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ABSTRACT

This booklet gives a brief overview of energy use patterns in vegetable production and gives examples of cutting the cost of energy in fertilization, weed management, insect pest management, irrigation, harvesting, use of equipment, and greenhouses. Finally, energy use recordkeeping is discussed. (BB)

A GUIDE TO ENERGY SAVINGS FOR THE VEGETABLE PRODUCER

UNITED STATES
DEPARTMENT OF
AGRICULTURE

FEDERAL
ENERGY
ADMINISTRATION

ONE PART OF A SERIES OF PUBLICATIONS ON ENERGY AND U.S. AGRICULTURE

This guidebook was prepared by N. A. Wynn, Fruits, Vegetables, Sweeteners, and Tobacco Program area, Commodity Economics Division, Economic Research Service, U.S. Department of Agriculture. It was prepared under the supervision of George B. Rogers, Energy Coordinator, Commodity Economics Division, and Earle E. Gavett, Energy Coordinator, National Economic Analysis Division, Economic Research Service; and Robert C. Marlay, Technical Project Officer, Federal Energy Administration.

Other publications in this series are A Guide to Energy Savings for the Poultry Producer, A Guide to Energy Savings for the Livestock Producer, A Guide to Energy Savings for the Orchard Grower, A Guide to Energy Savings for the Field Crops Producer, and A Guide to Energy Savings for the Dairy Farmer.

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*Listing does not imply official action to endorse the report or complete agreement with its contents.

JULY 1977

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The Nation's 2½ million farms consume 6.3 billion gallons of gasoline and diesel fuel, some 173 billion cubic feet of natural gas, 1.5 billion gallons of LP (liquified petroleum) gas, and 32.3 billion kilowatt-hours of electricity in a typical year.

While amounting to only 3 percent of all the energy used in the country, the energy required to keep our farms in operation is a vital and increasingly expensive resource. The cost of energy has nearly doubled in the last 10 years. The largest part of the increase has taken place in the last 3 years alone.

Farmers are coping with higher costs for energy in the same way they deal with other problems that arise. They are adjusting operations to get the last drop of value out of a gallon of fuel, to wring more work out of a kilowatt-hour of electricity.

Beyond the need to save money, farmers may well ask why they should be expected to be more conscientious about conserving energy; cost-consciousness is built into any successful farm operation. But farmers, like the rest of the Nation, are being forced by global energy problems to reassess their use of fossil fuels. The entire Nation is being made increasingly aware of the severe limits of what was once thought of as a limitless resource. For all to prosper, all must conserve, no matter how great the individual priority of use.

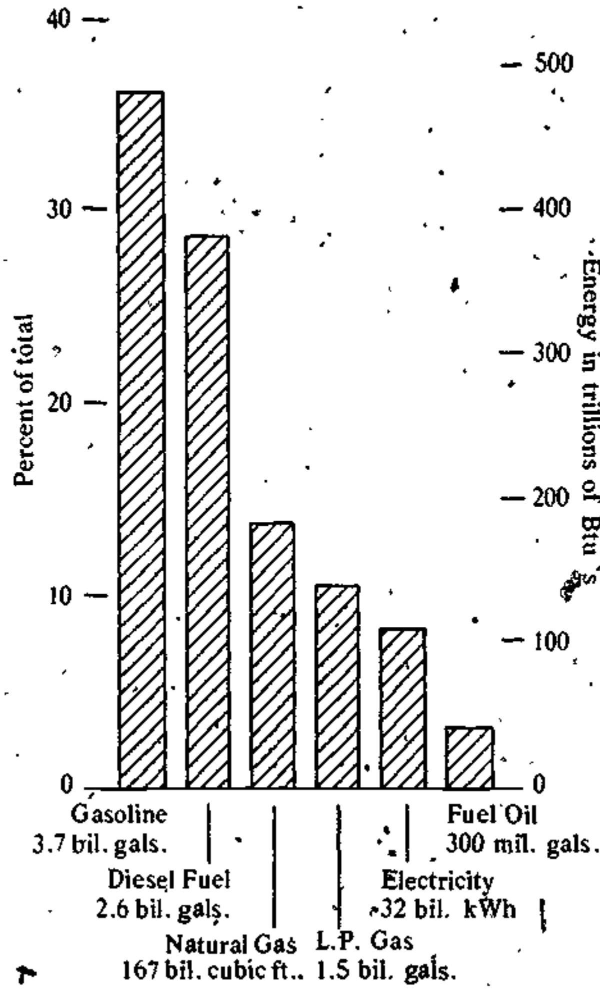

Figure 1. ENERGY USED IN AGRICULTURE (1974)

This guidebook contains a wide spectrum of ideas for operators of many sizes and types of farms, operators whose conception of energy conservation may vary. The ideas range from greater attention to daily details to substantial added investments in facilities and equipment. Not all the ideas will yield large dollar savings. Today energy conservation may seem secondary to other considerations because energy costs remain a small fraction of total costs. Tomorrow, as available quantities of energy become restricted, producers will have to adopt energy conservation measures irrespective of cost.

This effort is to help farmers to use energy resources even more prudently in the future.

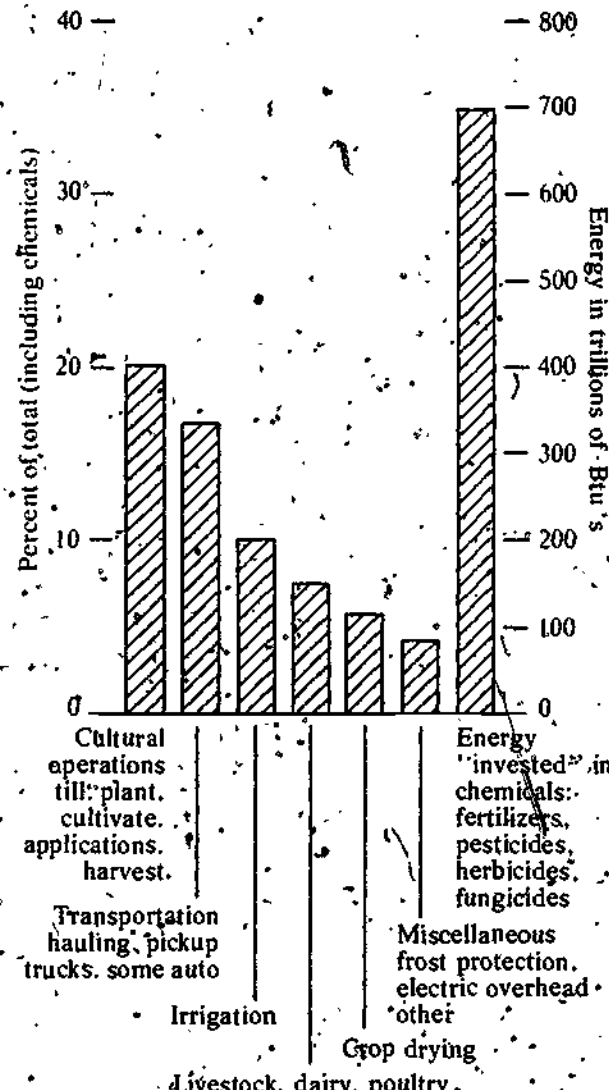

Figure 2. ENERGY USED IN AGRICULTURE, PLUS FERTILIZER AND CHEMICALS (1974)

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Table 1--Energy used in U.S. agriculture, by commodity, 1974 1/

Commodity	Acres 2/	Gasoline (gal)	Diesel (gal)	Fuel oil (gal)	LP Gas (gal)	Nat. Gas (ft³)	Electricity (kWh)	Coal	Invested energy (Btu) 3/	Total energy (Btu)	Energy per acre (Btu)
	Thousands					Millions		Tons	Billions		Thousands
Vegetables--fresh	1,552	50,816	35,525	--	3,734	518	351		9,548	23,109	14,893
Potatoes	1,381	33,373	36,511	--	1,077	211	572		17,021	28,578	20,694
Sweet potatoes	124	3,367	1,238	--	537	--	1		720	1,369	11,074
Vegetables--processing	1,773	50,283	45,721	--	8,561	45	181		12,228	26,394	14,884
Edible beans--dried	1,636	17,139	35,607	--	2,656	127	22		3,379	10,966	6,703
Edible peas--dried	220	773	1,085	--	85	--	1		35	295	1,345
Total crops	340,596	2,881,276	2,286,539	295,112	1,148,657	159,500	22,060		716,452	1,789,930	5,255
Total livestock	--	817,365	352,416	8,817	332,885	4,625	10,028	32,725	--	224,291	--
Total agriculture	--	3,698,641	2,638,955	303,929	1,481,542	164,125	32,088	32,725	716,452	2,014,221	--

1/ Data include all energy used directly on the farm for crop and livestock production purposes--field operations, irrigation, crop drying, mechanized feeding, space heating, farm business auto use, etc. Numbers may not add up to totals due to rounding.

2/ Harvested acreage except for planted acreage in the following: rice, rye, winter wheat, spring wheat, oats, barley, cotton, soybeans, peanuts, flaxseed, dry edible peas, sugar beets, and sweet potatoes.

3/ Invested energy includes the energy required to manufacture fertilizers and pesticides (including carrier solution).

Energy use in producing vegetable crops has expanded rapidly in recent years because cost relationships between energy and labor have provided strong incentives for mechanization. Present high fuel and electricity costs, however, are causing vegetable producers to reevaluate mechanization decisions. And they are looking at existing mechanized operations with an eye to making further energy savings.

Major energy-using vegetable cultural practices and the forms of energy used are discussed in this guidebook.

CULTURAL PRACTICES

Fertilization.--The manufacturing and application of fertilizer to vegetable crops consumed almost one-half of the total energy used to produce vegetable crops in 1974.

Potatoes and sweet potatoes were the largest per-acre users consuming over half the energy used in fertilizing. In general, processing vegetables took a larger proportion of the energy used in fertilizing than did fresh vegetables. The major exception in processing crops was peas, a legume with little need for fertilizer due to its nitrogen fixation capability.

Field operations.--This includes herbicides and pesticide applications as well as tillage and planting. It was the second largest item of energy usage in producing vegetables, taking almost 20 percent of the total energy.

There was little difference in the total amount of field operations energy used to produce fresh vegetables (19.6 percent) and processing vegetables (22 percent). Individually, however, there were striking differences ranging from a high of 34.2 percent for dry peas and beans to a low of 11.6 percent for potatoes.

Irrigation.--For all vegetable crops, less than one-tenth of the energy used in production was for irrigation. However, this amount varied considerably by crops. About 11 percent of energy usage on fresh vegetables was for irrigation, but slightly more than 4 percent on the processing crop. Both peas and sweet corn are exceptions to low energy usage for irrigation for processing vegetables, with corn using 13.5 percent and peas about 20 percent of total energy for irrigation.

Harvesting.--With the exception of some fresh crops, almost all major vegetable crops are mechanically harvested. Substitution of fuel-consuming machines for handpicking began with potatoes, followed rapidly by sweet corn, peas, and beans. One of the last hand-harvest holdouts in processing vegetables was tomatoes. The nearly complete adoption of a mechanical tomato harvest in California within 5 years of introduction is solid evidence of the attractiveness of substituting machines for hand labor. Presently, melons, lettuce, and fresh tomatoes have defied harvest mechanization, but experimental pickers for these crops are being tested.

Pesticides.--Only about 4 percent of the energy used on vegetable crops is for pesticides. Vegetables for fresh market are usually harvested several times during the season requiring a greater use of pesticide than for processing vegetables, which are machine harvested in a single operation.

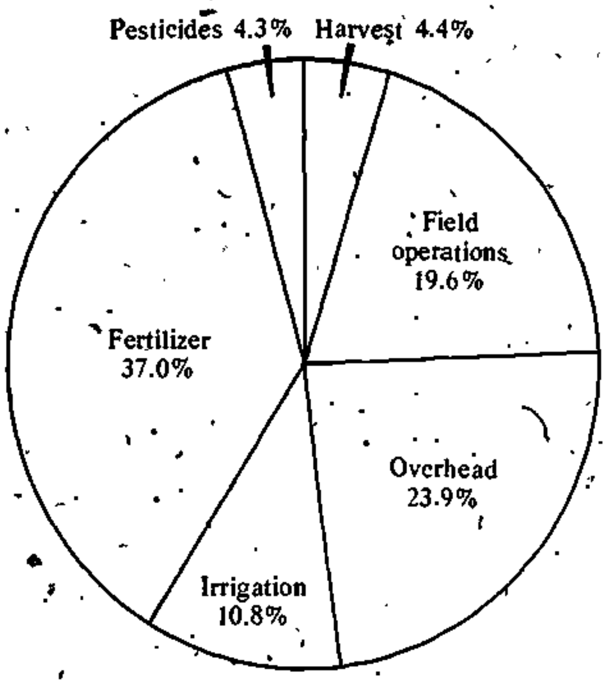

Figure 3. ENERGY USE BY FUNCTION
FRESH VEGETABLES, USA, 1974

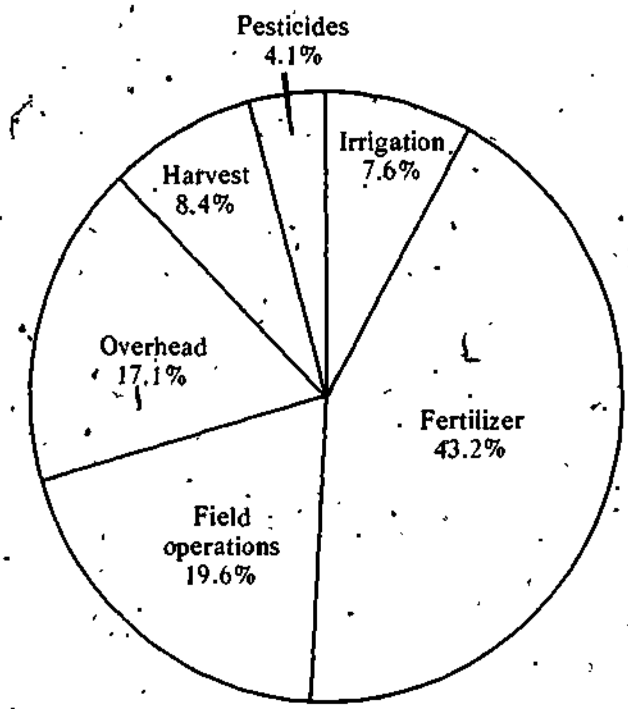

Figure 5. ENERGY USE BY FUNCTION,
VEGETABLE CROPS, USA, 1974

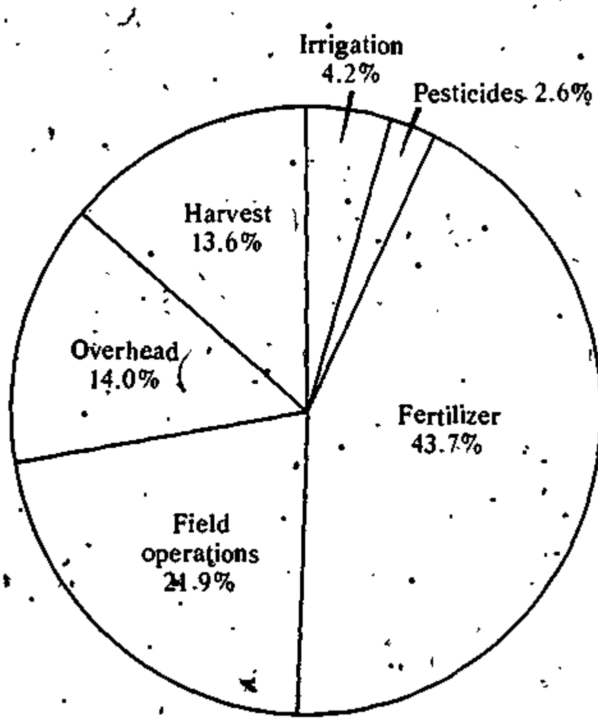

Figure 4. ENERGY USE BY FUNCTION
PROCESSING VEGETABLES, USA, 1974

The total vegetable harvest uses about 8 percent of all energy expended in vegetable production. About 14 percent of energy is used for harvesting processing vegetables while fresh vegetables, with more hand harvesting, take about 4 percent. Among the low energy users at harvest time are fresh snap beans with only about 2 percent, cabbage with less than 8 percent, and potatoes with about 4 percent. Peas that are machine harvested for processing use 22 percent of production energy (see table 2).

Table 2--Percentage of energy used on vegetable crops by function, 1974 1/

Crop	Fertilizer	Pesticides	Field operations	Irrigation	Harvest	Overhead	Total
	------------	------------	------------	Percent	------------	------------	------------
Fresh vegetables	37.0	4.3	19.6	10.8	4.4	23.9	100.0
Snap beans	33.0	3.1	19.0	21.8	2.3	20.9	100.0
Cucumbers	31.6	2.3	13.1	19.1	11.2	22.7	100.0
Cabbage	33.1	3.1	18.6	14.1	7.4	23.7	100.0
Processing vegetables	43.7	2.6	21.[illegible]	4.2	13.6	14.0	100.0
Sweet corn	35.7	4.4	15.9	13.5	15.2	15.3	100.0
Peas	7.8	2.3	25.5	20.3	21.5	22.5	100.0
Other							
Potatoes	54.0	5.6	11.6	9.9	3.9	15.0	100.0
Sweet potatoes	50.4	2.2	22.1	--	8.2	17.1	100.0
Dry peas and beans	26.4	3.9	34.2	4.4	15.6	15.8	100.0
Total vegetables	43.2	4.1	19.6	7.6	8.4	17.1	100.0

1/ Selection of vegetables cited here for purpose of illustration only.

FORMS OF ENERGY USE

As farmers increase machinery size for tillage practices, more of the power units purchased are diesel. Currently diesel fuel accounts for about 46 percent of all direct energy use. Gasoline accounts for over 40 percent of direct energy use in vegetable crop production. About three-fourths of that gasoline goes into automobiles and trucks used on the farm, harvesting and marketing activities, and other farm business. Vegetable harvesters use over a fifth of the gasoline, leaving only about 5 percent for tillage practices.

Electricity accounts for another 8 percent of all direct energy used on vegetable farms, of which almost 98 percent goes into pumping irrigation water and irrigating vegetable crops.

Natural and LP gas account for about 5.5 percent of direct energy used on vegetable crops. All the use of natural gas is for power units pumping irrigation water.

When total energy use on farms is analyzed, the energy used to produce and deliver fertilizer to farms accounts for 43 percent of all energy used (table 4). Proper care and use of fertilizers and fertilizer materials may be a key to total energy savings in agricultural production.

Table 3--Direct energy use on vegetable crops by type of fuel, 1974

Type of fuel	Unit	Amount	Btu	Percent of Btu
		Thousands	Billions	Percent
Gasoline	Gal	146,135	18,267	39.8
Diesel	Gal	152,399	21,336	46.5
LP gas	Gal	61,201	1,539	3.4
Natural gas	Ft^3	958,158	958	2.1
Electricity	kWh	1,107,858	3,781	8.2
Total			45,881	100.0

Table 4--Total energy on vegetable crops by type of fuel including fertilizer, 1974

Type of fuel	Btu	Percent of Btu
	Billions	Percent
Gasoline	18,267	21.8
Diesel	21,336	25.4
LP gas	1,539	1.8
Natural gas	958	1.1
Electricity	3,781	4.6
Fertilizer 1/	38,049	45.3
Total	83,930	100.0

1/ Mostly natural gas and electricity used in manufacturing fertilizers containing nitrogen.

FERTILIZATION

You can save energy in two ways in fertilizing vegetables: reduce the amount of fuel used to apply fertilizer, and increase efficiency in fertilizer use either by getting greater yields from the same amount of fertilizer or maintaining present yields with less fertilizer. Fertilizing can account for nearly half of the energy used in vegetable production. The following suggestions may help you reduce energy consumption:

1. Have your soil tested and follow recommendations closely. Failure to do so may result in misallocated fertilizer.

2. If you use plastic mulch culture, it may be possible to produce a second crop on the mulched field with less additional fertilizer than the second crop would require if grown independent of the first, since less of the unused fertilizer is leached away.

3. Calibrate machinery carefully. An applicator applying too much material not only wastes the material but also may do more harm than good. Application of too little will at best reduce the effectiveness and at worst yield no results.

4. If you have a sprinkler irrigation system, you may apply supplemental nitrogen through the irrigation water, thereby using less energy. It may also be possible with drip or furrow irrigation systems. Check the idea with your county extension agent.

5. If possible, combine fertilizing with some other operation, but be sure of compatibility before applying any materials simultaneously.

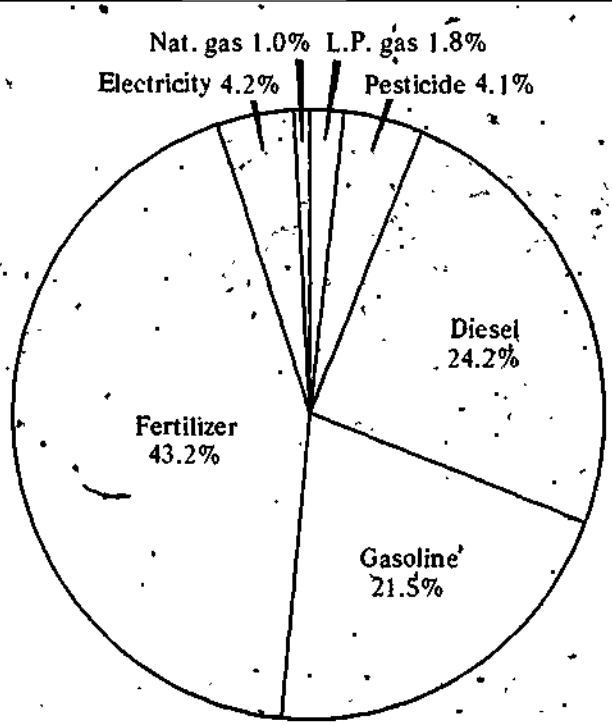

Figure 6. TOTAL ENERGY USE. VEGETABLE CROPS, 1974

6. Under most conditions phosphorus, and potassium, may be applied together. Split applications of fertilizers waste fuel but may be necessary to assure an effective fertilizing program.

7. Fertilizer applied at planting should be placed near the root zone area without damaging the plant from either the mechanical operation or fertilizer burn. Band application rather than broadcasting may result in better yields from a given amount of fertilizer.

8. Establish and maintain contact with your State and local Extension Service and Experiment Station. Their knowledge is specific to production in your local area. They can assist you in developing a fertilizing program geared to your particular needs.

EXAMPLE OF ENERGY SAVINGS FROM SOIL TESTS

$8.40 per acre savings from soil tests

Soil tests may yield indirect savings in energy by indicating the need for less fertilizer than might otherwise be used. One of several important pieces of information obtained from a soil test is the level of residual fertilizer nutrients already in place. Example: A grower produces 200 acres of sweet corn. Based on peat or muck soil, the recommended fertilizing rate is 0-120-180 pounds of nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O), respectively.

The average adjustment recommended on this type of soil is a one-third reduction in the recommended amount of phosphorus if the level of residual phosphorus is medium, and a one-third reduction in potassium if residual potassium is medium. High residual levels call for a two-thirds reduction.

Soil tests may also indicate a need for lime, micronutrients, or other adjustments in the fertilizer program which can in turn require adjustments in N-P-K recommendations. These adjustments are not necessarily always downward.

Table 5 shows the possible annual savings in fertilizer and dollars resulting from soil tests.

Table 5--Estimated savings from soil tests

	Fertilizer					
	Phosphorus			Potassium		
	Residual level					
	Avg.	Med.	High	Avg.	Med.	High
Fertilizer savings lbs.	0	40	80	0	60	120
Dollar savings/acre 1/	0	8.40	16.80	0	5.70	11.40
Dollar savings with 200 acres	0	1,680	3,360	0	1,140	2,280

1/ Phosphorus 21¢/lb, potassium 9.5¢/lb

EXAMPLE OF ENERGY SAVINGS FROM DOUBLE-CROPPING MULCHED FIELDS

$40.12 savings per acre in fertilizer costs using mulch culture

Double-cropping under full-bed black plastic mulch culture yields direct energy savings by allowing the production of a second crop without the usual fuel-consuming pre-plant operations. It also yields an indirect energy savings through the production of a second crop with less additional fertilizer than the second crop would have required had it been grown under conventional culture, since less of the unused fertilizer is leached away.

Example: Using full-bed mulch culture, a grower produces tomatoes followed by cucumbers. If the cucumbers are produced under conventional culture, a total of 2,975 pounds of fertilizer per acre is recommended for the production of both crops on this particular soil. The estimated cost for fertilizer is $225.72 per acre.

If cucumbers are produced on the same mulched field, a total of 2,180 pounds of fertilizer per acre is recommended. The estimated cost for fertilizer is $185.60 per acre. Production of cucumbers on the same mulched field yields an estimated savings of 795 pounds of fertilizer and $40.12 per acre. The illustration below shows the estimated cost and usage of the particular fertilizers under each method.

Tomatoes under full-bed mulch culture and cucumbers under conventional culture

Fertilizer	lbs/acre	cost/ton	cost/acre
6-12-12	1,330	$105	$69.82
Super-phosphate	750	100	37.50
Nitrate of potash	520	340	88.40
Ammonium nitrate	375	160	30.00
Total	2,975	--	$225.72

Tomatoes under full-bed mulch culture followed by cucumbers on the same mulched field

Fertilizer	lbs/acre	cost/ton	cost/acre
6-12-12	400	$105	$21.00
Super-phosphate	940	100	47.00
Nitrate of potash	560	340	95.20
Ammonium nitrate	280	160	22.40
Total	2,180	--	$185.60

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EXAMPLE OF ENERGY SAVINGS FROM PROPER CALIBRATION OF FERTILIZER DISTRIBUTOR

$6.38 per acre savings from proper calibration of equipment.

A properly calibrated distributor saves energy indirectly by reducing fertilizer waste. Each time you use a distributor check to make sure the proper application rate is set. The rate is influenced both by the granular characteristic of the fertilizer and by the humidity.

Example: A grower plans to distribute 1,000 pounds of fertilizer per acre with a drill. The rows are 30 inches apart. At a given setting the fertilizer drill is applying 6¼ pounds per 100 feet of row. A standard chart indicates that 5-3/4 pounds per 100 feet of row is equivalent to 1,000 pounds of fertilizer per acre.

Without recalibrating, approximately 85 pounds of fertilizer material per acre would be wasted. Table 6 shows the dollar savings obtained by recalibrating to 5-3/4 pounds per 100 feet of row given selected fertilizer costs.

Table 6--Estimated savings from recalibration

Cost per ton of fertilizer	Savings per acre from recalibration
--------Dollars--------	
100	4.25
125	5.31
150	6.38
175	7.44
200	8.50

USUAL CULTURAL PRACTICES

Preparation of a seedbed for vegetable crops is an involved process. Debris from previous crops, or anything that would interfere with planting and other operations, must either be removed or blended into the soil. Generally, the soil is disked, plowed, harrowed, rolled, or dragged. A seedbed is usually shaped through the use of special equipment, and seeds or transplants are planted on the tops of the shaped seedbeds. During the growing season plants are continually cultivated to control weeds and thus conserve soil moisture and nutrients.

HOW TO REDUCE ENERGY COSTS

Keep Equipment in Top Condition

Always have cultivating equipment in proper running order. Make certain that sweeps, shoes, shovels, and other cultivating equipment are in proper shape. Don't let the equipment develop dull leading edges. When possible, hardface cultivating equipment so that cutting edges remain sharp as they wear, thus reducing unnecessary friction.

Cultivate Shallow

Don't cultivate any deeper than necessary. The deeper you cultivate, the greater the fuel requirements, and the more damage you do to the plant's root structure. Cultivate while weeds are in the seeding stage. Timeliness is important in doing the most good with each cultivation and holding repetition to a minimum.

Use Pre-emergence Selective Sprays

Take advantage of pre-emergence selective sprays where feasible. These materials can eliminate mechanical cultivation, thus avoiding soil compactions and root damage. Consult your Agricultural Extension Service and chemical field representatives for appropriate sprays.

Narrow Row Spacings

Consider closer row spacing and greater plant density per acre. Various agricultural experiment stations are finding that closer row spacings reresult in higher yields per acre and reduced weed problems as plants cover the ground surface sooner, thus shading potential weed undergrowth. Oregon State University has fonnd that narrow rows of beans close up faster, shading the ground sooner. Using good initial weed control via a pre-emergence spray may thus eliminate cultivation altogether.

Direct Seeding

Where feasible, particularly in heavy clay soils, consider direct planting of seed instead of transplanting. Ohio tomato growers are finding that with shallow fall tillage a minimum of soil preparation in the spring permits direct seeding instead of transplanting. This tends to keep machinery off the beds. Lighter tillage also reduces horsepower requirements and speeds the soil preparation and planting in the spring.

No Spring Preplant Tillage

Experiments at Washington State University demonstrate that potatoes and possibly sugar beets can be directly seeded into the ground without previous soil preparation. This technique reduces preplant soil preparation, increases available soil moisture, reduces soil compaction, and thus reduces costs and fuel needs. Furthermore, in some instances, it has resulted in increased yield. Where soils are sandy and there are frequent spring and early summer winds, no tillage preplanting may be particularly helpful.

Herbigation

Where overhead sprinklers are used, growers frequently add fertilizer (nitrogen) through the irrigation system. Herbicides and insecticides can also be applied that way, keeping cultivation to a minimum. However, at this time only one herbicide has broad registration for application through irrigation systems. Consult your chemical dealer and Extension Service for advice on herbicides and herbigation.

Crop Rotation

If feasible, try to rotate crops. Successive cropping encourages a buildup of weeds, diseases, and insects. Depending on the crops and regions, some weeds and insects can be controlled by crop rotation. Alternate shallow rooted plants with deep rooted plants. Switch between crops supplying large quantities of organic matter and those crops that help break it down. Use soil-improving crops when land is not occupied with a money crop.

EXAMPLE OF ENERGY AND FUEL SAVINGS BY DIRECT PLANTING OF POTATOES

Washington State University has experimented with direct planting of potatoes without plowing and disking a seedbed. This avoids the normally expensive preplant operations. Where wind erosion is a problem, this is a soil-conserving practice. Yields have increased in some instances.

$525 annual savings on 100 acre potato farm using direct planting.

Plowing	2.5 gal/acre
Disking and seedbed	2.5 gal/acre
Total fuel saved	5.0 gal/acre

100 acres x 5 gal/acre = 500 gal
Cost of fuel saved $225

Fuel savings at 45¢/gal, 500 gal = $225
Labor savings 1 man hour/acre x 100 acres x $3/hr = $300
Net savings $525

Energy Savings at Various Fuel Prices

Cents/gal	35¢	45¢	55¢
Savings/year	$175	$225	$275

INSECT PEST MANAGEMENT

USUAL CULTURAL PRACTICES

Vegetables are high risk, high value crops involving considerable production and marketing expense. Vegetables are susceptible to many varied pests and diseases that can drastically reduce yields, lower quality, and increase costs of production. Pest problems are generally chemically controlled with some vegetable crops requiring almost continuous spraying. Insecticides may be contact sprays that kill target and nontarget insects on direct contact, selective contact sprays that kill target insects but largely leave certain beneficial insects alone, and systemics that are absorbed by the plants and kill chewing or sucking insects when they take a bite.

Chemicals are applied from the air, from ground rigs, or through irrigation systems. In some instances, insecticides can be applied along with fertilizer. Chemicals generally take the form of dusts, wettable powders, emulsifiable concentrates, or dry granules. Consult your county extension agents and chemical salesmen for proper recommendations.

Most vegetable crop failures resulting from poor pest management trace back to improper selection of insecticides, poor timing of application, unfavorable weather conditions, insufficient rate of application, equipment failure, or operator negligence.

HOW TO CUT ENERGY COSTS

An Integrated Pest Control Approach

The best pest control techniques is to develop an integrated program which can lead to fewer chemical applications and greater crop yields.

This program should begin with crop selection based on those vegetables that are best suited to the general geographic area. Next, seeds or plants should be selected that are disease free and of the best quality.

Planting dates as indicated by extension agents, seed fieldmen, and previous personal experience should be followed closely. While deciding on the crop to plant, the grower should also be learning from extension agents and chemical salesmen about pests, pest hosts, beneficial predators, various selective chemicals, and critical application periods. The critical period for insecticides is the minimum number of days before harvest when a particular chemical can be used; for pests it is the time that they are most susceptible to the insecticides; for plants it is the time that they are most susceptible to various pests. Other cultural practices conducive to good vigorous growth should be followed. Healthy, growing plants can generally tolerate and resist more pests and diseases than unhealthy plants.

Fields and crops should be monitored carefully and frequently for pests. Insecticides should be selected with beneficial predators in mind. Crop residues can act as harborers of insects and reservoirs of diseases and should be plowed under as soon after harvest as possible.

Crops should be rotated to avoid certain pest and disease problems that can occur as a result of successive cropping.

Following an integrated pest control program should enable vegetable growers to reduce the number of times a given crop requires treatment for insects and pests. In this way, fuel should be saved, energy costs reduced, and long-term profits improved.

Equipment and Operators

When applying insecticides, make certain that the equipment is properly calibrated, spray nozzles are of proper size and are clean, and that pump and motor are working efficiently. Operators should be properly trained and should understand the dangers inherent in chemicals.

EXAMPLE OF ENERGY AND FUEL SAVINGS WITH AN INTEGRATED PEST CONTROL PROGRAM

$39 annual fuel savings on 10-acre vegetable farm using 20 gal of diesel

An integrated pest control program begins with knowledgeable growers working with chemical field representatives and extension agents. A key to the integrated pest control program is an awareness of beneficial predator insects. Indiscriminate spray programs are to be avoided. The most selective sprays available should be used. Focus is on crop-damaging insects and not all insects. Good farming practices should always be followed. Crop residues that harbor diseases and insects should be incorporated into the soil immediately after harvest. With an integrated pest control program, growers can usually reduce the number of required spray applications over the long run. Assume the number of applications required is reduced by one.

Calculations:

10 acres x 2 gal/acre = 20 gal
Value of fuel saved at 45¢/gal, 20 gal = $9

Diesel Savings at Various Fuel Prices

Cents/gal	35¢	45¢	55¢
Savings/year	$7	$9	$11

Fuel savings $9
Labor savings x 1 hour/acre @ $3/hour = $30
Net savings $39

Irrigation can account for 60 percent or more of the energy used in vegetable production. Using water and irrigation equipment more efficiently can conserve energy and reduce pumping costs. The following suggestions are offered to help you reduce fuel and electricity consumption in irrigating vegetable crops:

1. Using drip irrigation can double the efficiency of water use by reducing the amount of water that must be pumped. Less pumping means a savings of energy dollars.

2. Replacing open header ditches in sandy soils with plastic pipe for delivering water to field ditches can save up to 50 percent of the water needed for irrigation.

3. Operating irrigation equipment at maximum efficiency will conserve energy and save on irrigation costs.

4. Using full-bed plastic mulch can reduce water losses due to evaporation, saving water and conserving energy used in irrigation.

In addition to direct energy savings, some of these practices may increase yield per acre, save labor, water, and fertilizer, and reduce disease problems.

EXAMPLE OF SAVINGS FROM USE OF DRIP IRRIGATION

$3,885 savings on 160 acres of tomatoes

Savings from the use of drip irrigation result from increased efficiency in water use and from applying water at relatively low pressure. In one California test area where water costs amounted to $100 per acre, drip irrigation reduced water use by two-thirds. Water must be pumped at pressures up to 125 pounds per square inch with some conventional irrigation systems. Drip irrigation water can be applied at pressures as low as 10 to 20 psi.

Example: A grower has 160 acres of processing tomatoes requiring 2 feet of irrigation water per acre applied with a high pressure gun system. By using trickle irrigation the water requirement can be reduced to 1.3 acre feet. The average lift for water is 50 feet. Total head for the high pressure gun system is 325 feet; for the drip system it is 85 feet. Initial cost for the present system is $275 per acre, for the drip system, $400 per acre. Operating costs for the two systems and energy savings are shown below:

Estimated direct energy savings on 160 acres of tomatoes from using drip irrigation

Cents/kWh	3¢	4¢	5¢
Savings/year	$3,885	$5,180	$6,475

Table 7--Estimated operating costs for drip and high pressure gun irrigation systems

Item	Drip	Gun
	Dollars per acre	
Materials	1.25	1.50
Labor	7.80	12.00
Pumping	4.97	29.25
Other	1.75	2.25
Total	15.77	45.30

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EXAMPLE OF SAVINGS FROM OPERATING AN EFFICIENT PUMPING PLANT

$3,432 estimated savings for 160 irrigated acres

The efficiency of a pumping plant is a measure of the energy output in work accomplished as a percentage of the energy input. Overall efficiency is a product of the efficiency of the power unit and the efficiency of the pump. Efficiency of a good electric power pumping plant should approach 70 percent. Tests conducted on operating plants indicate that efficiency varied from less than 10 to approximately 75 percent. A pump's performance varies with the speed at which it is turned, the amount of wear on the pump from past usage, normal operating friction, and other factors. Your county extension agent, electric company representative, or pump installer can help determine efficiency of your pumping plant. If it's less than 50 percent, it will probably pay to make repairs or adjustments.

Example: The example grower has 160 acres of processing tomatoes requiring 2 feet of irrigation water per acre with a pumping head of 325 feet. His present electric motor pumping plant is operating at 40 percent efficiency. Here are the energy savings from repairs and adjustments which would achieve 70 percent efficiency:

Cost of pumping at 40 and 70 percent efficiency and savings at 70 percent at varying electrical rates

Cost per kWh cents	Efficiency 40 percent	Efficiency 70 percent	Savings
	cents per acre foot per foot of head		
3	7.8	4.5	3.3
4	10.4	5.9	4.5
5	13.0	7.5	5.5

Total savings with 3¢/kWh electricity would be (3.3¢) x (325 ft head) x (2 acre feet) x (160 acres) = $3,432.

EXAMPLE OF SAVINGS FROM REPLACING OPEN HEADER DITCHES WITH PLASTIC PIPE ON SANDY SOILS

$112.50 annual savings by replacing open ditches with pipe line.

Using polyvinyl chloride (PVC) pipes to deliver water to field ditches can save 40 to 50 percent of your irrigation water in sandy soils. In addition, pumping requirements are reduced, saving on investment in equipment and reducing energy costs.

Example: A grower raises 200 acres of potatoes and cabbages on sandy soil. Irrigation water is delivered to field ditches with open header ditches. Current water needs are 30 acre inches per year, which must be lifted 10 feet into open header ditches. The system of open header ditches is to be replaced with 4-inch PVC pipe at a cost of $50 per acre. Water needs will be 15 inches per acre with the PVC header pipe installed. Estimated energy savings:

$112.50 estimated savings per year by replacing open header ditches with polyvinyl chloride pipes

Cents/kWh	3¢	4¢	5¢
Savings/year	$112.50	$150	$187.50

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EXAMPLE OF ENERGY SAVINGS BY IRRIGATING ACCORDING TO PLANT NEEDS

$229.50 energy savings per year per 40-acre field

Irrigate according to plant needs rather than by following a set number of days on the calendar. You can improve irrigation efficiency by using aids such as soil augers, evaporation pans, and moisture meters. They help to accurately determine when and how much water to apply. They are much better than trying to eyeball it. The results are reduced total water used in a season, reduced energy use for pumping and increased money in your pocket.

Suppose that overwatering results in a 10 percent waste of water per year. Assume also a medium power requirement of 60 psi and a 200-foot lift on a side roll system covering 40 acres with 30 acre inches applied per year. The extra water pumped requires 12.75 gallons of diesel fuel or 152.5 kilowatt hours per acre. On a 40-acre field this could mean $230 or more a year in saved energy.

Cost of monitoring equipment is relatively minor.

Calculations:

0.25 AC ft x 51 gal/AC ft = 12.75 gal
12.75 gal x 40 AC x $.35/gal = $178.50

Dollars Saved at Various Diesel Fuel Prices

Cents/gal	40¢	45¢	50¢	55¢
Savings/year	$204	$229.50	$255	$280.50

Calculations:

0.25 AC ft x 610 kWh/AC ft = 152.5 kWh
152.5 kWh x 40 AC x $.03/kWh = $183

Dollars Saved at Various Electrical Rates

Cents/kWh	3¢	4¢	5¢	6¢
Savings/year	$183	$244	$305	$366

EXAMPLE OF ENERGY SAVINGS BY MAINTAINING IRRIGATION EQUIPMENT IN EFFICIENT CONDITION

Keep irrigation equipment in top shape by repairing leaks in valves, pipes, and risers. Check gaskets in the sprinkler lines for leaks which waste water and power. Gaskets are easily replaced. Inspect your sprinkler nozzles. They enlarge after being used awhile and may apply water at a greater rate than needed. Enlarged sprinkler nozzles also shorten the distance water is thrown, overload the pump, and cause a pressure drop that increases the droplet size. Investigate the efficiency of the well. Clogged perforations or water screens at the water bearing strata may prevent water flowing freely into the well.

Suppose that inefficiencies in the irrigation system due to lack of maintenance result in a 5-percent increase in the workload of the pump unit. On a 40-acre field using a medium power system (60 psi) and a 200-foot lift delivering 30 acre inches per crop year, this increased workload can cost an additional $100 per year or more.

Although the cost of materials used in maintenance may well exceed energy cost savings, other benefits such as these can be an accrual of better water distribution and increased equipment life.

$114.75 savings per year per 40-acre field

<u>Calculations:</u>

2.5 AC ft x 51 gal/AC ft = 127.5 gal of diesel
127.5 gal x .05 energy loss x 40 AC x $.35/gal = $89.25

<u>Dollars Saved at Various Diesel Fuel Prices</u>

Cents/gal	40¢	45¢	50¢	55¢
Savings/year	$102	$114.75	$127.50	$140.25

<u>Calculations:</u>

2.5 AC ft x 610 kWH/AC ft = 1525 kWh
1525 kWh x .05 energy loss x 40 AC x $.03/kWh = $91.50

<u>Dollars Saved at Various Electrical Rates</u>

Cents/kWh	3¢	4¢	5¢	6¢
Savings/year	$91.50	$127	$152.50	$183

Some cultural practices may result in increased yields rather than in reduced fuel consumption per acre. However, by producing a high yield on less acreage, these cultural practices do achieve overall fuel conservation.

CROP POLLINATION

All cucurbitaceous crops (those belonging to the ground family of plants such as pumpkin, squash, and cucumber) require insect pollination. Squashes are native to this country and are pollinated by several kinds of wild bees as well as honey bees. Cantaloupes, watermelons, and cucumbers are from the Old World and require honey bees for pollination. It is not always necessary to move domesticated bees into fields or orchards for production but placement of bees, in sufficient numbers, near or in crops needing insect pollination will always result in increased yields where there are too few wild pollinators.

EXAMPLE OF ENERGY SAVINGS FROM PARTIAL ACREAGE PLANTINGS AND PROPER POLLINATION

$2,697 total savings by using bees and reducing acreage

Cucumbers are monoecious (having separate male and female flowers on the same plant) and require insects (usually honey bees) for pollination. In Louisiana experimentation the use of two hives of honey bees per acre increased yields by nearly 150 percent. (9)1/ Only 4.2 acres are needed when there are enough honey bees around to pollinate a crop of pickling cucumbers to produce the same size crop as would grow on 10 acres with no bees. Not planting and cultivating the 5.8 acres would save $2,697 in costs. (12)

1/ Numbers in parentheses refer to items in references at the end of this guidebook.

Calculations:

Practices	No bees	2 hives of bees per acre	
Acres	10	4.2	
	Costs		Savings
	Dollars		
Labor	1,250	525	725
Materials	680	286	394
Irrigation fuel	255	107	148
Tractor fuel	175	73	102
Other	2,290	962	1,328
Total	4,650	1,953	2,697

EXAMPLE OF ENERGY SAVINGS BY CHANGING HARVESTING METHODS

$1,760 annual fuel savings

$15,400 total savings for 350 acres of tomatoes

Typical costs of production for processing tomatoes were $42-44 per ton with a 25-ton yield per acre 2/. Assumptions include total tomato production of 350 acres on rented land.

Harvesting into bulk trailers showed a cost saving of nearly $2 per ton compared to bin handling.

2/ Univ. of California Agr. Ext., Sample Cost of Tomato Production in Contra Costa, San Joaquin, and Stanislaus counties, Oct. 1974.

Calculations:

	Bin Harvest	Bulk Harvest
Land rent	$200	$200
Cultural costs	417	417
Harvest costs	308	267
Total cash costs	$925	$884
Investment (depreciation and interest)	98	95
Management (5% of 25 tons at 55)	69	69
Total per acre	1,092	1,048
Cost per ton at 25 tons/acre	44	42

$1,092 - $1,048 x 350 acres = $15,400 savings

8.38 gal fuel saved @ $.60/gal x 350 acres = $1,759.80

EXAMPLE OF INCREASING YIELDS WITH WINDBREAKERS

Many crops benefit from the use of windbreakers. Spring cabbage in Texas yielded 143 percent more pounds when planted with winter wheat as a shield against wind. Cabbage heads in the windbreak strips averaged 119 percent larger. The cabbage field was seeded in February in three bed strips between rows of wheat four beds wide. Protection benefits are from reduced wind velocity resulting in increased temperature, more rapid growth, and earlier maturity. Protection results in less water loss from winds and less abrasion of crop leaves and stems from windblown particles.

$13 annual fuel savings $227 total savings on 235 cwt yield	Income increase of $1,627 per cabbage acre

Calculations:

Effect of crop practices on yield and income from cabbage

	Practices		
	Standard	Using windbreakers	Increase
Yield (cwt)	235	571	336
Income ($)	1,137	2,764	1,627

Inputs to produce average yield of 235 cwt

	Practices		
	Standard	Using windbreakers	Savings
Land (acres)	1.0	0.4	0.6
Cost ($)	386	159	227
Fertilizer ($)	44	18	26
Fuel ($)	22	9	13

TRACTOR AND TRUCK USE

All of the fuel saved through proper maintenance of tractors and trucks can be quickly lost with inefficient work routines.

Only a thorough work analysis can rid a vegetable farm of fuel waste. No grand scheme can be presented for every farm because each is different. There are, however, pitfalls common to many operations. Some of the following examples may point out fuel wasters that you have been too busy to recognize in the course of pressing day-to-day demands. Most are easy to correct once discovered.

When fuel savings are the result of reduced operating time, as is usually the case, you will save more in non-fuel costs such as repairs, oil, grease, tires and the like than the money you save in fuel. Reduction in associated labor costs is another benefit from reduced operating time of tractors and trucks.

EXAMPLES OF SAVING ENERGY THROUGH CHOICE OF TRACTOR FUELS

Every vegetable grower should be familiar with the efficiency of the various kinds of tractor fuels including diesel, gasoline, and LP gas. Most tractors now manufactured, even many of the smaller-sized units, use diesel fuel, but a rather wide selection of gasoline-powered tractors is available; some tractors operate on LP gas.

A rule of thumb: Given the horsepower and running time, a diesel tractor will use seven-tenths as many gallons of fuel as a gasoline tractor; an LP gas tractor will use 1.2 times as many gallons of fuel as a gasoline tractor. Not only are there differences in fuel requirements for a given power output, but there are differences in the cost and relative availability of the different kinds of fuels. All advantages point toward the diesel-powered tractors.

You may have a mixture of tractors with respect to kind of fuel, making it more economical to continue using your present tractors for awhile. When it is time to trade for newer machines, however, give strong consideration to going totally diesel.

If you are planning to purchase a new car or pickup, consider those with electronic ignition and radial tires because they provide better fuel economy.

Tractors with all-gear power transmissions are 25 percent more efficient on fuel than hydraulic drives even at reduced engine speed, and at part load as well as at full load, according to Nebraska tests (annual Nebraska Tractor Test Data). This consideration partly offsets the greater convenience of the hydrostatic transmission.

EXAMPLE OF ENERGY SAVINGS BY USING A DIESEL TRACTOR

$646 annual savings using a 75-hp diesel versus a 75-hp gasoline tractor operating 500 hours at 50 hp output.

A 75-horsepower diesel tractor which is used 500 hours a year and operates at an average output of 50 horsepower will use about 1,833 gallons of diesel fuel per year. The same size gasoline tractor operating under the same conditions will use about 2,675 gallons of fuel annually; a tractor fueled with LP gas will use about 3,210 gallons. The difference in total fuel cost on an annual basis can be substantial depending upon the price of the three kinds of fuel. If you now pay $.45 a gallon for diesel fuel, $.55 for gasoline and $.40 for LP gas, the yearly fuel bill would be $825 for diesel, $1,471 for gasoline or $1,284 for LP gas.

Calculations:

75-hp gasoline tractor: Average 50 hp output at full engine speed 500 hr x 5.35 gal per hr = 2,675 gal
2,675 gal x 55 cents/gal = $1,471

75-hp diesel tractor: Average 50 hp output at full engine speed 500 hr x 2,675 gal x .70 = 1,833
1,833 gal x 45 cents/gal = $825

75-hp LP gas tractor: Average 50 hp output at full engine speed 500 hr x 2,675 gal x 1.2 = 3,210 gal
3,210 gal x 40 cents/gal = $1,284

$1,471.25 (gasoline) - $825 (diesel)= $646

Fuel Cost at Various Prices Per Gallon

Dollars per gallon, diesel
.40 .45 .50 .55
Total fuel cost for 500 hours (1833 gal)
733.20 824.85 916.50 1008.15

Dollars per gallon, gasoline
.50 .55 .60 .65
Total fuel cost for 500 hours (2675 gal)
1337.50 1471.25 1605 1738.75

Dollars per gallon, LP gas
.35 .40 .45 .50
Total fuel cost for 500 Hours (3210 gal)
1123.50 1284 1444.50 1605

EXAMPLE OF ENERGY SAVINGS THROUGH ECONOMIZING ON THE USE OF A PICKUP TRUCK

The pickup truck is one of the most useful and necessary machines to farmers.

When gasoline was $.25 a gallon, few farmers gave much thought to fuel economy. With gasoline around $.60 a gallon and rising, some careful thought should be given to economical use of the pickup truck.

Careful planning may result in halving the hours of pickup truck use on most vegetable farms. Even minimal effort could result in a 10-percent reduction. Suppose that you drive your pickup truck 10,000 miles a year. A 10-percent reduction would cut fuel use per year by 100 gallons of gasoline if you average 10 miles per gallon.

Modest speeds are also recommended if you want to minimize fuel use.

$55 annual savings for the farm

Calculations:

Present pickup truck use: 10,000 miles per year

Planned travel to save 10 percent:
10 percent x 10,000 miles = 1,000 miles
1,000 miles ÷ 10 miles per gal = 100 gal

Dollar Savings at Various Prices for Gasoline

Cents/gal	50¢	55¢	60¢	65¢
Savings/year	$50	$55	$60	$65

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EXAMPLE OF ENERGY SAVINGS BY REDUCING IDLING TIME OF A TRACTOR

$13.50 annual savings

The typical farmer who uses a tractor in his chore work should be alert to fuel consumption problems that may be robbing him of earned income. For example, chances are that you leave the tractor engine idling when you step off to handle a quick chore. An idling engine does not use much fuel, and you have probably never given the matter any thought.

Suppose you leave the tractor engine idling for 10 minutes during an average day. During a year this amounts to 61 hours. Sixty-one hours of idling on a 75-horsepower diesel tractor will use about 30 gallons of fuel. This is a sizable amount of fuel, especially when it is accomplishing no useful purpose.

Make it a habit to turn off the tractor engine when you have some other work to do nearby. Some things will occur unexpectedly and you will not be able to turn off the tractor engine without making a special trip to do so. That may be impractical. On routine matters, however, you can certainly turn the engine off when you know that you will be working somewhere away from the tractor for a few minutes.

Calculations:

Present routine: Tractor engine idles unnecessarily an average of 10 minutes a day.

10 min x 365 days = 3,650 min
3,650 min ÷ 60 = 61 hr
61 hr x 0.5 gal per hour = 30 gal

Improved routine: Eliminate the Unnecessary Idling Time and Save 30 Gallons of Fuel

Cents/gal	40¢	45¢	50¢	55¢
Savings/year	$12	$13.50	$15	$16.50

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EXAMPLE OF ENERGY SAVINGS BY MATCHING TRACTOR SIZE TO LOAD	$22.50 annual energy saving for	200 acres of row-crop vegetables

A tractor working at 75 percent of capacity consumes less fuel per horsepower produced than a tractor working at 50 percent capacity.

It requires a 50-horsepower wheel tractor to operate a 6-row cultivator under most conditions. The 50-horsepower tractor will consume approximately 2 gallons of diesel fuel per hour performing this task. An 80-horsepower tractor will consume approximately 2.5 gallons per hour doing the same job.

Assuming the cultivator is used 100 hours per year for 200 acres, use of the larger tractor will result in extra fuel use of 50 gallons. Therefore, a proper matching of tractor and cultivator size could save $22.50 in diesel fuel costs.

The vegetable grower could save even more fuel if the tractor were even more closely matched to the task, but some overcapacity is desirable. This is especially true if field conditions are not ideal.

Calculations:

100 hours x .5 gal/hour = 50 gal
50 gal x $.45/gal = $22.50

Dollars Saved at Various Diesel Fuel Prices

Cents/gal	40¢	45¢	50¢	55¢
Savings/year	$20	$22.50	$25	$27.50

Tractor tires are not direct energy users themselves except for the materials and energy used in the manufacturing process. However, the proper type, size, and use of tractor tires can result in considerable energy savings.

The most familiar type of tractor tire is the bias ply tire which consists of layers or cord (plys) set diagonally to the tread and criss-crossed at an angle called a bias angle.

In contrast, the newer radial tires consist of plys that run at right angles to the tread. A belt of plys around the radial ply tire gives it strength and stability. The result is a tire with a flexible sidewall. A radial ply tractor tire is the most efficient tire in converting horsepower to drawbar pull. Fuel consumption per acre is decreased, area covered per hour is increased, tire slippage is reduced and the ride is much smoother.

Potential savings from use of radial tractor tires arise from three sources. There is less tire slippage resulting in more travel per engine revolution, an easier rolling force resulting in less fuel used and longer tread life, and larger equipment pulling capacity since traction is increased and power loss is reduced.

EXAMPLE OF ENERGY SAVINGS BY USE OF RADIAL TRACTOR TIRES

Assuming 700 hours of mixed tractor work on a farm using standard tires, only 623 hours would be needed to do the same amount of work with radial tires. Fuel per hour would be 5.52 gallons for bias tires while 5.14 gallons would be needed for the radials, resulting in an annual fuel savings of $330 at 50 cents per gallon for fuel. The reduction in labor costs for a tractor driver would be $231 at $3 per hour. Annual tire cost would be reduced to $68 from $80 because of additional tire life with the radials. Interest on investment would be increased from $13 to $21.

April 1977 prices in Galesburg, Ill., for 18.4 x 38.6 ply radial tires were $605 plus $16.85 Federal excise tax compared with $359.50 plus $11.59 excise tax for bias ply tires.

$565 total annual savings by using radial tractor tires

Calculations:

Comparative Annual Operating Cost

	Bias ply	Radial ply	
	Dollars		
Fuel: 700 hr x 5.52 gal/hr x .50/gal	1,932		
623 hr x 5.14 gal/hr x .50 gal		1,602	
Fuel savings =			$330
Labor: 700 hr @ $3/hr	2,100		
623 hr @ $3/hr		1,869	
Tire cost per year (85 percent of tread life)	94	80	
Interest on investment @ 8 percent	14	24	
Total annual cost	4,140	3,575	
Total annual savings			$565

Field Tire Tests 3/

	Radial ply	Bias ply
Acres/gal	.87	.72
Acres/hr	4.47	3.98
Fuel efficiency%	120.8	100.0
Acreage efficiency%	112.6	100.0
Tire life%	165.0	100.0
Tire prices%	167.3	100.0

3/ Adapted from material published by and research conducted by B. F. Goodrich Tire Co., Akron, Ohio 44318.

Gasoline- and diesel-powered engines are the biggest onfarm users of energy in crop production. Fuel conservation is one way that you can have a direct impact on reducing total energy use.

FUEL TIPS

The saving of fuel begins even before you start your tractor, truck, or car. The following tips may save you fuel, dollars, and problems.

1. Check tank, lines, fuel pump, and carburetor for leaks.

2. Keep full tank, especially in cold weather, to avoid moisture condensation.

3. Check your usage against your bill.

4. When filling tank don't forget to leave room for expansion.

5. Maintain dispensing records by vehicle and by task performed. This can identify high and wasteful usage.

ENGINE OPERATING TIPS

The way a vehicle is operated can save fuel without changing the amount of work or the way the work is done.

1. Avoid excessive warmups in cold weather.

2. Idling can consume 15 to 20 percent of the fuel used. Hold it to a minimum, and avoid excess idle speed.

3. Don't leave the choke out.

4. Let out the clutch slowly; quick starts waste fuel and are hard on equipment.

5. Run tractors in the proper gear for the load and condition. Improper shifting and use of the wrong gear can result in a 5-percent fuel loss.

6. Be sure the thermostat is working properly.

ENGINE MAINTENANCE TIPS

1. One fouled spark plug or one stuck valve lifter can cause a loss of 10 to 15 percent of the fuel used in a vehicle.

2. Too rich a mixture of fuel causes waste.

3. Too lean a mixture wastes fuel because it prompts excessive choke use.

4. Regularly scheduled tuneups can save up to 10 percent on your fuel usage.

5. Keeping the tires of your tractors and other implements properly inflated saves energy.

6. Improper lubrication, loose fan belt, or low oil level will increase fuel consumption.

EXAMPLE OF ENERGY SAVINGS BY FIXING A LEAKING CARBURETOR

$8.25 energy savings per month

A slowly dripping carburetor can waste .5 to 1.5 gallons of gas per day. Suppose the carburetor on one of your tractors starts leaking, and you do not find time to fix it for a month. This means at least 15 gallons of gasoline and $8.25 were wasted.

Calculations:

.5 gal/day x 30 days x $.55 gal = $8.25

Dollars Saved at Various Gasoline Prices

Cents/gal	50¢	55¢	60¢	65¢
Savings/month	$7.50	$8.25	$9	$9.75

EXAMPLE OF ENERGY SAVINGS BY PROPER SETTING OF THERMOSTAT AND ENGINE TEMPERATURE

$9.60 saving per winter season per operating tractor

Be sure the thermostat is functioning properly so the engine warms up quickly, especially in winter. Fuel consumption increases by approximately 25 percent when the engine is operating at 100°F instead of 180°F (3).

If the thermostat on your tractor is stuck open during the winter, your tractor may operate at 100°F or less no matter how long you use it. Assuming the tractor is used 40 hours during the 3 coldest months of the year, you could save $12.60 by having a properly functioning thermostat. A new thermostat costs about $3.

Calculations:

.7 gal/hr x 40 hr x $.45/gal = $12.60/ season
$12.60 - $3 = $9.60

Engine operating temperature °F	Gallons of fuel consumed per hour
100	3.5
140	3.2
160	2.9
180	2.8

Dollars Saved at Various Diesel Fuel Prices

Cents/gal	40¢	45¢	50¢	55¢
Savings/year	$8.20	$9.60	$11	$12.40

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Greenhouse area in the United States totaled nearly 275 million square feet (6,313 acres) in 1970, according to the U.S. Census of Agriculture. About 90 percent of this area was used for the production of florist and nursery crops. Vegetable production accounted for more than 25 million square feet (575 acres). The major vegetables produced under controlled environments were tomatoes, lettuce, and cucumbers.

Greenhouses were originally designed to produce flowers and vegetables during periods when outside weather conditions were unfavorable. Greenhouses are great energy users and are poorly designed for energy conservation. A typical greenhouse maintained at 68°F during an average mid-Atlantic winter may use about 2½ gallons of No. 6 fuel oil per square foot 4/. If No. 6 fuel oil costs 40 cents per gallon, the total fuel cost would be $1 per square foot for the season.

Costs vary, however, with the greenhouse design. Greenhouses with the least surface area of covering for a given enclosed ground area have a built-in efficiency. Ridge and furrow ranges require less heat for a given enclosed floor area than detached greenhouses (5). Similarly, greenhouse designs with small differences in height between eaves and ridge, such as a shallow arch, have reduced surface per area enclosed. Northern growers, in particular, must consider greenhouse design when planning a new greenhouse or range.

For existing greenhouses, however, the grower must cope with what he has. Considerable differences in rates of heat loss exist among the various covering materials. For each degree difference in inside and outside temperature, glass and a single film of polyethylene plastic both lose 1.18 to 1.25 Btu per hour. Fiberglass corrugated panels lose 0.90-0.95 Btu per hour degree differences in temperature, while two coverings of polyethylene film with 1-inch separation lose 0.60 to 0.65 Btu. However, two layers of polyethylene film reduce daylight levels 10 to 20 percent below glass, which may be objectionable in the winter.

Regardless of the type of greenhouse, careful attention to the following details should result in substantial fuel savings under current operating conditions.

IMPROVING THE EFFICIENCY OF THE STRUCTURE

1. Tighten up the house; close all possible openings.

2. Use polyethylene or fiberglass on the inside of gable ends.

3. Use reflectorized tar paper behind heating pipes to reflect the heat into the greenhouse.

4. Use a double layer of polyethylene on plastic houses where possible.

5. Use black cloth as a shield at night to reduce radiation heat loss to the atmosphere.

4/ See (15), p. 63.

IMPROVING THE EFFICIENCY OF THE HEATING AND/OR COOLING SYSTEMS (2, 11)

1. Use the proper fuel. The use of the wrong grade or type of fuel can result in carbon accumulations, decreasing heat transfer.

2. Protect fuel oil tanks. Twenty percent of service calls result from dirty fuel. Tanks should be away from dusty locations, and watertight fittings should be used.

3. Remove soot from inside the furnace. A 1/8-inch soot deposit can increase fuel consumption as much as 10 percent. Surfaces should be wire brushed and vacuumed, or special cleaning compounds should be used.

4. Change fuel filters. Uniformly clean fuel delivered to the burner results in more efficient combustion. Fuel supply line connections should be tight.

5. Use correct nozzle size and angle. Excessive fuel consumption will result from too large or too small a nozzle. The spray angle should fit the shape of the firebox.

6. Clean and adjust controls. Check gas valves, thermostats, and ignition mechanisms for clean, smooth operation.

7. Oil bearings on motors and pumps. Periodic lubrication of bearings increases their life.

8. Water must be clean. Drain off dirty water through drain cocks in steam and hot water systems. Flush steam boilers to remove scale and lime deposits.

9. Check combustion efficiency. The lower the stack temperature, the lower the oil consumption, while the higher the carbon dioxide content of the stack gases, the more completely the oil is being burned.

10. Replace burned oxygen. In polyhouses and tight glass and fiberglass houses, install an air intake from outside to near the heater. Allow 1 square inch of intake area for each 2,000 Btu furnace capacity.

11. Chimney must be high enough. Chimney should extend at least 2 feet above ridge of greenhouse. Top of chimney should be at least 8 to 12 feet above the furnace to develop sufficient draft. Use cap if necessary to prevent back drafts and possible air pollution injury to plants.

12. Chimney must be tight. Any air leaks will chill the gases and reduce the draft.

13. Chimney must be correct size. Too small a cross section, or a chimney lined with soot, will reduce the draft. Too large a diameter will cool the gases too quickly.

14. Draft control is necessary. Draft variations due to atmospheric conditions can be stabilized by installation of a draft regulator.

15. Install baffles. Turbulators or baffles installed in boiler tubes slow down and direct the flow of gases so that more heat can be absorbed. Ten to 15 percent savings in fuel consumption can be realized.

16. Blower timing. In forced warm air systems, blowers should operate until furnace is cooled to 100°-120°F, or continuously where desired.

17. Radiator valves are vital to fuel savings. Repack leaky valves and replace defective ones.

18. Clean radiators and pipes. Dust and dirt reduce heat transfer and increase fuel consumption.

19. Insulate distribution lines. In unheated areas and underground, insulate pipes to reduce heat loss. Insulation of mains can save 1½ gallons of oil per day for each 10 feet of 3-inch pipe.

20. Thermostat placement or location. Locate thermostats at plant height, away from heat pipes and hot-air streams. Shade and aspirate thermostats for most accurate control of temperature.

21. Furnace and fan thermostat differential. Set fan thermostat at least 10 degrees above heater thermostat to prevent simultaneous operation and possible back draft.

22. Check for steam or water leaks. A 1/16-inch diameter hole in a pressured water system can add 7½ gallons per day to fuel oil use.

23. Inspection record. Keep a record of furnace maintenance and repairs for future reference.

Following are figures 7 and 8 for (1) determining heat requirements for greenhouses, and (2) estimating annual heating costs for greenhouses. Also included are some specific examples of energy savings possible by strict adherence to good general management practices and good greenhouse maintenance procedures.

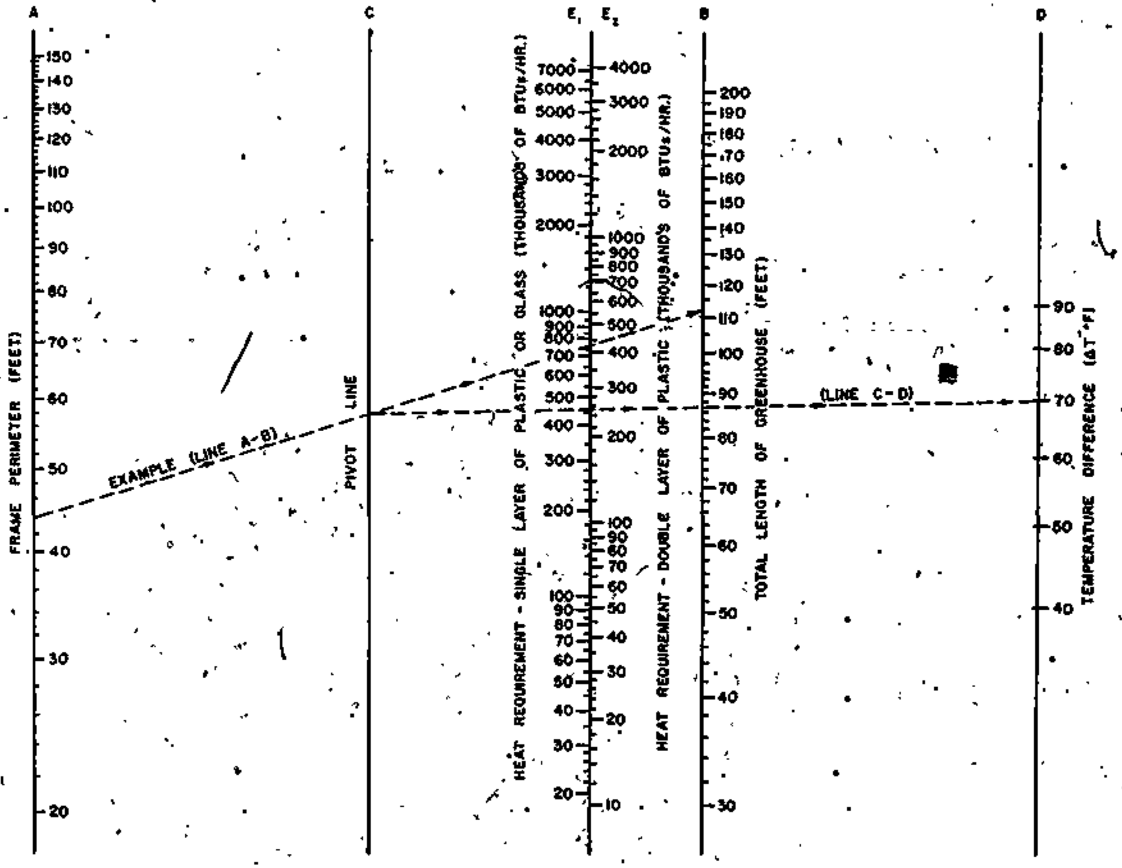
TABLE I - FRAME PERIMETER (FEET)

WIDTH (W) (FEET)					
12	28	19	20		
16	30	25	28		
20	34	31	36		
24	39	38	40	40	
28	44	44	48		
32	48	50	56	48	
36	53	56	64		54
40	57	63	72	56	
48				68	64
56				76	
60				80	78
64				84	
72				94	93
80				102	
84					108
96					120
108					135
120					147

TABLE II - EQUIVALENT LENGTH FOR END WALLS (FEET)
(ADD TO LENGTH OF HOUSE)

WIDTH (W) (FEET)					
12	8	6	7		
16	9	8	9		
20	10	10	11		
24	11	12	13	10	
28	12	14	15		
32	14	16	17	11	
36	15	18	20		11
40	16	20	22	12	
48				13	12
56				14	
60				15	15
64				16	
72				17	14
80				18	
84					15
96					16
108					17
120					18

GRAPH I - HEAT REQUIREMENT FOR GREENHOUSES



HOW TO USE THE GRAPH AND DETERMINE HEAT REQUIREMENT

1. FROM TABLE I, FIND FRAME PERIMETER OF HOUSE. LOOK UNDER SHAPE OF HOUSE AND WIDTH, MARK FRAME PERIMETER ON LINE A OF THE GRAPH
2. FROM TABLE II, FIND EQUIVALENT LENGTH OF HOUSE TO BE ADDED FOR END WALLS. ADD THIS TO THE ACTUAL LENGTH OF THE HOUSE. MARK THE TOTAL LENGTH ON LINE B.
3. DRAW A STRAIGHT LINE FROM THE POINT MARKED ON LINE A TO THE POINT MARKED ON LINE B.
4. DETERMINE DIFFERENCE IN OUTSIDE AND INSIDE TEMPERATURE AND MARK ON LINE D. SEE TABLE III FOR NORMAL WINTER DESIGN TEMPERATURE.
5. FROM THE POINT WHERE LINE A-B CROSSES LINE C, DRAW A STRAIGHT LINE TO POINT ON LINE D. LINE C-D
6. READ HEAT REQUIREMENT ON LINE E_1 OR E_2 WHERE LINE C-D CROSSES.

EXAMPLE:

1. GREENHOUSE (GABLE TYPE) 28 FEET X 100 FEET. OUTSIDE DESIGN TEMPERATURE 0°, INSIDE DESIGN TEMPERATURE 70°.
2. FRAME PERIMETER - 44 FEET. (TABLE I)
3. EQUIVALENT LENGTH 12 FEET, TOTAL LENGTH 112 FEET. (TABLE II)
4. TEMPERATURE DIFFERENCE 70°. (70° - 0°)
5. FOR SINGLE LAYER OF PLASTIC OR GLASS, HEAT REQUIREMENT = 460,000 BTU/HR, FOR DOUBLE LAYER OF PLASTIC, HEAT REQUIREMENT = 250,000 BTU/HR.

Credit:
Cooperative Extension in
College of Agriculture
University of Kentucky

Figure 7: HEAT REQUIREMENT FOR GREENHOUSES

GRAPH II ESTIMATING ANNUAL HEAT COST FOR GREENHOUSES

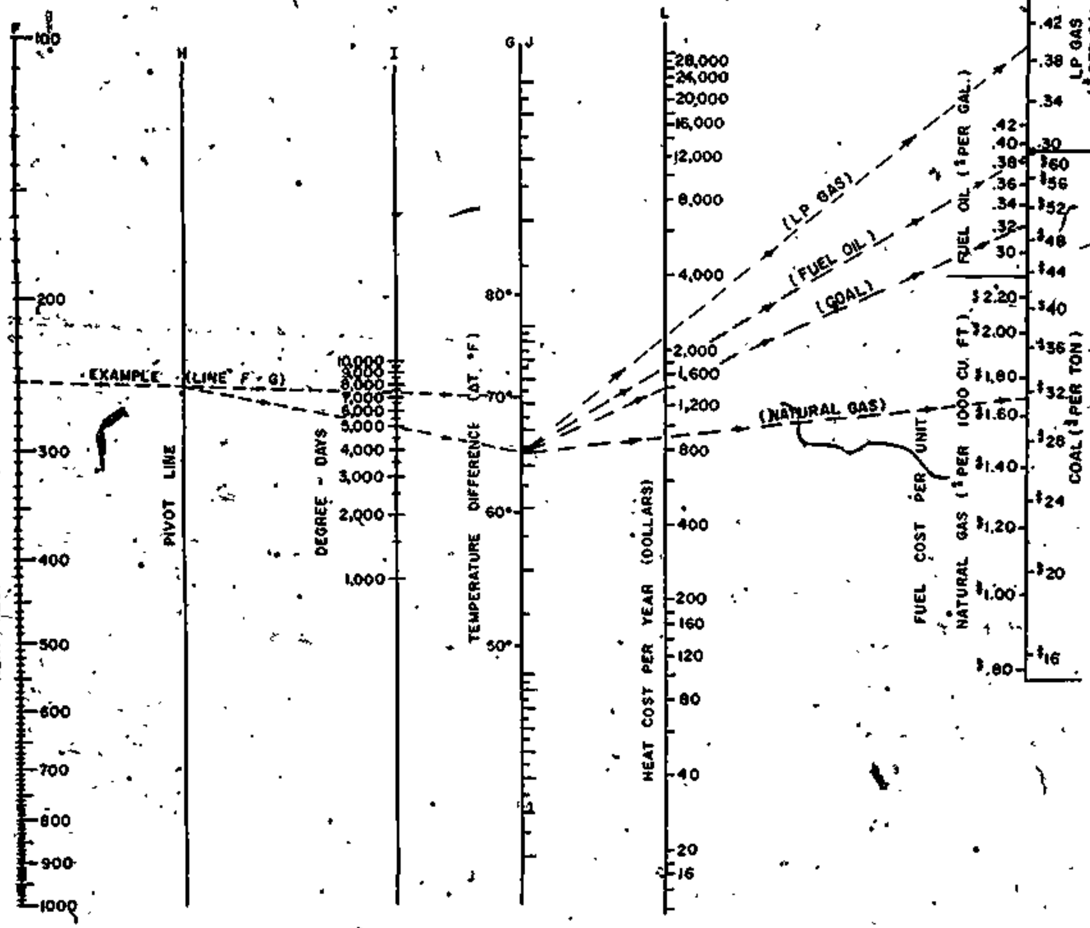


TABLE III WINTER DESIGN TEMPERATURE AND APPROXIMATE DEGREE DAYS

AREA: STATE	AREA: CITY	NORMAL OUTSIDE DESIGN TEMP FOR WINTER (°F)	APPROX. DEGREE DAYS INSIDE TEMPERATURE 70°F	60°F	50°F
ALABAMA	BIRMINGHAM	10	2800	850	100
	MONTGOMERY	15	2150	250	0
ARKANSAS	LITTLE ROCK	5	3000	1200	300
CALIFORNIA	LOS ANGELES	40	2000	20	0
	SAN FRANCISCO	35	3400	400	0
COLORADO	DENVER	-10	6100	3450	1550
FLORIDA	JACKSONVILLE	25	1250	100	0
GEORGIA	ATLANTA	10	2850	1200	100
	SAVANNAH	20	1700	250	0
ILLINOIS	CARIO	0	3750	2150	750
	CHICAGO	-10	6300	3750	2000
INDIANA	INDIANAPOLIS	-10	5400	2850	1400
KANSAS	TOPEKA	-10	5200	1850	1550
KENTUCKY	LEXINGTON	0	5000	2550	1200
LOUISIANA	NEW ORLEANS	25	1300	50	0
MASSACHUSETTS	BOSTON	0	5800	3600	1800
MARYLAND	BALTIMORE	5	4800	2500	1000
MICHIGAN	LANSING	-10	7000	4450	2350
MISSISSIPPI	MERIDIAN	15	2350	500	0
MISSOURI	COLUMBIA	-10	5100	3000	1250
NEVADA	RENO	0	6000	3500	1700
NEW JERSEY	TRENTON	0	5050	3000	1200
NEW YORK	ITHACA	-5	7000	4050	2450
	NEW YORK CITY	5	5050	3100	1100
NORTH CAROLINA	RALEIGH	10	3100	1100	250
OHIO	CLEVELAND	-5	6000	3800	1650
OREGON	PORTLAND	10	4650	1950	400
PENNSYLVANIA	PITTSBURG	-5	6000	3050	1400
SOUTH CAROLINA	COLUMBIA	20	2450	750	100
TENNESSEE	MEMPHIS	5	3150	1300	200
	KNOXVILLE	5	3600	1750	450
TEXAS	AMARILLO	5	4350	2250	800
	DALLAS	5	2300	750	0
	HOUSTON	20	1400	100	0
VIRGINIA	NORFOLK	15	3500	1500	250
	WYTHEVILLE	0	5100	2200	700
WASHINGTON	SEATTLE	15	5300	2200	400
WEST VIRGINIA	PARKERSBURG	-5	4750	2800	1150
WISCONSIN	MADISON	-20	7400	4850	3100
CANADA					
ONTARIO	LONDON	0	7400	---	----

HOW TO USE THE GRAPH AND ESTIMATE ANNUAL HEAT COST

1. USE HEAT REQUIREMENT ON LINE F AS FOUND FROM GRAPH I, LINE E_2, OR E_3. DIVIDE OR MULTIPLY BY 10, IF NECESSARY TO FIT SCALE
2. MARK TEMPERATURE DIFFERENCE ON LINE G - SAME AS LINE D
3. DRAW A STRAIGHT LINE FROM F TO G (LINE F-G) INTERSECTING LINE H
4. FROM TABLE III SELECT THE NUMBER OF DEGREE DAYS AND MARK ON LINE I.
5. DRAW A STRAIGHT LINE FROM INTERSECTION OF LINES H AND F-G THROUGH POINT ON LINE I TO LINE J. MARK POINT ON LINE F.
6. MARK LOCAL PRICES OF FUEL ON LINE K.
7. DRAW STRAIGHT LINES FROM POINT ON J TO POINTS ON K
8. READ ESTIMATED ANNUAL COST ON LINE L. IF LINE F WAS DIVIDED BY 10, MULTIPLY LINE L BY 10: IF LINE F WAS MULTIPLIED BY 10, DIVIDE LINE L BY 10.

EXAMPLE

1. GRAPH I, LINE E_1 HEAT REQUIREMENT -- 250,000 BTU/HR.
2. LOCATION - LEXINGTON, KENTUCKY - 5000 DEGREE DAY @ 70° (TABLE III)
3. MARK 250,000 BTU/HR ON LINE F AND 70° DIFFERENCE ON LINE G
4. DRAW LINE F-G.
5. MARK 5000 DEGREE DAYS ON LINE I AND DRAW LINE H-J.
6. ASSUMED PRICE OF FUEL $ — COAL - $30.00/TON; FUEL OIL - $.386/GAL. LP GAS - $.40/GAL.; NATURAL GAS - $1.68/1000 CU FT.;
7. MARK PRICES ON LINE K AND DRAW LINES FROM POINT ON J
8. READ ESTIMATED ANNUAL HEAT COST ON LINE L.

NOTE:

IN DEVELOPING THE CHART THE FOLLOWING FUEL HEAT CAPACITIES AND BURNING EFFICIENCIES WERE ASSUMED,

FUEL	HEAT CAPACITY	BURNING EFFICIENCY
COAL	13,000 BTU/LB.	60%
NATURAL GAS	1,000 BTU/CU.FT.	80%
LP-GAS	92,000 BTU/GAL.	80%
FUEL OIL	138,000 BTU/GAL.	70%

Credit:

Cooperative Extension in College of Agriculture University of Kentucky

Figure 8. ESTIMATING ANNUAL HEAT COST FOR GREENHOUSES

EXAMPLE OF FUEL SAVINGS FOR DOUBLE-LAYER PLASTIC GREENHOUSE (4)

For structural performance, economy of construction and economy in temperature control, three greenhouses 24 x 60 (1,440 square feet) were constructed, each supported by 3-inch-diameter steel posts with wooden gutters on top. House #1 (control) had an A-frame roof of 2 x 6 inch wood rafters covered with a single layer of 4 mil polyethylene film. House #2 was similar except that it was covered with two layers of film separated by 2-inch wooden strips. House #3 without A-frame roof had wires strung across the structure 10 feet apart and attached at the bottom edges of the wooden gutters. Two layers of film were stretched over the support wires, the lower layer tight and the upper slack, so that when air was injected between the layers, the roof arched with a maximum distance between the two films of 30 inches at the roof's center.

Each greenhouse had a gas-fired heater. Temperatures were held at 70°F at night and to a maximum of 80°F during the day using exhaust fans and ventilators.

Average daily fuel use for the period is shown in table 8. House #2 used 40 percent less fuel, and House #3 used 42 percent less. A cost analysis (table 9) indicates that house #3 cost 7 percent less to construct than house #1 and that house #2 was 6 percent more expensive.

$98.40 annual savings with double-layer film for a 1,440 square foot greenhouse, if natural gas is priced at $1.20 per 1,000 cubic feet

Calculations:

$234.29 x .42 (percent fuel savings) = $98.40

Table 8--Fuel consumption for three plastic greenhouses for 17 weeks and fuel savings for double-layered plastic

Week beginning	Average minimum outside Temp. °F	Average gas use per day		
		House 1 1/	House 2 2/	House 3 3/
		----------1,000 cubic feet----------		
Jan. 19	49	1.4	0.9	1.0
Jan. 26	--	1.7	1.1	1.1
Feb. 2	46	2.1	1.5	1.3
Feb. 9	47	1.9	1.3	1.2
Feb. 16	44	2.1	1.4	1.4
Feb. 23	49	1.8	1.1	1.1
Mar. 2	46	2.1	1.3	1.4
Mar. 9	48	1.4	1.0	1.0
Mar. 16	52	1.4	.8	.9
Mar. 23	52	1.2	.7	.8
Mar. 30	51	1.7	1.0	.9
Apr. 6	48	1.9	.9	--
Apr. 13	48	1.5	.9	.8
Apr. 26	50	1.7	1.0	.8
Apr. 27	54	1.3	.9	.6
May 4	57	1.2	.7	.5
May 11	55	1.2	.8	.5
Average	50	1.6	1.2	.9
Percentage fuel savings		0	40	42

Table 9--Construction cost comparisons for three greenhouses

Item	House 1	House 2	House 3
	----------Dollars----------		
Building materials	858.32	884.00	663.00
Plastic film	41.50	83.00	83.00
Labor	185.50	230.50	205.00
Equipment, heaters, fans, etc.	968.60	968.60	968.60
Pole blower (inflation)			11.00
Total cost	1,873.92	1,986.10	1,751.00

1/ Single layer
2/ Double layer 2-inch dead air space
3/ Double layer with forced air separation

EXAMPLE OF EFFECTS OF TYPES OF FUEL AND CONDITION OF EQUIPMENT ON HEATING COSTS

$1,860 estimated annual savings by increasing heating efficiency from 65 to 80 percent in an oil-heated 19,200 square foot greenhouse

A typical greenhouse heating system may have dirty flues and an inefficient boiler. With adequate maintenance and adjustments, nearly all heating systems will operate more efficiently.

Example: An opportunity to save $1,860 annually in fuel cost was discovered in an Ohio greenhouse heating plant when a flue gas analysis was run. The analysis showed insufficient air entering the burner and a dirty stack. After cleaning the boiler and stack and adjusting air inflow, oil use was reduced by 1½ gallons an hour on a typical cold day. For 3,875 hours of heating per year this amounts to 5812.5 gallons of fuel saved per year or $1,860.

Table 10--Estimated heating costs of typical greenhouse at various efficiencies

Fuel	Unit costs	Cost per 100,000 Btu		
		100% efficiency (theoretical)	Clean, efficient boiler	Typical greenhouse
		Cents		
Oil No. 2 140,000 Btu/gal	32 cents/gal	22.8	27.4 (80% efficiency)	30.8 (65% efficiency)
Oil No. 6 150,000 Btu/gal	34 cents/gal	22.6	27.1 (80% efficiency)	30.5 (65% efficiency)
Gas 1 therm = 100,000 Btu	12 cents/therm 1/	12.0	14.4 (80% efficiency)	15.6 (70% efficiency)
Coal - hard Pittsburgh anthracite 13,000 Btu/lb	$50/ton	19	24.7 (70% efficiency)	28.5 (50% efficiency)
Coal - soft Illinois 11,400 Btu/lb	$35/ton	15	19.5 (70% efficiency)	22.5 (50% efficiency)
Propane - large user 85,000 Btu/gal	30 cents/gal	35.3	42.4 (80% efficiency)	45.9 (70% efficiency)

1/ Cost is per 100,000 Btu. One therm equals 100,000 Btu and also equals 100 cubic feet of gas. Where gas is sold per 1,000 cubic feet, the 12 cents-per-100-cubic-feet rate would become $1.20 per 1,000 cubic feet.

Source: The Florists' Review, Oct. 16, 1975, p. 26. Taken from Grower Talks, August 1975, by Paul Slaughter, Slaughter, Schaffer and Associates, Northbrook, Ill.

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EXAMPLE OF FUEL SAVINGS BY SCREENING AT NIGHT

$930 annual net savings by screening at night in 4,000 square foot	greenhouse normally using $1,500 worth of fuel

Photoperiod materials can be pulled for night insulation with a possible fuel savings of as much as 40 percent. Recent research studies (1975) at Pennsylvania State University, as reported by Dr. John W. White, showed a possible maximum of 62 percent savings in heat loss with the use of an aluminized nylon cloth pulled eave to eave on a clear night. Part of this saving was due to reduced convective heat losses, but part was also due to reduced conductive-radiative heat losses. Many fabrics are being evaluated in a continuation of this research (table 11).

Calculations:

$1,500 x .62 (percent savings) = $930 savings

Table 11--Reduction in electrical heat use on a clear night with various interior screening systems

Interior screening	Percent reduction in heat use
Control-no screen	0.0
Foylon eave to eave 1/	61.7
Al/Blac-eave to ridge 2/	38.8
Foylon eave to ridge	52.9

1/ Foylon, a hybrid fabric blending nylon cloth and aluminum foil is manufactured by Duracote Corp., 350 North Diamond Street, Ravenna, OH.

2/ To simplify information, trade names of products have been used. No endorsement of named products is intended nor is criticism implied of similar products not mentioned.

Source: See (14).

EXAMPLE OF THE RELATIONSHIP OF THE PRICE OF FUEL AND COST OF HEAT

Example: If you presently pay 20 cents per gallon for No. 2 fuel oil, you can pay: 21.4 cents per gallon for No. 6 C bunker oil, 13.1 cents per gallon for liquid propane, $1.19 per 1,000 cubic feet for natural gas, 33.32 per ton for coal--and the cost of your heat will be the same.

Table 12--Relationship between price of fuel and cost of heat 1/

Btu of heat produced by one cent of fuel	Fuel oil No. 2 (cents/gal)	Bunker oil No. 6 C (cents/gal)	Liquid propane (cents/gal)	Natural gas ($/1,000 ft³)	Coal ($/ton)
Btu		Cents		Dollars	
11,200	15	16.1	9.8	$ .89	$25.00
10,500	16	17.1	10.5	.95	26.67
9,882	17	18.2	11.1	1.0[illegible]	28.33
9,333	18	19.3	11.8	1.07	30.00
8,842	19	20.4	12.4	1.13	31.68
8,400	20	21.4	13.1	1.19	33.32
8,000	21	22.5	13.8	1.25	35.00
7,636	22	23.5	14.4	1.31	36.38
7,304	23	24.6	15.1	1.37	38.34
7,000	24	25.7	15.7	1.43	40.84
6,702	25	26.8	16.4	1.49	41.67
6,462	26	27.9	17.4	1.55	43.40
6,222	27	28.9	17.7	1.61	45.00
6,000	28	30.0	18.4	1.67	46.76
5,793	29	31.4	19.0	1.73	48.33
5,600	30	32.2	19.7	1.79	50.12

1/ Any price below those shown will result in a savings, and any higher price will result in a loss if the alternative fuels were used.

Source: John W. White, Professor of Floriculture, Pennsylvania State University, University Park, Pennsylvania.

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To conserve energy, you should first know how much electricity, gasoline, diesel, and other fuels you now use in your vegetable operations. Some of the vegetable operations which have electrical usage (primarily those involving packing, storage, and frost protection) may be hooked up to the same meter as the farm residence. In such instances, an amount of electric usage should be subtracted for that of the residence.

Table 13 should help you estimate the number of kilowatt hours you use in your residence. The amount of electrical energy used in a typical home for lighting and appliances is 400-600 kilowatt-hours per month. This figure includes an electric range but not electric water heaters. The amount of electricity required for the water heater varies with family size, composition, habits, and temperature of the water supply. (One long hot shower, 10 minutes, requires about 7 kilowatt-hours of electricity to heat the water used.) Also excluded from the above figure are kilowatt-hour estimates for heating and air conditioning. Oil or gas furnaces require approximately 0.6 kilowatt-hour of electricity for the fan, etc., for each gallon of fuel burned. If your house is heated electrically, you already know how that increases your electricity use.

The following set of recordkeeping charts should help you in determining your electricity and fuel use for each vegetable production task. You will then be able to identify those parts of your operation where you can save the most energy and money.

Much of the monthly energy use information for your farm can be obtained by reading your electric, gas (propane or natural gas), and gasoline or diesel fuel meters each month and subtracting the reading for the previous month. If you don't have a gas, gasoline or diesel fuel meter, you can use the amounts of energy purchased as shown on your gas, gasoline and diesel fuel bills. Although these may not be on a monthly basis, they should still provide a basis for estimating monthly and annual energy use.

Energy use recorder I has a column in which you can enter the date of purchase or the date your fuel supplier read the meter. Gasoline or diesel fuel use also can be recorded as you use it in your vehicles, tractors, or engines. You may already have this data recorded for your gas tax refund claim.

Energy use recorder II should help you in recording hours you use various electrical equipment each month. It also can be used for logging monthly fuel use (the number of gallons of gasoline each task requires).

Since farmers may have their household electricity on the same meter as the electricity used in farming, we are including the following table so the reader may estimate the electric power used in the home.

Table 13--Annual energy requirements of electricity by household appliances 1/

FOOD PREPARATION	Est. kWh consumed annually
Blender	15
Broiler	100
Carving knife	8
Coffee maker	106
Deep fryer	83
Dishwasher	363
Egg cooker	14
Frying pan	186
Hot plate	90
Mixer	13
Oven, microwave (only)	190
Range	
with oven	1,175
with self-cleaning oven	1,205
Roaster	205
Sandwich grill	33
Toaster	39
Trash compactor	50
Waffle iron	22
Waste disposer	30
FOOD PRESERVATION	
Freezer (15 ft^3)	1,195
Freezer (frostless 15 ft^3)	1,761
Refrigerator (12 ft^3)	728
Refrigerator (frostless 12 ft^3)	1,217
Refrigerator/Freezer	
(14 ft^3)	1,137
(Frostless 14 ft^3)	1,829
LAUNDRY	
Clothes dryer	993
Iron (hand)	144
Washing machine (automatic)	103
Washing machine (nonautomatic)	76
Water heater	4,811

COMFORT CONDITIONING	Est. kWh consumed annually
Air cleaner	216
Air conditioner (room)	860 2/
Bed covering	147
Dehumidifier	377
Fan (attic)	291
Fan (circulating)	43
Fan (rollaway)	138
Fan (window)	170
Heater (portable)	176
Heating pad	10
Humidifier	163
HOME ENTERTAINMENT	
Radio	86
Radio/record player	109
Television	
black and white	
tube type	350
solid state	120
color	
tube type	660
solid state	440
HOUSEWARES	
Clock	17
Floor polisher	15
Sewing machine	11
Vacuum cleaner	46

1/ When using these figures for projections, such factors as the size of the specific appliance, the geographic area of use, and individual usage should be considered.

2/ Based on 1,000 hours of operation per year. This figure will vary widely depending on area and specific size of unit. You can approximate the energy used in air conditioning by multiplying tons of capacity (12,000 Btu = 1 ton) times hours used. This will approximate kWh of electricity consumed.

Source: Electric Energy Association, 90 Park Ave., New York, N.Y. 10016

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For example, in plowing, an 80-horsepower crawler tractor pulling a 5-16" one-way mold board plow will use 5.363 gallons of diesel fuel per hour or 2.2 gallons per acre (table 14). It would take 44 gallons of diesel to plow a 20-acre field with the above equipment (2.2 gallons per acre times 20 acres equals 44 gallons of diesel fuel).

Table 14--Estimated energy required for various vegetable farm tasks

Task	Size of implement	Size of tractor	Gasoline		Diesel	
			Gallons per acre	Gallons per hour	Gallons per acre	Gallons per hour
Plow	5-16" mold board	80 hp	2.697	6.578	2.200	5.363
Disk	14' offset	80 hp	1.512	6.578	1.233	5.363
Land	10' x 40'	65 hp	1.638	5.284	1.210	3.905
Harrow	20' 5 spike	65 hp	1.056	5.284	.781	3.905
Plant	6-row 30' row	45 hp	1.528	3.821	1.042	2.606
Cultivate	6-row 30' row	45 hp	.764	3.821	.521	2.606
Harvesters:						
Potato	2-row	65 hp	5.028	5.284	3.709	3.905
	auxiliary motor	30 hp	2.284	2.405	--	--
Tomato	self prop. 1-row	--	10.688	3.750	--	--

Energy use recorder III is to assist you in estimating the number of kilowatt hours that you use in your vegetable operation. The conversion factors needed can be obtained from table 15. The schedule should be used as follows:

1. First, enter the horsepower of the motor for each piece of electrical equipment used (for example, 5 hp).

2. Next, select the correct conversion factor for the size motor from table 15 (for example, 6.440 kilowatts are required per hour of use for a 5-hp motor).

3. Enter the hours of use per unit of time (for example, 40 hours per month).

4. Multiply 2 and 3 to get your usage per unit of time (for example, 6.440 x 40 = 257.6 kilowatt hours of usage per month).

5. Add the amount used by each motor or piece of equipment per unit of time to get your total electrical usage (this could be 500 to 1,000 kWh below the amount of your monthly bill because the bill usually includes your residential use too).

Energy use chart IV may be helpful for estimating your gasoline usage by task performed. It could be used in conjunction with your records on refueling to develop data for energy use recorder II. The number of gallons of fuel used by each vehicle and each task is valuable information for determining which ones are more efficient.

Although keeping energy use records takes time, the savings you could realize from recognizing problem areas should save you enough energy dollars to pay you for your trouble. It will also help you in evaluating your equipment and present operation. If you save just one kilowatt hour per day, you will save $14.60 per year (at $0.04 per kWh), not bad for the recordkeeping involved. You can save energy and money by knowing how and where you use the energy you purchase.

Energy Use--Recorder I

Date	Electricity (kWh hr)	Gasoline (gal)	Diesel (gal)	Fuel oil (gal)	LP gas (gal)	Nat. gas (1,000 ft^3)
January						
February						
March						
April						
May						
June						
July						
August						
September						
October						
November						
December						

Energy Use--Recorder II

Type of equipment	Average amount used per month 1/												Total for year
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	

1/ For example, number of hours per month your sprinkler system runs; gallons of gasoline used in plowing.

Energy Use--Recorder III

Type of equipment	Horsepower of motor	Conversion factor	Use per unit of time	kWh per unit of time

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Energy Use--Recorder IV.

Task performed	Date	Tractor or engine used	Hours used	Fuel used in performing task

Table 15--Kilowatts required to develop one horsepower with electric motors of various sizes for single and three-phase electric service 1/ 2/

Horsepower rating of the electric motor	Kilowatts required per hour of use	
	With single-phase service	With three-phase service 3/
1/4	.667	--
1/3	.828	--
1/2	1.127	.762
3/4	1.587	1.067
1	1.840	1.334
1-1/2	2.300	1.905
2	2.720	2.476
3	3.909	3.531
5	6.440	5.715
7-1/2	9.203	8.376
10	11.500	10.290
40	--	39.640

1/ Adopted from Farrell, (7), p. 53

2/ For motors with normal torque and speed characteristics. These are full load ratings that ignore the power factor; (which lowers the kilowatts required per hour of use) plus start-up current demand and other factors which increase the kilowatts demanded. Motors built for especially low speeds or high torque may require more current. If a specific motor is of concern, check the actual name-plate data.

3/ Where three-phase service is available.

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BTU ACCOUNTING

The producer can convert the quantities of different types of fuel used on his farm to a common measure, the Btu of energy used with the aid of the conversion factors in the tabulation below. The producer may find this measure useful when comparing total energy use from year to year or month to month or when comparing alternative equipment or practices in terms of energy use where more than one type of fuel is involved. For example, if one used 4,000 gallons of propane, 500 gallons of regular gasoline, and 25,000 kilowatt hours of electricity last year, the total energy use in Btu would be 515.3 million Btu. The calculations follow:

4,000 gallons propane x 92,000 Btu/gal	= 368,000,000
500 gallons reg. gasoline x 124,000 Btu/gal	= 62,000,000
25,000 kWh x 3,412 Btu/kWh	= 85,300,000
Total Btu	515,300,000

Btu Conversion Factors

Gasoline (regular)	6.12 lb/gal	124,000 Btu/gal
Diesel fuel (no. 2)	7.07 lb/gal	140,000 Btu/gal
Propane	4.25 lb/gal	92,000 Btu/gal
Natural gas		1,067.5 Btu/gal
Natural gas		100,000 Btu/therm
Fuel oil (no. 2)	7.2 lb/gal	138,500 Btu/gal
Coal (anthracite)		25,894,000 Btu/ton
Coal (high-volatile bituminous)		23,734,000 Btu/ton
Coal (lignite)		13,894,000 Btu/ton
Electricity		3,412 Btu/kWh

Sources: Environmental Engineering Analysis and Practice, Burgess H. Jennings, International Textbook Company, Scranton, PA, 1970 and Tractors and Their Power Units, by Barger, Liljedahl, Carleton and McKibbon, 2nd ed., Wiley and Sons, N.Y., 1963.

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