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# CC255 Energy Uses in Nebraska Agriculture

D. E. Lane

P. E. Fischbach

N. C. Teter

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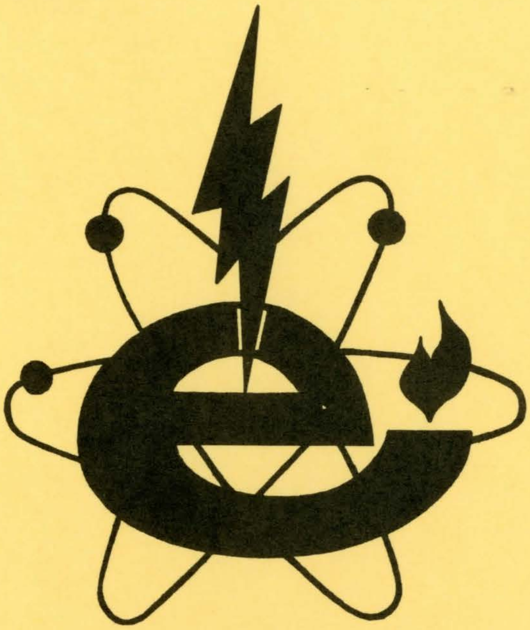

# nergy

## uses in

# NEBRASKA AGRICULTURE

BY

D. E. LANE
EXTENSION AGRICULTURAL ENGINEER

P. E. FISCHBACH
EXTENSION AGRICULTURAL ENGINEER

N. C. TETER
EXTENSION AGRICULTURAL ENGINEER

EXTENSION SERVICE, UNIVERSITY OF NEBRASKA-LINCOLN COLLEGE OF AGRICULTURE COOPERATING WITH THE
U.S. DEPARTMENT OF AGRICULTURE AND THE COLLEGE OF HOME ECONOMICS
J. L. ADAMS, DIRECTOR

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# INTRODUCTION

The efficient utilization of our energy resources is important at any time but it is of special importance today with the realization that oil and gas reserves within the continental United States have a finite and forseeable end point. Our standard of living is based upon the fact that each farmer has at his fingertips sufficient low cost power to allow him to feed himself and 45 others. Should this source of power be removed, the very foundation for our technological society is destroyed.

The very low cost of petroleum as a source of energy has allowed us to be very wasteful in the use of this fuel. The exhaustion of this source of cheap and convenient energy will create a serious cultural shock as we shift to lower levels of energy consumption or to other energy sources.

The purpose of this report is to survey the present demand level for fuels for Nebraska's agriculture, considering the mix of cultural practices, crops, and environment including irrigation, crop drying, and transportation to market. Opportunities are then discussed for reducing the energy demand for productive agriculture, based upon studies carried out at the University of Nebraska and elsewhere. This document is intended as a bench mark for programming to more efficient management practices while sustaining the current level of production.

W. E. Splinter, Chairman
Department of Agricultural Engineering

# ENERGY USES IN MACHINE OPERATIONS

D. E. Lane, Extension Agricultural Engineer

With 18 million acres of crops projected for Nebraska in 1974(1) the critical need for getting more work per gallon of fuel is great. Possibilities do exist for improving fuel efficiency in cropping methods, tractor operation, and tractor maintenance.

## CROPPING METHODS

Results of a survey indicate that most of Nebraska farmers use some form of minimum tillage. Minimum tillage is used in many forms including single pass operations such as the till planter, developed at the University of Nebraska, and other forms such as disking and planting, disking and listing, or shredding, disking, and planting. Of the 10.2 million acres which will be planted to corn, sorghum, or soybeans in Nebraska in 1974, we estimate farmers will use minimum tillage on 8.2 million acres, Table 1. The plow, a high consumer of energy requiring some 19 horsepower-hours per acre as compared to some 6 horsepower-hours per acre for the disk, is eliminated with minimum tillage.

To get some estimate of the amount of fuel needed to raise the principal crops grown in Nebraska, estimates of acreage and energy requirements are given in Table 1. The energy needs for various cultural operations in horsepower-hours per acre, given in Table 2, the number of operations required for each cultural operation, given in Table 3, and the number of acres(1,3) for the various cropping methods were used to calculate the gallons of fuel needed. This is summarized in Table 1 for the crops, cropping methods and acres estimated for each crop for 1974. The total of 73.22 million gallons of fuel includes the 15.8 million gallons for engine operating time other than field time.

Table 1

Cropping Methods - Estimated Acres[1] and Estimated Fuel Requirements[2]

| Crop | Method | Acres | | Diesel Fuel-Gallons |
|---|---|---|---|---|
| Corn | Minimum tillage | 5,287,000 | | 14,931,000 |
| | plow | 1,429,000 | | 6,736,000 |
| | | | 6,716,000 | |
| Milo | Minimum tillage | 2,007,000 | | 5,668,000 |
| | plow | 331,000 | | 1,324,000 |
| | | | 2,338,000 | |
| Soybeans | Minimum tillage | 929,000 | | 2,624,000 |
| | plow | 371,000 | | 1,484,000 |
| | | | 1,300,000 | |
| Other | plow | 200,000 | | 2,000,000 |
| | | | 200,000 | |
| | | | 10,554,000 | 34,757,000 |
| Wheat | Sweep plow | 769,500 | | 5,614,000 |
| | Chisel plow | 896,400 | | 5,214,000 |
| | Plow-disk | 507,600 | | 2,183,000 |
| | Plow-harrow | 550,800 | | 2,011,000 |
| | | | 2,724,300 | 15,022,000 |
| Rye, Oats Barley | Plow-disk | 603,000 | | 1,701,000 |
| | | | 603,000 | |
| | | | 3,327,300 | 16,723,000 |
| Hay - 3 cuttings | | 4,150,000 | | 6,225,000 |
| | | | 4,150,000 | |
| Total Acres | | | 18,031,300 | |
| | | | | 57,720,000 |
| Tractor Travel and Odd Jobs | | | | 15,800,000 |
| Total Fuel | | | | 73,220,000 |

1. Based on estimates from district extension supervisors and others.

2. Calculated using hp-hr/ac for field operations from Table 2.

Table 2
Machinery Data[1]

| | hp-hr/ac | hr/ac | Width ft. | Lb per ft. | Speed mph | Horsepower Requirement |
|---|---|---|---|---|---|---|
| Chop stalks | 10.0 | .11 | 15 | 345 | 5 | 69.0 |
| One-way | 8.7 | .11 | 15 | 300 | 5 | 60 |
| Sweep plow | 4.6 | .08 | 20 | 160 | 5 | 42.7 |
| Chisel plow | 14.5 | .14 | 15 | 500 | 4 | 80 |
| Moldboard plow | 19.0 | .25 | 6 2/3 | 650 | 5 | 57.8 |
| Disk | 5.5 | .11 | 15 | 190 | 5 | 38.0 |
| Field cultivate | 9.5 | .11 | 15 | 328 | 5 | 65.6 |
| Rodweed | 2.6 | .06 | 20 | 90 | 7 | 33.6 |
| Harrow | 5.5 | .08 | 15 | 190 | 7 | 53.2 |
| Drill | 4.5 | .12 | 10 2/3 | 155 | 5 | 22.0 |
| Plant | 4.0 | .16 | 15 | 138 | 3.5 | 19.3 |
| List | 6.7 | .16 | 15 | 230 | 3.5 | 32.2 |
| Cultivate | 3.3 | .14 | 15 | 114 | 4 | 18.2 |
| Combine | 8.6 | .16 | 15 | 390 | 3.5 | 55.0 |
| sprayer | 1.0 | .06 | 30 | 35 | 5 | 14.0 |

1. Calculated from Machinery Management Data, ASAE D230.2 American Society of Agricultural Engineers Yearbook, May 1973.

Table 3

Cropping Methods - Operations[1]

| Operations | Row Crop | | Small Grain | | | | Hay | |
|---|---|---|---|---|---|---|---|---|
| One way | | | | X(2) | | | | |
| Sweep plow | | | | | X(4) | | | |
| Chisel plow | | | | X(2) | | | | |
| Moldboard plow | X | | X | | | X | | |
| Disk | X | X(2) | X | | X(2) | | | |
| Field Cultivate | | | | | | | | |
| Rodweed | | | | X | X(2) | | | |
| Harrow | X | | X | | | X | | |
| Drill | | | X | X | X | X | | |
| Plant | X | X | | | | | | |
| Cultivate | X(2) | X(2) | | | | | | |
| Combine | X | X | X | X | X | X | | |
| Mow | | | | | | | X | X |
| Rake | | | | | | | X | X |
| Bale | | | | | | | X | |
| Buck-stacker | | | | | | | | X |

1. Based on operations given by extension supervisors and others.
2. The number in parenthesis is the number of times the operation is used.

The fuel requirements for field operations are for the time spent working the field with the tractor engine assumed to be loaded at 75% of maximum power. With the engine loaded this way the fuel consumption will be as good as can be expected for field work. However, much time is also spent in the field in turning, loading, unloading, adjustments, travel, and other jobs so added fuel is required for these jobs. Taking 65% of the total time(4) as the working time in the field and assuming 15% less work per gallon of fuel for the other 35% of the time, 73.22 million gallons of fuel are needed for overall field work.

Although, most methods of raising crops in Nebraska include some form of minimum tillage, such as disking and planting, disking and listing, till plant and slot plant could make field time even more effective, Table 4 and 5. Shallow listing in the old row can be as effective as till plant if one of the preplant operations is not used. For example, one disking at 5.5 horsepower-hours per acre should cut the stalks enough for planting which would eliminate a higher energy operation, stalk shredding, which requires 10 horsepower-hours per acre. With disking in place of stalk shredding for both till plant and listing, the energy requirements are; listing 27.4, and till plant 27.6 horsepower-hours per acre, Table 4.

Either till plant or listing, both proven methods, could make a big difference in the fuel bill. Both use about 2.3 gallons of fuel per acre for on-row time at 75% engine loading. This would amount to 24.27 million gallons for row crops in comparison to 34.757 million gallons estimated as needed with the present methods. This is a difference of 10.49 million gallons less fuel or about one fifth of the total fuel

Table 4

Energy Requirements - Tillage, Planting and Harvesting
hp-hr/ac

| Operation | Conventional | List | Till Plant | Slot Plant |
|---|---|---|---|---|
| Chop stalks | 9.9 | 9.9 | 9.9 | |
| Disk | 5.5 | 5.5 | | |
| Plow | 19.0 | | | |
| Disk | 5.5 | | | |
| Harrow | 5.5 | | | |
| Plant | 4.0 | 6.7 | 3.7 | 2.0 |
| Spray | 1.0 | | 1.0 | 1.0 |
| Cultivate | 3.3 | 3.3 | 4.4 | |
| Cultivate | 3.3 | 3.3 | 4.4 | |
| Combine | 8.2 | 8.2 | 8.2 | 8.2 |
| | 65.2 | 36.9 | 31.6 | 11.2 |

Table 5

Fuel Equivalents
Tillage, Planting, and Harvesting

gallons per acre

| Fuel | Conventional | List | Till Plant | Slot Plant |
|---|---|---|---|---|
| Diesel | 5.25 | 2.98 | 2.56 | .93 |
| Gasoline | 7.72 | 4.38 | 3.76 | 1.37 |
| LPG | 8.75 | 4.97 | 4.27 | 1.55 |

requirement.

Slot planting or till planting methods requires the least fuel of all the common cropping methods and uses only three operations; planting, spraying, and harvesting, Table 4. Less than 1.0 gallon of fuel per acre is used for on-row time and about one-third gallon would be used for other engine time. With more than 10 million acres of row crop, till planting or slot planting could save up to two-thirds of the fuel for row crop culture or about 20 million gallons per year.

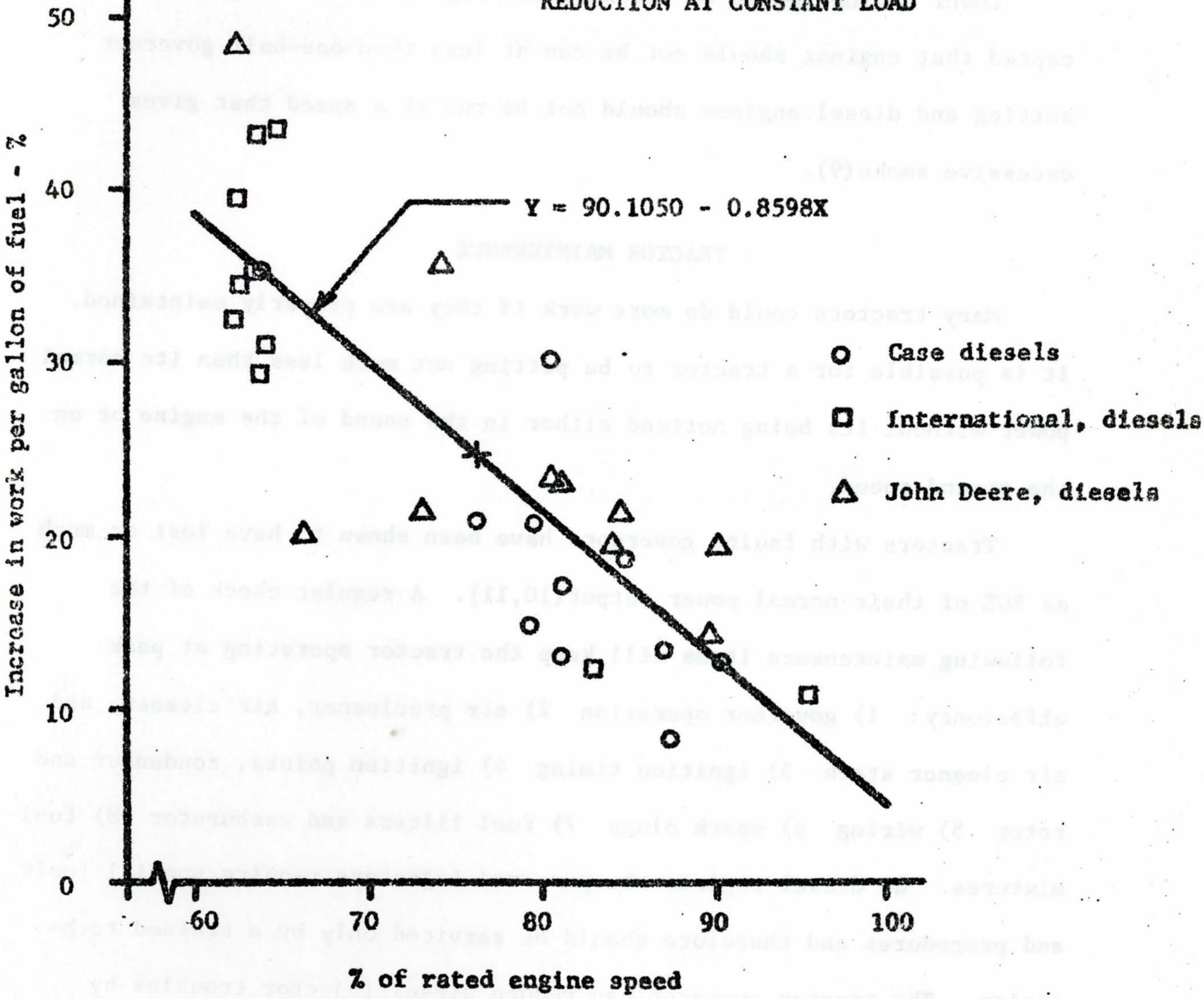
For the best possible use of fuel, farmers should eliminate any unnecessary field operations, eliminate unnecessary travel, eliminate engine idle time and choose operations that have lower energy requirements.

## TRACTOR OPERATION

Tractor engine characteristics of speed and load on work output per gallon of fuel makes it important that tractors be operated to take advantage of these characteristics. The more nearly an engine is loaded to its capacity the more work it will do per gallon of fuel(5). However, to get an acceptable life from an engine it should not be loaded continuously at more than 75% of maximum drawbar power (6,7). For efficient field work the engine should be kept loaded to as near this loading as possible. This can be accomplished in field work with lighter loads by shifting up and reducing the engine speed. However, care must be taken that the engine is not overloaded. If the loaded engine will respond quickly and smoothly when the speed control lever is opened quickly, the engine is operating at part throttle and has some reserve power.

Work output per gallon of fuel is increased at reduced engine speeds and at higher engine loads, Fig. 1, at the same drawbar load and ground speed. It has been found that tractors have an average annual loading

Figure 1.
EFFECT OF ENGINE SPEED
REDUCTION AT CONSTANT LOAD



of 50%(8) the tractor will be operating much of the time at part loads. Therefore for these loads, if the engine speed could be reduced to 65% of rated engine speed the increase in work per gallon of fuel is an average of 34%. This increase amounts to one-third more work per gallon of fuel.

Lower engine speeds do not harm the engine but it is generally accepted that engines should not be run at less than one-half governor setting and diesel engines should not be run at a speed that gives excessive smoke(9).

## TRACTOR MAINTENANCE

Many tractors could do more work if they are properly maintained. It is possible for a tractor to be putting out much less than its normal power without its being noticed either in the sound of the engine or on the ground speed.

Tractors with faulty governors have been shown to have lost as much as 80% of their normal power output(10,11). A regular check of the following maintenance items will keep the tractor operating at peak efficiency: 1) governor operation 2) air precleaner, air cleaner, and air cleaner stack 3) ignition timing 4) ignition points, condenser and rotor 5) wiring 6) spark plugs 7) fuel filters and carburetor 8) fuel mixtures. On diesel engines the pump and injectors require special tools and procedures and therefore should be serviced only by a trained technician. The tractor operator can reduce diesel injector troubles by keeping fuels and lubricants clean and free of dirt and water.

A regular maintenance schedule pays off in power and fuel economy which can increase efficiency an average of 14%(10,11). The maintenance schedule should be set up following the service and maintenance recommendations as given in the operator's manual.

## HARVESTING

Field losses go up as the grain becomes drier or as the season progresses(12). This is true of any crop that is not harvested at or near the optimum harvesting date and is affected by varietal characteristics, weather conditions, disease or insect damage or other field conditions that will cause preharvest losses or higher machine losses.

Minimum field losses for corn occur at about 25% grain moisture and may be less than 5% of the total yield. As the grain dries to 20% moisture the losses may be 11 to 13 per cent of the yield and at 16% moisture may be 15 to 16 per cent of the yield. If there are disease, insect, or weather problems that affect the strength of the stalk or the ear shank the losses may be much higher than this.

## TRANSPORT

Tremendous tonnages of crops must be moved from the field to the farmstead or market. There are about 38 million tons of grain and silage from row crops and small grain moved annually in Nebraska. For purposes of estimating fuel requirements for transport of these crops, calculations are based on a 250 bushel load moved ten miles at 15 miles per hour with an efficiency of 8.5 horsepower-hours per gallon. With these conditions it takes 27.849 million gallons of gasoline to move the tonnage of crops given in Table 6. The 15 mile per hour average speed is based on transport in the field and on country roads by farm trucks.

## MANAGEMENT

Business and inspection trips in the agricultural enterprise are an essential part of the business. Trips must be made to town for supplies and repairs and inspection of the crops is a regular chore.

Table 6

Transport - Estimated fuel Requirements[2]

| Crop | Tons $(x10^6)$ | Gasoline-Gallons |
|---|---|---|
| Corn | 20.02 | 14,644,000 |
| Milo | 4.30 | 3,146,000 |
| Wheat | 3.80 | 2,780,000 |
| Oats | .43 | 448,000 |
| Barley | .04 | 33,000 |
| Rye | .06 | 46,000 |
| Soybeans | .90 | 659,000 |
| Beets, beans, potatoes | 2.0 | 1,463,000 |
| | 31.55 | 23,219,000 |
| Silage | 6.36 | 4,630,000 |
| | | 27,849,000 |

1. Based on average yields and projected acres for 1974
2. Based on 250 bushels per load with 10 mile trip

   Average speed 15 mph and 8.5 hp-hr/gal

An estimate of the fuel required for business management trips is based on 4500 miles per year per farm for cars and pickups at an average fuel consumption of eight miles per gallon. With 72,000 farms in Nebraska, 40.5 million gallons of gasoline are needed to keep the business running.

## SUMMARY

The following figures are the summary of the totals for the various machine operations involved in crop production:

| | million gallons |
|---|---|
| Field operations and other tractor time, diesel fuel | 73.220 |
| Transport of crops, gasoline | 27.849 |
| Business and management, gasoline | 40.500 |

Estimating that 20% of the crop acreage is handled with gasoline tractors, the fuel requirements for field operations and other tractor time becomes 58.576 million gallons of diesel fuel and 21,536,000 gallons of gasoline. The total gasoline consumption for field, transport and management will be 89.885 million gallons.

The total diesel fuel equivalent for field operations, transport, and management is 119.698 million gallons.

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# ENERGY AND IRRIGATION

Paul E. Fischbach, Extension Irrigationist

During 1973 Nebraskan's irrigated more than 5 million acres. About 2300 new irrigation wells were registered in Nebraska during the past year bringing the total to nearly 40,968 wells, irrigating approximately 4.1 million acres (9). Roughly another 1.0 million acres are irrigated from rivers, streams or reservoirs. This past summer irrigators in several areas of Nebraska experienced fossil fuel shortages of diesel and propane. Some rural electric districts also found it was not feasible to connect additional electric loads. There is an indication that the situation will become more difficult. This is especially true in Nebraska which has an excellent water supply, undeveloped land and are experiencing good prices for agricultural products.

We estimated that Nebraska required 567.6 million kilowatts of electricity, 45.5 million gallons of diesel fuel, 60.7 million gallons of L. P. gas, and 3414 million cubic feet of natural gas to power their irrigation pumping plants in 1973, Table 7.

At the present rate of development Nebraskan's could conceivably install enough irrigation wells and pumping plants in 1974 to require an additional 230,000 horsepower. If the units were all diesel powered it would require about another 15 million gallons of diesel fuel. However, electricity, L. P. gas and natural gas will be used to power some of the new pumping plants. Irrigation development could be slowed down if the energy to operate them is not available as it appears about another 2300 new systems will be installed for the 1974 season. However, if the available irrigation technology is used wisely the total energy requirements could be reduced nearly one-half but this would require many

Table 7. Energy required for sprinkler and surface irrigation systems from various fuel sources.

| Energy | Units % | Surface irrigation 1/ Energy required | | Sprinkler irrigation 2/ Energy required | | TOTAL Energy |
|---|---|---|---|---|---|---|
| | | per acre | total | per acre | total | |
| Electric | 30 | 381 kw. | 309.6 million kw. | 656 kw. | 258 million kw. | 567.6 million kw. |
| Diesel | 29 | 30.9 gal. | 25.1 million gal. | 54 gal. | 20.4 million gal. | 45.5 million gal. |
| L. P. Gas | 25 | 48.9 gal. | 33.3 million gal. | 84.3 | 27.4 million gal. | 60.7 million gal. |
| Natural Gas | 15 | 5062 | 2056 million cu.ft. | 8709 cu.ft. | 1358 million cu.ft. | 3414 million cu.ft. |

1/ Based on 2.7 million acres irrigated by gated pipe or siphone tubes from wells total lift 120 feet - 900 g.p.m. applying 20 acre inches at 80 percent of Nebraska Performance Standards for pumping plants.

2/ Based on 1.3 million acres irrigated by sprinklers from wells - total lift of 273 feet, 900 g.p.m. applying 15 acre inches at 80 percent of Nebraska Performance Standards for pumping plants.

changes in irrigation procedures and the installation of newer types of irrigation systems (8).

There are four areas of irrigation technology which, if used properly, could accomplish this goal. They are: 1) increasing water application efficiency; 2) installation of reuse systems; 3) installation of automated surface irrigation systems; 4) increasing the pumping plant efficiencies.

Research and surveys conducted in Nebraska shows that irrigators could save nearly one-half their irrigation water and one-half the energy if they follow the recommended irrigation procedures (12, 17 & 18). Therefore, energy costs could be reduced 7.1 million dollars on the 1.3 million acres irrigated by sprinklers and 8.6 million dollars on the 2.7 million acres of surface irrigation with siphon tubes and gated pipe from irrigation wells, Tables 8 and 9. In addition another 3.1 million dollars in energy costs could be saved if all of the irrigation pumping plants met the Nebraska Performance Standards as described by Agricultural Engineering Dept., UNL, Table 10 (19 & 20).

## INCREASING WATER APPLICATION EFFICIENCY

The first possible way of reducing the energy requirements, with all types of irrigation systems, would be to use a fairly precise method of scheduling irrigations.

At the present time most irrigators use some methods of scheduling irrigations, that is, they don't operate their equipment continuously, except possibly during drouth periods or if they are operating a limited capacity system. Some irrigators schedule by their neighbors, that is, if the neighbor starts his system he immediately goes out and starts his. Other irrigators schedule their irrigations by the stage of

Table 8. Potential Energy savings per year in Nebraska by using "Programmed Soil Moisture Depletion" irrigation procedure with sprinkler systems 1/

| Energy | Units % | Energy 2/ per acre | Saved Energy per acre | Sprinkler 3/ Energy and Dollars saved - Nebraska | |
|---|---|---|---|---|---|
| | | | | | Dollars |
| Electric | 30 | 656 kw. | 328 kw. | 129 million kw. | 2.6 million |
| Diesel | 29 | 54 gal. | 27 gal. | 10.2 million gal. | 2.0 million |
| L. P. Gas | 25 | 84.3 gal. | 42.1 gal. | 13.7 million gal. | 2.1 million |
| Natural Gas | 15 | 8709 cu.ft. | 4354 cu.ft. | 679 million cu.ft. | 0.4 million |
| TOTAL | | | | | 7.1 million |

1/ Based on 1.3 million acres irrigated by sprinkler system from wells.

2/ Total energy per acre required if the pumping plant operating at 80 percent of Nebraska Performance Standards - Agricultural Engineering Dept., UNL.

3/ One-half energy saved by using "Programmed Soil Moisture Depletion" procedure of irrigation but requires automated center-pivot, or solid set sprinkler systems or additional labor on other sprinkler systems.

Table 9. Potential energy savings per year in Nebraska by installing automated surface irrigation system with a reuse system and using "Programmed Soil Moisture Depletion" procedure of irrigation 1/

| Energy | Units % | Energy 2/ per acre | Saved 3/ energy/ac. | Surface irrigation systems Energy and dollars saved - Nebr. | |
|---|---|---|---|---|---|
| | | | | Energy | Dollars |
| Electricity | 30 | 381 kw. | 191 kw. | 154.8 million kw. | 3.1 million |
| Diesel | 29 | 30.9 gal. | 15.5 gal. | 12.6 million gal. | 2.5 million |
| L. P. Gas | 25 | 48.9 gal. | 24.4 gal. | 16.7 million gal. | 2.5 million |
| Natural Gas | 15 | 5062 cu.ft. | 2531 cu.ft. | 1028 million cu.ft. | 0.51 million |
| TOTAL | | | | | 8.6 million |

1/ Based on 2,712,534 acres irrigated by gated pipe or siphon tubes from wells.

2/ Based on a total lift of 120 feet, 900 g.p.m., 20 acre inches applied per year with 975 hours of operation. Eighty percent of Nebraska Performance Standards - Agricultural Engineering Dept., UNL.

3/ One-half the energy and one-half the water saved.

Table 10. Potential energy savings per year in Nebraska through increased pumping plant efficiency.

| Method of Irrigation | Total Energy Cost 1/ Dollars | Saving in Pumping Costs 2/ Dollars |
|---|---|---|
| Sprinkler | 14.2 million | 1.4 million |
| Surface | 17.2 million | 1.7 million |

1/
a. Based on 40,968 registered irrigation wells

b. Average lift in Nebraska of 100 feet plus 173 foot of pressure for sprinklers and 20 foot of pressure for automatic surface irrigation systems.

c. Application of 15 acre inches of water per acre per year for sprinklers.

d. Application of 20 acre inches of water per acre per year for gated pipe and siphon tubes.

e. Pumping plant operating at 80% of Nebraska Performance Standards - Agricultural Engineering Dept., UNL.

2/ Pumping plant operating at 100% of Nebraska Performance Standards - Agricultural Engineering Dept., UNL.

growth of their crop. Adjustments in the schedule and amount of water applied is made according to rainfall and other weather conditions. Some irrigators have worked out very specific irrigation scheduling procedures using weather data, then making a prediction on how much water to apply the next irrigation. Adjustments of the schedule are made according to the rainfall and soil moisture conditions in the root zone. Other irrigators are using electrical resistance blocks to determine when to start irrigations and then apply 3 to 4 inches of water each irrigation. Still others are using a soil tube or auger to take soil samples to determine moisture content. This information is then used to determine when to irrigate.

There are nearly as many scheduling procedures as there are irrigators and most of them good. However, most of the older irrigation scheduling procedures recommended or were calculated to refill the root zone with water each irrigation.

With manually operated surface irrigation systems the big problem in the field appears to be applying the right amount of water and no more. A water meter or some method of measuring water, would be of great assistance in applying the right amount.

With sprinkler systems this is not a problem as the amount of water applied can be calculated from water pressure, nozzle size and time. If excess irrigation water was not applied then energy requirements would also be reduced.

Energy and water use for irrigation could be reduced still further if a limited amount of water was applied each irrigation. Rainfall could become more effective and some of the stored soil moisture in the root zone could be utilized during the peak consumptive use period of the crop.

A revised irrigation management procedure called, "Programmed Soil Moisture Depletion" could be used by irrigators with a deep-medium to fine textured soil to accomplish the effective use of rainfall and utilize stored soil moisture. A full capacity irrigation system (900 gallons per minute on 130 acres) would need to be operated about half the time to apply the needed one inch of water per week or 2 inches every 14 days during July and August. A limited capacity system (600 gpm on 130 acres) would need to be operated about 70 percent of the time. CAUTION - sandy soils with less than 1.7 inch water holding capacity per foot of soil would need a different procedure (1). This practice could be accomplished with very little additional equipment investment. The procedure would require good management and an investment in a soil tube and electrical resistance blocks (10, 11 & 14).

The procedure would require: 1) that the soil moisture be at field carrying capacity to a depth of nearly 5 feet by June 20; 2) the one inch per week will need to be applied before a soil moisture deficit exceeds 3 inches in the root zone; 3) the soil moisture would need to be monitored with a soil tube and/or electrical resistance blocks. A rain guage and water meter could also be useful in adjusting water application according to soil moisture; 4) irrigation may need to be continued until the corn kernels are well dented. Fall and spring rains will usually replenish the soil moisture to a depth of 5 feet by June 20 the next year. However, some off-season irrigation may be needed in western Nebraska. The irrigation management procedure would require that little or no deep percolation would occur. Also if there was irrigation water runoff it would be picked up with a reuse system and returned to the field. The limited water application each irrigation can be accomplished more easily with the automated irrigation systems such as center-pivot, and solid set sprinklers and the automated gated pipe system with a reuse system than with manually operated systems.

### Off Daily Peak Use of Electricity

The research data on "Irrigation Design Requirements for Corn" shows that applying 1.05 inches every 7 days produced the highest corn yield of 166 bushels per acre. This is equivalent to an irrigation system which could supply 2.8 gallons per minute per acre and operating 24 hours a day. A system supplying 1.9 gallons per minute per acre operating 24 hours per day produced 159 bushels per acre, while the check plot produced 102 bushels per acre (8).

Therefore a full capacity irrigation system (900 gallons per minute on 130 acres) on land that has a deep medium to fine textured soil would need to be operated about half the time during the day to apply the needed one inch of water per week during July and August. In the case of electric motor driven irrigation wells, these could be programmed by the electric power district to operate off the daily peak use rate of electricity. This could mean a great savings to some rural electric districts who pay for electricity on the basis of their peak electrical loads.

### Limited Capacity Irrigation Systems

The data also shows that a limited capacity (364 gallon per minute system on 130 acres) operating 24 hours a day could supply the needed water for the irrigation management procedure, Programmed Soil Moisture Depletion. However, irrigation systems break down, that is, center-pivots may get out of alignment during the night and the operator may not get it started until he checked it in the morning. The power to the irrigation well may be interrupted and the system may not be started for several hours. Therefore, the system probably should be designed for a higher capacity. For example, the system capacity for a 130 acre center-pivot could be 600 gallons per minute. The operator then could program the system to be idle 20 to 30 percent of the time. In the past, center-pivot systems have been designed with capacities of 900 to 1000 gallons per minute for 130 acres. By reducing the capacities of the system from 900 to 600 gallons per minute you would reduce the power plant requirement for the system by one-third, providing total lift remains the same.

INSTALLATION OF REUSE SYSTEMS

The third possible way to partially reduce the energy requirements for irrigation would be to install reuse (tailwater) systems on all surface irrigation systems (6). Twenty-five to 40 percent of the water could be saved. The average irrigation well requires a 40 HP electric motor lifting water 100 feet plus the pressure in gated pipe. However, it would require only a 5 HP motor to operate the reuse system to repump the runoff water. Just using reuse systems and good management would save about $2.6 million of the possible $8.6 million in pumping costs that could be saved by installing the auto-surface system with a reuse system.

INSTALLATION OF AUTOMATED SURFACE IRRIGATION SYSTEMS

The fourth possible way to reduce energy requirements for irrigation would be to install automated gated pipe systems with a reuse system on the 2,712,534 acres of land irrigated by wells which now use gated pipe and siphon tubes (4 & 7). This would save 12.6 million gallons of diesel fuel, 16.7 million gallons of L. P. gas, 154.8 million kilowatts of electricity, and 1028 million cubic feet of natural gas, Table 3. The installation of the auto-surface with a reuse system would provide the irrigator with a system with which he could use the revised irrigation management procedure, Programmed Soil Moisture Depletion with less labor than gated pipe and/or siphon tubes. The present problem with gated pipe or siphon tubes is the labor required to change irrigation sets (15). The irrigator usually changes irrigation sets twice a day but this practice often applies more than twice the needed water. However, with the auto-surface irrigation system irrigation sets can be changed every two or three hours automatically. The result is water applications of only 1 or 2 inches each irrigation. The auto-surface system with reuse has an irrigation efficiency of 92 percent and a uniformity coefficient of 91 (3).

INCREASING THE PUMPING PLANT EFFICIENCIES

The fifth possible way to reduce the energy requirements for irrigation would be to adjust or re-engineer the irrigation pumping plants to meet the Nebraska Performance Standards as provided by the Agricultural Engineering Department, UNL (2, 13, 16, 19 & 20). Performance Standard tests show that the average pumping plant is operating at about 80 percent of the Nebraska Performance Standard (5). Therefore, another 3.1 million dollars in energy costs could be saved by bringing all of the 40,968 irrigation pumping plants up to the Nebraska Performance Standards, Table 4.

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# ENERGY USE IN CROP DRYING

N. C. Teter, Extension Agricultural Engineer

Corn and grain sorghum are the two grains requiring the most energy for drying. Small grains, soybeans, and seeds require rather insignificant amounts. Production of both corn and milo are increasing so increasing supplies of fuel will be needed unless rather strict conservation practices are started soon.

In 1974 in Nebraska, 6,716,000 acres of corn are expected to yield 660 million bushels of corn, 70%, or 462 million bushels will be dried. Another 184 million bushels of grain sorghum produced on 2,340,000 acres needs to be dried.

Drying water from grain requires energy; about 1250 B.t.u.'s per pound of energy are required to evaporate a pound of water from grain. All of the energy in heated air cannot be used for drying. An efficiency of 50% is the best we can expect. Therefore, in practice, 2500 B.t.u.'s are required to evaporate a pound of water from grain. This amount of energy is released by burning 0.03 gallons of LPG, or about 0.024 gallons of No. 2 fuel oil in an indirect fired burner.

Fuel need for drying can be computed by estimating the pounds of water to be evaporated and multiplying the pounds by 0.03 or 0.024 gallons, depending upon the fuel used. Water to be removed is found by subtracting the weight of the dried grain from the weight of the wet grain. Take an example: a field is estimated to yield 130 bushels per acre at 15.5% moisture. If the corn is harvested at 25%, how much LP gas is needed per acre? The corn at 15.5% weighs 130 x 56 = 7280 pounds. The wet corn weighs 7280 x $(\frac{100 - 15.5}{100 - 25.0})$ = 8202 pounds, 922 pounds heavier wet than when dry. So 922 times 0.03 gallons of LP will be required per acre (27.7 gallons). The value of 0.03 agrees with two years of experimental data collected at the Nebraska Agricultural Experiment Station where 115,800 pounds of water were removed by burning 3180 gallons of LP gas (0.0275 gallons per pound). An additional 375 gallon of diesel fuel was required for operation of the dryer fans powered by the power take-off of a tractor.

Fuel needs for drying in Nebraska depends on the weather. If crops dry well in the field, fuel needs may be one-half that needed when crops do not dry well in the field.

When crops dry poorly in the field, corn may average 25% moisture at harvest, requiring the removal of 7.5 pounds of water per bushel. Grain sorghum is harvested dryer, having an estimated 3.8 pounds of water to be dried from each bushel in a year when it does not dry well in the field. Most drying is accomplished with LP gas. Requirements for 1974 are estimated at 125,000,000 gallons as found by multiplying the pounds of water evaporated by 0.03. A year that has harvesting weather that promotes field drying may require only one half as much energy for drying.

## CONSERVATION OF DRYING ENERGY

LP gas may be conserved by storing high moisture grain, by preserving grain with acids, by drying with unheated air, or by collecting solar energy to aid in drying(9).

### Ensiling

Shelled corn, grain sorghum heads, ear corn, or whole plants of either corn or milo can be ensiled. About 1½ gallons per acre more energy is required for harvesting as silage than is used in combining, but it is a small part of the power needed for drying.

To obtain good grain silage; harvest early, put it up at moisture between 25 and 30%, pack it well to exclude oxygen, and cover it well. Grain going into bunkers should be coarsely ground. Bunkers may have a cross sectional area of two square feet for each head of beef on feed (12).

## Preserving with organic acid

Acid preservation is similar to ensiling as it is artificial pickling. Propionic and acetic acids are the principal ones used although isobutyric and formic are also possible grain preservers. Acids are applied at the rate of 1.5 to 1.0 per cent by weight depending on the corn moisture. They must be applied uniformly and thoroughly. Costs at present are higher than drying costs. Acids are corrosive to galvanized steel so storage in wooden or coated concrete bins is preferred. Large piles of acid treated corn need to be aerated to prevent spoilage from moisture migration. Treated corn must be fed to livestock (10).

## Natural air drying

Natural air drying is costly and risky for grain over 24% in moisture, but is an economical and relatively trouble-free way to dry high quality grain below 24%.

In the western part of the state, drying with natural air by the layer-in-bin method (1,2,3,4,14) is practical for growers who start harvest as high as 28% moisture. This technique involves filling bins only four feet deep with corn as wet as 28%, then no deeper than eight feet for corn at 24% and no deeper than 12 feet for corn at 22%. A ten horsepower fan should be sufficient for a 30 foot diameter bin; a 3 horsepower for an 18 foot diameter bin (roughly 80 square feet of drying floor per horsepower). The layer-in-bin method using natural air with no heat requires more handling and management than many of the operators can provide at harvest time.

An alternative gas-conserving system is partial drying with heat, 21% being a logical moisture for discontinuation of heated air drying, and finishing the drying with natural air (13).

A variation of the partial drying consists of a process called dryeration where the grain is dumped from a batch or continuous flow dryer while it is hot. The hot grain is transferred to a cooling bin. After being cooled the grain is moved into a natural air drying bin for drying and storage. If the drying bins receive grain at 21% moisture or below the air flow requirement is 1 cubic foot of air per minute for each bushel.

Twenty five million gallon of LP gas might be saved annually in Nebraska by partial drying with heated air followed by natural air drying. This requires additional investment in drying floors, fans and handling equipment.

Recommended rates of ventilation are:

3 CFM/bu. for 24%

1½ CFM/bu. for 22%

3/4 CFM/bu. for 20%

3/8 CFM/bu. for 18%

In good seasons grain will dry in the field to a level that makes natural air drying practical for all of the drying. Conservation of energy dictates that harvesting be delayed as much as time permits. Too much delay in some seasons can cause serious loss, so delayed harvest is a last-resort method of energy conservation.

Although nearly as much overall energy is required to dry grain with heat followed by blowing with natural air, more of the total energy is electrical when more natural air is used.

## ELECTRICAL ENERGY USE

Electrical energy used on the farms of Nebraska is largely generated from coal, nuclear power, and water power. Although several municipal electrical generating plants use natural gas or oil. Their contribution to rural areas is small compared to the nuclear power and coal powered generating plants feeding the rural networks. For this reason, electrical energy use is encouraged for irrigation pumping, for grain processing, and handling, and for feed distribution systems.

Electrical heat energy is economical for drying when properly used (6,11). A modest supplemental electrical heater to increase air temperature 3 degrees will usually dry corn at a lower energy cost per bushel than that used by a system having a fan and no heat. The heater does not reduce air requirements; it shortens drying time. Here again, supplemental heat drying is recommended only for grain of 24% moisture or below. Calculations made by Dr. T. L. Thompson show that 24% corn harvested October 15, 1972 required an energy use of 4.72 kilowatt-hours per bushel for drying with natural air delivered through the grain at 3 CFM per bushel. When 3 degrees of supplemental heat were added to the air for the first nine weeks of continuous ventilation only 3.15 kilowatt-hours were needed and the dried grain was of higher quality.

Electrical energy supplied as supplemental heat saves in total energy required for drying only if the air supply is up to recommended levels for natural air drying. Air at 2 CFM per bushel with 3 degrees of supplemental heat required 4.45 kilowatt-hours for drying and the grain was not as good as that using only 3.15 kilowatt-hours per bushel.

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## SUMMARY

### MACHINE OPERATIONS

It is estimated that for 1974 field work in Nebraska, including tractor travel, idle time and other jobs, will require 73.22 million gallons of diesel fuel, transport of crops will require 27.849 million gallons of gasoline and management will require 40.5 million gallons of gasoline.

Fuel can go farther in field work and other machine operations by:

- use of minimum tillage
- elimination of idle and travel time
- shifting up and reducing engine speed on light loads
- keeping machines in top operating condition
- considering effects on following jobs

### IRRIGATION

It is estimated that irrigation will require 567.6 million kilowatts of electrical energy, 45.5 million gallons of diesel fuel, 60.7 million gallons of LP gas, 3414 million cubic feet of natural gas, plus 15 million gallons of diesel fuel equivalent for new systems in 1974.

Fuel would go further in irrigation by:

- increasing water application efficiency through scheduling
- installation of reuse systems
- installation of automated irrigation systems
- increasing pumping plant efficiency

### DRYING

It is estimated that for 1974 crop drying will require 125 million gallons of LP gas to remove an average of 7.5 pounds of water per bushel.

Less fuel could be used in drying by:

ensiling

preserving with organic acid

natural air drying following removal of water down to 24% grain moisture with heated air drying.

The use of all these practices by an individual could amount to 45% more work for the fuel used in tractor operations, 50% saving in fuel for irrigation and a 50% saving in fuel for drying.

The estimates of total diesel fuel equivalent for field operations, transport, management, irrigation, and grain drying for 1974 amounts to 363.91 million gallons.