energy.

4. Energy for home and personal use is to be severely rationed. Which of the following restrictions would you be most willing to accept? Explain your choice.

   (1) No electricity in your home for 12 hours each day.

   (2) Gasoline limited to ten percent of present use.

5. What evidence can I as your teacher expect to see that you have learned *and* changed your behavior as a result of this unit on attitudes and the energy situation our country is now experiencing?

Source: Beaulieu, *Low Energy Technology*, 1980

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HANDOUT #1

APPENDIX

ENERGY ETHIC

Below is a list of items and activities which require energy for their manufacture, use, and disposal. Number (rank) these items in order of importance and necessity to you. Mark your responses in **Column A** — number 1 being most important, down to number 20 for least important.

A		B	C
____	watching television	____	____
____	hot water for bathing	____	____
____	electric toothbrush	____	____
____	waffle iron	____	____
____	synthetic clothing	____	____
____	reading a book	____	____
____	eating a raw apple	____	____
____	TV dinner	____	____
____	car ride to the store	____	____
____	drive-in movie	____	____
____	making home-made ice cream	____	____
____	lipstick or cologne	____	____
____	aerosol deodorant	____	____
____	electric hair dryer	____	____
____	bike riding	____	____
____	a walk in the sun	____	____
____	candy	____	____
____	night-time football games	____	____
____	hot lunches	____	____
____	school buses	____	____

Now that you have ranked these items according to their importance to you, look through the list again and rank from 1 to 10 in **Column B** the ones you feel are **most energy intensive.**

Finally mark in **Column C** the items you could do without — and thus help yourself and our nation to conserve energy.

Adapted from J.C. Penney materials: *Decisions, Decisions* (teaching unit)

Material also from Beaulieu, Barbara, et al., *Low Energy Technology: A Unit of Instruction In Housing and Home Environment Attitudes.* Gainesville, Florida: University of Florida, 1980.

THINGS I LIKE TO DO

Things I Like to Do	$	E	e	F &/or M	"10"	Date
1.						
2.						
3.						
4.						
5.						

1. List 5 things you like to do.
2. Place a $ sign by any item which costs more than $3.00 each time to do it.
3. Put a capital "E" in the row of any item which uses a lot of "Purchased" energy to perform.
4. Put a small "e" next to any item which requires little "Purchased" energy to perform.
5. Using the code letters "F" and "M", record which of the items on your list you think your father (F) and mother (M) might have had on their lists if they had been asked to make one at YOUR age.
6. Place a number "10" for any item which you think **would not** be on your list 10 years from now.
7. Finally, go down your list and place the date when you did it last.
8. Answer the following questions:

   What does your list tell you about the things you like to do?
   What items require a lot of energy?
   List ways that you could conserve energy in this list of things you like to do.
   Did your parents use less energy at your age than you do? Why?
   What things are you going to keep doing for many years? What options are there for continuing to do these activities but with less energy?
   How could you get the same end result (satisfaction) for the short term items but use less energy?

Adapted from J.C. Penney materials, *Decisions, Decisions* (teaching unit)
Material also from Beaulieu, *Low Energy Technology*, 1980

HANDOUT #3

LEISURE-TIME ACTIVITIES
(Directions for Handout #4)

1. In handout #4, column 1, in the space provided list 10 leisure-time activities that you enjoy doing.
2. In column 2, rank these activities in the order of importance to you.
3. In column 3, under "Costs Money," place the score which best indicates the cost of this activity.

   3 points - high cost activity
   2 points - moderate cost activity
   1 point - low cost activity
   0 - no cost

4. In column 4, place the score that best evaluates the amount of "purchased" energy used for the activity.

   3 points - major amount used
   2 points - moderate amount used
   1 point - small amount used
   0 - no purchased energy used

5. In column 5, rate the activity on the frequency with which it is performed.

   3 points - performed a lot
   2 points - performed occasionally
   1 point - performed seldom
   0 - never done

6. To calculate the total value, add the points in columns 3, 4, and 5 together, and put the total in column 6. (Example 3 + 2 + 0 = 5)
7. In column 7, rank the items from high to low in the total value column. (A "9" would be ranked #1, a "0" would be ranked #10.)
8. After completing this activity, answer the following questions:
   - If faced with a severe energy crisis and the need to cut leisure-time activities by 50 percent, how would you cut your leisure-time activities?
   - How could you obtain the same enjoyment but use less energy?
   - Are you willing to reduce your activities by 50 percent to help conserve energy? Why or why not?
   - Does the ranking affect the decision to reduce activities? How?
   - Does the dollar value have an effect on energy use?
   - What activities can be done without "purchased" energy?

Source: Beaulieu, *Low Energy Technology*, 1980

LEISURE-TIME ACTIVITIES CHART

Activity 1	Order of Importance 2	Costs Money 3	Energy Used 4	Frequency 5	Total Value 6	Rank 7
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

Source: Beaulieu, *Low Energy Technology*, 1980

HANDOUT #5 - page 1

ENERGY MANAGEMENT CHECKLIST

Have done	Will do	
		Temperature control
☐	☐	Reduce daytime home heating in winter, maintaining 65°F (18°C) or lower temperature.
☐	☐	Set air-conditioning unit to recirculate cool air instead of pulling in warmer outside air.
☐	☐	Increase temperature setting for summer air conditioning to 78°F (26°C) or higher.
☐	☐	Reduce nighttime winter temperature 5°–8°F (3°–5°C) or more.
☐	☐	Use window and attic fans for cooling during summer when outside temperature is below temperature in home.
☐	☐	Maintain heating and cooling equipment in good operating condition.
☐	☐	Keep air filters clean to make it easier for heating and cooling system to do its job.
☐	☐	Close off unused rooms and closets.
☐	☐	Use kitchen and bathroom exhaust fans only when necessary.
☐	☐	Install an exhaust fan in the attic to remove hot air in the summer.
☐	☐	Shade windows from direct sun in summer with draperies and roll-up shades.
☐	☐	Open draperies and raise shades to receive sun's heat in winter.
☐	☐	Close door of attached garage in winter.
☐	☐	Close damper when fireplace is not in use.
☐	☐	Select an energy efficient air-conditioning unit the proper size for space to be cooled. It is better to buy a slightly undersized unit, rather than an oversized one.

Have done	Will do	
☐	☐	Repair leaks and insulate heating and cooling ducts in spaces not heated or cooled.
☐	☐	Adjust radiator valves, air duct dampers, or heat registers according to activity in area.
☐	☐	Reduce heating and cooling temperatures when away from home for long periods of time.
		Insulation reduces heat loss or heat gain, improves comfort, and reduces energy required for heating and cooling.
☐	☐	Ceiling — minimum R-Value of 19.
☐	☐	Walls — minimum R-Value of 11.
☐	☐	Crawl space or unheated basement — minimum R-Value of 13.
		Window and door protection for winter
☐	☐	Install storm windows and storm doors, or
☐	☐	Cover windows and doors with plastic.
		Protect home from cold winter wind.
☐	☐	Plant or build a windbreak landscape treatment.
☐	☐	Use garage entrance where possible.
☐	☐	Protect entrances with double-door arrangement.

(continued)

HANDOUT #5 - page 2

Energy Management Checklist *(continued)*

Have done	Will do	
		Seal air leaks.
☐	☐	Weather-strip doors, windows, and all movable joints.
☐	☐	Caulk interior and exterior cracks.
☐	☐	Seal unused doors.
☐	☐	Cap **unused** flues and (or) chimneys.
		Protect home from summer sun.
☐	☐	Plant deciduous trees.
☐	☐	Install a roof overhang to protect windows.
☐	☐	Use awnings or other treatment.
		Utilize breezes for cooling during warm season.
☐	☐	Close windows during midday.
☐	☐	Open windows in evening.
		Lighting
☐	☐	Turn off unnecessary lights, indoors and out.
☐	☐	Reduce lighting levels to minimum for task to be performed.
☐	☐	Use bulbs with lower wattage in halls, stairways, and other areas of general illumination.
☐	☐	Use light colors in decorating to improve lighting efficiency.
☐	☐	Do tasks that require a high light level during daylight hours when possible.
☐	☐	Keep lighting fixtures clean.
☐	☐	Use fluorescent lighting for maximum light from electrical energy used.
☐	☐	Use timers to turn lights on in the evening rather than leaving lights on all day when no one is home.

Have done	Will do	
		Food preparation
☐	☐	Use oven to capacity.
☐	☐	Use cooking utensils that fit surface unit.
☐	☐	Use tight-fitting lids on cooking utensils, when appropriate.
☐	☐	Reduce heat to maintain necessary cooking temperature when using surface units.
☐	☐	Use small appliances for cooking if they are more efficient than a range.
☐	☐	Preheat oven only for leavened foods. Do not preheat longer than needed to attain required temperature.
☐	☐	Turn off oven and surface units when food is cooked.
		Food preservation: refrigerator, freezer
☐	☐	Avoid opening door or holding it open unnecessarily.
☐	☐	Keep grilles and evaporator coils clean.
☐	☐	Locate cooling appliances away from heat sources such as range, hot air register, or direct sunlight.
☐	☐	Defrost as needed.
☐	☐	If cold air is leaking around door, have door adjusted or gasket replaced.
☐	☐	Turn off, empty, clean, and leave refrigerator door open when taking an extended vacation.
		Dishwashing
☐	☐	Accumulate dishes; hold until dishwasher is filled. If dishes are hand washed, rinse and hold breakfast and lunch dishes until evening.
☐	☐	Do not let hot water run continuously while washing or rinsing dishes.
☐	☐	Omit dishwasher drying cycle; open the door at end of the rinse cycle.

Energy Management Checklist *(continued)*

Have done	Will do	
		Heating water
☐	☐	Reduce amount of hot water used.
☐	☐	Insulate long hot water pipes, especially those under the home or those that go through unheated basements or crawl spaces.
☐	☐	Repair leaky faucets.
☐	☐	Maintain regular temperature setting of 110°-120°F (43°-49°C) on water heater if automatic dishwasher is not used, 140°F (60°C) if automatic dishwasher is used.
		Laundry
☐	☐	Wash only full loads of laundry.
☐	☐	Use heated water in only the wash cycle.
☐	☐	Use water no hotter than necessary for adequate soil removal and sanitation.
☐	☐	Use good laundry techniques to obtain satisfactory results in one washing process.
☐	☐	Avoid overdrying in clothes dryer.
☐	☐	Sort dryer loads by weight.
☐	☐	Line-dry garments and household items when practical.
☐	☐	Use dryer efficiently. Avoid drying one or two items at one time.
☐	☐	Vent electric dryer indoors during heating season.
☐	☐	Remove items when dryer stops to avoid unnecessary wrinkling, which will require ironing to remove.
☐	☐	Reduce ironing to a minimum by careful selection of garments and household linens.
		Cleaning and maintenance
☐	☐	Empty or replace vacuum cleaner bag frequently to keep it functioning efficiently.
☐	☐	Use hand equipment rather than power tools when practical.
☐	☐	Develop preventive maintenance practices. Routine check-up and servicing will prevent greater problems later.

Have done	Will do	
		Personal care
☐	☐	Minimize hot water used in bathing. Check to see if less water is used in showering than in tub bathing.
☐	☐	Add a flow restrictor to shower head.
☐	☐	Do not leave water running while shaving or brushing teeth.
		Recreation and Entertainment
☐	☐	Turn off home entertainment equipment when no one is really watching or listening.
☐	☐	Disconnect or use vacation setting on an instant-on television when you are not going to be using it regularly.
☐	☐	Use shop or hobby equipment efficiently.
☐	☐	Maintain tools in good operating condition.
☐	☐	Encourage family members to develop leisure activities that have low energy costs, such as bicycling, hiking, reading, and swimming.
☐	☐	Spend vacations closer to home.
☐	☐	Encourage home and neighborhood activities.
		Family Automobile
☐	☐	Drive at a moderate speed.
☐	☐	Drive smoothly with gradual starts and stops.
☐	☐	Drive slowly for first mile instead of letting car warm up by idling.
☐	☐	Provide proper maintenance; make sure you have well-tuned engine and properly inflated tires.
☐	☐	Combine errands by careful planning.
☐	☐	Carpool whenever possible.
		Other transportation
☐	☐	Walk, ride a bicycle, or use public transportation whenever possible.
☐	☐	Travel only when necessary.

Major Source: *Energy Management Checklist for the Home* (PA-1118). Washington, D.C.: USDA, Prepared by Science and Education Administration.

Items also from: Howell, D.L., et al. *Energy Conservation in the Home and on the Farm.* University Park, PA: The Pennsylvania State University, College of Agriculture, 1980.

HANDOUT #5 - page 4

Energy Management Checklist *(continued)*

FARM ENERGY MANAGEMENT CHECKLIST

	Have done	Will do
Farm Tractors and Equipment		
Select the proper tractor size to fit the operation.	( )	( )
Size the equipment to match the tractor.	( )	( )
Practice minimum tillage where practical.	( )	( )
Follow regular maintenance and tune-ups.	( )	( )
Merge small fields into large fields to reduce turning and have longer rows.	( )	( )
Keep all implements lubricated and properly adjusted.	( )	( )
Use tractor weights to distribute load for minimum wheel slippage.	( )	( )
Check tire pressure.	( )	( )
Replace faulty radiator thermostats.	( )	( )
Keep tillage tools sharp and properly lubricated.	( )	( )
Avoid excessive idling and engine warm-up time.	( )	( )
Remove tractor wheel weights when not needed.	( )	( )
Use preventative maintenance.	( )	( )
Tillage Management		
Omit plowing, harrowing, disking, or cultivation where good management practices will permit.	( )	( )
Don't plow quite as deep unless there is a plow plan.	( )	( )
Keep plow shares sharpened.	( )	( )
Plow when soil moisture is favorable, if possible.	( )	( )
Plow around fields instead of inlands.	( )	( )
Harrow fields diagonally when two passes are needed.	( )	( )

Energy Management Checklist *(continued)*

Farm Energy Management Checklist (*continued*)

Tillage Management *(continued)*	**Have done**	**Will do**
Work the long way of the field.	( )	( )
Have a good soil and water conservation plan.	( )	( )
Use contour strip cropping.	( )	( )
Combine some field operations into one.	( )	( )
Apply liquid nitrogen and herbicides.	( )	( )
Disk and apply herbicides.	( )	( )
Plant and apply herbicides.	( )	( )
Fertility Management		
Use high analysis fertilizers.	( )	( )
Use ammoniated starters to enhance early germination and reduce replanting risk.	( )	( )
Plow down all P & K when planting clear seeded alfalfa for 3 year stands.	( )	( )
Handle and store manure in semi-dry form.	( )	( )
Spread manure less frequently.	( )	( )
Plow down manure promptly.	( )	( )
Handle less weight.	( )	( )
Grow forage legumes.	( )	( )
Grain Drying		
Use early maturing varieties.	( )	( )
Field dry to the fullest possible extent.	( )	( )
Buy a good moisture tester and use it.	( )	( )
Do not overdry.	( )	( )

(continued)

Energy Management Checklist *(continued)*

Farm Energy Management Checklist *(continued)*

Grain Drying *(continued)*	**Have done**	**Will do**
Clean grain to remove fines and reduce power needed to move air through grain.	( )	( )
Use as little grain depth as possible and level the top.	( )	( )
Operate dryer at optimum levels recommended by manufacturer and keep serviced properly.	( )	( )
Use dryeration process.	( )	( )
Grain preservation with organic acid.	( )	( )
Farm Trucks and Autos		
Carry loads to vehicle capacity. Do not overload.	( )	( )
Plan and schedule trips.	( )	( )
Follow regular maintenance programs.	( )	( )
Buy the right size vehicle properly equipped to do the job.	( )	( )
Inflate all tires to proper pressure peak.	( )	( )
Avoid excessive motor idling.	( )	( )
Water Heating		
Preheat incoming water with heat exchanger.	( )	( )
Drain water heater and remove lime deposits on a periodic basis.	( )	( )
Repair all leaking faucets.	( )	( )
Use automatic waterers rather than continuous flow.	( )	( )
Insulate around outside of water heater and between its base and the floor.	( )	( )
Insulate hot water lines which run through unheated areas.	( )	( )

Energy Management Checklist *(continued)*

Farm Energy Management Checklist *(continued)*

Water Heating *(continued)*	**Have done**	**Will do**
Keep temperature setting at low level.	( )	( )
Use hot water conservatively.	( )	( )

Ventilation		
Eliminate mechanical ventilation in animal housing facility wherever practical by using natural ventilation.	( )	( )
When warm animal housing facilities are required, consider a convertible system, closed, warm, and mechanically ventilated during cold months - open and naturally ventilated during summer months.	( )	( )
Reduce ventilation rates (cfm) to minimum levels in animal housing facilities mechanically ventilated year round and increase air circulation within the structure during hot months to compensate.	( )	( )
Turn fans off when ventilation is not required.	( )	( )
Select fans with a high cfm/watt rating.	( )	( )
Clean fans and shutters frequently.	( )	( )
Lubricate fans per manufacturer's recommendation.	( )	( )
Keep belts tight.	( )	( )
Check thermostats.	( )	( )
Controls properly set to prevent over ventilation during cold weather months and wasting supplemental heat.	( )	( )
Temperature-controlled, variable speed fans, 2-speed fans or motor-operated fan shutters to reduce fuel consumption in heated buildings.	( )	( )

(continued)

Energy Management Checklist *(continued)*

Farm Energy Management Checklist *(continued)*

	Have done	Will do
Refrigeration		
A heat exchanger coupled with a refrigerant compressor.	( )	( )
Remove half of the heat from fruits or vegetables brought from the field.	( )	( )
A multitube pre-cooler, using well water to pre-cool milk.	( )	( )
Keep compressor condensors and fans clean.	( )	( )
Electric Motors		
Load motor with work as near as possible to its related capacity. Size motor to the job.	( )	( )
Avoid overheating.	( )	( )
Avoid letting motors run idle.	( )	( )
Start motors in sequence rather than simultaneously if there are 2 or more large motors.	( )	( )
Keep motors and equipment lubricated and clean.	( )	( )
If you are on demand billing, operate as few motors and lights at one time as practical.	( )	( )
Install electric wiring for motors which is heavy enough gauge for minimum voltage drops.	( )	( )
Maintain proper V-belt tension.	( )	( )
Electrical equipment powered by motors of correct type and size.	( )	( )
Distribution pole near center of load.	( )	( )
All equipment supplied with correct voltage.	( )	( )

HANDOUT #5 - page 9

Energy Management Checklist *(continued)*

Farm Energy Management Checklist *(continued)*

	Have done	Will do
Lighting		
Switch to lower wattage bulbs.	( )	( )
Switch incandescent to lower wattage or to lower wattage reflector bulbs.	( )	( )
Use task lighting and reduce whole area lighting.	( )	( )
Replace regular fluorescents with new GE Watt Misers.	( )	( )
Reduce total light burning hours by turning off when not in use.	( )	( )
Light dimmers used where total wattage of bulbs gives more light than needed.	( )	( )
Eliminate unnecessary dusk-to-dawn lights	( )	( )
Irrigation		
Diesel power instead of gasoline.	( )	( )
Sprinkler rather than furrow irrigation.	( )	( )
Trickler rather than furrow irrigation.	( )	( )
Irrigating under cloudy conditions, lower temperatures, and/or at night to reduce water requirements.	( )	( )
Maintain and tune the power unit engine.	( )	( )
Operate electric-powered units during low demand periods.	( )	( )

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Our Energy Problems and Solutions, Energy Conservation Research, 1977.

Howell, D.L., et al., *Energy Conservation in the Home and on the Farm*. University Park, PA: The Pennsylvania State University, College of Agriculture, 1980.

HANDOUT #6 - page 1

HOME ENERGY ANALYSIS QUESTIONNAIRE

Please print:

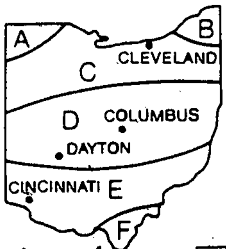
Name ______________ Last ______ First   Phone ______

Address ______________

City ______________ State OHIO Zip ______

Directions:
FOR QUESTIONS 1 THROUGH 18 WRITE THE LETTER THAT INDICATES THE *BEST* ANSWER IN THE BOX AT THE RIGHT OF THE QUESTION.

1. In the box at the right, enter the letter from the Ohio map that best indicates your location. ☐



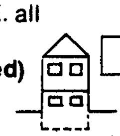
2. What is the *primary* type of energy used for heating your home? ☐
A. natural gas
B. LP gas
C. oil
D. coal
E. electric radiant or baseboard
F. electric furnace
G. electric heat pump
H. wood

3. Do you have air conditioning? ☐
A. yes B. no C. partially

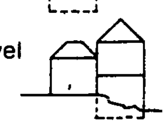
4. What type of construction is your home? ☐
A. frame with wood siding
B. frame with aluminum siding
C. frame with brick exterior
D. frame with stucco
E. frame with combination of above
F. frame with other exterior
G. block or solid brick masonry
H. log

5. How much of the first floor of your home is carpeted with either wall-to-wall carpet or padded rugs? ☐
A. none B. ¼ C. ½ D. ¾ E. all

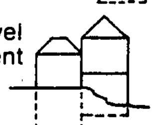
6. What type is your home? (Consider every answer listed) ☐
A. 1 story
B. 1½ story or 1 story w/finished attic
C. 2 story
D. 2 story w/ 1 story section or addition
E. 2½ story or 2 story w/finished attic
F. bilevel



G. split level (3 floor levels)



H. split level w/basement (4 floor levels)

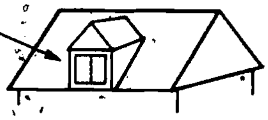


7. How many bedrooms are in your home? ☐
A. 1 B. 2 C. 3 D. 4 E. 5 or more

8. Generally speaking, what size are the bedrooms in your home? ☐
A. small B. medium C. large

9. Are there heated rooms over an unheated and uninsulated garage? ☐
A. no B. yes; over a 1-car garage
C. yes; over a 2-car garage

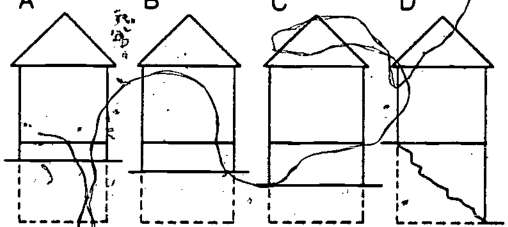
10. How many dormers does your home have? NOTE: This is a dormer: ☐
A. 0 B. 1
C. 2 D. 3
E. 4 or more



11. What type of foundation does your home have? ☐
A. basement
B. crawlspace
C. slab
D. piling
E. basement & crawlspace
F. basement & slab
G. crawlspace & slab

12. If you have a basement, is it heated to the same temperature as your home? ☐
A. no B. yes C. ½ heated

13. If you have a basement or crawlspace, which picture best shows the height of the basement walls or crawlspace walls above ground? ☐



14. Approximately what height are the ceilings in your home? ☐
A. 8′ (standard) B. 10′ C. cathedral

15. What does the insulation in your attic look like? ☐
A. loose particles
B. blankets or batts
C. none present
D. unknown

Cold air will leak into your house anywhere there is a crack, including around windows and doors, around water and electric openings, where walls meet windows, and at the foundation sill. **For questions 16, 17, and 18, choose the best description from answers A, B, and C below.**

A. TIGHT: completely caulked, weatherstripped, sealed. No drafts.
B. FAIR: partially sealed. Some drafts.
C. DRAFTY: needs to be sealed.

16. What is the condition of your windows? ☐

17. What is the condition of your doors? ☐

18. What is the condition of your floors, walls, and foundation? ☐

Home Energy Analysis Questionnaire *(continued)*

ANSWER QUESTIONS 19-26 IN THE SPACE PROVIDED.
NOTE: The small numbers at the left of the spaces are for computer use only.

19. What is the present insulation thickness in inches for each of the sections in your home? *(If unknown, leave blank)*

1___ceiling or attic 2___basement walls

3___floor 4___slab edge

5___walls

20. What is your average thermostat setting in the winter?

1___°F day 2___°F night

21. How many exterior doors of each type are in your home?

1___sliding glass 2___wood w/storm

3___metal 4___metal w/storm

5___wooden

22. What is the cost of the primary type of energy used for heating your home? If known, enter price of units specified below in boxes at right. ***(If unknown, leave blank)***

$ [ ][ ][ ].[ ][ ][ ][ ][ ]

Natural gas: $/100 cu. ft. (CCF)
LP gas: $/gal.
Oil: $/gal. *Wood:* $/cord
Electric: $/Kwh *Coal:* $/ton

23. Indicate in the table below how many windows of each size and type are in your home.

SIZE OF WINDOW	Small; about 2½' x 2½'	Medium; about 3' x 4'	Large; about 3' x 6'	Picture; about 5' x 8'
TYPE OF WINDOW	1___single pane 5___double glazed or single pane with storm	2___single pane 6___double glazed or single pane with storm	3___single pane 7___double glazed or single pane with storm	4___single pane 8___double glazed or single pane with storm

24. All of the information on this survey will be kept strictly confidential according to the provisions of the privacy act. May we have permission to contact you in the future to secure follow-up and additional information?

1___yes 2___no

You have now completed a mini-audit of your home. Remember that the mini-audit will only provide energy saving recommendations for a prototype of your home or one that is similar to yours in size, type and heat loss characteristics. To receive a specific analysis of your individual house or a maxi-audit, complete questions 25 and/or 26, depending on your particular type of residence. **Read and follow directions carefully.**

---

25. On the back of this page are pictures of several homes with various first floor plan shapes. Select the example which most closely resembles the shape of your particular house. If none of the examples match your home's layout exactly, you can still obtain a valuable energy analysis by approximating your home's design to one of the examples.

Once you have selected the picture which resembles your first floor plan, measure the lengths of the first floor sides labeled A, B, C, D, which apply to your home. **It is imperative that these dimensions are labeled exactly as in the appropriate example.** Exclude attached unheated additions such as garages and porches.

You can measure each side from the outside or inside of your home and estimate within the nearest foot of the exact length. If you know the approximate length of interior rooms or rugs, you can add these lengths to obtain the total dimensions. Another method of approximating the lengths of the sides is to pace off the distance.

What is the approximate length in feet of the first floor sides, labeled A, B, C, D, that apply to your home?

Side A______ft. Side B______ft.

Side C______ft. Side D______ft.

26. Complete this question *only if* you live in an attached home, such as a townhouse, condominium, twin single, row house, etc.

For condominiums, twin singles, townhouses, and other attached dwellings, check any side(s) of your home that are attached to another home.

1___one A side 2___side C

3___two A sides 4___one B side

5___side D 6___two B sides

Detach and return to
The Ohio Department of Energy
30 East Broad Street
34th Floor
Columbus, Ohio 43215

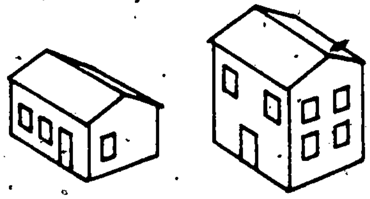
(continued)

HANDOUT #6 - page 3

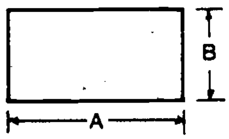
Home Energy Analysis Questionnaire *(continued)*

IT IS IMPORTANT THAT THE SIDES ARE LABELED EXACTLY AS IN THE EXAMPLES BELOW. Exclude attached unheated additions, but include garage if it is located below heated rooms.

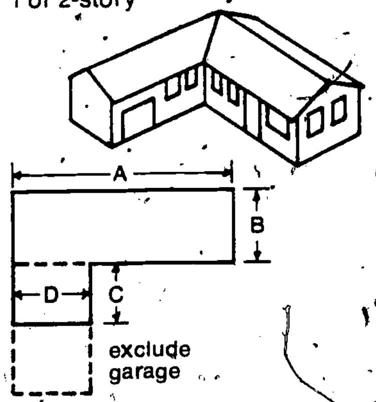
Rectangle shape home
1 or 2-story



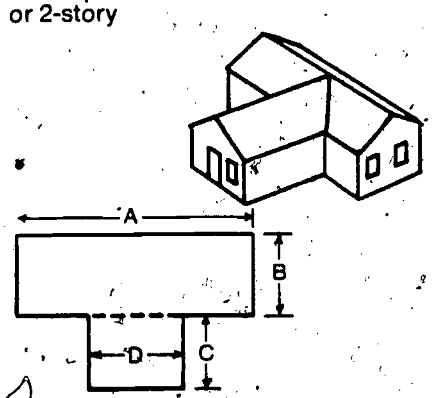
rectangle first floor plan requires only A and B



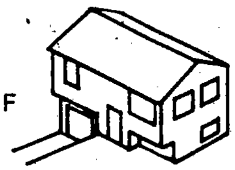
"L" shape home
1 or 2-story



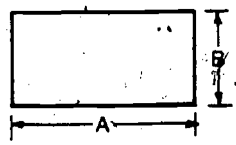
"T" shape home
1 or 2-story



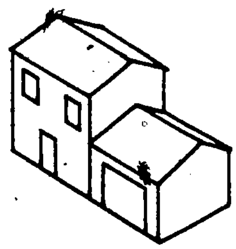
Bi-Level
Question 6 must be answered F



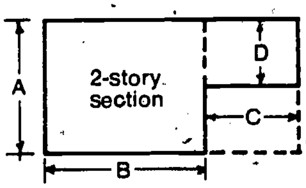
include garage

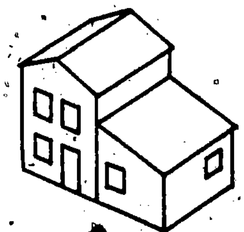


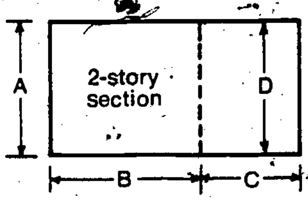
2-story with 1-story section or addition



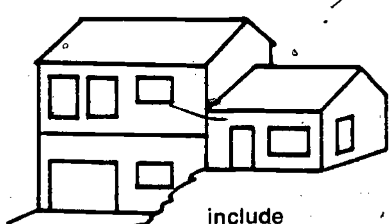
IMPORTANT: Question 6 must be answered D. A and B must be the sides of the 2-story section, and C and D the 1-story section.



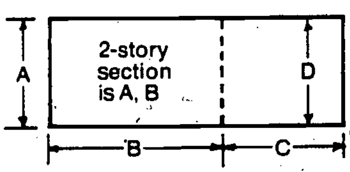




Split Level
Question 6 must be answered G or H.



include garage



OTHER SHAPES:
IMPORTANT: *D must be the length of the dotted line as shown in the examples and A must be directly across from D. Also, A and B must be the sides of the larger section or if the home is a split level or a two-story with a one-story addition, A and B must be sides of the two-story section.*

If none of the examples fit your home's shape exactly, you may still obtain a valuable energy analysis by approximating your home's shape to one of the examples.

For assistance call 1-800-282-9234

HANDOUT #7 - page 1

Summary of Our Energy Management Plan

A. Key person(s) responsible for good energy management on our farm:

Our Home ______________________ Farm equipment ______________________

Tenant House(s) ______________________ Farm buildings ______________________

B. Others we should involve in

(a) Development of our Energy Plan ______________________

(b) Energy Saving as we work and live ______________________

____

SUMMARY OF ENERGY COST SAVING ITEMS CHECKED

1. FARM EQUIPMENT USE AND MAINTENANCE

Potential Energy Saver	Help Needed (✓)	Who can help us Get the answer?	Estimated yearly Savings
			$
			$
			$
			$
			$
			$
			$
			$
			$
			$ Total

Notes: ______________________

____

____

____

____

(continued)

HANDOUT #7 - page 2

Summary cont'd.

2. FARM BUILDING USE AND MAINTENANCE

Potential Energy Saver	Help Needed (✓)	Who can help us Get the answer?	Estimated yearly Savings
			$
			$
			$
			$
			$
			$
			$
			$
			$
			$ Total

Notes:

HANDOUT #7 - page 3

Summary cont'd.

3. OUR HOME AND AUTOMOBILE(S)

Potential Energy Saver	Help Needed (✓)	Who can help us Get the answer?	Estimated yearly Savings
			$
			$
			$
			$
			$ Total

Notes:

4. TENANT HOUSE(S)

Potential Energy Saver	Help Needed (✓)	Who can help us Get the answer?	Estimated yearly Savings
			$
			$
			$
			$
			$ Total

Notes:

5. MISCELLANEOUS ITEMS

Potential Energy Saver	Help Needed (✓)	Who can help us Get the answer?	Estimated yearly Savings
			$
			$
			$
			$ Total

Notes:

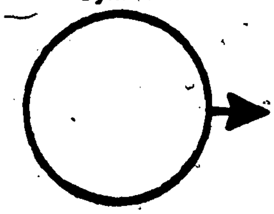
Source: Managing Energy on the Farm. Agway Inc., Attn: Mr. Norman Agor, Manager-Energy Management, Box 4933, Syracuse, NY 13221

HANDOUT #8 - page 1

Activity — Comparing the Flow of Energy in Two Agricultural Societies

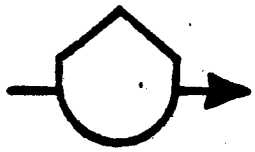
TRACING ENERGY FLOW

Symbol **Definition**



Energy Source

Represents source of energy from outside the agriculture system which will supply an unlimited amount of energy. An example would be sunlight.

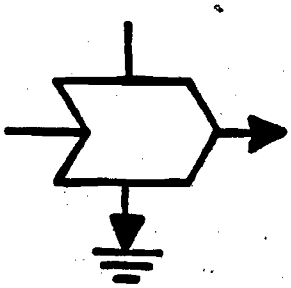


Energy Storage

Represents energy stored within the agricultural system (only in limited amounts) and when drawn upon can be exhausted. An example would be seeds.

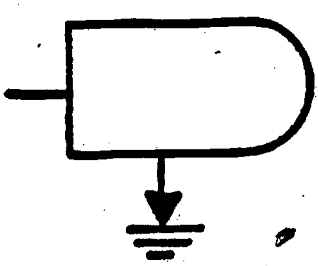
Heat Sink

Represents the heat loss from the agricultural system each time energy is changed from one to another (second law of thermo-dymanics). Examples would be the heat given off when sunlight is converted into food energy or when gasoline is converted into energy to drive a tractor.



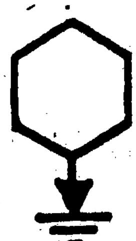
Work Gate

Represents the interaction of two or more energy flows (inputs) in an agricultural system. The net result is different from the in-puts. For example, sunlight inter-acts with nutrients and water in a corn plant which results in corn kernels.



Green Plant

Represents the photosynthesizing (food-making) of green plants.



Consumer

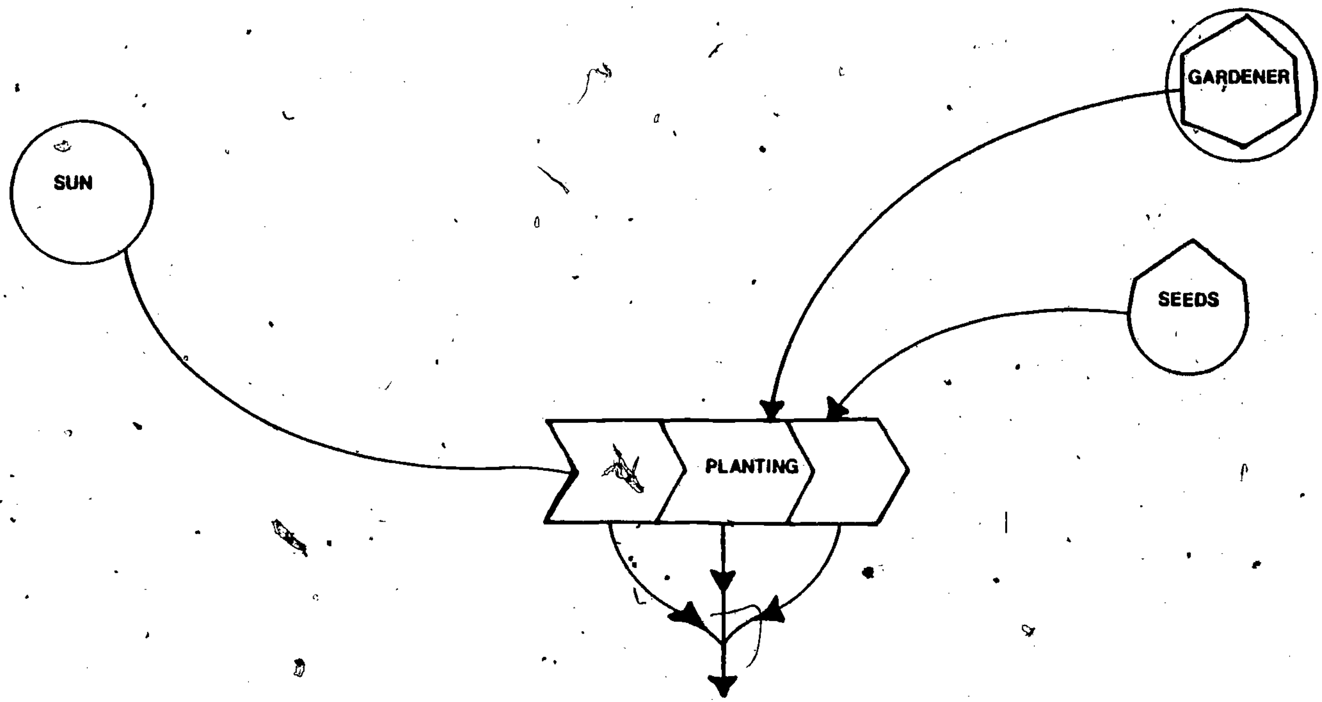
Represents anything with the ability to consume, grow, or reproduce from it. For example one animal, or a whole lot of animals. People are consumers.

Source: Agriculture, Energy, and Society: Grades 10, 11, 12. Washington, D.C.: U.S. Department of Energy, Reprinted September 1978.

HANDOUT #8 - page 2

Activity — Comparing the Flow of Energy in Two Agricultural Societies *(continued)*

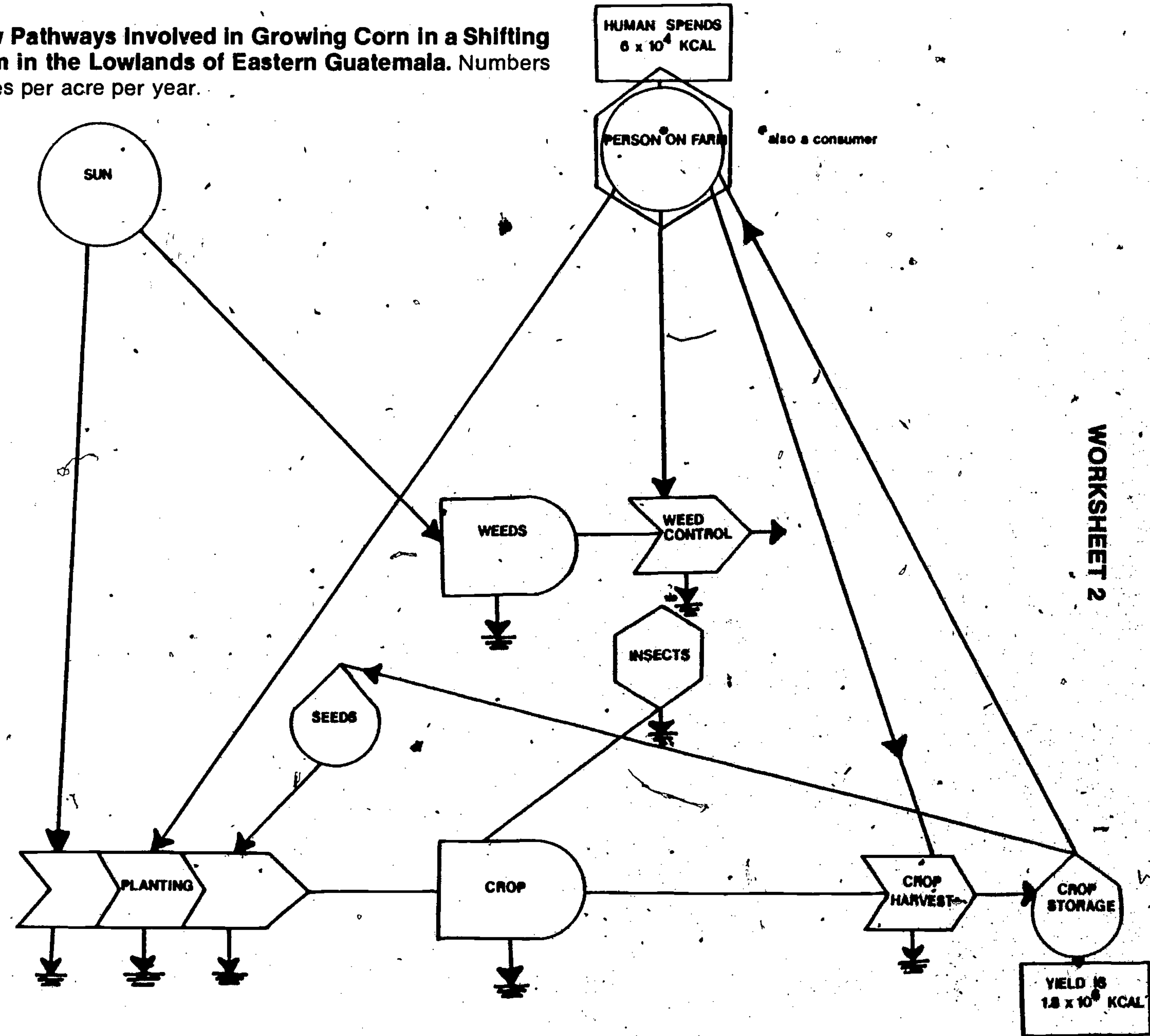
WORKSHEET 1: Garden Energy Flow Chart



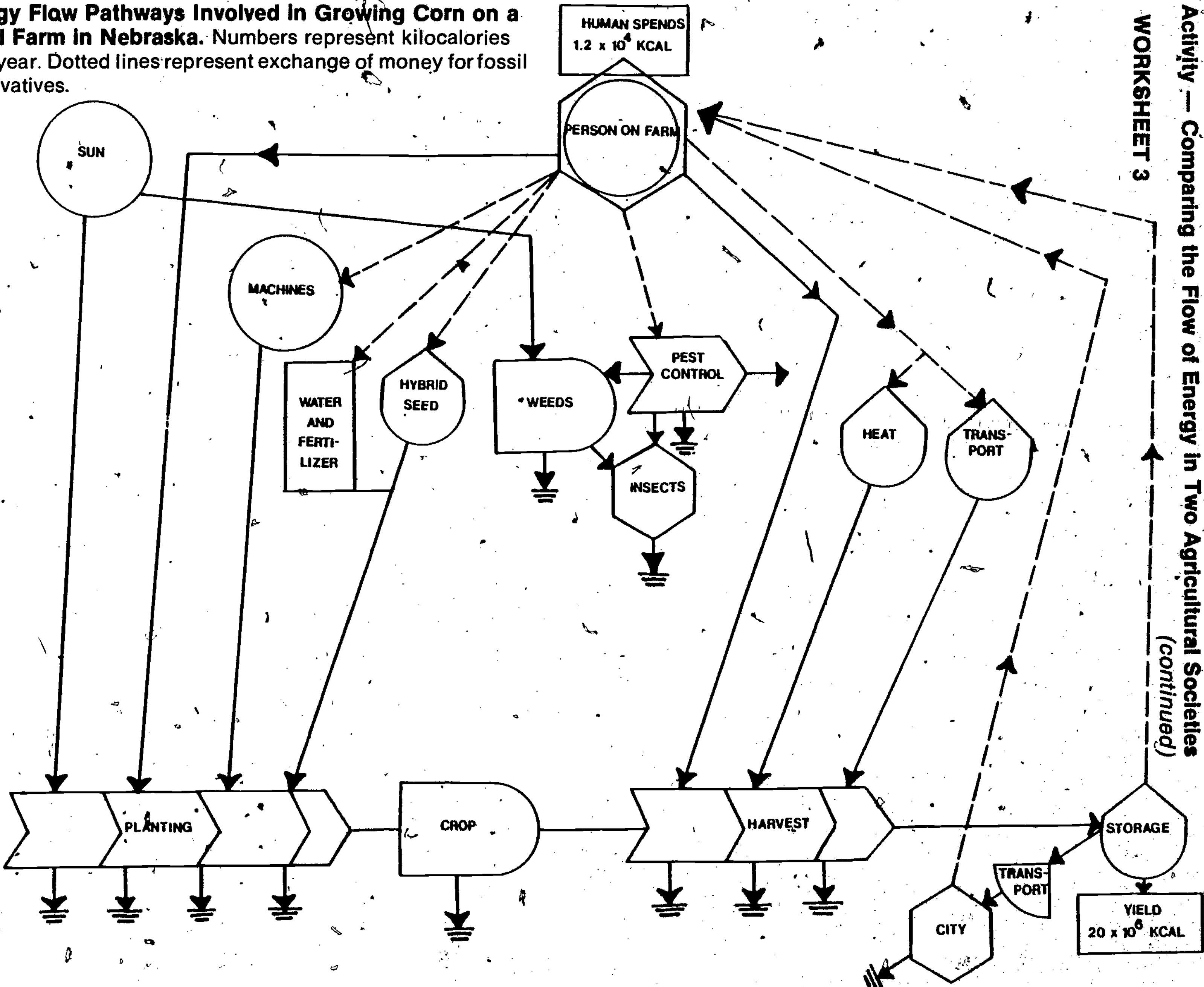
Use the correct symbols to complete the energy flow system growing peas in your garden. Include energy requirements in preparing the soil, planting and watering the peas, fighting pests, cultivating, harvesting and preparation for consumption.

WORKSHEET 2

Major Energy Flow Pathways Involved in Growing Corn in a Shifting Agriculture System in the Lowlands of Eastern Guatemala. Numbers represent kilocalories per acre per year.



Major Energy Flow Pathways Involved in Growing Corn on a Mechanized Farm in Nebraska. Numbers represent kilocalories per acre per year. Dotted lines represent exchange of money for fossil fuel and derivatives.



HANDOUT #8 - page 5

Activity - Comparing the Flow of Energy in Two Agricultural Societies *(continued)*

COMPARING TWO AGRICULTURAL SYSTEMS

Worksheets 2 and 3 both outline agricultural systems which grow corn. Follow the energy flow in both, then answer the questions.

1. What is the unlimited energy source in both systems?

2. Where does each system draw upon stored energy?

3. Where is energy (in the form of heat) lost in each system?

4. How do the following interact in a gardening agricultural system to produce a corn crop? Use Worksheet 1 or 2 to locate the interaction.

   Sun's energy
   Seeds
   Soil
   Work done by the farmer
   Weeds
   Collecting and storing corn

5. Which system gives the largest yield? By how much? How many times greater?

6. Compare the two systems in terms of the human energy needed per acre per year. Which is the greater? By how much? How many times greater?

7. Complete this statement. The yield of the mechanized farm is approximately ________ times greater than that of the gardening system, while the farmer on the mechanized farm did only about ________ times as much work to produce the crop.

8. In making your comparisons, why wouldn't it be quite fair to compare only the energy expended directly by each farmer?

9. Calculate the output in kilocalories for each one (1) kilocalorie of input. Do this for each system, mechanized and gardening. You will need to know that, in addition to human energy input in the mechanized system, there is also 7.14×10^6 kilocalories of fossil fuels.

$$\frac{\text{(output) yield}}{\text{(input) labor + fossil fuel}} = \text{ratio of output to input}$$

10. The above calculations show that mechanized farming is less efficient relative to energy input/output. Why are many of the areas that formerly used a gardening system introducing more mechanized farming?

REFERENCE #1 - page 1

Energy Conservation: An Economic Perspective

Fred J. Hitzhusen*

The Debate

Renewed appeals for energy conservation in the U.S. have been triggered by a series of events and realizations. Examples include the dramatic rise in OPEC oil prices, the continuing U.S. dependence on foreign oil imports, the unstable political situation in the oil rich Middle East, environmental and safety problems with coal and nuclear power, increased concern over the costs and lead times for synthetic fuels from coal and shale and the realization that alcohol fuels, at least in the short run, can substitute for only a relatively small part of our total gasoline use. Both the potential and definition of energy conservation are subject to widely divergent views. A recent study on energy futures at the Harvard Business School argues that if the United States were to make a serious commitment to energy conservation, it might well consume 30 to 40 percent less energy and still enjoy the same or an even higher standard of living. Contrast this with a statement by the head of the Texas Railroad Commission that "this country did not conserve its way to greatness, it produced itself to greatness."

Most people agree that energy conservation implies more efficient and/or reduced use of energy. Much less agreement exists on how conservation is to be actually realized, who gains and who loses as a result, and what if any distributional adjustment is necessary. Free market proponents argue that price alone should determine the extent and definition of conservation. Thus, energy conservation is a rational response to higher energy costs relative to other prices, and swift deregulation of energy markets is the way to realize energy conservation. Some of those calling for higher taxes on energy, particularly gasoline, may agree that deregulation is a necessary condition, but argue that it is not a sufficient condition for optimal energy use. The failure of the "free" market to reflect full social costs from such externalities as oil spills, air pollution and congestion from automobiles, balance of payment deficits, and the potential disruptive economic and national security costs of an oil embargo are frequently cited reasons for higher gasoline and other energy taxes. Others are concerned with the "windfall profits" or economic rents from higher energy prices accruing to a limited number of large producers. Regulation of energy prices for this reason makes conservation less attractive. On the other hand, lower income consumers bear relatively more of the burden of higher energy prices and many feel that they should be protected or compensated.

*Associate Professor, Resource Economics, Department of Agricultural Economics and Rural Sociology, The Ohio State University.

U.S. Energy Consumption

With only about 6 percent of the world's population, the United States uses one-third of the oil consumed in the world each day. Oil in turn makes up about one-half, natural gas one-quarter, coal one-fifth and all other sources about 5 percent of the total U.S. energy budget. About one-half of the oil is imported. The major consuming sectors and their percent of total U.S. energy consumption are as follows: residential/commercial 38 percent, industrial 36 percent, and transportation 26 percent.

A high rate of energy consumption in the U.S. has resulted in frequent comparisons with other advanced industrial countries. The comparisons can be misleading because of variations in climate, population concentration, end uses of various energy forms, pricing and taxing. For example, most retail gasoline prices in Europe exceed three dollars per gallon with taxes making up about 50 percent of the total. Small cars, electric trains, bike trails and mass transit are also more common in Europe. Nevertheless, the differences between the U.S. and Europe suggest that the link between energy use and economic growth may be much more elastic than is commonly assumed. For example, Table 1 shows that in comparison to the United States, West Germany consumed about three-quarters as much energy and France approximately one-half as much energy for each dollar of gross domestic product in 1976.

TABLE 1. Comparative Energy/Output Relationships, 1976

Country	Gross Domestic Product per Capita ($)	Energy Consumption per Capita (tons of oil equivalent)	Energy/GDP Ratio: Tons Oil Equivalent Per $ Mil GDP	Energy/GDP Ratio: Index (U.S. = 100)
United States	5960	8.3	1390	100
France	4740	3.5	750	54
West Germany	4350	4.5	1020	73
Sweden	5460	6.1	1190	82

The transportation sector uses about one-fourth of the energy consumed in the United States, and one-half of the oil. The private auto, in turn, uses over half of the transport sector's energy and has become a prime target for energy conservation. Daniel Yergin, a member of the Harvard Energy Project argues that car pooling and mass transit are possible transport conservation strategies, but are not as promising in the short or intermediate run as increasing the efficiency of vehicles, particularly the private auto. The increase in availability and sales of small cars is a response to higher gasoline prices, and a 1.6 percent decrease in total gasoline use during the past year is one of the results.

The industrial sector has generally responded more rapidly than other parts of the U.S. economy to clear economic signals on energy conservation

(continued)

Energy Conservation: An Economic Perspective *(continued)*

alternatives. As a result, the energy/GNP ratio in the industrial sector averaged an annual decline of 2.8 percent between 1973 and 1977. One of the most promising areas for industry is congeneration or the combined production of electricity and heat. The commercial and residential sector involves millions of decision makers particularly in private residences where both lack of information and limited income may slow adoption of cost-effective energy saving practices. The residential sector accounts for 20 percent of total U.S. energy use, two-thirds for space and water heating. In addition, potential "retrofit" savings from insulation, plugging air leaks, and storm windows and doors have been estimated at one-fourth of current residential energy use. Some progress has been made, but more information on alternatives and financial assistance for low income homeowners is needed.

Production agriculture in the U.S. accounts for about 2.8 percent of total energy use. Processing, marketing/distribution, input manufacture and food preparation brings total energy use in the U.S. food and fiber sector to about 16 percent of total U.S. use. Although the food and fiber sector uses only about 16 percent of total energy use, it is relatively more dependent on oil and natural gas (the liquid fuels which are of primary concern in the current energy crisis). These two liquid fuel energy sources provide about 75 percent of the total U.S. energy budget while accounting for 85 percent of energy use in the food and fiber system and over 90 percent of energy use in agricultural production. Research on efficient energy use in the food and fiber system has tended to focus on agricultural production and food preparation. More emphasis is needed on processing, marketing/distribution and input manufacture.

Toward Clarification of the Debate

The traditional fossil fuel energy sources are nonrenewable, exhaustible, or stock resources that do not increase in physical quantity over time. Some, such as coal, are not significantly affected by natural deterioration. Others such as oil and gas in cases of seepage and blow off can be significantly affected by natural deterioration. However, Wantrup argues that use of concepts such as exhaustible and inexhaustible have meaning only in an economic context. Long before a given resource is physically used up or even appreciably diminished, it may be exhausted in the sense that further utilization is discontinued in spite of continuing human wants. Alternatively, a resource may be inexhaustible in the sense that utilization continues indefinitely, even though it is relatively limited in physical quantity compared to other resources.

In a free or tax/incentive adjusted market where major externalities have been internalized, energy conservation is simply responding rationally to the relative increase in the price of energy as opposed to other goods and services. If energy prices are controlled either because of windfall profits or because of concern for lower income consumers, price incentives for conservation are reduced. As a result, more reliance must be placed on voluntary patriotic or involuntary schemes for rationing or curtailing energy use. Most economists argue that a more optimal use of energy occurs when intragenerational equity concerns from windfall profits and low income consumers are handled with some type of windfall profits tax and transfer payments, respectively. The resolution of intergenerational equity concerns is less clear, but most parents have some concern for the future energy needs of their children and grandchildren. Price controls clearly work against future generations.

An economic perspective on energy conservation may help to show that this important subject need not be exclusively the domain of the idealist, preservationist, politician, or bureaucrat. It also portrays conservation as an alternative energy source. As such, it can be compared to other sources in terms of cost-effectiveness, balance of payments, national security, environmental effects and equity impacts. Conservation looks attractive from the standpoint of balance of payments, national security and environmental effects. Less energy consumed means reduced oil imports, less air polution, etc. If it is compared to the marginal or replacement social costs of producing an additional unit of conventional or new synthetic sources of energy, it also looks increasingly attractive from the standpoint of cost-effectiveness. For example, some utilities are willing to subsidize energy conserving retrofitting of private residences because it is more cost effective than constructing new generating capacity. The impacts on low income consumers from higher market and/or tax induced energy prices can be off-set with various income transfer schemes.

A final caution is in order. The U.S. cannot conserve its way out of the energy crisis in the long run. However, energy prices reflecting full social costs of production and use would stretch out domestic supplies, buy time and provide incentive to develop new, particularly, renewable energy sources.

REFERENCE #2

PER CAPITA ENERGY CONSUMPTION AND RANK FOR SELECTED COUNTRIES 1950, 1969, and 1975

Group	Country	Energy consumption per capita					
		1950		1969		1975	
		Rank[a]	kce/capita[b]	Rank[a]	kce/capita[b]	Rank[a]	kce/capita[b]
Most populated countries	People's Republic of China	54	81	86	469	97	[illegible]93
	India	60	99	55	180	54	221
	Indonesia	40	54	36	110	47	178
	Pakistan	33	52	32	95	49	183
	Bangladesh					8	28
Western European countries	Italy	99	417	139	2515	137	2953
	France	130	1912	153	3654	149	3944
	Federal Republic of Germany	137	2490	163	5015	158	5345
	United Kingdom	145	4358	166	5120	156	5265
Eastern European countries	Bulgaria	101	469	152	3631	154	4781
	USSR	126	1593	159	4289	160	5546
	German Democratic Republic	139	2832	170	5717	168	6835
	Czechoslovakia	140	2979	172	6160	169	7151
Oil-producing countries	Kuwait	121	1332	175	9436	170	8178
	Bahrain	98	387	136	2421	175	12079
	Venezuela	117	901	132	2199	134	2639
	Saudi Arabia	74	164	111	791	124	1398
	Iran	50	75	103	666	123	1353
	Libyan Arab Republic	46	69	98	581	122	1299
Others	USA	147	7316	176	10745	174	10999
	Japan	110	554	144	2946	144	3622
	Chile	114	609	123	1153	102	765
	Nigeria	24	26	16	39	31	90
	Egypt	83	251	64	229	74	405
	Ethiopia	2	2	12	30	[illegible]	28

[a]High rankings correspond to high per capita energy consumption.

[b]The values are given in kilograms of coal equivalent (kce) per capita.

Source: M.C. Jacmart, M. Arditi and I. Arditi, "The World Distribution of Commercial Energy Consumption," Energy 7: 199-207, Table 8.4 - 1 (1979)

REFERENCE #3 - page 1

The Emerging Food/Fuel Trade-off

Fred J. Hitzhusen

Food production in the developed and developing countries of the world has shown similar upward trends over the past two decades. However, high population growth rates in the developing countries and increasing evidence of environmental constraints such as water supply and soil erosion and salinity have resulted in only slight increases in per capita food production. This is true in spite of the production increases from the much touted energy and water intensive Green Revolution technology. Data for world food production in 1979 show an absolute decline of over 2 percent. Per capita food output declined by 3 percent in developed countries and by 1 percent in developing countries in 1979.

The concern over high population growth rates and the ability of food production to keep pace is accentuated by increasing awareness of the world's dependence on a finite supply of fossil fuels, particularly those in liquid form. Declining availability and rapidly increasing prices of oil and natural gas have resulted in calls for conservation of these nonrenewable resources, substitution of the more abundant fossil fuels such as coal, and development of alternative renewable sources of liquid energy such as biomass. The latter alternative of biomass or grown organic matter for energy (particularly the use of grains to make liquid fuel) brings the discussion full circle to the initial concern with world food production i.e., to a food-fuel trade-off.

Modern agriculture is very energy intensive due to mechanization and the petroleum base of many agricultural chemicals currently used to increase crop yields and net returns. High demand for meat in diets in the developed countries results in increased demand for crops to feed livestock. The resulting direct or indirect human consumption of grain in the developed

The Emerging Food/Fuel Trade-off *(continued)*

countries is about four times higher per capita than in the developing countries. Developed countries are also consuming nonrenewable liquid fuels at a much higher rate. For example, the United States with less than six percent of the world's population, uses over one-third of the oil consumed in the world each day.

The emerging ethical issue is whether the developing countries will be able to buy food (or energy) for basic needs at world prices reflecting the demands for both liquid fuel and food from the world's cropland. Lester Brown of World Watch Institute has quantified the food-fuel trade-off in terms of annual pounds of grain and acres of cropland to meet competing food or fuel needs as follows: 1) subsistence diet = 400 lbs. of grain and .2 acres, 2) affluent diet = 1600 lbs. of grain and .9 acres, 3) fuel for typical European auto (7000 mi/yr at 25 mpg) = 6200 lbs. of grain and 3.3 acres, 4) fuel for typical U.S. auto (10,000 mi/yr at 15 mpg) = 14,000 lbs. grain and 7.8 acres, and 5) gasohol for U.S. auto (10% ethanol and 90% gasoline) = 1460 pounds of grain and .8 acres. Use of distillers grain for livestock feed would result in some net reduction in the grain and acreage requirements of an affluent diet and auto fuel combination.

An unfettered free enterprise response to the food-fuel issue is to let the market decide. If the developed countries have the purchasing power to out-bid the developing countries for both food and fuel from the world's cropland, so be it. An egalitarian response might be to intervene in the market and/or "ownership" of world resources for food and energy production and divide up equally the resulting output. If "private" property rights are violated and individual incentives to produce are reduced, so be it. Some compromise between these positions is possible and likely and those concerned with the intermediate and long run earthly prospects for humankind need to get on with working out this compromise.