Agriculture
Canada

Publication 1775/E

saving energy and dollars on the farm

Canada

Preface

This publication is aimed at farmers and extension personnel who are interested in energy conservation. It is intended to help determine where energy savings can be made and to estimate the potential savings.

Acknowledgement

This publication was written by Eric Jensen of Jensen Engineering Ltd. of Olds Alberta with the artwork and layout prepared by Edmund H. Perkins of the Saskatchewan Research Council. The Energy Research and Development in Agriculture and Food (ERDAF) program of Agriculture Canada provided funds through a contract managed by Dr. Wally Nicholaichuk formerly with Agriculture Canada at the Swift Current Research Station, Saskatchewan.

This publication was extensively reviewed by many people involved in energy management and their suggestions and contributions incorporated to develop the publication. The following people or their staff reviewed the manuscript.

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1 FARM ENERGY MANAGEMENT

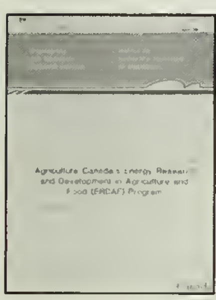
Modern Agriculture Runs On Energy. Energy and mechanization have made Canadian farmers some of the most productive food suppliers in the world, despite limitations of climate and geography. Farmers depend upon energy to power equipment, heat buildings and dry crops. Energy is also needed to produce other essential farm inputs such as fertilizers, pesticides and machinery.

Before the OPEC oil embargo of 1973, energy was not a major cost in farm production. Since then, farmers have begun to realize how vulnerable they are to energy prices and supply. Each year Canadian farmers spend more than $1 billion on fuels and electricity. Nitrogen fertilizer, made from natural gas, costs an additional $300 million per year.

Energy Management Saves Money. The energy invested in agriculture is generally well spent, producing food and fibre for Canadians and for export. However, like other industries, agriculture has opportunities to improve the efficiency of energy use. This publication discusses farm energy management and shows how energy costs can be reduced by at least 10% on most farms. It also discusses some of the opportunities and pitfalls of renewable energy on the farm.

Research. Various government agencies, universities and private companies conduct research on energy use in the food system. This study was commissioned by the Engineering and Statistical Research Institute of Agriculture Canada under the Energy Research and Development in Agriculture & Food (ERDAF) Program.

Information Sources. Material for this publication was compiled from a review of technical journals, farm magazines, extension factsheets and research reports. Selected references are listed for each subject discussed. Wherever possible references were chosen which are available free of charge from the sources listed. Your provincial extension agencies should be contacted for more detailed information specific to your region.



MORE INFORMATION:

1) **Agriculture Canada's Energy Research and Development in Agriculture and Food (ERDAF) Program.** Publication I-107R available from the Engineering & Statistical Research Institute, Research Branch, Agriculture Canada, Ottawa, Ontario. K1A 0C6.

2) **Energy for Agriculture and Food.** Publication 5142E, available from Communications Branch, Agriculture Canada, Ottawa, Ontario. K1A 0C7.

3) **Farm Energy Use Survey.** Statistics Canada has prepared a summary of energy data collected from a special survey of 7000 Canadian farms. The publication is available from the Energy Unit, Agriculture Statistics Division, Statistics Canada, Ottawa, Ontario. K1A 0T6.

4) **Energy Efficient Farming.** Booklet available from B.C. Hydro, Energy Use Engineering Dept., 625 Howe Street, Vancouver, British Columbia. V6C 2T6.

5) **Energy and Agriculture.** Engineering Notes No. 290.000, available from B.C. Ministry of Agriculture and Food, Engineering Branch, Abbotsford, British Columbia. V2S 2C5.

6) **Farm Energy Management in Alberta.** Publication available from Alberta Agriculture, Print Media Branch, 7000 - 113 St., Edmonton, Alberta. T6H 5T6.

7) **Saving Energy on Your Farm.** Booklet available from TransAlta Utilities, Energy Management, Box 1900, Calgary, Alberta. T2P 2M1.

8) **Energy Efficiency on the Farm.** Booklet available from Esso Petroleum Canada, Marketing Dept., 10025 Jasper Avenue, Edmonton, Alberta. T5J 2R5.

9) **The Saskatchewan Farm Energy Management Program.** C.S.A.E. Paper No. 82-110, available from Saskatchewan Agriculture, Family Farm Improvement Branch, 3085 Albert Street, Regina, Saskatchewan. S4S 0B1.

10) **Energy and Agriculture.** Report available from Ontario Ministry of Agriculture and Food, Agriculture Energy Centre, P.O. Box 1030, Guelph, Ontario. N1H 6N1.

11) **Energy Management on the Farm.** Publication available from Ontario Hydro, Energy Conservation Dept., 700 University Ave., Toronto, Ontario. M5G 1X6.

12) **Energy and Agriculture.** Agrologist. Volume 10, No. 2, Spring, 1981.

13) **Energy Research on the Farm — An Overview.** Agriculture Information Bulletin No. 447, available from U.S. Dept. of Agriculture, Energy Publications, Washington, D.C. 20250.

1.1 PRINCIPLES OF ENERGY MANAGEMENT

The efficiency of energy use in any system depends upon three factors:

1) **Design.** While most farmers do not design their own equipment they do select the machinery, buildings, vehicles and production methods used on their farms. This "systems engineering" function offers farmers their greatest opportunity for energy savings.

2) **Operation.** Design of an efficient system can be wasted effort if it is not operated efficiently. This applies equally to cars, trucks, tractors, livestock barns and cropping programs.

3) **Maintenance.** Efficient operation of equipment is impossible without good maintenance. This is the simplest requirement of all but is also the most commonly neglected.

In the following sections examples are used to show how energy efficient **design, operation & maintenance** can save money on any farm.

1.2 DOING AN ENERGY AUDIT

The first step in farm energy management is to add up your total energy costs for one year. This requires a review of receipts and farm records. The example below is an energy audit for a 650 ha grain farm near Swift Current, Saskatchewan. The audit shows that a major energy cost on this farm is for the gasoline used in cars and trucks. Diesel fuel use in tractors is quite modest due to the minimum tillage practiced in the region.

This example (Fig. 1.3) shows the importance of including all energy costs in a farm audit. Potential savings in the farm home and transportation categories are often as great as in the production section. Note that fertilizer and pesticide costs are also included to account for energy used in their manufacture.

Saving Energy. By applying the principles described in this book, most farmers could save at least 10% of their energy costs with little or no investment and no decrease in farm production. For this farm a 10% saving equals $2021., which could be added to the net farm income. Even greater savings are considered possible with future changes in equipment and farming methods.

Fig. 1.2 Energy Costs are Calculated from Receipts and Records.

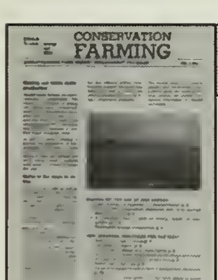
ENERGY TYPE	1983 AMOUNT	1983 COST	MAIN USES
GASOLINE	14,500 L	$ 4,350	Trucks, swather & combine
	8,013 L	2,964	Cars
Diesel Fuel	7,053 L	2,116	Tractors
Heating Oil	9,851 L	2,955	2 Homes
Propane			
Natural Gas			
Electricity	15,680 kWh	627	2 Homes, 1 farmstead
			1 shop
Oil & Grease	-	400	Vehicles, equipment
Nitrogen (N)	5,000 kg	2,500	
Phosphorus P_2O_5)	4,364 kg	2,400	
Potassium K_2O)	-	-	
Pesticides		1,900	Weeds / grasshopper
TOTAL COST		$20,212	

Fig. 1.3 Energy Audit — Example

ENERGY AUDIT — YOUR FARM

ENERGY TYPE	198__		MAIN USES
	AMOUNT	COST	
GASOLINE			
Diesel Fuel			
Heating Oil			
Propane			
Natural Gas			
Electricity			
Oil & Grease			
Nitrogen (N)			
Phosphorus P_2O_5)			
Potassium K_2O)			
Pesticides			
TOTAL COST			

Fig. 1.4 Energy Audit — Your Farm


CONSERVATION
FARMING

MORE INFORMATION:

1) **Conservation Farming.** Bulletin available from the Farm Energy Management Program, Saskatchewan Research Council, 30 Campus Drive, Saskatoon, Saskatchewan. S7N 0X1.

2) **Simple Farm Energy Audit.** Agdex 769-4, available from Alberta Agriculture, Print Media Branch, Main Floor, 7000 - 113 Street, Edmonton, Alberta. T6H 5T6.

3) **Energy Audit for Farms and Ranches.** Available from Farm Services Department, B.C. Hydro, 2485 Montrose Avenue, Abbotsford, British Columbia. V2S 3T2.

1.3 LOW-COST WAYS TO SAVE ENERGY AND $ ON YOUR FARM

Here are some simple ideas for saving energy and money on the farm. None of them are particularly new or revolutionary. But the combined effect of such small changes can save $1,000 to $5,000, with very little investment. How many of these ideas could save money on your farm?

Energy Management Action	Examples of Possible Yearly Savings*
FARMSTEAD	
• Develop a good windbreak	$200
• Shade, paint and install pressure relief valves in gasoline storage tanks	$140
• Turn off unnecessary lights	$50
• Select the most economical heating source	$200
• Plug in block heaters for only 2-3 hours	$100
• Reduce use of fuel for cleaning and burning	$50
FARM HOME	
• Lower the furnace thermostat 2° C	$100
• Lower the hot water thermostat 10° C	$50
• Use efficient appliances	$50
• Use less hot water	$60
• Turn off lights	$40
• Use smaller bulbs where adequate	$40
• Weatherstrip and seal cracks	$100
• Insulate the basement	$100
CARS AND TRUCKS	
• Use efficient vehicles	$500
• Reduce idling	$50
• Reduce unnecessary travel	$200
• Drive slower	$200
• Keep tires at maximum recommended pressure	$50
• Operate engines at recommended temperatures	$50
• Do tune-ups when needed	$100
TRACTORS	
• Use efficient tractors	$500
• Reduce idling	$100
• Clean air filters	$50
• Tune-ups when needed	$200
• Ballast for 10-15% slippage	$200
• Gear up/throttle down for light loads	$200

Energy Management Action	Examples of Possible Yearly Savings*
TILLAGE	
• Eliminate 1 tillage operation	$500
• Reduce depth of tillage	$200
• Match equipment for efficient operation	$150
• Keep blades sharp and clean	$100
• Improve field working patterns	$200
• Reduce overlap	$100
FERTILIZER	
• Use soil tests	$500
• Select "best value" formulations	$500
• Use best placement methods	$500
IRRIGATION	
• Use low-pressure irrigation	$500
• Maintain efficient equipment	$500
• Don't over-irrigate	$300
GRAIN DRYING	
• Harvest at lower moisture	$500
• Use a low-temperature drying system	$500
• Don't overdry grain	$200
• Feed high moisture grain to livestock	$800
LIVESTOCK BARNS	
• Select efficient equipment	$500
• Don't oversize fans and heaters	$100
• Prevent fans and heaters from competing	$500
• Operate at best temperature	$200
• Clean thermostats, fans and motors	$100
• Reduce lighting	$200
• Reduce feed processing	$500
• Reduce hot water use	$100
GENERAL	
• Use government grants	
• Apply for rebate on gasoline excise tax	
• Use tax incentives for heat recovery equipment, manure storage and drainage improvements	$500

* Potential savings vary widely between farms; depending upon energy sources, prices and farm size.

1.4 ENERGY ECONOMICS — MAKING SURE IT PAYS

The objective of farm energy management is to save money. This principle should be kept in mind when evaluating any farm energy idea. The most profitable conservation ideas are usually those which require no investment at all, just minor changes in habits and attitudes. This section discusses how to evaluate ideas that do require investment.

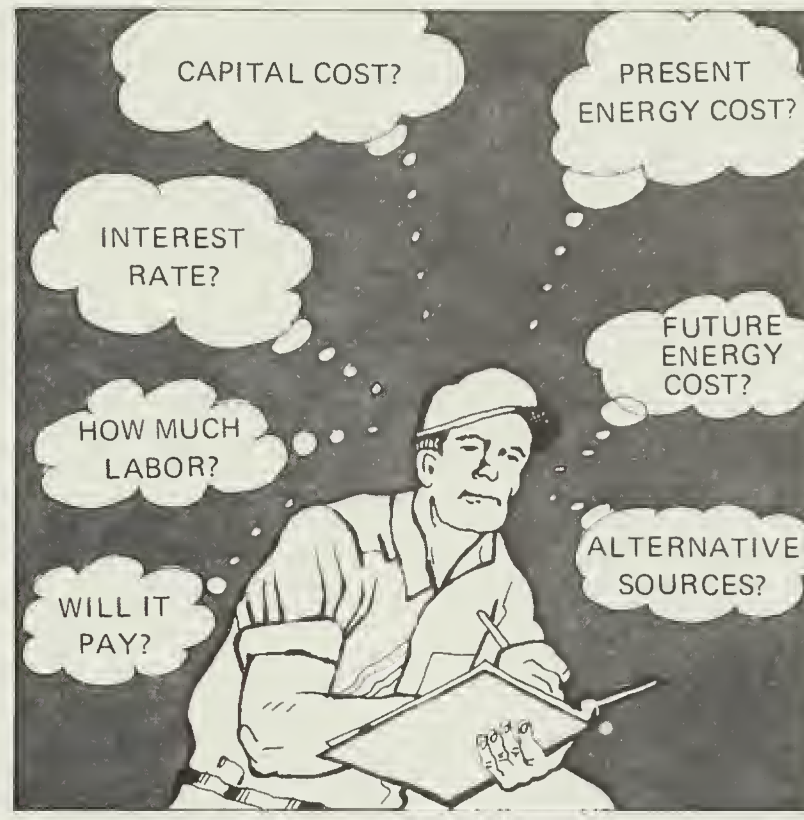


Fig. 1.5 Energy Saving Investments Must Also Be Profitable

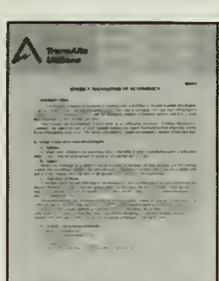
Payback Period. Several concepts can be used to measure the economics of an energy management option. The most common is the "payback period". A simple payback period is the number of years required for the saving in energy costs to "pay back" the cost of the investment. For example, if you spend $500 to add insulation to your house and the heating cost the next year is reduced by $50, the simple payback period is 10 years ($500/50 = 10). This common approach is based on the assumption that the annual rate of increase in energy cost will be equal to the rate of interest on the money invested. Obviously, this prediction may or may not be correct. In recent years some energy costs have increased at rates greater than interest rates.

Cash Flow. Other economic realities can often be more important than the payback period. For investments requiring borrowed money, the cash flow is a critical factor. Impressive energy savings and a good payback period are small consolation if money is not available to make the payments on the loan. Tax implications should also be considered. Government incentive grants and fast tax write-offs can make energy conservation much more attractive. A number of such programs are described in the following chapters.

A simple computer program has been used throughout this publication to analyze the cash flow impact of various energy management options. Its application is best illustrated by an example.

Cash Flow Example. A farmer is considering the installation of heat exchangers in a large livestock barn. The capital cost of the system (installed) would be $10,000. The expected reduction in heating costs in the first year is $2,300. This saving is expected to increase at 8% per year, as energy prices increase. Operating and maintenance costs are projected at $500/year, also expected to increase at 8% per year. Life expectancy of the equipment is 10 years. Financing is available at 12.5% interest. The farmer expects to be in the 25% taxable income bracket.* Heat exchangers are eligible for an accelerated straight-line tax write-off of 25% in year 1, 50% in year 2, and 25% in year 3, as provided for energy conservation equipment under Class 34. How would this investment affect his cash flow? Two financing options will be considered; a 3-year loan and a 10-year loan. (Fig. 1.6 and 1.7).

* Examples involving taxation are used for illustrative purposes only. Check with your accountant concerning specific applications to your farm business.



MORE INFORMATION:

1) **Energy Management Economics.** Factsheet B1050A, available from TransAlta Utilities, Energy Management, Box 1900, Calgary, Alberta. T2P 2M1.

2) A more detailed description of the After-Tax Cash Flow Program is available from Jensen Engineering Ltd., P.O. Box 1781, Olds, Alberta. T0M 1P0.

Conclusion. This example illustrates the importance of a cash flow analysis. While both cases show a positive net return from the investment, the 3-year loan could cause a serious negative cash flow which would not be offset by the energy savings early in the ownership period. Conversely, the 10-year financing generates a positive cash flow for each year of ownership. The simple payback is the same for both cases: ($10,000)/($2,300 - $500) = 5.6 years.

[Cash flow calculations can also be done manually. The advantage of the computer analysis is the rapid comparisons which can be made as input data is changed.]

Capital Cost	$10000	Revenue first year	$2300
Deduct Startup Costs	$0	Revenue Increase per yr (%)	8.0
Inputs (exp) first yr	$500	Loan Term (yrs)	3
Input Increase per yr (%)	8.0	Loan Interest Rate	12.50
Income Tax Rate (%)	25	Loan (1 = Ammort., 2 = Dim. Bal.)	2
General Inflation Rate	7	Loan Payments per year	1
C.C.A first year (%)	25.0	Study Scope (1 = all, 2 = part)	2
C.C.A. 2nd year (%)	50.0	Study Term In Years	10
C.C.A. other years (%)	25.0	Starting Year of Study	1
CCA Type (1 = dim, 2 = orig)	2	Downpayment	$0

Year	Inputs	Revenue	Principal	Interest	Taxes	Cashflow	Total CF	CCA
1	500.00	2300.00	3333.33	1250.00	-487.50	-2295.83	-$2295.83	2500.00
2	540.00	2484.00	3333.33	833.33	-972.33	-1250.33	-$3546.17	5000.00
3	583.20	2682.72	3333.33	416.67	-204.29	-1446.19	-$4992.36	2500.00
4	629.86	2897.34	0.00	0.00	566.87	1700.61	-$3291.75	0.00
5	680.24	3129.12	0.00	0.00	612.22	1836.66	-$1455.09	0.00
6	734.66	3379.46	0.00	0.00	661.20	1983.59	$528.51	0.00
7	793.44	3649.81	0.00	0.00	714.09	2142.28	$2670.79	0.00
8	856.91	3941.80	0.00	0.00	771.22	2313.66	$4984.45	0.00
9	925.47	4257.14	0.00	0.00	832.92	2498.76	$7483.21	0.00
10	999.50	4597.71	0.00	0.00	899.55	2698.66	$10181.86	0.00
End of run	Total Cash Flow (present value)				$5266.64			

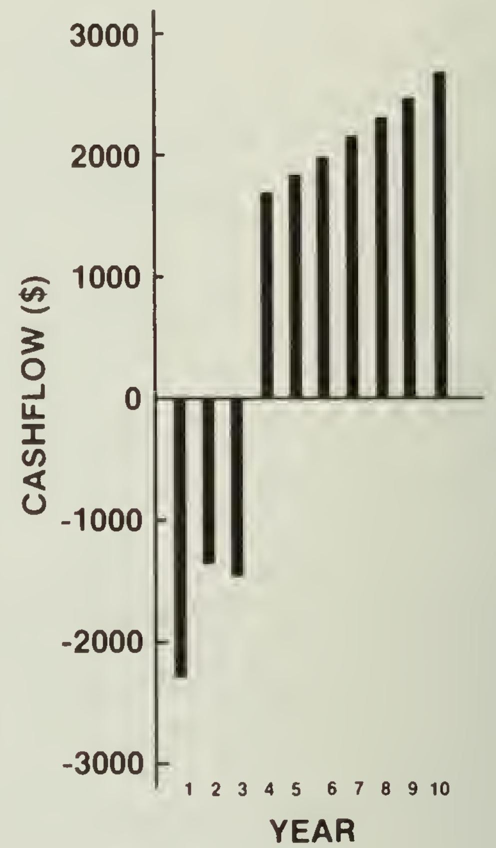


Fig. 1.6 Cash Flow Analysis: Conservation Investment — $10,000 — 3 Year Loan

Capital Cost	$10000	Revenue first year	$2300
Deduct Startup Costs	$0	Revenue Increase per yr (%)	8.0
Inputs (exp) first yr	$500	Loan Term (yrs)	10
Input Increase per yr (%)	8.0	Loan Interest Rate	12.50
Income Tax Rate (%)	25	Loan (1 = Ammort., 2 = Dim. Bal.)	2
General Inflation Rate	7	Loan Payments per year	1
C.C.A first year (%)	25.0	Study Scope (1 = all, 2 = part)	2
C.C.A. 2nd year (%)	50.0	Study Term In Years	10
C.C.A. other years (%)	25.0	Starting Year of Study	1
CCA Type (1 = dim, 2 = orig)	2	Downpayment	$0

Year	Inputs	Revenue	Principal	Interest	Taxes	Cashflow	Total CF	CCA
1	500.00	2300.00	1000.00	1250.00	-487.50	37.50	$37.50	2500.00
2	540.00	2484.00	1000.00	1125.00	-1045.25	864.25	$901.75	5000.00
3	583.20	2682.72	1000.00	1000.00	-350.12	449.64	$1351.39	2500.00
4	629.86	2897.34	1000.00	875.00	348.12	44.36	$1395.75	0.00
5	680.24	3129.12	1000.00	750.00	424.72	274.16	$1669.91	0.00
6	734.66	3379.46	1000.00	625.00	504.95	514.84	$2184.76	0.00
7	793.44	3649.81	1000.00	500.00	589.09	767.28	$2952.04	0.00
8	856.91	3941.80	1000.00	375.00	677.47	1032.41	$3984.45	0.00
9	925.47	4257.14	1000.00	250.00	770.42	1311.26	$5295.71	0.00
10	999.50	4597.71	1000.00	125.00	868.30	1604.91	$6900.61	0.00
End of run	Total Cash Flow (present value)				$4640.72			

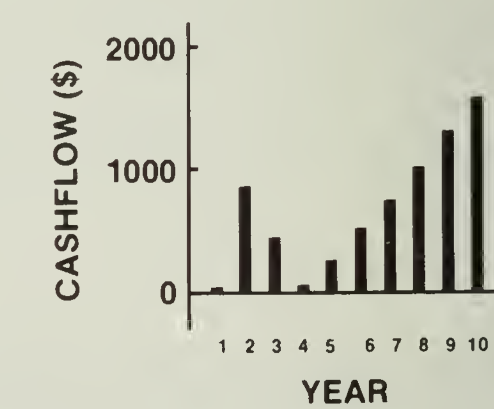


Fig. 1.7 Cash Flow Analysis: Conservation Investment — $10,000 — 10 Year Loan

2 *Saving Energy and $ on* THE FARMSTEAD

The farmstead can be considered as the "energy headquarters" where decisions are made that affect the energy efficiency of the whole farm. These include the layout of the farmstead itself; the design of the farm home, shop and barns; and the selection of utilities and fuel storages. This section discusses the following principles of good energy management on the farmstead.

Use Windbreaks to Cut Energy Costs. A good windbreak cuts farmstead heating costs. Careful planning also reduces the amount of fuel required for snow removal.

Size Utility Lines for the Future. Undersized electrical lines waste energy and may damage equipment due to low voltage. Undersized water lines waste pumping energy by causing excessive pipe friction.

Select the Most Economical Heating Energy Source. If you have a choice between propane, heating oil, electricity, and natural gas, the correct decision may save you hundreds of dollars per year.

Reduce Fuel Losses. Evaporation from gasoline storage tanks can be reduced by shading, painting them a light color, and installing pressure relief valves.

Fig. 2.1 Careful Farmstead Planning and Operation Reduce Energy Costs.

2.1 ENERGY CONSIDERATIONS IN FARMSTEAD PLANNING

Few farmers get the opportunity to develop a completely new farmstead. The layout of buildings, roads and utilities has often been established by previous owners. However, farmsteads do tend to keep growing, and it pays to review how farmstead planning can save energy in the future.

Use Windbreaks. Energy savings of up to 20% are possible by developing a good windbreak. Shelterbelts and windbreak fences can reduce the heat losses caused by wind chill and infiltration.

Control Snow. A well designed windbreak will also reduce the fuel used for snow removal. Locate shelterbelts and windbreak fences well upwind from the travelled area of the farmstead. Make sure you plan an untravelled area for snow to deposit. Locate driveways and building entrances to take advantage of the winter sunshine and protection from snow accumulation.

Air Condition With Trees. A properly located shelterbelt can channel summer breezes into the farmstead to remove heat. Trees can also provide shade and evaporative cooling. Leave the south side of the farmstead relatively open to let in the winter sun and summer breezes. If you want trees on the south side use deciduous trees to provide summer shade and still allow some solar penetration in winter after they shed their leaves.

Let The Sun Help With The Heating. The farmstead should be designed to take advantage of the low winter sun for passive solar heating, while shading buildings from too much sun in summer. Design buildings for solar gain in winter and shading in summer. This can be done with correct placement of windows and overhangs.

EXAMPLE

Consider an exposed farmstead with total heating costs of $1,000 year. Snow removal from driveways requires 25 hours per year with a tractor using 20 L/h of fuel.

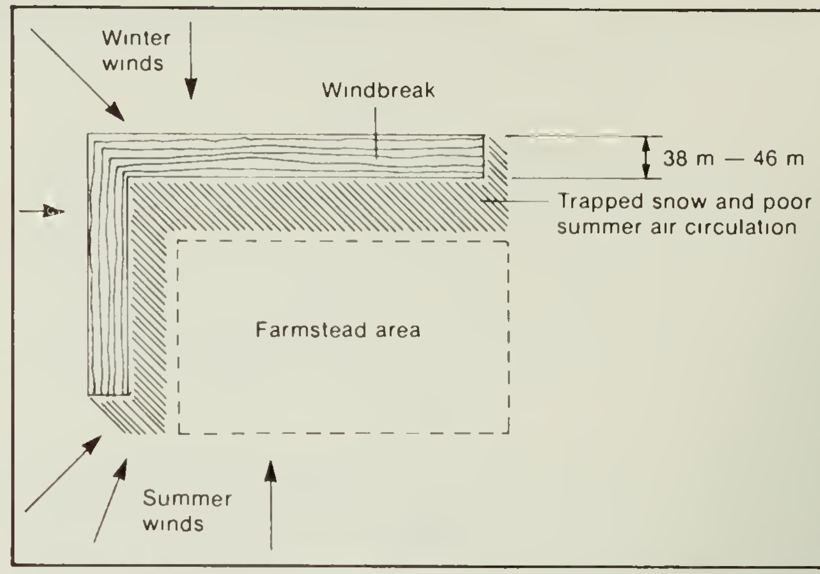


Fig. 2.2 A Good Windbreak Cuts Snow Removal Costs. *(Reference 1)*

Windbreak type	Snow zone	Wind protection zone
Solid fence	5H	15H
Porous fence	10H	20H
Shelterbelt	5H-10H	15H-20H

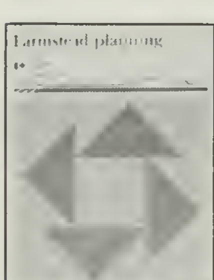
Fig. 2.3 Snow Collection and Wind Shelter Zones Created Downwind from Various Types of Windbreaks with Height H.

Savings Possible.

1) A good windbreak could cut the heating bill by 20%.
   $ saved = 0.20 x $1,000 = $200/year.

2) Snow control could cut the tractor operation by 50%:
   Fuel saved = 0.50 x 25 h x 20 L/h = 250 L.
   At 40¢/L, $ saved = $0.40 x 250 = $100/year.

Total = $300/year.



MORE INFORMATION:

1) **Farmstead Planning.** Publication 1674E, available from Communications Branch, Agriculture Canada, Ottawa, Ontario. K1A 0C7.
2) **Snow and Wind Control for Farmstead and Feedlot.** Publication 1561, available from Communications Branch, Agriculture Canada Ottawa, Ontario. K1A 0C7.
3) **Design Your Landscape to Conserve Energy.** Energy Factsheet No. 5, available from Co-operative Extension Service, Michigan State University, East Lansing, Michigan 48824.
4) **Farmstead Design for Energy Efficiency.** Leaflet available from Co-operative Extension Service, College of Agriculture, University of Illinois at Urbana-Champaign, Region Extension Office, R.R. 5 Macomb, Illinois 61455.

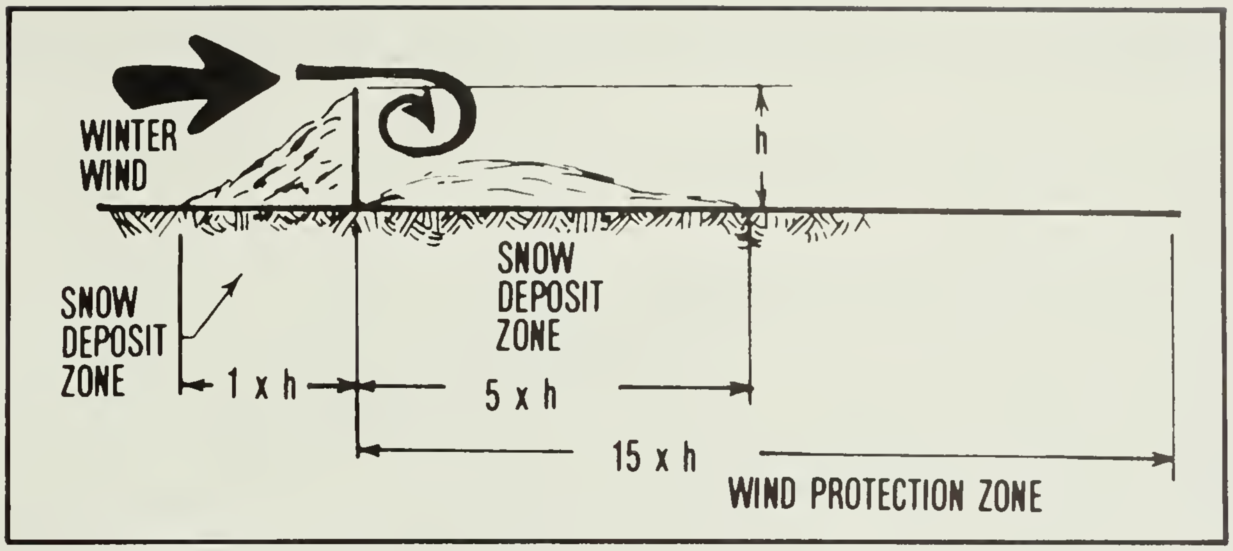


Fig. 2.4 Protection Zone for a Solid Windbreak Fence *(The Grain Grower, December 1982)*

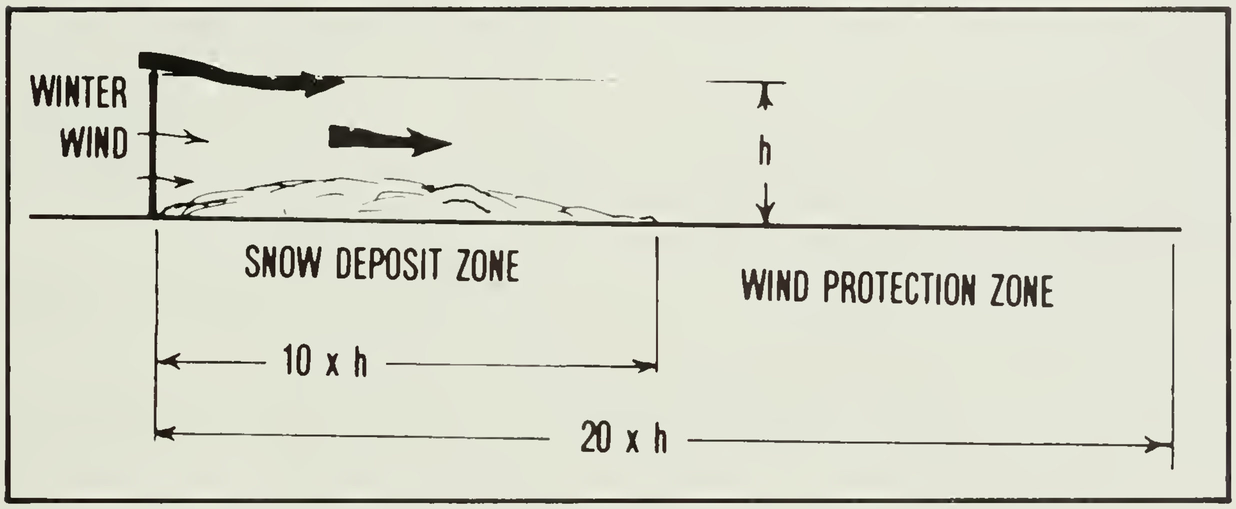


Fig. 2.5 Protection Zone for a Porous Windbreak Fence *(The Grain Grower, December 1982)*

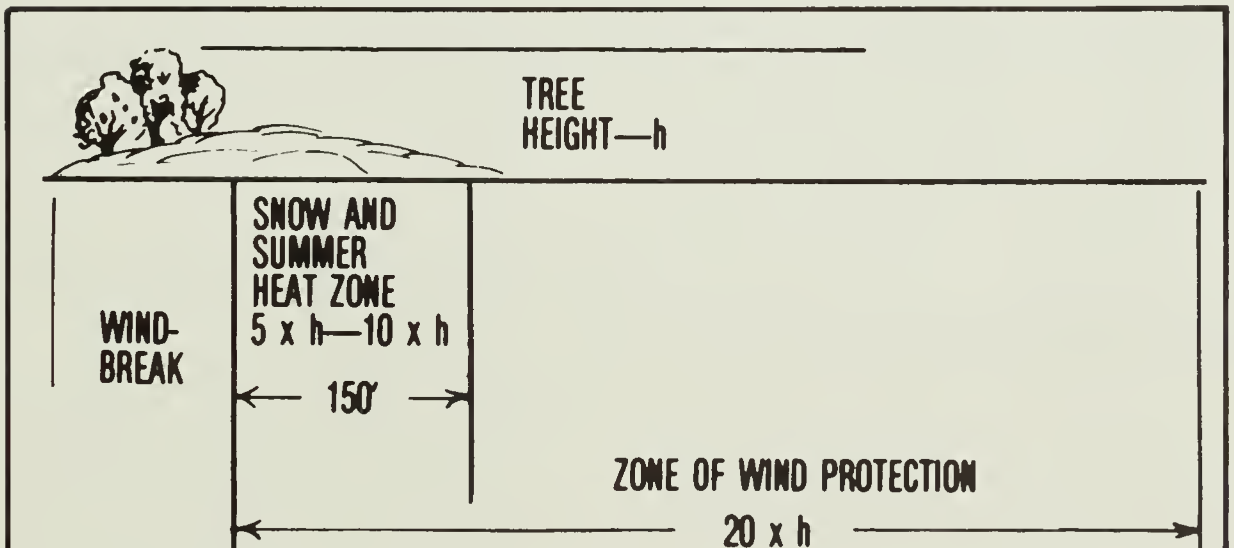


Fig. 2.6 Protection Zone for a Multiple-row Shelterbelt *(The Grain Grower, December 1982)*

2.2 PLANNING AN EFFICIENT ELECTRICAL SYSTEM

Electricity is a very efficient form of energy if it is used correctly. Here are some guidelines for efficient electricity use on the farm.

Balance Electrical Loads vs Distances. The transformer should be located nearest to the largest loads to reduce wire costs and line losses.

Don't Skimp on Wire Sizes. All wires should be sized for minimum voltage drop (2% is generally considered acceptable). Undersized wires waste energy due to heating and cause poor equipment operation. Fig. 2.7 shows recommended wire sizes for typical distances and amperages.

Use Efficient Motors. Standard small single-phase motors are approximately 50% efficient. Energy-efficient motors can reduce the amperage draw by nearly 40% due to improved construction and power factor. They also run cooler, quieter and last longer.

Use Efficient Lighting.

1) Review the need for lights on your farmstead. Are they turned off when not needed?

2) The light output per watt varies widely between types of lamps (Fig. 2.8). Are you using the most efficient lamps for each application?

Control Peak Loads. If your farmstead is on a demand meter, investigate the savings possible by controlling the peak electrical load. You could reduce your power bills considerably simply by scheduling your loads so they don't all occur together.

EXAMPLE 1
How much can you save by turning off lights?

Many farms have one or more mercury vapour yard lights operated automatically to come on at dusk. If you have a number of yard lights on the farmstead consider whether they are all required.

Calculations. Calculate the electrical cost of operating one 250 W mercury lamp for an average of 10 hours per day for one year.

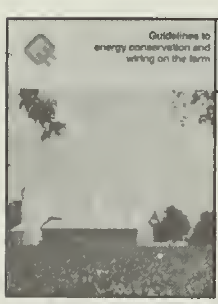
From Fig. 2.8, the total wattage equals 250 W for the lamp plus 35 W for the ballast = 285 W.
Electricity used/year = (285 W x 1kW/1000 W x 10 h/d x 365 d) = 1040 kWh.
Annual cost @ 4¢/kWh = (1040 kWh x $0.04/kWh) = $41.60

EXAMPLE 2
How much can you save by using lower wattage lights?

Not all locations on the farmstead or in the home require equal lighting intensity. Next time a light burns out try a smaller bulb.

Calculations. Consider if 10 lights are downsized from 100 W to 60 W and are on for an average of 8 hours per day:

Electricity saved/year = (10 lights x 40 W x 8 h/d x 365 d) = 1168 kWh.
$ saved @ 4¢/kWh = (1168 kWh x $0.04/kWh) = $46.72



MORE INFORMATION:

1) **Guidelines to Energy Conservation and Wiring on the Farm.** Publication available from Ontario Hydro, Energy Conservation Department, 700 University Avenue, Toronto, Ontario. M5G 1X6.

2) **Saving Energy on Your Farm.** Booklet available from TransAlta Utilities, Energy Management Services, 110-12th Ave., S.W. P.O. Box 1900, Calgary, Alberta. T2P 2M1.

3) **How Wires of Adequate Size Can Save You Power and Money.** Article in Farm News, Vol. 18, No. 1, available from B.C. Hydro, Box 248, Abbotsford, British Columbia. V2S 4N9.

4) **Energy Efficient Electric Motors.** Series of factsheets available from TransAlta Utilities, Energy Management Services, 110-12th Ave., S.W. P.O. Box 1900, Calgary, Alberta. T2P 2M1.

5) **Energy and Lighting.** Energy Line, Vol. 1, No. 3, available from Alberta Power Limited, 10040 - 104 St., Edmonton, Alberta. T5J 2V6.

6) **Lighting and Energy Conservation.** Extension bulletin E-1288, available from Co-operative Extension Service, Michigan State University, East Lansing, Michigan 48824.

7) **Alberta Farm Building Course — Lesson 7 — Service & Utilities.** Available from Rural Education Development Association, 14815 - 119 Avenue, Edmonton, Alberta. T4L 2N9. (Complete course plus binder costs $30.00.)

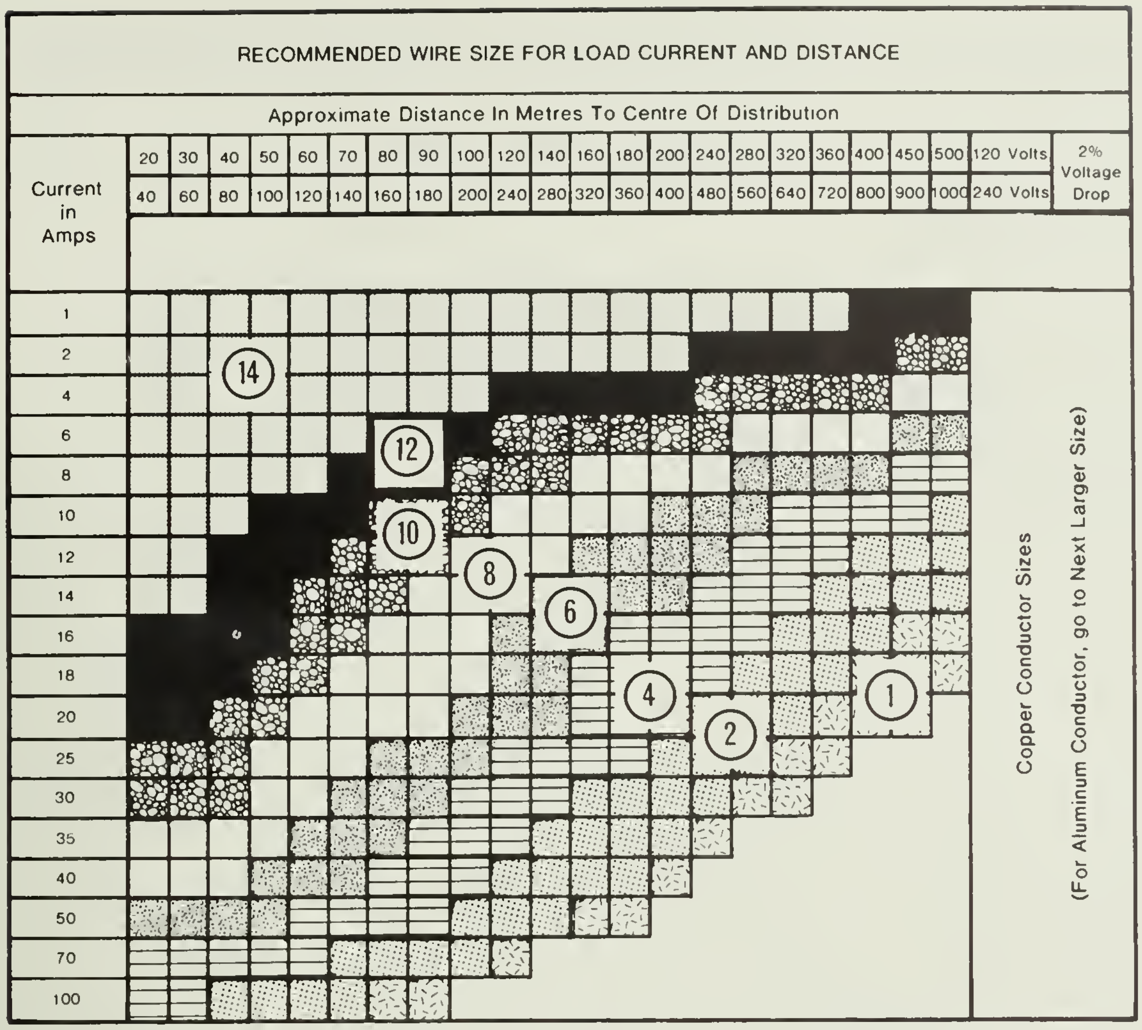


Fig. 2.7 Recommended Wire Size for Load, Current and Distance *(Reference 7)*

EXAMPLE 3

Fig. 2.7 shows the minimum wire sizes needed to keep voltage drops below 2%. Here is an example of the heating loss if you use a wire size too small:

Consider a 70 amperage load on a 240 volt circuit with 100 metres of wire. Fig. 2.7 shows that the recommended copper wire size is a No. 4. If a No. 6 wire was used the voltage drop would exceed 2%, possibly causing overheating of motors. Other calculations (reference 3) have estimated the cost of heating losses due to undersizing wires. In this case, the cost of energy lost due to line heating (with electricity @ 4¢/kWh and 1000 hours of operation) would be about $90.00 per year if a No. 6 wire is used, compared to $55.00 per year for the recommended No. 4 wire. Over a 10-year period the energy saved by using the recommended wire size, just for this circuit, would total $350.00.

TYPE	COLOR	LAMP WATTAGE	BALLAST WATTAGE	EFFICIENCY (LUMENS/ WATT)	LAMP LIFE (HOURS)	AGRICULTURAL APPLICATIONS
Incandescent	White	40	NO BALLAST REQUIRED	10	1,000	• Indoors and outdoors
		60		13	1,000	• Where temperature varies greatly
		100		15	1,000	• Where dimming is required
		300		20	1,000	
Fluorescent	White	40	8	65	20,000	• Indoors (use special cold start ballast if ambient temperature goes below 10°C)
		75	15	70	12,000	
Mercury	Bluish White	250	35	39	24,000	• Yard light
		400	50	46	24,000	• High ceiling indoors
Metal Halide	Bright White	175	40	65	7,500	• Yard light
		400	50	76	15,000	• High ceiling indoors
High Pressure Sodium	Golden White	100	16	82	20,000	• Yard light
		250	53	88	24,000	• High ceiling indoors
		400	75	105	24,000	• Color correction available
Low Pressure Sodium	Amber Yellow	35	29	75	18,000	• Yard light
		90	35	108	18,000	
		180	30	157	18,000	

Fig. 2.8 Comparison of Different Lamp Types *(Reference 2)*

2.3 COMPARING FARMSTEAD HEATING COSTS

Quick Comparison. Here is a useful chart for comparing various energy sources at typical prices and efficiencies. It does not, however, include differences in capital costs for equipment and installation. See a more detailed analysis on the next page.

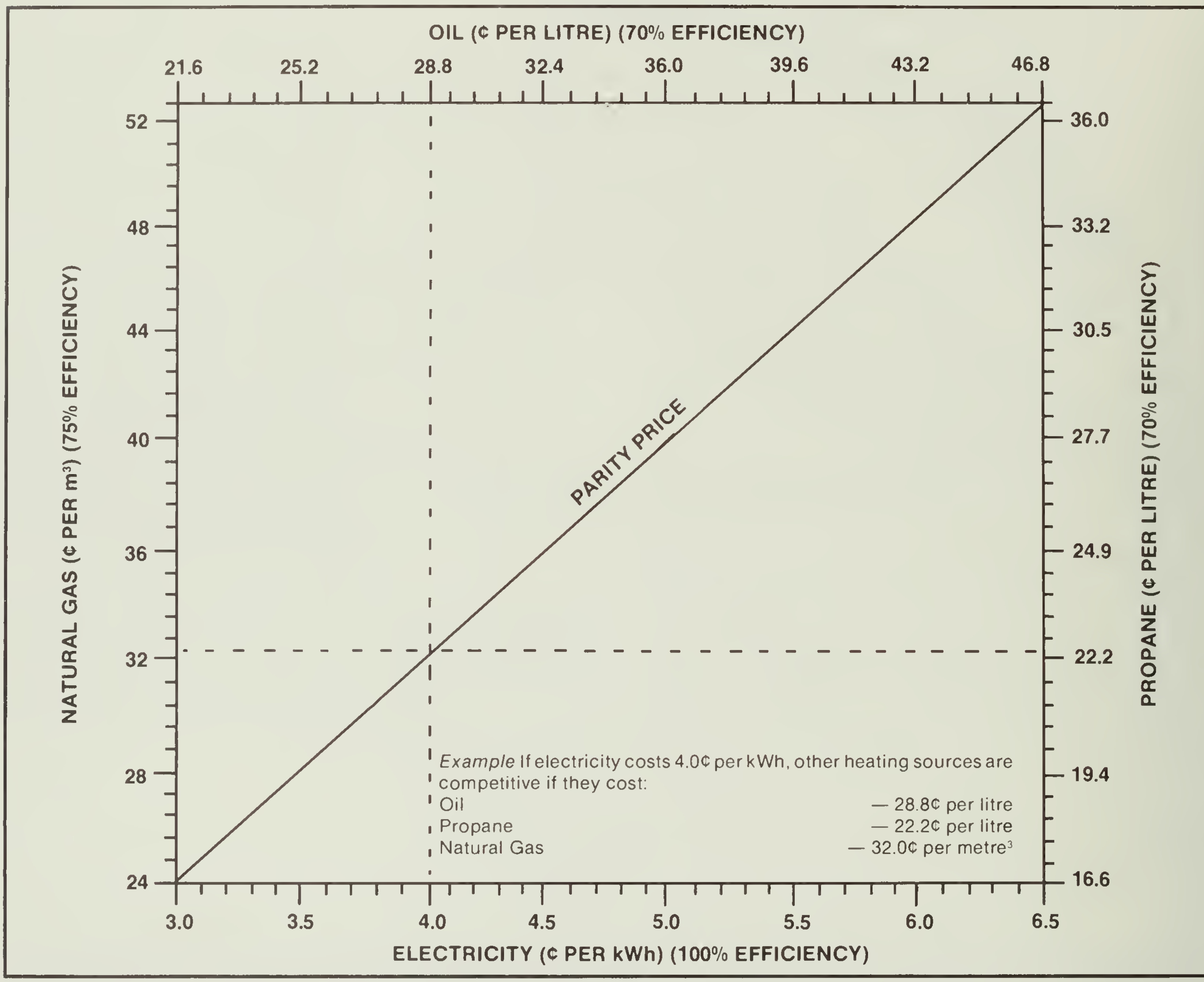
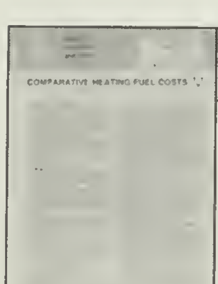


Fig. 2.9 Equivalent Costs for Heating Energy Sources (Use only if Capital Investments are Similar.)



MORE INFORMATION:

1) **Comparative Heating Fuel Costs** — Factsheet available from Ontario Ministry of Agriculture & Food, Information Branch, Legislative Buildings, Toronto, Ontario. M7A 1A5.

2) **Which Heat Source?** Factsheet available from Alberta Agriculture, Print Media Branch, Main Floor, 7000 - 113 Street, Edmonton, Alberta. T6H 5T6.

3) **Comparing Costs of Energy Sources.** — Factsheet available from Saskatchewan Agriculture, 3085 Albert St., Regina, Saskatchewan. S4S 0B1.

EXAMPLE

Consider a farmstead presently using 20,000 L of propane per year at 25¢/L, for a total cost of $5,000, which includes the tank rental. Natural gas is available at 20¢/m³ with a $2,000 installation charge. Would it pay to convert to natural gas?

Calculations. From Table A.2 (Appendix) the energy contents of propane and natural gas are 25.5 MJ/L and 37.2 MJ/m³, respectively. Therefore, if the efficiencies are the same, one litre of propane could be replaced by 25.5/37.2 = 0.685 m³ of natural gas. If converted to gas the farm would use:

20,000 x 0.685 = 13,710 m³ of natural gas.

At a price of 20¢/m³ the annual cost for natural gas would be 13,710 m³ x $0.20/m³ = $2,742.

Simple Payback

Capital Cost = $2,000

Year 1 fuel savings = ($5,000 - $2,742) = $2,258

Simple payback = ($2,000/$2,258) = 0.9 years

Cash Flow/Tax Analysis. Assume the investment of the $2,000 capital cost for the natural gas system is amortized over 5 years at 12.5% interest per year. (Fig. 2.10) The farmer expects to be in the 20% taxable income bracket. The capital cost allowance for utility installations is 100%. The owner estimates that 80% of the gas is used for farming and 20% for personal use.

Fig. 2.10

Conclusion. For the given fuel prices and consumption on this farmstead, conversion to natural gas would improve the cash flow by more than $25,000 over a 10 year period.

Capital Cost	$2000	Revenue first year	$2258
Deduct Startup Costs	$0	Revenue Increase per yr (%)	8.0
Inputs (exp) first yr	$0	Loan Term (yrs)	5
Input Increase per yr (%)	0.0	Loan Interest Rate	12.50
Income Tax Rate (%)	16	Loan (1 = Ammort., 2 = Dim. Bal.)	1
General Inflation Rate	8	Loan Payments per year	1
C.C.A first year (%)	100.0	Study Scope (1 = all, 2 = part)	2
C.C.A. 2nd year (%)	0.0	Study Term In Years	10
C.C.A. other years (%)	0.0	Starting Year of Study	1
CCA Type (1 = dim, 2 = orig)	1	Downpayment	$0

Year	Inputs	Revenue	Principal	Interest	Taxes	Cashflow	Total CF	CCA
1	0.00	2258.00	311.71	250.00	1.28	1695.01	$1695.01	2000.00
2	0.00	2438.64	350.67	211.04	356.42	1520.52	$3215.53	0.00
3	0.00	2633.73	394.51	167.20	394.64	1677.38	$4892.91	0.00
4	0.00	2844.43	443.82	117.89	436.25	1846.48	$6739.38	0.00
5	0.00	3071.98	499.30	62.41	481.53	2028.74	$8768.13	0.00
6	0.00	3317.74	0.00	0.00	530.84	2786.90	$11555.03	0.00
7	0.00	3583.16	0.00	0.00	573.31	3009.86	$14564.89	0.00
8	0.00	3869.82	0.00	0.00	619.17	3250.65	$17815.53	0.00
9	0.00	4179.40	0.00	0.00	668.70	3510.70	$21326.23	0.00
10	0.00	4513.75	0.00	0.00	722.20	3791.55	$25117.78	0.00
End of run	Total Cash Flow (present value)				$16981.56			

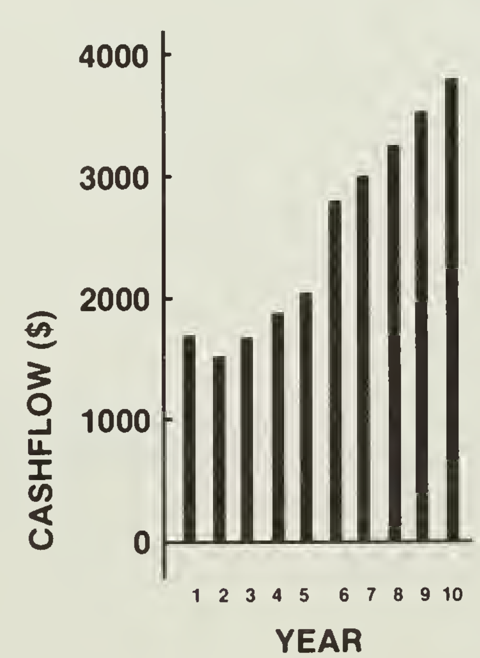


Fig. 2.10 Cash Flow Analysis: Conversion from Propane to Natural Gas

2.4 REDUCING FUEL STORAGE LOSSES

Evaporation From Gasoline Storage Tanks. Daytime heating of dark colored fuel tanks exposed to the sun can increase fuel temperatures as much as 10°C above the outside air temperature. Besides the harmful effects on fuel quality the evaporation loss from gasoline tanks is significant. Tests have shown that a dark-colored tank exposed to the summer sun may lose over 3% of its volume per month by evaporation (Fig. 2.11). Losses in the winter are less but still significant because winter fuel is more volatile. To reduce evaporation losses the storage tank should be shaded, painted a reflective silver or white color and be equipped with a pressure relief valve (PRV). This valve is built into the filler cap and prevents gasoline vapours from leaving the tank unless the pressure increases to 7 kPa.

An existing filler cap without a pressure relief valve can be simply replaced with a new cap. Further reduction in evaporation can be achieved by shading the tank and by keeping it full most of the time.

Diesel Fuel Storage. Even though evaporation of diesel fuel is not significant, the diesel storage tank should also be painted a light color, shaded and equipped with a PRV. The less the storage tank temperature varies, the less the tank "breathes". This results in less moisture condensing in the tank.

Underground Tanks. An underground storage tank will minimize evaporation, formation of gum deposits and fuel contamination. Before installing an underground tank you should get a copy of the regulations covering the storage and handling of inflammable liquids. This can be obtained from the Fire Commissioner's office or the Queen's Printer.

	Evaporation Loss per Month	
Tank Configuration	%	Litres from a 2300 litre Tank
Above ground, dark color	3.0	68.0
Above ground, dark color w/shade	1.5	34.0
Above ground, dark color w/shade & PRV	0.75	17.0
Above ground, light color	2.0	45.0
Above ground, light color w/shade	1.0	23.0
Above ground, light color w/shade & PRV	0.5	11.0
Underground	$\approx$ 0.0	$\approx$ 0.0

Fig. 2.11 Summer Vaporation Losses from various Gasoline Storage Tanks

How to Avoid Fuel Contamination.

1) Buy fuel from a responsible supplier.
2) Let new fuel settle at least 24 hours before filling equipment.
3) Slope storage tanks away from the outlet to provide a space for water settlement.
4) Drain water from the bottom of the tank at least once a year.
5) Install a fuel filter in the hose assembly to remove dirt and water.
6) Never store diesel fuel in a tank previously used for gasoline.
7) Keep storage tanks as full as possible at all times.

MORE INFORMATION:

1) **Fuel Storage — How to Avoid Problems and Save Money.** Publication available from Federated Co-operatives Limited, 401 - 22nd Street East, P.O. Box 1050, Saskatoon, Saskatchewan. S7K 3M9.
2) **Farm Fuel Storage.** Factsheet available from Saskatchewan Agriculture, 3085 Albert St. Regina, Saskatchewan. S4S 0B1.
3) **Farmstead Storage of Fuels — Reduction of Evaporation Losses.** Engineering Notes, available from B.C. Ministry of Agriculture, Engineering Branch, Abbotsford, British Columbia. V2S 2C5.
4) **Fuel Storage.** Factsheet available from Co-operative Extension Service, University of Nebraska, Lincoln, Nebraska 68583.

Fig. 2.12 a) Evaporation Losses are Highest from Dark-colored Exposed Gasoline Tanks.

Fig. 2.12 b) Light Colors, Shading and Pressure Relief Valves Reduce Evaporation Losses.

EXAMPLE

Consider a dark colored 2300 L gasoline tank exposed to the sun. Assume an average loss of 2% per month throughout the year:

Annual evaporation loss = (.02 x 2300 x 12) = 522 L.

Evaporation can be reduced to less than 0.5% per month by shading the tank, painting it a light color and installing a pressure relief valve (PRV).

Assuming a reduced average evaporation rate of 0.4% per month the annual reduced loss = (.004 x 2300 x 12) = 110.4 L

Fuel saved = (552 L - 110 L) = 442 L/year

$ Saved = (442 L x $0.40/L) = $176.80/year

3 *Saving Energy and $ in* THE FARM HOME

Energy costs in many farm homes are higher than necessary. The following ideas may save you several hundred dollars per year.

Lower The Thermostats. Tests have shown that even a 1 to 2° C decrease in temperature can significantly drop the heating bill. The same applies to the hot water temperature.

Reduce Energy Wasting Habits. Small things like turning off lights, using less hot water and washing only full loads of clothes and dishes can save a lot of energy throughout the year.

Buy Efficient Appliances. Check the ENERGUIDE labels to compare efficiencies of appliances. There can be big differences between makes and models.

Maintain Equipment. Furnaces operate more efficiently with clean filters and burners. Hot water tanks need regular draining of sediment. All appliances should be serviced as recommended in your operating manuals.

Weatherstrip and Caulk. Air leakage around doors, windows and other openings can cost you $100 to $200 per year. They can be easily sealed by weatherstripping and caulking.

Seal The Vapour Barrier. In most homes the vapour barrier is not well sealed. Don't add insulation to the attic until you have sealed the vapour barrier. You could get condensation and ice problems.

Insulate The Basement. If your home has an uninsulated basement, one third of your total heat loss is through the floor and walls. The basement, not the attic, is the first place to spend insulation dollars.

Plan A Low-Energy Home. If you are planning a new home have a look at some of the low-energy designs. Equally important, find a contractor who understands low-energy construction.

Consider An Energy Efficient Retrofit. Homeowners and contractors have developed some very ingenious ways to remodel older homes to new low-energy standards.

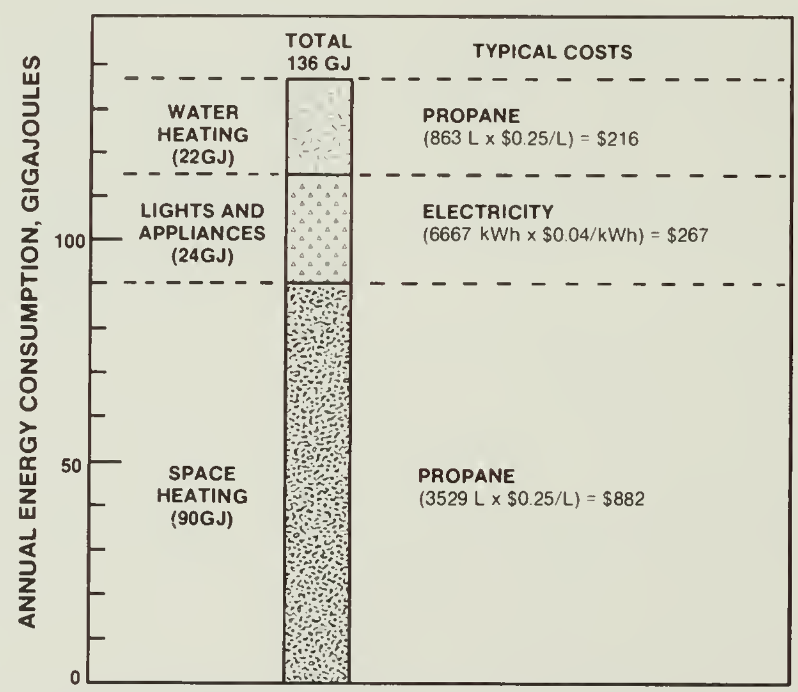
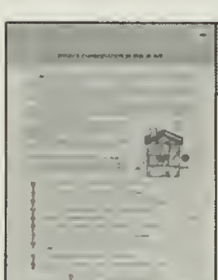


Fig. 3.1 Typical Distribution of Energy Costs in a Conventional Home



MORE INFORMATION:

1) **Energy Conservation In The Home.** Factsheet EC200B, available from B.C. Hydro, Energy Use Engineering Department, 625 Howe Street, Vancouver, B.C. V6C 2T6.

2) **Your Home Energy Quiz.** Publication available from Energy Conservation Branch, Alberta Energy and Natural Resources, 7th Floor, 9915 - 100 Street, Edmonton, Alberta T5K 2C9.

3) **Saving Energy In Existing Houses.** Factsheet PM 789 available from Cooperative Extension Service, Iowa State University, Ames, Iowa 50011.

3.1 PLUGGING THE ENERGY LEAKS IN YOUR HOUSE

Air Leakage. Heat losses by air movement are often overlooked in the mistaken idea that a house can be made efficient simply by piling more insulation into the attic. In fact, the first step in home energy conservation should be to seal the many cracks and openings which let hot air escape from the house. Air leakage can account for one-third of the total heat loss in an average home.

Weatherstripping. Air leaks around movable surfaces (doors, windows, hatches) can be controlled by installing weatherstripping materials. A variety of metal, plastic, felt and foam weatherstrips are available.

Caulking. Use caulking to seal cracks between surfaces that do not move, such as sills, joists, door and window frames, vents, electrical outlets and conduits. Different caulking compounds are recommended for different locations. Butyl rubber caulking is a good general purpose material which can be painted. Acoustical sealants are excellent for interior locations which are covered (eg., air/vapour barrier) but are not recommended for exposed exterior surfaces. Heat resistant cement is needed to seal gaps around chimneys.

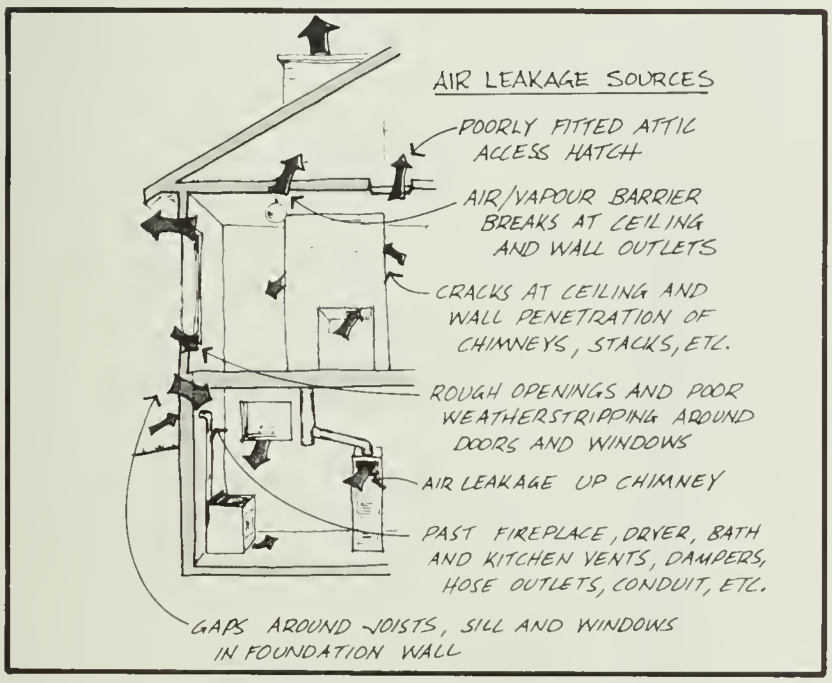


Fig. 3.2 Typical Air Leaks in a Home. *(Reference 2)*

EXAMPLE

Consider a $100.00 investment in weatherstripping and caulking materials reduces air leakage by 50%. If infiltration loss was one-third of total heat loss, and previous heating cost was $800/year, the year 1 savings will be:

(0.50 x 0.33 x $800) = $132.

Over a 10-year period, even with no increase in the real cost of energy, the $100 investment will return $1,320.

Fig. 3.3 Weather Stripping Reduces Heat Losses Around Doors and Windows. *(Reference 2)*

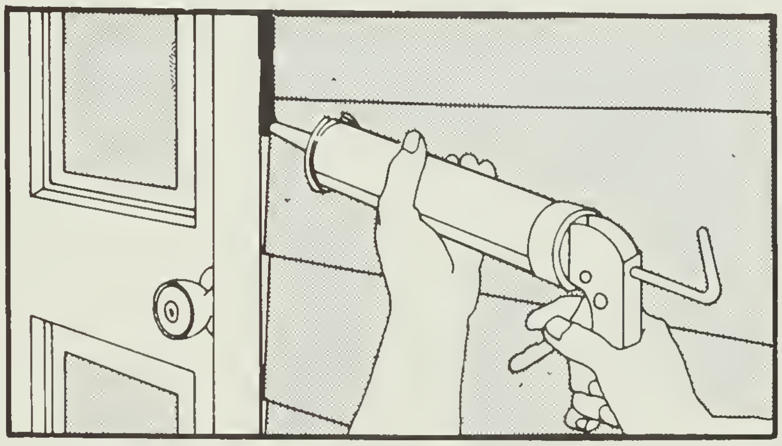
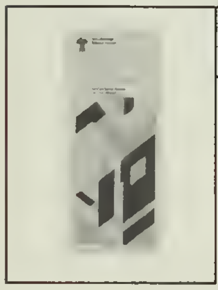


Fig. 3.4 Sealing Cracks with a Caulking Gun *(Reference 3)*



MORE INFORMATION:

1) **Seal Your House Before Re-Insulating.** Brochure available from Saskatchewan Energy and Mines, 1914 Hamilton Street, Regina, Saskatchewan S4P 4V4.

2) **How to Weatherstrip and Caulk Your Home.** Publication available from Energy Conservation Branch, Alberta Energy and Natural Resources, 7th Floor, 9915 - 100 Street, Edmonton, Alberta. T5K 2C9.

3) **Selecting Caulking Compounds For Home And Farm.** Factsheet No. 202, available from Cooperative Extension Service, Oklahoma State University, Stillwater, Oklahoma 74078.

4) **Caulking & Weatherstripping.** Factsheet, Housing Renovation and Energy Conservation Unit, Ministry of Municipal Affairs & Housing, Queen's Park, Toronto, Ontario.

3.2 ADDING INSULATION

Start With The Basement. If your home has an uninsulated basement it should be the first area to receive insulation. Besides controlling a big source of heat loss by upgrading the basement walls, you will also be developing usable space. Figures 3.5 and 3.6 show recommended ways to insulate a basement by either the interior or exterior method.

Ceiling. The first step in upgrading your ceiling insulation level is to plug the leaks in the vapour barrier (see section 3.1). Serious problems with moisture and ice buildups in attics have been documented when insulation was added without first sealing the vapour barrier. The danger is that moist heated air, which was previously removed by natural attic ventilation, may cause condensation in the colder attic which results after more insulation is added above the ceiling. This won't happen if you seal the leaks through the vapour barrier before putting in the new insulation. Also make sure the attic vents are not sealed off by the new insulation.

Walls. In older homes with no wall insulation, cellulose fibre insulation can be blown in by specialized equipment. Beware of settlement and bridging. This is a fairly major undertaking. You might want to consider an exterior retrofit, adding new insulation and siding outside the existing structure (see section 3.6).

Windows. Replace any single pane windows with double or triple-glazed units (or at least install storm windows).

Financial Assistance

1) The Canadian Home Insulation Program (CHIP) provides a grant for sealing and insulating single family homes that meet certain conditions. The grant pays for 60% of materials and labour to a maximum of $500.00. For details and application forms phone the CHIP office in your province.

2) In some provinces, power utilities offer low interest loans for home energy conservation projects. Check with your local utility office.

MORE INFORMATION:

1) **Checklist To Cut Home Energy Costs.** Available from Manitoba Department of Energy And Mines, Energy Information Centre, 500 Portage Ave., Winnipeg, Manitoba. R3C 0V8.

2) **Keeping The Heat In.** Publication available from Conservation And Renewable Energy Branch, Energy, Mines and Resources Canada, 580 Booth Street, Ottawa, Ontario. K1A 0E4.

3) **How To Insulate Your Basement — Interior Method.**

4) **How To Insulate Your Basement — Exterior Method.**

Publications available from Alberta Energy and Natural Resources, Energy Conservation Branch, 9915 - 108 Street, Edmonton, Alberta. T5K 2C9.

5) **ENER$AVE For Home Insulation.** Free computer analysis of expected savings from home insulation anywhere in Canada. For details and application forms contact ENER$AVE P.O. Box 5410, Station E, Ottawa, Ontario. K1S 5B5.

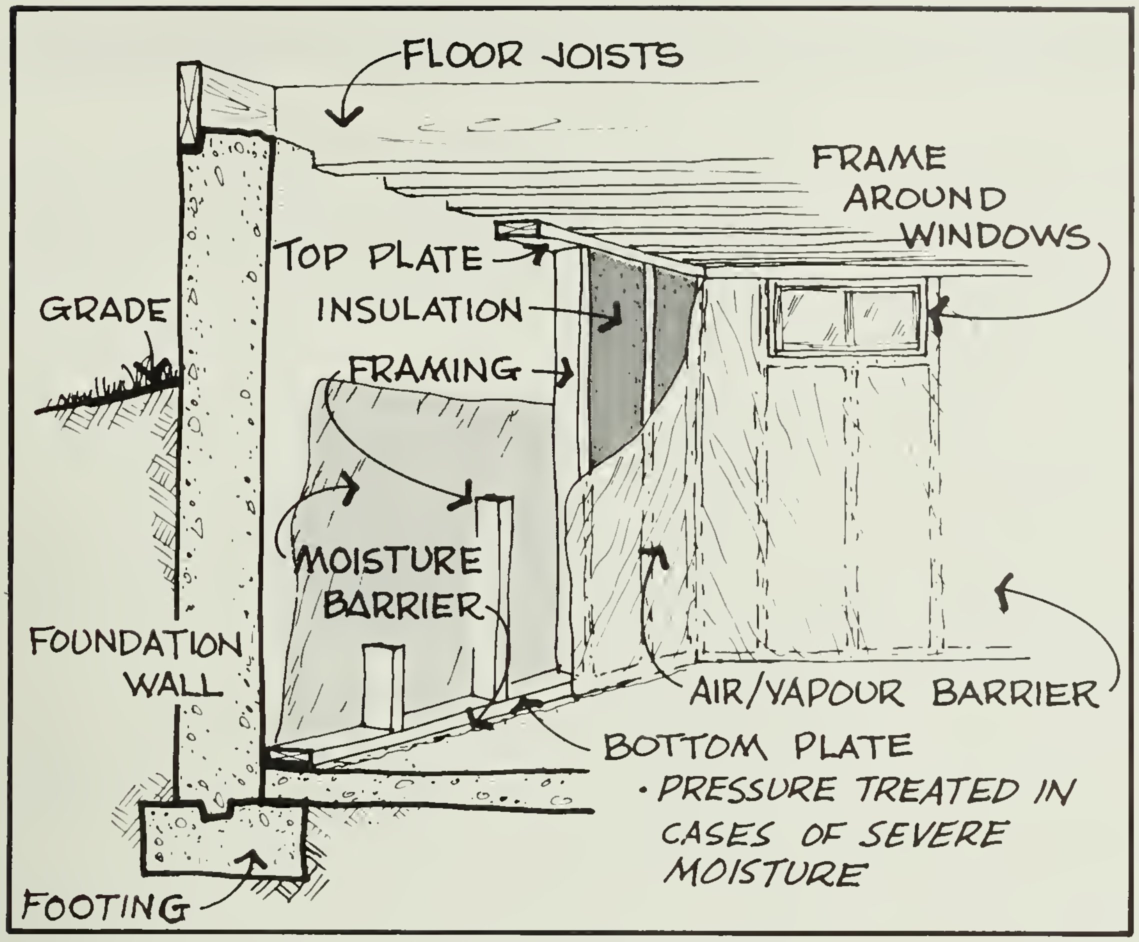


Fig. 3.5 Interior Insulation of Basement Walls *(Reference 3)*

Fig. 3.7 Installing Blanket Insulation in Unheated Attic

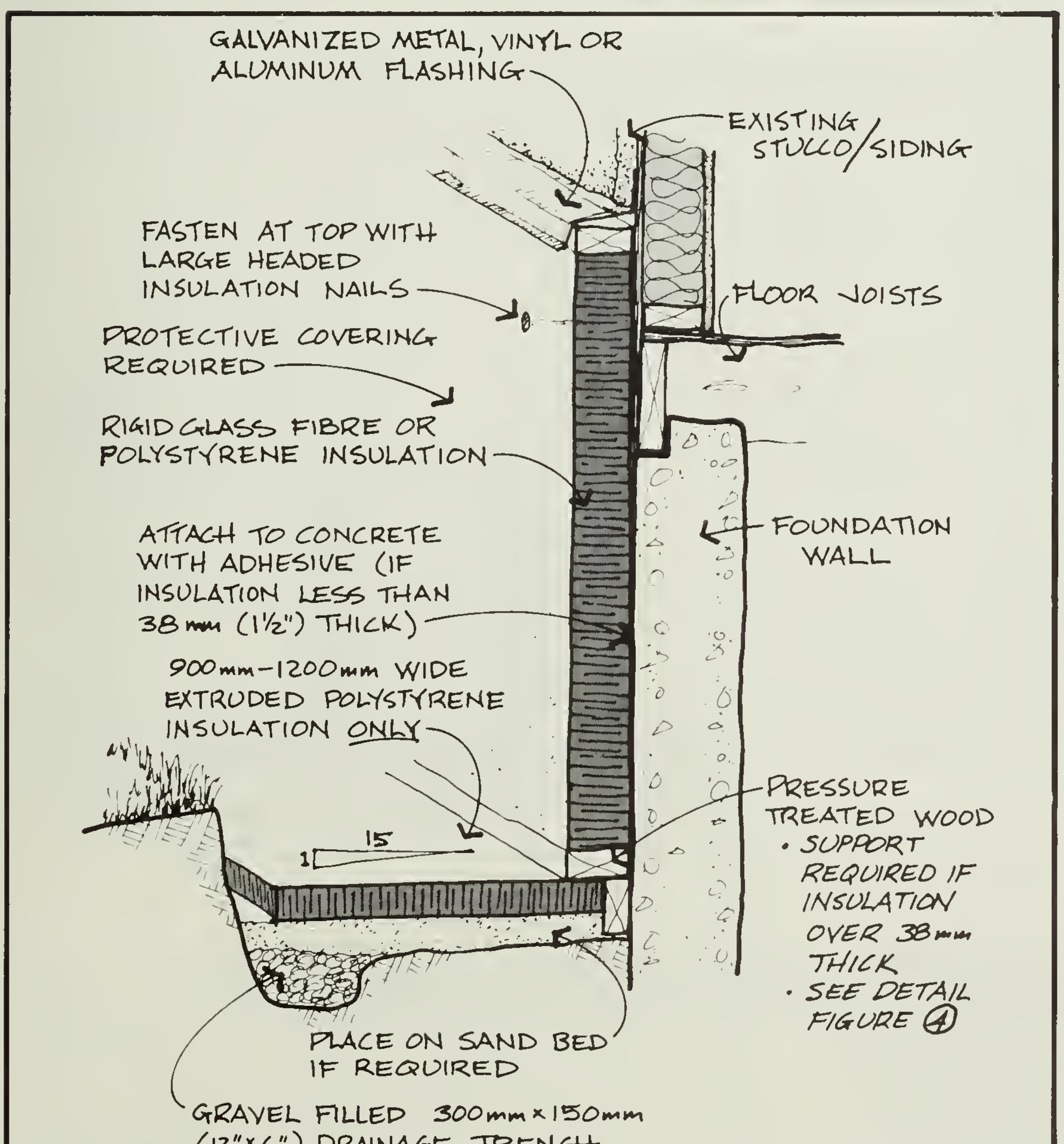


Fig. 3.6 Exterior Insulation of Basement Walls *(Reference 4)*

Fig. 3.8 Blowing Insulation Into Empty Wall Cavity

3.3 REDUCING HOT WATER COSTS

A study by the New Brunswick Electrical Power Commission of domestic hot water consumption and costs revealed some interesting findings:

Hot Water Consumption. For the 18 homes monitored, hot water use per day varied from 77 to 279 litres. The use per person varied from 19 to 135 litres per day (Fig. 3.9)

Temperature. Storage temperatures varied from 41° C to 65° C. Note the reduced energy consumption at the lower storage temperatures.

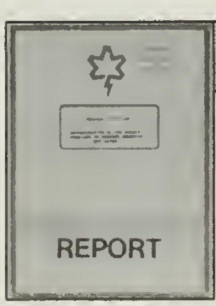
Cost. All of these systems were heated by electricity priced at 4¢/kWh. Annual hot water costs varied from $86 to $304.

Conservation Ideas:

1) Use less hot water. Install flow restrictors on taps and showerheads. Don't leave water running while shaving or rinsing dishes. Use cold water wherever possible.
2) Lower the temperature. Simply turning the hot water thermostat down from 65° C to 50° C could save 125 kWh per month, or 1500 kWh per year. At 4¢/kWh, you would save $60 per year. (Unfortunately, most dishwashers require high water temperatures. Only those models with built-in booster elements will operate properly at lower water temperatures.)
3) Insulate the storage tank and hot water lines. This will reduce the heat loss and save money. Be careful not to insulate the controls on the hot water tank. This could cause overheating.

Residence No.	Occupants	Average H.W. Consumption (Litres/Day)	(Litres/Occupant) Per Day	Storage Temp. (° C)	Annual Energy Use (kWh)	Annual Cost $ (@ 4¢/kWh)
1	3	87	29	55	2161	$86
2	4	264	53	55	5524	221
3	5	229	57	50	4039	186
4	2	147	74	43	2577	103
5	5	247	49	47	4966	199
6	2	271	135	49	4691	188
7	3	178	59	54	4130	165
8	2	170	85	48	3298	132
9	3	212	71	54	4880	195
10	6	279	47	65	7608	304
11	4	278	69	62	7243	290
12	2	163	82	41	2970	119
13	4	257	64	47	5906	236
14	2	102	51	65	3341	134
15	4	151	38	53	3811	152
16	2	152	76	46	3259	130
17	4	77	19	56	2309	92
18	3	199	66	60	4688	188

Fig. 3.9 Annual Hot Water Consumption in 18 Homes



MORE INFORMATION:

1) **Determination Of The Energy Required To Produce Domestic Hot Water.** Research report 913 U 160, available from the Canadian Electrical Association, Suite 580, One Westmount Square, Montreal, Quebec H3Z 2P9. (Price unknown).

3.4 BUYING EFFICIENT APPLIANCES

Under the ENERGUIDE program, initiated in 1978 by Consumer and Corporate Affairs Canada, major electric household appliances sold in Canada are tested to determine how much electricity they consume. Ratings can be found on ENERGUIDE labels placed on all new appliances.

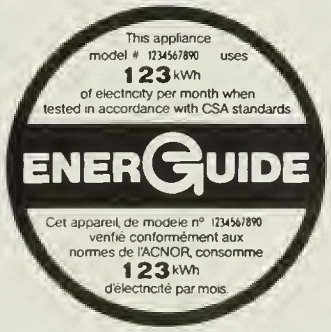


Fig. 3.10 Compare EnerGuide Labels on Electrical Appliances

Comparing Energy Costs. ENERGUIDE publications use the chart below to show the savings possible by energy-conscious shopping. The chart provides a rapid comparison of the 10-year energy costs for various consumption ratings and electricity prices. As shown, if electricity costs 4¢/kWh, the expected savings in 10 years with an appliance rated at 100 vs 150 kWh/month is $240. (720 - 480 = $240). Note that this does not take account of expected future increases in electricity costs, which might double or triple the potential savings. Also, the tests are based on "average" use patterns. For many appliances individual use patterns may easily vary by ± 50%.

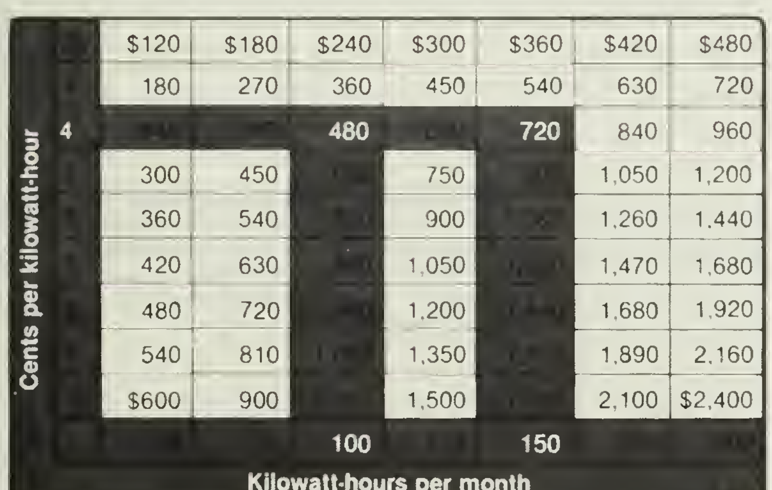


Fig. 3.11 Ten Year Electricity Costs For Appliances *(Reference 1)*

EXAMPLE

You will often find significant differences in ENERGUIDE ratings between different models of the same appliance from the same manufacturer. For example, all of the General Electric clothes washers shown below are the same size. Yet the most efficient model could save you 50 kWh per month. At 4¢/kWh you would save $24 in the first year. If electricity prices increased at 10% per year and you kept the washer for 10 years you would save a total of $382 by buying the most efficient model.

CLOTHES WASHERS
MACHINES À LAVER

Model / Modèle	Tub Capacity (L) / Capacité de la cuve (L)	Temperature Selection / Réglage de température	Special Cycles/Water Level / Cycles spéciaux/niveau d'eau	Energy Consumption, kWh/month / Consommation d'énergie, kWh/mois
BRENTWOOD Woolco Dapartmant Storas Div of F W Woolworth Co. Ltd 33 Adalaida Street Wast Toronto, Ontario M5H 1M1				
WWG1122	77.0	1	N	74
WWG1112	77.0	1	M	75
WWG1152	77.0	5	N	125
WWG1132	77.0	5	N	125
FRIGIDAIRE Frigidaira Division WCI Canada Ltd 503 Imperial Road Gualph, Ontario N1H 6N1				
LC-208	45.0	4	N	65
LC-240	45.0	4	N	65
LC-248	45.0	4	N	78
FWD190	90.0	4	N	120
FWD183	90.0	4	N	120
FWC190	90.0	5	N	128
FWC193	90.0	5	N	128
GENERAL ELECTRIC CAMCO Inc. Corporata Offica 185 Wright Avanua Weston, Ontario M9N 1E7				
VW523VG	77.0	1	N	74
VW523V	77.0	1	N	74
VW810V	77.0	1	M	75
W870V	77.0	5	N	110
W850V	77.0	5	N	110
W656V	77.0	5	N	110
W682V	77.0	5	N	110
W674V	77.0	5	N	110
W675V	77.0	5	N	110
W540V	77.0	5	N	110
W530V	77.0	5	N	125
W830V	77.0	5	N	125
W873V	77.0	5	N	125
W636V	77.0	5	N	125
W820V	77.0	5	N	125

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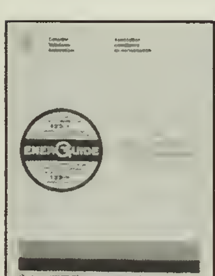
Fig. 3.12 Energy Consumption of Some Similar Clothers Washers *(Reference 1)*



MORE INFORMATION:

1) **ENERGUIDE.** Directories are available from all offices of Consumer and Corporate Affairs Canada. Look under Government of Canada in your telephone book.

2) **Household Appliances — Average Energy Consumption.** Factsheet, available from B.C. Hydro, Energy Use Department, 625 Howe Street, Vancouver, British Columbia V6C 2T6.

3.5 PLANNING A LOW ENERGY HOME

The Saskatchewan Conservation House, built in 1977, demonstrated several new concepts to save energy in housing, which have since been tested throughout Canada. Here are the key features that create a low-energy home:

Air Tightness. The air/vapour barrier has long been the most abused component in conventional house building. In low-energy construction a polyethylene air/vapour barrier is continuously sealed at *all* joints and openings, with special attention to electrical fixtures, sills, plates, windows and doors.

Insulation. Recommended minimum levels of insulation are: walls, RSI 4.9, ceiling, RSI 7.0 and basement, RSI 3.5. Some low-energy homes have much higher insulation levels. The cost-effective amounts vary with climatic regions and energy prices.

Windows. Double or triple glazed windows are located on the south side of the house for optimum solar gain. A roof overhang is designed to shade the windows in summer and prevent overheating.

Heating Systems. Low-energy homes do not require the large furnaces used in conventional houses. Several manufacturers now offer super-efficient smaller furnaces. Small electric heaters or hot water coils may also be used instead of a furnace.

Heat Exchangers. Controlled ventilation by an air-to-air heat exchanger recovers much of the heat in the exhaust air. It also prevents humid or unhealthy conditions which can occur in a tightly sealed house.

EXAMPLE

A common estimate for the added cost of a low-energy home is 10-15%. How do you decide if this is a good investment?

Consider a proposed 96m^2 farm home near Saskatoon, Saskatchewan.

The cost estimate for conventional construction was $52,000. Upgrading the design to low energy standards would add $6,000. Expected energy savings for space heating is 75 GJ. Propane is available at 20¢/L. Financing is available at 12.5% interest.

Calculations. Propane contains 25.5 MJ/L of energy, which equals 0.0255 GJ/L.

To supply 75 GJ at a typical efficiency of 65% would require [75/(0.025 x .65)] = 4615 L of propane.

At a cost of 20¢/L the propane saved in year 1 by low energy construction would be worth:

(4615 x $0.20) = $923.

The simple payback = ($6,000/$923) = 6.5 years.

This would be a good deal, considering the long life expectancy of a house. It would not be as cost-effective in a warmer climate or in areas with cheaper energy.

Cash Flow. Fig. 3.13 is the cash flow calculation for the added $6,000 capital cost compared to future energy savings. An annual inflation factor of 8% has

MORE INFORMATION:

1) **Low Energy Home Designs,** available from Alberta Agriculture, Print Media Branch, Main Floor, 7000 - 113 Street, Edmonton, Alberta T6H 5T6.
2) **Energy-Efficient Housing — A Prairie Approach,** available from Saskatchewan Energy and Mines, 1914 Hamilton Street, Regina, Saskatchewan S4P 4V3.
3) **Low Energy Prairie Housing.** Building Practice Note No. 38, available from Division of Building Research, National Research Council of Canada, Ottawa, Ontario K1A 0R6.
4) **Energy Efficient New Housing.** Project summary No. 017 available from Nova Scotia Department of Mines & Energy, P.O. Box 668, Halifax, Nova Scotia, B3J 2T3.
5) **Airtight Houses And Carbon Monoxide Poisoning.** Building digest No. UDC 614.8:728, available from the Division of Building Research, National Research Council, Ottawa, Ontario K1A 0R6.
6) **Selecting A New Furnace.** Publication No. 6 in "Energy Savers" series, available from Alberta Energy and Natural Resources, Energy Conservation Branch, 7th Floor, 9915 - 108 Street, Edmonton, Alberta T5K 2C9.
7) **Fresh Air And Humidity.** Factsheet available from Housing Renovation And Energy Conservation Unit, Ontario Ministry of Municipal Affairs And Housing, Queen's Park, Toronto, Ontario.
8) The **HOTCAN** micro-computer program, developed by NRC predicts heating costs for typical house designs at twelve locations in Canada. For details, contact the Prairie Regional Station, National Research Council, Saskatoon, Saskatchewan. (Also available at most HUDAC offices).

Capital Cost	$6000	Revenue first year	$923
Deduct.Startup Costs	$0	Revenue Increase per yr (%)	8.0
Inputs (exp) first yr	$0	Loan Term (yrs)	15
Input Increase per yr (%)	0.0	Loan Interest Rate	12.50
Income Tax Rate (%)	5	Loan (1 = Ammort., 2 = Dim. Bal.)	1
General Inflation Rate	8	Loan Payments per year	12
C.C.A first year (%)	5.0	Study Scope (1 = all, 2 = part)	2
C.C.A. 2nd year (%)	5.0	Study Term In Years	15
C.C.A. other years (%)	5.0	Starting Year of Study	1
CCA Type (1 = dim, 2 = orig)	1	Downpayment	$0

Year	Inputs	Revenue	Principal	Interest	Taxes	Cashflow	Total CF	CCA
1	0.00	923.00	145.57	741.85	-5.94	41.53	$41.53	300.00
2	0.00	996.84	164.84	722.57	-0.54	109.96	$151.49	285.00
3	0.00	1076.59	186.67	700.74	5.25	183.92	$335.41	270.75
4	0.00	1162.71	211.39	676.03	11.47	263.83	$599.24	257.21
5	0.00	1255.73	239.38	648.04	18.17	350.15	$949.39	244.35
6	0.00	1356.19	271.07	616.34	25.39	443.39	$1392.78	232.13
7	0.00	1464.69	306.97	580.44	33.19	544.09	$1936.87	220.53
8	0.00	1581.86	347.62	539.80	41.63	652.82	$2589.69	209.50
9	0.00	1708.41	393.65	493.77	50.78	770.22	$3359.90	199.03
10	0.00	1845.08	445.77	441.64	60.72	896.95	$4256.85	189.07
11	0.00	1992.69	504.80	382.61	71.52	1033.75	$5290.61	179.62
12	0.00	2152.10	571.64	315.77	83.28	1181.41	$6472.01	170.64
13	0.00	2324.27	647.34	240.08	96.10	1340.75	$7812.77	162.11
14	0.00	2510.21	733.06	154.36	110.09	1512.71	$9325.47	154.00
15	0.00	2711.03	830.12	57.29	125.37	1698.25	$11023.72	146.30
End of run	Total Cash Flow (present value)				$5310.55			

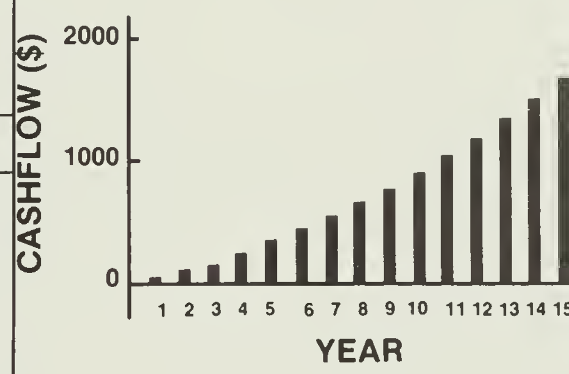


Fig. 3.13 Cash Flow Analysis: Added Cost vs. Savings for Low Energy Home

been assumed for the energy price. The 6,000 extra cost was amortized over 15 years. A marginal tax rate of 20% was assumed, with ¼ of the home costs allocated to farm expenses.

Conclusion. These calculations show that, if all assumptions are correct, the low energy option will improve the net cash flow of the farm by $11,024 over a 15 year period.

3.6 RETROFITTING AN OLD FARMHOUSE

If your farmhouse is poorly insulated, needs new siding and maybe a new roof you could consider doing an exterior retrofit as described in the following example:

Old House. This 35 year old stucco bungalow located on a farm near Fort Saskatchewan, Alberta, was almost unlivable before the retrofit. Insulation levels were very low. There were large cracks around the windows, doors, and sill plates. Estimated energy consumption for heating was 300 GJ per year.

Exterior Retrofit. The interior of the house was not changed during the remodelling project. Instead, new insulated walls and a roof were added to the outside.

Steps.

1) The entire house was wrapped in a polyethylene air-vapour barrier. Joints in the poly were overlapped and caulked.
2) Strapping boards were nailed horizontally to hold the poly in place and provide a nailing surface for new vertical studs and rafters.
3) Fibreglass batt insulation was installed between the studs and rafters.
4) The front porch was closed in to create an air-lock entrance.
5) New wood frame double-glazed windows were installed.
6) Cedar shakes and siding were used to complete the exterior.
7) Polystyrene insulation was installed outside the foundation.
8) A wood stove was installed.

Performance. The remodelled house is very comfortable. The wood stove supplies most of the heat, using wood from the farm. A heat exchanger may be needed to control humidity.

Economics. The total material and equipment cost was about $7,800. The work was done by the owners with an estimated total labour input of 500 man-hours. Before the retrofit in 1980 the heating bill was about $600/year (natural gas at $2.00/GJ.) Energy prices were expected to increase at a rate of 10% per year.

MORE INFORMATION:

1) **The Super-Insulated Retrofit Book.** Published by Renewable Energy In Canada, 334 King Street East, Studio 208, Toronto, Ontario M5A 1K8.

Fig. 3.14 Farmhouse Before Retrofit

Fig. 3.15 New Vapour Barrier, Walls and Roof

Fig. 3.16 New Home After Retrofit

Capital Cost	$7800	Revenue first year	$600
Deduct Startup Costs	-$500	Revenue Increase per yr (%)	10.0
Inputs (exp) first yr	$0	Loan Term (yrs)	15
Input Increase per yr (%)	0.0	Loan Interest Rate	12.50
Income Tax Rate (%)	6	Loan (1 = Ammort., 2 = Dim. Bal.)	1
General Inflation Rate	8	Loan Payments per year	12
C.C.A first year (%)	2.5	Study Scope (1 = all, 2 = part)	2
C.C.A. 2nd year (%)	5.0	Study Term In Years	15
C.C.A. other years (%)	5.0	Starting Year of Study	1980
CCA Type (1 = dim, 2 = orig)	1	Downpayment	$C

Year	Inputs	Revenue	Principal	Interest	Taxes	Cashflow	Total CF	CCA
1980	0.00	600.00	177.10	902.58	0.15	-479.83	-$479.83	195.00
1981	0.00	660.00	200.56	879.13	-35.96	-383.72	-$863.55	380.25
1982	0.00	726.00	227.11	852.57	-29.27	-324.42	-$1187.97	361.24
1983	0.00	798.60	257.19	822.50	-22.02	-259.06	-$1447.03	343.18
1984	0.00	878.46	291.24	788.44	-14.16	-187.07	-$1634.10	326.02
1985	0.00	966.31	329.81	749.88	-5.60	-107.78	-$1741.88	309.72
1986	0.00	1062.94	373.48	706.21	3.75	-20.50	-$1762.38	294.23
1987	0.00	1169.23	422.93	656.75	13.98	75.57	-$1686.81	279.52
1988	0.00	1286.15	478.94	600.75	25.19	181.28	-$1505.54	265.54
1989	0.00	1414.77	542.36	537.33	37.51	297.57	-$1207.96	252.27
1990	0.00	1556.25	614.17	465.51	51.06	425.50	-$782.47	239.65
1991	0.00	1711.87	695.50	384.19	66.00	566.18	-$216.28	227.67
1992	0.00	1883.06	787.59	292.09	82.48	720.89	$504.61	216.29
1993	0.00	2071.36	891.88	187.80	100.69	890.99	$1395.60	205.47
1994	0.00	2278.50	1009.98	69.70	120.82	1078.00	$2473.60	195.20
End of run	Total Cash Flow (present value)				$169.02			

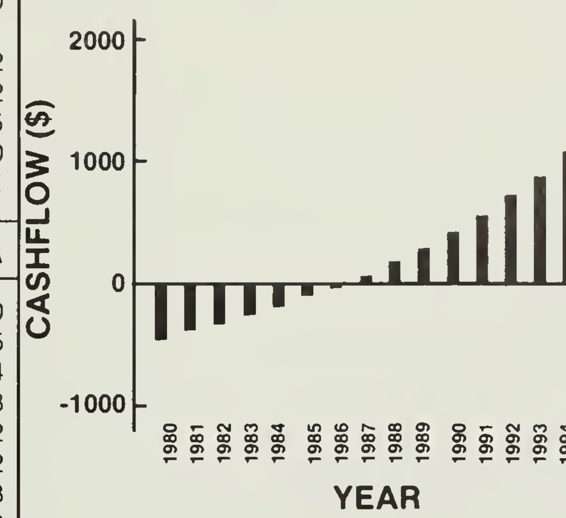


Fig. 3.17 Cash Flow Analysis: Farmhouse Retrofit

Cash Flow. Fig. 3.17 is a cash flow projection assuming a typical farm tax situation (25% marginal tax rate and ¼ of home deductible). The $600/year saved in heating costs has been considered as revenue to help pay for the retrofit.

Conclusion. As shown, the energy savings will pay for the retrofit in 11 years. More importantly, the renovation avoided the expensive alternative of paying for a completely new home.

4 *Saving Energy and $ in* FARM TRANSPORTATION

Many farmers use more fuel in their cars and trucks than in their tractors. Here are some ways to save money in both farm and personal transportation.

Shop For Efficiency. Check the Transport Canada guide for comparisons of fuel use. This varies widely with engine design, vehicle weight, transmission type and other features.

Match The Job. Consider one small efficient car or mini-truck to be used for personal travel and non-loaded trips.

Shut It Off. Idling and long "warm up" periods waste a lot of fuel and may actually damage an engine.

Keep It Tuned. Fuel efficiency decreases between tune-ups. A good maintenance schedule saves energy and money.

Check The Tires. Low pressure in the tires can waste fuel and reduce tire life. Check them cold and inflate to recommended pressures.

Check The Temperature. Use radiator covers and the correct thermostats to get to recommended engine temperatures quickly. Engine wear and fuel consumption are much higher in a cold engine.

Slow Down. When you have lots of time, slow down. Professional truckers have shown you can save on fuel, maintenance and tires.

Get Together. How many times do you have two or more vehicles in town on the same day? How many trips could be eliminated completely by a telephone call?

Fig. 4.1 Trucks and Cars are Large Energy Users on Many Farms.

Consider a CB Radio. Many farmers report that C.B. or F.M. radios save them considerable fuel and time by reducing travel, both on and off the farm.

Review Your On-Farm Travel Costs. Motor scooters and snowmobiles use a lot less fuel than 4-wheel drive trucks for tasks like inspecting livestock and crops. Many western ranchers are reviving the use of horses for feeding cows and checking fences.

4.1 BUYING AN EFFICIENT VEHICLE

Transport Canada publishes an annual Fuel Consumption Guide for new cars and light trucks. The following example shows how to use the guide for comparing vehicles.

EXAMPLE

If you were buying a new pickup how much could you save in fuel costs by getting one of the "mini-trucks". (This discussion would only apply if the truck is to be used mainly for transportation and light loads.)

Compare a 1983 4-cylinder, manual 5-speed Ford Ranger Pickup with a 1983 V-8, 3-speed automatic F150 Pickup.

Assume:
- Distance travelled/year = 25,000 km.
- Gasoline costs 40¢/L.
- All other operating costs equal for both vehicles.

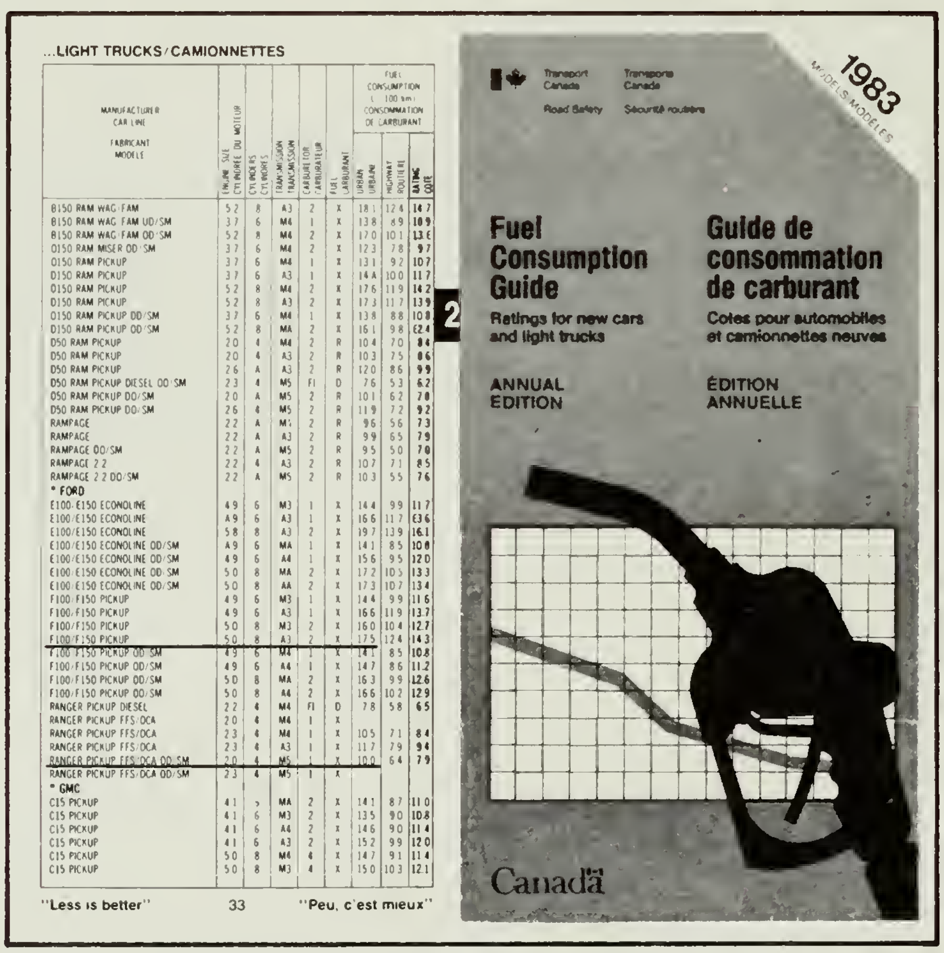
Calculations

The Fuel Consumption Guide shows that the rating codes for the F150 and the Ranger are 14.3 and 7.9 L/100 km, respectively. However, these figures are based on summer driving conditions on paved roads. Ironically, based on experience, the best figures to use for country driving appear to be the urban ratings; in this case, 17.5 and 10.0 respectively.

Expected fuel consumptions for the two vehicles are:

1) F150:(17.5L/100 km x 25,000 km)	= 4375 L/yr.
2) Ranger: (10.0L/100 km x 25,000 km)	= 2500 L/yr.
Fuel saved with Ranger	= 1875 L/yr.
$ saving = (1875L x $0.40/L)	= $750/yr.

If the fuel price increases at 8% per year, the total savings over five years would be **$4400.**



...LIGHT TRUCKS/CAMIONNETTES

MANUFACTURER CAR LINE / FABRICANT MODÈLE	ENGINE SIZE / CYLINDRÉE DU MOTEUR	CYLINDERS / CYLINDRES	TRANSMISSION / TRANSMISSION	CARBURETOR / CARBURATEUR	FUEL / CARBURANT	FUEL CONSUMPTION (L/100 km) CONSOMMATION DE CARBURANT: URBAN / URBAINE	HIGHWAY / ROUTIÈRE	RATING / COTE
B150 RAM WAG/FAM	5.2	8	A3	2	X	18.1	12.4	14.7
B150 RAM WAG/FAM OD/SM	3.7	6	M4	1	X	13.8	8.9	10.9
B150 RAM WAG/FAM OD/SM	5.2	8	M4	2	X	17.0	10.1	13.6
D150 RAM MISER OD/SM	3.7	6	M4	2	X	12.3	7.8	9.7
D150 RAM PICKUP	3.7	6	M4	1	X	13.1	9.2	10.7
D150 RAM PICKUP	3.7	6	A3	1	X	14.4	10.0	11.7
D150 RAM PICKUP	5.2	8	M4	2	X	17.6	11.9	14.2
D150 RAM PICKUP	5.2	8	A3	2	X	17.3	11.7	13.9
D150 RAM PICKUP OD/SM	3.7	6	M4	1	X	13.8	8.8	10.8
D150 RAM PICKUP OD/SM	5.2	8	M4	2	X	16.1	9.8	12.4
D50 RAM PICKUP	2.0	4	M4	2	R	10.4	7.0	8.4
D50 RAM PICKUP	2.0	4	A3	2	R	10.3	7.5	8.6
D50 RAM PICKUP	2.6	4	A3	2	R	12.0	8.6	9.9
D50 RAM PICKUP DIESEL OD/SM	2.3	4	M5	FI	D	7.6	5.3	6.2
D50 RAM PICKUP OD/SM	2.0	4	M5	2	R	10.1	6.2	7.8
D50 RAM PICKUP OD/SM	2.6	4	M5	2	R	11.9	7.2	9.2
RAMPAGE	2.2	4	M5	2	R	9.6	5.6	7.3
RAMPAGE	2.2	4	A3	2	R	9.9	6.5	7.9
RAMPAGE OD/SM	2.2	4	M5	2	R	9.5	5.0	7.0
RAMPAGE 2.2	2.2	4	A3	2	R	10.7	7.1	8.5
RAMPAGE 2.2 OD/SM	2.2	4	M5	2	R	10.3	5.5	7.6
* FORD								
E100/E150 ECONOLINE	4.9	6	M3	1	X	14.4	9.9	11.7
E100/E150 ECONOLINE	4.9	6	A3	1	X	16.6	11.7	13.6
E100/E150 ECONOLINE	5.8	8	A3	2	X	19.7	13.9	16.1
E100/E150 ECONOLINE OD/SM	4.9	6	M4	1	X	14.1	8.5	10.8
E100/E150 ECONOLINE OD/SM	4.9	6	A4	1	X	15.6	9.5	12.0
E100/E150 ECONOLINE OD/SM	5.0	8	M4	2	X	17.2	10.5	13.3
E100/E150 ECONOLINE OD/SM	5.0	8	A4	2	X	17.3	10.7	13.4
F100/F150 PICKUP	4.9	6	M3	1	X	14.4	9.9	11.6
F100/F150 PICKUP	4.9	6	A3	1	X	16.6	11.9	13.7
F100/F150 PICKUP	5.0	8	M3	2	X	16.0	10.4	12.7
F100/F150 PICKUP	5.0	8	A3	2	X	17.5	12.4	14.3
F100/F150 PICKUP OD/SM	4.9	6	M4	1	X	14.1	8.5	10.8
F100/F150 PICKUP OD/SM	4.9	6	A4	1	X	14.7	8.6	11.2
F100/F150 PICKUP OD/SM	5.0	8	M4	2	X	16.3	9.9	12.6
F100/F150 PICKUP OD/SM	5.0	8	A4	2	X	16.6	10.2	12.9
RANGER PICKUP DIESEL	2.2	4	M4	FI	D	7.8	5.8	6.5
RANGER PICKUP FFS/DCA	2.0	4	M4	1	X			
RANGER PICKUP FFS/DCA	2.3	4	M4	1	X	10.5	7.1	8.4
RANGER PICKUP FFS/DCA	2.3	4	A3	1	X	11.7	7.9	9.4
RANGER PICKUP FFS/DCA OD/SM	2.0	4	M5	1	X	10.0	6.4	7.9
RANGER PICKUP FFS/DCA OD/SM	2.3	4	M5	1	X			
* GMC								
C15 PICKUP	4.1	6	M4	2	X	14.1	8.7	11.0
C15 PICKUP	4.1	6	M3	2	X	13.5	9.0	10.8
C15 PICKUP	4.1	6	A4	2	X	14.6	9.0	11.4
C15 PICKUP	4.1	6	A3	2	X	15.2	9.9	12.0
C15 PICKUP	5.0	8	M4	4	X	14.7	9.1	11.4
C15 PICKUP	5.0	8	M3	4	X	15.0	10.3	12.1

"Less is better" 33 "Peu, c'est mieux"

Fig. 4.2 Using the Fuel Consumption Guide *(Reference 1)*

MORE INFORMATION:

1) **Fuel Consumption Guide For New Cars And Light Trucks,** available from Public Affairs Branch, Transport Canada, Ottawa, Ontario, K1A 0N5.

4.2 WILL ENERGY SAVINGS PAY FOR A MORE EFFICIENT PICKUP?

If your pickup is a gas-guzzler, how far would fuel savings go toward paying for a more efficient model? Compare your situation to the following example.

EXAMPLE

Consider a full-sized, 3-year old pickup, driven 25,000 km per year. Fuel consumption averages 25 L/100 km. A new model in a smaller size class is expected to consume 14 L/100 km. It can be purchased for $5,000 plus trade.

Expected fuel saving = (25 - 14) = 11 L/100 km.

Fuel savings/year = (11 L/(100 km) x (25,000 km) = 2750 L

At 40¢/L, $ saved = (2750 L x $0.40/L) = **$1100/year**

Other Assumptions.

- Fuel prices increasing 8%/year.
- Repair and maintenance costs of old pickup expected to be $200/year greater than for new vehicle. (Also escalated at 8%/year.)
- Financing available at 12.5% for 3 years.
- Farm operates at 25% marginal tax rate.
- Pickup is used totally for farm business.

Cash Flow. (See Fig. 4.3)

Conclusion. Reduced fuel costs would pay for the more efficient pickup in 4½ years.

Capital Cost	$5000	Revenue first year	$1300
Deduct Startup Costs	$0	Revenue Increase per yr (%)	8.0
Inputs (exp) first yr	$0	Loan Term (yrs)	3
Input Increase per yr (%)	0.0	Loan Interest Rate	12.50
Income Tax Rate (%)	25	Loan (1 = Ammort., 2 = Dim. Bal.)	1
General Inflation Rate	7	Loan Payments per year	12
C.C.A first year (%)	15.0	Study Scope (1 = all, 2 = part)	2
C.C.A. 2nd year (%)	30.0	Study Term In Years	5
C.C.A. other years (%)	30.0	Starting Year of Study	1
CCA Type (1 = dim, 2 = orig)	1	Downpayment	$0

Year	Inputs	Revenue	Principal	Interest	Taxes	Cashflow	Total CF	CCA
1	0.00	1300.00	1464.22	543.00	1.75	-708.97	-$708.97	750.00
2	0.00	1404.00	1658.11	349.11	-55.03	-548.19	-$1257.16	1275.00
3	0.00	1516.32	1877.67	129.55	123.57	-614.46	-$1871.62	892.50
4	0.00	1637.63	0.00	0.00	253.22	1384.41	-$487.21	624.75
5	0.00	1768.64	0.00	0.00	332.83	1435.81	$948.60	437.33
End of run	Total Cash Flow (present value)				$467.47			

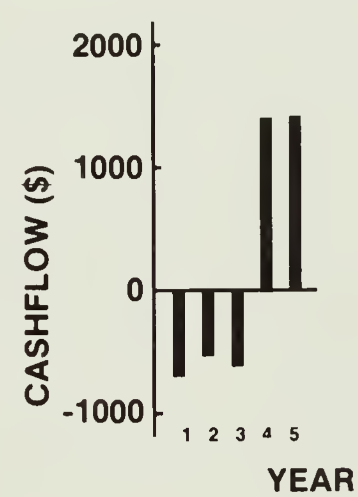


Fig. 4.3 Cash Flow Analysis: Trading Up to a More Efficient Pickup

4.3 SHOULD YOU GO DIESEL?

If you were buying a GMC C15 Pickup would the extra cost for the diesel option be justified by lower fuel costs?

- Assume 25,000 km per year, mostly light load, on a combination of gravel and paved roads.
- Net extra cost for the diesel option = $2200.
- Financing at 12.5% for 4 years.
- Used totally for farm business.
- Marginal tax rate = 25%.
- Assume two cases for fuel prices:

  1) Gasoline = 40¢/L, Diesel = 35¢/L
  2) Gasoline = 55¢/L, Diesel = 50¢/L
- Escalate fuel prices at 8%.

Expected Fuel Use. Compare the two vehicles in the Transport Canada Fuel Consumption Guide. Note that the diesel engine has a 9.6 L/100 km rating vs 12.3 L/100 km for the gasoline model. However, experience has shown that these figures are too optimistic for country driving. We suggest that the urban figures (12.3 and 15.6 L/100 km, respectively) are more realistic.

Gasoline: (15.6 L/100 km) x 25,000 km = 3900 L/yr.

Diesel: (12.3 L/100 km) x 25,000 km = 3075 L/yr.

Reduced Fuel Costs.

1) **Case 1:**

Gasoline: (3900 L x 40¢/L)	= $1560
Diesel: (3075 L x 35¢/L)	= $1076
Fuel Cost Saving (Yr. 1)	= $ 484

2) **Case 2:**

Gasoline: (3900 L x 55¢/L)	= $2145
Diesel: (3075 L x 50¢/L)	= $1538
Fuel Cost Saving (Yr. 1)	= $ 607

Simple Payback.

1) Case I: Payback = (Investment/Year 1 Saving) = ($2200/$484) = 4.5 years

2) Case II: Payback = (Investment/Year 1 Saving) = ($2200/$607) = 3.6 years

Cash Flow. (See Fig. 4.5 & 4.6)

...LIGHT TRUCKS/CAMIONNETTES

MANUFACTURER CAR LINE / FABRICANT MODELE	ENGINE SIZE / CYLINDREE OU MOTEUR	CYLINDERS / CYLINDRES	TRANSMISSION / TRANSMISSION	CARBURETOR / CARBURATEUR	FUEL / CARBURANT	FUEL CONSUMPTION L/(100 km) CONSOMMATION DE CARBURANT: URBAN / URBAINE	HIGHWAY / ROUTIERE	RATING / COTE
C15 PICKUP	5.0	8	A4	4	X	15 6	10 0	12.3
C15 PICKUP	5 0	8	A3	4	X	16 6	10.8	13.2
C15 PICKUP DIESEL	6.2	8	M4	FI	D	11.3	7 6	9.1
C15 PICKUP DIESEL	6 2	8	A4	FI	D	12.3	7.7	9.6
G15 VAN/FDURGDN	4 1	6	M4	2	X	14 8	9 4	11.7
G15 VAN/FDURGDN	4 1	6	M3	2	X	13 5	9 0	10.8
G15 VAN/FDURGDN	4 1	6	A4	2	X	14 6	9 0	11.4
G15 VAN/FDURGDN	5 0	8	M4	4	X	14 7	9 0	11.4
G15 VAN/FOURGDN	5 0	8	M3	4	X	15 3	10 6	12.4
G15 VAN/FOURGDN	5 0	8	A4	4	X	15.6	10 0	12.3
G15 VAN/FDURGDN	5 7	8	A4	4	X	18.1	11 4	14.2
S15 CAB & CHASSIS	2 8	6	M4	2	X	15.3	12.2	13.1
S15 CAB & CHASSIS	2.8	6	A4	2	X	15 7	12.5	13.5
S15 PICKUP	1 9	4	M5	2	X	9 0	5 4	6.9
S15 PICKUP	1 9	4	M4	2	X	9 7	6.0	7.5
S15 PICKUP	2.0	4	M5	2	X	10.8	6.7	8.4
S15 PICKUP	2 0	4	M4	2	X	10 6	6 7	8.3
S15 PICKUP	2.0	4	A4	2	X	11 8	7.5	9.3
S15 PICKUP	2.8	6	M5	2	X	11.7	7 1	9.0
S15 PICKUP	2 8	6	M4	2	X	11 3	6 9	8.7
S15 PICKUP	2.8	6	A4	2	X	11 7	6 7	8.9
S15 PICKUP DIESEL	2 2	4	M5	FI	D			
S15 PICKUP DIESEL	2 2	4	M4	FI	D			
S15 UTILITY BODY	2.8	6	M4	2	X	11 3	6 9	8.7
S15 UTILITY BDDY	2.8	6	A4	2	X	11 7	6 7	8.9
• MAZDA								
B2000	2.0	4	M5	2	X	9.6	6 2	7.6
B2000	2.0	4	M4	2	X	9 6	6 2	7.6
B2200 DIESEL	2.2	4	M5	FI	D	8 1	5.9	6.7
• SUBARU								
BRAT 4X4	1.8	4	M4	2	X	9 7	6.6	7.8
• TOYOTA								
TRUCK	2.4	4	M5	2	X	·10.7	7.2	8.6
TRUCK	2.4	4	M4	2	X	10 1	7.3	8.3
TRUCK	2.4	4	A4	2	X	10.3	7.6	8.6
TRUCK DIESEL	2 2	4	M5	FI	D	7.8	6.0	6.6
• VOLKSWAGEN								
PICKUP	1 7	4	M5	FI	X	10.9	6.3	8.3
PICKUP	1.7	4	M4	FI	X	10.0	6.2	7.8
PICKUP DIESEL	1 6	4	M5	FI	D	7 0	4 8	5.7
VANAGDN	2.0	4	M4	FI	R	15 0	9.2	11.7
VANAGON	2.0	4	A3	FI	R	16 1	10.0	12.5
VANAGON DIESEL	1 6	4	M5	FI	D	8.3	7 2	7.4

"Less is better" 34 "Peu, c'est mieux"

Fig. 4.4 Comparing Diesel and Gasoline Engines

Conclusion. The cash flow projections for both cases show that the diesel option begins to pay off in the 5th year of ownership, after the loan is repaid. Differences in performance, service costs, expected lifetime and resale value should also be considered.

Capital Cost	$2200	Revenue first year	$484
Deduct Startup Costs	$0	Revenue Increase per yr (%)	8.0
Inputs (exp) first yr	$0	Loan Term (yrs)	4
Input Increase per yr (%)	0.0	Loan Interest Rate	12.50
Income Tax Rate (%)	25	Loan (1 = Ammort., 2 = Dim. Bal.)	1
General Inflation Rate	7	Loan Payments per year	12
C.C.A first year (%)	15.0	Study Scope (1 = all, 2 = part)	2
C.C.A. 2nd year (%)	30.0	Study Term In Years	5
C.C.A. other years (%)	30.0	Starting Year of Study	1
CCA Type (1 = dim, 2 = orig)	1	Downpayment	$0

Year	Inputs	Revenue	Principal	Interest	Taxes	Cashflow	Total CF	CCA
1	0.00	484.00	452.03	249.68	-23.92	-193.79	-$193.79	330.00
2	0.00	522.72	511.88	189.83	-57.03	-121.96	-$315.75	561.00
3	0.00	564.54	579.66	122.05	12.45	-149.62	-$465.38	392.70
4	0.00	609.70	656.42	45.29	72.38	-164.39	-$629.77	274.89
5	0.00	658.48	0.00	0.00	116.51	541.96	-$87.80	192.42

End of run Total Cash Flow (present value) $159.19

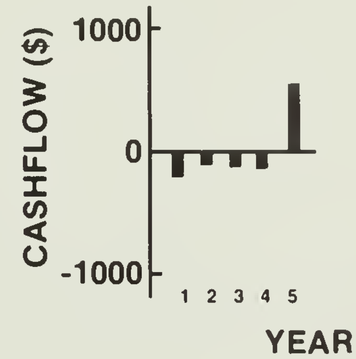


Fig. 4.5 Cash Flow Analysis: Diesel Option — Case 1: Gasoline 40¢/L., Diesel Fuel 35¢/L.

Capital Cost	$2200	Revenue first year	$607
Deduct Startup Costs	$0	Revenue Increase per yr (%)	8.0
Inputs (exp) first yr	$0	Loan Term (yrs)	4
Input Increase per yr (%)	0.0	Loan Interest Rate	12.50
Income Tax Rate (%)	25	Loan (1 = Ammort., 2 = Dim. Bal.)	1
General Inflation Rate	7	Loan Payments per year	12
C.C.A first year (%)	15.0	Study Scope (1 = all, 2 = part)	2
C.C.A. 2nd year (%)	30.0	Study Term In Years	5
C.C.A. other years (%)	30.0	Starting Year of Study	1
CCA Type (1 = dim, 2 = orig)	1	Downpayment	$0

Year	Inputs	Revenue	Principal	Interest	Taxes	Cashflow	Total CF	CCA
1	0.00	607.00	452.03	249.68	6.83	-101.54	-$101.54	330.00
2	0.00	655.56	511.88	189.83	-23.82	-22.33	-$123.87	561.00
3	0.00	708.00	579.66	122.05	-48.31	-42.02	-$165.90	392.70
4	0.00	764.65	656.42	45.29	111.12	-48.18	-$214.08	274.89
5	0.00	825.82	0.00	0.00	158.35	667.47	$453.39	192.42

End of run Total Cash Flow (present value) $310.76

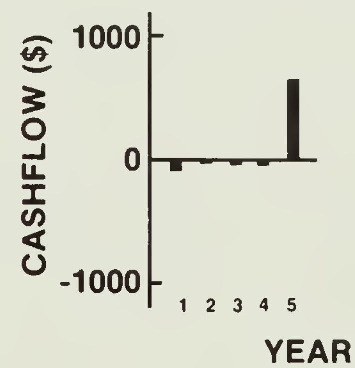


Fig. 4.6 Cash Flow Analysis: Diesel Option — Case 2: Gasoline 55¢/L., Diesel Fuel 50¢/L.

4.4 PROS AND CONS OF PROPANE CONVERSION

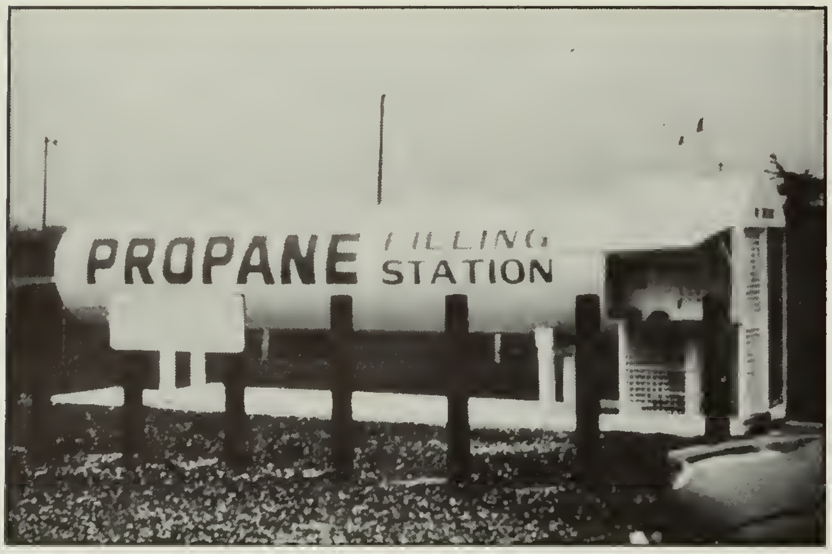


Fig. 4.7 Propane is Becoming a Popular Transportation Fuel in Many Areas.

Liquified petroleum gas (LP-Gas), commonly known as propane, is a byproduct of oil and gas refining operations. Propane has been used on farms for many years, mainly for space heating and grain drying. Some farmers have also had experience with propane as a tractor fuel.

Recent interest in propane as a vehicle fuel has been encouraged by the federal government. Farmers who convert gasoline powered cars or trucks to operate on propane are eligible for a $400 grant per vehicle. Application forms are available from propane suppliers or from: The Propane Vehicle Grant Program, Conservation and Renewable Energy Branch, Energy, Mines and Resources Canada, Box 4513, Station E, Ottawa — K1S 5K6. The grant applies for any vehicle used for farming.

ADVANTAGES

- Lower priced fuel (at present time).
- Less engine maintenance required.
- Longer engine life (?)
- No fuel spillage or evaporation.
- No noxious fumes.
- Emission controls are not required.
- No tank water condensation.

DISADVANTAGES

- Tank takes up cargo space.
- Not as readily available as gasoline.
- Tank filling slightly more complex.
- Overfilling very dangerous.
- Minor leaks may create an explosion hazard in a building.
- Not permitted into underground parkade and some tunnels.
- Proper engine lubrication oil required (to prevent oil nitrification and thickening).
- May affect vehicle resale value.

Fig. 4.8 Pros and Cons of Propane Conversion

HOW TO COMPARE THE ECONOMICS OF PROPANE vs GASOLINE

It costs about $1600 to have a vehicle converted to propane. This is partially offset by the $400 federal grant. Most farmers will be able to refuel at a local service station equipped for propane sales. If you already have a propane tank on your farm you might want to invest another $550 for a hand pump to refuel your truck at home.

MORE INFORMATION:

1) **Switching To Propane — A Guide For Fleet Operators.** Available from Ontario Ministry of Transportation and Commerce, 3rd Floor, Central Building, 1201 Wilson Avenue, Downsview, Ontario M3M 1J8.

2) **Propane Use As A Farm Transportation Fuel.** Factsheet No. 82-062 available from Ontario Ministry of Agriculture and Food, Information Branch, Legislative Buildings, Toronto, Ontario M7A 1A5.

3) **Propane As A Fuel For Vehicles And Tractors.** Factsheet available from Alberta Agriculture, Print Media Branch, Main Floor, 7000 - 113 Street, Edmonton, Alberta T6H 5T6.

4) **The Economics of Converting Gasoline Trucks and Farm Machinery to Propane.** Canadex factsheet No. 325.028, available from Communications Branch, Agriculture Canada, Ottawa, Ontario. K1A 0C7.

Capital Cost	$1600	Revenue first year	$625
Deduct Startup Costs	-$400	Revenue Increase per yr (%)	8.0
Inputs (exp) first yr	$0	Loan Term (yrs)	3
Input Increase per yr (%)	0.0	Loan Interest Rate	12.50
Income Tax Rate (%)	25	Loan (1 = Ammort., 2 = Dim. Bal.)	1
General Inflation Rate	7	Loan Payments per year	1
C.C.A first year (%)	100.0	Study Scope (1 = all, 2 = part)	2
C.C.A. 2nd year (%)	0.0	Study Term In Years	5
C.C.A. other years (%)	0.0	Starting Year of Study	1
CCA Type (1 = dim, 2 = orig)	1	Downpayment	$0

Year	Inputs	Revenue	Principal	Interest	Taxes	Cashflow	Total CF	CCA
1	0.00	625.00	353.92	150.00	-181.25	302.33	$302.33	1600.00
2	0.00	675.00	398.16	105.76	142.31	28.77	$331.11	0.00
3	0.00	729.00	447.93	55.99	168.25	56.83	$387.94	0.00
4	0.00	787.32	0.00	0.00	196.83	590.49	$978.43	0.00
5	0.00	850.31	0.00	0.00	212.58	637.73	$1616.16	0.00
End of run	Total Cash Flow (present value)				$1347.40			

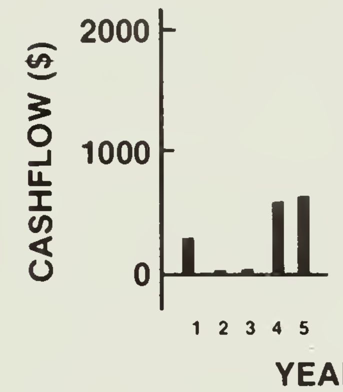


Fig. 4.9 Cash Flow Analysis: Propane Conversion of a Farm Pickup

EXAMPLE

Suppose that a vehicle presently uses 5000 L of gasoline per year at a price of 40¢/L, for annual gasoline cost of $2000. If propane is available at a local station for 25¢/L, calculate the economics of conversion.

Calculations. It takes 1.2 L of propane to supply the same energy content as 1.0 L of gasoline. However, most propane users report that it burns more efficiently than gasoline, producing an equivalence of 1.1 L of propane to 1.0 of gasoline.

Propane required = (5000 L x 1.1) = 5500 L/year
Cost of propane = (5500 L x $0.25/L) = $1375/year
Fuel savings (year 1) = ($2000 - $1375) = $625
Conversion cost = ($1600 - $400) = $1200

Simple Payback = (Investment/Year 1 Savings) = ($1200/$625) = 1.9 years

Cash Flow. Assume a 25% marginal tax rate, 8% fuel price escalation per year and money borrowed at 12.5% interest for three years. (Fig. 4.9)

Conclusion. For the assumed use and fuel prices propane conversion is an attractive option provided that refuelling is possible at a local station. It would not, however, justify investment in a farm storage and pump.

4.5 WHAT ABOUT CNG?

Many farmers in Canada use natural gas for heating, drying grain, and operating irrigation pumps. Could this abundant fuel also be used to power other farm equipment?

Compressed Natural Gas (CNG). CNG is natural gas stored in steel tanks at high pressure to provide a mobile fuel. It differs from propane in that CNG remains gaseous in storage. This limits the amount of fuel that can be stored on board a vehicle. It takes 4 litres of CNG to deliver the same energy as 1 litre of gasoline.

Engine Operation. Any gasoline engine will operate on natural gas, with only minor modifications to the carburetor. The obstacle to using natural gas as a *mobile* fuel, is to store enough gas on board to operate for a practical period of time between re-fillings.

Filling the CNG Cylinder. Cylinders can be filled by either of two methods:

1) A "Quick-Fill" system fills two 50-litre tanks in 2 to 3 minutes, from high pressure storage tanks, or a high-volume compressor.

2) A "Slow-Fill" system requires several hours to fill a cylinder with compressed gas, using a small compressor.

Costs Require High Usage. The filling systems are expensive ($40,000.+). This investment would not be justified on many farms, but may warrant investigation by rural natural gas co-operatives, which are common in some provinces. If enough farmers in the co-op agreed to convert their trucks to CNG, a central filling station may be economical. This obviously depends upon the price advantage of natural gas compared to other fuels. Table A-1 (Appendix A) shows that 1m^3 of natural gas contains 37.2 MJ of energy, compared to 34.7 MJ in 1 L of gasoline. If their efficiencies are equal, natural gas at 15¢/m^3 ($4.00/GJ) supplies energy at about one-third the cost of gasoline at 40¢/L ($11.53/GJ).

EXAMPLE

The following data was supplied by B.C. Hydro, as typical of fleet CNG conversion costs and savings in the Vancouver area.

25 Fleet Vehicles

Vehicle Conversion cost — 25 Vehicles @ $1,650.		= $41,250
Compressor (Installed Cost) 17 Vehicles using slow fill 8 Vehicles using fast fill		= $94,000.
		TOTAL COST = $132,250.
Motor Fuel Volume Per Year 25 Vehicles @ 5455 Litres		= 136,375 litres
Cost Comparison Gasoline Price		= 45.90¢/L
CNG (equivalent Energy)	= 11.85¢/L	
Electricity & repairs for compressor	= 3.30¢/L	
Total CNG Variable Cost	= 14.15¢/L	- 14.15¢/L
CNG advantage		= 30.75¢/L
Fuel Savings Using CNG (136,375 L x 30.75¢/L)		**= $41,935 Annually**

Economic Analysis
Loan term = 5 years . . . . Interest Rate = 10.5%

Year	Loan Payments	Net Savings
1	$ 35,300.	$ 6,635.
2	$ 35,300.	$ 6,635.
3	$ 35,300.	$ 6,635.
4	$ 35,300.	$ 6,635.
5	$ 35,300.	$ 6,635.
6	None	$41,935.

Fig. 4.10 Economics of CNG Conversion for a 25 Vehicle Fleet.

Conclusions

1) CNG offers significant savings for operators of fleet vehicles.

2) Most farmers would not consume enough fuel to justify the cost of a compressor.

3) Rural natural gas co-operatives could offer CNG to their members.

MORE INFORMATION:

1) **CNG Newsletter** — available from B.C. Hydro, Energy Use Engineering Dept, 625 Howe St., Vancouver, B.C. V6C 2T6.

2) **Using Compressed Natural Gas for Tractor Fuel.** Engineering Note 290.000-2. Available from B.C. Ministry of Agriculture and Food, Engineering Branch, Abbotsford, British Columbia. V2S 2C5.

3) **Canadian Alternative Fuels.** — Publication available from the Biomass Energy Institute, 1329 Niakwa Road, Winnipeg, Manitoba R2J 3T4.

4) **Energy Alternatives.** — A report by the Special Committee On Alternative Energy and Oil Substitution, Catalogue No. XC2-321/2-01E, available from Canadian Government Publishing Centre, Supply and Services Canada, Ottawa, Ontario. K1A 0S9 ($4.95)

4.6 TRUCKING — LEARNING FROM THE PRO'S

Professional truckers have achieved fuel savings of 25% or more. Some of their ideas may be useful to you if your farming involves any long-distance hauling.

Diesel Engines. Diesels have long been dominant in heavy trucks. Better fuel economy and longer engine life are the main reasons.

Drive Trains. Some truck dealers have access to computer simulation programs to help specify the most efficient drive train for your loads and driving conditions. Fuel economy is improved by careful selection of power, torque, transmission and rear axle ratios.

Turbo-Charging. A turbo-charged engine receives a greater flow of air by using the pressure of exhaust gases to compress intake air. This improves performance, reduces exhaust smoke, and decreases engine noise.

Thermostat Fan Drive. This device has several benefits. It stops the fan when it is not needed for cooling. This provides faster warmups, more even temperatures, less cab noise, and reduced power used to run the fan.

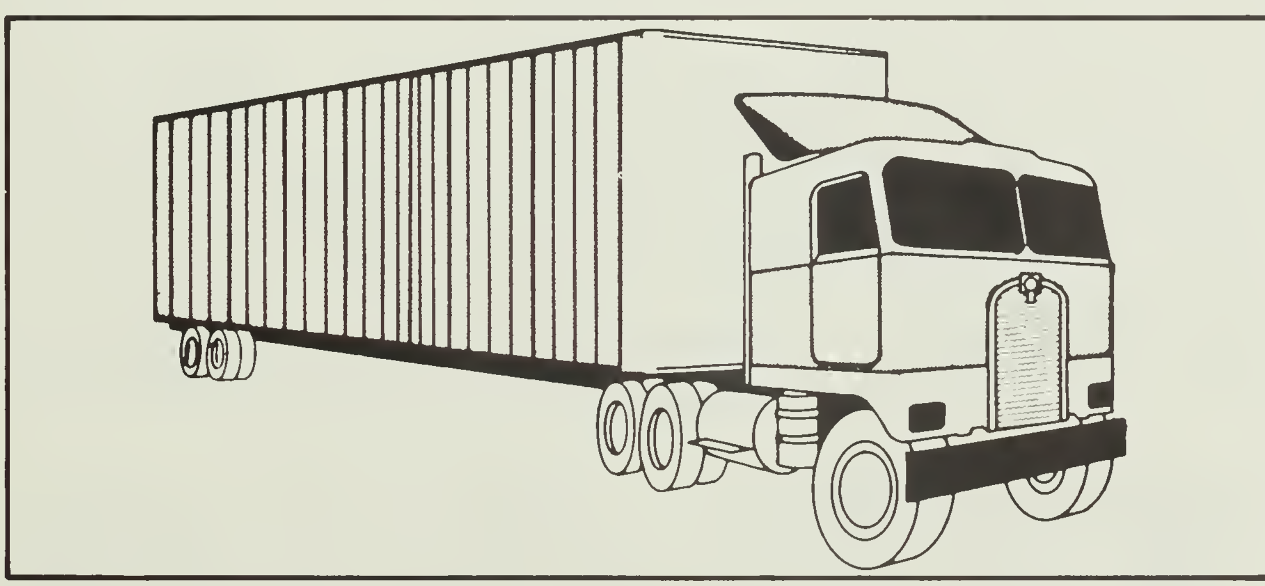
Radial Tires. Fuel savings with radial tires result from reduced rolling resistance. Reported improvements in efficiency range from 3% to 12%.

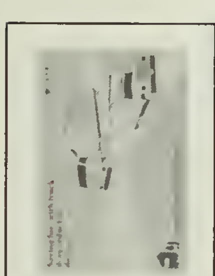
Air Deflectors. These devices are used to streamline the air flow around a truck. Typical fuel savings at highway speeds are in the range of 2.5 to 3.5 L/100 km. For a truck operating 100,000 km/year the deflector could save about 3000 L of fuel. At 40¢/L the annual savings = $1200, more than twice the cost of the deflector. (There are exceptions to the benefits of air deflectors. For example, on a tractor operated alone or with a flat deck the deflector actually increases fuel consumption.)

Speed. Fig. 4.12 shows recorded differences in operating costs for tractor-trailers at various speeds. Note that increasing speed from 90 km/h to 105 km/h added nearly $10,000 to the cost of fuel, tires and maintenance over 160,000 km of use.

Idling. An idling diesel truck engine consumes about 2 litres of fuel per hour. In addition to wasting fuel, excessive idling fouls injector nozzles, causes oil dilution and overcooling. Automatic shutoff devices are available to stop an idling engine after a 3 minute cooling down period.

Engine Temperature. Running an engine below the recommended temperature wastes fuel and increases wear. Operation at 65° C uses 4% more fuel than required at 85° C. Follow the manufacturer's recommendations for best engine temperature. Block heat-





MORE INFORMATION:

1) **Trucker's Guide To Energy Conservation.** Available from Canadian Trucking Association, 130 Albert Street, Ottawa, Ontario K1P 5G4.

2) **Spec'ing A Fuel-Efficient Truck.** Series of 8 booklets, available from Ontario Ministy of Transportation and Communication, 1201 Wilson Avenue, Downsview, Ontario M3M 1J8.

3) **Saving Fuel With Truck Drag Reduction Devices.** Available from Canadian Trucking Association, 130 Albert Street, Ottawa, Ontario K1P 5G4.

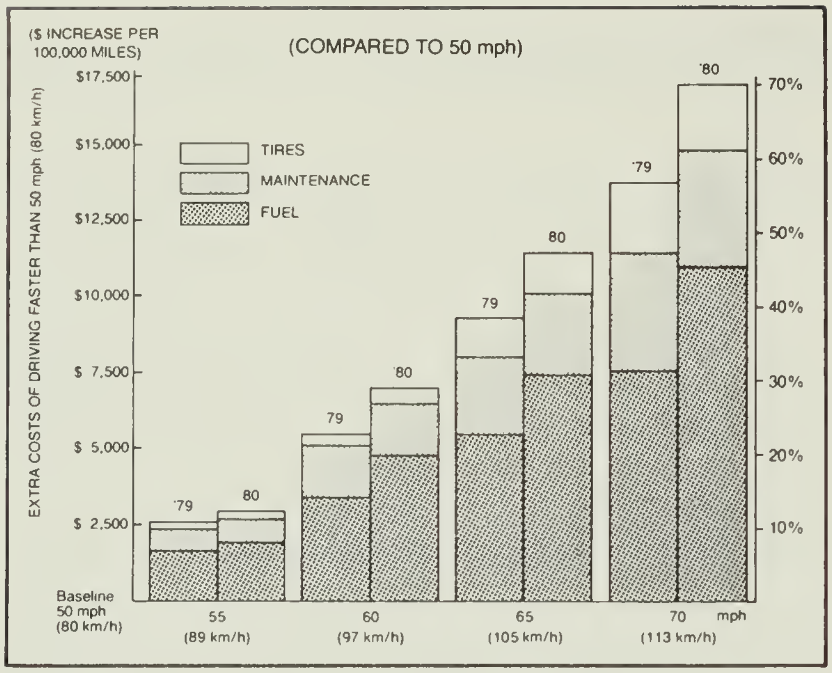


Fig. 4.12 How Trucking Costs Increase with Speed.

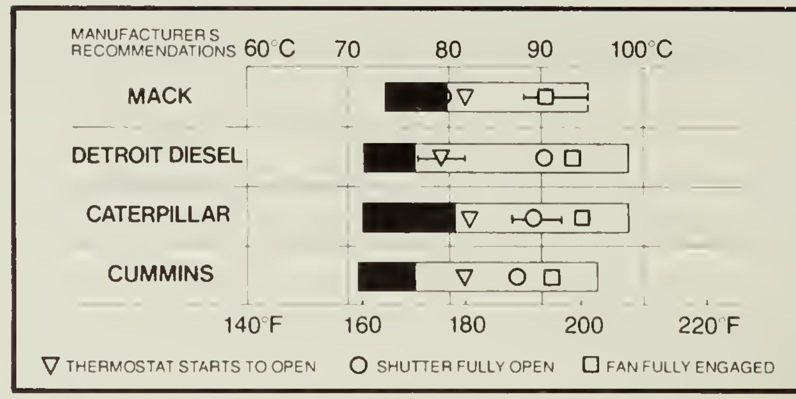


Fig. 4.13 Recommended Operating Temperatures

ers, shutters, fan clutch drives and radiator covers can all help to get an engine warmed up quickly. Check the thermostat and temperature gauge for accurate operation.

Oils. Synthetic motor oils have been shown to provide fuel efficiency gains of about 4%. They also reduce starting loads and warmup periods. Use multigrade oils designed for cold weather operation.

5 *Saving Energy and $ by* EQUIPMENT MANAGEMENT

A large portion of the fuel consumed on farms is used to operate field equipment. Even a small improvement in the efficiency of operation can save several hundreds of dollars in production costs. Following are some suggestions that apply to most farms.

Shop For Efficiency. Fuel consumption should be an important consideration when buying tractors and other powered equipment. Differences between makes and models can be very significant.

Maintain Equipment. Well-tuned engines and properly adjusted equipment use less fuel. Simple things like dirty air filters and incorrect tire pressure can waste a lot of fuel. Keep tillage tools and other cutting edges clean and sharp.

Control Slippage. Best tractive efficiency is achieved at 10 to 15% slippage. Adjust your speed, ballast and implement size to save fuel and time.

Match The Load. A tractor should be able to pull an implement at about 8 km/h. If the tractor cannot pull the machine faster than 6 km/h it is probably overloaded. High slippage and/or early powertrain failure can be expected. Wherever possible the tractor should be matched to the load and desired speed to utilize most of its power output. This will provide the most efficient engine operation.

Gear Up/Throttle Down. If a big tractor must be used for a light job, best engine efficiency can be obtained by the so-called "gear up/throttle down" technique. This means shifting to a higher gear and reducing the engine RPM. However, care must be taken to avoid overloading. Warning signals of engine overloading include black smoke, rising engine temperatures and poor throttle response.

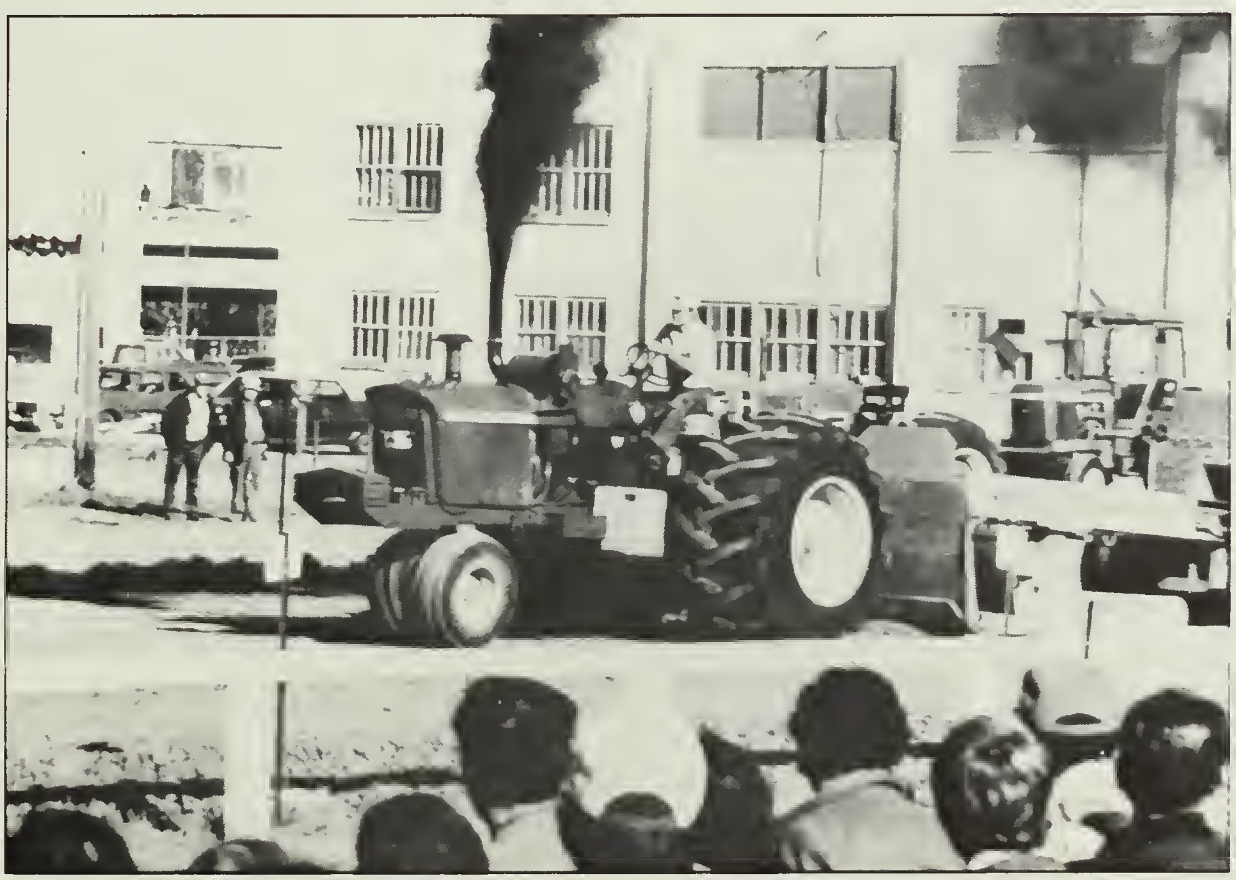
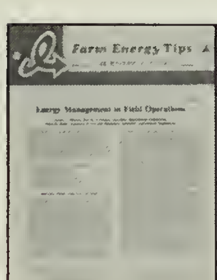


Fig. 5.1 Tractor Overloading can Result in Expensive Repair Bills.



MORE INFORMATION:

1) **Energy Management In Field Operations.** Factsheet CC277, available from Cooperative Extension Service, University of Nebraska, Lincoln, Nebraska 68583.

2) **Tractor Selection, Operation And Service For Minimum Fuel Consumption.** Factsheet No. 1211, available from Cooperative Extension Service, Oklahoma State University, Stillwater, Oklahoma 74078.

5.1 SAVING MONEY BY EQUIPMENT MAINTENANCE

Guidelines for good maintenance of farm equipment are usually well outlined in operator's manuals and manufacturer's literature. What are the effects on energy consumption if maintenance is neglected? Here are some estimations.

Gasoline Engine Tune-ups. Fuel efficiency of gasoline engines decreases significantly between tune-ups. In older engines, points and spark plugs should be replaced every 100 to 400 hours, depending upon duty cycle. Electronic ignition systems in newer engines have eliminated ignition points and increased spark plug life by supplying higher voltage.

Example: Consider a 5.7 L V-8 truck engine with normal fuel use of 14 L/100 km. If operated with one intermittently misfiring spark plug it could consume 10% more fuel.

Added fuel cost = (20,000 km/yr. x 1.4 L/100 km x \$0.40/L) = **\$112/yr.**

Diesel Engine Tune-ups. Check timing and injectors at recommended intervals.

Example: Assume a 134 kW (180 hp) tractor is operated for one year beyond the recommended tune-up interval and runs at a 7% loss in engine efficiency:

Added fuel cost = (600 h) (7/100) (36.3 L/h) (\$0.35/L) = **\$534/yr.**

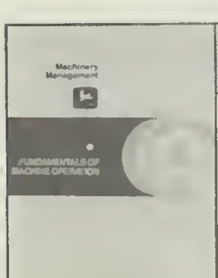
Engine Air Filters. A partially plugged air filter can increase fuel consumption by 15%.

Example: Consider a 134 kW (180 hp) tractor operated for one week with a plugged air filter:

Added fuel cost = (60 h x 36.3 L/h x 15/100 x \$0.35/L) = **\$114.**

Tillage Tools. Dirty and rusted plow-shares or cultivator shovels can increase draft by 25% until they are scoured by the soil. This could take up to 10 hours of operation at increased pull.

Added fuel cost = (10 h x 36.3 L/h x 25/100 x \$0.35/L) = **\$32.**



MORE INFORMATION:

1) **Fundamentals of Machine Operation.** Text available from John Deere Service Training, Department F, John Deere Road, Moline, Illinois 61265 (\$10.35 U.S.).

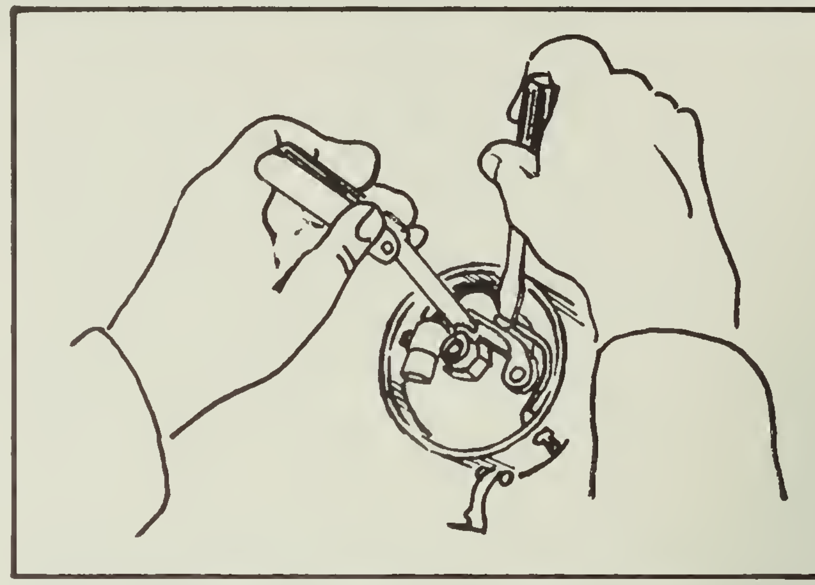


Fig. 5.2 Frequent Tune-ups Keep Gasoline Engines at Their Best Efficiency.

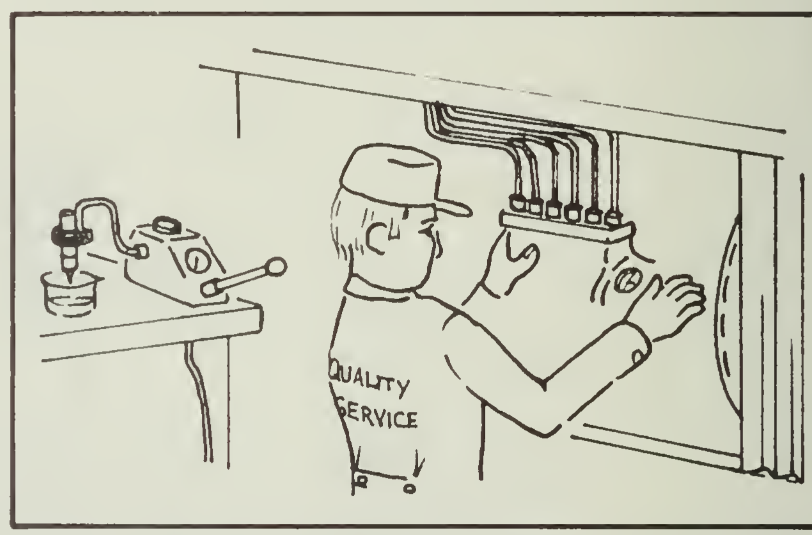


Fig. 5.3 Diesel Pump Timing and Injector Operation Should be Checked by a Qualified Mechanic.

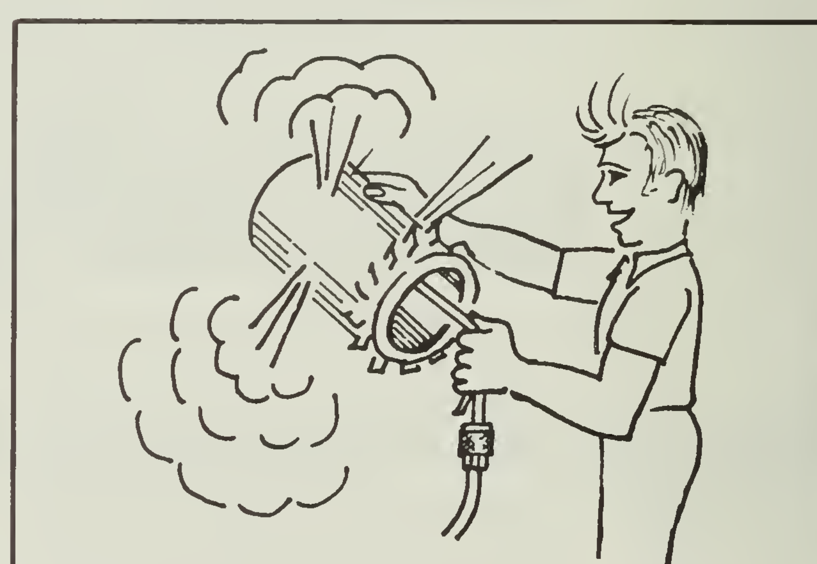


Fig. 5.4 Recommended Air Pressure Should be Used to Clean an Air Filter.

Cutting Tools. Dull cutting edges and excess knife clearance can increase power requirements by as much as 30%.

Example: Consider a forage harvester with dull knives and excess shear bar clearance:

Added fuel cost = (36.3 L/h x 30/100 x 10 h/day x $0.35/L) = **$38/day.**

Dull knives will also cause longer cutting lengths. The reduced density decreases the efficiency of hauling and packing operations.

Tire Pressures. Inflation pressures in car and truck tires are hard to judge by eye. It is quite possible to operate for long periods with low pressures, especially in radial tires.

Example: Operation of a vehicle for 20,000 km with tire pressures 20% below recommendations:

Added fuel cost = (20,000 km x 15L/100 x 10/100 x $0.40/L) = **$120.** Prolonged operation at low pressure will also cause sidewall damage and shorten tire life.

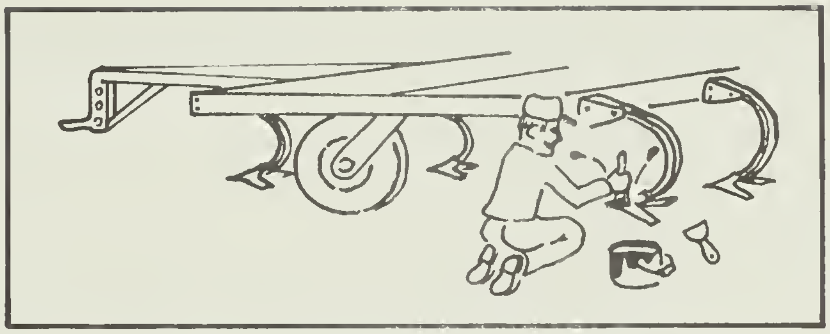


Fig. 5.5 Scraping and Oiling Will Prevent Shovels from Rusting Between Use Periods.

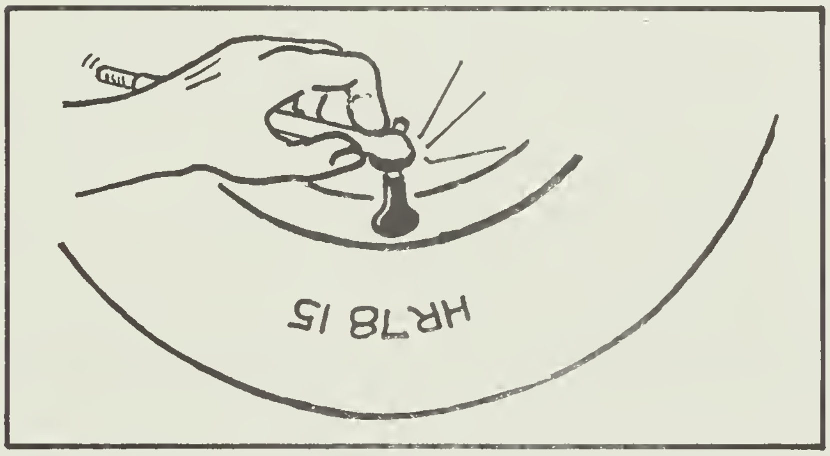


Fig. 5.6 Pressure Should be Checked When Tires are Cold.

5.2 COMPARING TRACTORS FOR ENERGY EFFICIENCY

The Nebraska Tests provide measurements of power output and fuel efficiency for most tractors sold in North America.

Here is an example of how to use the Nebraska Tests to predict the fuel costs for different tractors:

EXAMPLE

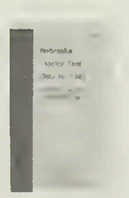
Compare expected annual fuel costs for a John Deere 4240 and a Deutz DX-120, assuming 600 hours of operation per year and diesel fuel at 35¢/L.

Calculations

Steps	John Deere 4240	Deutz DX-120
A. Multiply maximum PTO power (kW) by 0.55 (55% is the average long-term loading level for tractors).	(0.55 x 82.82 kW) = 45.55 kW	(0.55 x 82.99 kW) = 45.65 kW
B. Multiply by the annual hours of use.	(45.55 kW x 600h) = 27.330 kWh	(45.65 kW x 600h) = 27,390 kWh
C. Divide by the kWh/L output at 75% drawbar load	$\frac{(27{,}330 \text{ kWh})}{2.295 \text{ kWh/L}}$ = 11,909 L	$\frac{(27{,}390 \text{ kWh})}{2.655 \text{ kWh/L}}$ = 10,316 L
D. Multiply by fuel price	(11,909 L x $0.35/L) = $4168	(10,316 L x $0.35/L) = $3611

Conclusion For the specified operating conditions, the fuel savings with the more efficient tractor would be about $557 per year. If fuel prices increase at an annual rate of 8%, the savings in 5 years would total $3,268.

It is not suggested that tractors should be chosen solely on fuel efficiency. Maintenance costs and dealer service are still more important. However, as shown above, fuel costs should also be considered.



MORE INFORMATION:

1) **Nebraska Tractor Test Data.** Summary booklet published annually by University of Nebraska, Department of Agricultural Engineering, Lincoln, Nebraska 68583. ($1.00 U.S.)

2) **Interpret Nebraska Tests For Fuel Efficiency.** Factsheet available from Alberta Agriculture, Print Media Branch, Main Floor, 7000 - 113 Street, Edmonton, Alberta T6H 5T6.

3) **How To Use Nebraska Tests for Tractor Comparisons.** Handi-Fact #762.1, available from Saskatchewan Agriculture, Family Farm Improvement Branch, 3085 Albert Street, Regina, Saskatchewan S4S 0B1.

4) **Buying A Tractor: Compare And Save.** Factsheet No. 383, available from Cooperative Extension Service, Michigan State University, East Lansing, Michigan 48824.

5) **Tractor Fuel Economy.** Factsheet available from Cooperative Extension Services, Division of Agriculture, Oklahoma State University, Stillwater, Oklahoma 74078.

POWER TAKE-OFF PERFORMANCE

Power Hp (kW)	Crankshaft speed rpm	Fuel Consumption gal/hr (l/h)	lb/hp hr (kg/kW h)	Hp hr/gal (kW h/l)	Temperature °F (°C) Cooling medium	Air wet bulb	Air dry bulb	Barometer inch Hg (kPa)
MAXIMUM POWER AND FUEL CONSUMPTION								
Rated Engine Speed—Two Hours (PTO Speed—1011 rpm)								
111.06 (82.82)	2200	7.822 (29.608)	0.492 (0.299)	14.20 (2.797)	193 (89.3)	62 (16.7)	75 (23.9)	29.030 (98.030)
Standard Power Take-off Speed (1000 rpm)—One Hour								
111.43 (83.09)	2176	7.744 (29.315)	0.485 (0.295)	14.39 (2.834)	193 (89.4)	62 (16.7)	75 (23.9)	29.050 (98.097)
VARYING POWER AND FUEL CONSUMPTION—Two Hours								
97.40 (72.63)	2272	7.064 (26.740)	0.506 (0.308)	13.79 (2.716)	189 (87.2)	62 (16.7)	75 (23.9)	...
0.00 (0.00)	2365	2.685 (10.166)	...	...	178 (80.8)	62 (16.7)	75 (23.6)	...
49.98 (37.37)	2333	4.744 (17.956)	0.663 (0.403)	10.54 (2.076)	183 (83.6)	62 (16.7)	75 (23.9)	...
111.93 (83.47)	2200	7.824 (29.619)	0.488 (0.297)	14.31 (2.818)	193 (89.4)	62 (16.7)	76 (24.4)	...
25.20 (18.79)	2350	3.717 (14.069)	1.030 (0.626)	6.78 (1.336)	179 (81.4)	62 (16.7)	75 (23.9)	...
74.13 (55.28)	2305	5.848 (22.137)	0.551 (0.335)	12.68 (2.497)	186 (85.3)	62 (16.7)	75 (23.9)	...
Av 59.77 *Av (44.57)*	**2304**	**5.314** (20.114)	**0.621** (0.378)	**11.25** (2.216)	**184** (84.6)	**62** (16.7)	**75** (23.9)	**29.040** (98.064)

DRAWBAR PERFORMANCE

Power Hp (kW)	Drawbar pull lbs (kN)	Speed mph (km/h)	Crankshaft speed rpm	Slip %	Fuel Consumption gal/hr (l/h)	lb/hp hr (kg/kW h)	Hp hr/gal (kW h/l)	Temp. °F (°C) Cooling med	Air wet bulb	Air dry bulb	Barom inch Hg (kPa)
Maximum Available Power—Two Hours 4th Gear											
92.70 (69.12)	7692 (34.21)	4.52 (7.27)	2199	6.38	7.645 (28.938)	0.576 (0.350)	12.13 (2.389)	195 (90.6)	73 (22.5)	78 (25.3)	28.965 (97.810)
75% of Pull at Maximum Power—Ten Hours 4th Gear											
76.14 (56.77)	5961 (26.51)	4.79 (7.71)	2286	4.60	6.535 (24.738)	0.599 (0.365)	11.65 (2.295)	193 (89.2)	71 (21.4)	86 (29.8)	28.836 (97.375)
50% of Pull at Maximum Power—Two Hours 4th Gear											
52.79 (39.36)	4001 (17.80)	4.95 (7.96)	2323	3.09	5.210 (19.721)	0.689 (0.419)	10.13 (1.996)	185 (84.7)	73 (22.8)	79 (25.8)	28.940 (97.726)
50% of Pull at Reduced Engine Speed—Two Hours 6th Gear											
52.50 (39.15)	3982 (17.71)	4.94 (7.96)	1374	2.98	3.795 (14.367)	0.505 (0.307)	13.83 (2.725)	187 (86.1)	75 (23.6)	82 (27.5)	28.915 (97.642)
MAXIMUM POWER IN SELECTED GEARS											
70.93 (52.89)	12450 (55.38)	2.14 (3.44)	2298	14.77	2nd Gear			185 (84.7)	64 (17.8)	70 (21.1)	28.890 (97.557)
93.57 (69.78)	10365 (46.11)	3.39 (5.45)	2200	9.29	3rd Gear			193 (89.2)	68 (20.0)	72 (22.2)	28.980 (97.861)
95.65 (71.33)	7947 (35.35)	4.51 (7.26)	2197	6.48	4th Gear			193 (89.4)	67 (17.4)	70 (21.1)	28.980 (97.861)
93.89 (70.01)	5854 (26.04)	6.01 (9.68)	2200	4.58	5th Gear			193 (89.4)	69 (20.6)	73 (22.8)	28.980 (97.861)
93.79 (69.94)	4464 (19.86)	7.88 (12.68)	2200	3.35	6th Gear			194 (90.0)	71 (21.7)	75 (23.9)	28.980 (97.861)

LUGGING ABILITY IN 4th GEAR

Crankshaft Speed rpm	2197	1981	1757	1541	1317	1095
Pull—lbs (kN)	7947 (35.35)	8694 (38.67)	9252 (41.16)	9304 (41.39)	9331 (41.51)	9258 (41.18)
Increase in Pull %	0	9	16	17	17	16
Power—Hp (kW)	95.65 (71.33)	93.57 (69.77)	87.72 (65.41)	77.28 (57.62)	66.17 (49.34)	54.61 (40.72)
Speed—Mph (km/h)	4.51 (7.26)	4.04 (6.50)	3.56 (5.72)	3.11 (5.01)	2.66 (4.28)	2.21 (3.56)
Slip %	6.48	7.23	7.77	8.04	8.17	8.04

POWER TAKE-OFF PERFORMANCE

Power Hp (kW)	Crankshaft speed rpm	Fuel Consumption gal/hr (l/h)	lb/hp hr (kg/kW h)	Hp hr/gal (kW h/l)	Temperature °F (°C) Cooling medium	Air wet bulb	Air dry bulb	Barometer inch Hg (kPa)
MAXIMUM POWER AND FUEL CONSUMPTION								
Rated Engine Speed—Two Hours (PTO Speed—1158 rpm)								
111.29 (82.99)	2400	6.901 (26.123)	0.435 (0.264)	16.13 (3.177)	air cooled	59 (15.0)	75 (24.1)	29.160 (98.469)
Standard Power Take-off Speed (1000 rpm)—One Hour								
101.90 (75.99)	2072	6.214 (23.523)	0.427 (0.260)	16.40 (3.230)	air cooled	60 (15.4)	76 (24.3)	29.110 (98.300)
VARYING POWER AND FUEL CONSUMPTION—Two Hours								
97.10 (72.41)	2463	5.946 (22.508)	0.429 (0.261)	16.33 (3.217)	air cooled	60 (15.6)	76 (24.4)	...
0.00 (0.00)	2604	1.708 (6.465)	...	...	air cooled	60 (15.6)	76 (24.4)	...
49.85 (37.17)	2538	3.741 (14.161)	0.526 (0.320)	13.33 (2.625)	air cooled	60 (15.6)	76 (24.4)	...
111.94 (83.47)	2399	6.978 (26.415)	0.437 (0.266)	16.04 (3.160)	air cooled	60 (15.6)	76 (24.4)	...
25.45 (18.98)	2576	2.727 (10.323)	0.751 (0.457)	9.33 (1.839)	air cooled	60 (15.3)	75 (23.6)	...
73.98 (55.17)	2504	4.786 (18.117)	0.453 (0.276)	15.46 (3.045)	air cooled	59 (15.0)	74 (23.3)	...
Av 59.72 *Av (44.53)*	**2514**	**4.314** (16.330)	**0.506** (0.308)	**13.84** (2.727)	**air cooled**	**60** (15.4)	**75** (24.1)	**29.077** (98.188)

DRAWBAR PERFORMANCE

Power Hp (kW)	Drawbar pull lbs (kN)	Speed mph (km/h)	Crankshaft speed rpm	Slip %	Fuel Consumption gal/hr (l/h)	lb/hp hr (kg/kW h)	Hp hr/gal (kW h/l)	Temp. °F (°C) Cooling med	Air wet bulb	Air dry bulb	Barom inch Hg (kPa)
Maximum Available Power—Two Hours 9th (1H) Gear											
92.86 (69.25)	5787 (25.74)	6.02 (9.68)	2399	4.82	6.831 (25.860)	0.516 (0.314)	13.59 (2.678)	air cooled	62 (16.7)	78 (25.3)	28.820 (97.321)
75% of Pull at Maximum Power—Ten Hours 9th (1H) Gear											
76.40 (56.97)	4504 (20.03)	6.36 (10.24)	2507	3.70	5.669 (21.458)	0.520 (0.316)	13.48 (2.655)	air cooled	51 (10.3)	62 (16.7)	29.009 (97.959)
50% of Pull at Maximum Power—Two Hours 9th (1H) Gear											
52.59 (39.21)	3010 (13.39)	6.55 (10.54)	2548	2.49	4.370 (16.542)	0.582 (0.354)	12.03 (2.371)	air cooled	62 (16.7)	79 (26.1)	28.820 (97.321)
50% of Pull at Reduced Engine Speed—Two Hours 13th (3H) Gear											
52.28 (38.98)	2999 (13.34)	6.54 (10.52)	1459	2.69	3.478 (13.166)	0.466 (0.284)	15.03 (2.961)	air cooled	62 (16.4)	67 (19.4)	28.990 (97.895)
MAXIMUM POWER IN SELECTED GEARS											
87.95 (65.59)	12615 (56.12)	2.61 (4.21)	2448	14.98	4th (1M) Gear			air cooled	55 (12.8)	58 (14.4)	28.970 (97.827)
94.27 (70.30)	10405 (46.28)	3.40 (5.47)	2400	9.78	5th (4L) Gear			air cooled	61 (16.1)	71 (21.7)	28.810 (97.287)
94.94 (70.80)	8985 (39.97)	3.96 (6.38)	2400	7.83	6th (2M) Gear			air cooled	60 (15.6)	70 (21.1)	28.810 (97.287)
94.42 (70.41)	8229 (36.60)	4.30 (6.93)	2399	6.97	7th (5L) Gear			air cooled	59 (15.0)	69 (20.6)	28.810 (97.287)
95.93 (71.54)	7260 (32.29)	4.96 (7.97)	2400	5.94	8th (3M) Gear			air cooled	58 (14.4)	68 (20.0)	28.800 (97.253)
96.29 (71.80)	6003 (26.70)	6.01 (9.68)	2399	4.89	9th (1H) Gear			air cooled	57 (13.9)	66 (18.9)	28.800 (97.253)
97.41 (72.64)	4990 (22.20)	7.32 (11.78)	2398	3.98	10th (4M) Gear			air cooled	62 (16.7)	72 (22.2)	28.820 (97.321)
94.62 (70.56)	4077 (18.14)	8.70 (14.01)	2399	3.36	11th (2H) Gear			air cooled	62 (16.7)	73 (22.8)	28.820 (97.321)

John Deere 4240 Power Shift Diesel

Deutz DX-120 Diesel

Fig. 5.7 Nebraska Test Comparison

5.3 TRACTOR OPTIONS AFFECTING FUEL CONSUMPTION

Modern tractors offer a variety of options which affect performance and fuel efficiency.

Turbocharging. This increases the air supply to an engine, producing greater power output and more efficient combustion of fuel. A turbocharger also assists the engine in responding to overloads by increasing the torque reserve. The engine and transmission should be designed to handle the extra power.

Intercooling (Aftercooling) Engine coolant is passed through a heat exchanger to cool the intake air after compression and heating by turbocharging. This increases the air density and develops extra power from a given size of engine.

Torque Rise. New engine designs attempt to improve lugging ability to reduce shifting the transmission during overload. The fuel efficiency may drop during overload operations. Continuous lugging may damage the engine.

Power-Shift Transmissions. Power-shift planetary transmissions have been available in agricultural tractors for over 20 years and have steadily gained in popularity. Early models of power-shift transmissions reduced fuel efficiency by 5% to 10%. Newer models have become more efficient, nearly matching the manual shift transmissions. With this improved efficiency the power shift transmission is capable of producing greater field efficiencies by permitting desired changes in ground speed without stopping the tractor to shift gears.

Hydrostatic Transmissions. The infinite range in speeds supplied by a hydrostatic transmission must be weighed against a 15% to 20% loss in efficiency, compared to a gear-type transmission.

Radial Tires. Reported improvements in fuel efficiency due to radial tires vary from 5% to 20%, depending upon soil conditions, ballasting, speed, etc.

4-Wheel Drive. When properly ballasted, a 4WD tractor may achieve 5% to 10% higher tractive efficiency than a 2WD. Increased tractive efficiency reduces fuel consumption and increases field work rates. A front wheel drive (FWD) assist option is gaining popularity. Fuel savings alone will seldom justify the extra capital cost of 4WD or FWD. Other benefits may justify the extra investment, particularly the better capabilities in wet soil conditions and hilly topography.

Air Conditioners. Generally considered essential for control of heat and dust in tractor cabs, air conditioners are standard equipment on most new tractors. Fuel savings are possible by reducing their use because they draw up to 15 kW of power. Future options may include evaporative cab coolers, which take much less power.

Monitors. Watch for on-going developments of tractor monitors to provide useful data for improvement of tractor efficiency (% slippage, drawbar pull, ground speed, fuel use, etc.) Problems of durability and accuracy must be overcome.

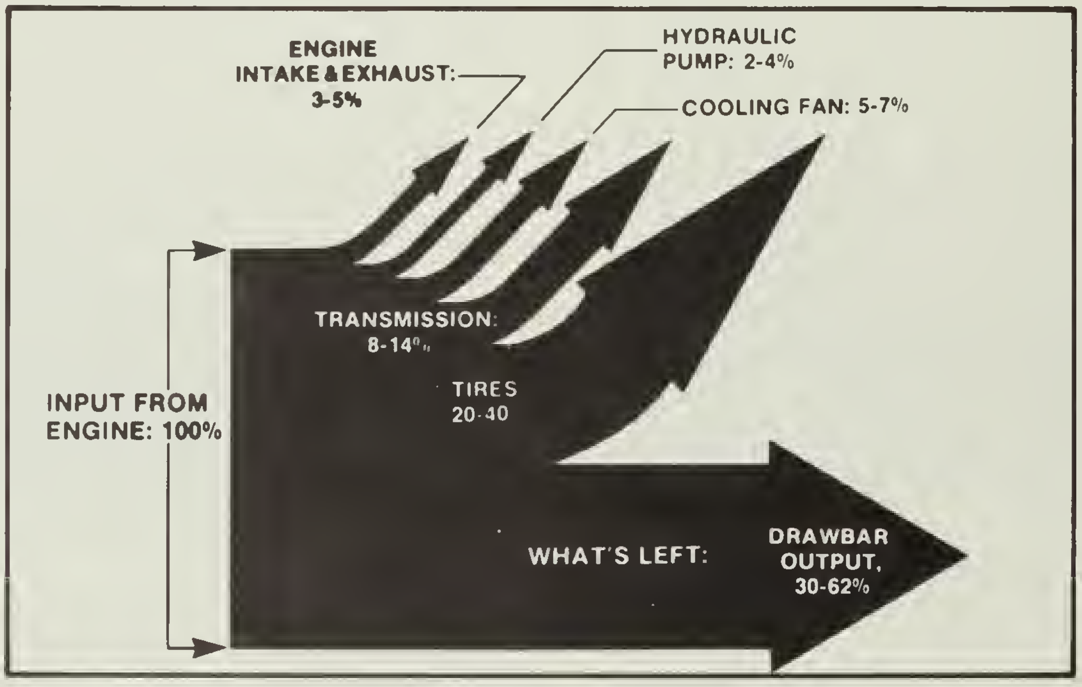


Fig. 5.8 Typical Tractor Power Losses: Engine To Drawbar
(Source: Grain Grower, June 1983)

5.4 CONTROLLING SLIPPAGE

Some slippage is necessary to create traction and protect the transmission when pulling a load. The goal of proper ballasting is to achieve the right amount of slippage for the given load and soil conditions. Fig. 5.9 shows typical tractive efficiencies for 2 WD tractors operated on various types of surfaces. Note that the best efficiency for tilled soil requires 10 to 15% slippage. The curves also show that overballasting to keep slippage below 8% will actually decrease the tractive efficiency very sharply due to the higher rolling resistance.

The examples on the following page show that either too much or too little slippage can waste fuel and money.

How To Measure Slippage

1) Mark one rear tire so you can easily count the revolutions.
2) Walk beside the tractor while it is pulling field equipment at the selected speed and tillage depth.
3) Measure the distance covered in 10 wheel revolutions.
4) Raise or unhook the implement and again travel 10 revolutions. Measure the distance.
5) Calculate the slippage by:

   % slippage = [(No load distance - loaded distance)/No load distance)] x 100

   Example: Loaded distance travelled in 10 revolutions = 40 m.
   Unloaded distance travelled in 10 revolutions = 50 m.

   % slippage = [(50 - 40)/50)] x 100 = 20%

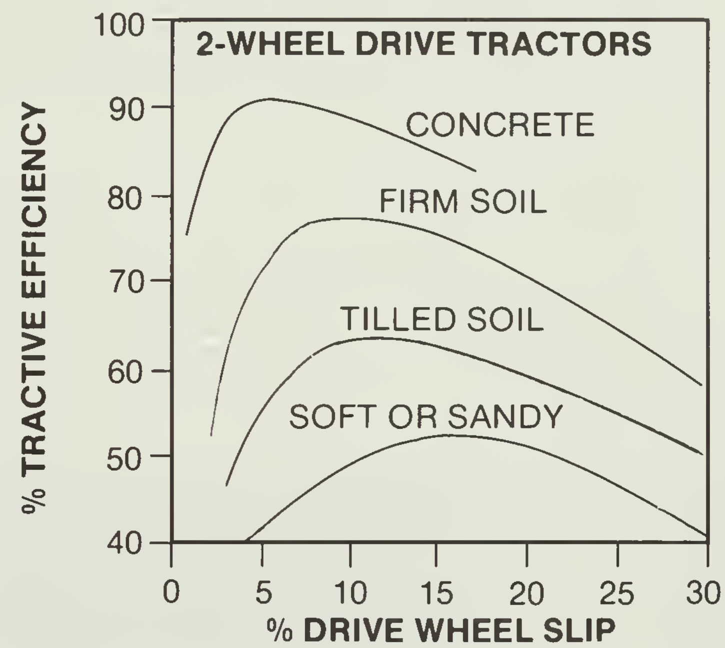
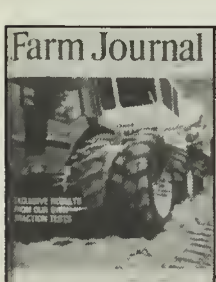


Fig. 5.9 Tractive Efficiency on Different Surfaces and with Different Percentage of Drive Wheel Slip

Fig. 5.10 Measuring Slippage

Fig. 5.11 Reading Tire Tracks



MORE INFORMATION:

1) **Wheel Slip Is Stealing Your Time And Your Fuel.** Article in Farm Journal, November, 1982.
2) **Tractor Traction.** Handi-Fact, available from Saskatchewan Agriculture, 3085 Albert Street, Regina, Saskatchewan S4S 0B1.

EXAMPLE

1) **Slippage Too High.** Consider a 112 kW (150 HP) tractor operated 500 hours per year on high draft loads in firm soils with 20% slippage versus recommended slippage of 10%. This could be caused by insufficient ballasting or by a load too large for the tractor.

Losses		Cost/Yr.
1. Time wasted = (10% x 500 hours) = 50 hours. At $8.00/h, cost = ($8.00/h x 50 h)	=	$400
2. Fuel wasted = (50 h x 35 L/h) = 1550 L/yr. At 35¢/L, cost = ($0.35/L x 1750 L)	=	$613
3. Increased tire wear (estimated 30 to 40%)	=	$100
TOTAL	=	$1,113

2) **Slippage Too Low.** Consider the same tractor but with 5% slippage. This occurs due either to underloading or to excessive ballasting. As shown in Fig. 5.9 overballasting decreases tractive efficiency. Each 1% decrease may require 1 L/h of extra fuel.

Losses		Cost/Yr.
1. Fuel wasted = (5 L/h x 500 h) = 2500 L/yr. At 35¢/L, cost = ($0.35/L x 2500 L)	=	$875
2. Overballasting will shorten the life of the driveline components, resulting in premature repair costs of several thousand dollars.		
3. Excessive soil compaction due to an overweighted tractor can reduce crop yields and increase the power needed for tillage.		

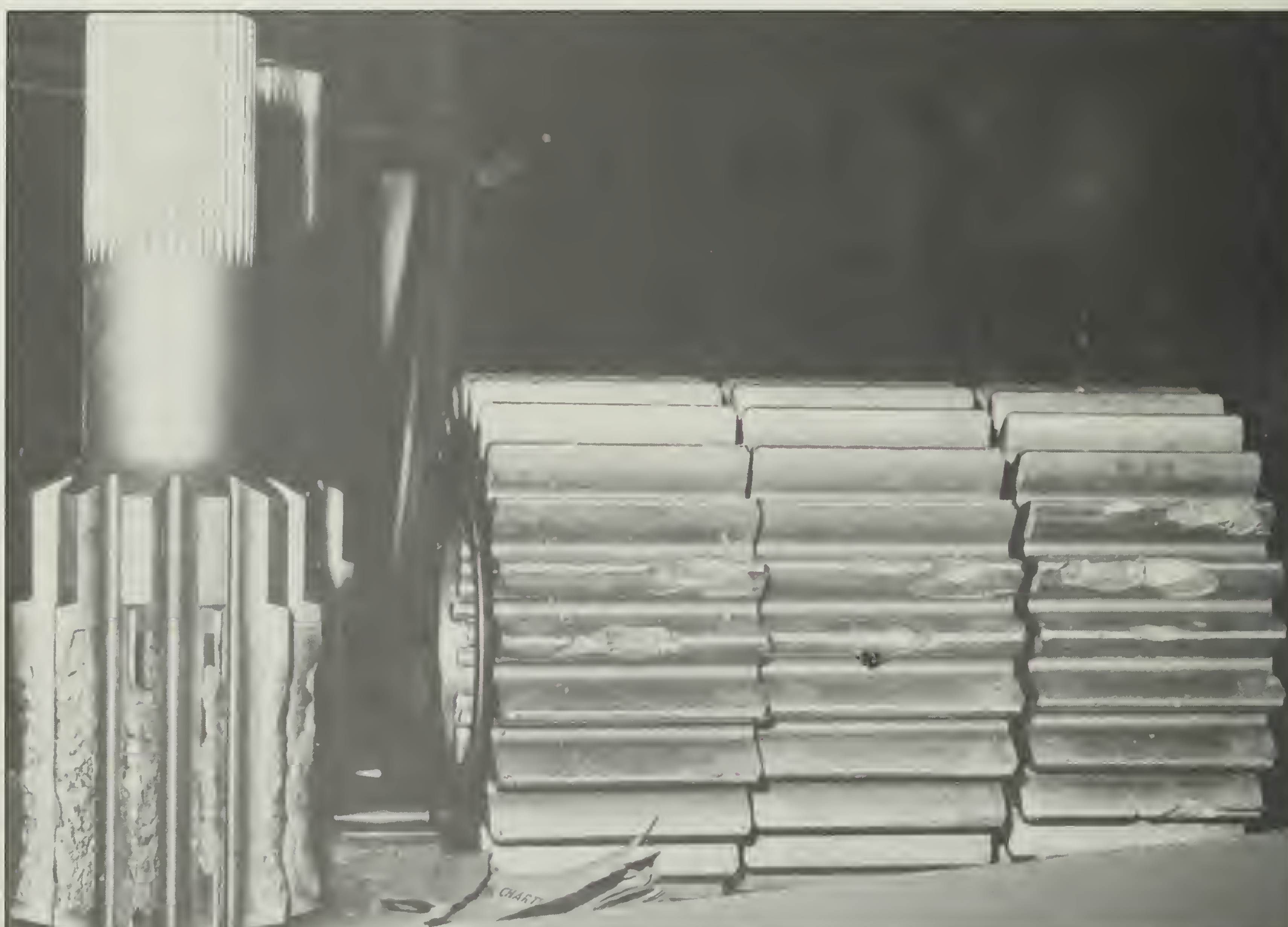


Fig. 5.12 Overballasting Causes Expensive Driveline Failures.

5.5 BALLASTING FOR PEAK EFFICIENCY

The objective of ballasting is to add just enough weight to achieve the 10-15% slippage that gives you maximum drawbar power. The total tractor weight needed varies with operating speed. New tractors are designed to operate at higher speeds with less weight. Most manufacturers recommend ballasting for a minimum speed of 8 km/h.

The following weight recommendations are based on a review of Nebraska Tests, extension bulletins and manufacturers' literature.

Indicated Speed km/h	Recommended Total Tractor Weight kg/PTO kW
8	80
10	65
12	55

Fig. 5.13 Recommended Total Weight For 2WD and 4WD Tractors.

To develop traction most of the tractor weight must be on the drive wheels. Fig. 5.14 shows typical recommendations for weight distribution. This can be checked by separately weighing the front and rear of the tractor.

	Rear Wheels	Front Wheels
2WD		
For towed implements	75%	25%
For semi-mounted implements	70%	30%
For mounted implements	65%	35%
With front wheel drive assist	60%	40%
4WD		
For towed implements	45%	55%
For mounted implements	40%	60%

Fig. 5.14 Recommended Weight Distribution.

These recommendations should produce approximately 10 to 15% slippage under most soil conditions. A slippage test should be made in the field to check the results and make the final adjustments in ballasting. (Also check that the ballasted tractor weight does not exceed the maximum load on the tires. On large tractors dual wheels may be required to carry the added weight.) Be sure to check maximum allowable weights as specified by tractor and tire manufacturers.

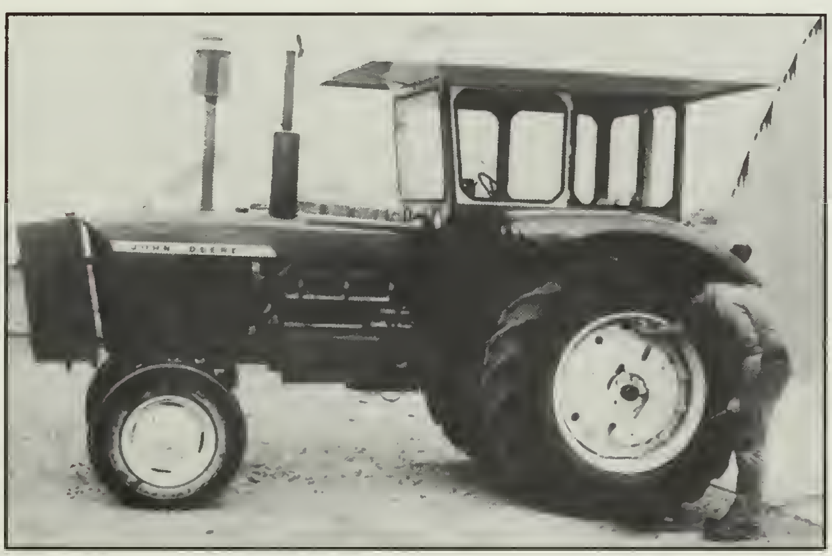


Fig. 5.15 Wheel Weights and Tire Fluid are Used For Tractor Ballasting.

MORE INFORMATION:

1) **Ballasting Slide Rule.** Available from John Deere Ltd., P.O. Box 1000, Grimsby, Ontario L3M 4H5 ($3.00).

2) **Farm Traction.** Bulletin available from Manitoba Agriculture, Technical Services Branch, 911 - 401 York Avenue, Winnipeg, Manitoba R3C 0V8.

3) **Tractor Ballasting.** Factsheet CC 278, available from The Cooperative Extension Service, Institute of Agriculture and Natural Resources, University of Nebraska, Lincoln, Nebraska 68583.

4) **Wheel Slip And Proper Tractor Weight For Maximum Efficiency.** Factsheet No. 364, available from Cooperative Extension Service, Michigan State University, East Lansing, Michigan 48824.

5) **Tractor Ballasting to Save Fuel.** Factsheet No. Pm-852, available from Cooperative Extension Service, Iowa State University, Ames, Iowa 50011.

6) **Tractor Weight Versus Performance.** Article in Grainews magazine, February, 1983.

5.6 MATCHING EQUIPMENT

Tractor power required for tillage operations varies widely with soil texture, moisture, depth, speed and cutting tool. Fig. 5.17 shows some typical values of power requirements for common soils and equipment.

Most farmers match equipment largely by trial and error, relying on previous experience with the soils in their district. The following guidelines may also be useful:

1) Match the high draft implements, such as plows and cultivators. Lighter loads can then be handled by the "gear up-throttle down" technique (see section 5.7).

2) Beware of slow speeds. A common mistake is to select an implement that the tractor can only pull at 4-5 km/h. Modern tractors are simply not built to continually handle the high torques developed at slow speeds. While slippage may be controlled by overballasting, early driveline failure can be expected.

3) The percentage of engine power actually delivered to the drawbar is greatly affected by the soil conditions (see Fig. 5.16).

4) Have some reserve power for hills and wet spots. A 20% slope will commonly require 40% more power than level ground.

5) Compare your conclusions with other farmers, implement dealers and machinery specialists familiar with the area.

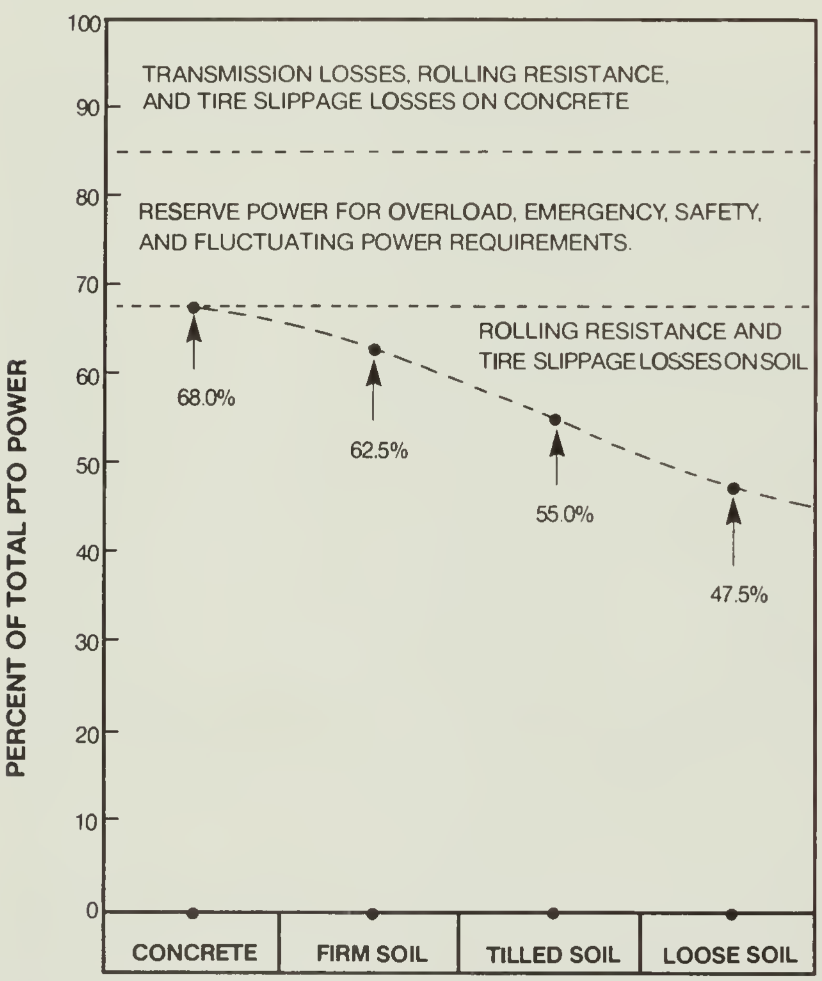
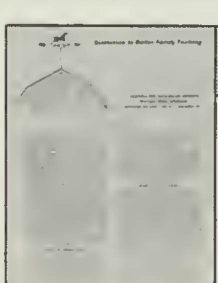


Fig. 5.16 Net Drawbar Power Available For Use at the Tractor Drawbar on Four Surface Conditions *(Reference 1)*

Operation	Typical Speed, km/h	Drawbar Kilowatt per Metre of Width
PLOWING (20 cm DEEP)		
Gumbo	6.4	32.5
Clay	6.4	27.3
Loam	7.2	27.8
Sandy Loam	8.0	22.7
Sand	8.0	11.5
CHISEL PLOWING (20 cm DEEP)		
Hard, Dry	6.4	20.7
Medium Clay Loam, Good Moisture	8.0	16.3
Sandy, Sandy Loam	9.7	7.8
FIELD CULTIVATOR		
Heavy Clay Soils or Dry and Hard Conditions	6.4	16.8
Clay Loam	8.0	14.6
Sandy Loam	8.0	9.8
Sand	9.7	5.9
TANDEM DISK HARROW		
Heavy Draft	6.4	7.8
Medium Draft	8.0	6.6
Light Draft	9.7	3.9
OFFSET OR HEAVY TANDEM DISK		
Heavy Draft	6.4	10.5
Medium Draft	8.0	10.5
Light Draft	9.7	9.8
ONE-WAY DISK		
Heavy Draft	6.4	10.5
Medium Draft	8.0	9.8
Light Draft	9.7	7.8

Fig. 5.17 Power Requirements for Tillage Operations.



MORE INFORMATION:

1) **Matching Tractor Horsepower And Farm Implement Size.** Extension bulletin E-1152, available from Cooperative Extension Service, Michigan State University, East Lansing, Michigan 48824.

2) **Deere's Dyna-Cart: Toward More Efficient Tractors.** Article in Implement & Tractor, March, 1982.

3) **Matching Tillage Implements To Tractors.** Factsheet available from Cooperative Extension Services, Oklahoma State University, Stillwater, Oklahoma 74078.

EXAMPLE

Deere & Company has developed a mobile dynamometer which measures tractor performance in the field. Here is an example of a test which demonstrated the effect of trying to pull an implement too large for the tractor.

Dyna-Cart Test Results

One of 13 tests demonstrated that the use of too large an implement resulted in a 35% reduction in productivity (hectares per hour), and a 23% loss of efficiency (hectares per litre) using a 8.2 metre disk on a model 4440 tractor, compared with using a 5.8 metre disk on the same tractor. The tests were conducted using the same pre-programmed field conditions in the Dyna-Cart's computer.

Tractor: Deere 4440

Type of Test:	**Using Too Large an Implement**	
Implement	**5.8 Metre Disk**	**8.2 Metre Disk**
Slip (%)	16.8	28.7
ha/h	5.2	3.9
ha/L	0.15	0.12
L/h	35.4	32.5
Power (kW)	64.0	47.7
Pull (kN)	24.7	30.0
Speed (km/h)	9.4	5.8
Engine rpm	2156	2324
Gear	C-2	B-1

Cost. The use of too large an implement, as in this example, could incur the following costs in one year, assuming that the necessary tillage could be done in 200 hours of operation with the smaller implement.

	Losses		**Cost/Yr.**
1.	Time wasted = 68 hrs. @ $8.00/h	=	$544
2.	Fuel wasted = 1641 L @ 35¢/L	=	$574
3.	Increased tire wear (estimated)	=	$50
	TOTAL	=	$1,168

5.7 GEARING UP AND THROTTLING DOWN

Running a big tractor at full engine speed (RPM) on a light load wastes fuel. For light drawbar loads fuel efficiency can be improved by shifting to a higher gear and reducing the engine speed. The amount of fuel saved by throttling back varies between tractors and can be estimated from Nebraska Tests (see example). Some diesel engines even run more efficiently at 50% load and reduced RPM than at 100% load and full engine speed.

Don't Lug The Engine. It is generally safe to reduce engine RPM by 20 to 30% below rated RPM. To make sure you are not overloading the engine check the response when you rapidly open the throttle. If the engine readily picks up speed it is not overloaded at that gear and throttle setting.

No Good For PTO Work. Most PTO equipment is designed for rated engine RPM. Poor performance may result if the engine speed is reduced.

Maximum Power, Percentage	Total Time, Percentage
Over 80%	16.8%
60-80%	23.9%
40-60%	22.6%
20-40%	17.5%
Under 20%	19.2%

(Agricultural Engineering Dept., University of Illinois)

Fig. 5.18 Percentage of Time Tractors Operate at Selected Levels of Power

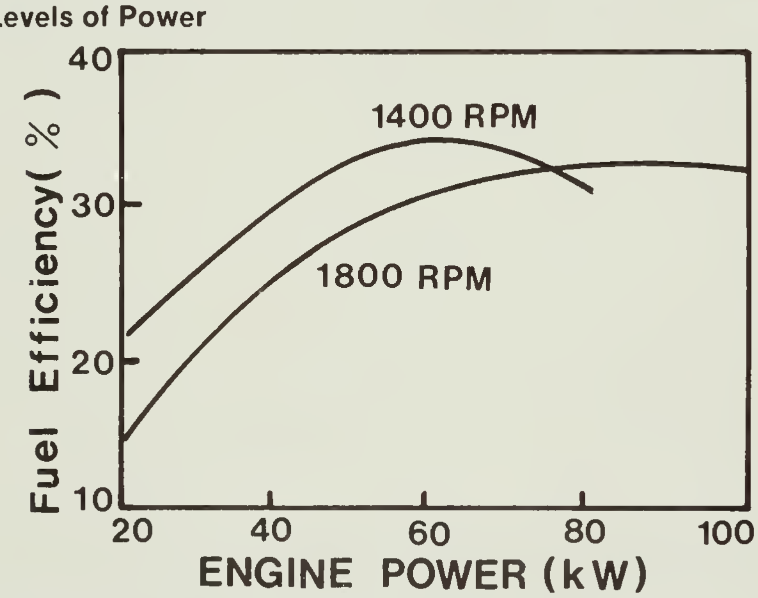


Fig. 5.19 A Higher Gear and Lower RPM Saves Fuel on Light Loads.

EXAMPLE

Consider a John Deere 4850. From Nebraska Test data we see that the fuel consumption at 2287 RPM and 50% load was 27.595 L/h when operated at 10.57 km/h in 10th gear. The same power and speed were achieved by shifting up to 13th gear and throttling back to 1434 RPM. Fuel consumption dropped to 22.171 L/h, a saving of 5.42 L/h.

Assume fuel costs 35¢/L and this tractor is used on light loads for 100 hours per year. The potential saving simply by shifting gears and adjusting the throttle is: (5.42 L/h x $0.35/L x 100 h) = **$189.70/year.**

NEBRASKA TRACTOR TEST 1461
JOHN DEERE 4850 POWERSHIFT DIESEL
15 SPEED

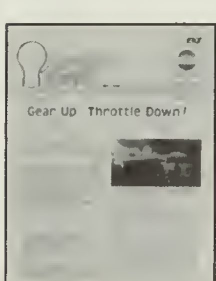
POWER TAKE-OFF PERFORMANCE

Power Hp (kW)	Crank shaft speed rpm	Fuel Consumption gal/hr (L/h)	lb/hp.hr (kg/kW.h)	Hp.hr/gal (kW.h/L)	Temperature °F (°C) Cooling medium	Air wet bulb	Air dry bulb	Barometer inch Hg (kPa)
MAXIMUM POWER AND FUEL CONSUMPTION								
Rated Engine Speed—Two Hours (PTO Speed—998 rpm)								
192.99	2200	11.046	0.390	17.47	194	59	75	29.224
(143.91)		(41.814)	(0.243)	(3.442)	(90.0)	(15.1)	(23.[illegible])	(98.681)
VARYING POWER AND FUEL CONSUMPTION—Two Hours								
166.58	2233	9.843	0.411	16.86	188	58	72	
(124.22)		(37.[illegible])	(0.252)	(3.320)	(86.[illegible])	(14.2)	(21.9)	
0.00	2333	2.579			172	57	71	
(0.00)		(9.763)			(77.[illegible])	(13.9)	(21.[illegible])	
85.19	2288	6.211	0.509	13.71	183	60	71	
(63.52)		(23.511)	(0.310)	(2.702)	(83.9)	(15.3)	(21.6)	
191.94	2199	11.039	0.401	17.39	196	60	76	
(143.13)		(41.[illegible])	(0.244)	(3.425)	(91.1)	(15.8)	(24.4)	
43.00	2302	4.518	0.733	9.52	176	62	76	
(32.07)		(17.102)	(0.446)	(1.875)	(80.3)	(16.4)	(24.2)	
126.56	2263	8.068	0.445	15.69	185	60	74	
(94.38)		(30.541)	(0.271)	(3.090)	(85.0)	(15.3)	(23.1)	
Av 102.21	**2270**	**7.050**	**0.481**	**14.50**	**183**	**59**	**74**	**29.240**
Av (76.22)		**(26.687)**	**(0.293)**	**(2.856)**	**(84.1)**	**(15.2)**	**(23.2)**	**(98.739)**

DRAWBAR PERFORMANCE WITH BIAS PLY TIRES

Power Hp (kW)	Drawbar pull lbs (kN)	Speed mph (km/h)	Crank shaft speed rpm	Slip %	Fuel Consumption gal/hr (L/h)	lb/hp.hr (kg/kW.h)	Hp.hr/gal (kW.h/L)	Temp °F (°C) Cooling med	Air wet bulb	Air dry bulb	Barom inch Hg (kPa)
Maximum Available Power—Two Hours 10th Gear											
162.53	9875	6.17	2199	4.54	11.069	0.475	14.68	188	49	56	28.690
(121.20)	(43.92)	(9.93)			(41.900)	(0.289)	(2.892)	(86.[illegible])	(9.4)	(13.3)	(96.882)
75% of Pull at Maximum Power—Ten Hours 10th Gear											
127.90	7496	6.40	2249	3.31	9.267	0.506	13.80	183	49	58	28.762
(95.37)	(33.34)	(10.30)			(35.080)	(0.308)	(2.719)	(83.6)	(9.6)	(14.2)	(97.125)
50% of Pull at Maximum Power—Two Hours 10th Gear											
87.52	4998	6.57	2287	2.26	7.290	0.581	12.01	176	38	42	28.805
(65.26)	(22.23)	(10.57)			(27.595)	(0.354)	(2.365)	(79.[illegible])	(3.1)	(5.3)	(97.270)
50% of Pull at Reduced Engine Speed—Two Hours 13th Gear											
87.54	4997	6.57	1434	2.26	5.857	0.467	14.95	179	45	53	28.805
(65.28)	(22.23)	(10.57)			(22.171)	(0.284)	(2.944)	(81.[illegible])	(6.9)	(11.7)	(97.270)

Fig. 5.20 Nebraska Tests Show Fuel Savings by Gearing Up and Throttling Down at 50% Pull.



MORE INFORMATION:

1) **Gear Up — Throttle Down.** Circular AE-651, available from Cooperative Extension Service, North Dakota State University, Fargo, North Dakota 58105.

2) **Shift Up — Throttle Back To Save Fuel.** Factsheet PM-860, available from Cooperative Extension Service, Iowa State University, Ames, Iowa 50011.

3) **Saving Energy (And $) While Operating A Tractor.** Factsheet No. 384, available from Agricultural Engineering Department, Michigan State University, East Lansing, Michigan 48824.

6 *Saving Energy and $ in* CROP PRODUCTION

Patterns of energy use in crop production vary widely across Canada and even between adjacent farms. Fuel and fertilizer are the major crop energy inputs on most farms. Irrigation and crop drying are also energy-intensive practices required in some regions.

Aim For More Crop With Less Energy. A note of caution is necessary on energy management in crop production. Beware of any ideas that will reduce your yield. It probably won't pay. Look for ideas that save energy without major risks to farm income. Here are some suggestions.

Reduce Tillage. Research is demonstrating that many farmers work the soil more often and deeper than necessary. Even one less tillage operation per year may save you hundreds of dollars.

Use Lower Energy Tillage Equipment. There is a big difference in the fuel needed for plowing, cultivating or discing. Could you switch to a lower energy system?

Integrate Equipment. Fuel and time can be saved by doing two or more jobs at once. Examples include harrowing and discing together, spraying and fertilizing while seeding, etc. New equipment, such as air seeders and no-till drills, are designed to reduce the number of trips over a field.

Use Efficient Working Patterns. Best field efficiency is usually achieved by working a field in the longest direction. Avoid unnecessary overlapping and fancy turning patterns.

Eliminate Field Obstructions. Ditches, sloughs, rockpiles and other obstructions increase the time and fuel needed to work a field. Field shape is also important. Small, irregular fields require much more turning and overlapping than large, rectangular fields.

Fertilize On The Basis Of Soil Tests. Get the most from your fertilizer investment by soil testing and uniform application.

Fig. 6.1 Fuel and Fertilizer are the Main Energy Inputs in Crop Production.

Don't Ignore Manure. A surprising number of farmers who spread manure on their fields don't consider its nutrient value when they plan their fertilizer application rates.

Consider Legumes. There is renewed interest across Canada in legume crops as a nitrogen source and soil builder. Do any of them fit your farm?

Herbicides Can Save Energy. Tillage is an energy-intensive way to kill weeds. Look for increased use of herbicides as fuel costs rise. New application methods require less chemical. However, since herbicides cost is also rising, proper and timely application of herbicides is important.

If You Irrigate. How efficient are your pump systems? Recent pump tests in Canada and the U.S.A. found poor designs and lack of maintenance, contributing to wasted energy.

If You Dry Grain. Compare dryer efficiencies. Investigate low-temperature and/or natural air drying and heat recovery.

6.1 COMPARING TILLAGE SYSTEMS

Fuel Requirements. There are big differences in the amounts of fuel used for tillage on different farms. Fuel use is affected by types of equipment, speed, depth, soil type, crop residues, moisture content, field shape and the number of tillage operations. Fig. 6.2 shows some typical values of fuel use for various tillage machines.

Reduced Tillage. The most effective way to reduce energy in tillage is to do less of it. Fig. 6.3 illustrates the variation in fuel consumption for nine tillage/planting systems used for corn production. The no-till system saved 33.1 L/ha compared to the conventional plow/disc tillage system.

Yield/Tillage Relationships. You can't afford a drop in yield just to save fuel. Most studies have shown that tillage can be reduced without decreasing yield. But there are exceptions, particularly in heavy soils with poor aeration.

Soil Conservation. Reduced tillage is also referred to as conservation tillage. Besides saving fuel, it also reduces erosion by wind and water, and conserves the organic matter in the soil.

	Diesel Fuel (L/ha)		
Operation	Low	Average	High
Stalk shredder	3.92	5.88	8.87
Moldboard plow	8.49	16.99	33.99
Chisel plow	5.23	10.46	20.92
Rotary plow	11.39	19.61	32.12
Heavy tandem disc	3.64	7.19	14.38
Standard tandem disc			
Plowed soil — first time	2.98	5.88	11.76
Plowed soil — second time	2.33	4.57	9.15
Cornstalks	2.61	5.23	10.46
Spring tooth harrow	1.96	3.92	7.84
Spike tooth harrow	1.30	2.61	5.23
Field cultivator	3.26	6.53	13.07
Planting 40-inch rows	2.98	4.57	6.91
Planting 30-inch rows	3.92	5.88	8.87
Grain drill	2.33	3.26	4.95
Potato planter	5.88	8.87	13.07
Vegetable planter	5.88	8.87	13.07
Transplanter	7.84	11.76	17.65
Cultivation — first	2.61	3.92	5.88
Cultivation — second	2.33	3.26	4.95
Rotary hoe	1.02	1.68	2.61
Sprayer	0.65	1.02	1.58

Fig. 6.2 Estimated Fuel Requirements for Selected Field Operations Related to Tillage.

MORE INFORMATION:

1) **Zero Tillage.** Publication available from Saskatchewan Agriculture, 3085 Albert St. Regina, Sask. S4S 0B1

2) **How Much Tillage Is Enough?** Discussion paper, available from Manitoba Agriculture, Technical Services Branch, 911 - 401 York Avenue, Winnipeg, Manitoba R3C 0V8.

3) **Tillage Practices For Field Crops In Ontario.** Publication available from Ontario Ministry of Agriculture And Food, Information Branch, Legislative Buildings, Toronto, Ontario M7A 1A5.

4) **Conservation Farming.** Publication available from Saskatchewan Research Council, 30 Campus Drive, Saskatoon, Saskatchewan S7N 0X1.

5) **Fuel Requirements For Field Operations.** Extension Bulletin E-1535, available from Cooperative Extension Service, Michigan State University, East Lansing, Michigan 48824.

6) **Energy Requirements For Various Tillage-Planting Systems.** Publication ID-141 available from Cooperative Extension Service, Purdue University, West Lafayette, Indiana 47907.

7) **Crop Residue and Tillage Considerations in Energy Conservation.** Factsheet No. 6 available from Cooperative Extension Service, Michigan State University, East Lansing, Michigan 48824.

8) **Conservation Tillage Information Centre.** Operated by the National Association of Conservation Districts, Suite 730, 1025 Vermont Avenue N.W., Washington, D.C. 2005.

	Tillage System								
	1	2	3	4	5	6	7	8	9
Tillage Operation	Conventional Tillage		Reduced Tillage	Plow and Plant	Plow-Plant	Chisel Plow	Tandem Plow	Rotary Plow	No-Till
	L/ha								
Moldboard plow	16.99			16.99					
Plow with trailing tool			19.61						
Chisel plow		10.46							
Chisel plow		10.46				10.46			
Disc harrow	5.88	5.88					7.19		
Disc harrow	4.57	4.57					4.57		
Drag harrow	3.92	3.92				3.92	3.92		
Drag harrow	2.61	2.61							
Spray*	a	1.02	a	a	a	a	a	a	1.02
Rotary plow								19.61	
Plant	5.88	5.88	5.88	5.88		5.88	5.88	5.88	5.88
Plow-plant					18.68				
TOTAL	39.85	44.80	25.49	22.87	18.68	20.26	21.56	25.49	6.90
No. of operations	6	8	2	2	1	3	4	2	2

*a = bandspray with planter

Fig. 6.3 Estimated Diesel Fuel Requirements for Planting Corn Under 9 Tillage Systems.

EXAMPLE

Location: Harrow, Ontario

Soil Type: Brookston Clay Loam

Crop: Corn

Consider a 100 hectare farm. Primary tillage is presently done with a moldboard plow operated 30 cm deep, requiring 34 L/ha of diesel fuel.

1) **How much fuel could be saved by reducing the plowing depth?**

   Reducing the plowing depth to 15 cm would save at least 17 L/ha of fuel. (17 L/ha x 100 ha) = 1700 L. At 35¢/L, savings = $595/year.

2) **What would happen to the yield?**

   It would probably increase, perhaps by as much as ½ tonne per hectare. (See Fig. 6.4 of tests conducted by Agriculture Canada.)

Depth of Moldboard plowing (cm)	Grain Yield (t/ha)
10	7.6
20	7.1
30	7.0

Average results for years 1968-1974 on Brookston clay; E.F. Bolton, Agriculture Canada, Harrow, 1976b.

Fig. 6.4 Effect of Depth of Plowing on Yield of Corn

6.2 IMPROVING FIELD EFFICIENCY

Field efficiency is a measure of the amount of work you get done with a machine in a given period of time compared to its theoretical capacity. You will never achieve 100% field efficiency for very long because time is lost in turning, overlapping, adjustments, maintenance, and other miscellaneous interruptions. Typical field efficiencies for most operations range from 65% to 85%.

OPERATION	FIELD EFFICIENCY, PERCENT
Tillage	
Moldboard Plow	75-85%
Disk Harrow, Disk Plow	77-90%
Field Cultivator	75-85%
Spring-Tooth or Spike-Tooth Harrow	65-80%
Cultivation	
Row Crop	65-80%
Rotary Hoe	75-85%
Seeding	
Corn Planter	
1. Corn Only	60-75%
2. With Fertilizer and/or Pesticide Attachment	45-65%
Grain Drill	65-80%
Broadcast	65-70%
Harvesting	
Mower	75-85%
Rake	65-90%
Baler	65-80%
Loose Hay Stacking Wagon	65-80%
Forage Harvester	50-70%
Combine	60-75%
Corn Picker	55-70%
Cotton Picker	60-75%
Swather	70-85%
Miscellaneous	
Sprayer	55-65%

Fig. 6.5 Field Efficiency Table

Here are some ways to get into the higher efficiency range:

1) **Reduce Overlap.** Consider a field cultivator used on 250 hectares of heavy textured soil. An overlap of 10% would, in effect, cultivate an extra 25 ha. of land, using 10% more fuel than necessary. This could amount to 325 L of wasted fuel (13 L/ha x 25 ha). At a price of 35¢/L the extra fuel used would cost $114.

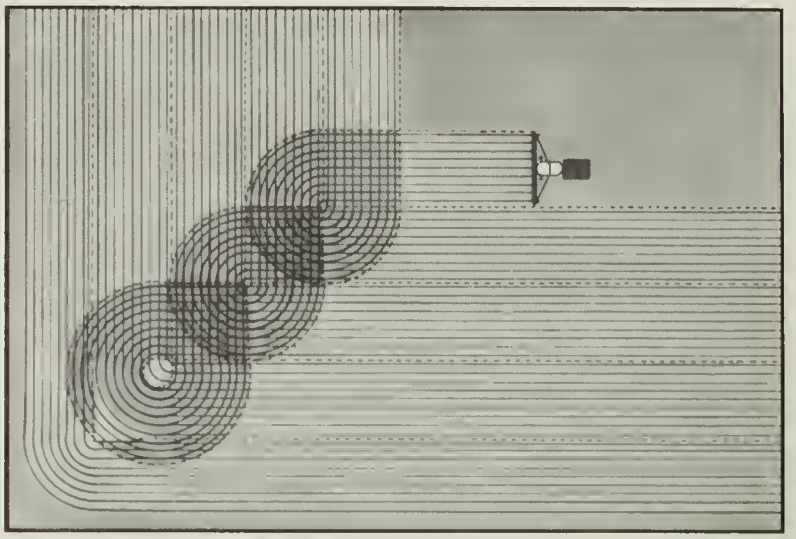


Fig. 6.6 Cloverleaf Turns Waste Time and Energy.

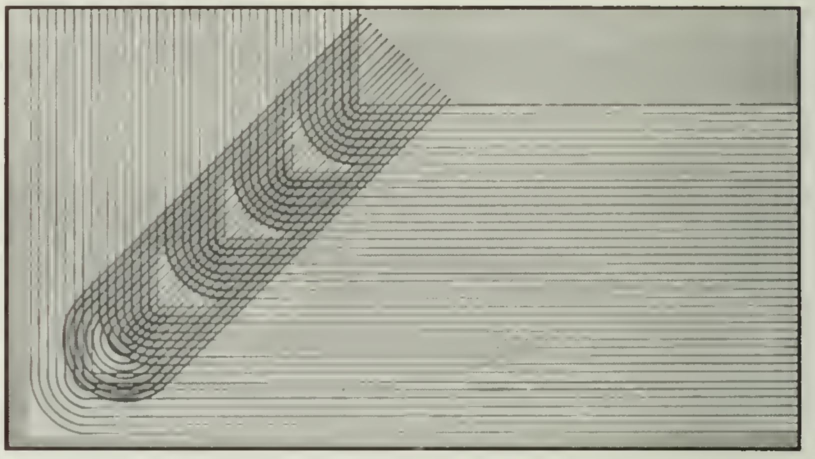


Fig. 6.7 Square Corner Turns are More Efficient.

2) **Reduce Turning Time.** The number of turns can be reduced by working the field in the longest direction. The time lost in turning depends a lot on the patterns you use. Consider the neat looking cloverleaf turns in Fig. 6.6. On a square 64 hectare field with an 11 m cultivator this type of turn double-tills about 14% of the field. Fig. 6.7 shows a more efficient turning pattern using square corners.

3) **Improve Drainage.** Subsurface drainage improves traction and reduces tillage energy. (It also speeds up crop maturity which reduces the amount of energy for artificial drying.)

4) **Consolidate Sloughs.** Millions of hectares of cultivated land on the Canadian prairies are severely affected by potholes and sloughs. These obstructions greatly reduce field efficiency. Many farmers are consolidating their sloughs into one or two areas to improve the productivity and efficiency of the farming operations.

EXAMPLE

Assume the following operations and fuel inputs are used to produce one crop:

Operation	Fuel Use (L/ha)
Disc	7.2
Cultivate (2X)	13.0
Rod Weed	4.0
Disc/seed	4.5
Spray	1.0
Swath	3.0
Combine	10.0
TOTAL	42.7

Consider a field containing several small sloughs comprising a total area of 10 hectares. It usually takes more time to go around a slough than it would to farm through the area it occupies. Therefore, a very conservative estimate of the wasted fuel is that amount needed to crop an area equal to the area of the sloughs:

$$(10 \text{ ha} \times 42.7 \text{ L/ha}) = 427 \text{ L}$$

At a fuel price of 35¢/L the energy cost of the sloughs = $150/year. Other wasted inputs due to overlapping around sloughs include time, fertilizer, herbicides and seed. Many farmers estimate that the extra inputs needed to crop the slough areas are already being applied to the fields as wasted inputs. The same analysis has been suggested for seepage and saline areas in both dryland and irrigated fields.

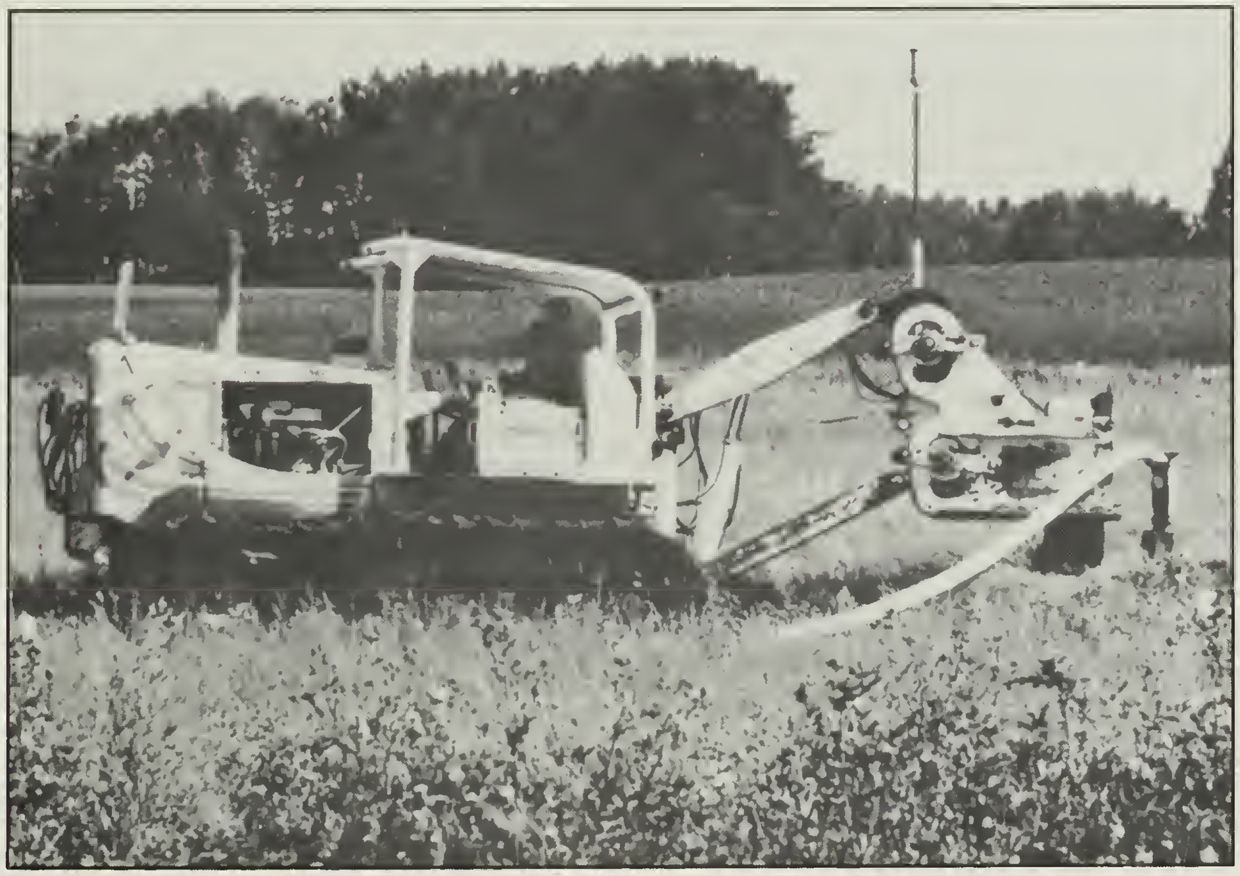


Fig. 6.8 Subsurface Drainage Improves Field Efficiency and Crop Yield.

MORE INFORMATION:

1) **Draining Your Troubles Away.** Country Guide, September, 1981.

2) **Farm Machinery Performance.** Factsheet 200.200, available from B.C. Ministry of Agriculture, Engineering Branch, 33832 South Fraser Way, Abbotsford, British Columbia V2S 2C5.

3) **Adverse Effects Computer Model For Calculating Additional Farming Costs.** Examples available from Deloitte Haskins & Sells Associates, 18th Floor, Toronto Dominion Tower, Edmonton Centre, Edmonton, Alberta T5J 3P9.

4) **Soil Salinity.** Proceedings of Conference On Water and Soil Research, available from Alberta Agriculture, Land Use Branch, 7000 - 113 Street, Edmonton, Alberta T6H 5T6.

6.3 MAKING THE MOST OF FERTILIZER

Most people tend to think of energy as fuels and electricity. They are often surprised to learn that fertilizer may actually be the largest energy input on a farm. Fig. 6.11 shows the energy required for production of chemical fertilizers, mainly in the forms of natural gas and electricity.

Used efficiently, chemical fertilizers are a good energy investment, returning more food energy than the fossil energy required in their manufacture.

Following are some ways to save energy and $ in fertilizer management.

Use Soil Tests. "If you aren't test'n — you're guess'n". Available fertilizer nutrients in the soil can vary widely between farms, between fields, and between areas of the same field. Soil tests and lab analyses are essential for efficient use of fertilizers. All provincial extension agencies offer soil sampling instructions and fertilizer recommendations based upon sample analyses.

Compare Fertilizer Formulations. When buying fertilizer, figure out the cost per unit of nutrient (N, P_20_5, or K_20). As shown in Fig. 6.11, the energy inputs vary between different forms of nitrogen and phosphorous. These differences in energy costs will be reflected in the retail prices of the fertilizers. For example, to produce 1 kg of N as anhydrous ammonia requires 15.8 MJ less energy than is required to pro-

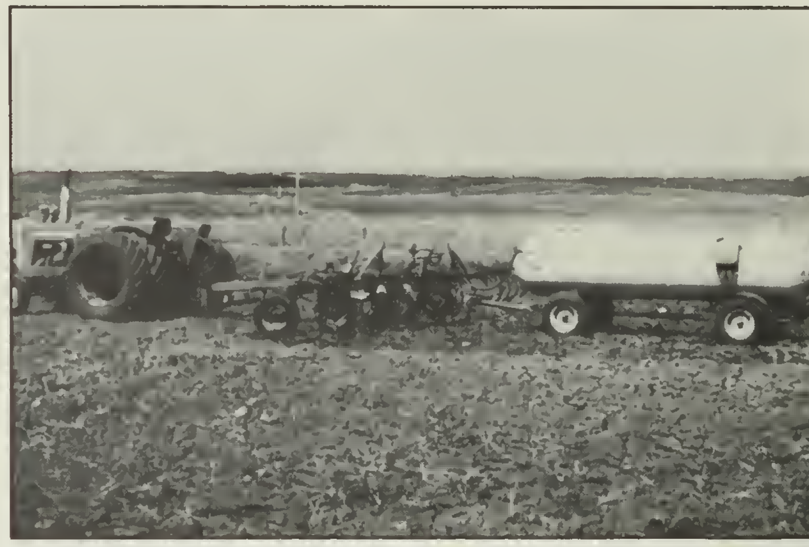


Fig. 6.9 Anhydrous Ammonia is the Least Energy Intensive Form of Nitrogen Fertilizer.

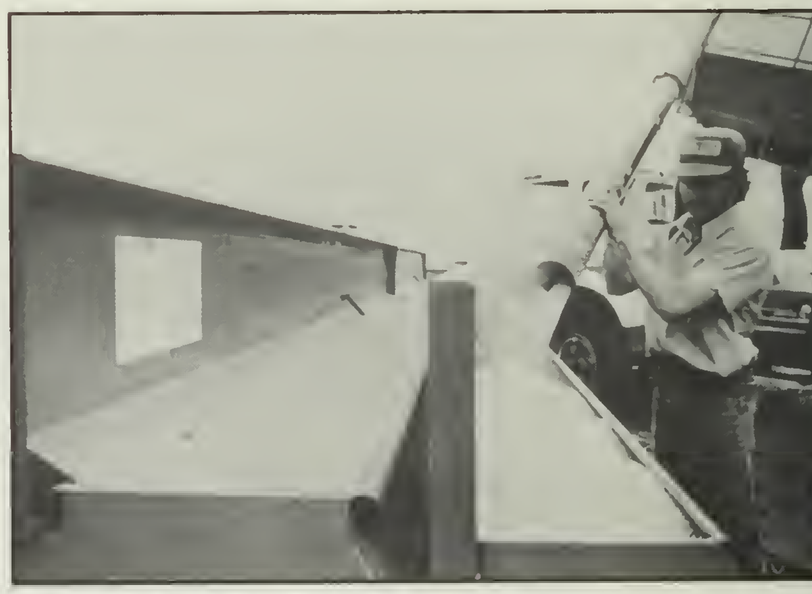


Fig. 6.10 Fertilizer Applied During Seeding

MORE INFORMATION:

1) **Fertile Fields and Fertilizers.** Booklet available from Imperial Oil Limited, Agricultural Chemicals Consumer Division, 10025 Jasper Avenue, Edmonton, Alberta T5J 1S6.
2) **Fertilizer Management to Save Energy.** Factsheet No. 8, available from Cooperative Extension Service, Michigan State University, East Lansing, Michigan 48824.
3) **Fertilizer Management.** Farm Energy Tips, available from Cooperative Extension Service, University of Nebraska, Lincoln, Nebraska.
4) **Fertilizing Crops: The Guesswork's Going.** The Furrow Magazine, Ontario/Coastal Edition, January, 1982.
5) **How Your Profits Are Influenced by Fertilizer Application Methods.** Grainews, September 1983.
6) **Nitrogen — New Rules For Conservation Tillage.** Successful Farming, Vol. 81, No. 4, March 1983.
7) **Straighten Up and Spread Right.** Crops and Soils Magazine, August/September 1981.
8) **Double-Deep Banding In A Single Pass.** Country Guide, March 1983.
9) **Fertilizer Application Through Sprinkle Irrigation.** Engineering Notes, No. 572.100.1, available from B.C. Ministry of Agriculture and Food, Engineering Branch, Abbotsford, British Columbia. V2S 2C5.
10) **Types of Nitrogen Fertilizer And The Best Time To Apply Them.** Factsheet, available from Farm Information Services, United Grain Growers, Box 6600, Winnipeg, Manitoba R3C 3A7.
11) **Fertility Variations Within Fields and Implications For Management of Nitrogen Fertilizer Application.** Report by Farmwest Management Ltd., available from Saskatchewan Research Council, Farm Energy Management Program, 30 Campus Drive, Saskatoon, Saskatchewan S7N 0X1.
12) **Soil Fertility: Precision Is In.** The Furrow, May/June, 1983.

	Natural Gas (m^3/t)	Fuel Oils (L/t)	Electricity (kWh/t)	Total (MJ/t)	Energy Input Per Unit of Nutrient
Nitrogen (N)					
Anhydrous Ammonia (82%N)	1190	38	60	46,069	56.2 MJ/kg N
Aqueous Ammonia (20%N)	298	10	15	11,557	57.8
Ammonium Nitrate (33%N)	569	44	79	23,286	70.6
Urea (45%N)	702	121	346	32,406	72.0
Phosphate (P_2O_5)					
Single Superphosphate (20% P_2O_5)	42	15	69	2,436	12.2 MJ/kg P_2O_5
Triple Superphosphate (46% P_2O_5)	88	24	215	5,048	11.0
Potash K_2O					
Muriate of Potash (60% K_2O)	20	112	119	5,843	9.7 MJ/kg K_2O

Source: Southwell and Rothwell
University of Guelph, Ontario

Fig. 6.11 Energy Inputs Required for Fertilizer Production.

duce 1 kg of N as urea (72.0 MJ - 56.2 MJ = 15.8 MJ). If the fertilizer plant pays an average of $3.00/GJ for energy, the difference in energy cost is:

(15.8 MJ/kg x 0.001 MJ/GJ x $3.00/GJ) = $0.0474 kg of N.

If you were applying 100 kg/ha on 200 ha, the $ **energy savings** with anhydrous ammonia would be:

(0.0474/kg x 100 kg/ha x 200 ha) = $948.

(The total savings may be greater than this amount because of more efficient handling and application methods with the anhydrous ammonia.)

Applying Fertilizer Uniformly. Broadcast spreading of fertilizer is often haphazard and wasteful. Overlapping and misses occur if the operator can't tell where he has travelled in the field. This problem is compounded by field obstructions and irregular shapes. Spreading equipment should be checked each year for uniformity of spreading pattern and proper rates of application. Required overlap should be determined for uniform application. When practical, spreaders should be driven around fields to minimize the effect of variations in spreading patterns. "Back and forth" travel patterns should be used only if the distribution to each side is symmetrical and uniform.

Consider Banding for Maximum Response. It has long been known that banded fertilizer (placing fertilizer near the seed at planting) gives a better crop response, in most soils, than fertilizer broadcast on the soil surface. Figure 6.12 shows results of a research project comparing yield difference in barley for two fertilizer application methods; deep banding versus broadcasting and incorporation. The results show that banding gave much greater yield increases per unit of fertilizer applied. Banding attachments are

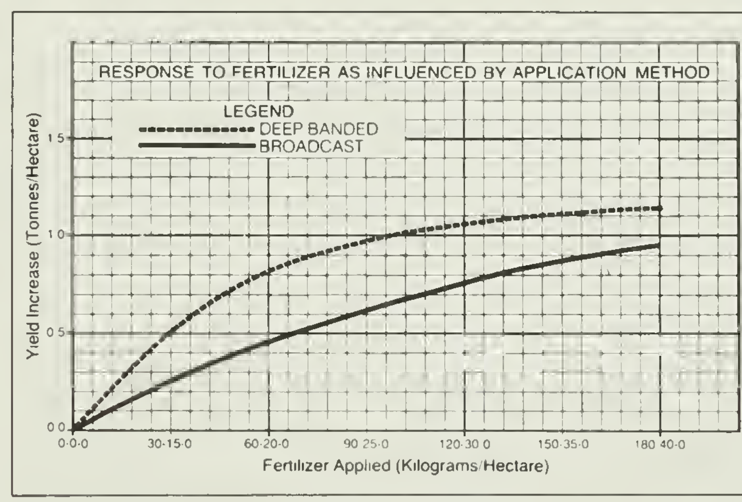


Fig. 6.12 Response to Fertilizer as Influenced by Application Method

now available for most seeding equipment. Banding makes efficient use of fertilizer, reduces trips over the field and produces higher yields.

Timing Is Important. In general, fertilizers are most efficient when applied in the spring, either just prior to seeding or as part of the seeding operation. Some crops, such as corn and potatoes, have a high need for nitrogen later in the growing season. Side-dressing part of the N application when required by these crops may be a profitable technique.

For irrigated crops, applying N through the irrigation system is another means of improving nitrogen efficiency, especially on sandy soils where leaching of N is a problem.

6.4 USING LEGUMES TO SAVE ENERGY

Legumes are plants that "fix" nitrogen from the air. The amount of nitrogen stored by a legume crop depends upon many factors; including plant species, yield, inoculation effectiveness, soil type and climate. Fig. 6.14 shows the wide ranges in the amounts of nitrogen fixed by some common legumes.

Energy Comparisons. Legumes in a crop rotation reduce the amount of chemical nitrogen which must be purchased. For example, Fig. 6.15 shows a comparison of total energy inputs for production of soybeans versus grain corn. The soybean crop requires only 2,626 MJ/ha of fertilizer energy, compared to 14,368 MJ/ha for the corn crop; an energy saving of 11,742 MJ/ha for the legume. Additional energy is saved because soybeans do not require artificial drying.

The corn production costs are very vulnerable to rising energy prices. For example, an increase of all energy costs by the equivalent of $10.00 per barrel of crude oil would add about 0.16¢/MJ. (See Appendix A-2). Soybean input costs would rise by ($0.0016/MJ x 6,867 MJ/ha) = $10.99/ha while corn production costs would increase by ($0.0016/MJ x 25,679 MJ/ha) = $41.09/ha. This example illustrates the potential advantage of legume crops if energy costs continue to rise.

Plowdown Legumes. Farmers throughout Canada are rediscovering the benefits of legume forages grown specifically to supply nitrogen and increase soil organic matter. This practice is also called "green manuring". In areas of adequate rainfall interseeding is becoming a popular technique. This involves seeding a legume, like red clover, along with a cash crop, like corn. The clover grows between the corn rows and is incorporated into the soil when the field is tilled in the fall.

In drier regions, plowdown legumes are being studied as an alternative to summerfallowing. Fig. 6.16 summarizes 18 years of legume research at Indian Head, Saskatchewan. These tests showed that both energy efficiency and net income were improved by including sweet clover in wheat/summerfallow rotations.

Inoculation Is Important. To produce nitrogen effectively, a legume seed must be inoculated with the correct strain of rhizobium bacteria. Seed inoculants die rapidly when exposed to sunlight, high temperatures and drying. They should be bought fresh and stored in a refrigerator until used.

For effective application to the seed a "sticking agent" should be applied first, such as a sugar solution or skimmed milk. Spray the seed with the sticky solution and spread on the inoculant. Transfer the seed through an auger to get the inoculant in contact with all of the seeds. It may also pay to increase the application rate of the inoculant. Fig. 6.18 shows the results of one experiment which demonstrates the importance of good inoculation procedures.

Fig. 6.13 Nitrogen-Fixing Nodules on a Legume Root

	kg/ha of N
Alfalfa	57-510
Fababeans	127-505
Red Clover	45-477
Sweet Clover	151-454
Soybeans	42-170
Vetch	68-136
Sainfoin	57-136
Birdsfoot Trefoil	68-117
Lentils	57-117
Peanuts	45-113
Field Peas	52-87
Dry Beans	43-79

Fig. 6.14 Annual Nitrogen-Fixing Capacity of Legumes

Input	Grain Corn MJ/ha	Soybean MJ/ha
Plowing	854	854
Discing	494	494
Harrowing (spike tooth)	—	132
Planting	364	364
Fertilizer materials	14,368	2,626
Fertilizer Application	497	—
Herbicide Materials	1,826	1,381
Herbicide Application	136	68
Combining	892	842
Drying	6,062	—
Hauling to storage	186	106
Total Energy Input	25,679	6,867

Fig. 6.15 Energy Input for Grain Corn and Soybean Production

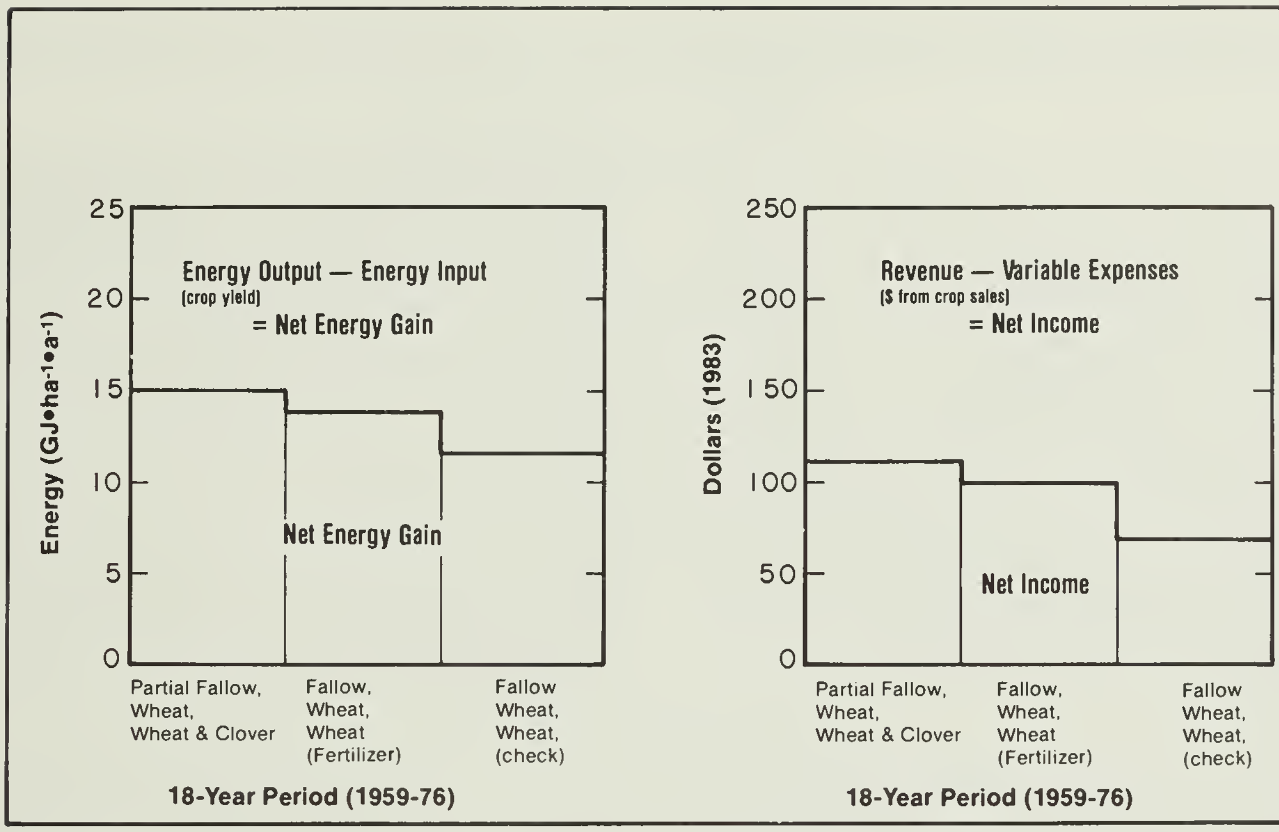


Fig. 6.16 Benefits of Legumes in a Grain Rotation. For the past 18 years. experiments with sweet clover were conducted in the thin black soil zone at Agriculture Canada Research Station in Indian Head. In three year wheat-wheat-fallow rotations including sweet clover, they found wheat yields were similar to the same rotation using 10 kg. of nitrogen per hectare per year in each crop.

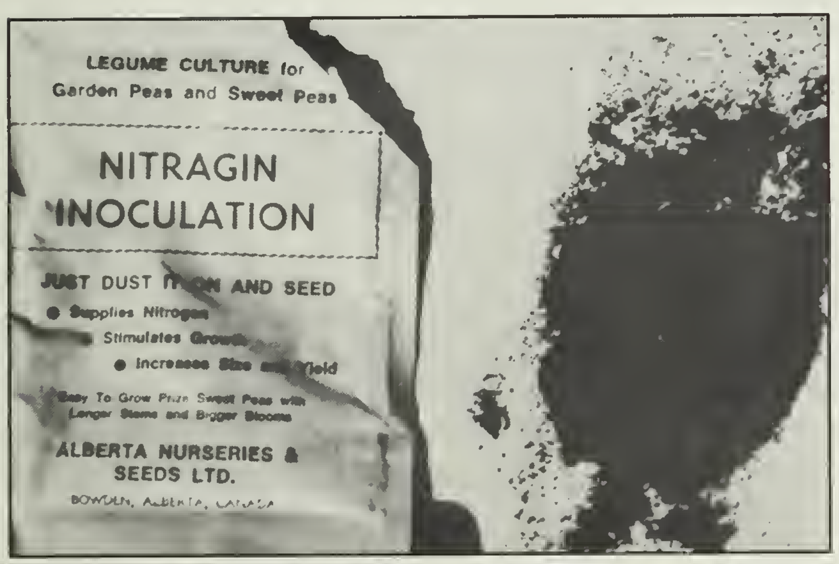
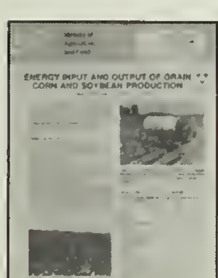


Fig. 6.17 Inoculant Should be Bought Fresh and Stored in a Refrigerator Until Used.

Method of Inoculation	Yield 2 cuts kg D.M./ha
No Inoculant	1370
Applied to dry seed (waterless)	1406
Applied with sticker	2197
Applied with sticker @ 10 x recommended rate	2536
Pre-inoculated with seed coating	2236

Fig. 6.18 Effect of Method of Inoculation on the Yield of Angus Alfalfa Grown on a Black Solod Soil with pH 5.8.



MORE INFORMATION:

1) **Energy Input And Output Of Grain Corn And Soybean Production.** Factsheet No. 82-084, available from Ontario Ministry of Agriculture & Food, Information Branch, Legislative Buildings, Toronto, Ontario M7A 1A5.

2) **Plowdown — A Strategy For The Eighties.** Forage Seed Notes, available from Alberta Forage Seed Council, 2nd Floor, 7000 - 113 Street, Edmonton, Alberta T6H 5T6.

3) **Conservation Farming.** Publication available from Saskatchewan Research Council, 30 Campus Drive, Saskatoon, Saskatchewan S7N 0X1.

4) **Nitrogen: You May Be Growing More.** The Furrow, Prairie Edition, November/December 1981.

5) **Legume Inoculation.** Publication 1299, available from Communication Branch, Agriculture Canada, Ottawa, Ontario K1A 0C7.

6) **Correct Inoculation Saves Fertilizer.** Agdex 121.123 available from Farm Information Services, United Grain Growers, Box 6600, Winnipeg, Manitoba. R3C 3A7.

7) **Seed Inoculation In Pulse Crops.** Canadex Factsheet 255.24, available from Communication Branch, Agriculture Canada, Ottawa, Ontario K1A 0C7.

6.5 IDEAS FOR LOW—COST WEED CONTROL

On most farms weed control involves a combination of tillage and herbicides. In general, it takes less energy to kill weeds by spraying them than by tillage. (Fig. 6.21). But, because energy content has very little to do with the cost of herbicides, spraying is not necessarily the least expensive. This is particularly evident in the case of zero tillage programs requiring some of the newer herbicides for which the manufacturers are still recovering their development and registration costs.

The simplest way to save energy (and money) in herbicide applications is to use the minimum amount of chemical needed to control the weeds. Here are some suggestions from top farmers on how to achieve that goal:

1) Use clean seed. Don't plant your own weed problems.
2) Use crop rotations. Different weeds build up in different crops.
3) Control small infestations before they spread. A knapsack sprayer is often sufficient.
4) Reduce or eliminate plowing. Turning the soil over activates weed seeds which would remain dormant under a minimum tillage program.
5) Check sprayer calibration and distribution pattern.
6) Spray at the right time.

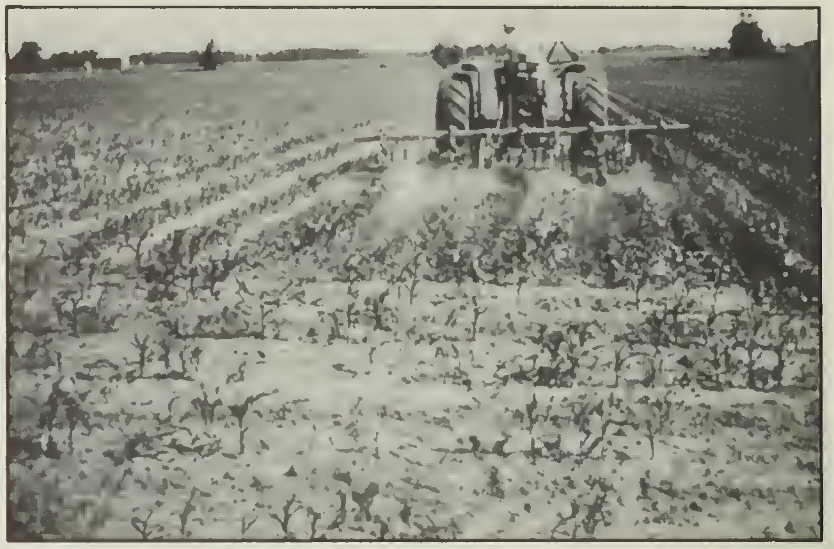
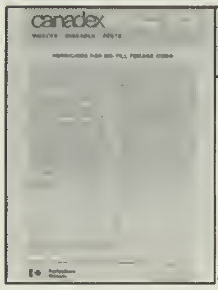


Fig. 6.19 Weed Control by Tillage

Fig. 6.20 A Farm Sprayer for Herbicide Applicaiton



MORE INFORMATION:

1) **Herbicides For No-till Forage Corn.** Canadex Factsheets available from Communications Branch, Agriculture Canada, Ottawa, Canada. K1A 0C7.

2) **Alternate Methods of Weed Control for Conserving Energy.** Canadex Factsheets available from Communications Branch, Agriculture Canada, Ottawa, Canada. K1A 0C7.

3) **Integrated Weed Control Recommendations.** Weed Facts, Agdex 641, available from Distribution Centre, Manitoba Agriculture, 911 York Avenue, Winnipeg, Manitoba. R3C 3M1.

4) **Aerial vs Ground Spraying — An Energy Comparison.** Report 1-61, available from Engineering & Statistical Research Institute, Research Branch, Agriculture Canada, Ottawa, Ontario. K1A 0C6.

5) **Pest Control.** Agologist magazine, Winter, 1983.

6) **An Economic Assessment of 2,4-D In Canada.** Canadian Farm Economics, Vol. 18, No. 1, Summer, 1983.

7) **More Weed Control From Less Herbicide.** Country Guide, June, 1983.

8) **Banding Benefits.** Country Guide, October, 1983.

9) **Sprayers That Speak Of Speed And Convenience.** Successful Farming, February, 1983.

10) **Can You Save On Pesticides?** Sperry New Holland News, Vol. 28, No. 8, available from Sperry New Holland, Dept. 224, New Holland, Pennsylvania. 17557.

11) **Killing Weeds With Disease.** The Furrow, Prairie Edition, September-October, 1983.

12) **A Thinking Man's Approach To Weed Control.** The Furrow, January, 1977.

13) **Earthcare: Ecological Agriculture In Saskatchewan.** The Earthcare Group, Box 1048, Wynyard, Saskatchewan. S0A 4T0. ($13.00)

14) **Proceedings Of The P.E.I. Conference On Ecological Agriculture.** Institute Of Man And Resources, 50 Water Street, P.O. Box 2008, Charlottetown, P.E.I. C1A 1A4. Price unknown.

15) **Natural Plant Defences May Pose 'Pesticide' Peril.** The Globe And Mail, October 21, 1983.

Fig. 6.22 A Rope-Wick Herbicide Applicator

Equipment Innovations.

Monitors. Electronic spray monitors assist in calibration and delivering a more precise application of herbicide at varying speeds by providing instantaneous reading of application rates.

Markers. To reduce overlap and misses, a number of field marking systems are available.

Rope-Wick Applicators. Recent interest in more efficient ways to get the herbicides in contact with the weeds has prompted development of various wiper/-roller applicators. The rope-wick applicator requires only 50% as much herbicide as an application with a conventional sprayer. For example, a chemical fallow program compared a rope-wick application to a conventional sprayer, applying Roundup in both cases. The rope-wick saved $18.75 per hectare in one season, by reducing the amount of chemical needed.

Herbicide	Input energy
	MJ/kg of active ingredient
Paraquat	415
Glyphosate	387
Diquat	369
Dicamba	286
Propachlor	280
Diuron	274
Propanil	212
Atrazine	201
Chloramben	179
Trifluralin	142
2, 4, 5-T	130
MCPA	129
Dinoseb	91
2, 4-D	82

Source: Southwell, P.H. and T.M. Rothwell, *Report on Analysis of Out/Input Energy Ratios of Food Production in Ontario,* School of Engineering, University of Guelph, p.55, 1977.

Fig. 6.21 Energy Costs of Herbicide Manufacture

6.6 IRRIGATION ENERGY COSTS

Irrigation farming is generally much more energy-intensive than dryland farming. Greater energy inputs are not only the fuel or electricity used for pumping water but also the higher application rates of fertilizers and herbicides. While the irrigation farmer can produce much more crop output per acre, his energy costs **per unit of product** are nearly always higher than on a dryland farm. Therefore, irrigation farmers will benefit greatly from good energy management.

Energy required for irrigation varies widely with the source of water, application system, and the amount of water applied. Within each of the many irrigation methods there are design and operating factors which can also affect the efficiency of energy use.

Water Sources. Most irrigated farms on the Canadian prairies obtain water from large district reservoirs and canal networks. The Irrigation Districts in southern Alberta and Saskatchewan operate several thousand kilometres of such canals. With this system the energy needed for water **delivery** to farms is very low because flow is developed by gravity.

Some irrigation farmers in British Columbia make even better use of gravity. Water is moved by pipelines from mountain reservoirs down to the valleys and delivered to the farms under pressure, ready for use in a sprinkler system without a pump.

However, in most other areas of Canada, irrigation water must be pumped to the fields from rivers, lakes, ponds or wells. Energy required for water pumping can be substantial, and is controlled by the following factors: elevation lift, delivery pressure, flow rate, pipe size, pipe length, and pump efficiency.

Pumping Systems. A pumping system should be carefully designed for each situation. Equipment suppliers and government irrigation engineers can assist in planning an efficient pumping system. Here are some general guidelines:

1) The pump should be located as close to the water surface as possible to minimize the suction lift and reduce the number of fittings needed. Suction lifts greater than 4.5 metres will cause inefficient pump operation.

2) The suction pipe should be at least one or two sizes larger than the intake on the pump.

3) Pipe friction charts should be used to select the best pipe size for a given flow rate and pumping distance.

4) Pump performance curves should be used to select a pump which will operate efficiently at the specified flow and total pumping head.

Irrigation Methods. Water can be distributed to crops by several different methods, including gravity, sprinkler or trickle systems. Topography, labour, crop characteristics and equipment costs influence which method is used.

Labour vs Energy. Energy costs are lowest for the gravity type of irrigation systems, but the higher labour costs often makes them as expensive to operate as the more automated high-energy sprinkler systems. Development of automatic controls for gravity irrigation may greatly reduce this labour cost in the future and may encourage a shift away from sprinkler systems where gravity irrigation is possible.

Low Pressure Sprinkler System. There is a difference in the energy needed to operate different sprinkler systems. Pressure is the most important factor. Where soil and crop conditions are suitable many irrigators

MORE INFORMATION:

1) **Irrigation Age.** This is a technical magazine available free to farmers who irrigate. Write to Circulation Department, Irrigation Age, 1999 Shepard Road, St. Paul, Minnesota 55116.

2) **Irrigation Water, Its Use And Applications.** Publication 1199, available from Agriculture Canada, Ottawa, Ontario K1A 0C7.

3) **Irrigation On The Prairies.** Publication 1488, available from Communications Branch, Agriculture Canada, Ottawa, Ontario K1A 0C7.

4) **Selecting Irrigation Equipment.** Factsheet No. 80-006, available from Ontario Ministry of Agriculture & Food, Information Branch, Legislative Buildings, Toronto, Ontario M7A 1A5.

5) **Irrigation Pump Testing.** Brochure available from the Irrigation Division, Alberta Agriculture, Lethbridge, Alberta T1J 4C7.

6) **Energy Efficient Gravity and Pump Assisted Gravity Supplied Irrigation Systems.** Factsheet available from B.C. Hydro, Energy Use Dept., 625 Howe St., Vancouver, B.C. V6C 2T6.

7) **Trickle Irrigation Emitter Selection.** Engineering Notes No. 565,510-1, available from B.C. Ministry of Agriculture & Food, Engineering Branch, Abbotsford, British Columbia V2S 2C5.

8) **Energy Conservation Through Better Irrigation Practices.** Extension Bulletin E 1143, available from Cooperative Extension Service, Michigan State University, E. Lansing, Michigan 48824.

Fig. 6.23 Sprinkler Irrigation Requires Energy for Pumping.

are converting to lower pressure systems to reduce operating costs. Savings of 35 to 40% on pumping energy costs are possible.

Trickle Irrigation. The ultimate conservation of both water and energy is achieved by trickle irrigation. This method is most appropriate for permanent installation in orchards or greenhouses. The potential for nearly total automation is also an attractive benefit. Disadvantages are high capital cost and problems with plugged emitters if the irrigation water is not properly filtered.

Irrigation Scheduling. Regardless of the irrigation method used it is important to apply the water when it is needed. To avoid over-irrigating the operator needs to know the water storage capacity of the soil and the amount of water used by each crop. This varies with types of crops and weather conditions. Many irrigation farmers have discovered from experience when to irrigate. Others rely on irrigation scheduling techniques based upon climatic data for their areas. Limited use has also been made in Canada of direct moisture measuring devices such as tensiometers.

EXAMPLE — COMPARING PUMPING ENERGY ALTERNATIVES

Location: Champion, Alberta.

Pumping/Irrigation System. An existing pump is powered by a 260 kW Cummins diesel engine. Water is pumped from the Little Bow River against a total dynamic head of 145 metres, irrigating 200 ha of cereal grains. A 20 kW diesel/electric generator supplies electricity to operate the irrigation pivot wheels.

Energy Costs. In 1983 the system required 70,600 L of diesel fuel, costing $18,000. Oil and maintenance for the diesel engines cost about $1000. per year.

Electric Alternative. The farmer is considering the installation of a 3-phase power line and electric motor to replace the diesel engines. Estimated costs are as follows:

1) power line extension (5km)	$25,000.
2) electric motor	$12,000.
3) switches & wiring	$10,000.
Total	$47,000.
minus salvage value of diesel system	- $10,000.
Net capital cost =	**$37,000.**

The predicted electricity consumption is 269,000 kWh/year, at an average price of 5.28¢/kWh, for a total cost in year 1 of $14,204, (including all utility service charges). Expected energy saving ($18,000. -14,203.) = $3,797. Reduced labour and maintenance are expected to save $1,000. per year, increasing the total saving to about $5,000.

Economic Analysis. Assume 10-year financing at 12.5% interest, a 25% marginal tax rate, and an 8% annual escalation in energy prices. The electrical installation would be eligible for an investment tax credit of 7%, a 10% capital cost allowance in year 1, and 20% in subsequent years.

Investment tax credits are deductible from the total federal income tax payable. This is really equivalent to non-taxable income in the year of purchase. We can approximate the effect on the cash flow by reducing the capital cost by the amount of the tax credit:

Previous net capital cost	= $37,000.
Minus investment tax credit (0.07 x $47,000.)	= $ 3,290.
Revised net capital cost	= $33,710.

(a) **Simple Payback** = ($33710/5000) = 6.7 years.

(b) **Cash Flow.** Fig. 6.24 shows that this investment would generate a positive cash flow after year 1.

Conclusion. If all assumptions are correct, conversion to electric pumping would be a good investment on this farm. Reduced energy, maintenance and labour costs would pay for the conversion in 6.7 years. The after-tax cash flow to the farm would improve by $7641. over a 10-year period.

Capital Cost	$33710	Revenue first year	$5000
Deduct Startup Costs	$0	Revenue Increase per yr (%)	8.0
Inputs (exp) first yr	$0	Loan Term (yrs)	10
Input Increase per yr (%)	0.0	Loan Interest Rate	12.50
Income Tax Rate (%)	25	Loan (1 = Ammort., 2 = Dim. Bal.)	1
General Inflation Rate	7	Loan Payments per year	1
C.C.A first year (%)	10.0	Study Scope (1 = all, 2 = part)	2
C.C.A. 2nd year (%)	20.0	Study Term In Years	10
C.C.A. other years (%)	20.0	Starting Year of Study	1
CCA Type (1 = dim, 2 = orig)	1	Downpayment	$0

Year	Inputs	Revenue	Principal	Interest	Taxes	Cashflow	Total CF	CCA
1	0.00	5000.00	1875.01	4213.75	-646.19	-442.57	-$442.57	3371.00
2	0.00	5400.00	2109.39	3979.37	-1161.79	473.03	$30.46	6067.80
3	0.00	5832.00	2373.06	3715.70	-684.48	427.72	$458.19	4852.24
4	0.00	6298.56	2669.69	3419.07	-250.97	460.77	$918.96	3883.39
5	0.00	6802.45	3003.40	3085.36	152.59	561.09	$1480.05	3106.71
6	0.00	7346.64	3378.83	2709.93	537.83	720.05	$2200.10	2485.37
7	0.00	7934.37	3801.18	2287.58	914.62	930.99	$3131.09	1988.30
8	0.00	8569.12	4271.33	1812.43	1291.51	1188.85	$4319.93	1590.64
9	0.00	9254.65	4810.87	1277.89	1676.06	1489.83	$5809.76	1272.51
10	0.00	9995.03	5412.23	676.53	2075.12	1831.14	$7640.91	1018.01
End of run	Total Cash Flow (present value)				$4914.50			

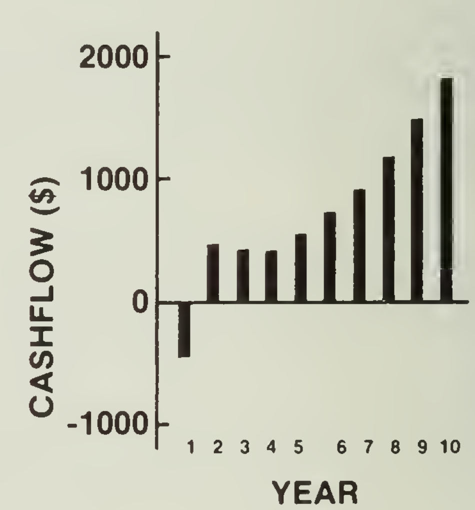


Fig. 6.24 Cash Flow Analysis: Conversion From Diesel to Electric Irrigation Pumping

6.7 COMPARING GRAIN DRYING SYSTEMS

Energy for drying is a major cost on many farms in eastern Canada. In some areas all grain crops are artificially dried, either on the farm or at local elevators. Grain drying has also become more common in western Canada. Instead of drying only during very wet harvest seasons, many prairie farmers now use drying as part of their normal grain-harvesting system. Drying can extend the harvest season, reducing the size of combine needed. It permits earlier harvesting, reduces field losses and eliminates grain spoilage in storage. Grain drying will increase as more farmers use direct combining to leave a higher stubble for snow trapping.

Types of Dryers. Hot air grain drying systems remove moisture by blowing heated air through the grain. The three basic types used on farms are:

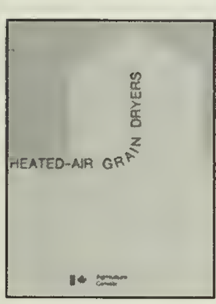
1) non-circulating batch,
2) recirculating batch, and
3) continuous flow.

The three types are available as portable dryers or as stationary bin dryers.

Fuels. Propane and natural gas are commonly used fuels for heated-air grain drying. A few dryers use heating oil or electricity.

Fig. 6.25 Heated Air Grain Drying with Propane

MORE INFORMATION:



1) **Heated-Air Grain Dryers.** Publication 1700, available from Communication Branch, Agriculture Canada, Ottawa, Ontario K1A 0C7.

2) **Guide To Grain Dryers.** Factsheet No. 81-028, available from Ontario Ministry of Agriculture and Food, Information Branch, Legislative Building, Toronto, Ontario M7A 1A5.

3) **Grain Drying.** Factsheet F701, available from B.C. Hydro, Energy Use Engineering Department, 625 Howe St., Vancouver, B.C. V6C 2T6.

4) **Research In Corn Drying To Improve Quality And Reduce Energy Demand.** Canadex Factsheet No. 111.62, available from Communications Branch, Agriculture Canada, Ottawa, Ontario K1A 0C7.

5) **Natural Air Drying.** Publication available from Saskatchewan Agriculture, 3085 Albert St., Regina, S4S 0B1.

6) **Movement of Natural Air Through Grain.** Publication No. 732-1, available from Manitoba Agriculture, 911 Norquay Building, Winnipeg, Manitoba R3C 0V8.

7) **The Prairie Agricultural Machinery Institute (PAMI)** has tested a number of heated-air grain dryers. Their evaluation reports include energy consumption data. For more information and prices of reports write to PAMI, P.O. Box 1150, Humbolt, S0K 2A0.

Natural Air Drying. Natural air drying, using unheated air, is most common on the prairies. Energy used in this system is the electricity needed to operate the fans which move air through the grain for a considerable period of time each fall.

Efficiency. Drying efficiencies are influenced by dryer design, types of grain, temperature of drying air, ambient air temperature, air flow rates, etc. Many dryer types are now equipped with heat reclaimers which recirculate part of the exhaust air to the dryer. The efficiency of drying systems varies widely. In general, the fastest drying rates require the most energy.

Ideas for Saving Energy.

1) Don't dry grain fed to livestock. A high moisture feed storage system may be a better investment.

2) Harvest at lower moisture. Drying grain from 27% to 15% requires twice as much energy as drying from 22% to 15%.

3) Consider energy efficiency when planning a drying system. Weigh the benefits of fast drying against the higher fuel costs.

4) Consider dryeration or combination drying. These systems use high temperature dryers to remove the initial moisture. The grain is then transferred to a bin dryer for low temperature or natural air drying to remove the last few "points" of moisture. Advantages include greater dryer capacity, better quality grain and lower energy costs.

5) Operate dryers at recommended temperatures and air flows.

6) Avoid drying in cold weather. Fuel consumption at -10° C can be 50% greater than at +10° C.

7) Don't overdry. This not only wastes energy but also results in less total weight of saleable grain.

6.8 TESTING A GRAIN DRYER HEAT EXCHANGER

The following information is based on a research project conducted by Ralph G. Winfield & Associates for the Ontario Agricultural Energy Centre.

EXAMPLE

Location: Woodstock, Ont.

Crop: Grain corn, 4372 tonnes, dried from 26.9% to 15.5%

Dryer: Continuous Flow

Fuel: Propane

Heat Exchanger. Fig. 6.26 shows a schematic plan of the experimental heat exchanger. It consists of 450 corrugated metal pipes (150 mm diameter) each 9 m long positioned inside an insulated chamber. The dryer exhaust air is blown through the chamber. Heat from the exhaust air transfers through the pipe walls and preheats drying air, which is drawn through the pipes.

Energy Saved. The heat exchanger becomes effective at air temperatures below 10° C. At 0° C the heat exchanger is more effective than recycling cooling air. A 13.6% improvement in drying efficiency was obtained. The heat exchanger saved 20,484 L of propane.

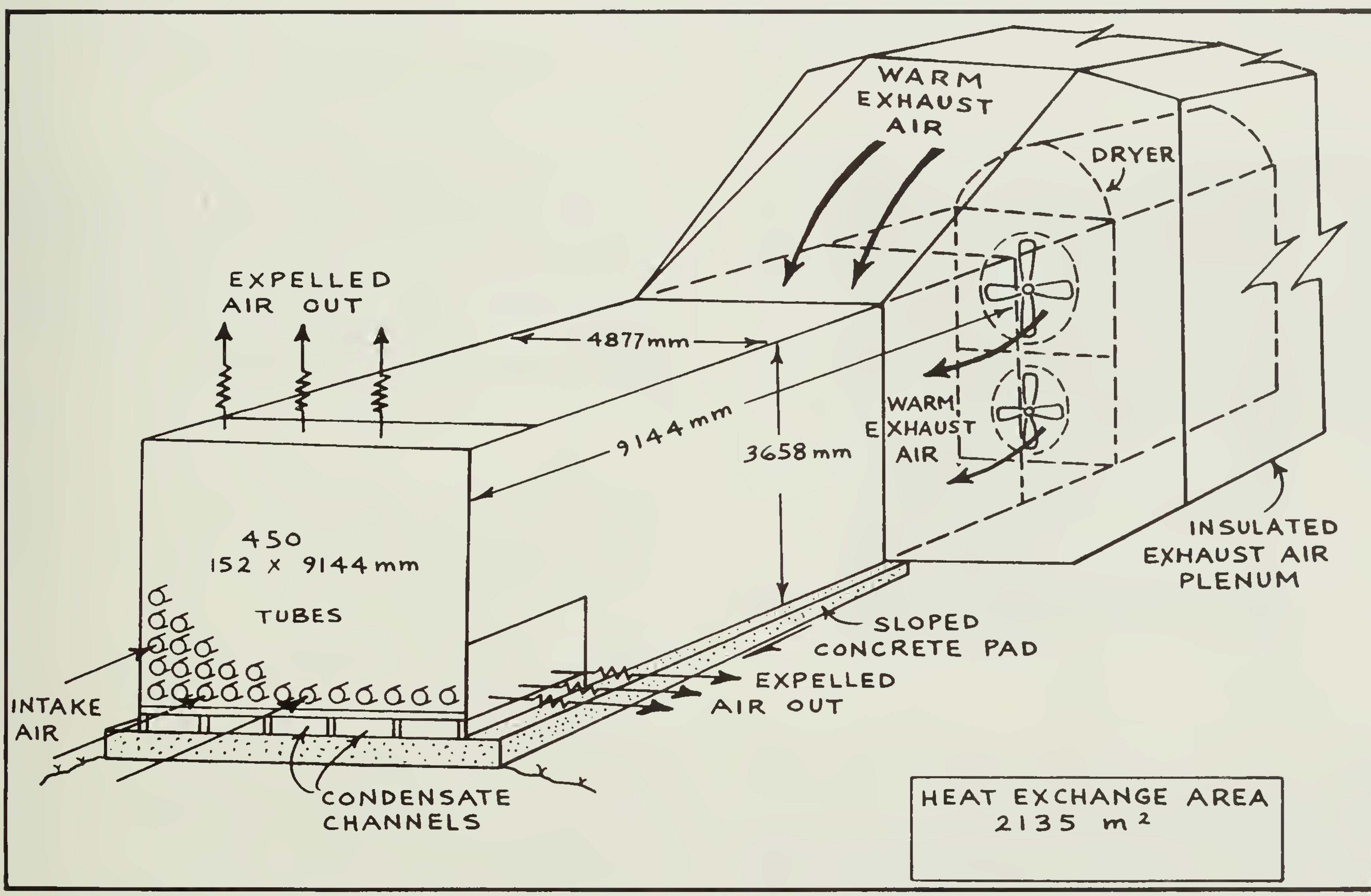


Fig. 6.26 Schematic of Heat Exchanger/dryer System *(Reference 1)*

MORE INFORMATION:

1) **Reclaiming Heat Energy For Grain Corn Drying.** Report available from Agricultural Energy Centre, Ontario Ministry of Agriculture and Food, P.O. Box 1030, Guelph, Ontario N1H 6N1.

2) **Tax Considerations.** This type of heat recovery system may qualify for a fast tax write-off. For details and application forms contact: Tax Incentive Program, Energy, Mines and Resources, 580 Booth Street, Ottawa, Ontario K1A 0E4.

Capital Cost	$25000	Revenue first year	$5121
Deduct Startup Costs	$0	Revenue Increase per yr (%)	8.0
Inputs (exp) first yr	$0	Loan Term (yrs)	10
Input Increase per yr (%)	0.0	Loan Interest Rate	12.50
Income Tax Rate (%)	25	Loan (1 = Ammort.,.2 = Dim. Bal.)	2
General Inflation Rate	7	Loan Payments per year	1
C.C.A first year (%)	25.0	Study Scope (1 = all, 2 = part)	2
C.C.A. 2nd year (%)	50.0	Study Term In Years	10
C.C.A. other years (%)	25.0	Starting Year of Study	1
CCA Type (1 = dim, 2 = orig)	2	Downpayment	$0

Year	Inputs	Revenue	Principal	Interest	Taxes	Cashflow	Total CF	CCA
1	0.00	5121.00	2500.00	3125.00	-1063.50	559.50	$559.50	6250.00
2	0.00	5530.68	2500.00	2812.50	-2445.45	2663.64	$3223.14	12500.00
3	0.00	5973.68	2500.00	2500.00	-694.22	1667.35	$4890.49	6250.00
4	0.00	6450.99	2500.00	2187.50	1065.87	697.61	$5588.10	0.00
5	0.00	6967.06	2500.00	1876.00	1273.02	1319.05	$6907.15	0.00
6	0.00	7524.43	2500.00	1562.50	1490.48	1971.45	$8878.60	0.00
7	0.00	8126.38	2500.00	1250.00	1719.10	2657.29	$11535.89	0.00
8	0.00	8776.50	2500.00	937.50	1959.75	3379.25	$14915.13	0.00
9	0.00	9478.62	2500.00	625.00	2213.40	4140.21	$19055.34	0.00
10	0.00	10236.91	2500.00	312.50	2481.10	4943.30	$23998.65	0.00
End of run		Total Cash Flow (present value)			$16460.14			

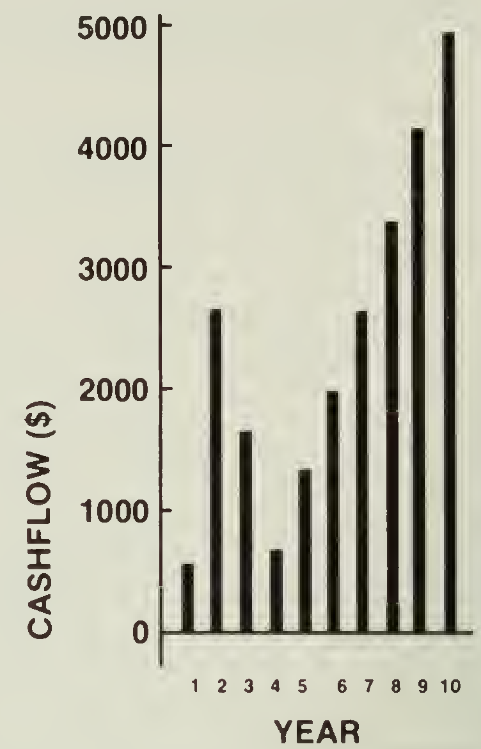


Fig. 6.27 Cash Flow Analysis: Grain Dryer Heat Exchanger

Economic Analysis. The experimental heat exchanger cost $40,000, including monitoring equipment. It is expected that a commercial unit could be built for $25,000. If propane costs 25¢/L the simple payback period would be:

Payback Period = ($25,000.)/(20,484 L x $0.25/L) =

4.88 years

Cash Flow. Fig. 6.27 shows an after-tax cash flow analysis for this investment, assuming 10-year financing at 12.5%, an 8% annual fuel price escalation, and a 25% marginal tax rate. The analysis shows that this is a very attractive investment, provided that the same drying system will be in use for several years and the annual throughput is relatively high.

7 *Saving Energy and $ in* LIVESTOCK PRODUCTION

Livestock producers depend upon energy to light, heat, and cool their barns; and to operate equipment for efficient handling of feed and manure. Egg and milk producers have the added requirement of refrigerated storages. There are many opportunities to increase profit by better energy management in livestock barns.

Match The Environment To The Livestock. Chickens and pigs pay for well-heated barns by better health and feed conversion. Don't waste fuel by overheating the barns. Other livestock, such as beef and dairy cattle, dry sows and sheep do just as well at lower temperatures.

Use "Spot-Heating". Heat lamps and brooders can provide the higher temperatures needed by piglets and pullets, allowing a lower temperature in the rest of the barn.

Insulate, Seal and Ventilate. A well-insulated, tightly constructed barn is essential for good operation of the ventilation system.

Don't Oversize Fans and Heaters. Choose small fans for the minimum continuous winter ventilation needed to control moisture. Similarly, a small heater operating nearly full time in cold weather is more efficient than an oversized heater which cycles off at frequent intervals.

Make Sure Fans and Heaters Don't Compete. A simple interlocking thermostat prevents the furnace from operating when the ventilation is higher than the minimum rate. It could cut your heating costs by 30%.

Consider Heat Exchangers. Heat recovery from milk and ventilation air could be a good investment. But choose the equipment carefully. Some systems require a great deal of maintenance.

Consider Electrical Feed Processing and Handling. Electric motors are more efficient than your tractor as a power source for processing and distributing feed.

Control Your Peak Power Load. Selection of efficient equipment and the use of simple controls can save money if you are on a demand meter for electrical power. Make sure electrical loads do not all come on at once.

Save the Nutrients in Manure. A good manure storage and handling system will pay for itself by reduced fertilizer costs.

Fig. 7.2 Spot Heating for Young Pigs

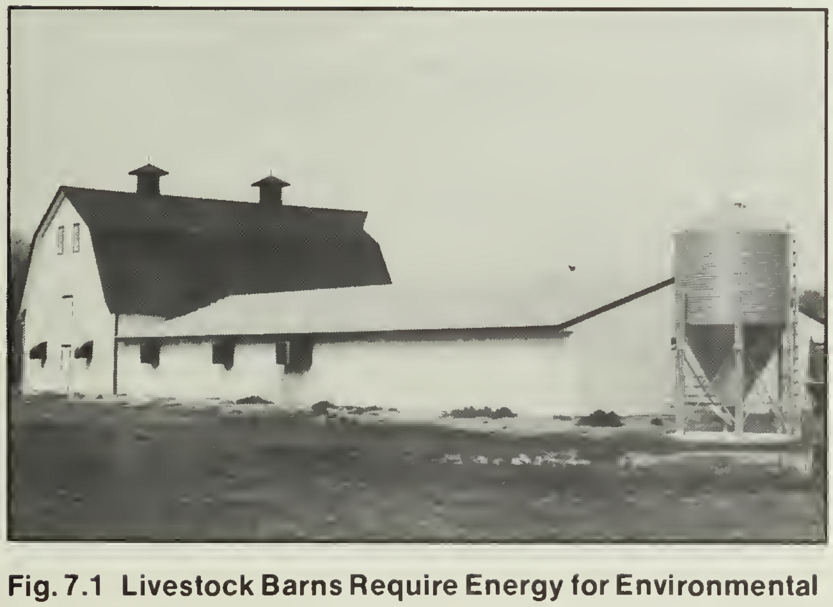


Fig. 7.1 Livestock Barns Require Energy for Environmental Control.

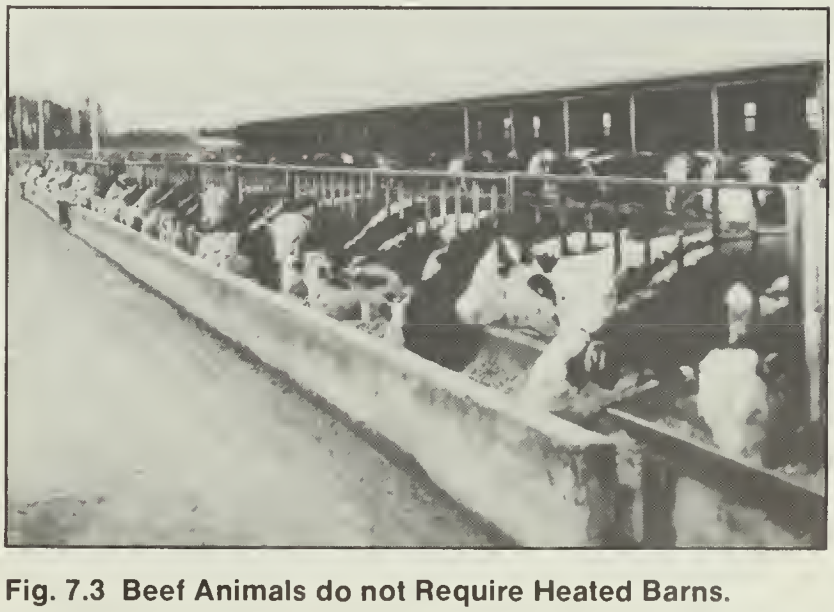


Fig. 7.3 Beef Animals do not Require Heated Barns.

7.1 USING ENERGY TO IMPROVE LIVESTOCK PRODUCTIVITY

Energy is a key input to the efficient production of meat, milk and eggs on Canadian farms. Improved feed conversion and animal health are the main reasons for using energy to heat and ventilate barns.

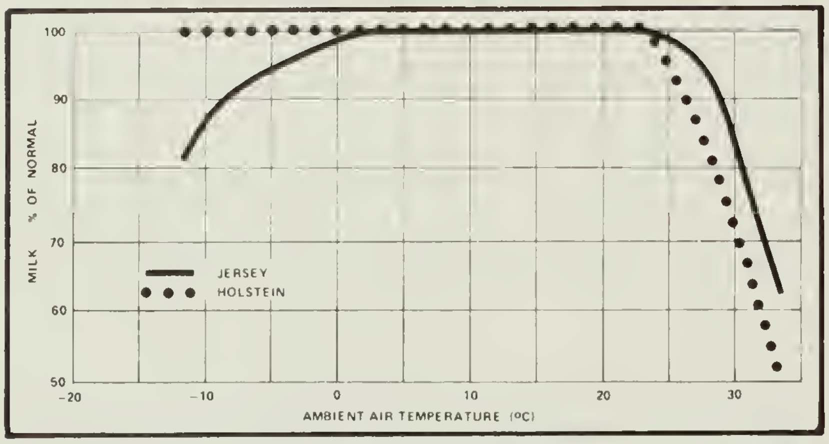


Fig. 7.4 Percent of Milk Production at Various Environmental Temperatures for Jersey and Holstein Cows

However, not all livestock require warm environments. For example, Fig. 7.4 illustrates the wide temperature range acceptable for dairy cattle. Holstein cows maintain full milk production between - 10° C and 22° C, provided that drafts and humidity are controlled. This explains the increasing popularity of "cold confinement" free-stall barns with natural ventilation (see section 7.5). Beef cattle, sheep, and dry sows can also tolerate wide ranges in temperature without adverse effects (Fig. 7.5).

Conversely, the growth rate and feed conversion of pigs is greatly affected by temperature. Lower feed costs more than offset the investment in well-insulated barns with automatic environmental control, as illustrated in the following example.

Class of Animal	Recommended Inside Temp., °C		Recommended Inside Relative Humidity %	
	Min.	Max.	Min.	Max.
Dairy Cattle				
cows	-5	25	25	75
calves (under 6 weeks)	10	27	25	75
calves (over 6 weeks if draft free)	-18	27		
Beef Cattle	-18	27	25	75
Sheep and goats	-18	27	50	75
Swine				
breeders	5	20	50	75
piglets	20	30	50	75
finishers	15	20	50	75
Poultry				
chicks (1 week)	30	35	50	75
hens	10	30	50	75
turkeys	10	20	50	75
Rabbits	-5	30	50	75
Horses	-5	30	25	75

Fig. 7.5 Recommended Temperature and Humidity Limits for Closed Animal Production Buildings

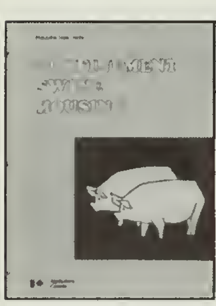
Mean live weight kg	Average Daily Gain, kg/(pig-day). at air temperature of 5° C	10° C	15° C	20° C	25° C	30° C	35° C
45		0.63	0.71	0.87	0.90	0.73	0.40
68	0.58	0.67	0.79	0.95	0.87	0.64	0.22
91	0.55	0.72	0.85	0.99	0.84	0.55	0.03
113	0.52	0.76	0.92	0.96	0.78	0.45	—0.15
136	0.50	0.80	1.00	0.95	0.72	0.35	—0.36
159	0.47	0.86	1.05	0.93	0.67	0.26	—0.55

Fig. 7.6 Effect of Air Temperature on Rate of Gain with Swine *(Reference 1)*

Live weight kg	Feed Conversion, kg feed/kg gain, at air temperature of 5° C	10° C	15° C	20° C	25° C	30° C	35° C
32 to 65	4.8	4.4	3.7	2.8	2.6	5.5	7.8
75 to 118	10.0	5.1	3.7	4.0	4.2	9.0	

Fig. 7.7 Effect of Air Temperature on Feed Conversion with Swine *(Reference 1)*

MORE INFORMATION:



1) **Confinement Swine Housing.** Publication 1451, available from Communications Branch, Agriculture Canada, Ottawa, Ontario. K1A 0C7.
2) **The Influence Of Barn Temperature On Swine Production.** Agrifax 717-6, available from Alberta Agriculture, Print Media Branch, 7000 -113 Street, Edmonton, Alberta. T6H 5T6.
3) **Effects Of Winter Cold On Livestock.** Canadex No. 400.10, available from Communications Branch, Agriculture Canada, Ottawa, Ontario. K1A 0C7.
4) **Planning For Fuel Conservation In Your Broiler House.** Publication available from Cooperative Extension Service, University of Maryland, College Park, Maryland 20742.
5) **Tie-Stall Dairy Cattle Housing.** Publication 1714, available from Communications Branch, Agriculture Canada, Ottawa, Ontario. K1A 0C6.
6) **Free-Stall Dairy Cattle Housing.** Publicaiton 1715E, available from Communications Branch, Agriculture Canada, Ottawa, Ontario. K1A 0C6.
7) **Builder Boo-Boos.** Booklet available from Farm Building News, 260 Regency Court, Waukesha, Wisconsin 53186. ($4.70 U.S.).

EXAMPLE

Many farmers face the decision of what to do with an old two-story barn that is standing empty. A common temptation is to remodel it for finishing hogs. In many cases, this may be a mistake because the barn will not provide optimum conditions for good feed conversion.

Consider a choice between spending $20,000. to remodel a barn to house 250 hogs, or spending $40,000. to build a new barn with the same capacity. At first glance the remodelling option looks very attractive. But consider some of the drawbacks:

1) probably more labour needed for handling feed and manure,

2) probably not easy to expand,

3) almost certainly lower winter temperatures or high heating costs.

From Fig. 7.6 and 7.7, we can estimate the extra feed costs as the barn temperatures drop below optimum. Assume that the temperature of the remodelled barn drops to 10°C for 100 days each winter. For hogs weighing 32 to 65 kg, feed conversion at 10° C is 4.4 kg of feed per kg of gain, compared to 2.6 kg of feed per kg of gain at 25° C, a loss of 1.8 kg of feed per kg of gain. If the hogs gain 0.63 kg per day, the extra feed consumed = (250 hogs x 0.63 kg gain/day x 1.8 kg of feed/kg gain x 100 days) = 28,350 kg.

If feed costs $250./t, the extra feed costs in the remodelled barn = (28,350 kg x $0.25/kg) = $7088/year.

In addition, the slower rate of gain per day means less pigs will be marketed per year.

ECONOMIC ANALYSIS

Payback Period for Added Cost of New Barn. For this example the added cost of a well-insulated, modern hog barn would be repaid by lower feed costs in:

($20,000./7,088.) = 2.8 years

Cash Flow. The analysis (Fig. 7.9) assumes that financing is available at 12.5% interest for 10 years, and the farm operates at 25% marginal tax rate.

Conclusion. In this case, the new barn is a better investment than remodelling the existing barn. The extra $20,000. in construction costs will be repaid by lower feed costs in less than 3 years. After-tax cash flow will be about $2500./year greater with the new barn than with the remodelled barn, assuming 10-year financing of the extra $20,000. construction cost.

A better use for old barns is to house dry sows.

Fig. 7.8 Pigs Require a Warm Environment for Optimim Feed Conversion.

Capital Cost	$20000	Revenue first year	$7088
Deduct Startup Costs	$0	Revenue Increase per yr (%)	0.0
Inputs (exp) first yr	$0	Loan Term (yrs)	10
Input Increase per yr (%)	0.0	Loan Interest Rate	10.50
Income Tax Rate (%)	25	Loan (1 = Ammort., 2 = Dim. Bal.)	1
General Inflation Rate	0	Loan Payments per year	1
C.C.A first year (%)	2.5	Study Scope (1 = all, 2 = part)	2
C.C.A. 2nd year (%)	5.0	Study Term In Years	10
C.C.A. other years (%)	5.0	Starting Year of Study	1
CCA Type (1 = dim, 2 = orig)	1	Downpayment	$0

Year	Inputs	Revenue	Principal	Interest	Taxes	Cashflow	Total CF	CCA
1	0.00	7088.00	1112.44	2500.00	1022.00	2453.56	$2453.56	500.00
2	0.00	7088.00	1251.49	2360.95	938.01	2537.55	$4991.11	975.00
3	0.00	7088.00	1407.93	2204.51	989.31	2485.26	$7477.37	926.25
4	0.00	7088.00	1583.92	2028.52	1044.89	2430.68	$9908.05	879.94
5	0.00	7088.00	1781.91	1830.53	1105.38	2370.18	$12278.23	835.94
6	0.00	7088.00	2004.65	1607.79	1171.52	2304.05	$14582.28	794.14
7	0.00	7088.00	2255.23	1357.21	1244.09	2231.48	$16813.75	754.44
8	0.00	7088.00	2537.13	1075.31	1323.99	2151.57	$18965.32	716.71
9	0.00	7088.00	2854.27	758.17	1412.24	2063.33	$21028.65	680.88
10	0.00	7088.00	3211.05	401.38	1509.95	1965.62	$22994.27	646.83

End of run Total Cash Flow (present value) $22994.27

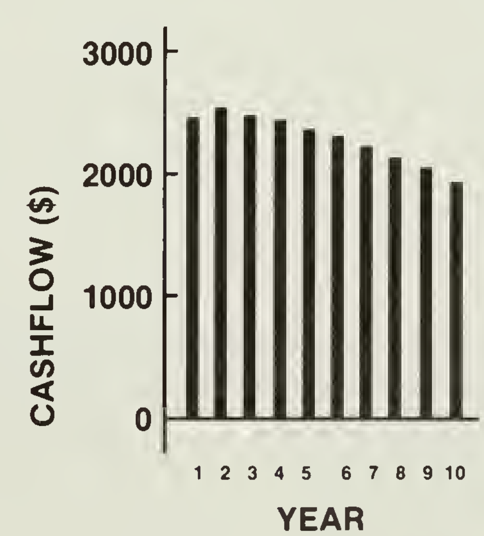


Fig. 7.9 Cash Flow Analysis: New vs Remodelled Swine Finishing Barn

7.2 PLANNING A LOW-ENERGY BARN

Fortunately, livestock give off nearly enough heat to maintain a well-insulated barn at the desired minimum temperature, even in cold weather. The need for supplemental heat depends upon the climate, type of livestock, density, insulation levels and the ventilation system.

The following examples of heat losses and gains in two similar hog barns illustrate the importance of adequate insulation.

Barn Comparisons. In both examples 500 grower/finishing pigs averaging 57 kg in weight are housed in a 12 m x 27 m building. It is desired to maintain an inside temperature of 15° C and 75% relative humidity. The design outside temperature is -18° C. (This value varies for locations across the country.)

Insulation Levels. Barn 1 (Fig. 7.10) contains RSI 1.4 of batt type insulation in the walls and ceiling, and no insulation around the foundation. Barn 2 (Fig. 7.11) contains RSI 4.9 in the ceiling, RSI 3.5 in the walls and RSI 1.4 of rigid insulation outside the foundation.

Heat Balance Comparisons. Barn 1 has a heat deficit at 15° C inside temperature. As shown, the heat gain from the pigs equals 58,600 watts (W), while the heat losses from ventilation and conduction equals 64,506 W. To maintain adequate ventilation for moisture control and keep the temperature at 15° C will require supplemental heating of (64,506 W - 58,600 W) = 5906 W. Using electrical energy at 5¢/kWh, the daily cost of heating this barn, when the outside temperature averages -18° C, will be:

(5906 W) x (1 kW/1000W) x ($0.05/kW) x (24 h/d) = $7.09

Barn 2, with its better insulation level, requires no supplemental heat. In fact the total heat gain from the animals (58,600 W) is greater than the total heat loss (55,567 W). The barn will either operate at slightly higher temperature or at a higher ventilation rate.

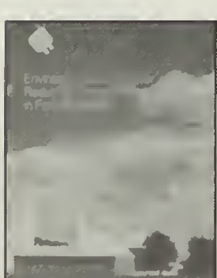
Other Benefits. Barn 2 will have much drier conditions than Barn 1 because the higher insulation levels help to prevent condensation on the inside surfaces of the walls, ceiling and foundation.

Where Supplemental Heat is Needed. As shown in this example, good insulation levels and ventilation control can save energy by using livestock heat effectively. However, in the colder regions of Canada, some supplemental winter heating is usually required, especially for farrowing and weanling barns, and poultry buildings. Heat exchangers can also greatly reduce the energy requirement by capturing heat from the ventilation air (see Section 7.5).

Infiltration. Heat also escapes from a building through cracks, around windows, doors and eaves. This can be reduced by caulking, weather-stripping, and careful installation of the vapour barrier.

Windows. Most new poultry and swine barns have no windows. Glass has a low insulation value and a high maintenance requirement. If windows are required they should be double glazed.

MORE INFORMATION:



1) **Environmental Control For Reducing Energy Waste In Farm Buildings.** Publication available from Energy Conservation Dept., Ontario Hydro, 700 University Ave., Toronto, Ontario M5G 1X6.

2) **Insulation In Farm Buildings.** Publication 1601, available from Communications Branch, Agriculture Canada, Ottawa, Ontario K1A 0C7.

3) **Insulation For Farm Buildings.** Factsheet No. 80-011, available from Ontario Ministry of Agriculture & Food, Information Branch, Legislative Buildings, Toronto, Ontario. M7A 1A5.

4) **The Canada Plan Service,** prepares detailed plans of modern livestock housing systems. Plans suitable for your specific climatic area are available from your local provincial agricultural engineer or extension advisor.

Heat Gain	Heat Losses	
Sensible heat produced by pigs 58 600 W	Heat required for sufficient ventilation to remove respired moisture	46 880 W
	Building Heat Loss:	
	Ceiling	8 438 W
	Walls, doors	5 186 W
	Footing	4 102 W
Total Gain 58 600 W	Total Loss	64 606 W

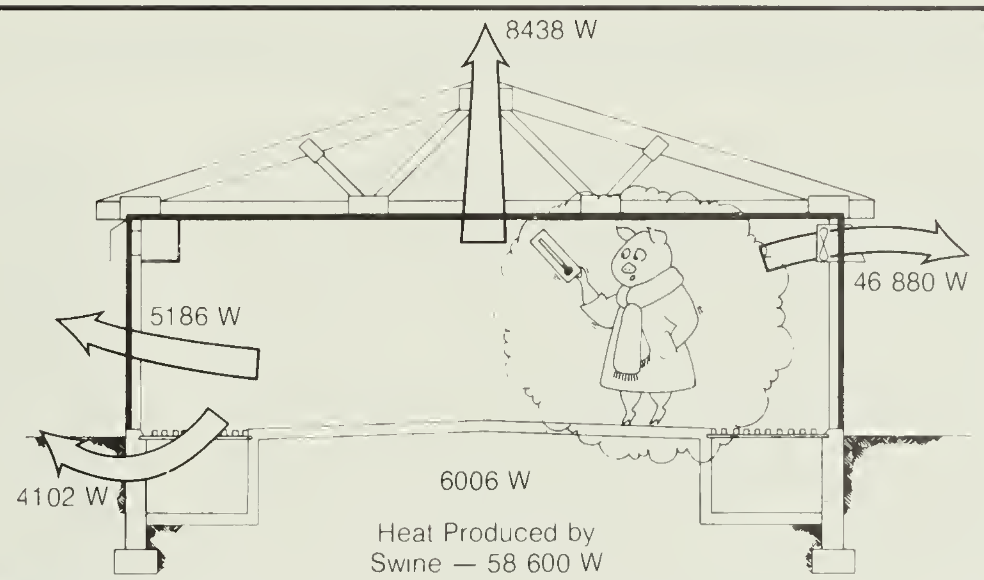


Fig. 7.10 Barn 1 — Inadequate Insulation, No Heat Balance
(Reference 1 of Section 7.2)

Heat Gain	Heat Losses	
Sensible heat produced by pigs 58 600 W	Heat required for ventilation to remove respired moisture	46 880 W
	Building Heat Loss:	
	Ceiling	3 076 W
	Walls, doors	2 783 W
	Footing	2 827 W
Total Gain 58 600 W	Total Loss	55 567 W

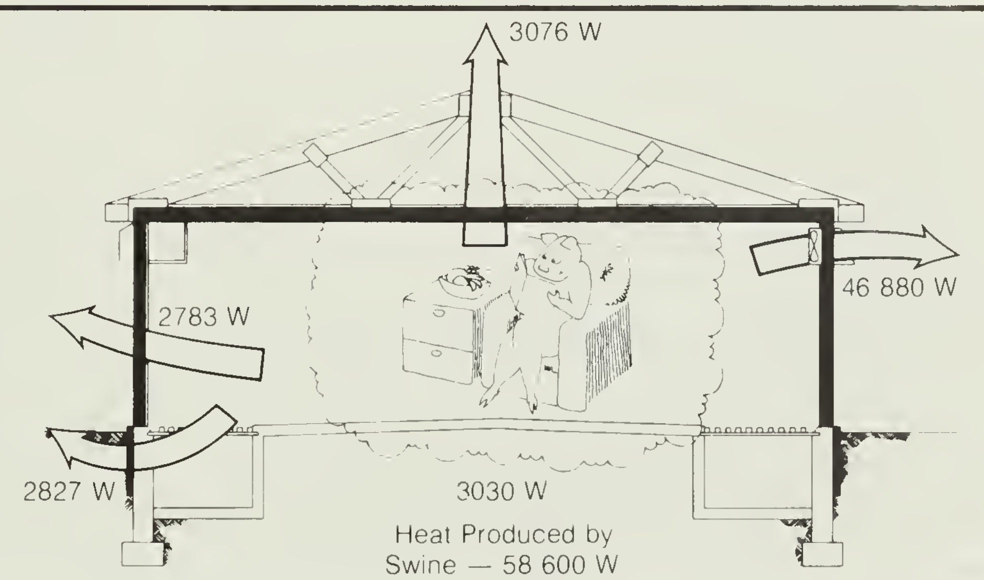


Fig. 7.11 Barn 2 — Adequate Insulation, Good Heat Balance
(Reference 1 of Section 7.2)

7.3 GETTING ALONG WITH YOUR VENTILATION SYSTEM

Modern confinement swine and poultry barns are designed to provide the best environment for livestock performance. But farmers often find that these barns don't create the ideal conditions they had expected, or that their heating costs are prohibitive.

Discussions with farmers, agricultural engineers and equipment suppliers suggest many reasons why a confinement barn may fail to perform as intended. Here are some ways to get the most from your barn investment.

1) Make sure you know exactly how the ventilation and heating systems were designed to operate. Learn the recommended thermostat settings and air inlet adjustments for all weather conditions. Don't expect the control systems to be totally automatic. They need careful, on-going adjustments by the operator. Ask the contractor or equipment supplier to check the system (and your management of it) at least once after the barn is in operation.

2) Keep the barn full. This is especially important in cold weather because the livestock help to heat the barn.

3) Check the thermostats. Buy a good thermometer and use it to calibrate the thermostat readings. Also, try to obtain a maximum/minimum indicating thermometer. This device will record how much the temperature fluctuates within the barn as weather conditions change. (Fig. 7.12)

4) Avoid overventilation in cold weather. The fans should be sized and controlled to provide "steps" of ventilation rates to match changes in outside temperature. A continuous, low-level, ventilation rate is necessary to control humidity in the barn (Fig. 7.14).

5) Ensure that the heating system operates only in conjunction with the minimum ventilation rate required for moisture control. Incorrect thermostat settings and/or inaccurate calibration, can cause the heaters and fans to work against each other, wasting large amounts of energy. The controls can be interlocked to prevent this problem. (See section 7.4)

6) Avoid rapid and frequent temperature changes in the barn. Oversized heating equipment wastes energy and causes animal stress by continually cycling on and off. A smaller heater running more of the time saves energy and creates a better environment.

Fig. 7.12 Thermostats Should be Checked Regularly with a Good Thermometer.

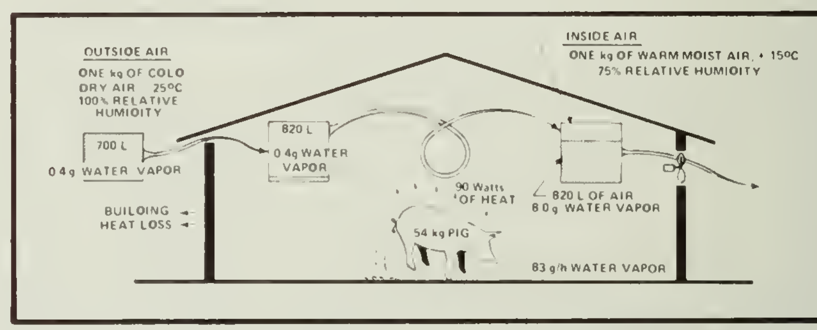


Fig. 7.13 Winter Ventilation for the Growing Pig in a Controlled Environment *(Reference 1 of Section 7.1)*

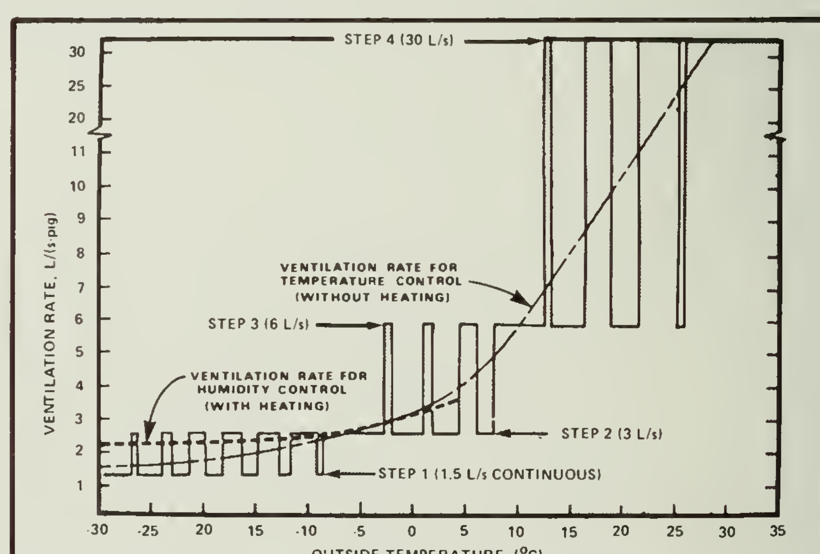
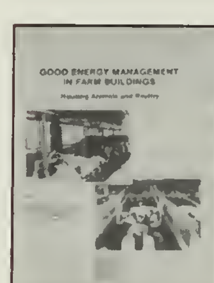


Fig. 7.14 Recommended Ventilation Rates in a Pig Barn *(Reference 1 of Section 7.1)*



MORE INFORMATION:

1) **Good Energy Management In Farm Buildings.** Report available from Engineering & Statistical Research Institute, Agriculture Canada, Research Branch, Ottawa, Ontario. K1A 0C6.

7.4 PREVENTING COMPETITION BETWEEN FANS AND HEATERS

Tests have shown that most ventilation and heating systems installed in livestock barns waste energy by working against each other. The cause is easy to correct. All that is needed is an interlocking control system which prevents the larger fans from coming on while the heating system is operating.

EXAMPLE

Location: London, Ontario

Barn: Insulated calf barn 5.5 x 10.7 m, housing 7 calves and 14 heifers. Environmental control is achieved by a forced air electric heater and two 2-speed ventilation fans. The heating/ventilating controls were operated with and without an interlocking system for alternating periods.

Results: The interlocking controls reduced the heating energy consumption by 32% with no ill effects on the calves.

Economics: The added cost of the interlocking control was about $100. With electricity priced at $0.05/kWh, the annual saving was estimated at $50.00, for a payback period of 2 years. (Note that this is a relatively small barn. In larger operations the interlocking system may save several hundred dollars per year.)

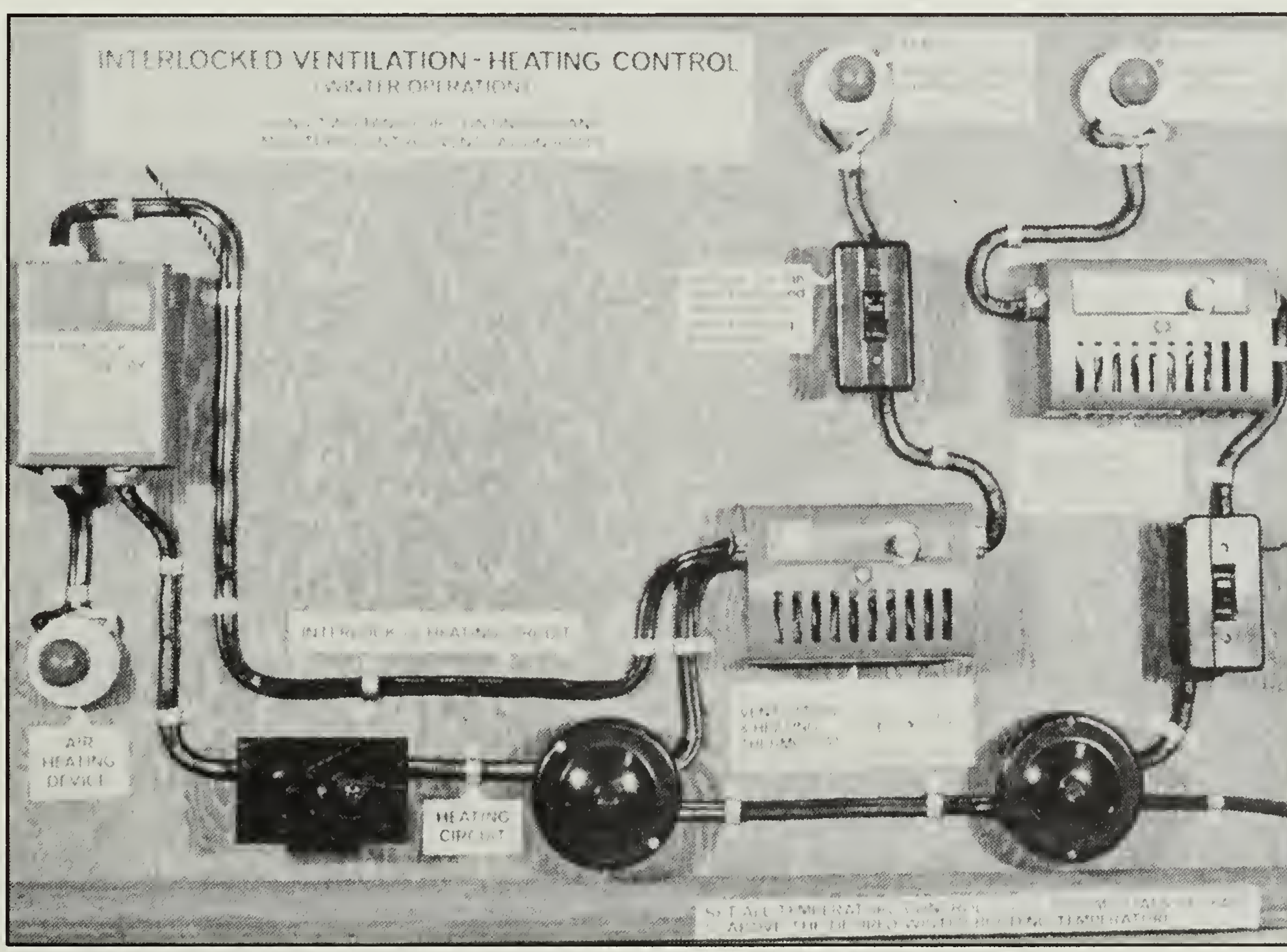
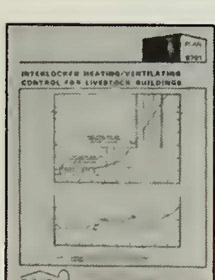


Fig. 7.15 Interlocked Ventilation — Heating Controls *(Reference 1. Section 7.2)*



MORE INFORMATION:

1) **Interlocked Heating/Ventilating Control For Livestock Buildings.** Canada Plan Service, Plan 9701, available from provincial agricultural engineers or extension advisors.

2) **Saving Energy By Interlocked Heating/Ventilating Controls In Livestock Barns.** Publication No. I-205, available from Engineering and Statistical Research Institute, Agriculture Canada, Ottawa, Ontario K1A 0C6.

7.5 WILL NATURAL VENTILATION WORK FOR YOU?

Natural vs Mechanical Ventilation. Natural ventilation was used extensively in the original two-story livestock barns built throughout Canada. The system required frequent manual adjustment especially in varying weather conditions. The shift to specialized confinement livestock buildings in the 1960's provided automated control of mechanical ventilation systems. Electrical fans controlled by thermostats are now considered the "standard" ventilation system in most types of confinement barns.

Renewed interest in natural ventilation has developed for certain types of barns:

1) **Cold Confinement Barns.** Typically used for beef and dairy animals, these barns are ventilated by natural air movement through adjustable wall panels and ridge vents. Insulation helps to prevent condensation under the roof.

   Figure 7.17 shows a simple system for a wall inlet named a "turkey curtain" due to its origin in turkey barns in the southern United States. This concept is now used in several Ontario beef barns. The curtain is made from a plastic material called lumite. It is commercially available, complete with cables and a winch to raise and lower the curtain.

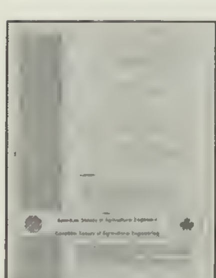
   Natural ventilation works fairly well in cold confinement barns, provided that someone is responsible for adjusting the inlets when required.

2) **Warm Confinement Barns.** Farmers who have witnessed the poor winter performance of open-front hog barns in Canada may be justifiably skeptical of natural ventilation. The important criteria for design of a natural ventilation system in warm confinement barns is that the controls must automatically adjust for sudden changes in weather conditions. Adaptation of automatic controllers from the greenhouse industry have been used to ventilate hog barns with natural air movement. The vents are opened and closed by electrical power or pneumatic actuators controlled by thermostats.

Economics. A fully automatic natural ventilation system for a warm confinement barn costs as much or more than a comparable fan ventilation system. However, the operating costs are much less. Improved animal health and reduced noise are also cited as reasons for installing a natural ventilation system.

Pitfalls. A successful natural ventilation system requires careful design and management. The control technology is changing very rapidly. The experience of existing installations should be evaluated before proceeding with this concept.

Fig. 7.16 Cold Confinement Beef Barn



MORE INFORMATION:

1) **A Swine Finishing Barn With Automatically Controlled Natural Ventilation.** Report available from Ontario Ministry of Agriculture and Food, Stratford, Ontario. N5A 5W2.
2) **Natural Ventilation Of Swine Buildings: Alberta Observations.** Report available from Alberta Agriculture, 4920 - 51 Street, Red Deer, Alberta. T4N 6K8.
3) **Is Natural Ventilation The Answer For Manitoba's Swine Farms?** Paper available from Manitoba Agriculture, Engineering Section, 911-401 York Ave., Winnipeg, Manitoba R3C 0V8.
4) **Turkey Curtain For Cold Confinement Ventilation.** Factsheet No. 81-059, available from Ontario Ministry of Agriculture and Food, Information Branch, Legislative Buildings, Toronto, Ontario. M7A 1A5.
5) **Natural Ventilation of Hog Barn.** Pilot Projects Summary #050, available from Nova Scotia Dept. of Mines and Energy, P.O. Box 668, Halifax, Nova Scotia, B3J 2T3.

Fig. 7.17 Adjusting a Turkey Curtain

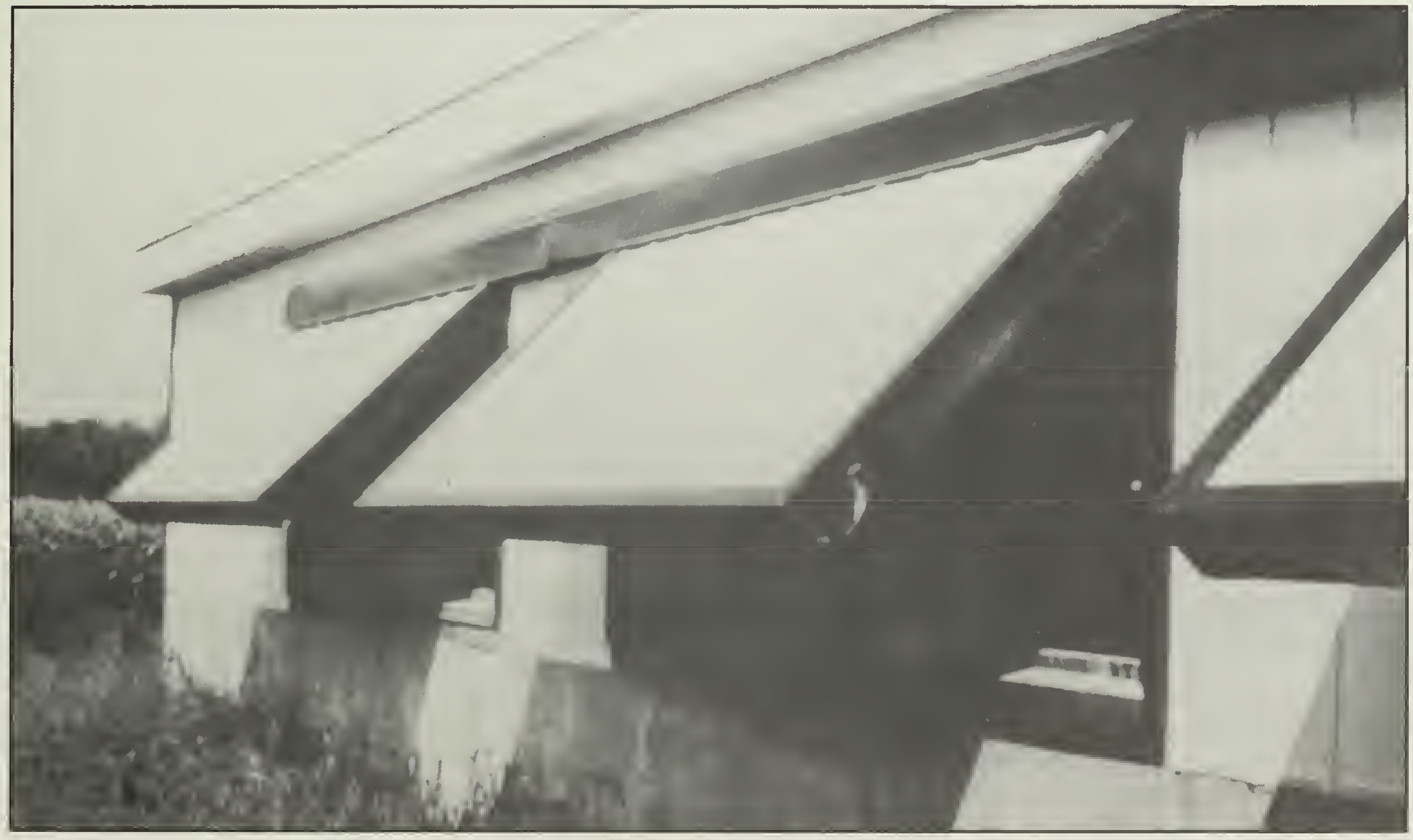


Fig. 7.18 Wall Panels for Natural Ventilation

7.6 HEAT EXCHANGERS — RECYCLING ENERGY

Opportunities to recover and reuse heat energy occur in mechanically ventilated barns and in refrigeration systems used for milk cooling.

VENTILATION HEAT RECOVERY.

During the winter 85% of heat loss from an insulated livestock barn is through the ventilation system. If the ventilation rate drops below the recommended minimum air flow the environment will become too humid, resulting in condensation problems within the barn. (Fig. 7.19). In most parts of Canada, supplemental heat is needed to allow adequate ventilation in cold weather.

Heat exchangers can provide some of the energy needed by recovering heat from the ventilation air. Various configurations and materials are used in the heat exchanger construction, but they all operate on the same basic principle. The warm moist air is exhausted across a series of tubes or plates, transferring heat to the cold intake air. (Fig. 7.20).

Benefits. In addition to saving energy, heat exchangers can improve the barn environment by maintaining drier, fresher conditions.

Problems.

1) In dusty conditions some heat exchangers require frequent cleaning to prevent plugging.
2) Freezing can occur in the heat exchanger if the plate temperature drops below 0° C. Freezing can be prevented by adjusting air flows, or by automatic defrosting.
3) Condensation from the unit must be disposed of to prevent ice buildup outside the barn.
4) Ventilation patterns can be disrupted by adding heat exchangers to an existing barn. Care must be taken to prevent drafts and maintain a proper air distribution within the barn.

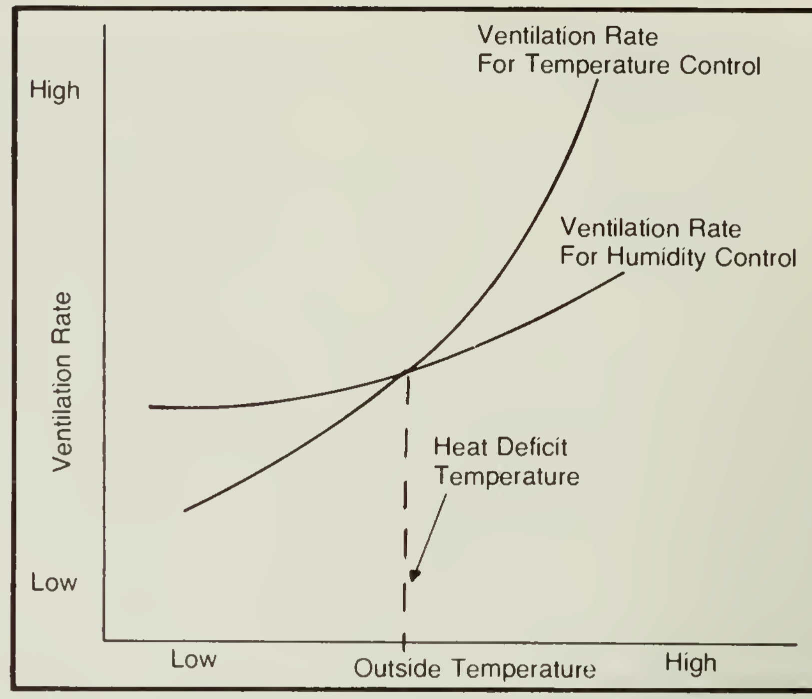


Fig. 7.19 Ventilation Rate vs Outside Air Temperature *(Reference 3)*

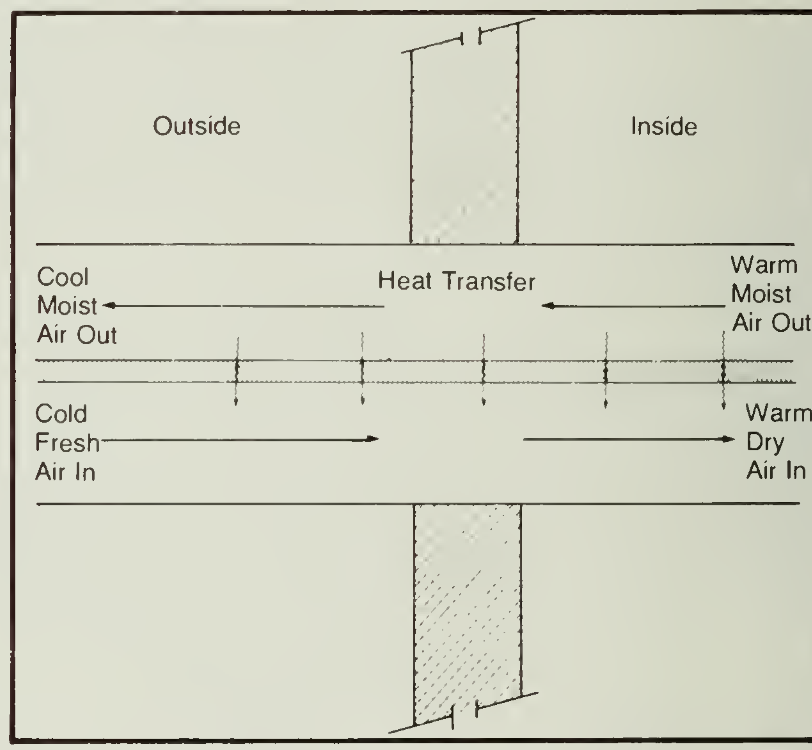
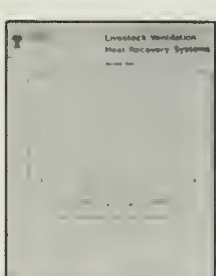


Fig. 7.20 Heat Transfer in an Air to Air Heat Exchanger. Heat is Transferred from the Exhaust Air to the Intake Air but the Two Air Streams Never Mix. *(Reference 3)*



MORE INFORMATION:

1) **Livestock Ventilation Heat Recovery Systems.** Publication available from Family Farm Improvement Branch, Saskatchewan Agriculture, 3085 Albert Street, Regina, Saskatchewan. S4S 0B1.
2) **Reclaiming Ventilation Heat Losses With Heat Exchangers.** Report available from the Engineering & Home Design Branch, Alberta Agriculture, 7000 - 113 St., Edmonton, Alberta. T6H 5T6.
3) **Air To Air Heat Exchangers For Winter Ventilation.** Factsheet No. 82-054, available from Ontario Ministry of Agriculture & Food, Information Branch, Legislative Buildings, Toronto, Ontario M7A 1A5.
4) **Heat Exchangers: Field Experience for Alberta.** Technical paper, available from the Engineering & Home Design Branch, Alberta Agriculture, 7000 - 113 St., Edmonton, Alberta. T6H 5T6.

EXAMPLE

Location: Walkerton, Ontario.

Livestock — 100 weaner pigs.

Economic Analysis. A heat exchanger costing $1500 is expected to reduce the heating cost by $288 in year 1, based on electrical heating at 4¢/kWh. Operation and maintenance cost is expected to be $50.00/year. Calculate the payback period and the cash flow, assuming a 10-year lifetime, a 3 year loan at 12.5% interest, and a 25% marginal tax rate.

Payback period = (Capital Cost/Net Year 1 Savings) = ($1500)/($288-$50) = 6.3 years.

Cash Flow. (See Fig. 7.21)

Conclusion. Energy savings will pay for this heat exchanger in 6.3 years. Improved environmental conditions should also be considered.

Capital Cost	$1500	Revenue first year	$288
Deduct Startup Costs	$0	Revenue Increase per yr (%)	8.0
Inputs (exp) first yr	$50	Loan Term (yrs)	3
Input Increase per yr (%)	8.0	Loan Interest Rate	12.50
Income Tax Rate (%)	25	Loan (1 = Ammort., 2 = Dim. Bal.)	1
General Inflation Rate	8	Loan Payments per year	1
C.C.A first year (%)	25.0	Study Scope (1 = all, 2 = part)	2
C.C.A. 2nd year (%)	50.0	Study Term In Years	10
C.C.A. other years (%)	25.0	Starting Year of Study	1
CCA Type (1 = dim, 2 = orig)	2	Downpayment	$0

Year	Inputs	Revenue	Principal	Interest	Taxes	Cashflow	Total CF	CCA
1	50.00	288.00	442.40	187.50	-81.13	-310.77	-$310.77	375.00
2	54.00	311.04	497.70	132.20	-156.29	-216.57	-$527.34	750.00
3	58.32	335.92	559.91	69.99	-41.85	-310.45	-$837.78	375.00
4	62.99	362.80	0.00	0.00	74.95	$224.86	-$612.93	0.00
5	68.02	391.82	0.00	0.00	80.95	242.84	-$370.08	0.00
6	73.47	423.17	0.00	0.00	87.43	262.28	-$107.80	0.00
7	79.34	457.02	0.00	0.00	94.42	283.26	-$175.45	0.00
8	85.69	493.58	0.00	0.00	101.97	305.92	$481.37	0.00
9	92.55	533.07	0.00	0.00	110.13	330.39	$811.76	0.00
10	99.95	575.71	0.00	0.00	118.94	356.82	$1168.59	0.00
End of run	Total Cash Flow (present value)				$472.05			

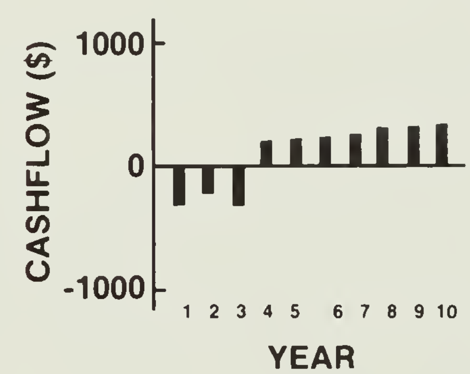


Fig. 7.21 Cash Flow Analysis: Barn Heat Exchanger — $1500 — 3 Year Loan

HEAT RECOVERY FROM MILK.

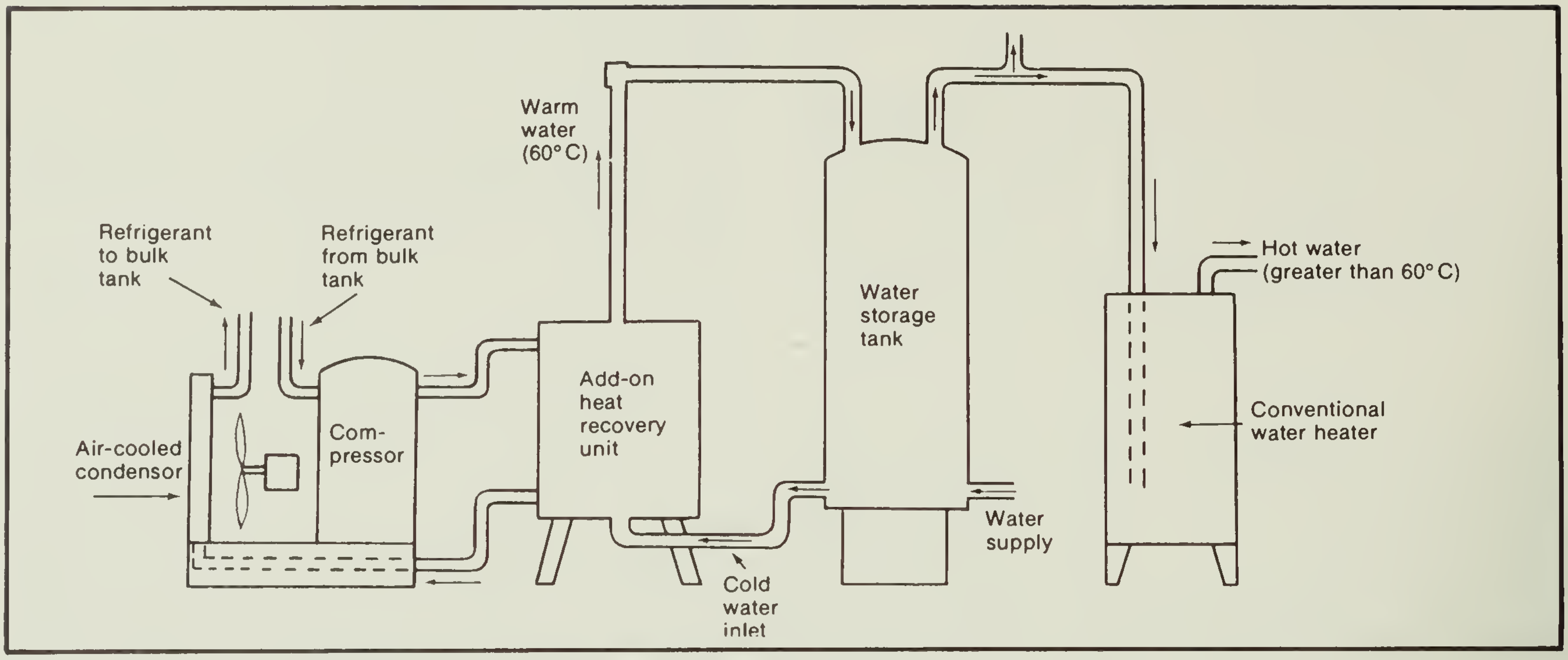


Fig. 7.22 Add-on Heat Exchanger for a Milk Cooling System *(Reference 2)*

Milk refrigeration equipment offers a source of "free" energy which can be used to heat water in a dairy operation. Various types of commercial heat reclaimers are available from dairy equipment suppliers. Fig. 7.22 shows a typical layout for an add-on heat recovery unit.

Daily Milk Production (L)	Daily Hot Water Used (L)	Annual Energy Saving (kWh)
500	310	3110
700	430	4360
900	560	5605
1100	680	6850
1300	800	8090
1500	930	9340

Fig. 7.23 Examples of Expected Energy Savings with a Milk Heat Exchanger *(Reference 2)*

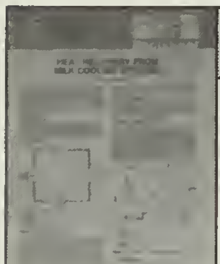
Energy Savings. As shown in Fig. 7.23, the potential energy savings with a milk-heat exchanger depends upon the amount of milk produced and the amount of hot water required.

Economic Analysis. Assume a $1700 heat recovery unit is installed in a dairy which produces 1100 L of milk per day and uses 680 L/d of hot water, supplied by electrical heating at 4¢/kWh. From Fig. 7.23 the expected annual energy saving = 6850 kWh. At 4¢/kWh, the year 1 savings = ($0.04/kWh x 6850 kWh) = $274.00.

Payback period = (Capital Cost/Year 1 Savings) = ($1700/$274) = 6.2 years.

Cash Flow. Fig. 7.24 shows cash flow projections for the investment, using a 10-year loan.

Conclusion. This is an attractive investment for larger dairy operations with water heating costs of several hundred dollars per year.



MORE INFORMATION:

1) **Heat Recovery From Milk Cooling Systems.** Factsheet No. 82-065, available from Information Branch, Ontario Ministry of Agriculture and Food, Legislative Buildings, Toronto, Ontario. M7A 1A5.
2) **Economic Analysis of Milk Heat Reclaimers.** Canadex No. 825.028, available from Communications Branch, Agriculture Canada, Ottawa, Ontario. K1A 0C7.
3) **This Tottenham Dairy Farm Produces Hot Water As Well As Milk.** Factsheet No. 1, available from Energy Conservation Dept., Ontario Hydro, 700 University Ave., Toronto, Ontario. M5G 1X6.
4) **Energy Recovery From Milk.** Report available from The Agricultural Energy Centre Ontario Ministry of Agriculture and Food, P.O. Box 1030, Guelph, Ontario. N1H 6N1.
5) **Energy Conservation In The Milking Parlour.** Report I-354, available from Engineering & Statistical Research Institute, Research Branch, Agriculture Canada, Ottawa, Ontario. K1A 0C6.

Capital Cost	$1700	Revenue first year	$274
Deduct Startup Costs	$0	Revenue Increase per yr (%)	8.0
Inputs (exp) first yr	$0	Loan Term (yrs)	10
Input Increase per yr (%)	0.0	Loan Interest Rate	12.50
Income Tax Rate (%)	25	Loan (1 = Ammort., 2 = Dim. Bal.)	2
General Inflation Rate	7	Loan Payments per year	1
C.C.A first year (%)	25.0	Study Scope (1 = all, 2 = part)	2
C.C.A. 2nd year (%)	50.0	Study Term In Years	10
C.C.A. other years (%)	25.0	Starting Year of Study	1
CCA Type (1 = dim, 2 = orig)	2	Downpayment	$0

Year	Inputs	Revenue	Principal	Interest	Taxes	Cashflow	Total CF	CCA
1	0.00	274.00	170.00	212.50	-90.88	-17.63	-$17.63	425.00
2	0.00	295.92	170.00	191.25	-186.33	121.00	$103.38	850.00
3	0.00	319.59	170.00	170.00	-68.85	48.45	$151.82	425.00
4	0.00	345.16	170.00	148.75	49.10	-22.69	$129.13	0.00
5	0.00	372.77	170.00	127.50	61.32	13.96	$143.09	0.00
6	0.00	402.60	170.00	106.25	74.09	52.26	$195.35	0.00
7	0.00	434.80	170.00	85.00	87.45	92.35	$287.70	0.00
8	0.00	469.59	170.00	63.75	101.46	134.38	$422.08	0.00
9	0.00	507.16	170.00	42.50	116.16	178.49	$600.57	0.00
10	0.00	547.73	170.00	21.25	131.62	224.86	$825.43	0.00
End of run		Total Cash Flow (present value)			$538.57			

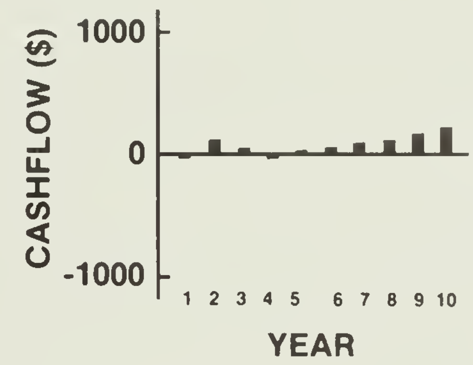


Fig. 7.24 Cash Flow Analysis: Milk Heat Reclaimer — $1700 — 10 Year Loan

7.7 ENERGY COSTS IN FEED PROCESSING

Feed processing systems vary greatly in energy requirements. The impact of rising energy costs should be a major consideration in selecting a system.

Fig. 7.25 shows a 1982 comparison of two common on-farm feed processing systems; (1) a mobile grinder-mixer powered by a tractor PTO, and (2) a stationary blender-grinder powered by an electric motor.

This comparison was made when diesel fuel cost 22¢/L and electricity cost 3.3¢/kWh. Let us examine the effects of higher energy prices on these two systems:

1) **PTO Grinder-Mixer.** If fuel and lubricant prices increased by 100% (to 44¢/L for diesel fuel), the processing cost would increase by **$2.37/t.** If you process 500 tonnes of feed per year, your costs would increase by (500t x $2.37/t) = **$1185.00.**

2) **Electric Blender-Grinder.** If the electricity price increased by 100% (i.e., to 6.6¢/kWh) the processing cost would increase by only **$0.29/t.** If you process 500 tonnes of feed per year, your costs would increase by (500t x $0.29/t) = $145.00.

Conclusion. Based solely upon energy efficiency, all feed processing should be done by electric power. However, many other factors may influence the system requirements on a given farm; including, for example:

- the size of electrical service on the farm,
- the need for mobility in feed distribution,
- existing feed storage and handling systems,
- safe storage time of high moisture feed.

For a more complete discussion of feed processing options, consult Agriculture Canada Publication 1572E.

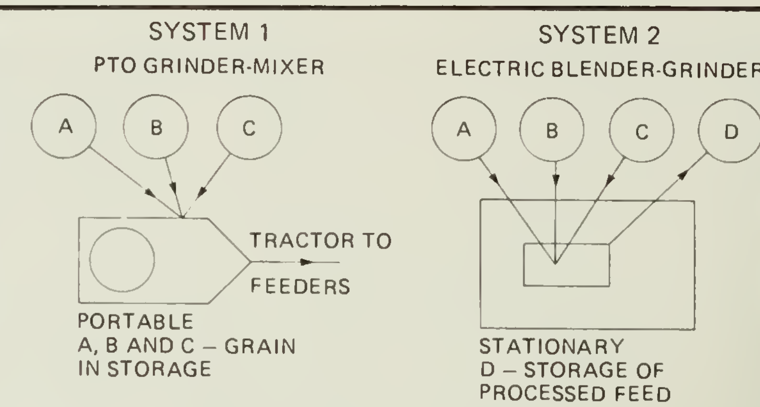


Figure 1 Economic analysis of three feed processing systems

Capital investment	*Cost*
PTO grinder-mixer	$5500
3 augers and motors plus wiring	$1200
Total	$6700
Annual fixed costs	
Depreciation	$ 670
Repairs	$ 201
Interest 18%	$ 603
Insurance	$ 23
Total	$1497
Variable costs	
Capacity 2 t/h	
Horsepower used 45 kW	
Fuel costs/h	$ 4.12
Lubricant costs/h	.62
Fixed costs/h on tractor	$ 4.00
Labor costs/h	$ 6.00
Total variable costs/h	$14.74
Variable costs/t	$ 7.37

Capital investment	*Cost*
3.7 kW mix mill with motor	$3200
4 augers and motors	$ 800
Controls for automation	$ 400
Wiring	$1000
Processed feed bin (16t)	$2200
Total	$7600
Annual fixed costs	
Depreciation on equipment	$ 540
Depreciation on buildings	$ 110
Repairs	$ 228
Interest 18%	$ 684
Insurance on equipment	$ 11
Insurance on buildings	$ 22
Total	$1595
Variable costs	
Capacity 500 kg/h	
Electrical costs/t	$0.29
Labor costs/t	$3.00
Total variable costs/t	$3.29

Fig. 7.25 Comparison of Feed Processing Costs *(Reference 1)*

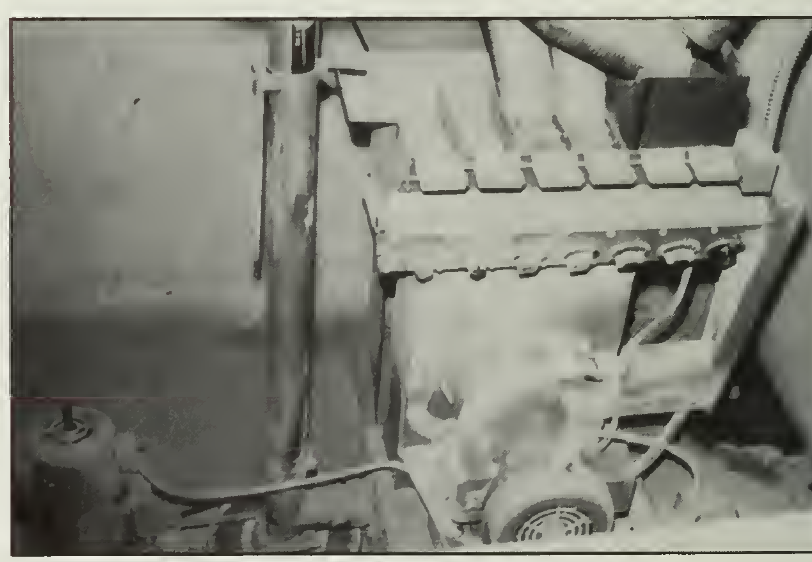
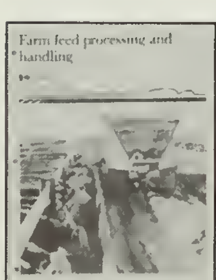


Fig. 7.26 An Electric Blender Grinder



MORE INFORMATION:

1) **Farm Feed Processing And Handling.** Publication 1572E, available from Communications Branch, Agriculture Canada, Ottawa, Ontario. K1A 0C7.

2) **Feed Mill Energy Consumption.** Report available from Co-operative Extension Service, Virginia Polytechnic Institute And State University, Blacksburg, Virginia 24061.

3) **Stationary Blender-Grinders — A Field Evaluation.** Report available from Agricultural Energy Centre, Ontario Ministry of Agriculture and Food, P.O. Box 1030, Guelph, Ontario. N1H 6N1.

4) **Grain Handling On The Farm.** Publication 1713E, available from Communications Branch, Agriculture Canada, Ottawa, Ontario. K1A 0C7.

7.8 ELECTRIC LOAD CONTROL IN A LIVESTOCK OPERATION

A farmer designing a large hog barn was advised by his electrician that the total power demand for the proposed barn would be 97.3 kW. Since the maximum single phase load allowed by the utility was 75 kW, this would have required installation of a 3-phase power line at a cost of about $45,000.

In consultation with the local utility representative and agricultural extension engineer the electrical system was redesigned to reduce the peak demand to 64.4 kW, as shown below.

Load	Design 1	Design 2
Feeding System Motors	14.0 kW	5.1 kW
Ventilation motors	46.4 kW	37.7 kW
Misc. motors	9.3 kW	5.1 kW
Indoor Lighting	23.7 kW	12.6 kW
Outdoor Lighting	0.9 kW	0.9 kW
Office Load	3.0 kW	3.0 kW
TOTAL	97.3 kW	64.4 kW

Load Control Methods Used

1) **Feeding System.** Time clocks were used to control the number of motors operating at one time in the feeding system. This reduced the electrical load by 8.9 kW.

2) **Ventilation Motors.** Specifying high efficiency motors for 29 ventilation fans reduced the electrical demand by 8.7 kW. This also reduced the operating cost by an estimated $198.50 per month during summer operation. The more efficient motors cost an extra $45.00 each for a total of $1,305.00.

3) **Lighting.** The first design specified 150 incandescent lights at 100 W each, totalling 15 kW. Replacing them with moisture proof fluorescent fixtures reduced the lighting load by 3.9 kW. The increased installation cost was about $3,000. However savings in operating costs would make this a good investment even if load control was not needed. Annual estimated saving with fluorescent lights included $169.20 for reduced demand charge, $1,434.96 for reduced electricity use, and $420.00 for less bulb replacement.

Summary. Many farms could benefit from electrical load control. If you are on a demand meter, peak load reduction will save you money. Savings on this farm were over $40,000 in reduced capital costs plus $2,600 per year in lower operating costs.

MORE INFORMATION:

1) The details used in this example were supplied by Bill Henley, Saskatchewan Agriculture and Rand Luhning, Saskatchewan Power Corporation.

7.9 MAKING THE MOST OF MANURE

Livestock manure should be considered as a valuable resource rather than a waste product. Here are some tips on profitable manure management.

1) Use a storage system that saves the liquids in manure. Liquid runoff or seepage wastes valuable nutrients.
2) Calculate the fertilizer content of manure from standard tables (or lab analysis, if available).
3) Save on fertilizer by including manure application rates in the soil test information.
4) Spread manure uniformly on unfrozen ground.
5) Work the manure into the soil immediately after spreading to reduce nitrogen losses.

EXAMPLE

Estimate the fertilizer value of the manure produced in one year by a 1000 head grower/finisher hog operation.

Calculations.

1) From Fig. 7.29, the annual nutrient output (in liquids and solids) is:

N = (0.032 x 365 x 1000) = 11,600 kg

P_2O_5 = (0.018 x 365 x 1000) = 6,270 kg

K_2O = (0.011 x 365 x 1000) = 4,015 kg

2) At commercial fertilizer prices the **potential** value of the manure is:

N = (11,660 kg x $0.70/kg) = $8,162

P_2O_5 = (6,370 kg x $0.65/kg) = $4,076

K_2O = (4,015 kg x $0.40/kg) = $1,606

Total = $13,844

Fig. 7.27 **Manure is a Valuable Fertilizer Source.**

Method of application	Type of waste	Nitrogen lost
Broadcast	Solid	21%
	Liquid	27%
Broadcast with immediate cultivation	Solid	5%
	Liquid	5%
Knifing	Liquid	5%
Sprinkler irrigation	Liquid	30%

Fig. 7.28 **Ammonium Nitrogen Losses to the Air.**

3) Assuming a minimum loss storage and handling system the nutrient value retained for crop use may be about 90% of the P_2O_5 and K_2O, and 65% of the N:

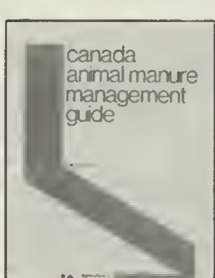
N = ($8,162 x 0.65) = $5,305

P_2O_5 = ($4,076 x 0.90) = $3,668

K_2O = ($1,606 x 0.90) = $1,445

Total = $10,418

Other Benefits. Manure also supplies trace elements and improves soil tilth.



MORE INFORMATION:

1) **Canada Animal Manure Management Guide.** Publication 1534, available from Communications Branch Agriculture Canada, Ottawa, Ontario K1A 0C7.
2) **Experiences With Floating Covers For Cylindrical Concrete Manure Storages.** Report I-229, available from Engineering & Statistical Research Institute, Research Branch, Agriculture Canada, Ottawa, Ontario K1A 0C6.
3) **Manures And Compost.** Publication 868, available from Communications Branch Agriculture Canada, Ottawa, Ontario K1A 0C7.
4) **Management And The Nutrient Value Of Manure.** Factsheet No. 380.700-1, available from British Columbia Ministry of Agriculture and Food, Victoria, B.C. V8W 2Z7.
5) **Investigate Tax Benefits.** Environment Canada encourages better pollution control systems. If your farm was producing livestock before 1974 you could be eligible for an accelerated tax write-off (3 years) on the proposed manure tank and the associated equipment. Details and application forms are available from Environment Canada, ACCA Program, Ottawa, Ontario K1A 0H3.

Animal	Volume of manure /animal* (L/day)	Volume of manure & bedding /animal* (L/day)	Undiluted manure moisture (%)	Urine in manure (%)	Nutrients/animal** N (g/day)	P_2O_5 (g/day)	K_2O (g/day)
Cattle							
Beef or dairy calf (0-3 mo)	5.4						
Beef or dairy calf (3-6 mo)	7.1						
Beef feeder or dairy heifer (6-15 mo)	14.2	17.0		35	77	36	91
Beef feeder or dairy heifer (15-24 mo)	21.2	22.6					
Beef cow (545 kg)	28.3	34.0					
Dairy cow (545 kg)	45.3		87	30	172	82	204
Open pen loose housing		56.6					
Free stall loose housing		48.1					
Tie stall		50.9					
Swine							
20-90 kg (8-22 wk)	5.1		91	45	**32**	**18**	**11**
5-10 kg (3-6 wk)	1.1						
11-20 kg (6-9 wk)	2.3						
21-35 kg (9-12 wk)	3.4						
36-55 kg (12-16 wk)	5.1						
56-80 kg (16-20 wk)	7.4						
81-90 kg (20-22wk)	9.1						
Sow	11.3	13.6					
Chicken				0			
Broiler (0-1.8 kg)	0.08	0.14	litter-25				
Laying hen (1.8 kg)	0.14		77		1.45	1.1	0.6
Turkey			75	0			
Broiler (0-14 wk)	0.13						
Growing hen (0-22 wk)	0.18						
Growing tom (0-24 wk)	0.28						
Breeder	0.34						
Rabbit (doe and litter)	0.71						
Ewe sheep	2.8	4.2	75	50	20	7	17
Horses	26.0	56.6	80	20	122	50	91
Mink (female and kits)	0.20						

*Adapted from Canadian Farm Building Code, Associate Committee on the National Building Code, National Research Council of Canada, Ottawa.
**Manure analyses by an appropriate laboratory are advisable since the actual nutrient contents can vary in practice.

Fig. 7.29 Animal Manure Characteristics (Nominal Values for Urine and Feces as Voided)
(Reference 1)

8 RENEWABLE ENERGY — OPPORTUNITIES AND PITFALLS

Could A Farm Operate On Renewable Energy? Yes. A modern farm could be made nearly self-sufficient in energy. Part of the farmland would be needed to produce fuel crops. Solar, wind and biomass energy could supply heat and electricity.

Is It Economical? No. Nearly all renewable energy sources are more expensive than conventional forms of energy.

Is It Reliable? Generally, no. The technology of renewable energy systems for farms is still in the research and development stage.

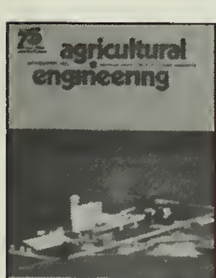
Will The Farm Of The Future Be Energy Self-Sufficient? Maybe, but not in the near future. The best economics are presently in conservation and efficient use of commercial energy. However, some applications of renewable energy may become competitive in the next few years.

Could Energy Become A Cash Crop? Yes. Instead of trying to become self-sufficient in energy, farmers might supply the feedstock for energy production by a local industry. This concept has already been demonstrated by alcohol plants converting corn to ethanol for use in "gasohol" fuels.

Isn't There A Food Versus Fuel Controversy? Yes. But seldom among farmers. They continually produce more crops than the market can absorb. Farmers would welcome another market for some of their products.

Is Research Underway On Renewable Energy? Yes. Agriculture Canada and other institutions are investigating the potential energy production and substitution on farms. A major effort involves an assessment of special crops which might provide liquid fuels in the future. Work is also underway to test methane digesters, solar collectors, windmills and straw burners for farm use.

Fig. 8.1 Agriculture Canada has Sponsored Several Farm-Scale Energy Projects. This is a Straw Burner Under Evalua-tion in Nova Scotia. *(See Section 8.5)*



MORE INFORMATION:

1) **The Energy Farm Concept.** Agricultural Engineering, November, 1982.

2) **Agriculture Canada's Liquid Fuels R & D Program.** Report I-349, available from Engineering and Statistical Research Institute, Agriculture Canada, Ottawa, Ontario K1A 0C6.

3) **Bioenergy Research And Development.** Available from Publications, National Research Council of Canada, Ottawa, Ontario K1A 0R6.

4) **Alternatives To Our Present Use Of Fossil Fuels In The Agriculture And Food System.** Report No. 253, available from Engineering and Statistical Research Institute, Agriculture Canada, Ottawa, Ontario K1A 0C6.

8.1 SOLAR ENERGY

Agriculture is the business of converting solar energy to food energy. Farmers are well aware of the power and importance of solar energy.

Can solar energy replace some of the heating fuels and electricity presently used on farms? The answer is "yes, but it has to pay".

Here is an evaluation of some potential uses for solar energy on farms:

Passive Home Heating. Southerly orientation of windows can provide free solar heat, and help reduce the cost of heating a farm home. But don't add extra windows beyond what you want for a view. The added heat loss through windows at night usually offsets the solar gain in the daytime. Windows should be at least double glazed to prevent heat loss.

Shop Heating. A passive solar collector can help to heat a farm shop. When built into the original structure the added cost is about $15 per square metre (m^2) of wall. This is an excellent application to get some experience with solar heating at a low cost.

Solar Ventilation Wall. Research by the University of Saskatchewan, Agriculture Canada, and Ralph G. Winfield & Associates has developed the concept of a "solar wall" to preheat ventilation air in livestock barns. Special heavy concrete blocks are used to provide thermal mass to store daytime solar heat for release throughout the night. The added construction cost is about $55/m^2. The estimated payback period is 3-5 years for most locations.

Fig. 8.2 A Solar Wall For Preheating Ventilation Air In a Swine Barn

Water Heating. Deceptively simple in concept, many solar water heaters are plagued by leaks, corrosion, freezing, poor performance and high costs. You could build your own system as a hobby but be prepared to babysit it.

Grain Drying. Widely suggested as a perfect use for the solar energy, the opposite is nearer the case. The problem is very basic: when you need drying the most you get the least sunshine. This means you have to invest in a conventional drying system anyway as a backup.

Electrical Generation. An exciting potential use of solar energy is to produce electricity through photovoltaic conversion. (Fig. 8.3) While presently very expensive ($1.00/kWh) the technology is evolving very rapidly. Most experts predict that the cost of solar generated electricity will continue to decrease as more efficient systems become available.

MORE INFORMATION:

1) **The Sun Book.** Booklet available from Nova Scotia Department of Mines and Energy, P.O. Box 668, Halifax, Nova Scotia. B3J 2T3.

2) **Passive Solar Shop Heating.** (Factsheet No. 81-069). **Solar Ventilation Wall With Heat Storage** (Factsheet No. 82-066). Available from Ontario Ministry of Agriculture and Food, Information Branch, Legislative Buildings, Toronto, Ontario. M7A 1A5.

3) **Thrombe Wall Solar Collector.** CREDA report, available from Energy Technology Branch, Saskatchewan Energy & Mines, 1914 Hamilton St., Regina, Saskatchewan. S4P 4V4.

4) **Prospects For Solar And Wind Energy Utilization In Alberta.** Booklet available from Resource Information Services, Alberta Energy And Natural Resources, 7th Floor, South Petroleum Plaza, 9915 - 108 Street, Edmonton, Alberta. T5K 2C9.

5) **An Analysis Of Solar Radiation Data For British Columbia.** RAB Bulletin 14, available from British Columbia Ministry of Environment, Resources Analysis Branch, Victoria, B.C.

6) **Turn On The Sun.** Booklet available from Ontario Ministry of Energy, Information Office, 56 Wellesley Street West, Toronto, Ontario. M7A 2B7.

7) **Active Solar Collectors — Are They A Good Investment?** Factsheet Pm-1034, available from Cooperative Extension Services, Iowa State University, Ames, Iowa 50011.

8) **Solar Energy Program.** Publication list available from: Publication Sales and Distribution Office, National Research Council, Building M-58, Montreal Road, Ottawa, Ontario. K1A 0R6.

9) **"Photovoltaics" — Sunlight To Electricity In One Step.** Published by Brickhouse Publishing Co., 34 Essex St., Andover, Mass., U.S.A. 01810.

10) **Solar Heating For Livestock Buildings** Available from U-Learn Center, University of Saskatchewan, Saskatoon, Saskatchewan. S7N 0X1

EXAMPLE — PHOTOVOLTAICS

Location: Colinton, Alberta.

Application: Photovoltaic panels and a propane generator supply electricity for a country home located 3 km from the utility power grid.

System Specifications.

- 14 ARCO photovoltaic panels, peak combined output = 500 watts.
- 1 ONAN propane — powered generator (5 kW).
- 12 GOULD deep discharge batteries.
- 1 inverter (12 volt DC to 110 volt AC).

Loads. Lights, television, small appliances and a home computer are all operated on 12 volts DC. Larger appliances and power tools are operated on 110 volts AC. The generator is operated about 10 hours per month, as required for heavy loads or during prolonged periods of cloudy weather.

Costs. Capital cost of complete system = $11,000. (1983)

Estimated propane consumption = 650 L/year.

At 22¢/L, propane cost = $143./year.

The alternative of having the power line extended 3 km would have cost about $12,000. (1983). The service charge for a 1.5 kW transformer would be $9.65 per month, in addition to the electricity cost of 4.6¢/kWh.

Estimated annual consumption is 1200 kWh, half of which is supplied by the solar panels.

The annual cost of utility power, assuming the same consumption, would be:

1) electricity: (1200 kWh x $0.046)	= $ 55.20
2) service charge: ($9.65/m x 12 m)	= $115.80
Total	= $171.00/year.

Summary.

1) A complete economic comparison is not possible without more information on equipment life and maintenance.
2) Most people would probably prefer to pay the extra $1000 capital cost to obtain the convenience of utility power.
3) The generator and batteries could have been used alone (without the solar panels) to provide a lower cost system.

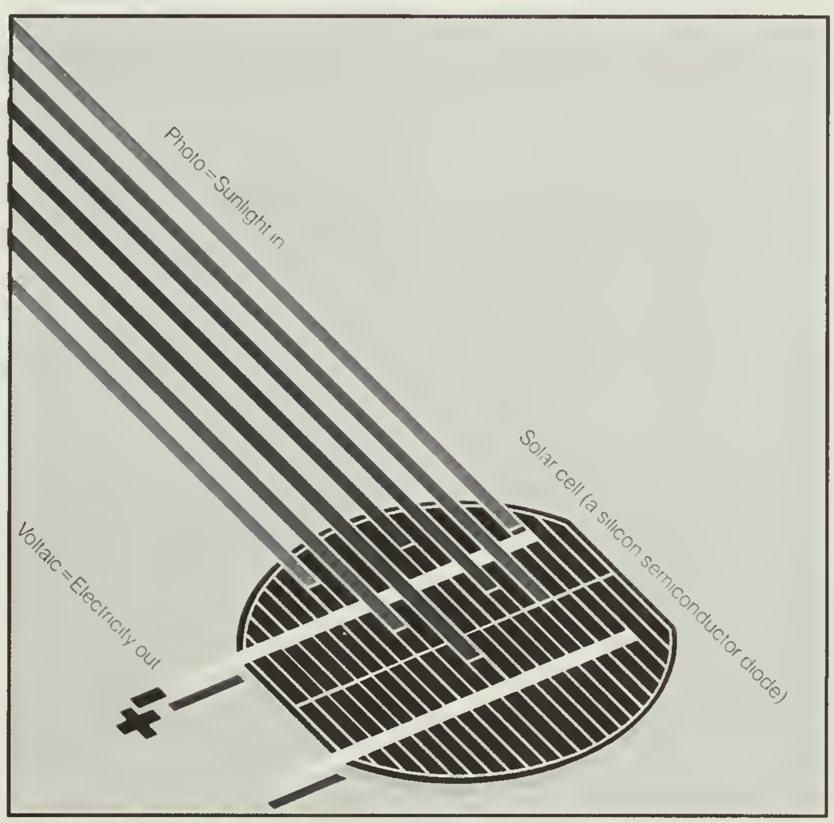
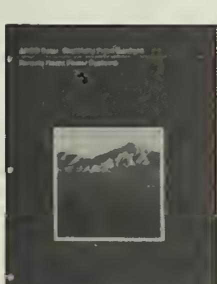


Fig. 8.3 Principle of a Photovaltaic Cell



MORE INFORMATION:

1) **ARCO Solar: Electricity From Sunlight.** Brochure available from ARCO, 20554 Plummer St., Chatsworth, California 91311.
2) **Solar Fields Forever.** Article in Harrowsmith Magazine, No. 51, October/November, 1983, describes this installation in greater detail.

8.2 WIND POWER

Revived interest in wind as an energy source has been encouraged by new designs in windmills. Researchers around the world are developing large sophisticated wind energy conversion systems which may become a significant source of power in areas with good wind regimes.

Potential Farm Uses of Wind Energy. Wind energy can be converted to mechanical or electrical energy for such uses as:

- pumping water (for livestock, drainage and irrigation)
- heating
- lighting
- feed processing

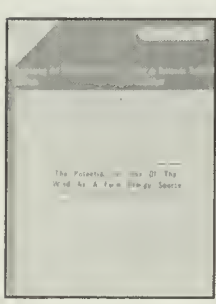
All of these applications of wind are technically possible but, in most cases, are presently not competitive with conventional sources of energy.

There are some exceptions:

1) where the cost of extending electrical power to a site is prohibitive. Examples include remote wells on livestock ranches and pumping outlets for field drainage systems. (A few farmsteads in newly settled areas of Canada may also be remote from utility power.)

2) where power requirements are very low, for example, electric fence chargers or lighting systems.

Fig. 8.4 Prototype of a Large Scale Canadian Wind Pump. (Courtesy Deltx Corporation, Calgary, Alberta).



MORE INFORMATION:

1) **The Potential For Use Of The Wind As A Farm Energy Source.** Report I-321, available from Engineering and Statistical Research Institute, Agriculture Canada, Ottawa, Ontario K1A 0C6.

2) **Wind Power Application.** Factsheet available from Canadex, Communications Branch, Agriculture Canada, Ottawa, Ontario K1A 0C7.

3) **An Introduction To Wind Power — Its Uses And Potential.** Booklet available from Trans-Alta Utilities, Energy Management Services, Box 1900, Calgary, Alberta T2P 2M1.

4) **Wind Power.** Booklet available from Nova Scotia Department of Mines and Energy, P.O. Box 668, Halifax, Nova Scotia B3J 2T3.

5) **The Canadian Wind Energy Research And Development Program.** Technical memorandum TM-WE-005, available from: Publications, National Research Council, M-58, Montreal Road, Ottawa K1A 0R6.

6) **Wind Energy.** Project Summary, Small-scale Energy Demonstration, available from Nova Scotia Department of Mines and Energy, P.O. Box 668, Halifax, Nova Scotia B3J 2T3.

7) **The Atlantic Wind Test Site** provides scientific testing and reports on electrical wind energy systems. Contact AWTS, P.O. Box 189, Tignish, Prince Edward Island C0B 2B0.

8) **The Alberta Wind Energy Pumping Program** was established to test and demonstrate the use of wind pumping machines for drainage, irrigation and livestock watering. Contact Alberta Agriculture, Drainage Branch, Agriculture Centre, Lethbridge, Alberta T1J 4C7.

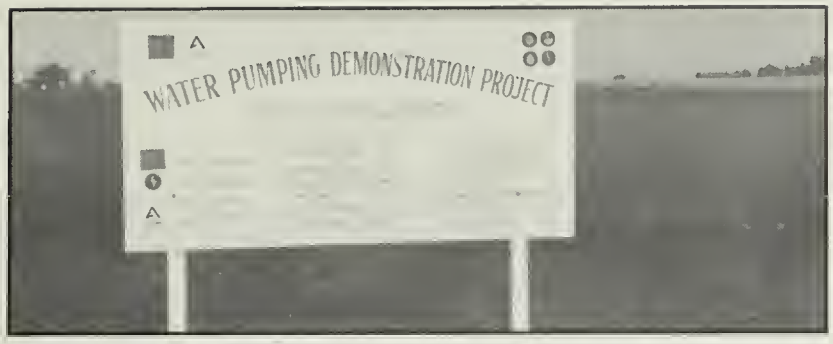


Fig. 8.5 Wind Pumping Test Site at Lethbridge, Alberta

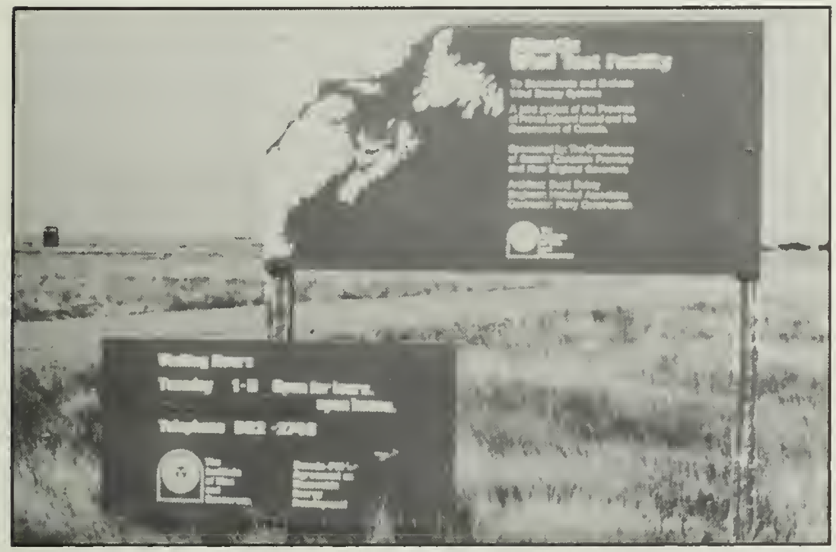


Fig. 8.6 Atlantic Wind Test Facility

Wind Power Available. Fig. 8.7 shows that total wind energy varies widely throughout Canada. The best wind regimes are on the southern prairies and parts of the east and west coastal regions. Local geographic features, such as hills, valleys, trees and lakes, may create good wind regimes in areas with low regional wind speeds. Wind surveying instruments are required to evaluate a proposed site.

Economics. A quick estimation can easily be made of the value of wind energy at a given site. For example, consider a location with total wind energy of 1,000 kWh/m²/yr. (Fig. 8.7) The maximum usable power captured by a windmill might be 30%.

Consider a 4 meter machine: Area = (3.14×2^2) = 12.56 m².
Power Output = $(12.56\ m^2 \times 1000\ kWh/m^2/yr \times 0.30)$ = 3768 kWh/yr.

If utility power is available at 4¢/kWh the wind power output is worth (3768 x \$0.04) = **\$151/yr.**

A machine of this size with battery storage might cost \$6000. The simple payback (without counting maintenance costs) = (\$6000/\$151) = 40 years. This illustrates the economic problem with small-scale wind systems. (However, if the extension of a utility power line costs \$12,000 the wind machine may be quite attractive.)

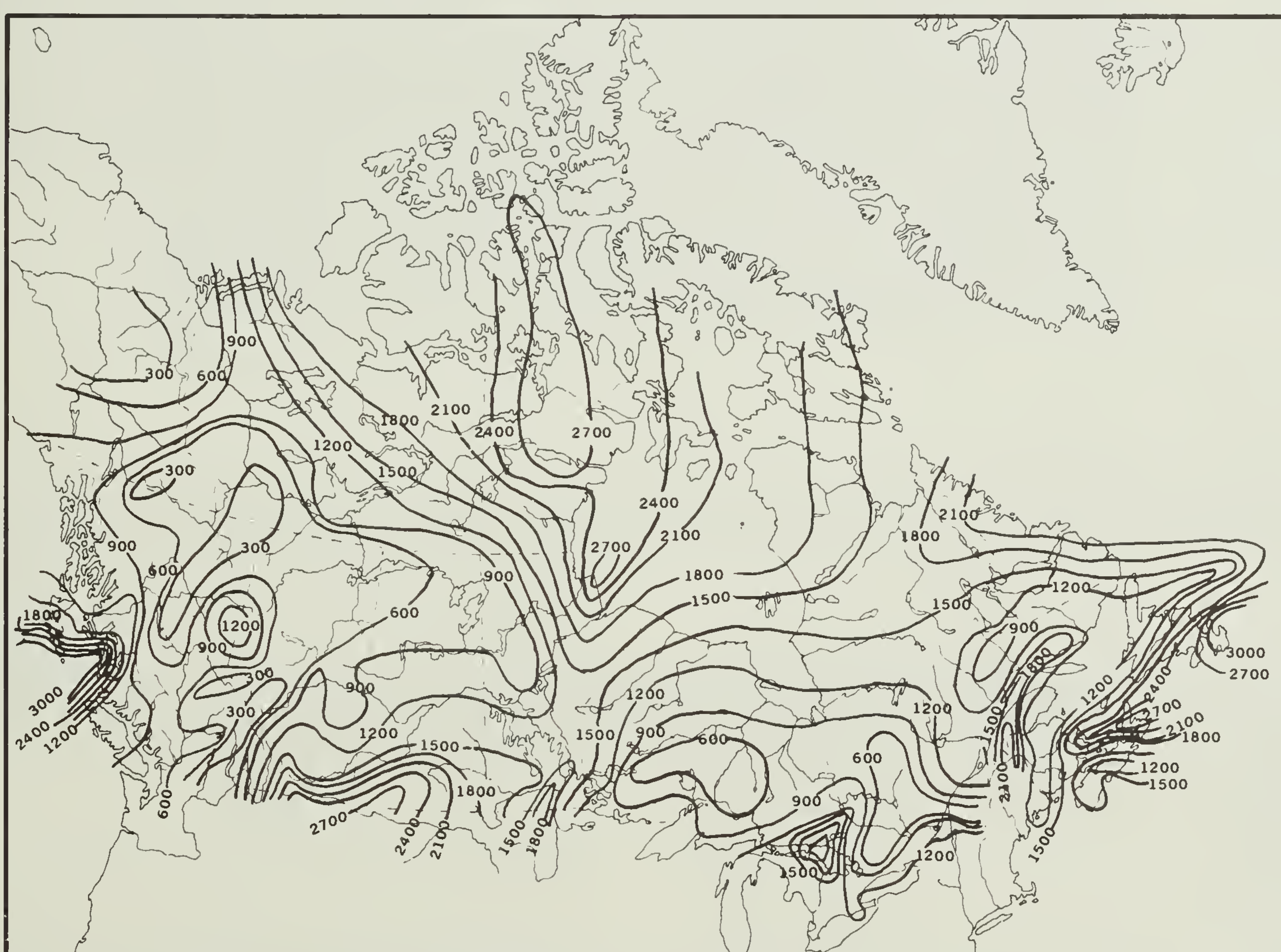


Fig. 8.7 Mean Annual Rate of Kinetic Wind Energy Flow (kWh/m²yr.) *(Reference 1)*

8.3 WATER POWER — A MICRO HYDRO INSTALLATION

Location. Mabou, Nova Scotia. This project is located on a small farm 1½ km from a utility power line. The estimated cost of obtaining utility power was $15,000. The presence of a small stream on the property led to investigation of hydroelectric generation as an alternative power source.

Site Description. A survey determined that the small stream was about 30 m higher elevation than the proposed generator location. The stream flow varied from 2.5 to 25 L/s, with an average flow of 17.3 L/s.

System Description. A hydroelectric system was installed in 1980. It consists of a 25 cm Pelton turbine, a 5 kW 32 V marine alternator, a 48 VDC to 110/220 VAC inverter, and six 8 volt 300 Amp-hr. marine batteries. Water is piped from the stream to the turbine through 328 m of 19.4 cm rubber pipe.

Performance. The power output has averaged 56 kWh/day. Loads on the system include lights, a T.V., a refrigerator, a 3 kW water heater, 2 kW of electric space heat and other miscellaneous uses. Periods of low water flow have caused some restriction in electrical use. Maintenance problems have been minor, related mostly to keeping debris out of the water intake.

Economics. The total system plus installation costs $23,000. This is $8,000 more than it would have cost to connect to the power line. At an average price of 4.6¢/kWh and a monthly service charge of $5.00, the hydro system replaces power costs of (56 kWh/d x 365 d x $0.046) + ($5/mo. x 12 mo.) = $1000/yr. Maintenance and operating costs would be required for a more complete economic evaluation.

Fig. 8.8 A Micro-hydro Installation *(Reference 1)*

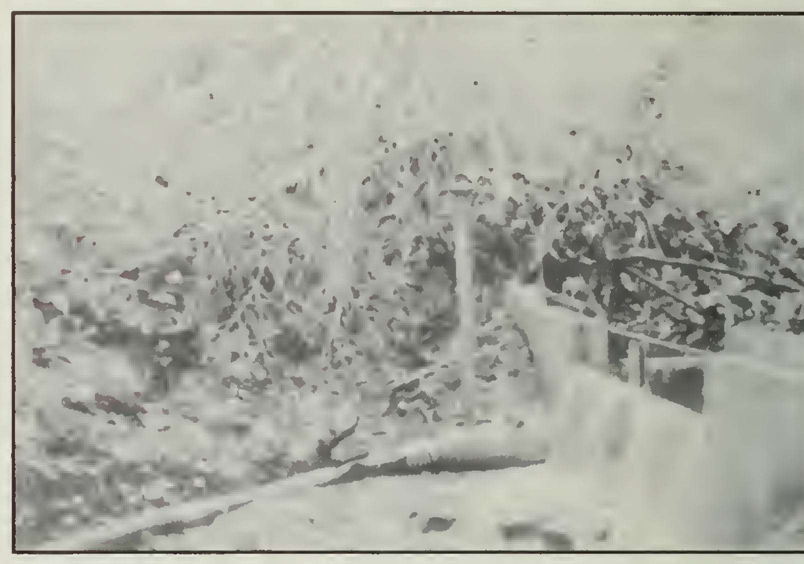
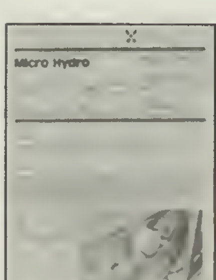


Fig. 8.9 A View of the Settling Pond and the Rubber Pipe to the Turbine. *(Reference 1)*



MORE INFORMATION:

1) **Micro Hydro.** Project Summary — Pilot Projects Program, available from Nova Scotia Department of Mines and Energy, P.O. Box 668, Halifax, Nova Scotia B3J 2T3.

2) **Small Water Power Systems.** Publication 764, available from Extension Division, Cooperative Extension Service, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.

3) **Water Power For Your Home.** Article in Popular Science, May, 1977.

4) **Micro-Hydro Power — Energy From Ontario Streams.** Available from Ontario Publications Services, 5th Floor, 880 Bay St., Toronto, Ontario M7A 1N8 ($2.00)

8.4 WOOD GASIFIERS FOR FARM HEATING

Location: Kings County, Nova Scotia.

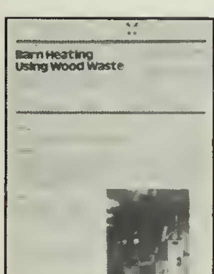
Application. Two farmers have installed wood gasifiers to provide hot water to heat their farm buildings, using sawdust and wood chips from local lumber mills. One system heats a home and a large hog barn. The other system heats two homes and two broiler chicken barns.

Equipment. The Firefly wood gasifiers are built in P.E.I. by The Saturn Corporation, based on a Swedish design. Wood chips are fed to the gasifier's hopper by a conveyor and a tractor loader. Heated water is stored in a boiler and automatically circulated to the farm buildings.

Energy Saved. Annual heating oil consumptions before the gasifiers were installed were 30,000 L on one farm and 82,000 L on the other farm. Expected savings were 24,000 L and 57,000 L respectively.

Economics. Projected capital costs were $45,400 and $76,200. Operating and labour costs were not yet available.

Fig. 8.10 A Wood Gasifier for Farm Heating



MORE INFORMATION:

1) **Barn Heating Using Wood Waste.** Project Summary — Pilot Projects Program, available from Nova Scotia Department of Mines and Energy, P.O. Box 668, Halifax, Nova Scotia B3J 2T3.

2) **The Wood Book.** Booklet available from Nova Scotia Department of Mines and Energy, P.O. Box 668, Halifax, Nova Scotia B3J 2T3.

3) **A Wood Chip Primer.** Booklet available from the New Brunswick Energy Secretariat, P.O. Box 6000, Fredericton, New Brunswick E3B 5H1.

4) **Heating With Wood.** Publication available from Energy Mines and Resources Canada, 580 Booth Street, 17th Floor, Ottawa, Ontario K1A 0E4.

5) **The Woodburner's Manual — Managing The Woodlot For Profit.** Publication available from Ontario Ministry of Natural Resources, Tree Improvement and Forest Biomass Institute, Maple, Ontario L0J 1E0.

6) **Burning Wood.** Publication NE-191 available from N.E. Regional Agricultural Engineering Service, Riley Robb Hall, Cornell University, Ithaca, New York 14853. ($1.00 U.S.)

7) **Drying Grain Corn Using Sawdust As A Heat Source.** Project report, available from Agricultural Energy Centre, Ontario Ministry of Agriculture and Food, P.O. Box 1030, Guelph, Ontario N1H 6N1.

8.5 CROP RESIDUES FOR HEATING AND DRYING

Heat Values. Crop residues vary considerably in their potential as heating fuels. Fig. 8.11 shows some typical heat values based upon lab measurements. Note that the moisture content also has a big influence on the amount of heat produced.

Material	Lower Heat Value (MJ/kg) Moisture Content (% WB)		
	10%	20%	30%
Oat Straw	10.8	7.6	6.0
Barley Straw	11.0	8.3	7.7
Flax Straw	12.1	9.0	7.3
Wheat Straw	17.5	15.4	12.2
Corn Cobs	17.4	15.9	13.0
Corn Stover	—	14.0	13.0
Sunflower Hulls & Pulp	21.9	17.6	13.1

Fig. 8.11 Typical Heat Values of Crop Residue

Uses. Farm applications for residue combustion include grain drying, space heating and water heating. Electrical production by steam generation and mechanical power from Stirling engines would also be possible but have received little attention to date.

Equipment. A wide selection of biomass furnaces has evolved in recent years. Many of them, particularly the home-built units, have burned out after one year of use.

Constraints.

1) In many areas of Canada all crop residues should be returned to the land to maintain the soil and prevent erosion.
2) Collection, storage and handling of crop residues is often expensive and labour intensive.

EXAMPLE

Location: Canning, Nova Scotia

Farm Size: 700 ha

Crops: Grain cereals, grain corn and legumes.

Livestock: 250 sow farrow to finish swine operation.

Biomass Combustion System. A two-stage German PSW straw burner was installed in 1977 to supply heat for grain drying and space heating. Straw is collected and burned in the form of large round bales. The burner supplies hot gases to a modified MC-600B grain dryer and a heat exchanger for a 60,000 L hot water storage tank.

Performance. The system dries 4000 tonnes of grain per year and heats all of the barns. The straw burner has performed well, after some modification and improvements by the supplier. The major challenge, under Maritime weather conditions, is to keep the straw dry enough to burn.

Economics (Owner's Evaluation).

Energy saved = 250,000 L of propane

Value (1979) = ($0.15/L x 250,000 L) = $37,500

Capital Cost = $100,000

Depreciation = (0.10 x $100,000) = $10,000/yr.

Interest = [($100,000 + $10,000)/2] x .16) = $8,800/yr.

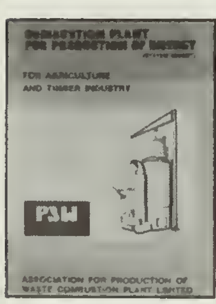
Maintenance = ($100,000 x 0.05) = $5,000/yr.

Straw Collection and Handling = (400 t x $23/t) = $9,200/yr.

TOTAL = $33,000/yr.

Savings (1979) = ($37,500 - $33,000) = $4,500

Note: The owner considers this a very conservative analysis because the excessive amounts of straw produced would have to be removed from the fields even if it was not used as an energy source. The burner lets him recover the costs of baling and removing the straw.



MORE INFORMATION:

1) **Evaluation Of A System Utilizing Biomass Sources (Straw) For Crop Drying And Heating On The Farm.** Research report available from Engineering and Statistical Research Institute, Agriculture Canada, Ottawa, Ontario K1A 0C6.
2) **Crop Residue Availability For Fuel.** Factsheet No. 440, available from Cooperative Extension Service, Michigan State University, East Lansing, Michigan 48824.
3) **Crop Refuse: Fuel For The Future.** Article in The Furrow, April, 1982.
4) **Biomass Furnace For Grain Drying.** Project report, available from: Agricultural Energy Centre, Ontario Ministry of Agriculture and Food, P.O. Box 1030, Guelph, Ontario N1H 6N1.
5) **Central Heating System Using A Flax Straw Burner.** CREDA reports available from Saskatchewan Energy & Mines, Energy Technology Branch, 1914 Hamilton St., Regina, Saskatchewan S4P 4V4.
6) **Energy From Crop Wastes.** Pilot Project Summary #036, available from Nova Scotia Dept. of Mines and Energy, P.O. Box 668, Halifax, Nova Scotia B3J 2T3.

EXAMPLE

The following example is from data supplied by CANVIRO CONSULTANTS LTD. Kitchener, Ontario.

Location: Kitchener, Ontario

Livestock: Beef feedlot (5,000 head).

Barns: Slatted Floor/Liquid manure.

Digester Operation. Fig 8.12 shows a schematic diagram of the anaerobic digester which was installed in 1980, in response to environmental problems due to odours from the lagoon system used previously.

The digestion tank is a sealed reinforced concrete silo 9.1 m in diameter x 11 m high. The manure is centrifuged to separate the solids and liquid components.

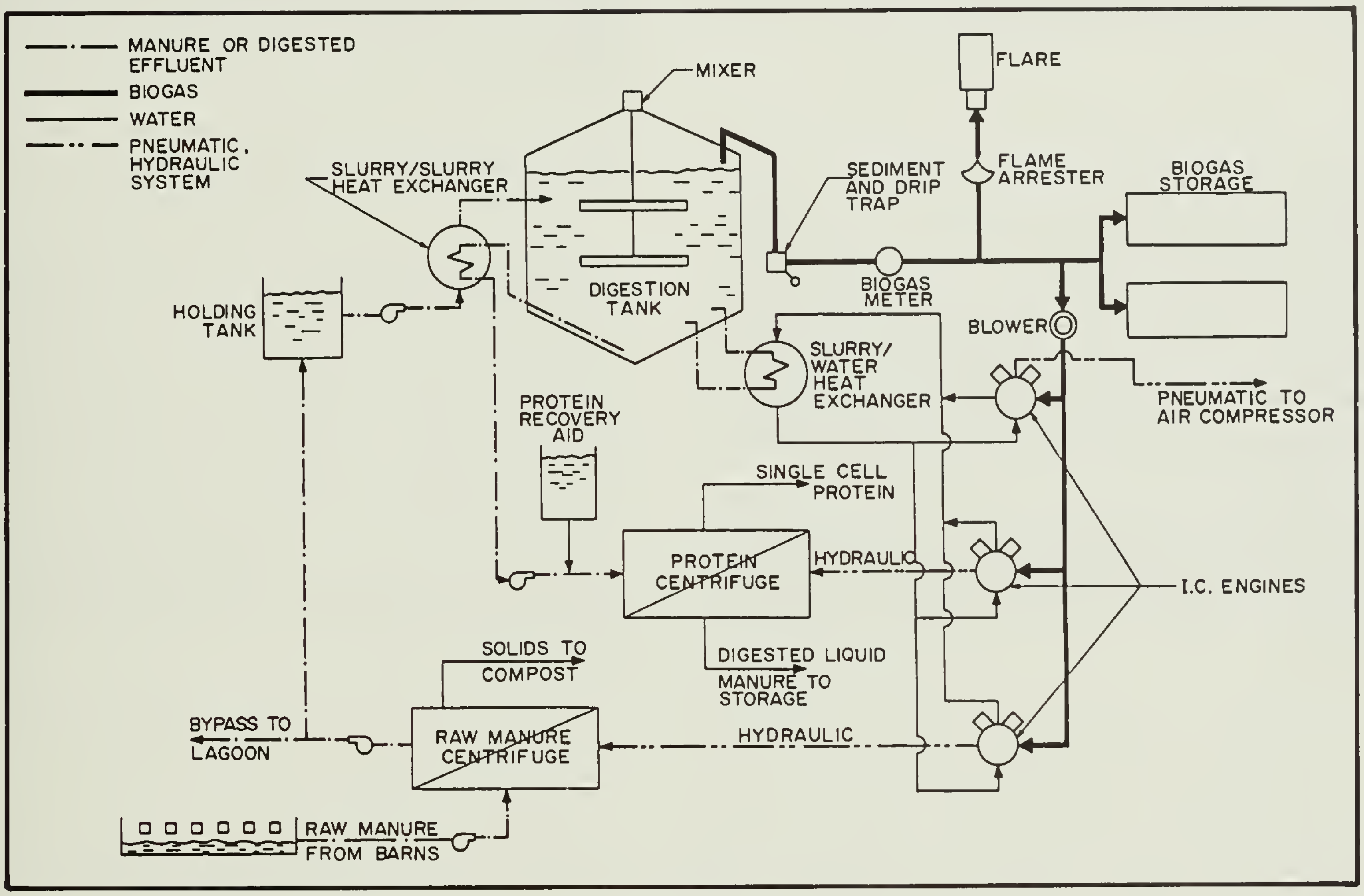


Fig. 8.12 Schematic Diagram of Anaerobic Digestion and Protein Recovery System for a 5,000 Head Beef Feedlot.

MORE INFORMATION:

1) **Energy Production by Anaerobic Digestion of Livestock Wastes.** Report available from Canviro Consultants Ltd., Kitchener, Ontario. N2H 5M5.
2) **Comparative Evaluation of Five Full Scale Anaerobic Digesters.** C.S.A.E. Paper No. 83-411, available from Engineering & Statistical Research Institute, Agriculture Canada, Ottawa, Ontario. K1A 0C6.
3) **Methane Gas Production From Animal Wastes.** Publication 1528, available from Communications Branch, Agriculture Canada, Ottawa, Ontario. K1A 0C7.
4) **Biogas Production from Animal Manure.** Available from Biomass Energy Institute, P.O. Box 129, Postal Station C, Winnipeg, Manitoba. R3M 3S7.
5) **Methane Production From Livestock Manure.** Factsheet No. 82-067, available from Ontario Ministry of Agriculture and Food, Information Branch, Legislative Buildings, Toronto, Ontario. M7A 1A5.
6) **Agricultural Anaerobic Digesters — Design and Operation.** Bulletin 827, available from The Pennsylvania State University, College of Agriculture, Agricultural Experimental Station, University Park, Pennsylvania.
7) **The Gasser Farm Anaerobic Digester.** Description available from Urgel Delisle et Associes, 426 Chemin des Patriotes, St. Charles-sur-Richelieu, Quebec. J0H 2G0.
8) **The Olds College Farm Waste Management System.** Report available from Olds College, Olds, Alberta. T0M 1P0.

Fig. 8.13 Construction of an Anaerobic Digester

Fig. 8.14 Beef Animals on Slotted Floor. Manure is pumped to the Digester.

Only the liquid component is used as feed stock for the digester. The solids are composted and sold as fertilizers. Effluent from the digester is also centrifuged to recover the single cell protein, which is added to the livestock ration to replace commercial protein supplement. Biogas is used partly to maintain the temperature of the digester and partly to operate three internal combustion engines. One engine drives an air compressor; the other two engines drive the centrifuges.

Energy Balance. In winter operation all of the biogas, plus some supplemental heat, is needed to run the system, including manure pumping, centrifuging and digester heating.

Economics (CANVIRO Evaluation).

Capital cost = $476,430	
Amortization (20 yrs. @ 15%)	$81,469.
Annual operating & maintenance cost	$49,500.
Total annual cost	$130,969.
Annual revenue (protein recovery)	$238,000.
Net annual profit	$107,031.

Conclusion. Protein recovery and pollution control are the main incentives for considering a digester for livestock manure.

8.7 ALCOHOL POTENTIAL FROM FARM CROPS

Forms of Alcohol. The two types of alcohol usually considered as potential fuels are ethanol (C_2H_5OH) and methanol (CH_3OH). Ethanol produced from grain is commonly used in alcoholic beverages. Methanol (also called wood alcohol) is familiar to most people as a deicing additive for gasoline.

Methanol Production. Methanol is formed by combining carbon monoxide (CO) with hydrogen (H_2) under high pressure and temperature. Commercially, it is manufactured from natural gas, coal and wood. Although methanol could also be made from farm biomass material such as straw or manure, the process is suitable only for large-scale production, which would require an industrial plant drawing feedstock from a large area. Secondly, methanol is a low-energy fuel, with only half the energy content of gasoline.

Ethanol Production. Ethanol can be produced chemically from ethylene, an abundant natural gas product. However, the interest by the farm community relates more to the biological production of ethanol from the fermentation of carbohydrates. While the best feedstocks for fermentation are products high in sugar and starch, such as sugar beets and potatoes, nearly any biomass product can be converted to some quantity of ethanol.

Fig. 8.15 shows the steps involved in biological production of ethanol.

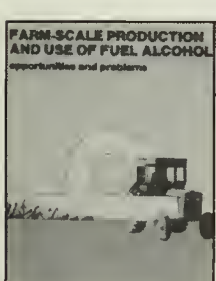
1) The feedstock material is ground and mixed with water to form a mash.
2) The mash is cooked and agitated to release the sugars.
3) Yeast and enzymes are added to promote fermentation.
4) Fermentation for 60-70 hours, produces a "beer mixture" which contains 12-17% ethanol.
5) After fermentation, the beer mixture is run through a distillation column. Since ethanol boils at a lower temperature than water, it rises to the top of the column and escapes to the condenser where it is liquified. However, the output product is not pure alcohol. Depending upon the type of distillation column, and number of times the process is repeated, the alcohol content may vary from 50% to 95% (100-190 proof). To obtain pure ethanol requires sophisticated equipment and special additives. It is generally beyond the capabilities of a farm-scale alcohol plant.

Energy Inputs. A heat source is required to operate the fermentor and the distillation column. If fossil fuels are used for the heat source, the non-renewable energy consumed will be greater than the renewable energy produced in the form of alcohol. To produce any net energy, the process must be powered by renewable energy, such as wood or straw.

Fuel Characteristics. Pure ethanol contains about 65% as much energy as an equal volume of gasoline. As demonstrated by the "gasohol" program in the U.S.A. (Fig. 8.16) a 10% addition of pure ethanol to gasoline is suitable for operation in vehicles without engine modifications. Alcohol containing water is **not** suitable for blending with gasoline, especially in cold weather because the water will cause the gasoline and alcohol to separate.

However, alcohol and water mixtures (with no gasoline) will operate in gasoline engines with some modifications (advanced timing, bigger carburetor jets, replacement of plastic components, and addition of a heat exchanger to help vaporize the ethanol).

Use of ethanol in diesel engines is much more complicated. It will not blend satisfactorily with diesel fuel, and could cause serious damage to the injection pump. A number of researchers are testing "alcohol



MORE INFORMATION:

1) **Farm Scale Production And Use Of Fuel Alcohol: Opportunities And Problems.** Publication 1712, available from Communications Branch, Agriculture Canada, Ottawa, Ontario K1A 0C7.
2) **Farm Scale Alcohol: Food For Thought.** (Report I-265)
3) **Agricultural Resources For Ethanol Production.** (Report I-201)
4) **Alcohol Fuels From Agriculture — A Discussion Paper.** (Report I-165)

The above reports are available from the Engineering & Statistical Research Institute, Research Branch, Agriculture Canada, Ottawa, Ontario K1A 0C6.

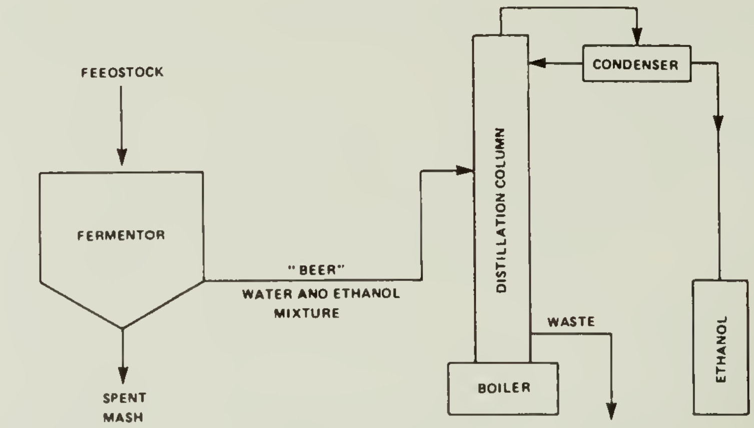
5) **Alcohol As A Motor Fuel.** Factsheet No. 81-043, available from Ontario Ministry of Agriculture and Food, Information Branch, Legislative Buildings, Toronto, Ontario M7A 1A5.
6) **Alcohol Still Analysis — A Telplan User's Manual.** Factsheet No. 439, available from Co-operative Extension Services, Michigan State University, East Lansing, Michigan 48824.

fumigation" systems which inject mixtures of alcohol and water into the air intake to blend with diesel fuel in the combustion chamber. Such systems are commercially available, but their use may invalidate the warranty on a tractor.

Economics. The cost of ethanol depends largely upon the cost of the feedstock material and its carbohydrate content. Fig. 8.15 shows the potential alcohol yield from some common crops. The total cost of ethanol produced from these products can be estimated as double the feedstock cost. For example, if barley costs $120.00 per tonne, the approximate ethanol cost would be:

C = (2 x $120.00 per tonne)/(390 litres per tonne) = 62¢ per litre

Fig. 8.16 Alcohol Commercially Produced from Farm Crops can be Added to Gasoline for use in Transportation Vehicles.



POTENTIAL ALCOHOL YIELD FROM FIELD CROPS*

Crop	Yield (L/t)
Starch	680
Sugar	610
Spring Wheat	380
Winter Wheat	410
Oats	270
Barley	390
Mixed Grains (West)	350
Mixed Grains (East)	330
Rye	390
Corn	430
Buckwheat	350
Peas, Beans	350
Potatoes	110
Field roots	30
Sugar beets	70

*Yield assumes a maximum theoretical conversion efficiency to alcohol of 95%. The efficiency on farms would more likely be 50 to 85%.

Fig. 8.15 Schematic of Fermentation and Distillation Process

EXAMPLE

The following example is based on a paper entitled "On-Farm Production Of Fuel Alcohol", presented by Otten, Walczak & Brubaker at the 1982 meeting of the Canadian Society of Agricultural Engineers (paper No. 82-107).

Location: Zurich, Ontario

Farm Size: 330 ha.

Crops: Corn, wheat, barley and beans.

Livestock: Hogs

Alcohol Plant. Fig 8.17 shows a schematic plan of the alcohol plant which was built by the farmer in 1981. It has been operated intermittently since January, 1982.

Alcohol Output. In the first 5 months of operation a total of 9000 L of 170 proof ethanol was produced. (A car, pickup truck and small tractor have been converted to permit injection of alcohol into the gasoline air mixture.)

Performance. This plant has been monitored by the Ontario Agricultural Energy Management Resource Centre. Preliminary technical results were as follows:

Feedstock Conversion: 0.276 L/kg of corn
Average Proof: 171
Energy Content: 16.0 MJ/L
Process Energy: 18.5 MJ/L

Economics. The capital cost of this plant was not fully documented. Estimated cost of materials was $50,000. Feedstock and production costs were estimated to be $0.87/L, based upon a corn value of $133/tonne and labour at $5/hour. (This analysis did not assign a value to the stillage, which is fed to hogs on the farm.)

Conclusion. This installation demonstrates the technical feasibility of on-farm ethanol production. However, the economics are not attractive if the grain feedstock is valued at its market price.

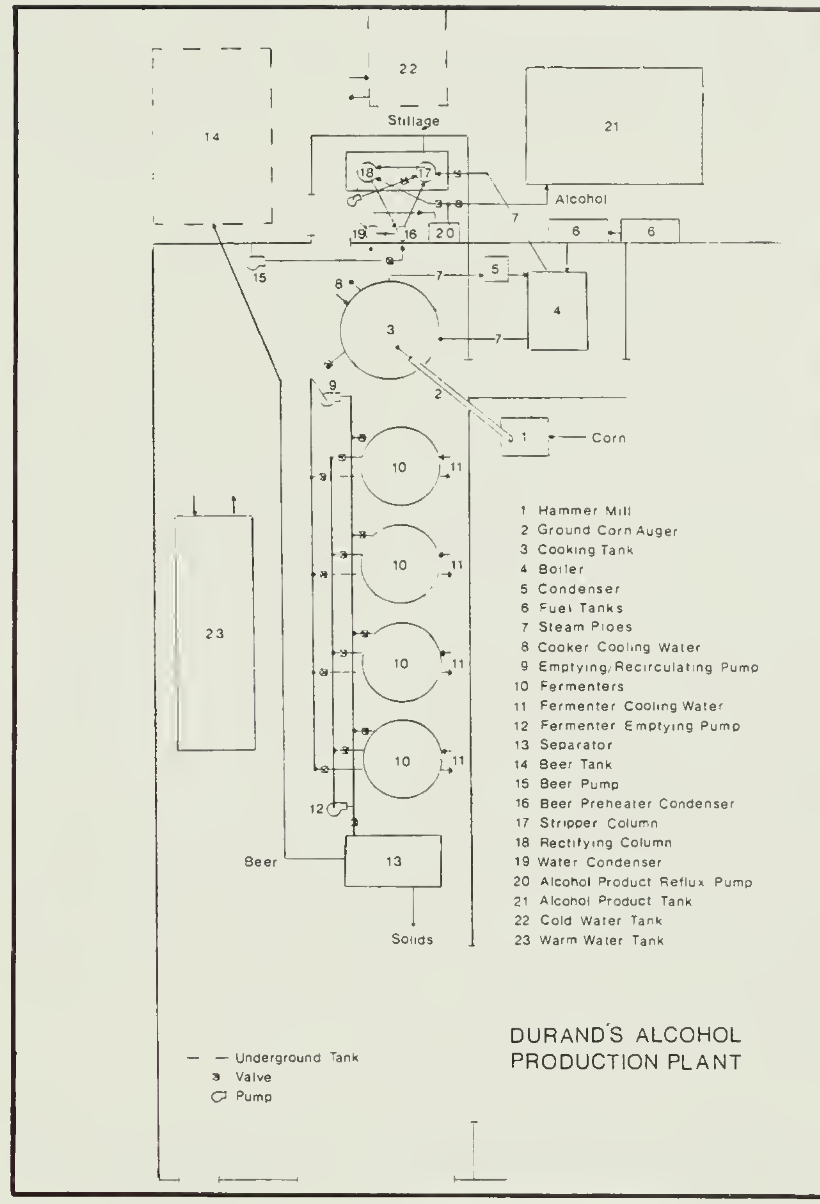


Fig. 8.17 Schematic of a Farm-Scale Alcohol Plant

8.8 VEGETABLE OILS FOR DIESEL ENGINES

Tests are underway in several countries to evaluate the performance of vegetable oils in diesel engines. Many researchers believe that, if required, vegetable oils could provide an alternative farm fuel.

Oil Types. Diesel engines have been tested on various types of vegetable oils, including sunflower oil, corn oil, soybean oil, peanut oil and canola (rapeseed) oil. All of the oils performed satisfactorily as temporary fuels for diesel engines, either as complete fuels or in various blends with No. 2 diesel fuel. Power output and engine performance were generally equivalent to diesel operation for short test periods.

Problems. Extended operating tests are being conducted to evaluate the long-term effects of vegetable oils on diesel engines. The following problems have been encountered:

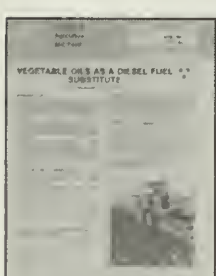
1) Coked injector tips under part-load conditions.
2) Clogging of fuel filters.
3) Lubrication problems due to dilution of the crankcase oil.
4) Viscosity problems in cold weather.

Until these problems are overcome, farmers should be advised not to try vegetable oils in expensive diesel engines.

Future Farm Fuel Self-Sufficiency. The potential of farmers to grow their own fuel is influenced considerably by the amount of land required. Using canola as an example, it has been estimated that a grain farmer would have to use about 10% of his land to produce the fuel needed for all farm operations, including field work, trucking and personal transportation. Interestingly, this is nearly equal to the percentage of cropland required to feed horses when they were the main power source on farms.

Fig. 8.18 Testing a Diesel Engine with Canola Oil Fuel

Food vs. Fuel. Many people consider it wrong to use a food product for fuel. Proponents of alternate fuels argue that the extraction process would still supply a protein byproduct for food use. Perhaps a more practical assessment is that Canadian farmers have repeatedly shown that they can produce more grain than the transportation and marketing system can handle. "Selling" part of his crop to himself to replace petroleum fuels may become an attractive option under conditions of surplus grain, poor markets and high fuel prices. The question will remain academic until the technical problems of using vegetable oils as a fuel are overcome.



MORE INFORMATION:

1) **Vegetable Oils As A Diesel Fuel Substitute.** Factsheet No. 83-033, available from Ontario Ministry of Agriculture and Food, Information Branch, Legislative Buildings, Toronto, Ontario. M7A 1A5.
2) **Canola Oil As A Fuel For Diesel Engines.** Technical paper available from the Agricultural Engineering Dept., University of Saskatchewan, Saskatoon, Saskatchewan. S7N 0X1.
3) **Producing Farm Fuels For Diesels.** Article in the March/April, 1982 issue of Small Farm Energy, published by the Small Farm Energy Project, P.O. Box 736, Hartington, Nebraska 68739.
4) **Vegetable Oil As A Fuel For Diesel Engines.** Factsheet No. 444, available from Cooperative Extension Service, Michigan State University, East Lansing, Michigan 48824.
5) **Sunflower For Power.** Circular AE-735, available from Cooperative Extension Service, North Dakota State University, Fargo, North Dakota 58105.
6) **Vegetable Oil Fuels.** Proceedings of International Conference on Plant and Vegetable Oils as Fuels, August 1982. Available from ASAE, 2950 Niles Road, St. Joseph, Michigan 49085 ($23.50 U.S.).

APPENDIX A

TABLE A.1 ENERGY UNITS

There are many different terms used to describe energy, power and work in both the Imperial and Metric Systems of measurement. Here are some useful conversions between the two systems:

Liquid Fuels	gasoline, diesel fuel, heating oil and propane are now sold in litres (L)	1 L = 0.22 gal 1 gal = 4.546 L
Natural Gas	used to be sold by the thousand cubic feet (MCF), but is now sold in cubic meters (M^3) or on the basis of energy value in gigajoules (GJ).	1 m^3 = 35.31 ft^3 1 MCF = 28.32 m^3 or about 1.055 GJ
Electrical energy	will continue to be measured and sold in kilowatt hours (kWh)	1 kWh = 3.6 MJ
Powered equipment	or mechanical power is now rated in kilowatts (kW) rather than horsepower (hp)	1 kW = 1.34 hp 1 hp = 0.746 kW
Work	a form of energy, previously measured in ft lb or horsepower hour units is now stated in megajoules (MJ) or kilowatt-hours (kWh)	1 MJ = 0.37 hp h 1 hp h = 2.68 MJ 1 hp h = 0.746 kWh 1 J = 0.74 ft lb 1 ft lb = 1.36 J
Heat	or thermal energy, formerly measured in Btu is now stated in kilojoules (kJ)	1 kJ = 0.95 Btu 1 Btu = 1.055 kJ
Heat output	or thermal power, of furnaces or heaters, formerly rated in Btu/h is now stated in watts (W) or kilowatts (kW)	1 kW = 3414 Btu/h 1 Btu/h = 0.293 W

SI PREFIXES

1 kilojoule (kJ) = 1,000 Joules (J)
1 Megajoule (MJ) = 1,000 Kilojoules (kJ)
1 Gigajoule (GJ) = 1,000 Megajoules (MJ)

TABLE A.2 ENERGY CONTENT OF FUELS AND ELECTRICITY

Energy Type	Energy Content	Data Source
Gasoline	34.7 MJ/L	(1)
Diesel Fuel	38.7 MJ/L	(1)
Light Fuel Oil	38.7 MJ/L	(1)
Heavy Fuel Oil	41.7 MJ/L	(1)
Kerosene	37.7 MJ/L	(1)
Propane	25.5 MJ/L	(1)
Natural Gas	37.2 MJ/m^3	(1)
Electricity	3.6 MJ/kWh	(1)
Coal	(15-30) MJ/kg	(1)
Wood	(15-20) MJ/kg	(2)

(1) Statistics Canada, Quarterly Report on energy supply-demand in Canada.

(2) Ontario Ministry of Agriculture and Food, Farm Energy Accounting Manual.

MORE INFORMATION:

1) **Metric Conversion Tables.** Booklet available from Canada Mortgage And Housing Corporation, 1500 Meriville Road, Neapean, Ontario K2C 3N7.

2) **Comparing Energy Units,** factsheet No. 769-5 available from Alberta Agriculture, Print Media Branch, Main Floor, 7000 - 113 Street, Edmonton, Alberta T6H 5T6.

3) **Comparative Heating Fuel Costs,** factsheet No. 82-003, available from Ontario Ministry of Agriculture and Food, Information Branch, Legislative Buildings, Toronto, Ontario M7A 1A5.

APPENDIX B

WHAT DOES $1.00 PER BARREL ADD TO YOUR FARMING COSTS?

How does an energy price increase equivalent to $1.00 per barrel of crude oil affect your farming costs? Find out below:

SAMPLE FARM

Location: Taber, Alberta

Size: 372 ha.

Crops: Irrigated wheat, barley and sugar beets.

Farmstead: Two homes plus summer housing for casual workers.

The Price of Oil has a Direct Effect on Farming Costs.

INPUT		SAMPLE FARM (1982)		
FUEL				
Gasoline	41,724	L x $0.008/L	= $	334
Diesel	30,107	L x $0.008/L	= $	241
Heating Oil	–	L x $0.008/L	= $	–
Propane	–	L x $0.005/L	= $	–
Natural Gas	–	m^3 x $0.007/$m^3$	= $	–
	1,349	GJ x $0.20/GJ	= $	270
Electricity	192,277	kWh x $0.0006/kWh	= $	115
FERTILIZER				
Nitrogen (N)	34.9	t x $12/t	= $	419
Phosphorus (P_2O_5)	25.3	t x $3/t	= $	76
Potassium (K_2O)	10.3	t x $2/t	= $	21
PESTICIDES				
(Total active ingredient)	2,600	kg x $0.05	= $	130
		TOTAL ADDED COST/YR.		$ 1,606

TABLE B.1 ESTIMATED IMPACT OF HIGHER ENERGY COSTS ON FARM OPERATING COSTS

			ENERGY USE IN YR. STUDIED (GJ)			ADDED COST DUE TO $1.00/BBL OIL EQUIV.
FARM NO.	FARM TYPE	PRODUCTION OUTPUT/YR.	PRODUCTION	HOME(S)	TRANSPORT	TOTAL FARM
1.	Dryland Grain	533.4 tonnes of wheat	1,131	745	913	$ 456
2.	Irrigated crops	Wheat - 526 t. Potatoes - 1496 t. S. Beets - 2534 t.	9,242	2,281	2,028	$2,215
3.	Beef (Cow/Calf)	250 finished steers 250 stocker heifers	7,822	883	2,116	$1769
4.	Dairy	381,120 litres of milk	3,250	490	426	$ 681
5.	Swine (Farrow-Finish)	960 finished hogs	3,754	523	875	$ 842
6.	Chicken Broilers	45,000 broilers (52 days old)	3,712	1,153	506	$ 878

Table B.1 shows estimated increases in operating costs on specific farms due to a $1.00 per barrel equivalent rise in energy costs. The few studies conducted of actual farms have shown that energy costs per unit of production vary widely with farming practices, geographic regions and climate.

WHAT DOES $1.00 PER BARREL ADD TO YOUR FARMING COSTS?

INPUT		YOUR FARM (198)		
FUEL				
Gasoline	______	L x $0.008/L	= $	______
Diesel	______	L x $0.008/L	= $	______
Heating Oil	______	L x $0.008/L	= $	______
Propane	______	L x $0.005/L	= $	______
Natural Gas	______	m^3 x $0.007/$m^3$	= $	______
	______	GJ x $0.20/GJ	= $	______
Electricity	______	kWh x $0.0006/kWh	= $	______
FERTILIZER				
Nitrogen (N)	______	t x $12/t	= $	______
Phosphorus (P_2O_5)	______	t x $3/t	= $	______
Potassium (K_2O)	______	t x $2/t	= $	______
PESTICIDES				
(Total active ingredient)	______	kg x $0.05	= $	______
		TOTAL ADDED COST/YR.		______

NOTES:

1) Based upon a crude oil content of 6.118 GJ per barrel, a price increase of $1.00 per BBL is equivalent to $0.16345 per GJ.
2) Conversions include a 20% markup in energy cost from manufacturer to retailer.
3) The main energy input to fertilizers is natural gas. These calculations assume an increased energy cost equivalent to $1.00 per BBL of oil.
4) Energy required for pesticide production varies widely between formulations. The conversion used is considered an average energy input.

MORE INFORMATION:

1) **Energy For Agriculture and Food.** Publication 5142E, available from Communications Branch, Agriculture Canada, Ottawa, Ontario K1A 0C7.
2) **Total Energy Budgets For Selected Farms In Western Canada.** Available from Jensen Engineering Ltd., Box 1781, Olds, Alberta T0M 1P0. ($20.00)

APPENDIX C

WHERE TO GET MORE TECHNICAL INFORMATION

Various agencies of the federal and provincial governments are doing research on energy conservation and substitution. A number of these sources are summarized below. Provincial departments of agriculture, utilities and universities are also good sources of information on farm energy management.

ESRI REPORTS. The Engineering and Statistical Research Institute of Agriculture Canada has published a number of reports on energy and the food system. A complete listing of the available reports can be obtained from the Technical Information Section, Engineering & Statistical Research Institute, Research Branch, Agriculture Canada, Ottawa, Ontario K1A 0C6 — Phone (613) 995-9671.

ERDAF REPORTS. Contract research projects conducted under the Energy Research and Development In Agriculture And Food (ERDAF) Program are summarized in a publication by the Engineering and Statistical Research Institute. Complete reports of contract research are available from the Canadian Institute for Scientific and Technical Information (CISTI), operated by the National Research Council. Copies of reports may be borrowed for two weeks through the Interlibrary loan system or may be purchased for the cost of photocopying. Reports are also available on microfiche.

CISTI also offers a computer retrieval service to search for information on a given subject. Fees for this service vary with the amount of computer time required to conduct the search. The minimum fee is $30.00 per topic.

To obtain reports or computer searches, contact Client Services, Canada Institute of Scientific and Technical Information, National Research Council, Ottawa, Ontario K1A 0S2 — Phone (613) 993-2013.

CREDA. In 1979, Energy, Mines and Resources Canada initiated the Conservation and Renewable Energy Demonstration Agreement (CREDA). This is a joint federal/provincial program which has sponsored numerous energy demonstration projects across Canada. For more information about CREDA, contact the Renewable Energy Division, Energy, Mines and Resources, 6th Floor, 460 O'Connor, Ottawa, Ontario K1A 0E4. Phone (613) 995-9447.

FEMP. One of the agricultural projects established under CREDA was the Farm Energy Management Program in Saskatchewan, co-ordinated by Saskatchewan Agriculture. Energy use on 21 farms has been monitored for three years. For more information, contact the Family Farm Improvement Branch, Saskatchewan Agriculture, 3085 Albert Street, Regina, Saskatchewan, S4S 0B1. Phone (306) 565-6587.

ONTARIO AGRICULTURAL ENERGY PROGRAM. The Ontario Ministry of Agriculture and Food has established a province-wide service to provide information on farm energy management and to assist farmers in testing new energy concepts. For more information, contact the Agricultural Energy Centre, Ontario Ministry of Agriculture And Food, P.O. Box 1030, Guelph, Ontario N1H 6N1. Phone (519) 823-5700.

SWERP. Alberta Research Council operates a Solar And Wind Energy Research Program (SWERP) which maintains a library of energy information open for public use. Computer searches can also be conducted for references on specific subjects. For more information contact: SWERP, Alberta Research Council, 4th Floor, Terrace Plaza, 4445 Calgary Trail South, Edmonton, Alberta T6H 5R7 — Phone (403) 438-1555.

ENERTIC. The Nova Scotia Research Foundation provides an Energy Information Retrieval Service. Technical information on a desired subject is obtained by searches of scientific literature, libraries and computer bases. For more information contact: Energy Test And Information Centre, P.O. Box 790, Dartmouth, Nova Scotia B2Y 3Z7. Phone (902) 463-8555.

U.S. ENERGY INTEGRATED FARM SYSTEMS. In the United States the Department of Energy and USDA have initiated seven joint projects described as Energy Integrated Farm Systems. The objective is to test conservation and renewable energy on commercial scale farms. Technical and economic evaluations of the systems will be made available to other farmers. Systems being tested include solar, wind, methane, alcohol, heat recovery, reduced tillage and other conservation measures.

The Energy Integrated Farm Projects were described in the November, 1982 issue of Agricultural Engineering. Copies are available for $2.50 (U.S.) from the Order Department, ASAE, 2950 Niles Road, St. Joseph, Michigan 49005.