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ENERGY NEEDS FOR MINNESOTA AGRICULTURE PRODUCTION 1974 - 1985

Revised March 1976

Minnesota Energy Agency
Forecasting Division

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ENERGY USE IN MINNESOTA FOOD PRODUCTION-1974

In 1974, 93.8 trillion BTU's were directly consumed in food production and its related activities. This amount is equal to 8.8 % of the total energy consumed in Minnesota that year.

Farm Production

		Trillion BTU
Gasoline	134.2 million gallons	16.8
Diesel	50.4 million gallons	7.0
L.P. Gas	91.4 million gallons	8.7
Electricity	1844.0 million kwhrs.	6.3
		38.8

Product Transport

	Rail	Trucks	Barge & Ship	Total	Trillion BTU's
	(Million Gallons)				
Diesel	48.3	27.5	11.6	82.9	11.5
Gasoline	-	89.5	-	89.5	11.2
					22.7 Total

Food Processing

	SIC 20	Trillion BTU's
Distillate	14.7 million gallons	2.0
Residual	16.5 million gallons	2.5
*Natural Gas	14.7 billion cubic feel	14.7
Coal	447.3 thousand tons	9.5
Electricity	1058 million kwhrs.	3.6
		32.3 Total

*Large Natural Gas Users in the Food Processing Sector-1974

	Million Cubic Feet
Meat Products	2804
Dairy	4362
Canning, Fruits & Vegetables	951
Flour, Grain Mills	911
Soybean Oil	1977
Beverages (Malt)	2527
Other	1217
	14,749 Total

Percent of Total State Energy Consumption

	Agriculture	State Total	Agriculture as a Percent of Total State
Gasoline	223.7 million gallons	1963.0	11%
Diesel & Distillate	148.0 million gallons	1028.4	14%
Residual	16.5 million gallons	247.0	7%
Natural Gas	14.7 billion cubic feet	337.5	4%
Coal	447.3 thousand tons	9668.0	5%
Electricity	2902 million kwhrs.	24,554.0	12%

PREFACE

This analysis of energy requirements of Minnesota Agriculture: 1974-1985 is one of a series of papers on energy needs in Minnesota.

Future papers will cover the topics of transportation, commerce, mining, government, households, utilities and refining, manufacturing and construction.

Present information on supply availability and energy requirements has brought the Energy Agency to the conclusion that public and private action will be necessary during the next five years to avoid major disruption of our socio/economic system. Possible solutions to this dilemma are outlined in the report "Minnesota's Energy Situation; A Biennial Report to the Governor and the Legislature, January 1976."

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SUMMARY AND CONCLUSIONS

The viability and growth of the Minnesota economy depends on its large agricultural base. Grain exports and consumer sales of crop and livestock products are major sources of state income. In addition, agriculture supports the large food processing industry in terms of raw material deliveries.

On-farm agricultural production uses about 3.6% of Minnesota's energy. Fuel scarcities in the state are a threat to farmers and related producers. In 1974, farms used approximately 7% of all gasoline, 23% of all diesel fuel, 24% of all liquefied petroleum gas (LPG) and 8% of all electricity. These fuels are frequently critical to farm production and must be available in large quantities for short periods of time.

The energy requirements of agriculture are small compared to its income potential. However, fuel shortages in Minnesota which result in increasing costs of production may have an adverse effect on the competitive position of Minnesota farmers.

The anticipated growth of farm acreage in response to food demands from U.S. and foreign consumers as well as raw materials for local food processing industries results in a long-term annual growth rate of 3% for gasoline and diesel, 5% for LP gas and 4% for electricity. Greater use of reduced tillage on crop farms can reduce this growth rate for diesel fuel and gasoline. Moreover, a shift from gasoline to diesel tractors will dramatically reduce gasoline consumption while simultaneously lowering the combined gasoline and diesel fuel costs.

Energy saving technology should be introduced rapidly in agriculture. New practices that will involve less use of energy for particular operations should be demonstrated. The implicit substitution of farm capital and fuels to labor in the past may be reversed because relative prices and availabilities of resources have shown substantial changes.

I. INTRODUCTION

Purpose

This paper estimates farm consumption of gasoline, diesel fuel, liquefied petroleum gas (LPG), and electricity during the 1974 crop year. Estimates for 1975 and projections for later years are made under alternate tillage practices. For example, reduced tillage on different crop acreages could be introduced in order to lower gasoline and diesel fuel consumption. This paper also examines the implications of rising prices of fuels and other energy related inputs, as well as the effects of various tillage practices on farm production costs.

Background

There are 118,000 farms in Minnesota, covering over 30 million acres of land (14), 55% of the state's land area. Thirteen percent of the population of the state resides directly on farms (23,24).

Minnesota ranks with the top ten producers in agricultural enterprises, and is at least fifth in corn and other cash grains, sugar beets, hogs and milk cows (15). Minnesota led all states in the production of oats, timothy seed and sweet corn in 1973. During that same year, Minnesota farmers raised more turkeys and manufactured more butter and dried milk than any other state (15).

During 1974, Minnesota was first among all states in dairy product exports and sixth in all agricultural exports. The value of these exports during 1974 was $1.16 billion, a threefold increase from the $350 million in 1971-1972 (26,1).

Only 10% of the state's workers are employed on farms, but cash receipts from farming amount to almost 19% of total personal income (29,17,15,20).

In addition, Minnesota's food processing industry, which produces one-third of all shipments by manufacturers and employs 15% of all manufacturing workers, is heavily dependent on the output of Minnesota farms (30,12).

Minnesotans sold $1.6 billion of crops and $2.0 billion of livestock during 1973. The leading farm products were beef cattle, dairy products, hogs, soybeans and corn.

Changes in government farm policies have resulted in major increases in acreages of corn, soybeans and wheat since 1969. Livestock production is expected to grow over the long term with population and income in the U.S. and importing countries. If growth in the livestock industry is sustained, larger plantings of hay and feed grains will be required.

Energy Inputs

Gasoline, diesel fuel, liquefied petroleum gas (LPG) and electricity are the major energy inputs to agriculture in Minnesota. A shortage of these fuels would restrict the use of agricultural machinery, tractors, motors and drying equipment. Higher prices for these basic fuels and for inputs to agriculture derived from petroleum and natural gas, such as fertilizer and farm chemicals, will affect productivity, income and food prices.

Agricultural production is basic to the economy of the state and the well-being of the nation. The Energy Agency has measured the fuel requirements of agriculture and estimated the "energy cost" of continued high levels of output. We have concluded that the extent of mechanization in agriculture has made fuel availability a critical factor in planning for increased production. Furthermore, the seasonality of farm operations requires that

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large volumes of fuels be available for use during very short periods of time. In addition, enormous amounts of fuel and transport facilities are required to move the high volume of output from farms throughout the state.

II. ENERGY USE BY MINNESOTA AGRICULTURE, 1974

Estimation Procedures

Fuel requirements in producing various crops and livestock are estimated for 1974 using tillage intensities, types of machinery and crop acreages or livestock numbers (Figure 1). For example, conventional tillage on corn requires 7.1 gallons of gasoline per acre for land preparation and planting, 0.7 gallons for weed and pest control and other crop care practices, and 2.4 gallons for harvesting (Appendix Table A). Fuel use by diesel tractors for these operations is also developed. Another 20% is added to account for hauling and other uses of farm machineries (16). Thus, consumption of 42 million gallons of gasoline and 13 million gallons of diesel fuel was estimated for the 1974 corn crop (Table 1), based on the assumption that gasoline tractors were used on 70% of total corn acreage. Farm drying 57% of harvested corn at a use rate of 5 bushels per gallon of propane resulted into consumption of some 62 million gallons (6,10,3). In addition, production of 1974 crop output required 372 million kilowatt hours of electricity, given 1974 farm use rates (28,20,21).

Livestock numbers and fuel use intensities for feeding, cleaning and other activities are used to determine fuel consumption in livestock production (21). Estimates for 1974 show 20 million gallons of gasoline, 15 million gallons of diesel fuel, 24 million gallons of propane and 1,473 million kilowatt hours of electricity used in livestock operations. As in crops, a 20% allowance for indirect and other uses of machineries is included. More than half of the estimated fuel consumption was in other livestock, composed primarily of beef cattle and hogs.

Figure 1

ESTIMATION OF FARM FUEL REQUIREMENTS

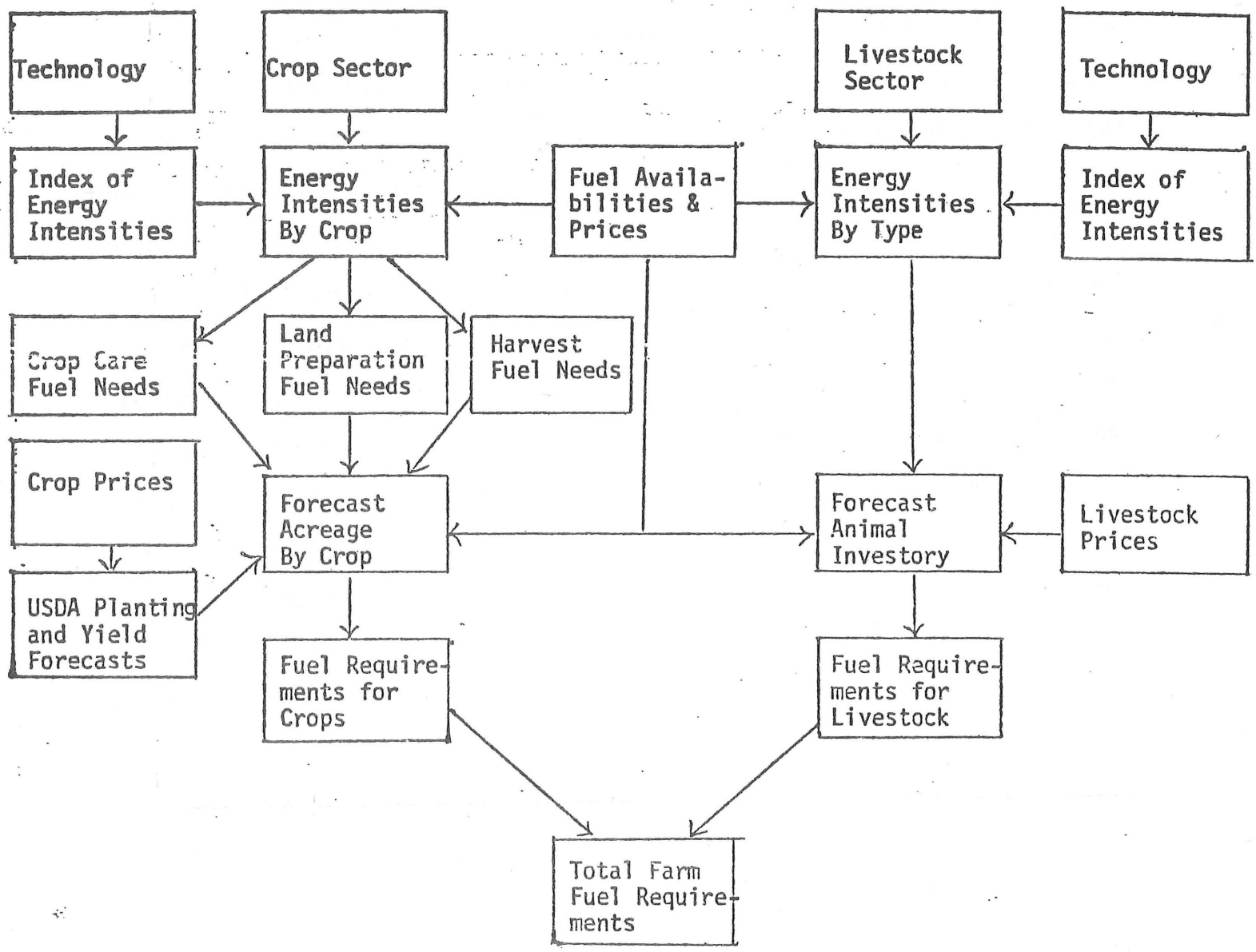


Table 1 - Estimated Fuel Use on Minnesota Farms, 1974

Crop/Livestock	FUEL TYPE			
	Gasoline	Diesel	LP Gas	Electricity
	(1,000 gallons)			(Million kilowatt-hours)
CROPS				
Corn	42,126	13,275	62,552	
Small Grains	31,595	9,799	0	
Soybeans	23,190	7,151	3,347	
Dry Peas, Beans	505	156	0	
Sugar Beets	1,571	497	320	
Potatoes	678	211	0	
All Hay	11,781	3,856	0	
Sunflower, Etc.	1,493	445	500	
Vegetables	1,003	290	212	
Fruits & Nuts	73	10	16	
SUBTOTAL CROPS	114,015	35,690	66,947	372
LIVESTOCK				
Poultry	2,810	2,023	3,372	
Dairy	5,143	3,708	6,163	
Other Livestock	12,267	8,938	14,888	
SUBTOTAL LIVESTOCK	20,220	14,670	24,423	1,473
TOTAL AGRICULTURE	134,235	50,360	91,370	1,844
State Total Fuel Use	1,963,000	218,190	388,700	24,554
Agriculture as a Percent of State Total Fuel Use (%)	6.8	23.1	23.5	7.5

Direct Energy Use On Farms

Minnesota farms required an estimated 7.5% of all electricity, 6.8% of all gasoline, 23.1% of all diesel fuel and 23.5% of all LPG used in the state.

Transportation of farm products required approximately 188 million gallons of gasoline, almost 10% of the gasoline used in Minnesota.

The fuel requirements in Minnesota agriculture by fuel type and crop and livestock classes are shown in Table 1 and Figure 2.

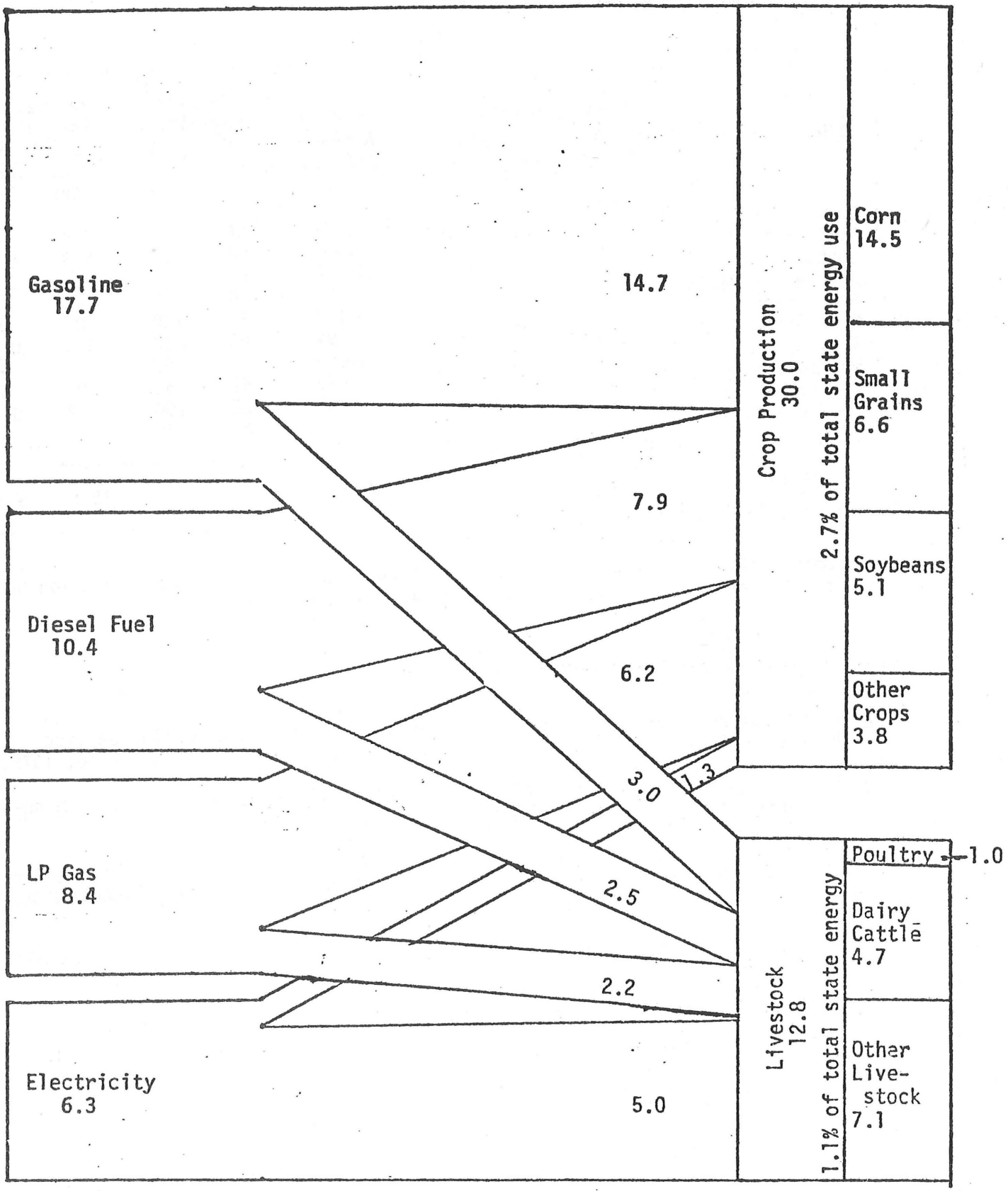
Indirect Energy Use

Substantial petroleum and natural gas are required for the production of fertilizers, pesticides, new machinery and other farm inputs.

The natural gas used in producing nitrogenous fertilizer for application of Minnesota farms is estimated at 20 billion cubic feet. If this natural gas were consumed in Minnesota, it would amount to 6% of the total gas consumed in 1974.

The natural gas requirements for fertilizer by type of crop are given in Table 2.

ENERGY USE FOR FARM OPERATIONS IN MINNESOTA, 1974



Numbers shown are trillions of British thermal units (BTU). See tables for actual fuel units and BTU conversion factors.

Scale: 1cm=2 trillion BTU or 14.5 million gal. crude oil equivalent.

TABLE 2. Estimated natural gas used in producing nitrogenous fertilizer applied on Minnesota farms, 1974.

Crop	Recommended Use 1/ A	Recommended Use 1/ B	1974 2/ Acreage	Percent Fertilized 3/ B	Percent Fertilized 3/ C	Natural Gas Equivalent 4/ B	Natural Gas Equivalent 4/ C
	-lbs Nitrogen/acre-		-1,000 Acres-	(%)		Billion -Cubic Feet-	
Corn	10	120	5,900	56	72	9.9	12.7
Small Grains	30	60	5,939	56	72	5.0	6.4
Soybeans	4	5	4,040	56	72	0.3	0.4
Dry Peas & Beans	4	5	88	56	72	-	-
Sugarbeets	0	0	184	88	100	0	0
Potatoes	20	100	94	88	100	0.2	0.2
All Hay	0	0	3,060	45	58	0	0
Sunflowers, etc.	0	0	270	45	58	0	0
Vegetables 3/	54	54	186	80	100	0.2	0.2
Fruits & Nuts 3/	46	46	5	62	79	-	-
Total	-	-	19,766	-	-	15.6	19.9

1/ University of Minnesota, Agricultural Extension Service, "Crop Production Guide for Minnesota", Extension Pamphlet #194, Revised, 1973.

A = with preceding legume crop
B = without preceding legume crop

2/ Minnesota Department of Agriculture, Crop and Livestock Reporting Service, "Minnesota Crops, 1974 Annual Summary Fall Harvested Crops", January 16, 1975.

3/ B = U.S. Bureau of Censes, 1969 Census of Agriculture Part 15, Vol. 1, Minnesota, Washington, D.C., U.S. Government Printing Office, 1972.

C = Census estimate plus 5% annual growth rate since 1969, D.C. Dohl and W.W.Grant, "The Fertilizer Problem...Situation and Outlook", Minnesota Agricultural Economist, #559, September 1974.

4/ B = Recommended use with no legume crop on fertilized acreage, and at 25,000 BTU or 25 cu. ft. natural gas per lb. of nitrogen nutrient produced.

C = Percent fertilized increased at an annual rate of 5% since 1969.

III. PROJECTIONS OF FUEL REQUIREMENTS FOR FARMING, 1975-1985

Short term - 1975

Planting intentions and livestock numbers on farms in January were used to estimate fuel requirements for 1975 (11). Table 3 shows expected consumption of various fuels. Larger agricultural crop and livestock production results in increases of 9% in gasoline and diesel requirements, 12% in LP gas and 18% in electricity. Reduced tillage on 10% of crop acreage keeps gasoline and diesel use to a 7% increase over 1974 levels.

Long term projections - 1985

Long term projections of fuel requirements in crop and livestock production depend on increases in acreage and livestock numbers over 1974 levels. Assuming that farm acreages and livestock numbers will grow over the long term according to forecasts of output requirements in agriculture by the Minnesota Energy Agency Sectoral Growth Model (Table 4), crop acreages in Minnesota will reach 24 million acres in 1985, or 80% of the potential usable farm area of 30 million acres (19). This is some 12% larger than 1975 planting intentions. It is assumed that acreage expansion will be the primary source of output growth, given increasing prices of fertilizer and chemicals and environmental constraints on use of chemicals. In addition, high yield levels were obtained in the past with heavy applications of fertilizers and chemicals so that further productivity response from additional inputs may already be marginal. Continued growth in agriculture will translate into larger future fuel requirements. Gasoline use may increase 1.8% annually, to a total of 162.5 million gallons in 1985 (Table 5). Diesel fuel, LP gas and electricity

Table 3 - Estimated Fuel Requirements in Farm Production, Conventional and Reduced Tillage, 1975 Planting Intentions.

Crop/Livestock	CONVENTIONAL TILLAGE			
	Gasoline	Diesel	LP Gas	Electricity
	(1,000 gallons)			(Million kilowatt-hours)
CROPS				
Corn	48,052	15,142	71,351	
Small Grains	35,681	11,067	0	
Soybeans	23,419	7,222	3,381	
Dry Peas, Beans	505	156	0	
Sugar Beets	1,913	605	366	
Potatoes	678	211	0	
All Hay	11,781	3,856	0	
Sunflower, Etc.	1,493	445	500	
Vegetables	1,003	290	212	
Fruits & Nuts	73	10	16	
SUBTOTAL CROPS	124,598	39,004	75,826	403
LIVESTOCK				
Poultry	2,839	2,044	3,406	
Dairy	7,337	5,290	8,793	
Other Livestock	11,518	8,392	13,977	
SUBTOTAL LIVESTOCK	21,694	15,726	26,176	1,767
TOTAL AGRICULTURE	146,292	54,729	102,002	2,170
Percent change over 1974	9.0	8.7	11.6	17.7

TABLE 3. (con't.) Estimated Fuel Requirements in Farm Production, Conventional and Reduced Tillage, 1975 Planting Intentions.

	Reduced Tillage on 10% of Crop Acreage			
	Gasoline	Diesel	LP Gas	Electricity
	. . . . .	1,000 Gallons	. . . . .	(million Kwhrs)
CROPS				
CORN.	47063.	14799.	71351.	
SMALL GRAINS.	34695.	10745.	0	
SOYBEANS.	22819.	7026.	3381.	
DRY PEAS,BEANS. . . .	492.	152.	0	
SUGAR BEETS	1864.	591.	366.	
POTATOES.	664.	207.	0	
ALL HAY	11781.	3856.	0	
SUNFLOWER,ETC.. . . .	1453.	433.	500.	
VEGETABLES.	992.	287.	212.	
FRUITS & NUTS	72.	10.	16.	
SUBTOTAL CROPS	121897.	38104.	75826.	403.
LIVESTOCK				
POULTRY	2839.	2044.	3406.	
DAIRY	7337.	5290.	8793.	
OTHER LIVES	11518.	8392.	13977.	
SUBTOTAL LIVESTOCK	21694.	15726.	26176.	1767.
TOTAL AGRICULTURE	143590.	53830.	102002.	2170.
Percent change over 1974	7.0	6.9	11.6	17.7

TABLE 4. Projected Crop Acreages and Livestock Numbers in Minnesota Farms, 1974-1985.

Crop/Livestock	Annual Rate of Growth U.S. 1/	Annual Rate of Growth Minn. 2/	Acreage/Livestock 1974	1975 A 3/	1975 B	1980	1985
	%			(1,000 acres)			
CROPS							
Corn	4.00	2.00	5,900	6,730	6,018	6,643	7,334
Small Grains	2.59	1.30	5,939	6,707	6,016	6,418	6,848
Soybeans	3.30	1.65	4,040	4,080	4,107	4,457	4,836
Dry Peas, Beans	2.59	1.30	88	88	89	95	101
Sugar Beets	2.59	1.30	184	224	186	199	212
Potatoes	2.59	1.30	94	94	95	102	108
All Hay	4.00	2.00	3,060	3,060	3,121	3,446	3,804
Sunflower, Etc.	2.59	1.30	270	270	274	292	311
Vegetables	2.59	1.30	186	186	188	201	214
Fruits & Nuts	2.59	1.30	5	5	5	5	6
LIVESTOCK			(1,000 Head)				
Poultry	4.00	1.70	37,472	37,848	38,221	41,444	45,116
Dairy	4.00	1.70	900	1,284	918	995	1,084
Other Livestock	4.00	1.70	7,731	7,236	7,886	8,550	9,308

1/ U.S. Department of Agriculture, Economic Research Service, "American Agriculture, Its Capacity to Produce", ERS-544, 1974.

2/ About Half of U.S. Growth Rates According to Minnesota Energy Agency Sectoral Growth Model.

3/ Based on 1975 Planting Intentions.

Table 5 - Projected Increases in Fuel Requirements by Minnesota Farms, Annualized Long Term Change, 1974-1985. (Base Case)

Year	FUEL TYPE			
	Gasoline	Diesel	LP Gas	Electricity
	(Million Gallons)			(Million Kilowatt-hours)
1974	134.2	50.4	91.4	1844
1975	136.6	51.3	93.2	1880
1976	139.0	52.2	95.0	1917
1977	141.4	53.1	96.9	1954
1978	143.9	54.1	98.8	1992
1979	146.4	55.0	100.8	2030
1980	148.9	56.0	102.8	2070
1981	151.6	57.0	104.8	2110
1982	154.2	58.1	106.9	2151
1983	156.9	59.1	109.0	2192
1984	159.7	60.2	111.2	2235
1985	162.5	61.2	113.4	2278

consumption may reach 61.2 million gallons, 113.4 million gallons and 2,278 million kilowatt hours, respectively.

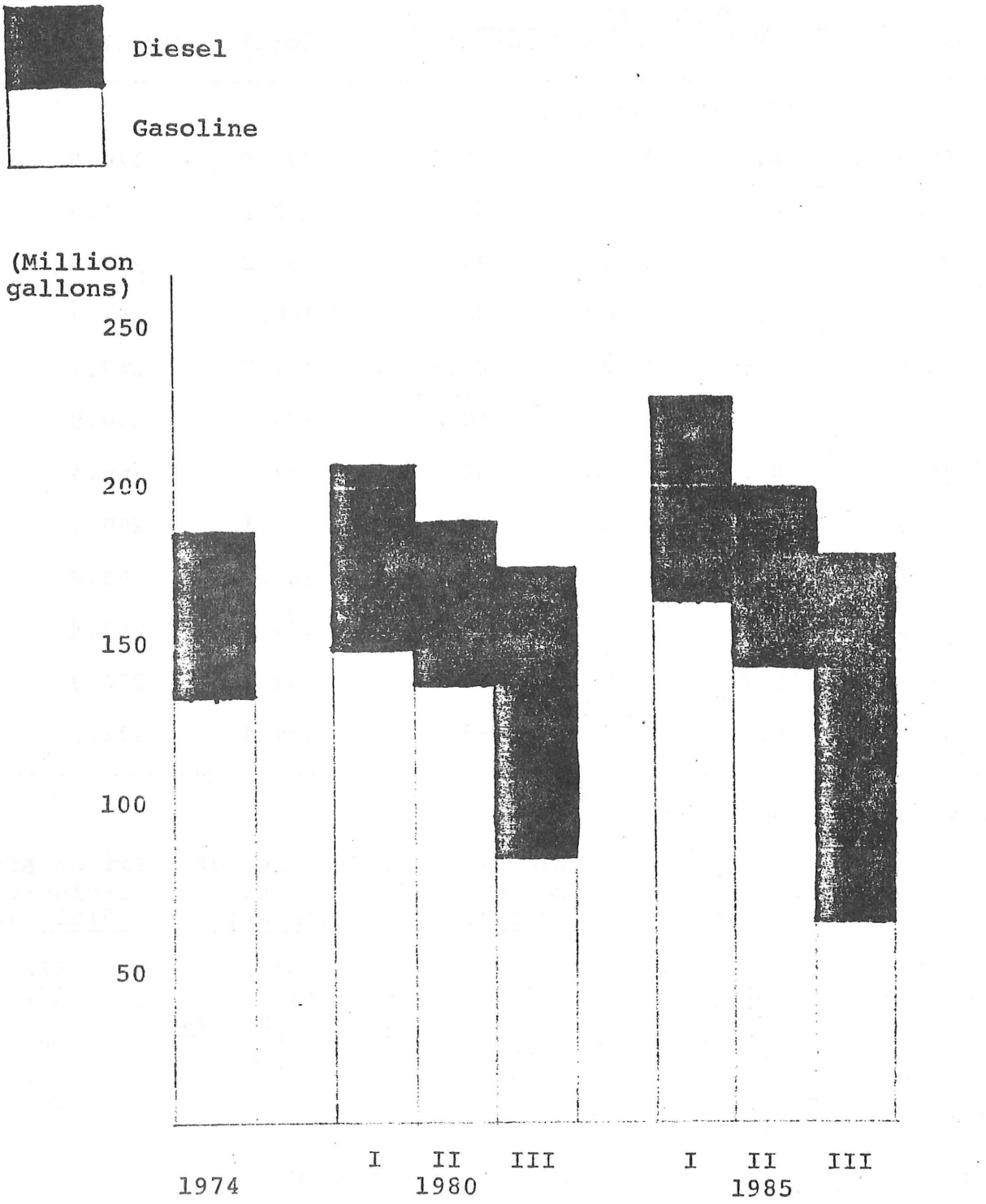
If farmers reduce tillage and shift types of farm machinery (4,3), fuel use intensities will vary. These are ways by which technology revises fuel use through a change in energy intensities (see Figure 1). If reduced tillage is applied on crop acreages at the rate of an incremental 10% of acreage each year, fuel consumption may be expected to rise less rapidly (Figure 3). Reduced tillage on an increasing portion of crop acreage will dampen the growth rate in gasoline and diesel requirements. By 1985, acreage under reduced tillage will reach 68% of crop acreage, but its effect on fuel consumption is offset by prospective increases in total farm acreage.

Replacement of depreciated tractors to the extent that 10% of acreage worked by gasoline tractors is shifted to new diesel tractors every year causes dramatic reductions in gasoline requirements (see Figure 3). Diesel fuel use is expected to rise rapidly but at a reduced annual rate due to a combination of lower fuel consumption per acre and a declining number of gasoline tractors replaced annually.

Effects of Fuel Price Increases on Farm Costs

By multiplying each fuel requirement by the price of the fuel, we can directly transform the requirements into farm production cost. It is estimated that farms used $131 million worth of fuels and electricity in 1974 (Table 6). Another $120 million was spent for nitrogenous fertilizer. Assuming that increases in crude oil and gas prices will cause fuel and fertilizer prices to rise in 1975, the value of these inputs will increase by 26% and 98%,

Figure 3 - Forecasts of gasoline and diesel consumption in Minnesota farm operations under alternative assumptions on tillage and tractor types.



I = base case with projected growth of agricultural output
II = base case plus 10% annual shift to reduced tillage
III = II plus 10% annual shift to diesel tractors

Table 6 - Farm cost of Fuels and Fertilizer, Minnesota, 1974 Estimates and Projections to 1985[1]

Year	FUEL TYPE				Total	Fertilizer[2]	Total Inputs
	Gasoline	Diesel	LP Gas	Electricity			
	(Million Dollars)						
1974	60.4	14.4	21.0	35.0	130.8	120.0	250.8
1975	70.1	16.6	28.5	47.0	162.2	234.3	396.5
1976	71.3	16.9	29.1	47.9	165.2	238.0	403.2
1977	72.5	17.2	29.6	48.8	168.1	241.7	409.8
1978	73.8	17.5	30.2	49.8	171.3	247.2	418.5
1979	75.1	17.8	30.8	50.8	174.5	250.9	425.4
1980	76.4	18.1	31.4	51.8	177.7	256.4	434.1
1981	77.8	18.4	32.1	52.8	181.1	260.1	441.2
1982	79.1	18.8	32.7	53.8	184.4	263.8	448.2
1983	80.5	19.1	33.4	54.8	187.8	269.4	457.2
1984	81.9	19.4	34.0	55.9	191.2	274.9	466.1
1985	83.4	19.8	34.7	57.0	194.9	278.6	473.5

[1]Fuel prices are assumed at:

	Unit	1974 Prices Exclusive of State Tax	Increase of $3/Barrel Crude Oil	Prices After 1975 Exclusive of State Tax
Gasoline	¢/gallon	45.0	14%	51.3
Diesel	¢/gallon	28.5	14%	32.3
			Change 1973-74	
LP Gas	¢/gallon	23.0	33%	30.6
Electricity	¢/Kwh	1.9	31%	2.5
Fertilizer	¢/lb. N	19.2	92%	36.9

[2]Assumption B on percent of crop acreages fertilized.

respectively (see Table 6). These price changes will increase the value of fuels used on 1974 farm area from $141 million to $159 million.

The cost of nitrogenous fertilizer between 1974 and 1975 almost doubled because large price changes in 1973-74 was expected to continue during 1975. This is likely if another natural gas scarcity leads to lower fertilizer output and higher production cost for fertilizer. On the other hand, fertilizer cost will amount to only $122 million if 1974 prices hold. This is equivalent to a 2% increase over 1974, due mainly to expansion of crop acreage.

Fuel costs to Minnesota farms are expected to grow at annual rates of 3% for gasoline and diesel, 5% for LP gas and 4% for electricity. The cost of fertilizer may increase 8% annually, due to a combination of dramatic price increases between 1974 and 1975 and continued growth of Minnesota agriculture.

Reduced tillage and shifts from gasoline to diesel tractors will reduce fuel cost growth rates over the long term (Table 7). The cost of farm fuels will rise less rapidly with a 10% annual acreage conversion to reduced tillage, while a simultaneous shift to diesel tractors has the effect of reducing farm fuel costs. However, savings will decline as the effects of shifts to lower-priced diesel fuel are offset by increases in total farm acreage.

Table 7 - Projections of Total Gasoline and Diesel Cost to Minnesota Farms Under Alternative Fuel Conservation Measures.

Year	Base Case	10% Annual Acreage Conversion To Reduced Tillage	Reduced Tillage Plus 10% Annual Shift To Diesel Tractors
		(Million Dollars)	
1974	74.8	74.8	74.8
1975	86.7	85.1	81.9
1976	88.2	85.2	79.2
1977	89.7	85.4	76.9
1978	91.3	85.7	74.9
1979	92.9	86.1	73.2
1980	94.5	86.6	71.8
1981	96.2	87.3	70.7
1982	97.9	88.0	69.7
1983	99.6	88.8	69.1
1984	101.3	89.7	68.5
1985	103.2	90.6	68.2

IV. ENERGY CONSERVATION IN AGRICULTURE

Farm equipment used 3.8% of Minnesota's total energy in 1974. Based on national estimates, farmers' cars and trucks used almost as much, and energy required for fertilizer production (mostly outside of Minnesota) was equally significant (31). The many ways energy use for cars and trucks can be minimized through purchase of energy efficient models, good maintenance, fewer and shorter trips, and good driving habits are well covered elsewhere. The following section summarizes how energy use for farm field operations and fertilizer production can also be minimized.

Equipment Operation and Design

It has been estimated that 9% of the gasoline and 12% of the diesel fuel used by farm equipment could be saved through improved operation procedures and better design (4). Regular tuneups and other routine maintenance, better training of equipment operators and avoidance of unnecessary idling are all basic energy conservation measures that apply to farm equipment as to other types of machinery. In addition, farmers can get more work out of the same energy investment by being careful to match tractor and load as closely as possible, adjusting tractor gearing and speed to the load being pulled, and using multiple implement operation wherever feasible. Government or industry action requiring tractors to be labeled with drawbar horsepower and implements with the horsepower required to pull them would assist farmers in choosing what equipment to buy of use for a given operation. Optimum tractor balasting will also improve energy efficiency by providing enough weight for proper traction without creating excessive rolling resistance.

Tillage Practices

There has been much discussion in agricultural literature of the pros and cons of reduced or minimum tillage, in which some field operations for soil conditioning and weed control are eliminated or combined with others and increased use is made of herbicides and pesticides for crop protection. Since one pound of herbicide with petroleum carrier is equivalent to about 0.95 gallons of diesel fuel (4), there is a tradeoff involved whenever increased herbicide use is required to make up for reduced cultivation. Whether reduced tillage will save energy depends on the type of soil, the crop being grown, and the weeds involved.

Although some sources report significant yield reductions under reduced tillage, this problem appears to be most evident with extreme "no-till" systems. Since an estimated 75% of U.S. corn acreage was already under some form of reduced tillage in 1972 (4), it appears that many farmers find the energy and labor savings possible under such methods outweigh the disadvantages.

Fertilizer Use

The energy required to produce, transport, and apply 100 pounds of nitrogen fertilizer to an acre of farmland is equivalent to more than 19 gallons of diesel fuel, but Minnesota experiments have shown that 3 to 7 times that amount of equivalent food energy can be recovered through increased yields resulting from fertilizer use (32). Energy efficiency must, therefore, be increased through better use of fertilizer or use of other methods of providing soils with the nutrients they need for high crop yields.

Greater use of soil testing is a vital prerequisite to optimum fertilizer use. Many farmers use more fertilizer than the soil actually needs for desired yields, while others use too little and

could improve their production through greater fertilization. The result of all farmers using the optimum amount of fertilizer as determined by soil testing would probably not be a decrease in the total fertilizer used, but an increase in crop production using the same amount of fertilizer.

Improved timing is another way to achieve the greatest benefits from fertilization. By applying fertilizer as close as possible to the time crops are planted, nitrogen loss into the air or drainage water and phosphorus or potassium loss through reaction with other soil elements can be minimized. Localized placement of fertilizer in a band close to the crop row may also save energy over broadcast fertilization.

Substitution of plant or animal nutrients for chemical fertilizers can save significant amounts of energy while maintaining yields. In a Pennsylvania experiment, corn grown through a stand of crown vetch produced the same yield with 50 lb/acre of nitrogen fertilizer as conventionally grown corn with three times as much fertilizer (4). Traditional crop rotation systems similarly make use of legumes to fix nitrogen in the soil for other crops.

Animal manure, of course, has long been used to nourish field crops and is still a major alternative to chemical fertilizers. While fall spraying of liquid manure has come under attack because of runoff pollution, use of knife-down techniques should minimize this problem. Plowing down of legumes--sometimes called "green manure"--is another traditional way of fertilizing crops which can also be a valuable substitute for costly and energy-intensive chemicals.

Herbicides and Pesticides

These heavily used substances have a high level of energy input but they may also pay high dividends in crop yields. According to one study of wild mustard control in wheat, each unit of energy input in the form of herbicides returned 130 units of food energy in increased crop production (33). Nevertheless, significant energy savings may be achieved without sacrificing yields through the careful application and use of herbicides and pesticides.

For example, band application of herbicides may save 25 to 50% of the energy required for broadcast techniques, depending on whether additional cultivation is required. For pesticides, changing from routine treatment of crops to a "treat when necessary" approach based on pest monitoring systems could save an estimated 35% where such an approach is feasible (4). Another way energy might be saved in the future is if non-petroleum carriers, such as peanut oil or corn oil, can be successfully used with herbicides and pesticides.

Irrigation

An estimated 111,233 acres, or about 0.4% of Minnesota's farmland, was irrigated in 1974. An estimated 40% of the state's irrigation pumps run on electricity, with the rest using diesel fuel (35%), gasoline (15%), or LPG (10%). The major factors affecting energy requirements for irrigation are amount of water pumped, distance to water, losses in piping, and discharge pressure (34).

The two major ways of reducing the energy use per acre for irrigation are by increasing system efficiency and by decreasing the amount of water pumped. System efficiency can be maximized by purchasing the most appropriate type and size of pump, piping, and

gaskets and making sure that they are operated under the proper pressure and receive regular maintenance. The amount of water pumped can often be decreased by using soil moisture sensors to turn the irrigation system on only when the soil is dry and off again when sufficient water has been delivered. Further savings may be possible if the irrigator takes advantage of a knowledge of crop-soil-plant relationships to concentrate on supplying adequate moisture during the periods most critical to plant growth.

Crop Drying

Removal of excess moisture from corn and other crops through machine drying has become very widespread in recent years. This procedure allows crops to be harvested before they are fully dry, significantly reducing field losses, and eliminates mold formation and other problems which would occur in handling and storing wet grain. LP gas is the major crop drying fuel, but electric dryers are gaining popularity due to recent increases in LP gas prices and perceived future scarcities.

Several techniques have been proposed to reduce energy use for crop drying. One of the most promising is "dryeration", a procedure by which grain is removed from the dryer hot but not quite dry, kept 4 to 12 hours with no air flow, and then cooled slowly with aeration to make use of the stored heat for moisture vaporization. Besides saving energy, dryeration is said to result in a 50 to 60% increase in throughout and improved product quality due to decreased kernel stress (4).

Use of solar energy is another promising way to reduce dependence on scarce fuels in crop drying. A solar crop dryer with an electric fan and backup electric heater was successfully demonstrated

in South Dakota in the fall of 1973. The backup electric heater was not needed in the test, and the exclusive use of solar heat resulted in a saving of 2.5-3 kilowatt-hours per bushel (35). If electric heating had been required, it would have been only during the off-peak nighttime hours, thus easing the burden on the electric utility supplying power. Materials for a do-it-yourself solar dryer with a 5000 bushel capacity bin are estimated to cost $500. Use of solar energy is estimated to save 2 cents per bushel at current energy prices, leading to a saving of $100 per year (35).

Livestock

Compared to the crop sector, studies of energy use and potential conservation in the livestock sector are generally lacking. One major way energy can be conserved indirectly in livestock operations is through improving efficiency of feed use. This includes not overfeeding grain to animals beyond their optimum weight and making maximum use of agricultural residues as feed for animals able to digest them.

The most important area where direct energy use can be reduced is in the heating of animal shelters. Building insulation and environmental controls can improve use of feed energy and provide healthier conditions for animals as well as save fuel. Solar collectors can provide auxiliary heating, while heat pumps and heat exchangers can make possible the recapture and re-use of exhaust heat. Heating requirements for poultry can often be reduced through greater poultry densities and use of curtains within buildings to reduce the volume of heated space.

V. AGRICULTURAL WASTES AS AN ENERGY SOURCE

Crop residues and livestock wastes, like other organic materials, are potential energy sources because they contain carbon. However, their low density, high moisture content, and lack of geographic concentration have made their use uneconomical compared to fossil fuels in recent years. Rising prices of those fuels may make agricultural wastes an attractive energy source in the near future. In fact, it has even been suggested that future "energy farms" will raise high-BTU crops for their fuel energy alone.

According to a University of Minnesota study (39) the 27 million tons of harvestable residues from Minnesota's major crops have an energy content of over 430 trillion BTU, or about 40% of the state's total yearly energy use. Animal manures containing 6.5 million tons of volatile solids add another 100 trillion BTU per year to the gross energy contained in Minnesota's agricultural wastes.

In practice, only a fraction of this energy may actually be recovered because of conversion inefficiencies. Besides direct burning for heat or power generation, organic wastes may be converted to fuel gas by biological processes such as anaerobic digestion, transformed into alcohol or other chemicals by biochemical processes, or used to produce liquid or gaseous fuels through pyrolysis. Anaerobic digestion of livestock manure, besides producing cleanburning methane gas, also serves as primary pollution control treatment, thus alleviating environmental problems associated with feedlots and other high density livestock operations. The residue from the process has desirable characteristics as a fertilizer and soil conditioner (39).

Peoples Natural Gas Company of Chicago has already contracted to purchase 1.2 billion cubic feet per year of methane gas--enough to heat 7,000 Chicago homes--generated from 170,000 tons of cattle manure from feedlots in Oklahoma and Texas (38). Researchers at the University of Minnesota are working to develop a biogas generator for farm use which could make farms energy self-sufficient at the same time as it aids in the disposal of livestock waste.

Not only fuel (methanol) but also useful chemicals such as anhydrous ammonia, urea, nitric acid, and ammonium nitrate would be generated by a process developed by Battelle Northwest Laboratories in Richland, Washington (37). The Koppers Company of Pittsburgh has also developed a conversion process for organic materials.

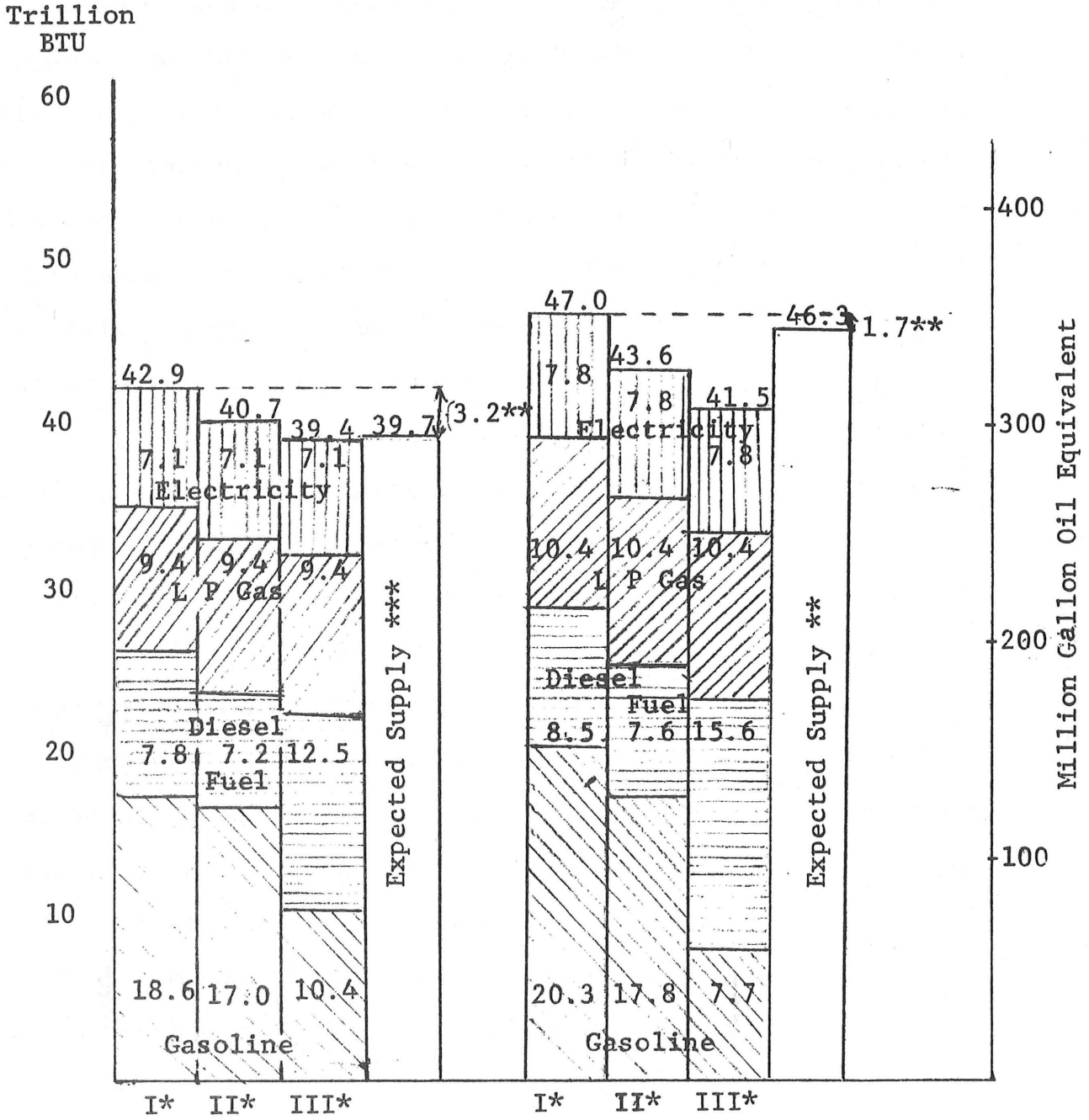
In a related area, the HYGAS process, originally designed for gasifying coal, is being tested by the Minnesota Gas Company for possible use in producing gas from Minnesota's abundant peat supplies. Though not planted like farm crops, peat is a renewable organic material which can be harvested annually.

VI. PROSPECTS FOR AGRICULTURAL ENERGY SUPPLY AND DEMAND

Given the supplies of conventional fuels foreseen for the short run (36), and allocating to farm operations the same proportionate share of the State's total energy as they used in 1974, Figure 4 shows the difference which must be made up through new energy sources, conservation measures as in Cases II and III, or the reallocation of energy from other uses. Shortfalls in 1980 came to about 3.2 trillion BTU, but with alternative practices as in Cases II (reduced tillage) and III (reduced tillage plus shift to large diesel tractors), expected energy supplies will be sufficient. In 1985, faster growth of supplies relative to agriculture output growth results into smaller demand-supply gap. However, conservation needs to continue in order to safeguard against uncertainties of additional supplies beyond 1980. Should energy supply to agriculture stabilize at the 1980 level, shortages will occur even with reduced tillage and tractor shifts.

The importance of food production to Minnesota's economy far outweighs agriculture's share of the state's energy consumption. Nevertheless, substantial energy savings are possible in farm operations as elsewhere. Often these savings require little or no capital investment and offer significant money savings to the farmer. If farmers and other Minnesotans all work to conserve energy wherever possible, we can help insure that we will have enough fuel to produce the food and other goods we will need in years to come.

Fig. 4 Supply and Demand for Energy for Minnesota Farm Operations



I* = Base case with projected growth of agricultural Output
II* = Base case plus 10% annual shift to reduced tillage
III* = II plus 10% annual shift to diesel tractors

** Represents shortfall from base case, need for conservation measures as in Cases II and III, new energy sources, additional energy imports, and/or reallocation of energy from other sectors.

*** Based on 3.6% of total conventional energy supplies expected to be available.

APPENDIX TABLE A. Estimated Fuel Use Intensities in Minnesota Agriculture, By Crop Sector and Type of Tillage

Crop/Livestock	All Gasoline 1/						All Diesel 1/						LPG	Electricity
	Land Prep.		Crop Care		Harvest		Land Prep.		Crop Care		Harvest			
	C	R	C	R	C	R	C	R	C	R	C	R		
CROPS	Gallons Per Acre													--Kwh/Acre--
Corn	7.1	5.1	0.7	0.6	2.4	2.4	5.3	3.7	0.5	0.4	1.7	1.7	18.6	18.8
Small Grains	5.9	3.8	0.1	0.1	1.6	1.6	4.3	2.7	0.1	0.1	1.1	1.1	0	18.8
Soy Beans	5.9	3.8	0.7	0.7	1.6	1.6	4.3	2.7	0.5	0.5	1.1	1.1	4.1	18.
Dry Peas & Beans	5.9	3.8	0.7	0.7	1.6	1.6	4.3	2.7	0.5	0.5	1.1	1.1	0	18.8
Sugar Beets	7.5	4.4	0.5	0.5	4.2	4.2	5.5	3.5	0.5	0.5	3.0	3.0	1.2	18.8
Potatoes	5.9	3.8	0.6	0.6	3.8	3.8	4.3	2.7	0.5	0.5	2.7	2.7	1.2	18.8
All Hay	0.0	0.0	0.3	0.3	5.2	5.2	0.0	0.0	0.2	0.2	4.0	4.0	0	18.8
Sunflowers	5.9	3.8	0.1	0.1	1.9	1.9	4.3	2.7	0.1	0.1	1.1	1.1	1.8	18.8
Vegetables	2.6	2.3	2.6	2.3	2.5	2.3	1.7	1.5	1.7	1.5	1.8	1.6	1.1	18.8
Fruits & Nuts	0.0	0.0	10.4	9.4	10.4	9.4	0.0	0.0	3.2	2.9	3.3	3.0	3.2	18.8

LIVESTOCK	Gasoline	Diesel	LPG	Electricity
	Gallons/1,000 Animals			M Kwh/1,000 H
Poultry	0.075	0.054	0.090	0.0001
Dairy	5.714	4.120	6.848	0.8790
Hogs	2.646	1.906	3.180	0.0877
Beef Cattle	0.800	0.600	1.000	0.0877
Sheep & Lambs	0.600	0.450	0.700	0.0877

1/ C = Conventional Tillage
R = Reduced Tillage

Sources: J. True, "Fuel Use in Crop Production", Dept. of Agric. Engineering, University of Minnesota, 1974.
Iowa State University, "Fuel Requirements for Field Operations", March 1974.
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U.S. Dept. of Agriculture, Statistical Reporting Service, Agricultural Prices, November 1973.

*M Kwh - means millions of kilowatt-hours

APPENDIX B

EQUATIONS USED IN ESTIMATING AGRICULTURAL ENERGY USE

Crop Acreages

$$A_{i,\ t+1} = [A_{i,t}] \times [1 + r_i]$$

where: $A_{i,t}$ = Planted acreage for crop (i,i=1,...,10) at year (t, t=1970,...,1985)

r_i = Projected annual rate of growth of acreage for crop (i, i=1,10) at the national level (27).

Livestock numbers

$$L_{i,\ t+1} = [L_{i,t}] \times [1 + p_i]$$

$L_{i,t}$ = Number of livestock of type (i,i=1,...,5) at end of year (t, t=1970,...,1985),
P_i = projected annual rate of growth of livestock numbers at the national level (27).

Fuel Use in Crop Production:

Gasoline

$$GA_{i,j,t} = ([A_{i,t}]\ [R_i]\ [T_{i,j}] + [A_{i,t}]\ (1-R_i)\ (G_{i,j})\ PG_t$$

and

$$GC = \sum_{i=1}^{10} \sum_{j=1}^{3} GA_{i,j,t}$$

$GA_{i,j,t}$ = Gasoline use in crop (i,i=1,...,10) for field operation (j,j=1,2,3) at year (t,t=1970,...,1985).

R_i = Proportion of crop acreage i under reduced tillage practices.

$T_{i,j}$ = Gasoline use per acre crop i for operation j under reduced tillage.

$G_{i,j}$ = Gasoline use per acre crop i for operation j under conventional tillage.

PG_t = Proportion of crop acreage under gasoline tractors at year t.

GC_t = total /Gasoline consumption in crop production at year t.

Diesel

Using the formulation for gasoline consumption above, diesel use for different crops under various operations are substituted for gasoline use and PG_t becomes $(1-PG_t)$.

Electricity

$$E_{i,t} = A_{i,t}\ [Wi]$$

Wi = Electric consumption per acre of crop i (20, 21, 3)

Fuel Use in Livestock Production:

$$GL_{i,k,t} = L_{i,\ t}\ [Y_{i,k}]$$

Y_i = Consumption of fuel (k, k = 1,2,3) per 1,000 units of livestock (i,i=1,...,5) (21,20).

and

$$Gl_{n,k,t} = \sum_{i} GL_{i,k,t}$$

GLn,k,t = Consumption of fuel k in livestock group (n, n=1,2,3), i being a subset of n, at year t.

APPENDIX C

CONVERSION FACTORS FOR MINNESOTA

				Source
Coal	1 pound	=	10,615 BTU	(1)
Natural Gas	1 cubic foot	=	1,000 BTU	(2)
Liquefied Petroleum Gas	1 gallon	=	92,000 BTU	(3)
Gasoline	1 gallon	=	125,000 BTU	(4)
Distillate Oil	1 gallon	=	138,690 BTU	(4)
Kerosene	1 gallon	=	135,000 BTU	(4)
Residual Oil	1 gallon	=	149,690 BTU	(4)
Electricity				
Consumption	1 KWH	=	3,412 BTU	(5)
Production	1 KWH	=	10,500 BTU	(4)

Sources:

(1) U.S. Bureau of Mines, "Bituminous Coal and Lignite Distribution, 1973", and information provided by telephone (weighted average of coal shipped to Minnesota in 1973).

(2) American Gas Association, Gas Facts, 1972 and 1973. (Average BTU value of natural gas sold in Minnesota).

(3) Approximate value based on conversion factors used by Twin City area propane dealers.

(4) U.S. Bureau of Mines. "Crude Petroleum, Petroleum Products, and Natural Gas Liquids: 1972", (average values for U.S.).

(5) U.S. Congress, Subcommittee on Energy of the House Committee on Science and Astronautics, "Energy Facts", 1973.

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