A Comparative Study of Energy Use in Hog Barns on the Prairies

Final Report
September 1999

Mohammad Khakbazan

Table of Contents

List of Tables

List of Figures

Chapter I

1.1. Introduction

Energy is the backbone of the agricultural industry. Farmers depend on it every day of the year in some form or other. Whether it is diesel to run tractors, electricity to light buildings, gasoline to run trucks or fuel to heat homes, farmers require this resource in all their farming operations. In turn, consumers depend on farmers to provide enough food to satisfy their needs. Agriculture is heavily dependent on a supply of energy that will maintain or improve on the current level of agricultural production, at minimum. This is a one side of the coin.

The other side is that agriculture uses only a small percentage of all the energy consumed in Canada. A significant potential does, however, exit for reducing farm energy consumption. Estimations show that it would be possible to reduce energy consumption by 50 percent for some production practices without suffering a reduction in output.

Hog operations are energy intensive, and success depends to a large extent on efficient use of inputs in general and efficient use of energy in particular. Energy use in hog operations differs over the year due to seasonal variation in the temperature and other environmental variables. However, this difference is relatively more noticeable in Saskatchewan, in part because of the high temperature differentiation between summer and winter conditions.

1.2. Energy Analysis and hog production

The energy analysis seeks to use physical units to measure how much energy is embodied in a unit of hog production in Saskatchewan. This measurement represents the energy requirement for the heating and powering of hog farm operations. The energy analysis is a broad measure that may include not only the energy used directly for the manufacturing or service process itself, but also the energy required to make available the

raw materials and equipment needed for the process, tracing each of them back to their primary source.

Direct energy inputs on a hog farm include some or all of the following;

- Fuel for farm transport;
- Energy consumed by hammermills, mixers, pelletizing machines, and other hog feed processing equipment on the farm;
- Energy used in conveying feed to the hogs;
- Energy used in lighting, ventilation, heating and cooling used to provide a suitable environment for the hogs;
- Energy used in the supply of water to the hogs, etc;
- Energy used to process and/or dispose of the waste products produced.

Indirect energy inputs are represented by the energy inputs in the production, transport and processing of hog feed off the farm, and the energy inputs in the production, supply and erection of buildings, machines, etc. These may represent a larger input than the direct inputs. Hence substitution of direct energy input to reduce indirect energy input can result in overall energy conservation.

1.3. The Objective

The hog crisis in the winter of 1998-99 caused great concern with regard to efficiency of input use in hog operations. This was an incentive for this study to analyze energy use in the hog production industry.

The main objective of this research is to analyze the cost efficiency of different energy sources in hog production in Saskatchewan. Energy use comparison is done by using 19 hog operations of an ILO[1] Group in Saskatchewan and Manitoba. These operations are ideally suited since construction is uniform but location, energy source, and management practices are different. Other objectives of this report are to provide an

[1] ILO = Intensive Livestock Operation.

overview of hog industry and energy use in Saskatchewan. The final objective of this report is to find the current best practices.

Energy for heating and power in a hog production facility is a significant production cost since a suitable and constant environment is extremely important for the survival of hogs. For example, newborn hogs require an ambient air temperature of about 30° C; whereas sows feel discomfort at temperatures above 20° C. Small hogs therefore need access to a special brooder area and possibly a separate heat source. Because of the energy intensive operation and temperature sensitivity, various energy costs and sources need to be considered for any new operation or expansion of hog production in Saskatchewan. This report identifies the pattern of energy consumption rates and compares the local consumption rates with the industrial averages. The analysis will help individual hog producers understand their consumption behaviour and find problems in their energy system, so that they can determine what areas to improve on. It will also help hog producers and the public sector predict the needs for energy in the future.

1.4. The Organization of the Report

The remainder of the body of the report is organized into two chapters. In Chapter Two, an overview of Saskatchewan hog industry along with energy consumption of this sector is provided. This chapter includes a review of hog production, farm input prices, cash receipts from hog farming operations, farm energy expenses, and the value of Saskatchewan livestock export. In Chapter Three, the model, data, and empirical analysis are discussed. The methodology includes statistical descriptive analysis and econometric analysis. Using these two methods, energy consumption in different hog farms has been compared and conclusions on the energy efficiency of hog barns have been drawn considering both of these two methods.

Chapter II

2.1. Introduction

Saskatchewan's agriculture is experiencing a crisis. With increasing input costs and lower grain prices, the realized net farm income in Saskatchewan dropped 41% last year to $487 million, an average of roughly $8,500 per farm. The federal Agriculture department has predicted Saskatchewan farmers will be $48 million in the red this year. It is expected that 1999 will be the worst year for farm income since statistics were first recorded in 1926 [10].

There is an urgent need to diversify the Saskatchewan agricultural economy. With a readily available supply of feed grains and a large land base, diversification into hog production is logical. The economic activities involved in hog production can generate revenues and employment to the Saskatchewan economy. For example, farmers need to purchase inputs necessary for the production of hogs on farms, such as processed feeds, energy (including fuel, heating fuel and lubricants) and utility, veterinarian services, equipment and machinery, trucks, and labour to operate the system. Each of these inputs has to be produced locally or imported from outside the region. Much of these economic activities would be reduced or probably not take place if the hog industry in Saskatchewan did not exist. On the other hand, the cost of these inputs directly or indirectly affect the cost of hog production and ultimately they affect what hog producers put in their pocket at the end of the day.

Among the costs of inputs that farmers have to spend in order to maintain a smooth operation, energy is one of the most important cash expenses. According to a survey conducted by the Saskatchewan Pork Producers Marketing Board (SPPMB) in 1988 [4], energy and utility together ranged from 5.9% to 56.2% of their total cash expenses, depending on the type of operation (farrow-to-finish or feeder-to-finish) and the size of the farm and barns.

2.2. Background of the Hog Industry in Saskatchewan

Hog production is an important farming operation in the Saskatchewan agricultural economy. The profitability of this operation depends mainly on reducing production costs and increasing throughput of the operation. With recent extremely low hog prices, Saskatchewan hog producers need to consider and apply any practices and factors that would result in lower operating expenses. Reduction in energy input costs will reduce total costs considerably over an extended period. This section provides a statistical picture of the hog industry in Saskatchewan.

2.2.1. Hogs on Farms

The hog industry in Saskatchewan has experienced a somewhat steady development during most of this century. The total number of hogs on Saskatchewan farms increased from 546.000 hogs in 1960 to 862,000 hogs in 1997, an increase of 57.9%. While the hog population increased over the last 30 years, it has fluctuated from year to year. In 1963, Saskatchewan farms had the lowest population with only 441,000 hogs. The Saskatchewan hog population stabilized in the range of 400,000 to 600,000 during the late 60's and then increased rapidly from 1969 to 1970 and peaked at 1971 with over 1,090,000 hogs (Figure 1). It then dropped to 492,000 in 1975, and stayed in the range of between 500,000 and 800,000 hogs in the 80's. Since 1990, production has stabilized at a mid 800,000 level.

This fluctuating trend of hog supply in Saskatchewan was largely influenced by the demand, represented here by the price, which had a cyclical pattern. The hog cycle is a biological-economic pattern that is an interaction of the production process of hogs and the use of a market price determined by supply and demand. If one starts the hog production with a low inventory of hogs, the output in the next biological period will be low. This will lead to higher prices since the supply will be low. Hog producers respond to this high market price through the expansion of the herd and output increases. The increase in supply drives down prices and producers sell off inventory to reduce production. This then completes the cycle. The cycle is approximately three to four years in length [3,5].

For example, in 1959, the average hog price was $20.16/cwt, the lowest price since 1946. The low price discouraged hog production and the hog population hit a ten-year low record at 1963. When the market price increased 27.0% from $26.65/cwt in 1967 to $33.85/cwt in 1969, the supply peaked at an all-time high of 1,090,000 in 1971 (Figure 2). Since 1989, the average market price increased 38.9% from $57.9/cwt to $80.42/cwt (in 1997) and the hog population also increased 9.0% from 791,000 in 1989 to 862,000 in 1997 (Figure 1).

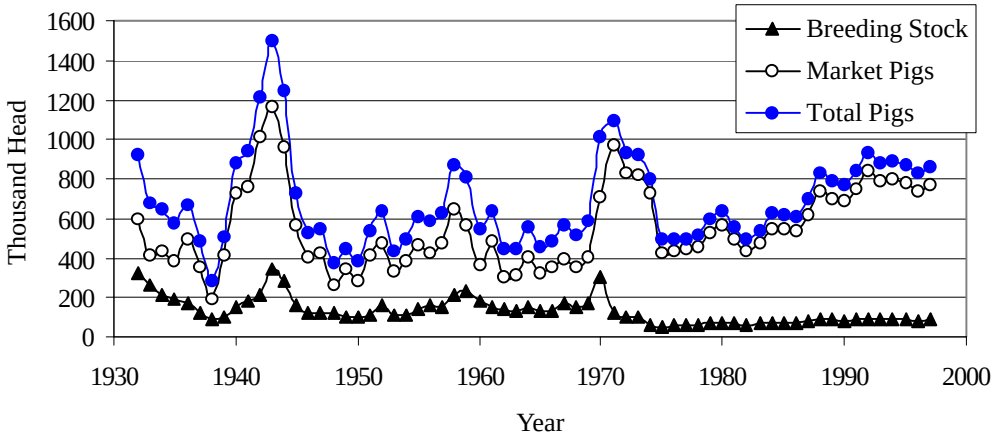

Figure 1: Hogs on Farms, Saskatchewan, 1932-1997.

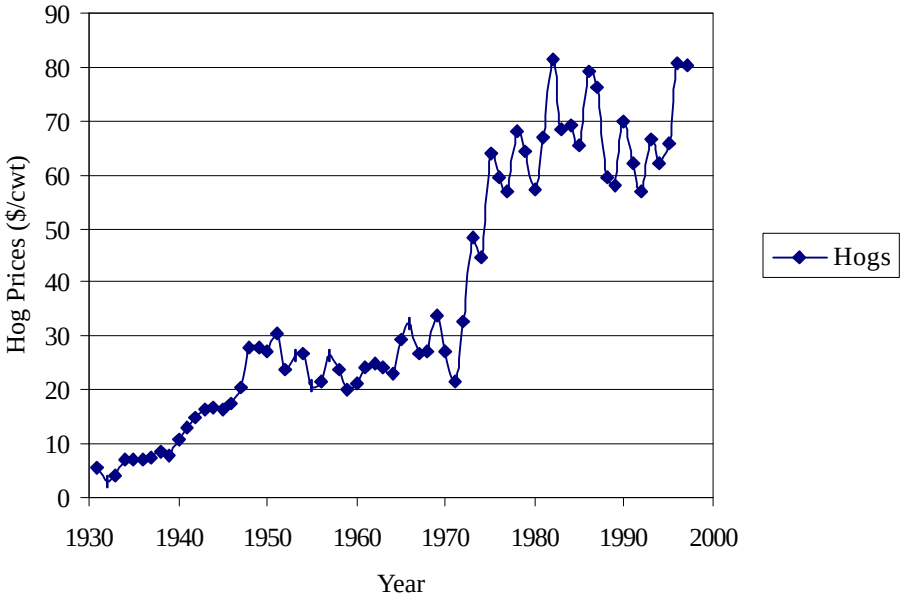

Figure 2: Average Hog prices, Saskatchewan, 1931-1997.

2.2.2. Cash Receipts from Hogs Farming in Saskatchewan

Saskatchewan hog operations are an important part of livestock activities in the province. Table 1 and Figure 3 show that the cash receipts from hog operations ranged from a low of 13.2 percent of total livestock cash receipts in 1989 to a high of 18.3 percent in 1996. However, the livestock industry and hog operations both (in absolute terms) received larger cash receipts in 1997 than over the period of 1989 to 1997.

Table 1: Cash Receipts from Hog Farming Operations, Saskatchewan, 1989 - 1997.

Year	1989	1990	1991	1992	1993	1994	1995	1996	1997
Hogs	121,462	140,807	128,141	129,016	154,344	150,985	157,393	190,119	197,256
Total Livestock Receipts	923,381	899,941	862,677	960,341	1,116,349	1,037,186	994,598	1,038,028	1,202,607
Share of Hogs to the Total Livestock Receipts	0.132	0.156	0.149	0.134	0.138	0.146	0.158	0.183	0.164

The cash receipts that farmers received from hog production also influence the supply of hogs in Saskatchewan. While the total livestock receipts increased 30.2% from $923,381,000 in 1989 to $1,202,607,000 in 1997, the hog cash receipts increased 62.4%

from $121,462,000 in 1989 to $197,256,000 in 1997. The share of hogs to total livestock receipt more than doubled in the recent 8 years period (Figure 3).

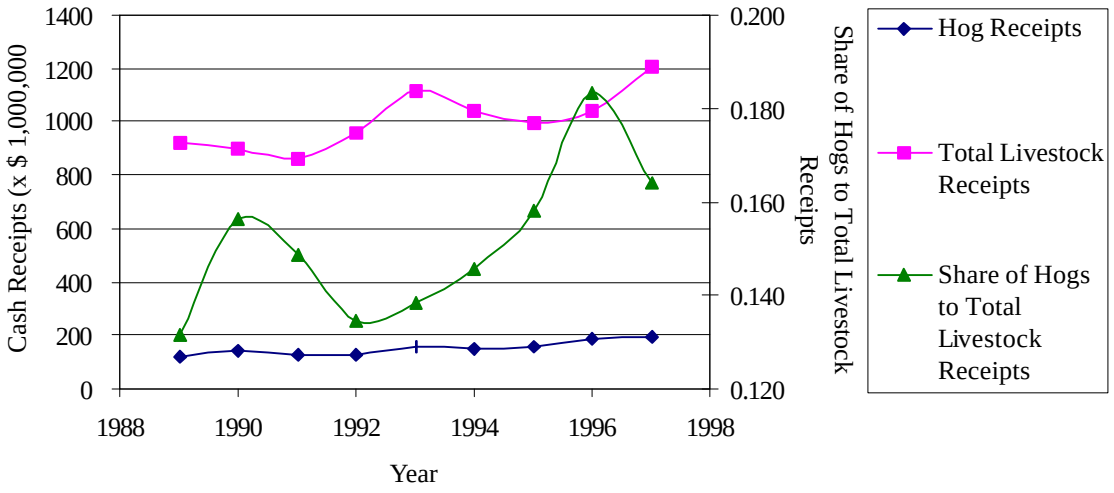

Figure 3: Cash Receipts from Farming Operations, Saskatchewan, 1989-1997.

Figure 4 illustrates the relative cash receipts of livestock operations for Saskatchewan in 1997. Cattle and calves livestock activity is the main livestock activity in Saskatchewan. This sector earned 65 percent of total livestock cash receipts in 1997 followed by hogs operation with 17 percent.

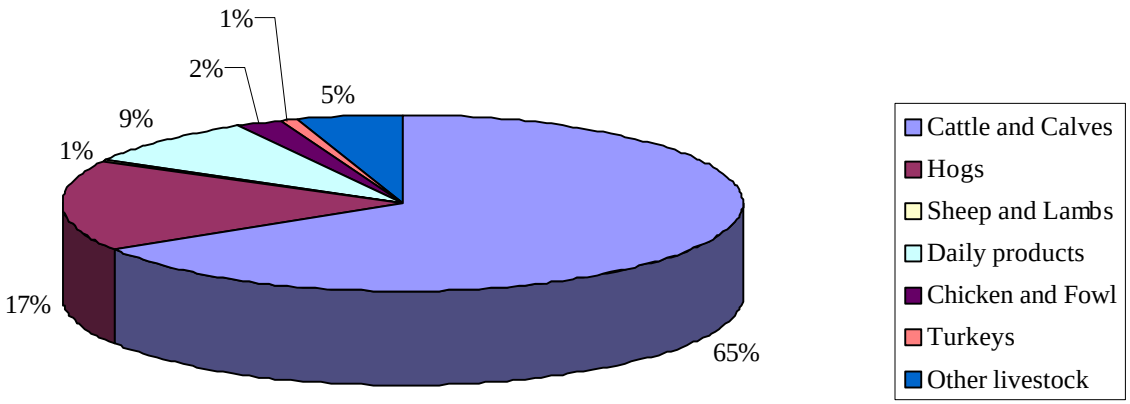

Figure 4: Relative Cash Receipts of Livestock Farming Operations, Saskatchewan, 1997.

While the hog population in Saskatchewan has increased over the last 30 years, the number of farms reporting hogs has consistently declined since 1961. The number of hog farms in Saskatchewan decreased 86% from 40,693 in 1961 to 5,778 in 1986. The average hogs per farm increased from 14 to 105 in 1986, a 650% increase in hogs per farm [4]. Although some of this change may be a result of changes in the definition of a farm, it does point out the rapid consolidation of hog productions (Figure 5).

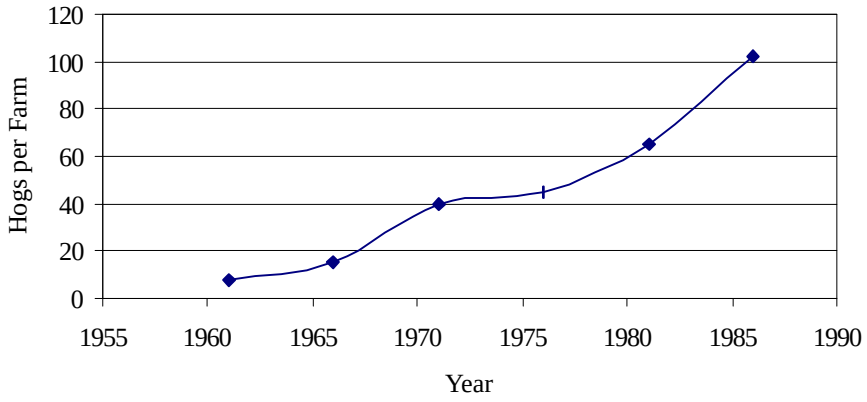

Figure 5: Hogs per Farm, Saskatchewan, 1961-1986.

2.2.3. Farm Input Prices

The trend of consolidation of hog farms in Saskatchewan resulted in a specialization of producers in hog production. With the increase of hog farm size, along with the inflation on almost every input hog producers have to purchase, the operating costs increased substantially during the last 18 years. Hog producers have two major concerns on their mind; the realized net income and the cost of farm inputs. Although the average market price increased 38.9% from $57.9/cwt in 1989 to $80.42/cwt in 1997 (Table 2 and Figure 6), the hog price index increased only by 18.9% from 71.5 in 1989 to 85 in 1997 (with 1986 price as 100) due to the effects of inflation (Table 3 and Figure 7). Note that the hog price indices are relatively lower than other livestock product prices for this period. The price of cattle, calves, hogs, and sheep and lambs all illustrate an upward trend. However, this trend is less significant for hog products.

Table 2: Average Livestock Prices (dollars per cwt), Saskatchewan, 1980 - 1997.

	Cattle	Calves	Hogs	Sheep and Lamb
1980	68.81	82.68	57.09	65.92
1981	64.63	68.60	67.02	60.36
1982	61.75	69.20	81.51	55.76
1983	65.20	80.70	68.54	58.69
1984	67.55	84.65	69.35	61.16
1985	67.75	85.10	65.53	73.06
1986	72.00	101.55	79.07	72.20
1987	83.65	119.36	76.28	81.62
1988	82.06	113.25	59.37	66.59
1989	80.40	109.09	57.90	61.47
1990	83.33	111.76	69.90	52.63
1991	83.07	111.30	62.09	46.25
1992	84.83	111.78	56.95	52.66
1993	99.29	134.98	66.42	66.33
1994	97.69	122.96	61.96	76.60
1995	80.28	100.16	65.74	85.06
1996	68.90	83.39	80.69	90.31
1997	85.58	114.41	80.42	100.38

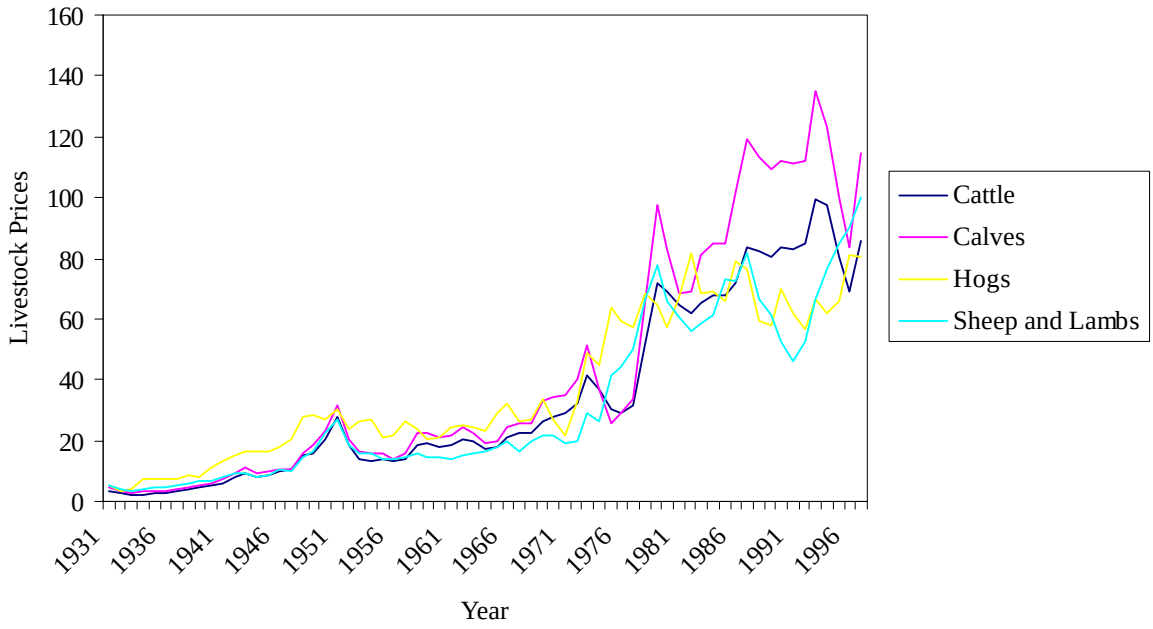

Figure 6: Average Livestock Prices (dollars per cwt), Saskatchewan, 1931 - 1997.

Table 3: Farm Product Price Index (1986 = 100), Saskatchewan, 1976 - 1996.

Year	Total Livestock	Cattle	Hogs	Poultry	Eggs	Dairy
1976	53.1	42.6	71	72.8	73.2	45.6
1977	53.4	44.9	65.9	70.4	73.4	47.9
1978	71.8	67.6	82.2	72.9	73	55.4
1979	89.1	96.7	79.2	84.1	77	60
1980	85.5	92.6	70.6	85.6	80.5	64.8
1981	87.1	89.5	83.6	98.1	98.1	69.9
1982	87.8	86.5	101.5	94.9	95.7	75.3
1983	87.7	89	86.1	94.3	98.8	75.7
1984	90.7	91.6	86.5	104.8	103.2	82.1
1985	91.4	92.4	82.1	98.3	102.5	89.5
1986	100	100	100	100	100	100
1987	108.7	114.2	95.2	99.4	91.2	98.8
1988	106.1	113.6	73	99.1	97	102.7
1989	104.2	110	71.5	106.7	101.3	105.1
1990	107	110.6	89.5	107	100.8	106.2
1991	106.4	111.5	79.1	103.2	98.3	106.8
1992	101.7	105.8	72.7	100	97.7	107.9
1993	113.7	120.5	86.2	100.8	100.1	109.3
1994	110.2	116.1	81	95.9	102.1	110.8
1995	101.5	101.9	85	96.4	107	114.8

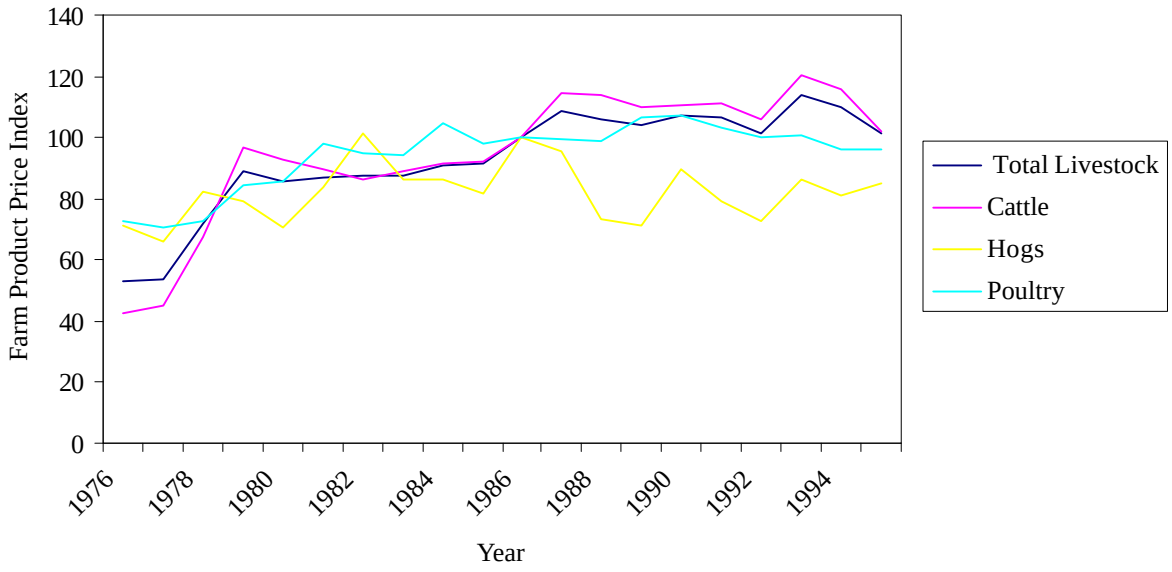

Figure 7: Farm Product Price Index (1986 = 100), Saskatchewan, 1976 - 96.

Total farm input prices, petroleum prices, and electricity prices show an upward trend over the period of 1981 to 1997 (Tables 4 and 5 and Figures 8 and 9). The total farm input price index increased 23.9% from 100 in 1986 to 123.9 in 1997. Among the total farm inputs, the price index of petroleum products increased 20.2% from 100 in 1986 to 120.2 in 1997. The price index of electricity increased 60.2% from 100 in 1986 to 160.2 in 1997. The lower price of petroleum products relative to other inputs may be the main reason why farmers are less careful about energy efficiency and more careful about other costs, such as feeding costs.

The rate of increase of total farm input cost (23.9%) surpassed the rate of increase in hog market price (18.9%) so that hog producers in Saskatchewan ended up with a reduced realized net income.

Table 4: Farm Input Price Index (1986 = 100), Western Canada: 1981 - 1997.

Year	Total Farm Inputs (WC)	Petroleum Products	Electricity
1981	92.4	86.5	77.1
1982	95.6	101.4	84.3
1983	95.7	106.9	88.8
1984	98.1	111.4	96.3
1985	98.7	117.3	99.9
1986	100.0	100.0	100.0
1987	98.7	94.3	107.8
1988	101.7	93.0	110.3
1989	106.2	93.1	114.3
1990	108.6	104.6	116.4
1991	106.3	113.2	116.0
1992	104.9	104.6	124.5
1993	109.9	105.0	128.4
1994	113.9	108.5	132.0
1995	119.7	114.8	134.0
1996	125.0	120.4	142.8
1997	127.7	124.0	144.5

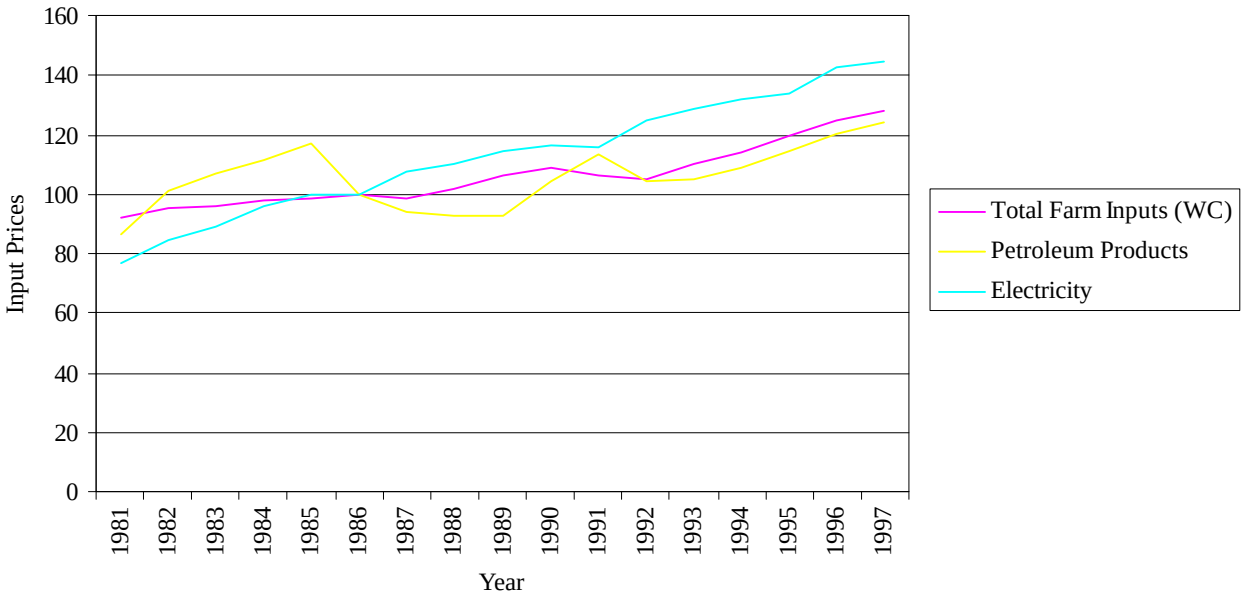

Figure 8: Farm Input Price Index (1986 = 100), Western Canada 1981 - 1997.

Table 5: Farm Input Price Index (1986 = 100), Saskatchewan, 1986 - 1997.

Year	Total Farm Inputs (S)	Petroleum Products	Electricity
1986	100.0	100.0	100.0
1987	n.a.	94.2	111.5
1988	n.a.	93.0	116.0
1989	n.a.	92.9	122.0
1990	n.a.	104.8	122.0
1991	n.a.	114.0	122.0
1992	102.7	105.7	127.4
1993	106.8	106.1	135.6
1994	110.1	105.8	138.2
1995	116.8	110.5	140.8
1996	123.0	115.6	160.2
1997	123.9	120.2	160.2

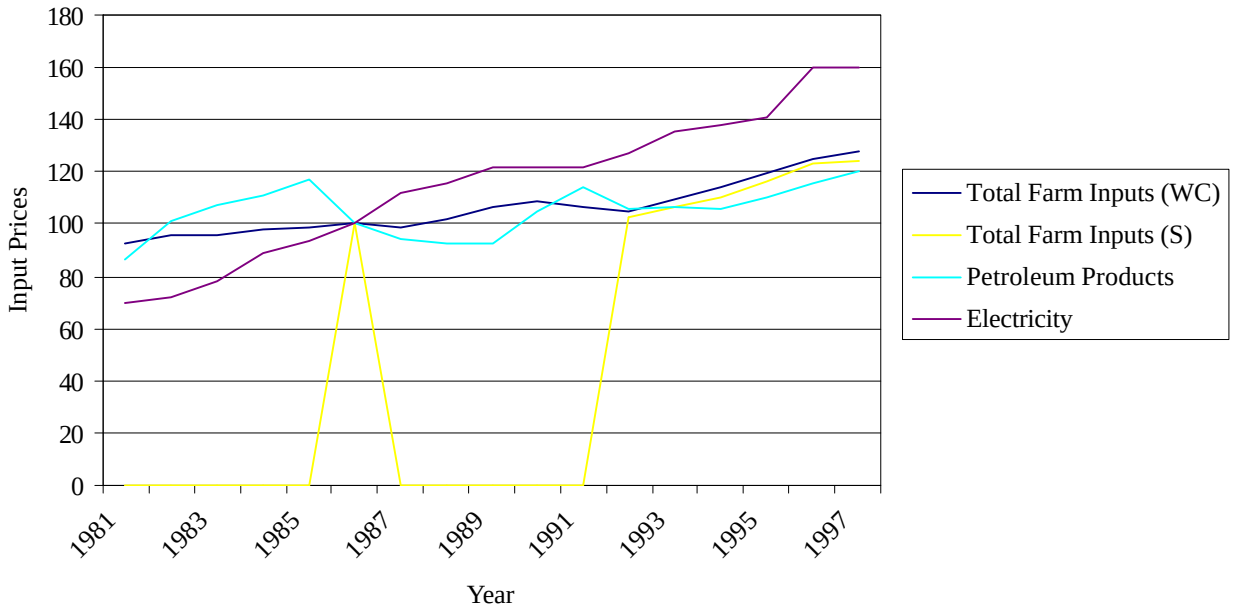

Figure 9: Farm Input Price Index (1986 = 100), Saskatchewan, 1981 - 1997.

2.2.4. Farm Energy Expenses in Saskatchewan

With their costs steadily increasing, hog producers need information about their energy and utility consumption patterns, so that they can identify the problems in their energy system and the potential to improve the efficiency of the system. They also need to know the consumption patterns on other farms so that measures can be taken to meet and exceed the industry standard.

Table 6 shows energy expenses for farming operations in Saskatchewan. Energy expenses include electricity, heating fuel, and fuel and lubricants. Although the energy costs increased 34.2% from $426,814 in 1989 to $606,624 in 1997, slightly lower than the rate of increase of gross operating cost, the ratio of energy expenses vs. total operating costs fluctuated greatly over the same period (Table 6 and Figure 10). Energy expenses in hog operations ranged from 13.4 percent of gross operating expenses to 15.4 percent of gross operating expenses over the period of 1989 to 1997. The share of energy expenses in livestock operations remained the same over this period, with the exception of the period 1991- 1993. This period overlapped with a world oil crisis due to the

Persian Gulf War. The higher world energy prices may lead to a higher share of energy expenses, though similar conclusions cannot be made from Table 4 and Figure 8.

Table 6: Farm Energy Expenses -Electricity, Heating, Fuel,Lubricants Sask. 1989 - 1997.

Year	1989	1990	1991	1992	1993	1994	1995	1996	1997
Gross Operating Expenses	3,190,199	3,150,831	3,147,994	3,202,315	3,387,817	3,595,891	3,9010,60	4,207,851	4,353,431
Energy Costs	426,814	453,639	469,357	485,934	522,915	543,830	557,899	602,317	608,624
Energy Expenses/Total Expenses	0.134	0.144	0.150	0.152	0.154	0.151	0.143	0.143	0.140

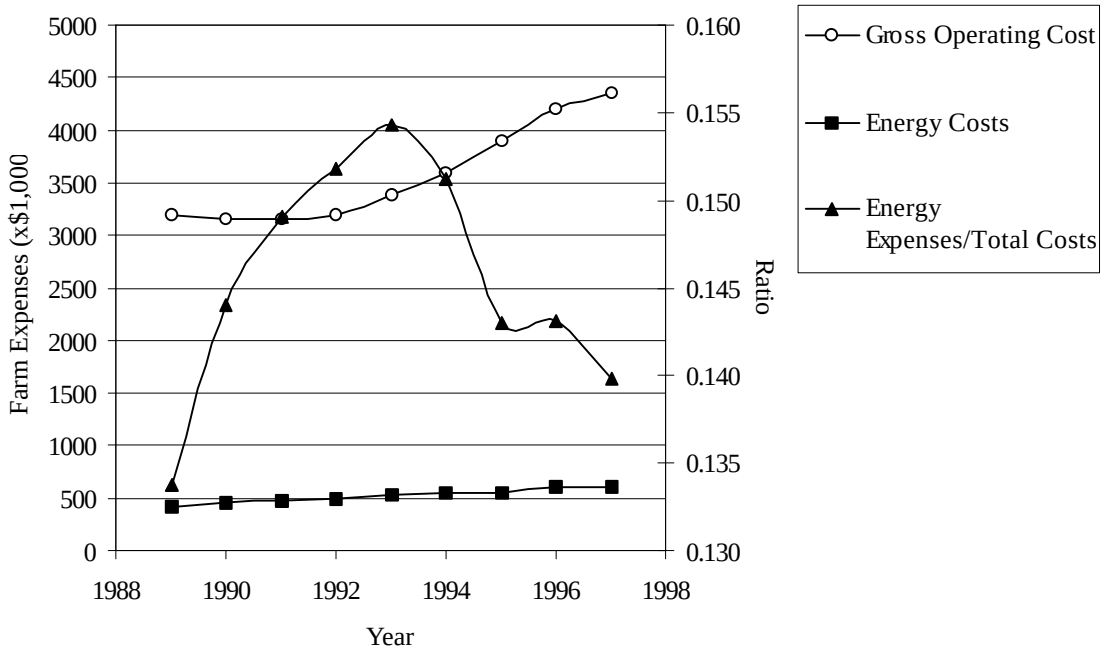

Figure 10: Operating + Energy Expenses - Electricity, Heating, Fuel, Sask. 1989 - 1997.

2.2.5. Value of Saskatchewan Livestock Export

The hog production industry in Saskatchewan provides products mainly for domestic markets, with approximately 97 percent of production being used in the domestic market. Only about 3 percent of total hog production is exported out of province. Cattle and calves provided about 55 percent of total value of Saskatchewan livestock export in 1997. The value of hog exports reached the highest of 4 percent of

total livestock export in 1995 (Table 7 and Figures 11-12). Therefore, it can be concluded that the hog industry is oriented to the domestic processing market and less attention is given to the export of hogs themselves.

Table 7: Value of Saskatchewan Agriculture and Food Exports 1994 - 1997.

Year	1994	1995	1996	1997
Cattle and Calves	202.5	158.5	205.4	205.9
Hogs	9.2	11.4	11.2	8.3
Other Livestock and Poultry	7.2	10.3	9.7	11.4
Animal Products	79.2	98.7	133.9	158.3
Total Export	3,665.5	4,218.4	4,579.5	5,081.2
Total Livestock Export	298.1	278.9	360.2	383.9
Hogs/Total Livestock Export	0.0309	0.0409	0.0311	0.0216

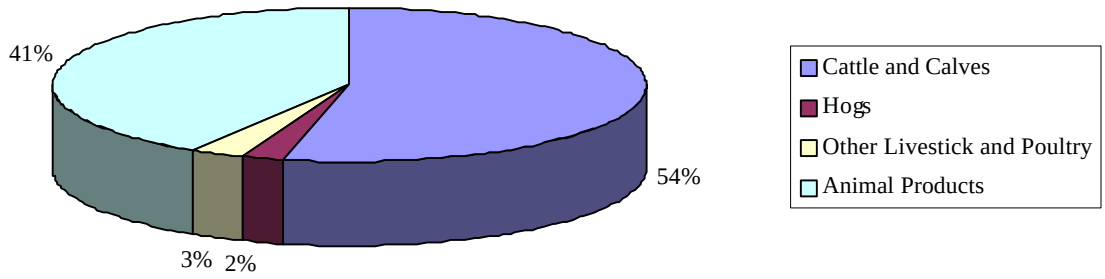

Figure 11: Value of Saskatchewan Livestock Exports 1997.

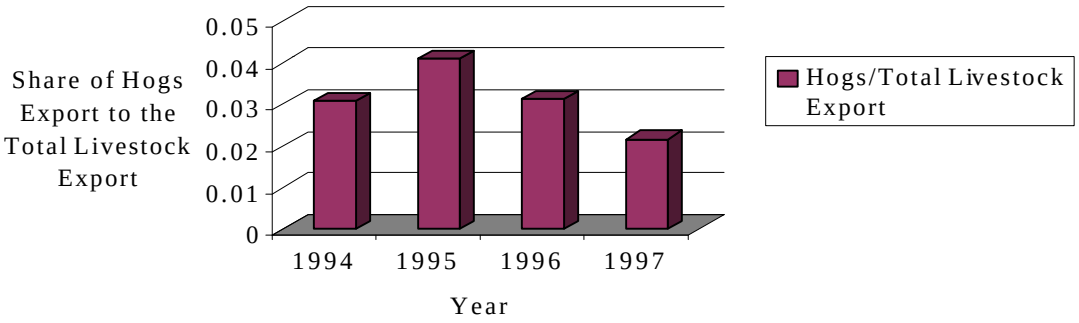

Figure 12: Share of Hogs Export to the Total Livestock Export, Saskatchewan 1997.

Numbers of livestock according to type are provided in Tables 8 and 9 and Figure 13. The number of cattle and calves show a significant upward trend with some fluctuation over the period 1997. This number is almost constant for hogs except that after 1975 there is an upward trend with some fluctuation. The number of sheep and lambs declined over this period.

Table 8: Livestock on Farms (Number of Head), Saskatchewan, 1980 - 1997.

Year	Horses	Cattle and Calves	Sheep and Lambs	Hogs
1980	n.a.	2415000	73000	640000
1981	60180	2401000	76000	560000
1982	n.a.	2387000	74000	500000
1983	n.a.	2308000	66000	540000
1984	n.a.	2249000	62100	625000
1985	n.a.	2071000	56500	620000
1986	67484	2036000	53000	608000
1987	n.a.	2074000	58700	700000
1988	n.a.	2127000	64300	829000
1989	n.a.	2146000	72000	791000
1990	n.a.	2173000	82500	770000
1991	53843	2279000	92000	843000
1992	n.a.	2382000	85000	929700
1993	n.a.	2484000	82000	878600
1994	n.a.	2607000	79000	889800
1995	n.a.	2838000	78200	868000
1996	66372	2952000	86000	829300
1997	n.a.	2885000	71900	862000

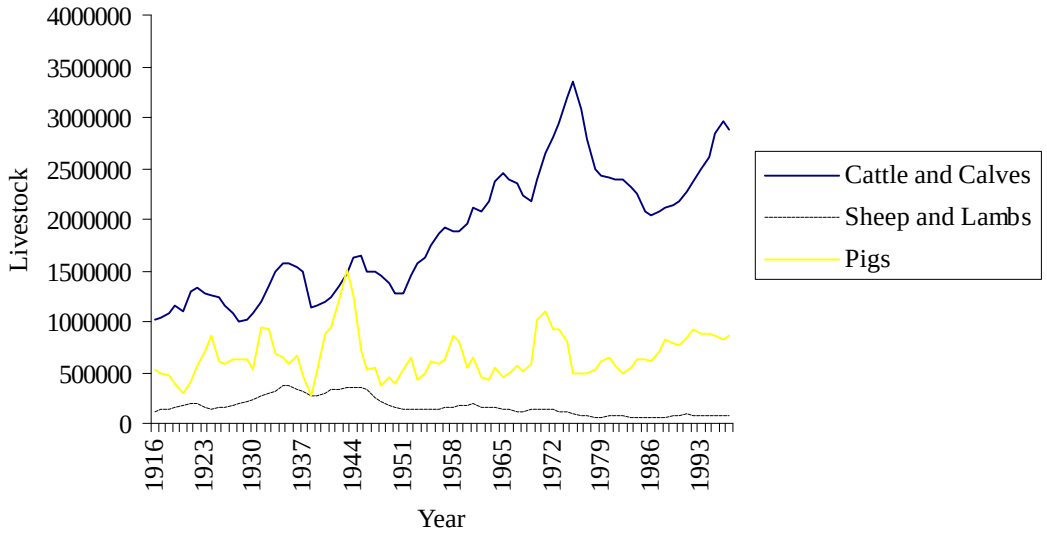

Figure 13: Livestock on Farms (Number of Head), Saskatchewan: 1916 - 1997.

Table 9: Hogs on Farms (thousand heads), Saskatchewan, 1985 – 1997.

	Breeding Stock	Market Hogs	Total Hogs
1985	71.5	548.5	620
1986	72	536	608
1987	83	617	700
1988	93	736	829
1989	88	703	791
1990	86	684	770
1991	90	753	843
1992	93	836.7	929.7
1993	90.3	788.3	878.6
1994	94.7	795.1	889.8
1995	87.2	780.8	868
1996	85.5	743.8	829.3
1997	90	772	862

2.3. Summary

This section provided a statistical picture of livestock with particular attention to the hog industry in Saskatchewan. Energy costs accounted for almost 15 percent of total gross farming operating costs. The price of petroleum products, used mostly for heating purposes, was lower than other input prices in period of 1989 to 1997. The hog production industry in Saskatchewan provides only 3 percent for export and most of the production is used in the domestic processing market.

Chapter III

3.1. The Model

Energy and utility costs on individual farms could be very different from one to the other. Individual variables such as weather, size of barns, managerial experience and skills, and stages of the barn development can affect the efficient utilization of energy and utilities. In this chapter, two methods of descriptive analysis and econometric analysis were used to study the efficiency use of energy in hog production.

3.2. Data

The data for this study were provided by a number of organizations in Saskatchewan and Manitoba. Environment Canada provided environmental data, such as temperature, and wind speed. SaskEnergy and Manitoba Hydro provided electricity data for Saskatchewan and Manitoba. SaskPower provided natural gas data. The Co-op in Saskatchewan and Manitoba provided propane use in two of the barns. Saskatchewan Agriculture and Food provided the data used in Chapter 2 of the study.

The ILO production group used in this study provided production data, such as number of sows, boars, piglets, nursery, etc. The ILO Group is a partner in 19 hog operations in Saskatchewan and Manitoba. The ILO Group is responsible for production at these locations. ILO uses different types of energy to heat/cool the barns. Some of these operations are connected to natural gas and some use propane and electricity. The availability of a range of facilities, locations, energy supply, weather conditions, and managers provide an excellent source for an economic study which will eventually have significant market impact for farmers and hog producers.

3.3. Empirical Analysis

The original data provided by Saskpower, SaskEnergy, Manitoba Hydro, and Co-op required preparation and transformation. For example, meter reading of the data registered in each barn did not follow a consistent time pattern. A method was required to transform all the data for all the barns to a monthly basis. Comparison over all the barns could be made only when the data for all barns were transformed to the same monthly measure.

When the energy data for all the barns was transformed to a monthly basis, a transformation factor was used to transform data from KWH, M^3, and litres to a unique unit of megajoules. One KWH of electricity was multiplied by 3.6 to transform it to megajoule. One cubic metre of natural gas was multiplied by 38.55 to transform it to megajoule, and one litre of propane was multiplied by 25.6 to transform it to megajoule (Tables 10-18).

Tables 10 to 18 provide transformed monthly energy use for different farms. The left margin of these tables is the time period and the top margin is the number assigned to each barn. Data in these tables are in KWH, M^3, and megajoules. Smaller barns were separated from larger barns. The data for double sized farms are presented in separate tables.

The tables also recognize the energy used for power, light and heat. In the bottom of these tables, a statistical description of each barn is provided. For example, in Table 16 the monthly energy use of 35 months of barn number 5 is provided. In a 35 months period, this farm consumed a monthly minimum of 15,640 megajoules to a maximum of 918,176 megajoules of energy. On average, this farm consumed 375,885 megajoules per month on energy. Weighted average of energy use for all the farms is 434,344 megajoules a month. Monthly energy use of this farm is therefore less than the weighted average. Similar comparisons can be made over other barns using original scale or transformed measure. This analysis provides a good sense of the energy use for all the barns in order to compare management of the barns. Comparisons can be easily made across all the barns.

Table 10: Monthly Electricity for Power in Barns: October 1996 to July 1999 (in KWH).

DATE	(1)	(2)	(3)	(4)	(5)
99/07				54883	
99/06	55891	52384	55665	52703	55990
99/05	56437	51638	54857	49884	53419
99/04	53547	47390	48250	48176	46364
99/03	54936	47598	46906	50308	47742
99/02	50520	41694	41997	45064	42338
99/01	56947	45356	47851	50774	46251
98/12	56449	46510	46173	48995	48169
98/11	52551	45040	42868	47118	45399
98/10	57349	48199	44175	49565	47298
98/09	52791	50220	48972	49978	51856
98/08	53860	58036	53902	53139	54800
98/07	55546	55516	44370	52323	56540
98/06	55536	46182	37366	52620	53935
98/05	56875	37888	33640	55236	54052
98/04	54473	34812	26100	52059	49242
98/03	54055	33199	22512	51137	48785
98/02	45976	26090	18823	44893	42383
98/01	54013	26859	20679	51783	49600
97/12	62299	21621	12360	45012	48070
97/11	54000	15531	11961	43560	46133
97/10	57382	10800		54293	50920
97/09	54118			45507	51247
97/08	57564			52110	54994
97/07	58995			54806	60542
97/06	57743				57661
97/05	58424				56787
97/04	57127				
97/03					
97/02					
97/01					
96/12					
96/11					
96/10					
Number of Months	27	21	20	25	26
Maximum	62299	58036	55665	55236	60542
Minimum	45976	10800	11961	43560	42338
Monthly Average in Each Farm	55385	40122	37971	50237	50789
Sum in Each Farm	1495404	842562	759427	1255925	1320518
Standard Deviation	3034	13246	14217	3443	4807
Total					
Weighted Average of All the Farms					

Table 10 Cont.: Monthly Electricity for Power in Hog Farms.

DATE	(6)	(11)	(12)	(13)	(14)	(7) (Powering)	
99/07						66443	
99/06	51389	45716	45964	39087		63582	
99/05	50620	41579	41086	26146	20082	65300	
99/04	47411	37504	37943	19642	18493	60014	
99/03	46179	33594	38286	19739	22776	56765	
99/02	41971	24352	29694	16055	21086	49603	
99/01	48401	28291	28073	22625	15646	55502	
98/12	50552	22560	28380	14041	10274	55205	
98/11	46723	14777	20834			51981	
98/10	48189		15394			55231	
98/09	52686					58426	
98/08	57232					66851	
98/07	49564					65949	
98/06	38680					60378	
98/05	29537					58268	
98/04	30058					54095	
98/03	25352					53670	
98/02	15744					48161	
98/01	16108					51182	
97/12	15326					52531	
97/11	10742					47924	
97/10	6084					46479	
97/09						42755	
97/08						38589	
97/07						32343	
97/06						19939	
97/05						26981	
97/04						23982	
97/03						10800	
97/02							
97/01							
96/12							
96/11							
96/10							
Number of Months	21	8	9	7	6	29	199
Maximum	57232	45716	45964	39087	22776	66851	
Minimum	6084	14777	15394	14041	10274	10800	
Monthly Average in Each Farm	37074	31047	31739	22477	18060	49618	
Sum in Each Farm	778546	248372	285654	157336	108357	1438929	
Standard Deviation	16128	10443	9913	8340	4519	14522	
Total							8691031
Weighted Average of All the Farms							43674

Table 11: Monthly Electricity for Power in Double Sized Farms: 1996 - 1999 (in KWH).

DATE	(8)	(9)	(10)	
99/07				
99/06	100643	89396	111219	
99/05	97565	84219	106782	
99/04	87036	76505	127567	
99/03	76973	75286	64920	
99/02	75384	66094	60326	
99/01	89726	73373	78694	
98/12	95485	76034	66173	
98/11	80260	77522	57473	
98/10	86146	87298	57346	
98/09	96711	97327	50325	
98/08	112159	109298	57227	
98/07	114565	109868	56698	
98/06	107585	103279	52866	
98/05	80940	100996	52126	
98/04	111019	92281	48540	
98/03	86634	84854	48210	
98/02	64888	73712	42990	
98/01	87758	83803	48360	
97/12	65319	84314	48408	
97/11	58440	85612	46719	
97/10	57326	90666	45742	
97/09	58687	90621	50908	
97/08	57639	100158	54649	
97/07	56912	101235	57342	
97/06	60866	96711	56300	
97/05	52965	94520	51308	
97/04	52886			
97/03				
97/02				
97/01				
96/12				
96/11				
96/10				
Number of Months	27	26	26	79
Maximum	114565	109868	127567	
Minimum	52886	66094	42990	
Monthly Average in Each Farm	80464	88653	61508	
Sum in Each Farm	2172517	2304981	1599216	
Standard Deviation	19865	11648	21340	
Total				6076714
Weighted Average of All the Farms				76920

Table 12: Monthly Electricity Used for Power: 1996 - 1999 (in Mj).

DATE	(1)	(2)	(3)	(4)	(5)
99/07				197580	
99/06	201207	188582	200392.3	189731	201564
99/05	203172	185895	197485.7	179583	192310
99/04	192771	170603	173698	173435	166912
99/03	197770	171353	168861	181110	171870
99/02	181872	150100	151189	162229	152416
99/01	205008	163282	172263	182787	166504
98/12	203217	167435	166223	176383	173410
98/11	189183	162145	154326	169624	163435
98/10	206458	173517	159029	178435	170273
98/09	190049	180791	176300	179919	186683
98/08	193897	208929	194047	191301	197279
98/07	199965	199856	159732	188364	203543
98/06	199928	166255	134516	189431	194164
98/05	204750	136397	121105	198851	194587
98/04	196103	125323	93961	187411	177271
98/03	194597	119516	81045	184094	175627
98/02	165514	93926	67761	161614	152578
98/01	194446	96692	74444	186420	178560
97/12	224278	77834	44496	162043	173052
97/11	194400	55913	43061	156816	166078
97/10	206575	38880		195453	183313
97/09	194823			163823	184490
97/08	207229			187596	197979
97/07	212383			197301	217952
97/06	207875				207581
97/05	210327				204435
97/04	205658				
97/03					
97/02					
97/01					
96/12					
96/11					
96/10					
Number of Months	27	21	20	25	26
Maximum	224278	208929	200392	198851	217952
Minimum	165514	38880	43061	156816	152416
Monthly Average in Each Farm	199387	144439	136697	180853	182841
Sum in Each Farm	5383454	3033221	2733933	4521333	4753865
Standard Deviation	10923	47685	51180	12395	17304
Total					
Weighted Average of All the Farms					

Table 12 (Cont.): Monthly Electricity Used for Powering October 1996 July 1999 (in Mj).

DATE	(6)	(11)	(12)	(13)	(14)	(7) (Powering)	
99/07						239194	
99/06	185000	164576	165471	140712.8		228894	
99/05	182232	149683	147910	94126.63	72295	235078	
99/04	170678	135015	136593	70712.23	66574	216051	
99/03	166246	120937	137829	71060.14	81993	204354	
99/02	151096	87667	106899	57799	75909	178572	
99/01	174243	101846	101063	81451	56325	199806	
98/12	181986	81216	102169	50549	36987	198738	
98/11	168202	53198	75001			187130	
98/10	173479		55420			198833	
98/09	189671					210335	
98/08	206034					240664	
98/07	178429					237418	
98/06	139249					217361	
98/05	106333					209763	
98/04	108207					194742	
98/03	91267					193213	
98/02	56678					173379	
98/01	57989					184255	
97/12	55174					189112	
97/11	38671					172525	
97/10	21903					167326	
97/09						153917	
97/08						138920	
97/07						116436	
97/06						71780	
97/05						97133	
97/04						86334	
97/03						38880	
97/02							
97/01							
96/12							
96/11							
96/10							
Number of Months	21	8	9	7	6	29	199
Maximum	206034	164576	165471	140713	81993	240664	
Minimum	21903	53198	55420	50549	36987	38880	
Monthly Average in Each Farm	133465	111767	114262	80916	65013.83	178626	
Sum in Each Farm	2802767	894138	1028355	566411	390083	5180143	
Standard Deviation	58060	37595	35685	30023	16269.27	52278	
Total							31287704
Weighted Average of All the Farms							157225

Table 13: Electricity for Power in Double Sized Hog Barns: 1996 - 1999 (in Mj).

DATE	(8)	(9)	(10)	
99/07				
99/06	362316	321826	400389	
99/05	351233	303187	384416	
99/04	313329	275419	459241	
99/03	277104	271031	233714	
99/02	271384	237938	217173	
99/01	323013	264143	283297	
98/12	343746	273721	238223	
98/11	288937	279079	206901	
98/10	310124	314275	206446	
98/09	348160	350377	181172	
98/08	403771	393471	206017	
98/07	412435	395526	204112	
98/06	387305	371806	190316	
98/05	291383	363585	187653	
98/04	399667	332211	174744	
98/03	311882	305473	173556	
98/02	233597	265364	154764	
98/01	315929	301692	174096	
97/12	235148	303529	174269	
97/11	210386	308203	168189	
97/10	206374	326397	164672	
97/09	211275	326234	183267	
97/08	207499	360571	196737	
97/07	204884	364446	206430	
97/06	219117	348161	202678	
97/05	190674	340271	184707	
97/04	190389			
97/03				
97/02				
97/01				
96/12				
96/11				
96/10				
Number of Months	27	26	26	79
Maximum	412435	395526	459241	
Minimum	190389	237938	154764	
Monthly Average in Each Farm	289669	319151	221430	
Sum in Each Farm	7821060	8297935	5757179	
Standard Deviation	71513	41934	76826	
Total				21876174
Weighted Average of All the Farms				276913

Table 14: Monthly Energy Used for Heating Farms, 1996 to 1999 (in M^3 and KWH).

DATE	(1)	(2)	(3)	(5)	(6)	(7) (Heating)[2]	
99/07					3370		
99/06	1360	2933	6311	2899	3312	959	
99/05	2885	4268	9336	5115	4096	14923	
99/04	6696	6639	15078	11051	5933	30009	
99/03	14476	6582	22219	21091	9600		
99/02	20683	4970	23269	21673	11777		
99/01	25892	4797	29327.97	23818	16260	161230	
98/12	18620	3753	23564	18508	19084	126321	
98/11	10497	8174	13336	12112	10751	103444	
98/10	5432	8279	9466	7789	7004	53841	
98/09	2839	5280	4628	3474	3799	8459	
98/08	1149	3418	3170	949	2511	5006	
98/07	1197	2577	3096	1857	3155	1253	
98/06	1679	3065	42772	3050	4433	28064	
98/05	4363	5730	23356	9417	7211	21203	
98/04	10331	11176	700	7177	12148	111845	
98/03	13956	18110	1399	12996	15831	224393	
98/02	10316	21761	3291	22701	17184	184958	
98/01	18389	25526	23644	17019	22316	273113	
97/12	15375	23827	4201	12182	23117	247545	
97/11	12065	23402		9916	5888	239827	
97/10	9204	5029		7336		179463	
97/09	4072			3593		47852	
97/08	1430			406		34245	
97/07	1037			2208		34880	
97/06	1004			2451		17888	
97/05	8347			5224		153332	
97/04	9438			8246		126641	
97/03	9753			14715			
97/02	44443			6664			
97/01	20284			18537			
96/12	16230			18704			
96/11	110483			14833			
96/10	14493			8169			
96/09	4789			3838			
96/08				1553			
Number of Months	34	21	19	35	21	25	130
Maximum	110483	25526	42772	23818	23117	273113	
Minimum	1004	2577	700	406	2511	959	
Monthly Average	13330	9490	13798	9751	9942	97228	
Sum	453208	199295	262163	341269	208780	2430696	
Standard Deviation	19398	7833	11693	7027	6654	88716	
Weighted Average of farms							11267

[2] This farm uses electricity and propane (starting October 98) for heating. Other farms in the Table use natural gas.

Table 15: Energy Used for Heating Double Sized Hog Barns: 1996 - 1999 (in M^3).

DATE	(8)	(9)	(10)	
99/07			4171	
99/06	3204	3815	7292	
99/05	5975	10453	15298	
99/04	9371	16012	22255	
99/03	20156	26272	26256	
99/02	22685	31051	41729	
99/01	27893	40138	46524	
98/12	36576	35427	43051	
98/11	16011	23917	19282	
98/10	8591	16817	7001	
98/09	3302	7509	2296	
98/08	2254	3596	1862	
98/07	2010	4611	1937	
98/06	3959	6916	2251	
98/05	3906	12430	2875	
98/04	16214	22141	5797	
98/03	41153	32085	11604	
98/02	38220	32942	12397	
98/01	52623	36199	19557	
97/12	37618	27123	12507	
97/11	10502	17031	11267	
97/10	5737	11133	6468	
97/09	1642	4991	2364	
97/08	1766	1943	1749	
97/07	1504	5870	1726	
97/06	1508	9243	1810	
97/05	3046	9551	3138	
97/04	5696	9243	6476	
97/03	7386	20339	11319	
97/02	9611	30462	14830	
97/01	9846	27363	17274	
96/12	10034	20624	20106	
96/11	6609	15535	8456	
96/10	4845		6730	
96/09	4047		3417	
96/08	2069			
Number of Months	35	32	35	102
Maximum	52623	40138	46524	
Minimum	1504	1943	1726	
Monthly Average in Each Farm	12502	17899	12088	
Sum in Each Farm	437568	572784	423070	
Standard Deviation	13623	11278	11952	
Total				1433422
Weighted Average of All the Farms				14053

Table 16: Energy Used for Heating Hog Barns: 1996 - 1999 (Mj).

DATE	(1)	(2)	(3)	(5)	(6)	(7)(Heating)	
99/07					129921		
99/06	52418	113050	243304	111768	127672	3452	
99/05	111212	164516	359894	197177	157897	53724	
99/04	258118	255952	581275	426033	228731	108031	
99/03	558045	253725	856553	813047	370085		
99/02	797314	191579	897001	835507	453991		
99/01	998151	184906	1130593	918176	626813	580428	
98/12	717813	144688	908377	713497	735693	454756	
98/11	404670	315115	514086	466908	414439	372398	
98/10	209399	319157	364932	300266	269985	193828	
98/09	109448	203530	178405	133908	146458	30454	
98/08	44311	131778	122202	36565	96806	18022	
98/07	46148	99333	119336	71598	121641	4513	
98/06	64717	118172	1648844	117592	170882	101030	
98/05	168213	220873	900383	363020	277979	76332	
98/04	398242	430826	27004	276664	468293	402643	
98/03	537998	698134	53927	500988	610282	807815	
98/02	397669	838904	126877	875114	662433	665850	
98/01	708905	984030	911472	656066	860300	983207	
97/12	592725	918539	161935	469606	891178	891163	
97/11	465115	902152		382276	226976	863376	
97/10	354807	193852		282802		646068	
97/09	156984			138514		172267	
97/08	55134			15640		123283	
97/07	39982			85136		125568	
97/06	38692			94495		64395	
97/05	321779			201397		551993	
97/04	363843			317893		455909	
97/03	375971			567254			
97/02	1713275			256893			
97/01	781960			714582			
96/12	625661			721039			
96/11	4259104			571804			
96/10	558688			314902			
96/09	184625			147968			
96/08				59862			
Number of Months	34	21	19	35	21	25	130
Maximum	4259104	984030	1648844	918176	891178	983207	
Minimum	38692	99333	27004	15640	96806	3452	
Monthly Average in Each Farm	513857	365848	531916	375885	383260	350020	
Sum in Each Farm	17471136	7682811	10106397	13155958	8048455	8750504	
Standard Deviation	747798	301963	450747	270876	256527	319377	
Total							56464756
Weighted Average of All the Farms							434344

Table 17: Energy Used for Heating in Double Sized Hog Barns: 1996 - 1999 (Mj).

DATE	(8)	(9)	(10)	
99/07			160804	
99/06	123503	147079	281126	
99/05	230322	402961	589729	
99/04	361233	617261	857918	
99/03	777015	1012788	1012186	
99/02	874500	1197007	1608665	
99/01	1075267	1547337	1793497	
98/12	1409989	1365712	1659601	
98/11	617227	921990	743328	
98/10	331201	648304	269884	
98/09	127287	289488	88511	
98/08	86892	138634	71766	
98/07	77486	177769	74654	
98/06	152619	266630	86768	
98/05	150576	479184	110821	
98/04	625047	853549	223482	
98/03	1586445	1236863	447323	
98/02	1473391	1269911	477892	
98/01	2028626	1395465	753928	
97/12	1450165	1045602	482147	
97/11	404864	656537	434339	
97/10	221159	429160	249332	
97/09	63282	192403	91119	
97/08	68077	74911	67437	
97/07	57960	226281	66525	
97/06	58114	356314	69775	
97/05	117419	368191	120972	
97/04	219576	356314	249646	
97/03	284721	784086	436353	
97/02	370516	1174322	571691	
97/01	379572	1054856	665920	
96/12	386825	795039	775075	
96/11	254780	598855	325987	
96/10	186775		259457	
96/09	156016		131711	
96/08	79756			
Number of Months	35	32	35	102
Maximum	2028626	1547337	1793497	
Minimum	57960	74911	66525	
Monthly Average in Each Farm	496004	710740	446920	
Sum in Each Farm	15376129	19900714	13407605	
Standard Deviation	550097	445603	477490	
Total				48684448
Weighted Average of All the Farms				477298.5

Table 18: Monthly Propane Use in Barn Number 4.

Barn # 4	House (L)	House (MJ)	Barn (L)	Barn (MJ)	Total (L)	Total (MJ)
DATE						
99/05			5443	139341		
99/04	355	9079	11301	289303	11656	298382
99/03	366	9382	16470	421634	16837	431016
99/02	409	10470	17600	450555	18009	461024
99/01	592	15149	18189	465649	18781	480798
98/12	598	15315	20129	515307	20727	530622
98/11	275	7042	16106	412320	16381	419362
98/10	284	7277	14262	365113	14546	372390
98/09	275	7042	4590	117516	4866	124559
98/08	123	3157	4166	106639	4289	109797
98/07	85	2169	4027	103089	4112	105257
98/06	82	2099	3897	99763	3979	101862
98/05	85	2169	208	5326	293	7495
98/04	82	2099	10854	277873	10936	279972
98/03	85	2169	21244	543843	21329	546011
98/02	234	5993	22238	569302	22472	575296
98/01	582	14908	31364	802912	31946	817821
97/12	260	6650	23069	590564	23329	597214
97/11	323	8266	20001	512021	20324	520286
97/10	334	8541	13044	333936	13378	342477
97/09	253	6478	6021	154125	6274	160603
97/08	153	3922	1577	40379	1731	44301
97/07	153	3922	1577	40379	1731	44301
97/06	148	3795	1526	39076	1675	42872
97/05	153	3922	4211	107800	4364	111722
97/04	240	6148	6143	157260	6383	163407
97/03	438	11214	10466	267921	10904	279135
97/02	396	10129	16586	424606	16982	434736
97/01	559	14307	25961	664593	26520	678901
96/12	672	17207	26008	665805	26680	683012
96/11	580	14855	14621	374298	15201	389152
96/10	336	8605	9890	253178	10226	261783
96/09	139	3556	7070	180981	7208	184537
96/08	144	3675	5434	139105	5577	142780
96/07	144	3675	5366	137362	5509	141037
96/06	139	3556	5113	130889	5252	134445
96/05	144	3675	9429	241390	9573	245065
96/04	139	3556	16884	432230	17023	435787
96/03	437	11177	24763	633937	25200	645115
96/02	581	14872	22262	569915	22843	584787
96/01	1083	27715	18125	463987	19207	491702

3.4. Descriptive Analysis of Each Barn

In this section, the energy and electricity consumption rates and the rate of energy per hog for 14 hog barns in Saskatchewan and Manitoba were analyzed. Among the 14 hog barns, three of them are double the size of the other 11 barns.

The Industrial Average Rate

To help determining the local efficiency, an "industrial average" charge for each of the consumption rates was developed using normal data of all hog barns.

3.4.1. Barn Number 1

The natural gas consumption rate at barn number 1 has a reverse cyclical pattern of weather as was expected (Figure 14). It had two abnormal peaks in November 1996 and in February 1996, at which the natural gas consumption were 1466% and 283% higher than the industrial average at the same period respectively. Since June 1998, consumption stabilized as it become close to the pattern of industrial average except the peak from December 1998 to February 1999.

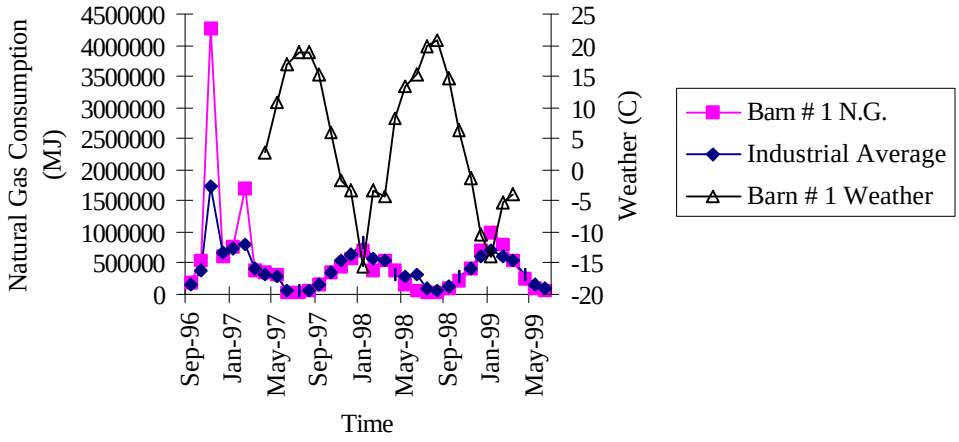

Figure 14: Natural Gas Consumption at Barn Number 1

The electricity consumption at barn number 1 was about 37% higher than the industrial average (Figure 15). Weather had little effect on the electricity consumption,

indicating that it did not use electricity as a main source of heating.

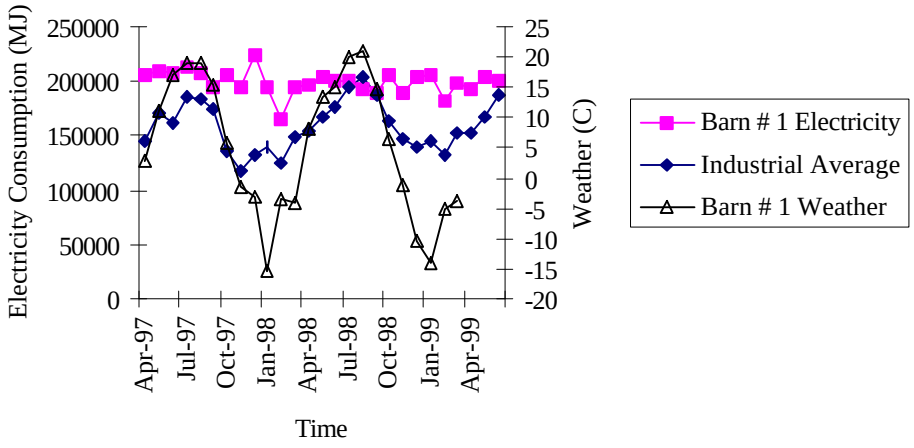

Figure 15. Electricity Consumption at Barn Number 1.

The pattern of energy per hog (E/P) at this barn from April 1997 to March 1999 was similar as the total energy consumption pattern over the same period for all barns (Figure 16). It experienced a higher than industrial average peak from December 1998 to February 1999.

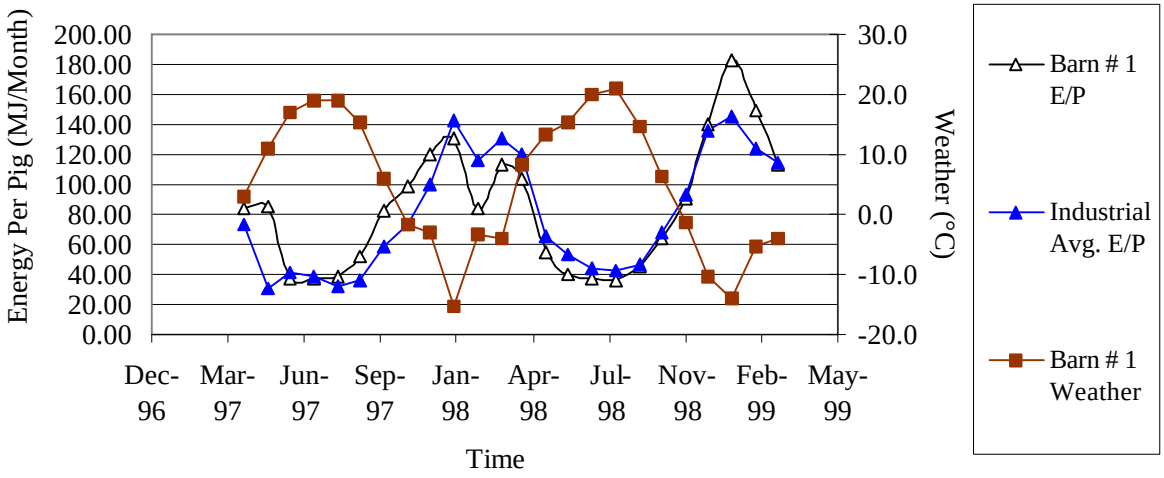

Figure 16: Energy Per Hog (E/P) at Barn Number 1.

3.4.2. Hog Barn Number 2

The natural gas consumption rate at barn number 2 had a similar pattern as the industrial average from October 1997 to October 1998 (Figure 17). Then starting in November 1998, it had a substantial lower consumption rate than the industrial average, until it returned to normal in May 1999.

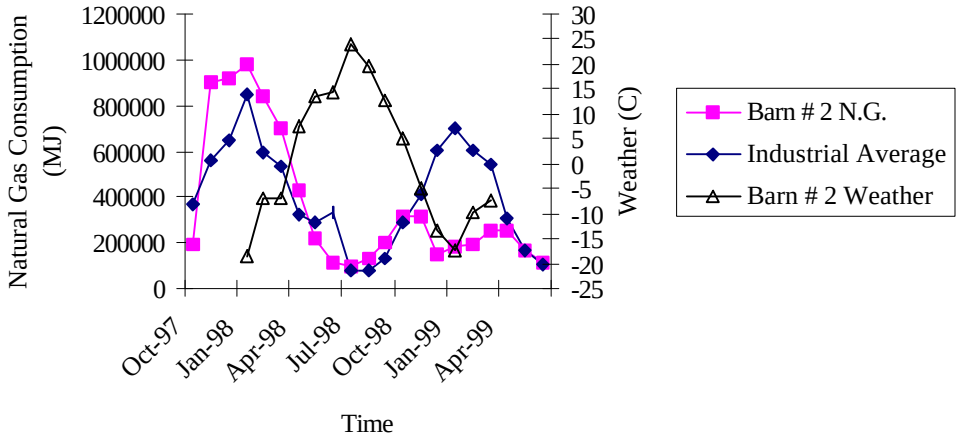

Figure 17: Natural Gas Consumption at Barn Number 2.

The electricity consumption at this barn was lower than the industrial average in the period of October 1997 to June 1998 and above the industrial average from July 1998 to May 1999 (Figure 18). The low initial rate in October 1997 and steep climb to reach the industrial average in July 1998 probably indicates that the barn was increasing its production during later 1997 and the first half of 1998. Once it reached its economical capacity, the electricity consumption stabilized and the barn used slightly more electricity than most of its peers in this industry.

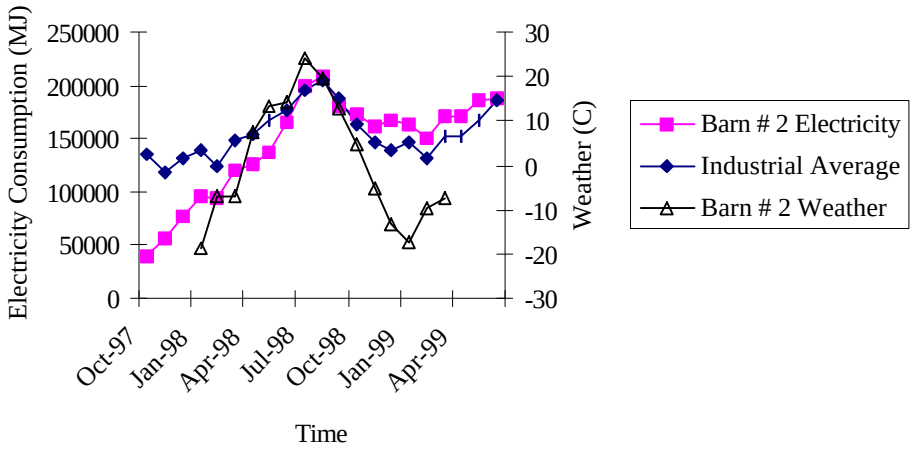

Figure 18: Electricity Consumption at Barn Number 2.

This observation was supported by the E/P data collected from January 1998 to March 1999 (Figure 19). During the initial five months, the energy consumption per hog was so high that it was more than 2300% of the industrial average. Since April 1999, it stayed at or below the industrial average.

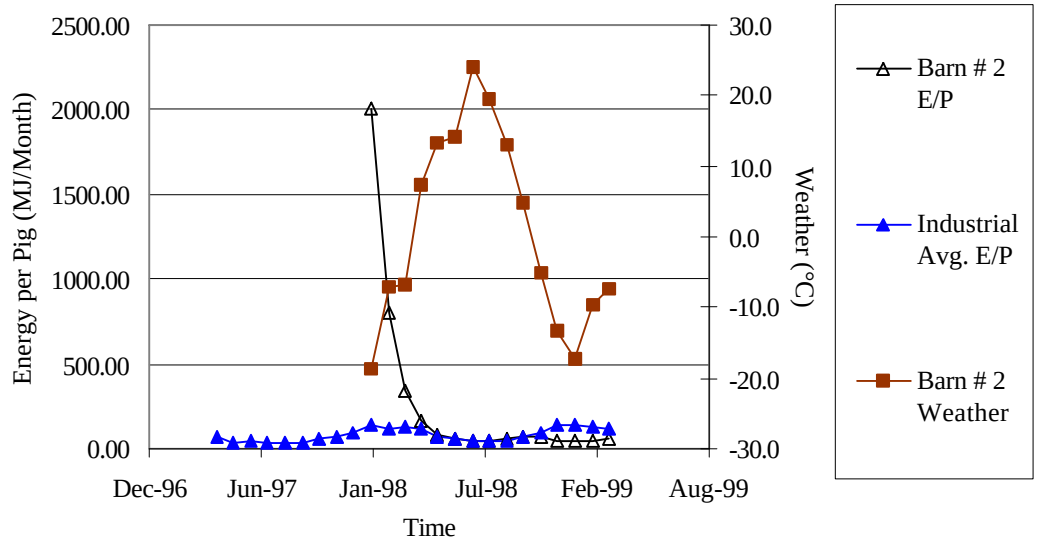

Figure 19: Energy Per Hog (E/P) at Barn Number 2.

3.4.3. Hog Barn Number 3

The natural gas consumption at barn number 3 was rather fluctuating (Figure 20).

It started about three times lower than the industrial average in December 1997 and then jumped to a level above the industrial average in January 1998, then dropped to a level about 3 times lower than the initial consumption rate over the next three months. Natural gas consumption rate soared to be 6-7 times higher than the industrial average during May and June 1998, even though the weather was well above 10 ^{0}C, indicating there was some problems in production. It returned to normal in July 1998. However, the natural gas consumption rate went higher than normal again October 1998, and stayed above the industrial average since then.

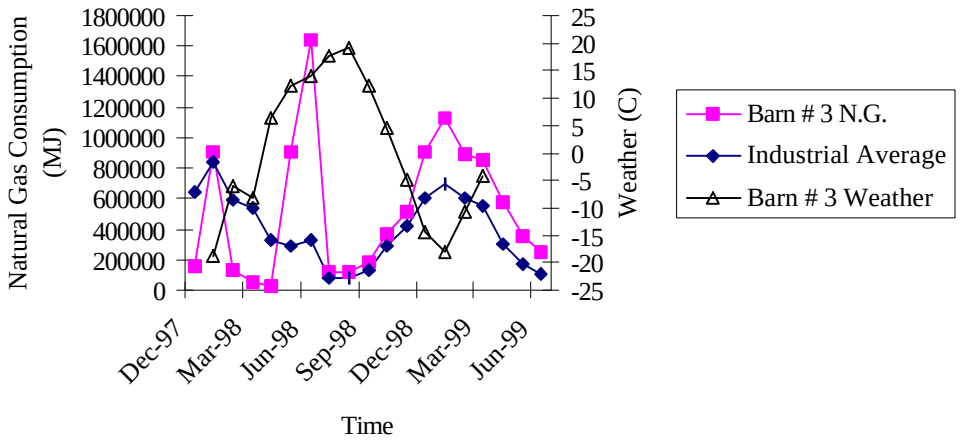

Figure 20: Natural Gas Consumption at Barn Number 3.

The electricity consumption at this barn was much more efficient than its natural gas consumption (Figure 21). The first 7 months of operation, from November 1997 to July 1998, are assumed to be the period of development. During this period, production was under capacity. Unlike the natural gas that was used to supply the heating and hot water to keep the barn and building warm during severe Saskatchewan winter, electricity was used to operate equipment and machinery, regardless of weather. After October1998, the electricity consumption rate was higher than the industrial average. This may be a concern to the management at this barn.

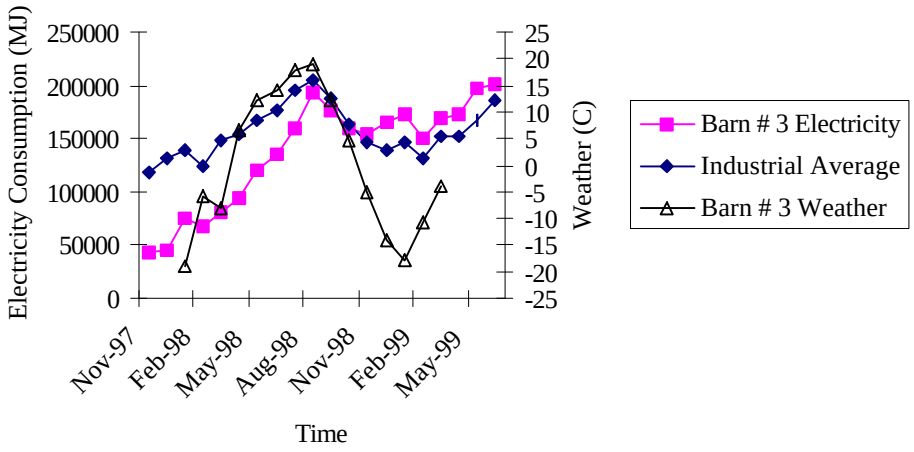

Figure 21: Electricity Consumption at Barn Number 3.

The E/P rate at this barn was very high at the first month when the barn started business, then it dropped sharply during the next two months (Figure 22). It became close to the industrial average during the fourth month. However, for some unknown reasons, the E/P rate went up again during April and May of 1998. In June 1998, it was reduced to normal level and stabilized since then. If the first peak can be explained by the reasons mentioned above, it is the second hike (which happened during the later spring and early summer with average temperature around 10 ^{0}C) that needs to be investigated in order to avoid the same hike happening again in the future.

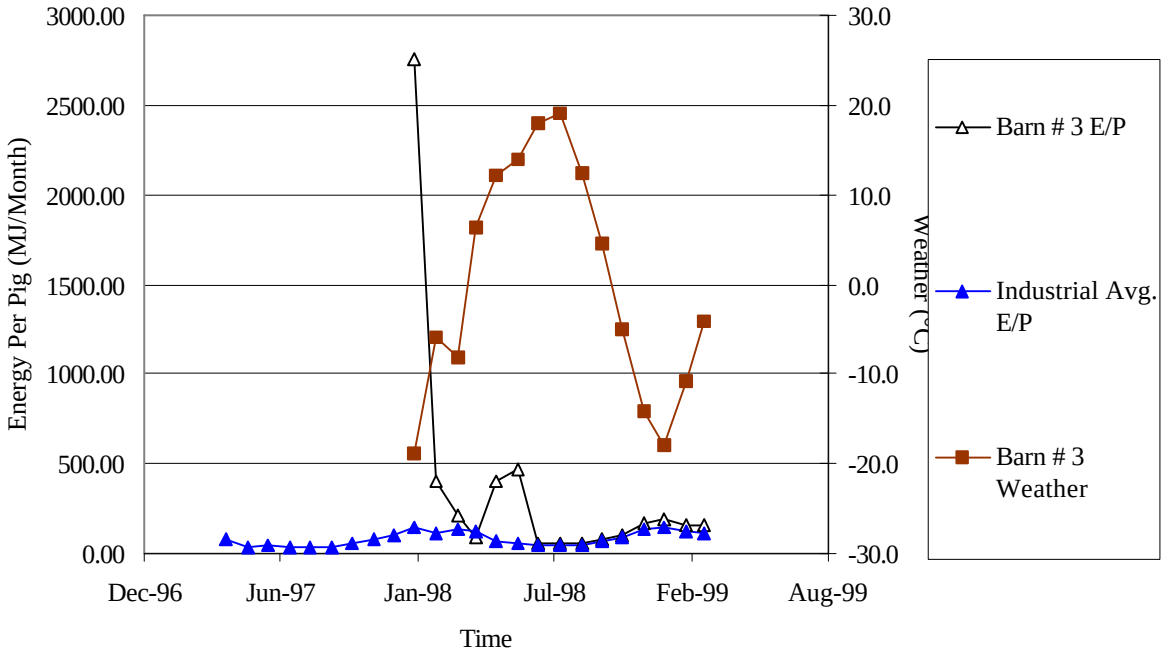

Figure 22: Energy Per Hog (E/P) at Barn Number 3.

3.4.4. Hog Barn Number 4

This barn uses propane to heat the barn. The propane consumption rate at this barn had very similar pattern as the industrial average with lower rate all the time during the period of study (Figure 23).

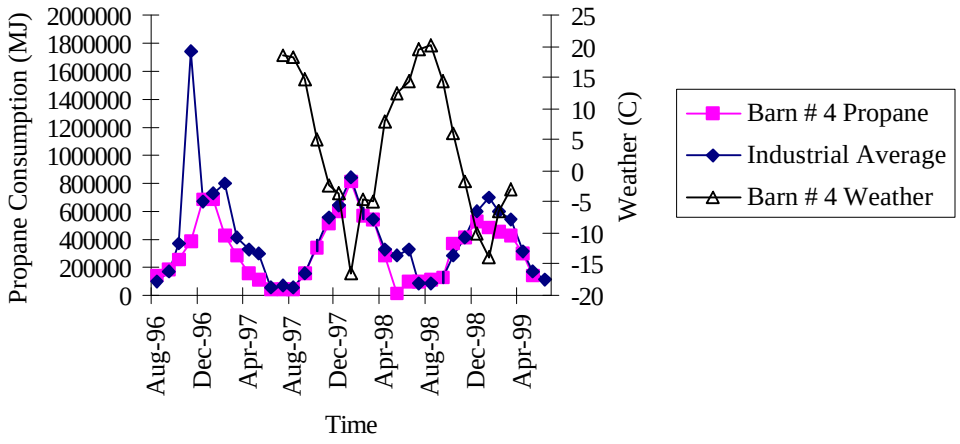

Figure 23: Propane Consumption at Barn Number 4.

The electricity consumption rate at this barn was about 20% to 30% higher than the industrial average during the last two years, except a short period between July and August in 1998 (Figure 24). Comparing with the industrial average, the electricity consumption was rather stable, reflecting a smooth operation at this barn.

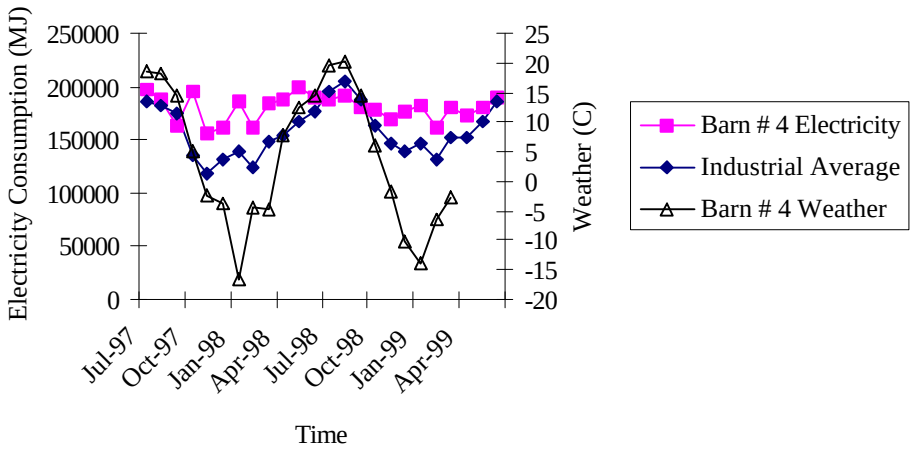

Figure 24: Electricity Consumption at Barn Number 4.

The E/P rate at this barn had a similar pattern as the industrial average (Figure 25). This is probably due to its mature and smooth operation. The E/P rate had been lower than the industrial average since February 1998.

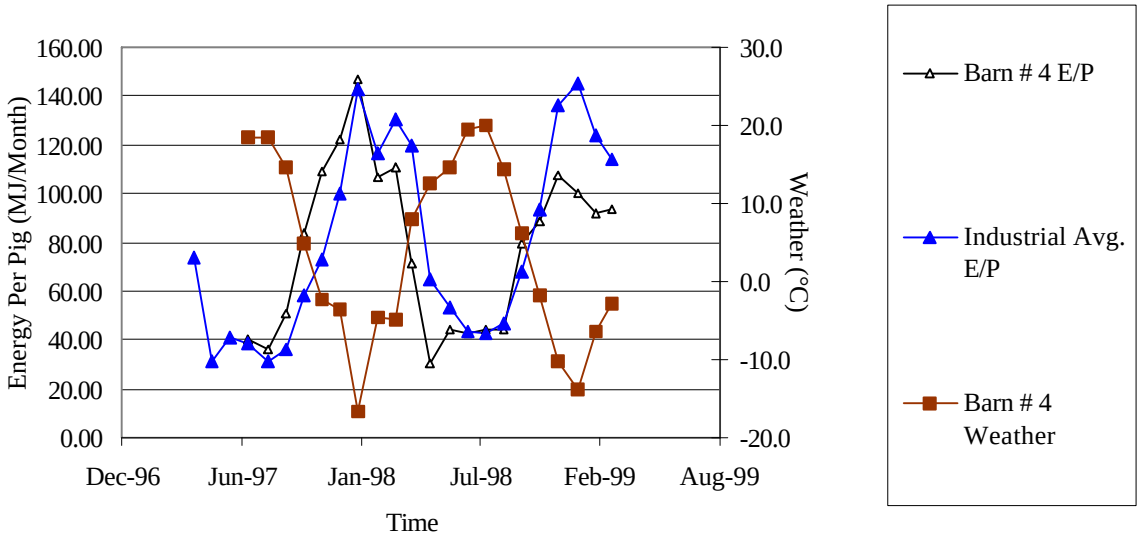

Figure 25: Energy Per Hog (E/P) at Barn Number 4.

3.4.5. Hog Barn Number 5

Natural gas consumption at barn number 5 was normal during last three summers. However, it experienced consumption rates over 40% to 50% higher than normal rate during winters of 1996-97 and 1998-99 (Figure 26). If these hikes were not caused by production fluctuation, the heating system needs to be checked before winter to avoid paying high-energy bill again in the coming winter.

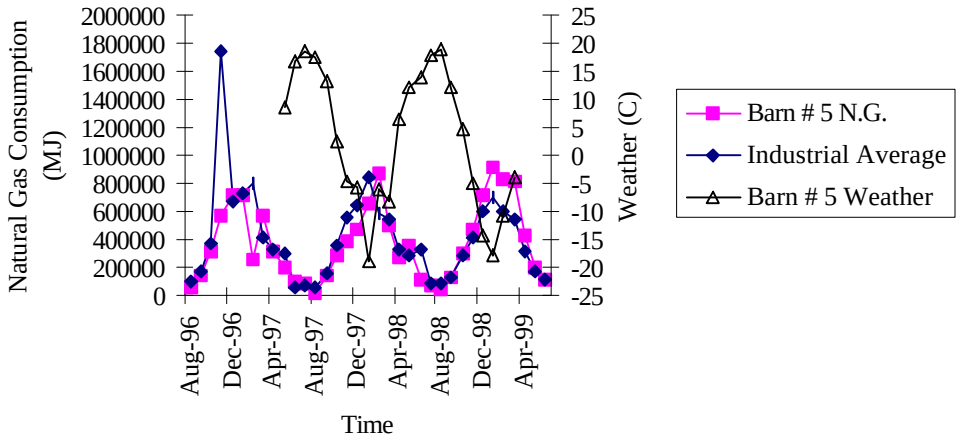

Figure 26: Natural Gas Consumption at Barn Number 5.

For some unknown reasons, the electricity consumption rate at this barn was always higher than the industrial average during the period of may 1997 to April 1999 (Figure 27). There was no apparent weather effect. The consumption peaks happened during the summer, indicating there was a lot production activity during the summer seasons of 1997 and 1998.

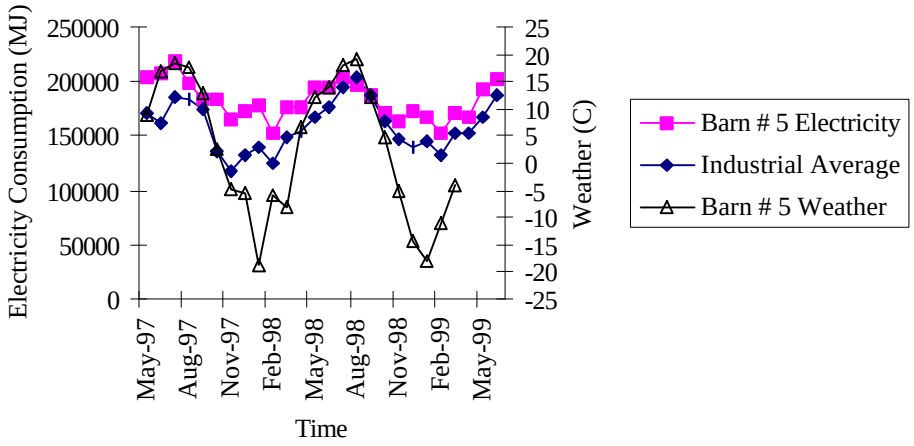

Figure 27: Electricity Consumption at Barn Number 5.

The E/P at this barn was very high the first month the barn started/resumed business, then dropped sharply the next two months (Figure 28). It was close to the

industrial average the fourth month. However, the E/P rate followed the pattern of industrial average, and was in the reverse cycle of weather, suggesting the barn was running at good conditions and achieved an efficient utilization of energy per hog.

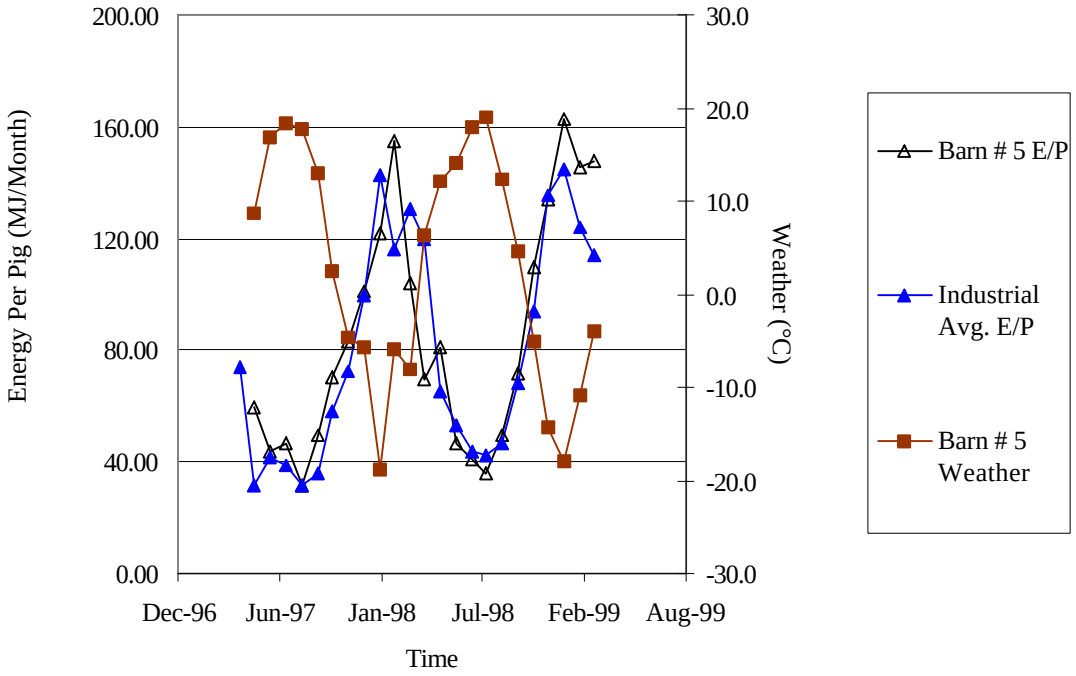

Figure 28: Energy Per Hog (E/P) at Barn Number 5.

3.4.6. Hog Barn Number 6

The natural gas consumption rate at barn number 6 generally followed the pattern of the industrial average, suggesting it was running at normal conditions and it had a relatively well performing heating system (Figure 29). There was no immediate concern for the management of this barn.

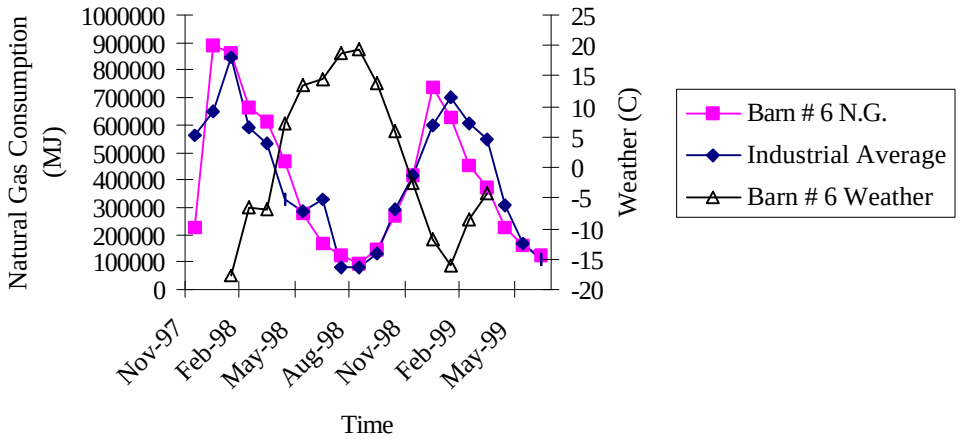

Figure 29: Natural Gas Consumption at Barn Number 6.

The electricity consumption rate at this barn was low when it started in October 1997 (Figure 30). It gradually approached the industrial average during the next ten months and stabilized at a level about 20% to 30% higher than normal during July 1998 and March 1999.

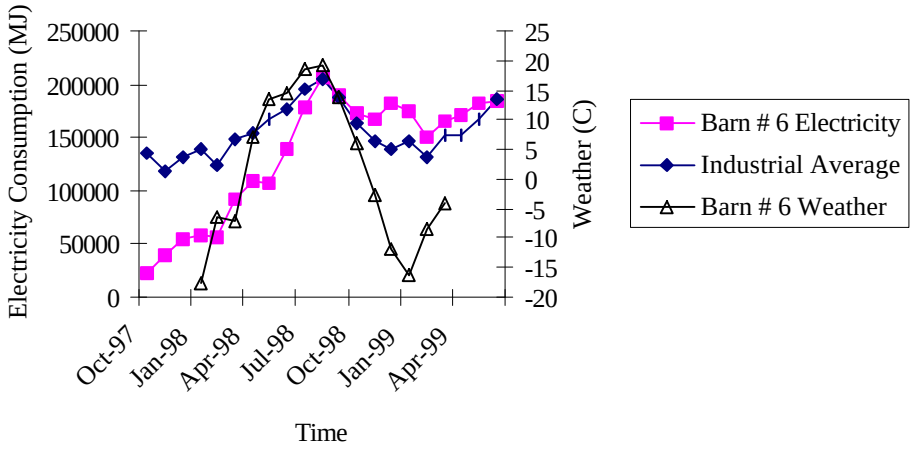

Figure 30: Electricity Consumption at Barn Number 6.

Barn number 6 had a typical E/P rate as a start-up barn (Figure 31). For the initial four months, the E/P started with a high rate of 2400% more than industrial average, then the rate reduced sharply during the next four months. In April 1998 it was almost at the

same level as the industrial average and stayed at this level until March 1999.

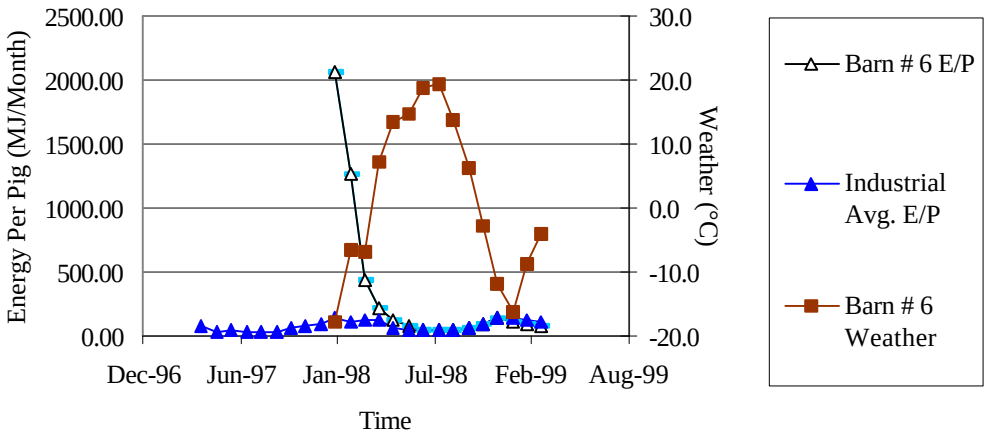

Figure 31: Energy Per Hog (E/P) at Barn Number 6.

3.4.7. Hog Barn Number 7

The barn number 7 uses electricity to power and to heat/cool the barn, though recently it started to use propane periodically for heating. The electricity consumption (heating) at this barn followed the cyclic pattern of the industrial average (Figure 32). However, it experienced a consumption of 20% to 30% higher than normal rate during the winter of 1998. Since then, the consumption rate has stayed below the industrial average, indicating it was operating efficiently.

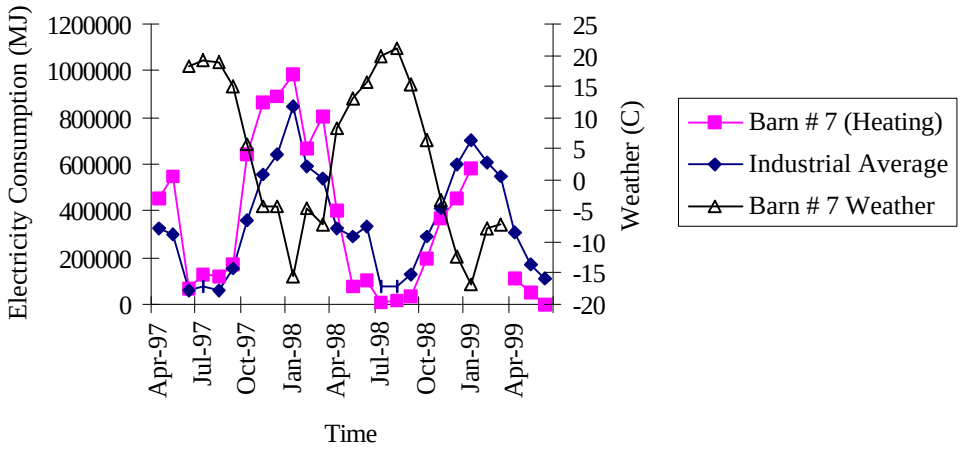

Figure 32: Electricity (heating) Consumption at Barn Number 7.

The electricity consumption (lighting) at this barn was abnormal (Figure 33). Although it followed the same pattern as the industrial average, it stayed more than 20% higher than the industrial average rate since November 1997. If the high rate was not caused by high output, the management of this barn should be alarmed about the persistent and high electricity consumption rate.

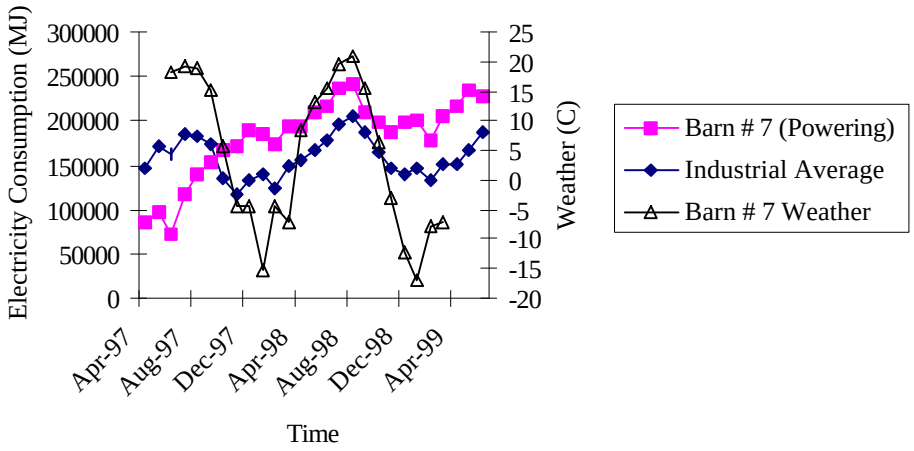

Figure 33: Electricity (lighting) Consumption at Barn Number 7.

The E/P rate at this barn used to be more than 30% higher than industrial average (Figure 34). Since April 1998, it dropped to a level about 5% to 10% lower than

industrial average. However, it started to exceed the industrial average again since February 1999. It would be useful to investigate the cause of this increase.

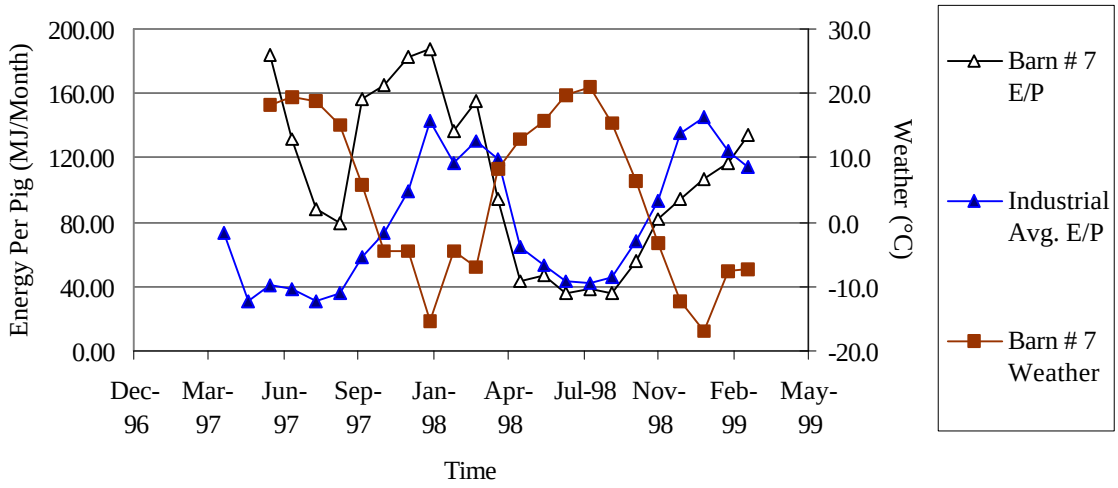

Figure 34: Energy Per Hog (E/P) at Barn Number 7.

3.4.8. Hog Barn Number 8 (Double Sized Farm)

The barn number 8 had twice capacity as the average barns so its natural gas and electricity consumption rate just compared with the double sized farms. The natural gas consumption rate was higher than the industrial average from April 1997 to December 1998 and then started to follow the industrial average (Figure 35). The electricity consumption rate dropped to the level less than the industrial average since December 1998 (Figure 36), all suggesting that it is approaching the consumption rate of a mature hog barn.

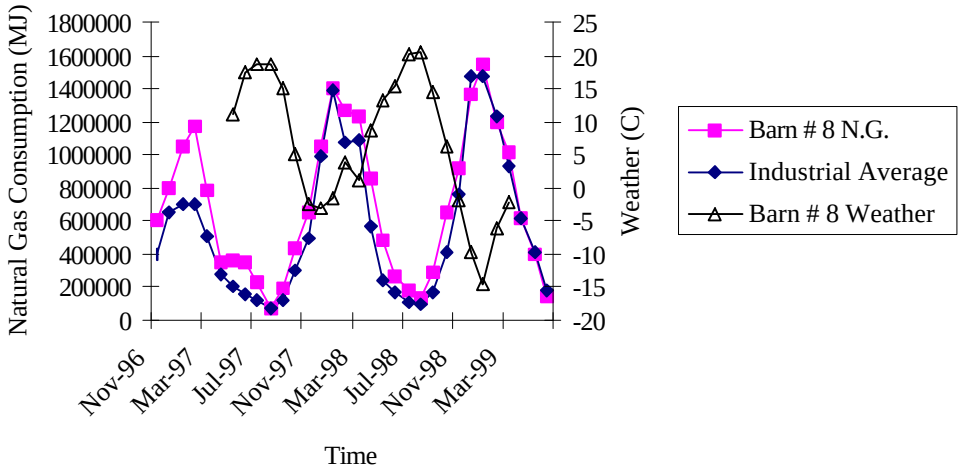

Figure 35: Natural Gas Consumption at Barn Number 8.

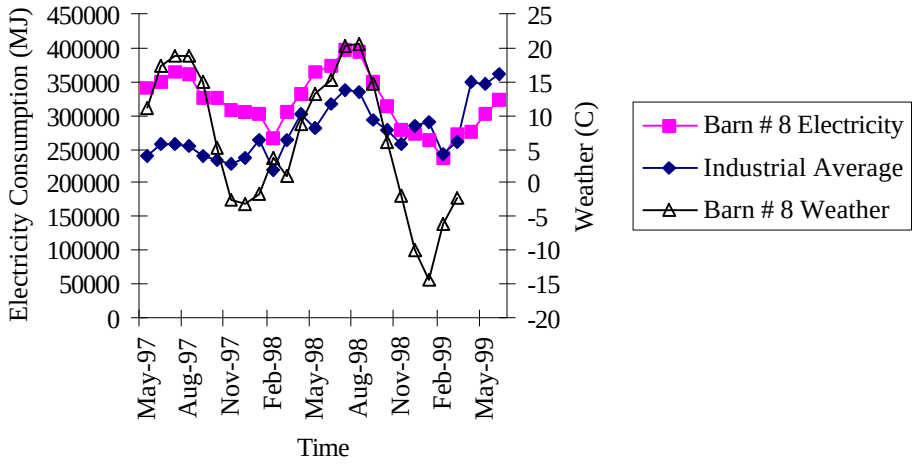

Figure 36: Electricity Consumption at Barn Number 8.

This observation was supported by the E/P rate (Figure 37). All E/P rates were lower than industrial average since January 98, indicating the barn approaching to a well-operated barn.

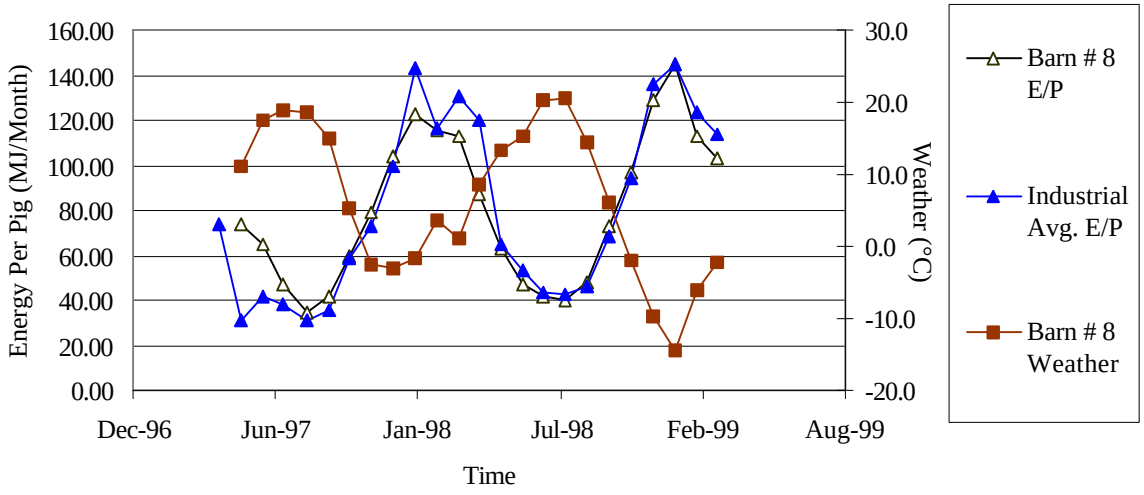

Figure 37: Energy Per Hog (E/P) at Barn Number 8.

3.4.9. Hog Barn Number 9 (Double Sized Farm)

The natural gas consumption rate at the barn number 9 was kept close (lower) to the industrial average during the last three years (Figure 38), except for the winters of 1998, when natural gas consumption rate exceeded by 250% the industrial average.

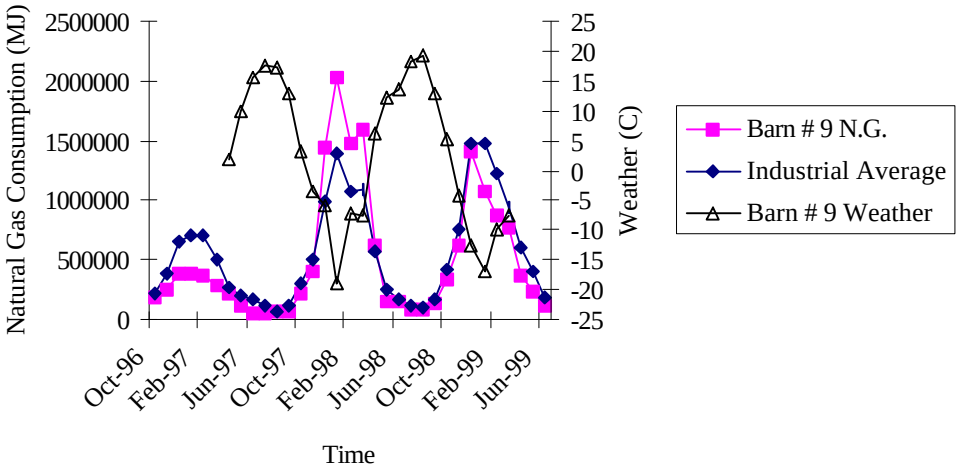

Figure 38: Natural Gas Consumption at Barn Number 9.

The electricity consumption rate had some fluctuations during the past three years, indicating that there might be some production changes (Figure 39).

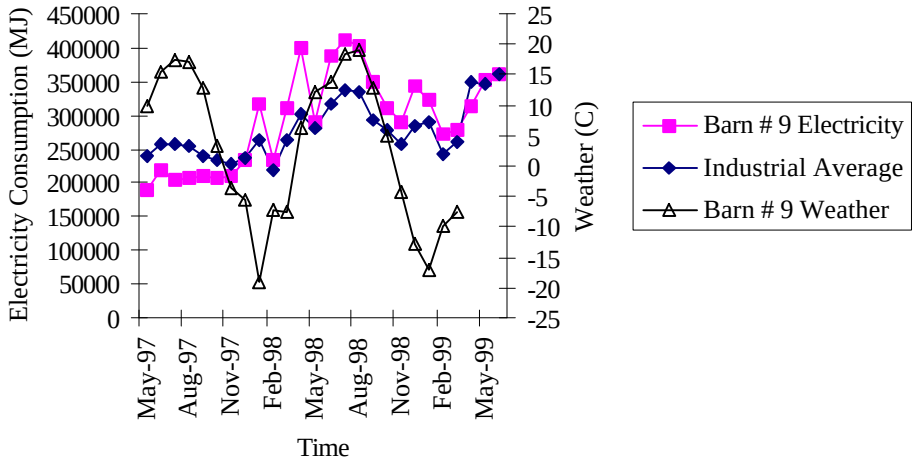

Figure 39: Electricity Consumption at Barn Number 9.

The E/P rate indicated that there was a sharp increase in energy per hog during the winter of 1997-98 (Figure 40). The E/P rate was 2000% higher than the industrial average in January 1998, and it took almost four months before the E/P rate back to normal.

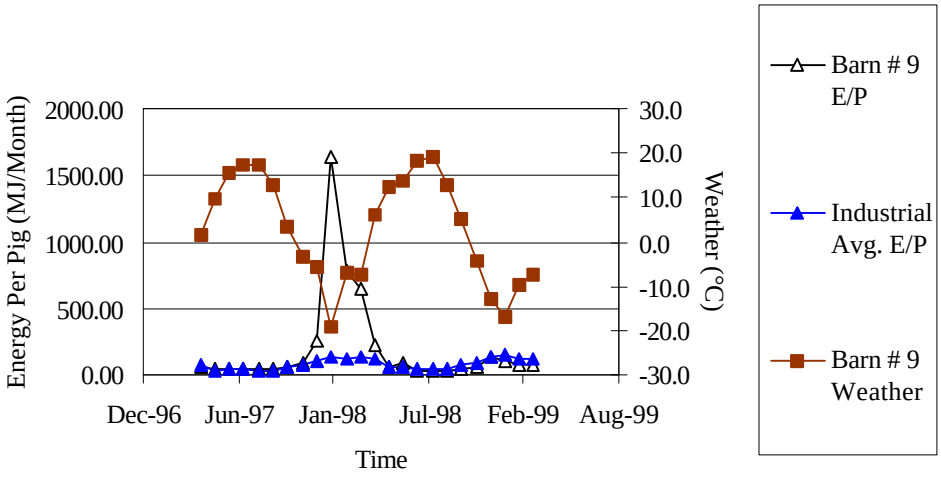

Figure 40: Energy Per Hog (E/P) at Barn Number 9.

3.4.10. Hog Barn Number 10 (Double Sized Farm)

Similar to the barns number 8 and 9, barn number 10 is also a double sized farm. The natural gas consumption for this barn has exceeded the industrial average from the winter of 1998-99, due to unknown reason(s) (Figure 41).

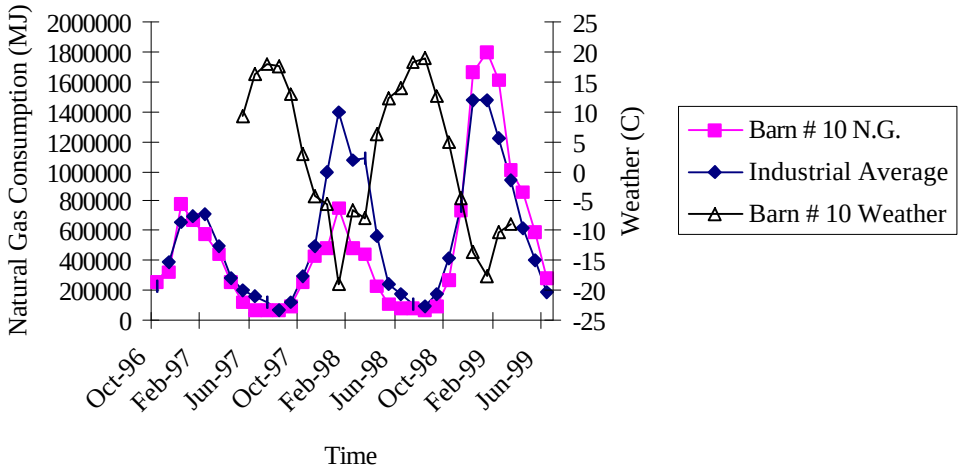

Figure 41: Natural Gas Consumption at Barn Number 10.

The electricity consumption rate was less than the industrial average from May 1997 to December 1998 (Figure 42). Then the electricity consumption rate started to increase until it peaked in April 1999. The management of this barn should pay attention to this sudden change in electricity consumption.

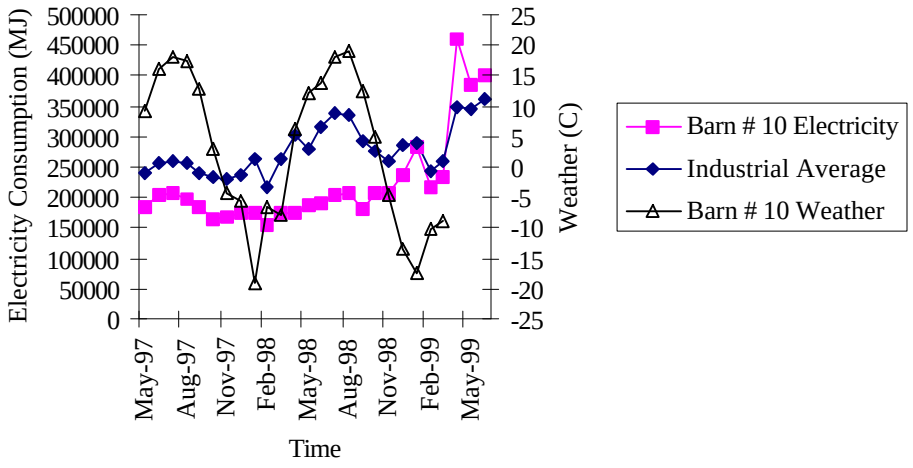

Figure 42: Electricity Consumption at Barn Number 10.

The E/P rate was rather normal. The E/P rate was reduced sharply during the first

four months and reached the industrial average in April 1998 (Figure 43). Since then, it stabilized and stayed in the level of industrial average.

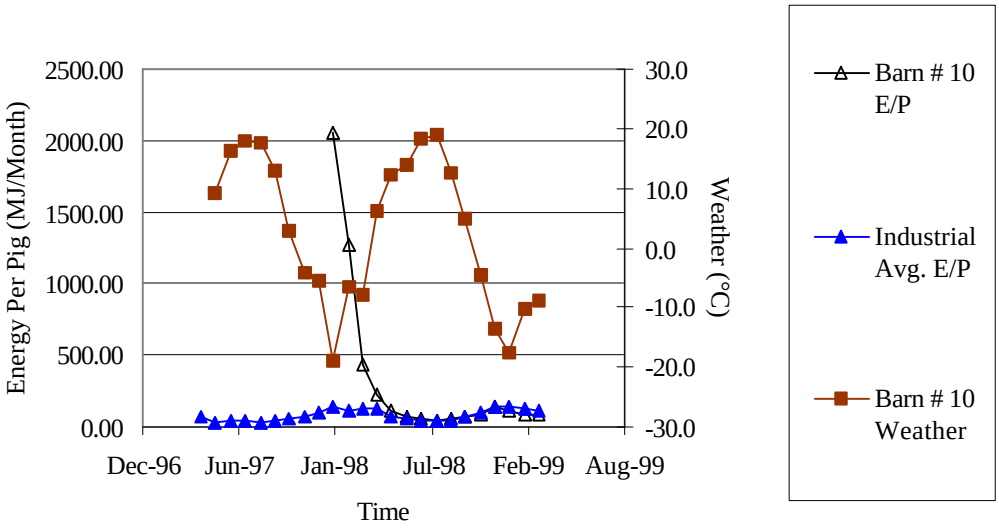

Figure 43: Energy Per Hog (E/P) at Barn Number 10.

3.4.11. Hog Barns Number 11, 12, 13, and 14

The electricity consumption at these hog barns was below the industrial average (Figures 44-47), partly because they were newly established and had not been operated at their full capacities. No natural gas consumption data available for these barns.

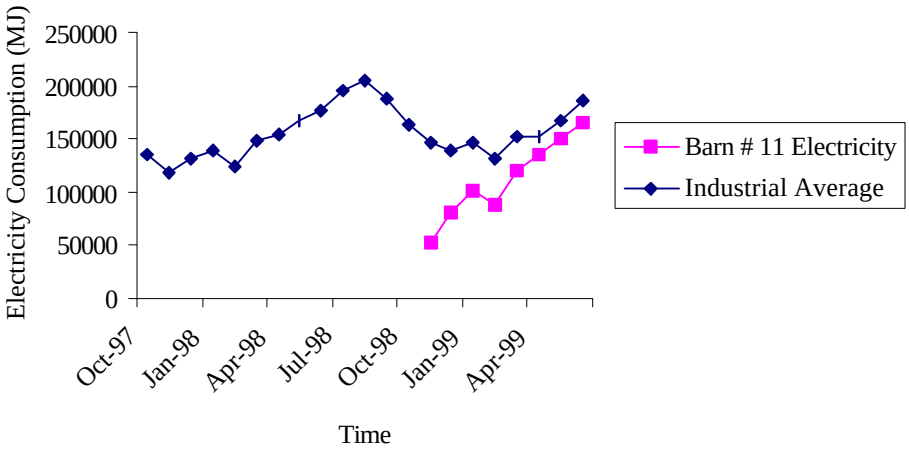

Figure 44: Electricity Consumption at Barn Number 11.

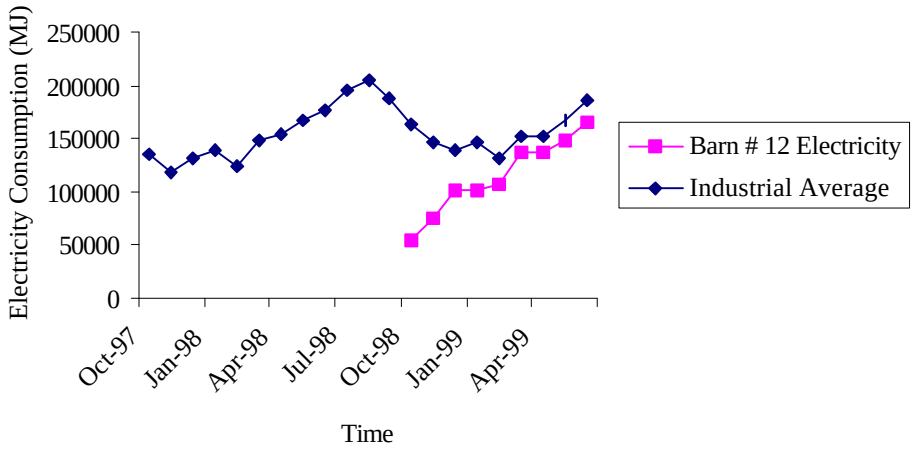

Figure 45: Electricity Consumption at Barn Number 12.

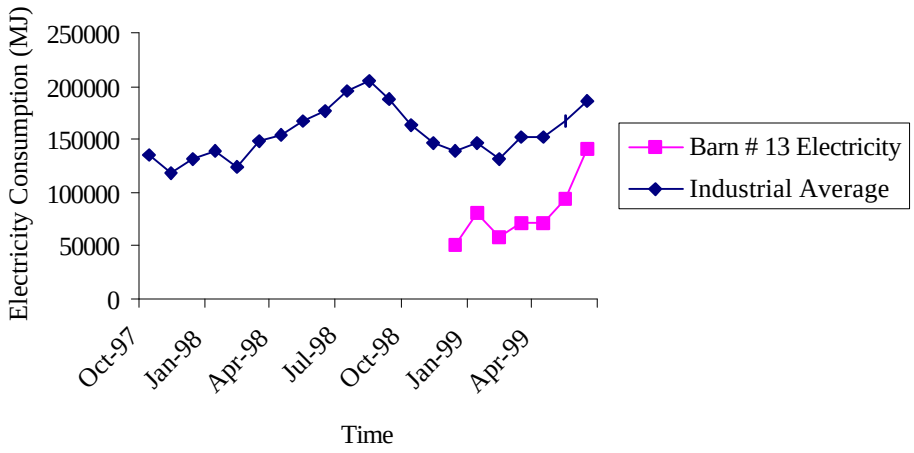

Figure 46: Electricity Consumption at Barn Number 13.

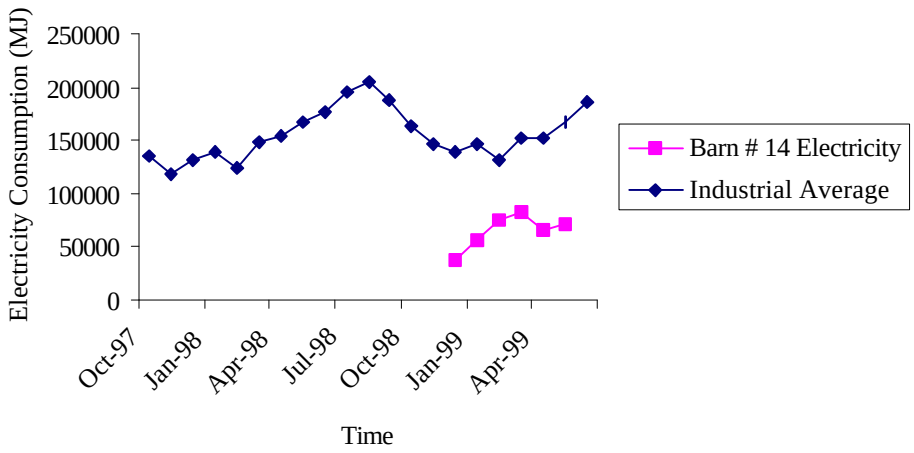

Figure 47: Electricity Consumption at Barn Number 14.

3.5. Econometric Analysis

Energy data and production data were applied to estimate energy use per hog in each barn, (Table 19 and Figure 48). Energy used per hog is shown per month and for the whole period. For example, in barn number 1, over the period of April 1997 to March 1999, on average of 84 megajoules of energy was used per hog. This requirement depends on the season. Barns need more energy (for heating) in winter relative to summer. Comparisons can be made in each barn on a per hog basis.

Considering the whole period of operation of each barn, a per-hog energy use criteria indicates that barn number 4 is the most efficient barn in terms of energy use. This barn uses propane as an energy source. The last column of Table 19 provides the rank of efficiency of energy use for each barn. Barn number 7 which uses electricity as an energy source is ranked 7^{th} in terms of efficiency of energy use. The energy used in each barn was compared by assuming the existing energy use system.

Table 19: Energy Use Per Hog - April 1997 to March 1999 (Mj).

Barns	(1)	(8)	(9)	(2)	(3)	(5)	(4)	(10)	(6)	(7)
	Energy Per Hogs	Energy Per Hogs	Energy Per Hogs	Energy Per Hogs	Energy Per Hogs	Energy Per Hogs	Energy Per Hogs	Energy Per Hogs	Energy Per Hogs	Energy Per Hogs
99/03	114	74	103	62	151	148	94	184	77	134
99/02	149	80	113	49	154	145	92	254	87	116
99/01	183	98	144	50	194	163	100	297	114	107
98/12	140	131	129	46	162	134	107	279	135	94
98/11	91	65	97	71	103	109	88	144	87	82
98/10	64	46	73	73	78	72	80	73	68	56
98/09	46	36	48	55	54	50	45	43	52	36
98/08	36	37	40	50	53	36	45	43	46	38
98/07	38	38	42	47	58	41	43	43	54	36
98/06	39	85	47	54	464	46	45	43	72	47
98/05	55	65	63	83	400	81	30	47	118	43
98/04	104	232	87	166	87	70	71	64	222	95
98/03	114	651	112	343	215	104	111	100	437	156
98/02	84	778	115	807	406	155	106	100	1273	137
98/01	131	1642	122	2005	2754	122	147	147	2059	187
97/12	120	262	104			101	122	105		182
97/11	99	97	79			83	109	95		165
97/10	83	63	60			70	84	66		156
97/09	52	41	42			49	51	44		79
97/08	39	44	35			32	36	41		88
97/07	38	42	47			47	40	41		131
97/06	37	42	65			44		42		184
97/05	85	47	73			60		49		
97/04	84	64								
Energy Per Hog	84	101	80	95	163	85	79	104	116	102
Rank of Efficiency	3	6	2	5	10	4	1	8	9	7

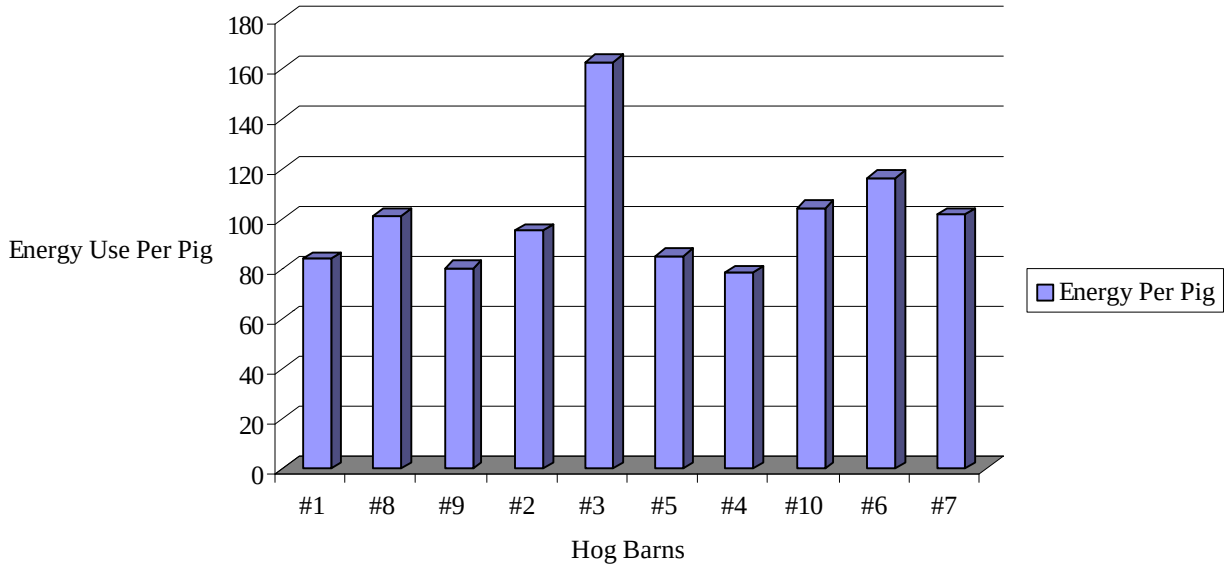

Figure 48: Energy Use Per Hog from April 1997 to March 1999 (Mj).

The energy per hog is regressed on the weather (temperature) variable to see the significance correlation of these two variables. The study applied a linear regression model as follows:

$$\left(\frac{E}{P}\right)_t = a_i + b_i T_t + e_t$$

Where, $(E/P)_t$ is the energy per hog variable, T_t is the weather temperature variable, and a_i and b_i are the parameters of the model.

The results are presented in Table 20 and the observations used for each barn are presented in the last column of this table. As expected, the weather variable is negative for all barns. That is, energy use (for heating) is negatively correlated with weather temperature. The *t* values are significant for almost all of barns with the exception of barns number 2 and 3. Only 15 observations were available for these two barns.

The R^2 value shows how good the regression line is estimated. When comparing Table 20 with Table 19 and combining this section with the descriptive analysis section,

some implicit statements about energy use in each of these barns can be made. For example, barn number 4, which received the number one rank in terms of efficiency of energy use in Table 19, obtained an R^2 value of 0.87 in Table 20. That is, 87 percent of factors affecting changes in energy use per hog is captured with this line and weather variable. On the other hand, the R^2 of barn number 8, a double sized farm, is 0.29. That is, the changes in energy used is poorly explained by this regression line and weather variable. Perhaps, there are some other variables such as barn management and other environmental variables that can explain the change in energy use. Note that this barn was ranked 6 in terms of efficiency of energy use in Table 19. Similarly, the R^2 for another double sized barn, barn number 10, is 0.70. This farm is ranked 8th among the 10 farms in Table 19.

Overall, barns that ranked from 1st to 4th in terms of efficiency of energy use in Table 19, R^2 values of 0.82 to 0.87. On the other hand, those farms that ranked low in terms of efficiency of energy use received low R^2 values. This would indicate that other factors affect the amount of energy use in these barns, such as managerial skills, size of barn, stages of the barn development, and other environmental variables.

Table 20: Regression Analysis of Energy Use per Hog on Weather Variable.

Farms	Intercept	*t* Value	Weather Variable (*X*)	*t* Value	*R* Square	Observations
(1)	102.31	28.24	-3.41	-11.52	0.86	24
(8)	246.38	3.77	-16.19	-3.00	0.29	24
(9)	98.72	29.77	-2.91	-10.54	0.84	23
(2)	276.82	2.21	-16.88	-1.80	0.20	15
(3)	357.40	2.16	-21.15	-1.61	0.17	15
(5)	94.38	23.81	-3.07	-9.70	0.82	23
(4)	89.18	30.62	-2.66	-11.05	0.87	21
(10)	117.39	12.23	-5.36	-6.99	0.70	23
(6)	353.89	2.66	-22.56	-2.10	0.25	15
(7)	115.72	11.33	-2.07	-2.67	0.26	22

3.6. Summary and Conclusion

In this chapter, two methods of descriptive analysis and econometric analysis were used to study the efficiency use of energy in hog production. The descriptive analysis developed the industrial average, weighted average of all the farms, and the energy per hog criteria to determine the local efficiency of each barn. Then, regression tools were used to learn more about energy use in the hog industry. Combining the descriptive analysis with econometric analysis (implicitly) suggest that barn number 4 is the most efficient barn in terms of energy use. This barn uses propane as an energy source. Overall, barns that ranked from 1st to 4th in terms of efficiency of energy use per hog had R^2 values of 0.82 to 0.87. On the other hand, those farms that ranked low in terms of efficiency of energy use per hog received low R^2 values. This would indicate that other factors affect the amount of energy use in these barns, such as managerial skills, size of barn, stages of the barn development, and other environmental variables.

References

1. Alberta Agriculture, 1981. *Saving Energy in Hog Operations*. Records and Analysis Section, Farm Business Management Branch.
2. Alberta Agriculture, 1982. *Program to Offset Farmers' Energy Costs*. Financial Management Section, Farm Business Management Branch.
3. Department of Agricultural Economics, 1991. *Economic Impacts of the Beef and Hog Sector on the Saskatchewan Economy*, Saskatchewan Beef and Hog Sector Study, Report 3, University of Saskatchewan
4. Department of Agricultural Economics, 1991. *Economies of Hog Production in Saskatchewan*, Saskatchewan Beef and Hog Sector Study, Report 1, University of Saskatchewan.
5. Department of Agricultural Economics, 1991. *Economies of size in Saskatchewan Hog Industry*, Saskatchewan Beef and Hog Sector Study, Report 2, University of Saskatchewan.
6. Lambert, J.M., 1980. *Solar Energy Application in Agriculture, IV. The Pig Industry*. Department of Civil Engineering, The University of Melbourne. Report T47/80 and Report No. 51/80.
7. Manitoba Agriculture, 1987. *Energy Requirements of Swine*. Swine Facts, AGDEX 440-51.
8. Stanhill, G., 1984. *Energy and Agriculture*. Advanced Series in Agricultural Science 14. Springer-Verlag, Berlin Heidelberg, New York, Tokyo.
9. Sulatisky M., and S. Hill, 1990. *Demonstrations of Compressed Natural Gas on Farms*. Saskatchewan Agriculture Development Fund. Final Report, V-86-02-0014.
10. The StarPhoenix, 1999. *Farming Doesn't Add Up*. August 7.