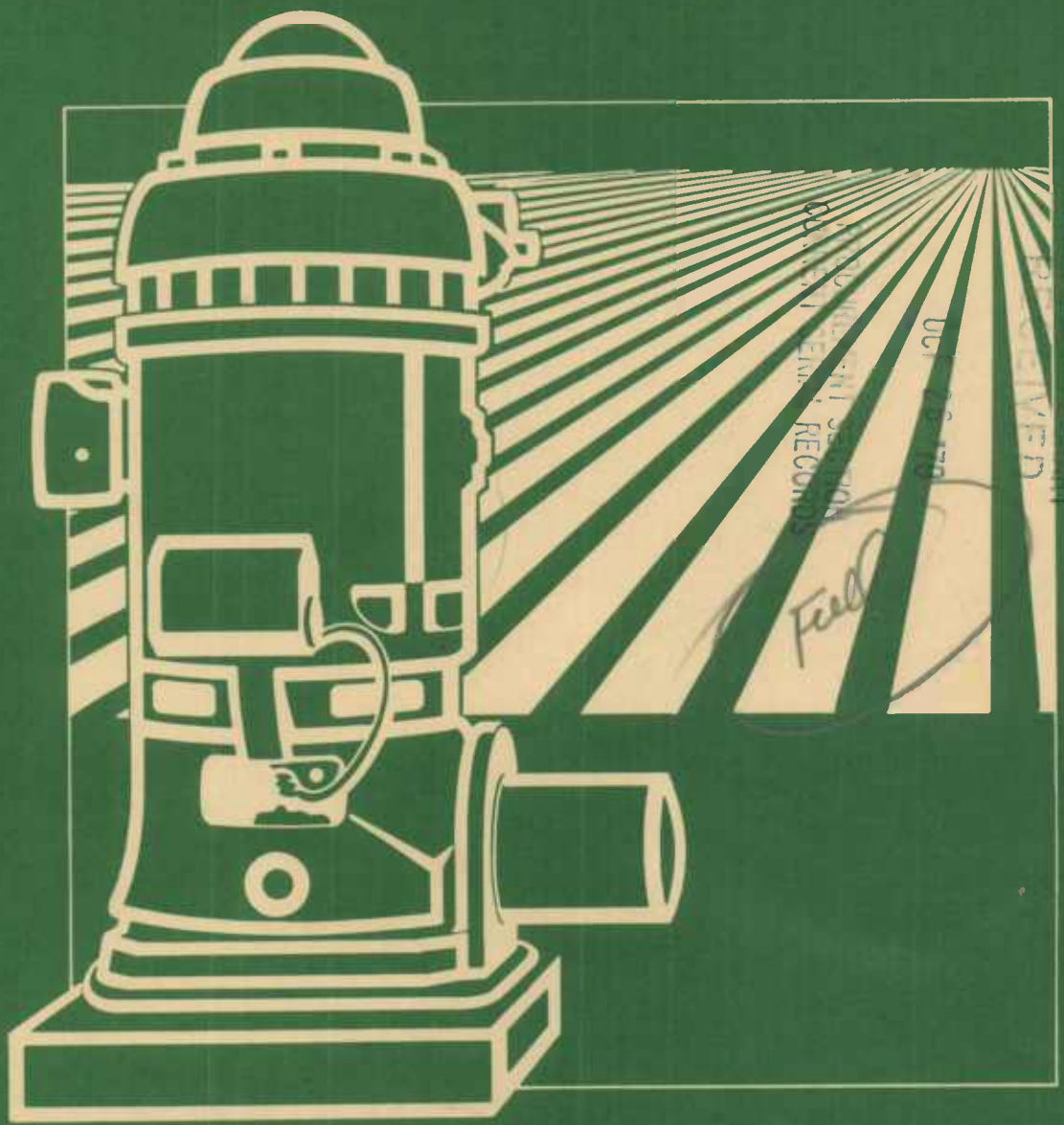
Energy and U. S. Agriculture: Irrigation Pumping, 1974-77

Gordon Sloggett



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ABSTRACT

Land irrigated with onfarm pump water increased by more than 5 million acres from 1974 to 1977. Energy costs to pump the water increased from $570 million to more than $1 billion during the period. Yet increased costs failed to slow pump irrigation. Electricity was used most to power pumps for irrigated acreage, followed by natural gas, diesel, liquified petroleum gas (LPG), and gasoline. Diesel used to pump irrigation water about doubled from 1974 to 1977, with modest increases for electricity and natural gas. The use of LPG and gasoline declined.

Keywords: Irrigation, Energy.

PREFACE

This report is an update of Energy in U.S. Agriculture: Irrigation Pumping, 1974 (AER-376). The update is necessary because of the changes in onfarm pump irrigation from 1974 to 1977. The author wishes to thank each State irrigation expert who provided valuable data needed to make the many estimates for this work. The author takes responsibility for the final estimates.

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SUMMARY

U.S. farmers increased onfarm-pump irrigation by about 5 million acres from 1974 to 1977. Electricity powered irrigation pumps on the most acreage, followed by natural gas, diesel, liquified petroleum gas, and gasoline. Diesel fuel use grew the most rapidly.

Onfarm-pump irrigation amounted to 23 percent of total energy used onfarm for crop production in 1974--the last year for comparable statistics. It is likely that this relationship still exists, considering the increased acreage of onfarm-pump irrigation.

The cost of energy for onfarm-pump irrigation rose from $570 million to more than $1 billion during 1974-77. The sharp increase was due to more acres irrigated and much higher energy prices.

Pump irrigation experienced rather rapid growth in spite of higher energy prices. The cost of energy for pumping irrigation water is a rather small portion of total crop production costs in many pump-irrigation areas. This fact, coupled with rather favorable crop prices during 1974-77, apparently allowed pump irrigators to expand.

Energy and U.S. Agriculture: Irrigation Pumping, 1974-77

by Gordon Sloggett*

INTRODUCTION

Land irrigated in the United States with the aid of energy-using pumps on farms and ranches increased from 35 to 40.3 million acres from 1974 to 1977. Irrigated farms accounted for about 27 percent of 1974 farm sales, according to the Census of Agriculture, and at least as much of 1977 sales. Thus, the importance of irrigated agriculture to U.S. food production cannot be overlooked.

Pumping irrigated water approached 23 percent of the onfarm energy used for agricultural production in 1974, the last year for comparable statistics. 1/ Substantial price increases and possible energy shortages heightened the importance of the types, amounts, and geographical patterns of energy consumed in pumping irrigation water.

This report is the second concerning energy used to pump and distribute farm irrigation water; the first report addressed 1974, while this one shows the change in energy use from then until 1977. 2/ These estimates take in the entire country, farm production regions, and individual States, including Alaska and Hawaii (fig. 1).

To estimate energy use, it was necessary to determine: (1) acreage irrigated from groundwater and from pumped surface water, (2) feet of lift required for grounwater and pumped surface water, (3) types of distribution systems used to apply water to fields, (4) types of power units used for pumping; and (5) acre-feet of water applied. These all were determined on a statewide basis. Estimates were also obtained of pumping unit efficiency and pressure needed to operate distribution systems. These factors were determined and applied uniformly for all States.

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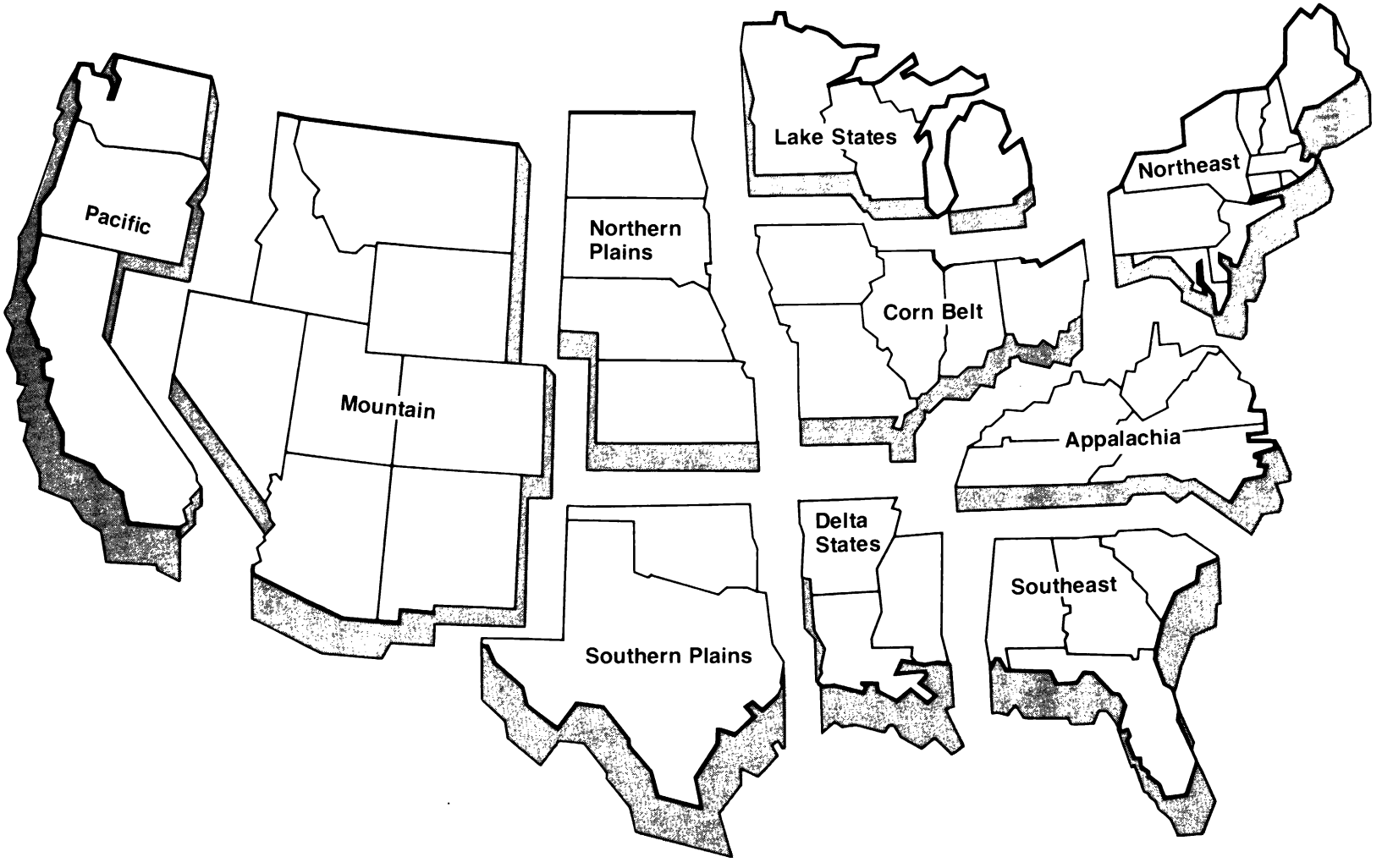
1/ Energy and U.S. Agriculture: 1974 Data Base, Federal Energy Administration, Office of Conservation, and U.S. Department of Agriculture, Economic Research Service, April 1977.

2/ Energy used by irrigation organizations to deliver water to farms is not included in this report. The Bureau of Reclamation used an estimated 3.6 billion kWh to pump irrigation water in 1974. (Dan Dvoskin, Ken Nicol, and Earl Heady, "Energy Use for Irrigation in the Seventeen Western States," Center for Agricultural and Rural Development, Iowa State University, Ames, July 1975.) This would be in addition to 16 billion kWh used for onfarm pumping of irrigation water in 1974 (table 5, p. 4).

Figure 1

Farm Production Regions



Data used in making estimates for 1974 were sent back to State irrigation experts for updating to 1977. 3/ Procedures for estimating the new data remained the same. However, studies of energy used in irrigation became available for California, Idaho, Oregon, and Washington after the 1974 estimates were made. In those States, changes were made to the 1974 estimates using the Knutson and King data. 4/ Electricity consumption for Kansas irrigation pumping also cited other data. 5/

The results presented in this report are based on estimates of statewide averages from various sources. They are not the result of scientific sampling; therefore, no procedure is available to determine the statistical accuracy of the results. These data, however, are considered reasonable estimates of the extent of pump irrigation. They indicate shifts that occurred with the use of different types of energy for pumping.

Acreage irrigated from groundwater.--Water in aquifers is commonly referred to as groundwater and must be pumped from wells for irrigation. Several sources were used to estimate acreage irrigated from groundwater. Several States conduct surveys or have other procedures to estimate acreage irrigated from groundwater. These estimates were used where available. Otherwise, total acreage irrigated in 1974 came from the 1974 Irrigation Survey in the Irrigation Journal. 6/ The proportion of acreage irrigated from groundwater as published by the U.S. Geological Survey (USGS) was then multiplied by total acreage irrigated to get an estimate of acreage irrigated from groundwater. 7/

Acreage irrigated from pumped surface water.--Surface water is in lakes, streams, or rivers. Some of this water is pumped onto fields for irrigation, but no data source was found for acres irrigated in this manner. Therefore, each State irrigation expert was asked to estimate how many acres were irrigated with water pumped from surface sources.

Feet of lift.--Feet of lift is the height water must be raised from its source to the field for application. State irrigation experts were asked for a weighted statewide average feet of lift for irrigation wells in their State. They were also asked for a weighted average feet of lift for onfarm-pumped surface water. The weight was approximate acreage irrigated according to pumping depths.

Distribution systems and power units.--Major water distribution systems include various sprinkler and flooding methods used to put water on fields. Power units considered were electric, diesel, gasoline, natural gas, and liquified petroleum gas (LPG). Information on numbers of distribution systems and types of power units in the

3/ A list of irrigation experts contacted for State estimates appears in Appendix III.

4/ G.D. Knutson and others, "Pumping Energy Requirements for Irrigation in California," Division of Agricultural Sciences, University of California, Special Publication, 3215. Larry King and others, "Energy and Water Consumption of Pacific Northwest Systems," Department of Agricultural Engineering, Oregon State University, Corvallis, BNWL-RAP-19-UC-11.

5/ John A. Anschutz, "Summary of 1977 Electrical Pumping Loads in Kansas," Department of Agricultural Engineering, Kansas State University, Manhattan.

6/ Irrigation Journal, Brantwood Publications, Inc., Elm Grove, Wisc., Nov.-Dec. 1974.

7/ C. Richard Murray and E. Bodette Reeves, Estimated Use of Water in the U.S. in 1970. USGS Circ. 676, U.S. Department of Interior, Geological Survey, 1972, pp. 22-23.

1974 Irrigation Survey in the Irrigation Journal were used where available. 8/ When the information was not available, knowledgeable people in the States were asked for estimates.

Acre-feet applied.--USGS data provided estimates of the quantity of water applied per acre; each State irrigation expert was asked to review the estimates. 9/ Several experts offered alternative estimates and, in some instances, USGS data were modified.

Pumping unit efficiency.--A new irrigation pump has an efficiency of about 75 percent (efficiency is a measure of energy input to water output). Efficiency declines as wear occurs. Irrigation engineers in several States having significant amounts of groundwater were asked to estimate average operational pump efficiency. Since their estimates varied, coefficients for three pump efficiency ratings were used to provide three estimates of energy consumption (table 1). Power units operating the pumps were assumed to be in average condition. All energy estimates in this report assume a 60-percent water pump efficiency and power units in average operating condition. Estimates of energy consumption for 55-percent pump efficiency may be determined by increasing the 60-percent estimates by 7.62 percent. Estimates for 65-percent efficiency may be made by decreasing the 60-percent estimates by 7.63 percent. All energy estimates in this report may be adjusted similarly.

Distribution system pressure requirements.--State engineers also were asked for pounds per square inch (PSI) requirements for various irrigation distribution systems. A middle range was selected because estimates varied.

Type of system	PSI
Big gun	165
Center pivot	100
Other sprinkler	70
Surface distribution	5

The estimates include the pressure required to overcome friction loss in lines from the pump through the distribution system and to apply water to the land. The pressure required to operate the system is in addition to that needed to get the water to ground level.

RESULTS

Study results are summarized for the Nation, as well as on a State and regional basis. Energy estimates are based on the number of acres irrigated with pumped water and quantity of water pumped. A review of estimates of irrigated acreage in the

8/ It was necessary to assume that each type of power unit pumped an equal amount of water in order to estimate area irrigated by type of energy. However, in States where natural gas is used extensively, those wells typically irrigate more acreage than non-natural-gas-powered wells. Therefore, the following assumptions were made: natural gas supplied power for 35 percent of the acreage irrigated in Arizona, and that each natural-gas-powered well irrigated 200 acres in Kansas, 120 acres in Texas and New Mexico, and 150 acres in Oklahoma. The remaining acreage in those States was then divided proportionately with Irrigation Journal figures.

9/ Murray and Reeves, op. cit.

Table 1--Fuel energy requirements for pumping 1 acre-foot of water at 1 pound per square inch (PSI)

Energy	Unit	Percent efficiency		
		65	60	55
		Unit fuel/acre-foot/PSI 1/		
Electricity	kWh	4.8544	5.25950	5.66030
Diesel	Gallon	.4000	.43300	.46590
Gasoline	do.	.5004	.54170	.58300
Natural gas	MCF 2/	.0625	.06771	.07287
LPG	do.	.6254	.67710	.72870

1/ PSI equals pounds per square inch.
2/ MCF equals 1,000 cubic feet.

Source: Material provided by Delbert Schwab, agricultural engineer, Oklahoma State University, Stillwater.

Statistical Reporting Service (now part of the Economics, Statistics, and Cooperatives Service) June enumerative surveys indicated that the estimates given by irrigation experts in the States tended to be on the maximum side of a reasonable range of estimated acres irrigated. Thus, there may be fewer acres than those cited in table 2. Therefore, the energy estimates also may be overstated.

Area Irrigated

Groundwater continues to be the major source of onfarm-pumped irrigation water, and 85 percent of the growth from 1974 to 1977 came from groundwater sources. Acreage irrigated from groundwater increased by 4.5 million acres, with Nebraska and Kansas accounting for 2.4 million acres. Georgia and Florida accounted for 400,000 of the 700,000-acre increase irrigated with onfarm-pumped surface water. Thus, growth in area irrigated with onfarm-pumped water was rather concentrated.

Distribution Systems

Big-gun-type sprinklers brought the largest percentage increase among types of distribution systems (table 3). Center pivots provided the largest increase in acreage irrigated. Nebraska alone experienced a 1.2 million-acre increase in center pivot irrigation from 1974 to 1977, according to the University of Nebraska's Remote Sensing Center. Sprinkler irrigation accounted for 75 percent of the overall increase in irrigation for the period.

Acres irrigated with gravity distribution systems had the smallest percentage increase from 1974 to 1977. These systems, generally the least expensive method of irrigating, were the first to be developed. They require relatively flat nonsandy land and an adequate water supply, so most of the areas in the Nation that can benefit from

Table 2--Acreage irrigated with onfarm-pumped water, by source of water

Item	1974	1977	Change	Percentage of total change
	Million acres			Percent
Groundwater	26.1	30.5	4.4	85
Surface water	7.3	8.0	.7	13
Both	1.7	1.8	.1	2
Total	35.1	40.3	5.2	100

Table 3--Acreage irrigated with onfarm-pumped water, by type of distribution system

Distribution system	1974	1977	Change	Percentage change, 1974 to 1977
	Million acres			Percent
Big gun	0.6	1.3	0.7	117
Center pivot	3.7	6.2	2.5	72
Other sprinkler	7.6	8.1	.5	7
Gravity	23.2	24.7	1.5	6
Total	35.1	40.3	5.2	15

irrigation and have these two attributes were developed before 1974. The widespread adoption of automatic sprinkler systems, such as center pivots, big gun, and side roll, in the sixties and seventies has been on rolling or sandy land with adequate water supplies for irrigation.

Types of Energy Used

There was an increase in the use of electricity, diesel, and natural gas to pump irrigation water during 1974-77, while gasoline and LPG use declined (table 4). The trend is unmistakable. The use of diesel grew most rapidly, followed by electricity and natural gas.

Natural gas usually is the least expensive fuel for pumping irrigation water, but it is not available in many areas. Some gas companies are not accepting new irrigation customers where gas is available. Electricity is usually the next best alternative.

Table 4--Acreage irrigated with onfarm-pumped water, by type of energy

Energy	1974	1977	Change	Percentage change, 1974 to 1977
	Million acres			Percent
Electricity	15.7	18.3	2.6	17
Diesel	3.9	6.8	2.9	74
Gasoline	1.5	1.3	-.2	-13
Natural gas	10.6	11.5	.9	8
LPG	3.3	2.4	-.9	-27
Total	35.1	40.3	5.2	15

Many electric utilities are at capacity, however, and are not anxious to add to peak loads with more irrigation customers. There was not a shortage of diesel fuel or engines, and being the next best alternative, diesel fuel had the most rapid growth from 1974 to 1977.

Quantity of Energy Used

The overall increase in energy used for onfarm-pump irrigation (table 5) reflects not only more acreage irrigated, but a greater use of sprinklers. Sprinklers irrigated 75 percent of the increased acreage, though they used much more energy than gravity-flow irrigation systems. The use of diesel fuel for onfarm-pump irrigation doubled from 1974 to 1977. All areas of the United States except the Mountain and Pacific regions showed significant gains in diesel fuel use (appendix table 4).

Costs of Energy Used

The 83-percent increase in spending for energy for onfarm pumping of irrigation water from 1974 to 1977 (table 6) reflects not only increased energy use, but much higher prices. Electricity was sharply higher everywhere except in the Pacific and Mountain regions (appendix table 8). A natural gas price of 75 cents per million cubic feet (MCF) was assumed in 1974 for all States because prices were not generally available at that time. The 1974 estimate may have been a little high for some States; 1977 prices were much higher in nearly every State. Diesel, gasoline, and LPG were also higher.

OBSERVATIONS AND IMPLICATIONS

Two general conclusions may be drawn from the change in pump irrigating between 1974 and 1977: the acreage and the cost of energy for onfarm-pump irrigation have increased. Few farmers stopped irrigating despite rising energy costs; in fact, irrigated acreage expanded.

Table 5--Quantity of energy used for onfarm-pumped irrigation water

Fuel	Unit	1974	1977	Change	Percentage change, 1974 to 1977
		Units of fuel			Percent
Electricity	Bil. kWh	16	19	3	19
Diesel	Mil. gal.	175	350	175	100
Gasoline	do.	65	78	13	20
Natural gas	Mil. MCF	132	149	17	13
LPG	Mil. gal.	238	217	-21	-9

Table 6--Total cost of energy for onfarm-pumped irrigation water

Energy	1974	1977	Change	Percentage change, 1974 to 1977
	Million dollars			Percent
Electricity	308	588	280	91
Diesel	62	156	94	152
Gasoline	31	37	6	19
Natural gas	101	187	86	85
LPG	68	73	5	7
Total	570	1,041	471	83

Average prices of energy in the United States about doubled from 1973 to 1977 (table 7). Natural gas showed the largest percentage increase, but it was still the lowest cost energy used for pumping irrigation water (table 8). Part of the reason these higher energy prices have not slowed the development of pump irrigation may be seen by comparing the cost of energy for irrigation with the total cost of irrigated crop production.

The cost of natural gas to pump irrigation water for Nebraska gravity-flow irrigated corn increased from less than 2 percent of production costs in 1973 to only about 5 percent of 1977 production costs. A 5-cent-per-bushel increase in the price of 130-bushel-per-acre corn from 1973 to 1977 would pay for the entire $6 increase in the cost

Table 7--Selected energy prices in the United States 1/

Item	Unit	1973	1974	1975	1976	1977
		Dollars per unit				
Electricity	kWh	0.023	0.027	0.030	0.033	0.035
Diesel	Gal.	.23	.37	.39	.41	.45
Gasoline	do.	.33	.47	.50	.54	.57
Natural gas 2/	MCF	.50	--	--	--	1.50
LPG	do.	.20	.30	.30	.33	.39

1/ Agricultural Statistics, U.S. Dept. of Agr., 1972-77.
2/ Estimated.

Table 8--Production costs per acre for irrigated corn in Nebraska and Oklahoma

Item	South Central Nebraska 1/		Oklahoma Panhandle 2/	
	Gravity flow	Center pivot	Gravity flow	Center pivot
	Dollars			
Production cost 3/	183.00	192.00	215.00	218.00
Irrigation fuel cost: 4/				
Electricity--				
1973	10.26	24.72	19.18	33.63
1977	15.61	37.62	29.20	51.20
Diesel--				
1973	8.81	21.23	16.47	28.88
1977	17.23	41.52	32.23	56.52
Natural gas--				
1973	2.98	7.18	5.41	9.48
1977	8.94	21.54	16.25	28.50

1/ The "Nebraska Farmer," June 4, 1977, VI-1.
2/ Okla. State Univ., Dept. of Agri. Econ., Budget Record No. 6667, February 1977.
3/ Exclusive of irrigation fuel and land charges. Feet of lift is 115 feet for Nebraska and 215 feet of Oklahoma.
4/ Prices used from table 7.

of natural gas to pump irrigation water. At the other extreme, the energy cost of diesel fuel for Oklahoma gravity-flow irrigated corn increased from less than 8 percent to about 15 percent of production costs from 1973 to 1977. It would take only a 12-cent price increase in 130-bushel-per-acre corn to overcome the increased cost of energy for pumping irrigation water. Using the same analysis for center pivot irrigation, corn price increases of 11 and 21 cents per bushel would cover the price increase of natural gas in Nebraska and diesel in Oklahoma, respectively.

The two preceding examples are typical for the Great Plains where most of the increase in onfarm-pump irrigation occurred from 1974 to 1977. While it is true that energy prices have increased significantly, relatively favorable crop prices during most of the period offset the increased energy prices. The seasonal average U.S. price for corn from 1968 to 1972 was $1.25, but the average was $2.35 from 1972 to 1977. Increased energy prices reduced pump-irrigator profits, but that did not deter farmers from irrigating or even expanding irrigation.

COST REDUCTION ALTERNATIVES

Pump irrigators hold little control over crop or energy prices, and they cannot be sure that crop prices will continue to cover projected increases in energy costs. They do, however, have some alternatives to help overcome the increasing cost of energy. They can: (1) irrigate more efficiently and use less water and energy, (2) grow crops that use less water, (3) use a less expensive energy source, or (4) stop irrigating.

Efficiency

Many pump irrigators could use less water without reducing yields by using either more timely applications of water or tailwater recovery systems, or both. Many irrigation pumping plants--pump and engine--operate below attainable efficiencies, thus causing longer than necessary engine operating time. Pumping less water or reducing engine operating times will lower energy requirements to help offset increased energy costs. However, neither improvement can be accomplished without substantial cost; therefore fuel cost savings must offset the cost of the improvement for pump irrigators to make the change.

Reduced Water Use

A farmer may switch to a crop that requires less water if he is irrigating efficiently but still losing ground to higher energy prices. A typical crop change in the Great Plains would be to substitute wheat for corn. The pump irrigator's decision to change to a crop using less water would depend on many factors, including the relative profitability of the alternate crop and the equipment complement needed for that crop. Hence, changing crops may not be a viable alternative.

Cheaper Energy Sources

Changing to another energy source involves several factors other than price. These include accessibility to the source, future availability of that source, and the capital cost of changing.

Electricity and natural gas are the two energy sources that would provide some accessibility problems for pump irrigators, because the type of electricity and power

lines needed for large pump motors are not always available at the well site. Building a power line increases capital costs and may eliminate any economic advantages of shifting to electric power. Only those pump irrigators who have access to pipelines can choose natural gas as an alternative energy source; but many pump-irrigation areas of the country do not have natural gas pipelines. Areas that have access to pipelines generally use natural gas, because it is the least expensive energy source for pump irrigators.

A decision to change energy sources will depend on future availability of that source, even if the pump irrigator is located close to all possible energy sources. Since many electric utilities are operating at or near capacity and pump irrigators add to peak load periods, some electric utilities are not anxious to add irrigators because of the high cost of adding generating capacity. Many utilities place an annual limit on the number of new irrigators they will add to their distribution system. Thus, electricity may not be available to all pump irrigators.

Natural gas for irrigation is a special case with respect to future availability because its use is regulated by the Federal Power Commission. Some have proposed lowering the priority for irrigation into an interruptible service classification. Yields could be reduced significantly if service was interrupted during the peak irrigation season. Thus, the possibility of an unfavorable decision by the Federal Power Commission weighs heavily when deciding to switch energy sources.

Another factor influencing the decision to change energy sources is the capital investment, or disinvestment. A pumping plant, replaced because of high energy cost, would have little salvageable value, since there would be little demand for such a unit.

The capital investment of a new unit is substantial considering the near-zero salvage value of the replaced pumping unit. Using the Nebraska and Oklahoma examples in table 8, investment costs in new pumping plants would be as follows (center-pivot pumping plant in parentheses):

	Nebraska	Oklahoma
Electric	$4,500 (6,850)	$5,700 (8,850)
Diesel	6,000 (9,500)	9,300 (12,400)
Natural gas	5,400 (7,400)	7,900 (9,120)

These are estimates based on irrigation cost data used at Oklahoma State University and include the power unit, pump, gearhead, and pump drive shaft. 10/

The difference between natural gas versus electricity and natural gas versus diesel in per-acre irrigation fuel costs for Oklahoma is $12.95 and $15.98, respectively, for gravity-flow irrigation systems (table 8). Assuming a 100-acre irrigated field, it would take 9.3 years ($7,900 ÷ $12.95) of energy savings to recover the investment cost amortized at 10 percent when converting from electricity to a natural gas. Energy cost savings by converting from diesel to natural gas would cover the

10/ D.D. Kletke and others, Irrigation Cost Program, Research Report, P770, Oklahoma State University, Agricultural Experiment Station, Stillwater, May 1978.

investment cost in only 7.2 years ($7,900 ÷ $15.98). In Nebraska, it would take 17.4 and 11.1 years of energy savings to cover the cost of converting to natural gas from electricity and diesel. Thirty years of energy savings would be required to convert from diesel to electricity in either Nebraska or Oklahoma.

The difference between natural gas and electricity, and natural gas and diesel in per-acre irrigation fuel costs of Oklahoma is $22.70 and $28.02, respectively, for center-pivot irrigation systems (table 8). Center-pivot irrigation systems require more energy to operate and, thus, the potential fuel savings by changing energy sources are greater. The payout period for a change to natural gas from either electricity or diesel would be 3.9 years and 3.6 years in Oklahoma, based on the same analysis for gravity systems above (except using 130 acres). Nebraska's payout period would be 4.5 years and 3.5 years for the same change. More than 20 years would be required to cover the cost of changing to electricity from diesel in either State.

Conversion to natural gas seems like a viable option for those pump irrigators who could make such a change. However, most irrigators already took the natural gas option when they installed their pumping unit. Converting to electricity from diesel is doubtful as a feasible means of overcoming higher energy prices. Of course, all of the above is true only for the relationships that exist in 1977 energy prices. If the price relationships between natural gas, electricity, and diesel change in the future, then the relative price advantage or disadvantage of each also will change.

The pump irrigator, in evaluating alternatives to higher energy prices, first should improve irrigation efficiency. This would be the least expensive approach in terms of capital and management. The next alternative should be to irrigate crops with a lower water requirement to lessen energy costs. If 1977 energy price relationships hold, the only alternative lower cost energy choice would be natural gas, where available. Again, this would not likely be an alternative for many pump irrigators. If all else fails, the irrigator should discontinue irrigation and shift to dryland farming.

APPENDIX I

PROCEDURE

The method used to estimate energy used for irrigation was to determine how much water was pumped, and then how much effort or work was required to pump and distribute that amount of water. The next step was to determine how much energy was needed to perform that amount of work. This was accomplished separately for groundwater and surface water.

The quantity of water pumped in each State was determined as follows:

$$AF_i = (AI_i)\ (AFA_i) \quad i = 1, \ldots 50, \tag{1}$$

where

AF_i = acre-feet of water used from groundwater (pumped surface water) sources in ith State,

AI_i = acres irrigated from groundwater (pumped surface water) in ith State, and

AFA_i = average annual acre-feet applied per acre in ith State.

The work required to pump the water to ground level is measured in psi. The psi is determined by dividing the feet of lift by 2.31. The total work (acre-feet psi) required to get the groundwater used for irrigation in each State to the surface is determined by:

$$TPW_i = (AF_i)\ (PW_i) \quad i = 1, \ldots 50, \tag{2}$$

where

TPW_i = total work required to get water to ground level in the ith State,

AF_i = equation (1), and

PW_i = PSI required to get water to ground level for the average feet of lift in ith State.

Work required to distribute groundwater (pumped surface water) in each State is estimated as follows:

$$TPD_i = AF_i \sum_{j=1}^{4} (DP_{ij})\ (PD_i) \tag{3}$$

$i = 1, \ldots 50$ States

$j = 1, \ldots$ four types of irrigation systems,

where

TPD_i = total work required to distribute groundwater (pumped surface water) in the ith State,

AF_i = equation (1),

DP_{ij} = percentage of acres irrigated in ith State by jth system, and

PD_j = pressure required to operate jth system.

The sum of equation (2) plus equation (3) is the total work (acre-feet psi) to irrigate with groundwater (pumped surface water) in a State. The amount of energy consumed to pump and distribute the irrigation water by each energy source is estimated as follows:

$$ER_{ij} = [TPW_i + TPD_i] [(ET_{ij}) (ETR_j)] \quad (4)$$

$i = 1, \ldots 50$ States

$j = 1, \ldots$ five types of power units,

where

ER_{ij} = energy required in ith State by the jth power unit,

TPW_i and TPD_i = equations (2) and (3),

ET_{ij} = proportion of acres irrigated in ith State with jth power units,

ETR_j = amount of fuel required to pump one acre-foot of water at one (1) PSI with jth power unit.

Equation (4) assumes that the various distribution systems use equal proportions of the types of power units in the State, that is, sprinkler systems power units are distributed proportionally the same as gravity-flow power units.

Appendix table 1--Feet of lift required for pumping and acre-feet of irrigation water applied by region and State 1/

Region and State	Groundwater		Surface water		Acre-feet applied
	1974	1977	1974	1977	
	Feet of lift				Acre-feet
Northeast:					
Connecticut	80	80	20	20	0.42
Delaware	50	50	20	15	.58
Maine	0	0	15	15	.20
Maryland	50	20	50	20	.85
Massachusetts	80	80	10	10	.42
New Hampshire	0	0	20	20	.42
New Jersey	175	175	20	20	.60
New York	80	80	25	25	.42
Pennsylvania	150	150	35	30	.42
Rhode Island	0	0	20	20	.42
Vermont	0	0	20	20	.42
Lake States:					
Michigan	100	100	20	20	.67
Minnesota	70	70	10	10	.75
Wisconsin	75	75	20	15	1.00
Corn Belt:					
Illinois	55	55	0	15	.50
Indiana	150	150	25	25	.83
Iowa	35	35	25	15	.58
Missouri	75	75	25	25	.50
Ohio	100	100	25	25	.50
Northern Plains:					
Kansas	180	180	15	15	1.70
Nebraska	100	100	20	20	1.75
North Dakota	75	75	35	35	1.00
South Dakota	70	80	150	150	1.25
Appalachia:					
Kentucky	75	75	25	25	.33
North Carolina	150	150	35	35	.50
Tennessee	100	100	25	25	.58
Virginia	12	12	30	30	.83
West Virginia	0	0	25	25	.45

Continued--

See footnote at end of table.

Appendix table 1--Feet of lift required for pumping and acre-feet of irrigation water applied by region and State 1/--Continued

Region and State	Groundwater		Surface water		Acre-feet applied
	1974	1977	1974	1977	
	Feet of lift				Acre-feet
Southeast:					
Alabama	150	150	40	40	0.50
Florida	85	95	5	6	1.00
Georgia	250	250	15	15	1.30
South Carolina	100	100	20	20	1.00
Delta States:					
Arkansas	45	60	15	15	1.83
Louisiana	100	100	10	10	1.83
Mississippi	110	50	15	15	2.00
Southern Plains:					
Oklahoma	200	200	20	16	1.83
Texas	200	200	40	40	1.50
Mountain:					
Arizona	350	375	0	0	5.40
Colorado	115	120	10	10	1.10
Idaho	266	266	0	11	3.20
Montana	100	100	60	60	2.70
Nevada	100	100	20	20	5.00
New Mexico	250	250	5	5	2.75
Utah	225	225	15	15	3.00
Wyoming	150	150	25	25	1.83
Pacific:					
California	110	110	10	10	3.17
Oregon	266	266	11	11	3.00
Washington	287	287	26	26	4.20
Alaska	100	100	10	10	.25
Hawaii	700	700	10	10	6.00
Total					

1/ Estimated statewide average weighted by number of wells at each depth.

Appendix table 2--Acreage irrigated with onfarm-pumped water by source of water and region and State

Region and State	Groundwater		Surface water		Both		Total	
	1974	1977	1974	1977	1974	1977	1974	1977
	1,000 acres							
Northeast	137	153	155	151	0	0	292	304
Connecticut	1	2	8	10	0	0	9	12
Delaware	20	26	6	4	0	0	26	30
Maine	0	0	7	7	0	0	7	7
Maryland	8	17	16	16	0	0	24	33
Massachusetts	1	1	31	31	0	0	32	32
New Hampshire	0	0	6	7	0	0	6	7
New Jersey	75	75	30	30	0	0	105	105
New York	30	30	29	24	0	0	59	54
Pennsylvania	2	2	17	17	0	0	19	19
Rhode Island	0	0	3	3	0	0	3	3
Vermont	0	0	2	2	0	0	2	2
Lake States	253	605	158	146	0	0	411	751
Michigan	56	56	53	53	0	0	109	109
Minnesota	82	352	50	45	0	0	132	397
Wisconsin	115	197	55	48	0	0	170	245
Corn Belt	274	490	96	135	0	7	370	632
Illinois	50	40	0	13	0	0	50	53
Indiana	19	36	14	20	0	2	33	58
Iowa	50	150	7	15	0	0	57	165
Missouri	143	248	55	57	0	5	198	310
Ohio	12	16	20	30	0	0	32	46
Northern Plains	6,380	8,977	684	676	186	185	7,250	9,838
Kansas	2,230	3,073	65	75	10	10	2,305	3,158
Nebraska	4,074	5,670	505	440	176	175	4,755	6,285
North Dakota	33	85	23	11	0	0	56	96
South Dakota	43	149	91	150	0	0	134	299
Appalachia	17	23	175	197	0	3	192	223
Kentucky	1	1	26	26	0	0	27	27
North Carolina	5	7	104	110	0	3	109	120
Tennessee	6	7	11	12	0	0	17	19
Virginia	5	8	31	47	0	0	36	55
West Virginia	0	0	3	2	0	0	3	2

Continued--

Appendix table 2--Acreage irrigated with onfarm-pumped water by source of water and region and State--Continued

Region and State	Groundwater		Surface water		Both		Total	
	1974	1977	1974	1977	1974	1977	1974	1977
	1,000 acres							
Southeast	1,058	1,343	980	1,359	3	8	2,041	2,710
Alabama	8	25	17	30	0	5	25	60
Florida	960	1,076	823	960	0	0	1,783	2,036
Georgia	80	230	114	347	0	0	194	577
South Carolina	10	12	26	22	3	3	39	37
Delta States	1,966	1,986	722	676	0	0	2,688	2,662
Arkansas	1,400	1,400	296	300	0	0	1,696	1,700
Louisiana	340	284	332	276	0	0	672	560
Mississippi	226	302	94	100	0	0	320	402
Southern Plains	7,770	8,320	1,491	1,569	256	256	9,517	10,145
Oklahoma	680	730	40	118	0	0	720	848
Texas	7,090	7,590	1,451	1,451	256	256	8,797	9,297
Mountain	3,587	3,636	1,149	1,206	1,284	1,325	6,020	6,167
Arizona	552	550	0	--0	391	390	943	940
Colorado	900	940	45	50	700	710	1,645	1,700
Idaho	1,106	1,149	528	549	0	0	1,634	1,698
Montana	40	57	284	316	0	0	324	373
Nevada	170	170	34	34	0	0	204	204
New Mexico	634	585	43	43	143	175	820	803
Utah	60	60	164	164	0	0	224	224
Wyoming	125	125	50	50	50	50	225	225
Pacific	4,561	4,912	1,725	1,845	0	0	6,286	6,757
California	4,073	4,388	380	410	0	0	4,453	4,798
Oregon	246	264	644	686	0	0	890	950
Washington	242	260	701	749	0	0	943	1,009
Alaska	3	1	4	1	0	0	7	2
Hawaii	70	80	6	6	0	0	76	86
Total	26,076	30,526	7,345	7,967	1,724	1,784	35,150	40,277

Appendix table 3--Acreage irrigated with onfarm-pumped water by types of distribution system and region and State 1/

Region and State	Big gun		Center pivot		Other sprinkler		Surface	
	1974	1977	1974	1977	1974	1977	1974	1977
	1,000 acres							
Northeast	19.24	25.85	17.99	42.56	249.56	229.76	5.63	5.76
Connecticut	0	0	.08	0	8.83	11.88	.01	.12
Delaware	7.00	11.48	8.56	13.56	10.38	4.96	0	0
Maine	0	0	.07	0	32.03	6.93	.34	.07
Maryland	1.19	3.96	3.58	23.43	19.07	5.61	0	0
Massachusetts	0	0	.32	0	5.88	31.68	0	.32
New Hampshire	0	0	.06	0	1.96	6.93	0	0
New Jersey	0	0	5.28	5.25	95.12	94.50	5.28	5.25
New York	8.22	7.56	0	0	50.49	46.44	0	0
Pennsylvania	2.82	2.85	0	0	16.01	16.15	0	0
Rhode Island	0	0	.03	.30	8.83	2.70	.01	0
Vermont	0	0	.02	.02	2.94	1.98	0	0
Lake States	49.16	178.80	209.41	440.06	127.15	120.32	36.73	11.82
Michigan	10.92	10.90	62.24	62.13	36.04	35.97	0	0
Minnesota	24.63	101.42	68.97	245.08	11.17	40.60	26.73	9.90
Wisconsin	13.61	66.48	78.20	132.85	79.95	43.75	0	1.92
Corn Belt	47.02	84.00	70.18	233.52	64.91	77.32	187.99	237.16
Illinois	10.00	11.98	25.00	27.60	14.00	13.02	1.00	.40
Indiana	2.66	16.02	11.97	22.96	11.30	11.84	7.31	7.18
Iowa	8.62	25.95	7.47	91.50	12.65	12.60	28.75	34.95
Missouri	20.99	26.01	20.99	85.12	4.84	4.24	150.93	194.63
Ohio	4.74	4.04	4.74	6.34	22.12	35.62	0	0
Northern Plains	60.31	115.42	1,536.07	3,178.23	580.12	721.23	5,073.73	5,823.12
Kansas	45.45	12.75	449.96	806.83	45.45	64.66	1,764.62	2,273.76
Nebraska	0	62.85	1,025.06	2,136.90	467.50	565.65	3,263.04	3,519.60
North Dakota	3.30	12.89	26.40	74.65	1.87	2.69	23.92	5.77
South Dakota	11.55	26.93	34.65	159.85	65.29	88.23	22.13	23.99
Appalachia	8.61	27.60	8.06	8.09	161.76	181.37	13.80	5.93
Kentucky	0	0	0	0	26.47	25.95	.27	1.04
North Carolina	0	5.50	6.54	6.10	91.52	106.30	10.89	2.10
Tennessee	1.64	2.06	1.52	1.99	11.17	12.16	2.56	2.79
Virginia	6.97	19.04	0	0	29.66	35.96	.05	0
West Virginia	0	1.00	0	0	2.94	1.00	.03	0

Continued--

See footnote at end of table.

Appendix table 3--Acreage irrigated with onfarm-pumped water by types of distribution system and region and State 1/--Continued

Region and State	Big gun		Center pivot		Other sprinkler		Surface	
	1974	1977	1974	1977	1974	1977	1974	1977
	1,000 acres							
Southeast	321.50	685.06	63.73	167.89	488.85	554.02	1,165.51	1,303.03
Alabama	5.63	38.10	5.96	16.20	13.00	5.70	.24	0
Florida	307.20	376.60	19.20	21.52	292.27	336.84	1,164.82	1,301.04
Georgia	0	256.58	38.57	129.12	154.29	191.30	0	0
South Carolina	8.67	13.78		1.05	29.29	20.18	1.45	1.99
Delta States	19.66	25.84	24.88	28.70	60.10	43.62	2,583.61	2,563.84
Arkansas	14.00	23.00	16.96	20.00	47.92	34.00	1,617.13	1,623.00
Louisiana	3.40	2.84	3.40	5.68	6.73	5.60	659.11	545.88
Mississippi	2.26	0	4.52	3.02	5.46	4.02	307.36	394.96
Southern Plains	103.38	107.56	521.48	774.89	1,766.17	1,836.76	7,121.34	7,425.78
Oklahoma	20.40	14.60	81.60	124.10	270.58	349.24	347.20	360.06
Texas	87.98	92.97	439.88	650.79	1,495.59	1,497.52	6,774.15	7,065.72
Mountain	.80	5.44	918.30	1,027.34	1,659.66	1,722.70	3,441.81	3,411.52
Arizona	0	0	28.29	28.20	37.72	28.20	876.99	883.60
Colorado	0	0	353.34	546.50	64.45	50.00	1,227.01	1,103.50
Idaho	0	0	179.74	186.78	1,209.16	1,256.52	245.10	254.70
Montana	.80	5.44	23.39	36.06	54.48	79.01	240.16	252.49
Nevada			10.22	10.54	10.22	10.54	184.57	182.92
New Mexico	0	0	233.25	129.20	15.98	30.83	571.07	642.97
Utah	0	0	19.56	19.56	179.60	179.60	24.84	24.84
Wyoming	0	0	70.50	70.50	88.00	88.00	66.69	66.50
Pacific	0	38.59	295.93	316.39	2,434.48	2,581.33	3,555.59	3,820.69
California	0	0	0	0	935.13	1,007.58	3,517.87	3,790.42
Oregon	0	28.50	97.90	104.50	792.10	817.00	0	0
Washington	0	10.09	198.03	211.89	707.25	756.75	37.72	30.27
Alaska	0	0	.80	0	3.19	1.98	0	0
Hawaii	0	0	0	.80	14.00	28.00	56.00	57.14
Total	642.32	1,294.16	3,667.83	6,218.47	7,609.91	8,098.41	23,232.61	24,665.79

1/ Includes only areas irrigated with pumped water.

Appendix table 4--Acreage irrigated with onfarm-pumped water by type of energy and region and State 1/

Region and State	Electricity		Diesel		Gasoline		Natural gas		LPG	
	1974	1977	1974	1977	1974	1977	1974	1977	1974	1977
	1,000 acres									
Northeast	30.44	29.93	67.58	100.13	176.24	160.07	0	0	18.17	13.87
Connecticut	.92	1.20	2.38	3.12	5.50	7.44	0	0	.12	.24
Delaware	2.59	3.56	7.78	18.22	11.67	6.98	0	0	3.89	1.24
Maine	.69	0	2.08	2.10	4.16	4.90	0	0	0	0
Maryland	2.38	1.82	9.54	16.83	7.15	11.55	0	0	4.77	2.80
Massachusetts	4.25	4.16	0	0	24.51	23.69	0	0	3.92	4.15
New Hampshire	.59	.70	1.78	2.03	3.56	4.27	0	0	0	0
New Jersey	10.57	10.50	15.85	31.50	73.98	57.75	0	0	5.28	5.25
New York	5.87	5.40	23.48	21.60	29.35	27.00	0	0	0	0
Pennsylvania	2.07	2.09	3.20	3.23	13.37	13.49	0	0	.19	.19
Rhode Island	.30	.30	.89	.90	1.78	1.80	0	0	0	0
Vermont	.20	.20	.59	.60	1.19	1.20	0	0	0	0
Lake States	295.76	452.83	81.34	236.91	23.17	49.38	0	0	10.52	11.88
Michigan	87.36	87.20	16.38	16.35	5.46	5.45	0	0		
Minnesota	72.32	237.30	39.45	119.55	9.20	32.21	0	0	10.52	7.94
Wisconsin	136.08	128.33	25.51	101.01	8.50	11.72	0	0		3.94
Corn Belt	71.43	155.23	74.66	255.08	122.88	94.40	1.81	24.90	99.31	102.39
Illinois	6.00	7.04	9.00	9.15	24.50	25.82	0	0	10.50	10.99
Indiana	3.32	16.78	4.65	15.78	13.30	13.60	.38	.38	11.59	11.46
Iowa	11.50	63.00	20.13	62.55	23.00	34.05	0	.90	2.88	4.50
Missouri	39.55	52.31	36.14	160.70	40.44	2.53	1.43	23.62	71.19	70.84
Ohio	11.06	16.10	4.74	6.90	12.64	18.40			3.16	4.60
Northern Plains	1,572.54	2,612.42	1,543.16	2,914.17	152.09	72.04	2,429.50	3,231.31	1,552.95	1,008.06
Kansas	169.90	503.03	138.20	534.53	22.40	0	1,792.00	1,911.46	183.00	208.98
Nebraska	1,308.34	1,885.50	1,360.00	2,262.60	118.34	62.85	637.50	1,319.85	1,331.42	754.20
North Dakota	42.18	80.42	8.88	13.88	3.33	1.70	0	0	1.11	0
South Dakota	52.12	143.47	36.08	103.16	8.02	7.49	0	0	37.42	44.88
Appalachia	104.60	18.38	21.72	87.24	62.01	114.28	.30	1.50	3.59	1.60
Kentucky	0	0	4.01	4.10	22.73	22.90	0	0	0	0
North Carolina	98.05	11.40	5.45	58.50	5.45	50.10	0	0	0	0
Tennessee	3.38	4.20	5.07	5.82	6.76	7.06	.30	1.50	1.39	.42
Virginia	2.93	2.52	6.60	18.48	24.94	32.82	0	0	2.20	1.18
West Virginia	.24	.26	.59	.34	2.14	1.40	0	0	0	0

See footnote at end of table.

Continued--

Appendix table 4--Acreage irrigated with onfarm-pumped water by type of energy and region and State 1/--Continued

Region and State	Electricity		Diesel		Gasoline		Natural gas		LPG	
	1974	1977	1974	1977	1974	1977	1974	1977	1974	1977
	1,000 acres									
Southeast	584.83	581.94	1,044.72	1,613.51	188.86	240.16	0.16	2.10	222.01	272.29
Alabama	3.72	6.00	9.93	38.10	9.93	10.20	.16	2.10	1.03	3.60
Florida	541.87	534.00	953.62	1,233.00	96.00	75.32	0	0	192.00	193.68
Georgia	7.71	34.62	73.29	317.35	82.93	150.02	0	0	28.93	75.01
South Carolina	32.52	7.32	7.88	25.06	0	4.62	0	0	0	0
Delta States	504.02	780.66	645.22	1,102.70	590.49	309.78	204.53	182.00	744.00	286.86
Arkansas	339.20	565.00	184.40	616.00	424.00	191.00	70.00	70.00	678.40	258.00
Louisiana	100.90	84.00	269.06	232.44	134.53	114.76	134.53	112.00	33.63	16.80
Mississippi	63.92	131.66	191.76	254.26	31.96	4.02	0	0	31.96	12.06
Southern Plains	2,006.68	2,346.75	151.25	166.18	108.38	114.65	6,742.20	6,949.07	508.88	568.35
Oklahoma	102.00	141.80	48.76	58.70	20.40	21.68	435.20	472.88	113.42	152.94
Texas	1,904.68	2,204.95	102.49	107.48	87.98	92.97	6,307.00	6,476.19	395.45	415.41
Mountain	4,297.28	4,499.86	307.18	350.43	85.97	77.14	1,151.64	1,103.75	183.64	135.82
Arizona	612.95	648.60	0	0	0	0	330.05	291.40	0	0
Colorado	1,100.00	1,138.00	100.00	100.10	20.00	20.00	330.00	332.00	100.00	100.00
Idaho	1,568.64	1,630.08	49.02	50.94	16.34	16.98	0	0	0	0
Montana	270.51	315.09	36.93	39.01	13.74	14.61	.40	0	3.25	4.30
Nevada	159.44	163.20	40.88	40.80	2.04	0	0	0	2.04	0
New Mexico	203.93	223.25	46.65	76.00	31.10	22.80	484.19	473.35	54.42	7.60
Utah	190.40	190.40	15.68	15.68	0	0	0	0	17.92	17.92
Wyoming	191.41	191.25	18.02	18.00	2.75	2.75	7.00	7.00	6.01	6.00
Pacific	6,197.39	6,716.80	3.61	9.00	0	0	85.00	31.20	0	0
California	4,364.39	4,757.80	3.61	9.00	0	0	85.00	31.20	0	0
Oregon	890.00	950.00	0	0	0	0	0	0	0	0
Washington	943.00	1,009.00	0	0	0	0	0	0	0	0
Alaska	2.80	1.60	.20	0	1.00	.40	0	0	0	0
Hawaii	71.63	85.14	0	0	.72	0	0	0	0	0
Total	15,737.32	18,281.54	3,937.94	6,835.35	1,511.81	1,231.90	10,615.13	11,525.83	3,343.07	2,401.12

1/ Includes only acres irrigated with pumped water.

Appendix table 5--Quantity of energy used for onfarm-pumped irrigation water by region and State 1/

Region and State	Electricity		Diesel		Gasoline		Natural gas		LPG	
	1974	1977	1974	1977	1974	1977	1974	1977	1974	1977
	- - -1,000 kWh- - -		- - - - -1,000 gallons- - - - -				- - -1,000 MCF- - -		- - -1,000 gallons- - -	
Groundwater:										
Northeast	6,751	6,206	1,149	2,042	4,362	3,005	0	0	546	370
Connecticut	30	46	0	9	18	29	0	0	4	1
Delaware	782	1,350	193	565	363	266	0	0	151	58
Maine	0	0	0	0	0	0	0	0	0	0
Maryland	320	509	105	356	99	306	0	0	82	87
Massachusetts	30	30	0	0	18	17	0	0	4	3
New Hampshire	0	0	0	0	0	0	0	0	0	0
New Jersey	4,740	3,414	285	843	3,417	1,933	0	0	305	219
New York	778	784	256	258	401	403	0	0	0	0
Pennsylvania	72	72	9	9	48	48	0	0	1	0
Rhode Island	0	0	0	0	0	0	0	0	0	0
Vermont	0	0	0	0	0	0	0	0	0	0
Lake States	90,975	233,124	2,131	9,336	750	2,404	0	0	462	899
Michigan	21,940	22,038	339	340	141	141	0	0	0	0
Minnesota	24,657	119,883	1,107	4,934	323	1,646	0	0	462	514
Wisconsin	44,378	91,202	685	4,061	286	615	0	0	0	385
Corn Belt	12,446	40,203	1,185	4,208	2,792	2,474	6	9	2,391	2,777
Illinois	2,435	2,024	301	199	1,024	653	0	0	549	347
Indiana	1,158	8,639	133	711	477	574	3	3	507	609
Iowa	2,156	18,907	312	1,439	446	973	0	0	70	182
Missouri	5,231	8,689	388	1,788	673	44	3	5	1,212	1,566
Ohio	1,455	1,943	51	68	171	228	0		54	71
Northern Plains	1,088,248	1,734,032	92,922	183,784	5,573	5,121	25,551	36,745	112,776	98,113
Kansas	131,744	198,000	7,747	39,578	1,938	0	19,383	23,982	16,961	23,208
Nebraska	926,210	1,416,233	84,140	139,913	3,289	4,862	6,166	12,762	94,569	72,929
North Dakota	17,445	52,048	302	714	142	127	0	0	59	0
South Dakota	12,850	67,752	732	3,578	204	131	0	0	1,187	1,974
							0	0	0	0
Appalachia	2,089	3,001	83	318	208	331	1	2	24	37
Kentucky			2	2	16	14	0	0	0	0
North Carolina	1,542	2,021	7	98	9	21	0	0	0	0
Tennessee	440	637	54	65	91	92	1	2	14	20
Virginia	106	342	20	151	92	202	0	0	10	16
West Virginia										

Continued--

See footnote at end of table.

Appendix table 5--Quantity of energy used for onfarm-pumped irrigation water by region and State 1/--Continued

Region and State	Electricity		Diesel		Gasoline		Natural gas		LPG	
	1974	1977	1974	1977	1974	1977	1974	1977	1974	1977
	1,000 kWh		1,000 gallons				1,000 MCF		1,000 gallons	
Groundwater:										
Southeast	143,931	211,628	12,666	38,689	6,029	13,258	1	0	10,723	19,911
Alabama	339	2,083	74	791	93	280	1	0	9	206
Florida	133,798	186,329	11,015	23,010	3,937	4,477	0	0	9,843	14,392
Georgia	1,805	19,045	1,412	14,373	1,999	8,500	0	0	872	5,312
South Carolina	7,988	4,170	164	514	0	0	0	0	0	0
Delta States	123,858	215,723	14,066	23,172	14,482	7,866	680	669	22,289	9,969
Arkansas	76,932	164,359	3,167	13,531	9,905	4,836	248	302	19,808	9,068
Louisiana	25,174	21,382	5,527	4,929	3,457	2,936	432	367	1,080	550
Mississippi	21,752	29,982	5,372	4,712	1,120	93	0	0	1,400	350
Southern Plains	1,376,236	1,649,840	8,783	8,622	8,759	8,888	66,344	70,385	43,792	51,559
Oklahoma	108,197	156,651	3,563	3,034	2,229	1,898	5,943	7,473	11,143	16,608
Texas	1,268,040	1,493,189	5,220	5,587	6,530	6,990	60,401	62,911	32,649	34,951
Mountain	5,210,556	6,187,045	22,781	24,946	11,173	7,628	34,421	35,733	21,427	6,195
Arizona	2,081,935	3,164,739	0	0	0	0	14,432	18,304	0	0
Colorado	397,900	411,627	1,178	1,296	300	300	4,700	4,747	1,842	1,842
Idaho	1,587,479	1,652,248	3,920	4,075	1,626	1,690	0	0	0	0
Montana	36,431	75,389	591	1,061	687	919	7	0	66	255
Nevada	372,417	200,281	7,862	4,122	492	0	0	0	615	0
New Mexico	398,884	347,577	9,383	11,922	7,825	4,474	15,161	11,559	17,117	1,864
Utah	134,031	134,031	908	908	0	0	0	0	1,624	1,624
Wyoming	201,484	201,153	1,561	1,558	244	243	122	121	610	609
Pacific	5,060,428	5,448,737	0	0	0	0	1,000	1,136	0	0
California	4,115,227	4,443,694	0	0	0	0	1,000	1,136	0	0
Oregon	319,547	342,841	0	0	0	0	0	0	0	0
Washington	625,654	672,202	0	0	0	0	0	0	0	0
Alaska	329	118	2	0	12	3	0	0	0	0
Hawaii	695,434	829,022	0	0	723	0	0	0	0	0
Total groundwater	13,811,275	16,558,683	156,132	295,120	54,864	50,982	128,004	144,680	214,877	189,833

See footnote at end of table.

Continued--

Appendix table 5--Quantity of energy used for onfarm-pumped irrigation water by region and State 1/--Continued

Region and State	Electricity		Diesel		Gasoline		Natural gas		LPG	
	1974	1977	1974	1977	1974	1977	1974	1977	1974	1977
	-1,000 kWh-		-1,000 gallons-				-1,000 MCF-		-1,000 gallons-	
Surface water:										
Northeast	3,904	3,284	718	947	2,259	1,964	0	0	333	253
Connecticut	138	173	34	37	85	110	0	0	0	4
Delaware	209	169	52	74	97	39	0	0	40	9
Maine	116	0	29	13	72	40	0	0	0	0
Maryland	551	446	182	374	170	321	0	0	142	103
Massachusetts	665	653	0	0	395	382	0	0	79	84
New Hampshire	103	121	26	28	64	76	0	0	0	0
New Jersey	1,039	731	128	180	749	414	0	0	67	47
New York	594	499	195	164	306	257	0	0	0	0
Pennsylvania	403	401	51	51	268	267	0	0	5	4
Rhode Island	52	54	13	13	32	33	0	0	0	0
Vermont	34	35	9	8	21	21	0	0	0	0
Lake States	41,842	30,344	828	2,451	310	493	0	0	115	42
Michigan	15,767	15,777	243	243	101	101	0	0	0	0
Minnesota	6,164	9,657	277	424	81	154	0	0	115	42
Wisconsin	19,911	4,909	307	1,783	128	237	0	0	0	0
								0		
Corn Belt	3,631	7,661	247	1,678	621	1,044	0	115	553	641
Illinois	0	327	0	50	0	227	0	0	0	121
Indiana	531	3,328	61	219	219	411	0	0	246	428
Iowa	307	813	44	157	63	113	0	3	10	0
Missouri	994	706	78	1,163	128	0	0	112	230	0
Ohio	1,800	2,485	63	87	212	292	0	0	66	91
Northern Plains	45,788	132,430	2,092	12,063	1,637	810	0	588	9,898	7,971
Kansas	1,664	2,000	274	1,440	0	0	0	0	428	1,310
Nebraska	10,931	65,303	0	6,451	1,126	224	0	588	6,567	3,362
North Dakota	1,857	3,937	32	71	15	0	0	0	6	0
South Dakota	31,336	61,189	1,786	4,100	497	586	0	0	2,896	3,297
Appalachia	21,013	2,939	336	1,819	1,173	3,172	0	3	98	59
Kentucky	0	0	45	43	317	309	0	0	0	0
North Carolina	19,756	1,310	90	1,078	113	1,214	0	0	0	0
Tennessee	538	619	66	75	111	118	0	3	35	0
Virginia	660	930	122	612	578	1,485	0	0	64	59
West Virginia	59	79	12	8	54	43	0			

Continued--

See footnote at end of table.

Appendix table 5--Quantity of energy used for onfarm-pumped irrigation water by region and State 1/--Continued

Region and State	Electricity		Diesel		Gasoline		Natural gas		LPG	
	1974	1977	1974	1977	1974	1977	1974	1977	1974	1977
	- - -1,000 kWh- - -		- - - - -1,000 gallons- - - - -				- - -1,000 MCF- - -		- -1,000 gallons- -	
Surface water:										
Southeast	29,422	48,794	6,205	25,593	1,384	9,514	0	11	568	5,654
Alabama	465	860	102	677	128	215	0	11	20	31
Florida	20,506	26,937	5,064	7,862	0	0	0	0	0	0
Georgia	1,135	20,157	888	16,212	1,257	8,996	0	0	548	5,622
South Carolina	7,317	840	151	841	0	302	0	0	0	0
Delta States	14,982	21,482	2,146	3,407	1,837	1,527	96	66	2,305	1,276
Arkansas	7,562	13,715	467	1,896	974	960	0	0	1,947	1,130
Louisiana	5,604	3,845	1,230	865	770	554	96	66	241	99
Mississippi	1,816	3,921	448	645	94	12	0	0	117	47
Southern Plains	138,798	166,455	1,122	2,535	477	1,010	3,574	3,536	6,420	8,952
Oklahoma	0	12,896	360	1,769	0	531	0	121	2,251	4,759
Texas	138,798	153,559	762	766	477	479	3,574	3,414	4,169	4,193
Mountain	678,172	739,415	3,785	4,208	909	1,077	4	3	2,356	2,461
Arizona	0	0	0	0	0	0	0	0	0	0
Colorado	2,100	2,172	0	0	1	1	0	0	0	5
Idaho	336,874	350,186	830	863	362	401	0	0	0	0
Montana	141,992	182,924	1,513	1,751	516	657	0	0	215	273
Nevada	9,317	16,880	197	347	12	0	0	0	15	0
New Mexico	5,159	4,519	0	0	0	0	4	3	0	0
Utah	175,492	175,492	1,189	1,189	0	0	0	0	2,126	2,126
Wyoming	7,239	7,239	56	56	18	18	0	0	55	55
Pacific	1,572,710	1,680,914	69,898	0	0	0	0	0	0	0
California	266,236	286,840	69	898	0	0	0	0	0	0
Oregon	533,998	568,761	0	0	0	0	0	0	0	0
Washington	772,476	825,313	0	0	0	0	0	0	0	0
Alaska	72	79	0	0	3	2	0	0	0	0
Hawaii	220	2,052	0	0	0	0	0	0	0	0
Total surface water	2,550,553	2,857,903	18,505	54,774	10,611	26,670	3,673	4,323	22,645	27,479
Total groundwater and surface water	16,361,828	19,416,586	174,637	349,894	65,475	77,652	131,677	149,003	237,522	217,146

1/ Total may not add due to rounding.

Appendix table 6--Quantity of energy used per acre for onfarm-pumped irrigation water by region and State

Region and State	Electricity		Diesel		Gasoline		Natural gas		LPG	
	1974	1977	1974	1977	1974	1977	1974	1977	1974	1977
	- - - -kWh- - - -		- - - - -Gallons- - - -				- - - -MCF- - - -		- - -Gallons- - -	
Groundwater:										
Northeast	489.93	408.59	35.05	34.10	53.32	41.99	0	0	63.45	58.57
Connecticut	228.86	230.51	0	18.98	23.57	23.74	0	0	29.46	29.68
Delaware	391.10	432.87	32.20	35.64	40.28	44.58	0	0	50.35	55.73
Maine										
Maryland	399.39	499.36	32.88	41.11	41.14	51.43	0	0	51.42	64.29
Massachusetts	227.44	230.51	0	0	23.42	23.74	0	0	29.28	29.68
New Hampshire										
New Jersey	631.98	455.21	52.03	37.48	65.09	46.88	0	0	81.36	58.60
New York	259.46	261.32	21.36	21.51	26.72	26.91	0	0	0	0
Pennsylvania	327.34	329.69	26.95	27.14	33.71	33.96	0	0	42.14	42.44
Rhode Island	0	0	0	0	0	0	0	0	0	0
Vermont	0	0	0	0	0	0	0	0	0	0
Lake States	500.14	619.73	42.41	52.16	52.49	61.90	0	0	70.38	81.91
Michigan	489.73	491.93	40.32	40.50	50.44	50.67	0	0	0	0
Minnesota	546.72	567.63	45.01	46.73	56.31	58.46	0	0	70.38	73.08
Wisconsin	482.37	758.94	39.71	62.48	49.68	78.17	0	0	0	97.71
Corn Belt	245.48	300.07	20.90	20.69	30.14	37.88	3.51	3.15	33.14	30.39
Illinois	405.89	337.40	33.42	27.78	41.80	34.75	0	0	52.25	43.44
Indiana	609.42	733.38	50.17	60.38	62.77	75.53	7.85	9.44	78.46	94.41
Iowa	216.63	315.12	17.83	25.94	22.31	32.46	0	0	27.89	40.57
Missouri	182.90	171.72	15.06	14.14	18.84	17.69	2.35	2.21	23.55	22.11
Ohio	346.47	347.13	28.52	28.58	35.68	35.75	0	0	44.60	44.69
Northern Plains	760.40	723.37	62.41	69.09	80.24	83.09	10.52	11.71	98.32	108.50
Kansas	840.20	450.74	69.17	80.23	86.54	0	10.82	12.55	108.17	125.47
Nebraska	751.49	807.66	61.87	66.49	77.40	83.18	9.67	10.40	96.75	103.98
North Dakota	695.40	728.97	57.26	60.01	71.64	75.08	0	0	89.55	0
South Dakota	766.24	857.95	63.08	70.63	78.92	88.36	0	0	98.64	110.45
Appalachia	342.27	365.11	26.83	34.49	30.07	14.41	4.72	4.88	40.61	56.11
Kentucky	0	0	14.61	14.47	18.28	18.11	0	0	0	0
North Carolina	342.66	342.66	28.21	28.21	35.29	35.29	0	0	0	0
Tennessee	366.88	379.33	30.20	31.23	37.79	39.07	4.72	4.88	47.23	48.83
Virginia	264.03	534.76	21.74	44.03	27.19	55.08	0	0	33.99	68.84
West Virginia										

Continued--

Appendix table 6--Quantity of energy used per acre for onfarm-pumped irrigation water by region and State--Continued

Region and State	Electricity		Diesel		Gasoline		Natural gas		LPG	
	1974	1977	1974	1977	1974	1977	1974	1977	1974	1977
	kWh		Gallons				MCF		Gallons	
Groundwater:										
Southeast	410.29	610.76	34.03	60.67	45.13	94.50	3.63	0	52.50	87.88
Alabama	282.24	534.10	23.24	43.97	29.07	55.01	3.63	0	36.34	68.20
Florida	398.21	577.23	32.78	47.52	41.01	59.45	0	0	51.26	74.31
Georgia	564.20	1,380.12	46.45	113.62	58.11	142.14	0	0	72.63	0
South Carolina	768.09	695.04	63.24	57.22	0	0	0	0	0	0
Delta States	329.23	341.19	34.17	28.98	32.87	39.37	4.93	5.28	37.17	43.81
Arkansas	274.76	335.43	22.62	27.61	28.30	34.55	3.54	4.32	35.37	43.18
Louisiana	493.60	501.94	40.64	41.32	50.84	51.70	6.35	6.42	63.55	64.62
Mississippi	481.23	300.84	39.62	24.77	49.56	30.99	0	0	61.95	38.73
Southern Plains	875.91	891.70	76.87	80.09	93.32	95.51	11.30	11.52	116.64	123.93
Oklahoma	1,060.75	1,262.30	87.33	103.92	109.25	103.01	13.66	16.25	136.56	162.51
Texas	863.08	865.06	71.06	71.22	88.89	89.10	11.11	11.14	111.11	111.37
Mountain	1,647.34	1,856.52	159.26	114.03	165.28	112.69	29.27	31.12	253.30	86.63
Arizona	3,396.58	4,879.34	0	0	0	0	43.73	62.82	0	0
Colorado	447.14	422.43	36.81	43.01	46.05	53.81	5.76	6.73	57.56	67.26
Idaho	1,435.33	1,435.33	118.17	118.17	147.07	147.07	0	0	0	0
Montana	1,282.79	1,740.29	105.61	143.27	132.12	179.24	16.51	0	165.14	224.04
Nevada	2,808.57	1,472.66	231.22	121.24	289.27	0	0	0	361.57	0
New Mexico	2,443.03	1,905.58	201.13	156.88	251.62	196.26	31.45	24.53	314.51	245.32
Utah	2,628.06	2,628.06	216.36	216.36	0	0	0	0	0	338.33
Wyoming	1,354.51	1,352.30	111.51	111.33	139.51	139.28	17.44	17.41	174.38	174.09
Pacific	1,264.81	1,264.81	0	0	0	0	13.69	15.00	0	0
California	1,010.36	1,010.36	0	0	0	0	13.69	15.00	0	0
Oregon	1,298.97	1,298.97	0	0	0	0	0	0	0	0
Washington	2,585.34	2,585.34	0	0	0	0	0	0	0	0
Alaska	156.47	147.66	12.88	0	16.12	15.21	0	0	0	0
Hawaii	10,035.16	0	0	0	1,033.60	0	0	0	0	0

Continued--

Appendix table 6--Quantity of energy used per acre for onfarm-pumped irrigation water by region and State--Continued

Region and State	Electricity		Diesel		Gasoline		Natural gas		LPG	
	1974	1977	1974	1977	1974	1977	1974	1977	1974	1977
	----kWh----		----Gallons----				----MCF----		--Gallons--	
Surface water:										
Northeast	234.30	222.84	20.63	23.54	23.92	22.20	0	0	34.81	33.63
Connecticut	173.92	173.07	14.32	14.25	17.91	17.83	0	0	0	22.28
Delaware	351.24	384.36	28.92	31.64	36.18	39.59	0	0	45.22	49.48
Maine	167.34	0	13.78	6.53	17.24	8.16	0	0	0	0
Maryland	348.11	557.48	28.66	45.90	35.85	57.42	0	0	44.82	71.77
Massachusetts	161.53	162.03	0	0	16.64	16.69	0	0	20.80	20.86
New Hampshire	173.92	172.96	14.32	14.24	17.91	17.81	0	0	0	0
New Jersey	338.44	243.78	27.86	20.07	34.86	25.11	0	0	43.57	31.38
New York	206.82	208.31	17.03	17.51	21.30	21.45	0	0	0	0
Pennsylvania	217.68	214.82	17.92	17.69	22.42	22.13	0	0	28.02	27.66
Rhode Island	173.92	181.14	14.32	14.91	17.91	18.66	0	0	0	0
Vermont	173.92	175.17	14.32	14.42	17.91	18.04	0	0	0	0
Lake States	367.47	395.84	26.61	42.34	34.96	46.86	0	0	29.15	47.63
Michigan	370.45	372.12	30.50	30.64	38.15	38.33	0	0	0	0
Minnesota	226.42	370.01	18.64	30.46	23.32	38.11	0	0	29.15	47.63
Wisconsin	451.70	601.69	37.19	49.54	46.52	61.97	0	0	0	0
Corn Belt	175.10	360.52	13.73	32.46	20.57	35.93	0	5.24	20.33	58.33
Illinois	0	314.78	0	25.92	0	32.42	0	0	0	40.52
Indiana	372.84	665.72	30.69	54.81	38.40	68.57	0	0	48.00	85.70
Iowa	204.37	271.19	16.83	22.32	21.05	27.93	0	3.49	26.31	0
Missouri	90.73	413.13	7.47	34.01	9.43	0	0	5.32	11.68	0
Ohio	262.32	236.68	21.60	19.48	27.02	24.38	0	0	33.77	30.47
Northern Plains	323.85	615.18	38.55	47.47	19.82	77.93	0	6.37	24.38	76.79
Kansas	127.02	205.13	10.46	34.93	0	0	0	0	16.35	54.62
Nebraska	144.13	494.72	0	40.73	14.84	50.95	0	6.37	18.55	63.69
North Dakota	108.61	436.54	8.94	35.94	11.19	0	0	0	13.98	0
South Dakota	886.55	948.68	72.99	78.10	91.31	97.79	0	0	114.13	122.13
Appalachia	213.31	289.31	18.04	23.32	21.29	29.70	0	3.16	32.90	63.73
Kentucky	0	0	11.59	11.20	14.49	14.01	0	0	0	0
North Carolina	211.17	238.26	17.38	19.61	21.75	24.54	0	0	0	0
Tennessee	246.99	245.72	20.33	20.23	25.44	25.31	0	0	31.80	0
Virginia	260.48	495.03	21.44	40.75	26.83	50.99	0	0	33.53	63.73
West Virginia	246.38	304.13	20.28	25.04	25.38	31.32	0	0	0	0

Continued--

Appendix table 6--Quantity of energy used per acre for onfarm-pumped irrigation water by region and State--Continued

Region and State	Electricity		Diesel		Gasoline		Natural gas		LPG	
	1974	1977	1974	1977	1974	1977	1974	1977	1974	1977
	----kWh----		----Gallons----				----MCF----		---Gallons---	
Surface water:										
Southeast	125.72	207.25	9.23	25.20	25.05	95.20	0	5.27	31.96	123.70
Alabama	183.99	409.58	15.15	33.72	18.95	42.18	0	5.27	23.69	52.73
Florida	99.60	127.54	8.20	10.50	0	0	0	0	0	0
Georgia	251.44	968.17	20.70	79.71	25.90	99.72	0	0	32.37	124.64
South Carolina	346.45	636.40	28.52	52.39	0	65.55	0	0	0	0
Delta States	117.21	144.76	9.18	11.24	12.25	13.89	1.45	1.20	15.96	21.53
Arkansas	127.74	182.87	10.52	15.06	13.16	18.83	0	0	16.44	23.54
Louisiana	112.31	92.88	9.25	7.65	11.57	9.57	1.45	1.20	14.46	11.96
Mississippi	97.00	122.55	7.99	10.09	9.99	12.62	0	0	12.49	15.78
Southern Plains	318.72	335.24	30.32	43.33	32.83	46.81	4.10	4.21	48.11	58.78
Oklahoma	0	728.60	45.22	59.98	0	75.84	0	9.38	70.72	93.80
Texas	318.72	320.70	26.24	26.40	32.83	33.03	4.10	4.13	41.03	41.29
Mountain	430.46	402.30	46.71	69.37	55.13	81.87	1.63	1.42	48.03	136.26
Arizona	0	0	0	0	0	0	0	0	0	0
Colorado	71.20	77.81	0	0	7.33	8.01	0	0	0	10.02
Idaho	638.02	638.02	52.44	52.44	73.14	73.14	0	0	0	0
Montana	586.49	673.11	48.28	55.42	60.40	69.33	0	0	75.50	86.66
Nevada	347.13	620.62	28.58	51.09	35.75	0	0	0	44.69	0
New Mexico	126.89	110.65	0	0	0	0	1.63	1.42	0	0
Utah	1,258.91	1,258.91	103.64	103.64	0	0	0	0	162.07	162.07
Wyoming	169.68	169.68	13.97	13.97	17.48	17.48	0	0	21.84	21.84
Pacific	861.42	861.42	19.24	99.86	0	0	0	0	0	0
California	700.62	700.62	19.24	99.86	0	0	0	0	0	0
Oregon	829.18	829.18	0	0	0	0	0	0	0	0
Washington	1,101.96	1,101.96	0	0	0	0	0	0	0	0
Alaska	103.87	99.01	0	0	10.70	10.20	0	0	0	0
Hawaii	801.42	345.55	0	0	0	0	0	0	0	0

Appendix table 7--Total cost of energy for onfarm-pumped irrigation water by region and State 1/

Region and State	Electricity		Diesel		Gasoline		Natural gas		LPG	
	1974	1977	1974	1977	1974	1977	1974	1977	1974	1977
	1,000 dollars									
Groundwater:										
Northeast	169	248	463	1,023	2,150	1,583	0	0	204	148
Connecticut	1	1	0	5	9	17	0	0	1	0
Delaware	20	54	73	276	178	125	0	0	48	23
Maine	0	0	0	0	0	0	0	0	0	0
Maryland	8	20	40	174	48	168	0	0	28	34
Massachusetts	1	1	0	0	9	9	0	0	1	1
New Hampshire	0	0	0	0	0	0	0	0	0	0
New Jersey	119	136	246	430	1,674	1,025	0	0	125	87
New York	19	31	100	131	208	214	0	0	0	0
Pennsylvania	2	2	3	4	23	26	0	0	0	0
Rhode Island	0	0	0	0	0	0	0	0	0	0
Vermont	0	0	0	0	0	0	0	0	0	0
Lake States	2,023	8,159	771	4,211	364	1,221	0	0	143	359
Michigan	505	771	122	163	72	71	0	0	0	0
Minnesota	542	4,195	410	2,220	155	823	0	0	143	205
Wisconsin	976	3,192	240	1,827	137	326	0	0	0	153
Corn Belt	274	1,311	438	1,868	1,335	1,288	4	12	722	1,058
Illinois	54	60	117	90	492	340	0	0	165	104
Indiana	25	345	51	355	239	287	2	5	157	243
Iowa	48	567	112	604	210	526	0	0	20	54
Missouri	115	260	140	786	310	21	3	6	364	626
Ohio	32	77	18	31	86	114	0	0	16	28
Northern Plains	21,748	75,296	31,857	81,839	2,687	2,614	19,163	34,501	20,305	29,631
Kansas	2,635	6,938	2,866	17,018	911		14,538	19,185	4,410	6,962
Nebraska	18,524	63,730	28,608	62,961	1,612	2,480	4,626	15,315	25,534	21,878
North Dakota	331	1,925	112	321	68	70	0	0	18	0
South Dakota	257	2,710	271	1,538	95	65	0	0	344	789
Appalachia	46	122	33	153	101	167	1	1	8	156
Kentucky	0	0	1	1	7	7	0	0	0	0
North Carolina	34	90	3	46	4	10	0	0	0	0
Tennessee	10	15	22	32	44	48	1	1	5	149
Virginia	2	15	7	72	45	101	0	0	4	6
West Virginia	0	0	0	0	0	0	0	0	0	0

See footnote at end of table.

Continued--

Appendix table 7-- Total cost of energy for onfarm-pumped irrigation water by region and State 1/--Continued

Region and State	Electricity		Diesel		Gasoline		Natural gas		LPG	
	1974	1977	1974	1977	1974	1977	1974	1977	1974	1977
	1,000 dollars									
Groundwater:										
Southeast	3,166	10,392	4,710	16,583	2,792	6,325	1	0	3,744	4,379
Alabama	7	72	29	356	42	140	1	0	3	61
Florida	2,944	9,316	4,076	9,204	1,851	2,105	0	0	3,445	4,317
Georgia	40	857	537	6,755	900	4,080	0	0	296	0
South Carolina	176	145	69	267	0	0	0	0	0	0
Delta States	2,725	8,732	5,076	10,610	6,684	4,329	510	801	7,125	4,072
Arkansas	1,693	6,574	1,045	6,224	4,556	2,757	186	544	6,339	3,627
Louisiana	554	598	1,990	2,218	1,590	1,527	324	256	324	275
Mississippi	479	1,559	2,041	2,167	538	45	0	0	462	140
Southern Plains	30,277	49,495	3,022	3,880	3,811	4,889	49,758	90,753	12,588	20,623
Oklahoma	2,380	4,699	1,247	1,365	1,003	1,044	4,457	8,968	3,120	6,643
Texas	27,897	44,795	1,775	2,514	2,808	3,845	45,301	81,785	9,468	13,980
Mountain	96,383	135,202	9,382	10,411	5,289	3,772	25,816	53,869	6,817	2,265
Arizona	41,639	66,459	0	0	0	0	10,824	27,456	0	0
Colorado	8,754	14,274	424	538	138	154	3,525	5,459	534	718
Idaho	25,400	26,435	1,303	1,833	780	845	0	0	589	0
Montana	583	1,206	207	424	330	414	5	0	20	76
Nevada	5,586	6,008	3,145	1,854	246	0	0	0	197	0
New Mexico	7,978	10,427	3,378	4,649	3,678	2,237	11,371	20,807	4,793	559
Utah	2,010	3,350	363	408	0	0	0	0	520	649
Wyoming	4,433	7,040	562	701	117	122	92	146	165	262
Pacific	91,463	198,409	127	0	0	0	750	1,704	0	0
California	82,304	186,215	0	0	0	0	750	1,704	0	0
Oregon	4,154	4,800	127	0	0	0	0	0	0	0
Washington	5,005	7,394	0	0	0	0	0	0	0	0
Alaska	11	4	1	0	7	2	0	0	0	0
Hawaii	22,253	41,451	0	0	433	0	0	0	0	0
Total groundwater	270,538	528,825	55,880	130,581	25,652	26,187	97,831	181,643	61,657	62,665

Continued--

See footnote at end of table.

Appendix table 7--Total cost of energy for onfarm-pumped irrigation water by region and State 1/--Continued

Region and State	Electricity		Diesel		Gasoline		Natural gas		LPG	
	1974	1977	1974	1977	1974	1977	1974	1977	1974	1977
	1,000 dollars									
Surface water:										
Northeast	98	132	280	474	1,127	1,044	0	0	119	117
Connecticut	3	6	13	18	43	58	0	0	0	2
Delaware	5	6	20	36	47	18	0	0	13	4
Maine	3	0	11	6	37	20	0	0	0	0
Maryland	14	17	69	183	83	176	0	0	48	49
Massachusetts	17	26	0	0	202	202	0	0	28	37
New Hampshire	3	6	10	15	33	41	0	0	0	0
New Jersey	26	29	54	92	367	219	0	0	27	21
New York	15	20	76	83	159	136	0	0	0	0
Pennsylvania	10	16	19	26	129	141	0	0	2	2
Rhode Island	1	2	5	6	16	17	0	0	0	0
Vermont	1	1	3	4	11	10	0	0	0	0
Lake States	962	1,062	268	1,110	152	254	0	0	36	18
Michigan	363	552	88	116	52	50	0	0	0	0
Minnesota	142	338	102	191	39	77	0	0	36	18
Wisconsin	458	171	108	802	62	126	0	0	0	0
Corn Belt	84	287	90	750	304	531	0	140	168	258
Illinois	0	9	0	22	0	118	0	0	0	46
Indiana	12	133	23	109	109	205	0	0	76	175
Iowa	7	24	16	66	29	61	0	5	3	0
Missouri	23	21	28	511	59	0	0	0	69	0
Ohio	41	99	23	40	106	146	0	0	19	36
Northern Plains	916	5,600	774	5,317	792	401	0	706	2,726	2,948
Kansas	33	70	101	619	0	0	0	0	246	419
Nebraska	219	2,938	0	2,903	552	114	0	706	1,773	1,176
North Dakota	37	145	12	32	7	0	0	0	52	
South Dakota	627	2,447	661	1,763	233	287	0	0	839	1,352
Appalachia	483	120	127	862	571	1,562	0	0	34	25
Kentucky	0	0	17	20	152	154	0	0	0	0
North Carolina	454	58	33	507	55	583	0	0	0	0
Tennessee	12	15	27	37	53	61	0	0	12	0
Virginia	15	41	45	294	283	742	0	0	22	25
West Virginia	1	4	4	3	27	19	0	0	0	0

Continued--

See footnote at end of table.

Appendix table 7--Total cost of energy for onfarm-pumped irrigation water by region and State 1/--Continued

Region and State	Electricity		Diesel		Gasoline		Natural gas		LPG	
	1974	1977	1974	1977	1974	1977	1974	1977	1974	1977
	1,000 dollars									
Surface water:										
Southeast	677	2,021	2,315	11,493	623	5,219	0	16	193	2,373
Alabama	11	30	39	305	57	107	0	16	7	12
Florida	472	1,346	1,874	3,145	0	0	0	0	0	0
Georgia	26	604	337	7,606	566	4,948	0	0	186	2,361
South Carolina	168	39	63	437	0	163	0	0	0	0
Delta States	345	860	767	1,559	847	841	72	49	734	576
Arkansas	174	548	154	872	448	547	0	0	623	508
Louisiana	129	107	443	389	354	288	72	49	72	49
Mississippi	42	203	170	297	45	6	0	0	39	18
Southern Plains	3,192	4,993	385	1,141	205	555	2,680	4,585	1,839	3,939
Oklahoma	0	386	126	796	0	292	0	146	630	2,094
Texas	3,192	4,606	259	344	205	263	2,680	4,439	1,209	1,845
Mountain	10,751	14,737	1,410	1,833	488	496	3	5	123	1,004
Arizona	0	0	0	0	0	0	0	0	0	0
Colorado	48	133	0	0	1	2	0	0	0	1
Idaho	5,390	5,602	307	388	205	263	0	0	39	0
Montana	2,272	2,926	529	700	248	295	0	0	65	0
Nevada	139	506	79	156	6	0	0	0	4	0
New Mexico	103	158	0	0	0	0	0	5	0	0
Utah	2,632	4,387	475	535	0	0	0	0	0	871
Wyoming	166	1,025	20	102	8	35	0	0	15	95
Pacific	18,444	29,088	26	449	0	0	0	0	0	0
California	5,324	12,047	26	449	0	0	0	0	0	0
Oregon	6,941	7,963	0	0	0	0	0	0	0	0
Washington	6,179	9,078	0	0	0	0	0	0	0	0
Alaska	2	3	0	0	2	1	0	0	0	0
Hawaii	7	102	0	0	0	0	0	0	0	0
Total surface water	37,129	59,035	6,482	24,992	5,110	11,008	2,755	5,503	5,972	11,332
Total groundwater and surface water	307,667	587,860	62,362	155,573	30,762	37,195	100,586	187,146	67,692	73,487

1/ Total may not add due to rounding.

Appendix table 8--Prices used for energy cost calculations by region and State

Region and State	Electricity per kWh		Diesel per gallon		Gasoline per gallon		Natural gas per MCF		LPG per gallon	
	1974	1977	1974	1977	1974	1977	1974 1/	1977	1974	1977
					Dollars					
Northeast:										
Connecticut	0.025	0.040	0.39	0.51	0.51	0.53	0	0	0.36	0.45
Delaware	.025	.040	.38	.49	.49	.47	0	0	.32	.45
Maine	.025	.040	.39	.50	.51	.50	0	0	.36	0
Maryland	.025	.040	.38	.49	.49	.55	0	0	.34	.48
Massachusetts	.025	.040	.39	.51	.51	.53	0	0	.36	.45
New Hampshire	.025	.050	.39	.52	.51	.55	0	0	.36	0
New Jersey	.025	.040	.42	.51	.49	.53	0	0	.41	.45
New York	.025	.040	.39	.51	.52	.53	0	0	.36	.45
Pennsylvania	.025	.040	.37	.51	.48	.53	0	0	.40	.45
Rhode Island	.025	.040	.39	.51	.51	.53	0	0	.36	0
Vermont	.025	.040	.39	.52	.51	.50	0	0	.36	0
Lake States:										
Michigan	.023	.035	.36	.48	.51	.50	0	0	.31	0
Minnesota	.023	.035	.37	.45	.48	.50	0	0	.31	.43
Wisconsin	.023	.035	.35	.45	.48	.53	0	0	.32	.43
Corn Belt:										
Illinois	.023	.030	.39	.45	.48	.52	0	0	.30	.38
Indiana	.023	.040	.38	.50	.50	.50	0	1.50	.31	.41
Iowa	.023	.030	.36	.42	.47	.54	0	1.90	.29	.38
Missouri	.023	.030	.36	.44	.46	.46	0	1.20	.30	.42
Ohio	.023	.040	.36	.46	.50	.50	0	0	.30	.40
Northern Plains:										
Kansas	.020	.035	.37	.43	.47	.50	0	.80	.26	.32
Nebraska	.020	.045	.34	.45	.49	.51	0	1.20	.27	.35
North Dakota	.020	.037	.37	.45	.48	.55	0	0	.30	0
South Dakota	.020	.040	.37	.43	.47	.49	0	0	.29	.41
Appalachia										
Kentucky	.023	.029	.38	.46	.48	.50	0	0	.33	.45
North Carolina	.023	.045	.37	.47	.49	.48	0	0	.31	0
Tennessee	.023	.025	.40	.50	.48	.52	0	0	.34	.38
Virginia	.023	.045	.37	.48	.49	.50	0	0	.35	.42
West Virginia	.023	.055	.37	.45	.49	.45	0	0	.35	0

Continued--

See footnote at end of table.

Appendix table 8--Prices used for energy cost calculations by region and State--Continued

Region and State	Electricity per kWh		Diesel per gallon		Gasoline per gallon		Natural gas per MCF		LPG per gallon	
	1974	1977	1974	1977	1974	1977	1974 1/	1977	1974	1977
					Dollars					
Southeast:										
Alabama	0.023	0.035	0.39	0.45	0.45	0.50	0	1.50	0.34	0.39
Florida	.023	.050	.37	.40	.47	.47	0	.90	.35	.37
Georgia	.023	.030	.38	.50	.45	.55	0	0	.34	.42
South Carolina	.023	.035	.42	.52	.47	.54	0	0	.35	.50
Delta States:										
Arkansas	.023	.040	.33	.46	.46	.57	0	1.80	.32	.45
Louisiana	.023	.028	.36	.45	.46	.52	0	.75	.30	.50
Mississippi	.023	.052	.38	.46	.48	.48	0	0	.33	.40
Southern Plains:										
Oklahoma	.023	.030	.35	.45	.45	.55	0	1.20	.28	.44
Texas	.023	.030	.34	.45	.43	.55	0	1.30	.29	.44
Mountain:										
Arizona	.020	.021	.37	0	0.48	0	0	1.50	0.30	0
Colorado	.023	.035	.36	.45	.46	.52	0	1.15	.29	.39
Idaho	.016	.016	.37	.45	.48	.50	0	0	.29	0
Montana	.016	.016	.35	.40	.48	.45	0	0	.30	0.35
Nevada	.015	.030	.40	.45	.50	0	0	0	.32	0
New Mexico	.020	.035	.36		.47	0	0	1.80	.28	0
Utah	.015	.025	.40	.45	.50	0	0	0	.32	.41
Wyoming	.023	.035	.36	.45	.48	.50	0	0	.27	.43
Pacific:										
California	.020	.042	.37	.50	.48	0	0	0	.30	0
Oregon	.013	.014	.35	0	.46	0	0	0	.30	0
Washington	.008	.011	.35	0	.49	0	0	0	.30	0
Alaska	.032	.040	.30	0	.60	.70	0	0	0	0
Hawaii	.030	.050	0	0	.60	0	0	0	0	0

1/ Natural gas is assumed to be 75 cents per MCF.

APPENDIX III

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