A Descriptive Analysis of energy consumption in the agriculture and food sector in Canada

Final Report
February 2000

CAEEDAC

Table of Contents

1. Introduction 5
2. Scope of the Report 5
2.1. Farm Energy Consumption 5
2.2. Food and Beverage Processing Energy Use 6
2.3. Residential Energy Use 6
2.4. Commercial Energy Use 6
2.5. Transportation 6
3. Agricultural Energy Consumption 7
3.1. Expenditures on Farm Energy 7
3.2. Direct Energy Used in Farm Production 9
3.3. Indirect Energy 12
3.3.1. Energy Used in Fertilizers 12
3.3.2. Energy Used in Pesticide Production 15
3.3.3. Energy Sequestered in Farm Machinery and Buildings 16
4. Food and Beverage Processing Energy Use 17
4.1. Expenditures on Energy in Food and Beverage Processing 17
4.2. Quantities of Energy Consumed in Food and Beverage Processing 20
5. Summary 21
6. Conclusion 25

Table of Tables

Table 1: Total Expenditures on Farm Operations in Canada (in Billions of 1992 dollars) 7
Table 2: Expenditures on Direct and Indirect Energy as a Percent of Total Farm Expenditures..... 8
Table 3: Direct Agricultural Energy Used in Canada and Provinces..... 9
Table 4: Direct Energy Consumed on Farms by Energy Type and Region, 1995 (PJ)..... 10
Table 5: Percentage Direct Energy Used for Farm Business Activities by Energy Source for Canada..... 11
Table 6: Total Direct Farm Energy Used for Farm Business Activities in Canada (in PJ) 11
Table 7: Percentage Distribution of Direct Farm Energy Demand by Energy Type for Canada..... 12
Table 8: Quantities of Fertilizer Sold in Canada (thousands of tonnes)..... 13
Table 9: Calculated Quantities of Energy Used in the Production and Transportation of Fertilizer Sold in Canada (in PJ) 13
Table 10: Average Energy Used in Fertilizer Production (GJ/thousands tonnes) 14
Table 11: Reduced Average Energy Used in Fertilizer Production (GJ / thousand tonnes)..... 14
Table 12: Estimates of Energy Used in Fertilizer Production in Canada (PJ)..... 14
Table 13: Estimated Quantities of Energy Used in Pesticide Production, Packaging, Transportation and Application in Canada (PJ)..... 15
Table 14: Energy Used in Manufacturing Farm Machinery (MJ/kg) 16
Table 15: Energy Sequestered in Farm Machinery in Canada (PJ) 17
Table 16: Energy Sequestered in Farm Buildings in Canada (PJ)..... 17
Table 17: Number of Food Processing Establishments by Province in 1995..... 18
Table 18: Estimated Quantities of Energy Consumed by the Food and Beverage Processing Industry in Canada (in PJ) 20
Table 19: Percentage Distribution of Energy Use by Energy Type for Selected Food Processing Industries in the United States in 1973..... 20
Table 20: Total Energy Used at the Farm Level in Canada (in PJ) 21
Table 21: Total Expenses on Direct and Indirect Farm Energy in Canada ($ millions)..... 21
Table 22: Quantity and Dollar Value of Energy Used in Food and Beverage Processing in Canada..... 22
Table 23: Quantity of Energy Used in Home, Restaurant, and Hotel Food Preparation in Canada (in PJ).. 22
Table 24: Percentage of the Total Canadian Energy Used by the Canadian Food System, Excluding the Energy in Farm Machinery and Buildings..... 22
Table 25: Percentage of the Total Energy Used by the Canadian Food System, Including Farm Machinery and Buildings, 1990-1996 22
Table 26: Farming and Food Processing Energy Consumption (Excluding Energy in Farm Machinery and Buildings) in PJ, the Corresponding GDP (in Billions of Dollars) and Energy to GDP Ratio 23
Table 27: Total Exports and Imports of Agriculture and Food Products in Canada..... 23
Table 28: Total Energy Used by Canadians on Nutrition (Excluding the Energy in Farm Machinery and Buildings)..... 24
Table 29: Total Energy Used by Canadians on Nutrition Including Farm Machinery and Buildings 25

Table of Figures

Figure 1: Percentage Distribution of Total Farm Operating Expenses by Province in 1995 (Statistics Canada) 8
Figure 2: Percentage Distribution of the Quantities of Fertilizer Sold by province in Canada, 1995 (Agriculture and Agri-Food Canada, 1996) 15
Figure 3: Percentage Distribution of Expenses on Energy by Industry in 1995 (Statistics Canada) 18
Figure 4: Percentage Distribution of Expenses on Energy for the Processing Food Industry in 1995 (Statistics Canada) 19
Figure 5: Percentage Distribution of Spending on Energy in the Beverage Industry in 1995 (Statistics Canada) 19

1. Introduction

This report focuses on the amount of non-renewable energy consumed in the agriculture and food sector. The aim is to provide policy makers with data on the quantities and values of total energy consumed in farming, processing, transporting, and preparing farm products. This report collected provincial data from 1990 to 1996 with the exception of confidential data that were not available.

Comparisons of total expenditures on various farm inputs, during different years, were performed with constant 1992 base year dollars. Natural units used to measure the quantities of energy consumed were converted to Terajoules (1TJ = 10^{12} Joules) or Petajoules (1PJ = 10^{15} Joules) using Statistics Canada unit conversion factors. Appendix 1 provides a list of selected conversion factors.

2. Scope of the Report

The majority of studies on energy consumed by the agriculture and food sector have been carried out in the United States, the United Kingdom and Australia. Stout (1984) reported that according to a study prepared for the US Federal Energy Administration, 16.5% of the total US energy consumption was used by the agriculture and food processing sectors (Food System). This percentage varied between 12% and 20% depending on the boundaries given to the Food System and the extent to which indirect energy usage (machinery, buildings, roads, etc.) was charged to the Food System. The scope of this report is on energy used in farm production, food and beverage processing, residential and commercial food and beverage processing and residential and commercial food preparation.

2.1. Farm Energy Consumption

Both direct and indirect energy (refined petroleum products, natural gas, coal, steam and electricity) are consumed during various farming operations.

For example, direct energy is consumed by:

- Crop production: crops include cereal grains, oilseeds, pulses, fruits, vegetables and forage production;
- Livestock production: cattle, pigs, sheep, horses, and exotic animals;
- Poultry production: hens, chickens, turkeys, and exotic birds;
- Animal products production: milk, cream, eggs, wool, furs, and meat;

- Other farm products production: greenhouse and nursery products, Christmas trees, mushrooms, sod, honey and maple syrup products;
- Transportation of farm products.

Indirect energy consists of the energy used in the manufacture, packaging and transport of fertilizers, pesticides, and farm machinery. Some studies have also included the energy used in farm buildings (Stirling and Kun, 1995; Coxworth, 1997), machine repairs, manpower and animal power (Bowers, 1992). This report used estimates of energy consumed in farm machinery and buildings reported by Coxworth (1997). Energy consumed in fertilizer production was estimated using the results from Mudahar et al, (1982). Coxworth (1997) and Green (1987) also reported estimates of energy used in fertilizer and pesticide production based on methods and effects described later by Bhat et al., (1994).

2.2. Food and Beverage Processing Energy Use

At the food and beverage processing level, energy is consumed in:

- Cooking, heating, packaging, storing, handling, sterilizing, freezing, and refrigerating various farm products,
- Transportation of processed products.

2.3. Residential Energy Use

The total energy used for home food preparation includes energy consumed by appliances (stoves, refrigerators, freezers, microwaves, ovens, heating and lights) and energy used for transportation of food items from the grocery store to the home.

2.4. Commercial Energy Use

At the commercial level (restaurant or hotel dining and grocery stores), energy use includes cooking, cooling, heating, lighting, freezing, refrigerating and transportation.

2.5. Transportation

Data on energy used in the transportation of farm and processed food products were not available. According to Statistics Canada, the amount of fuel and electricity used by the agriculture and commercial sectors are included in the total energy demanded by these sectors (Statistics Canada, 57-003 XPB).

3. Agricultural Energy Consumption

The energy consumed in agriculture consists of all direct and indirect energy used on the farm. Direct energy includes electricity, heating fuel and machinery fuel used in crop production, grain drying, animal and animal product production, poultry, transportation of farm products and personal energy use (for example, heating farmhouse and driving to town). The Farm Energy Use Survey conducted by Statistics Canada in 1997 estimated that the following percentages were used for farm business purpose on energy: 74.1% of total gasoline, 88.4% of total diesel, 48.4% of total liquid petroleum gas (LPG), 57.3% of total natural gas and 66.1% of total electricity. The remainder was used for non-farm activities such as leisure, home heating and lighting. Indirect energy consists of the energy consumed in the production, packaging and transport to the farm gate of fertilizers, pesticides, farm machinery and buildings.

3.1. Expenditures on Farm Energy

Total farm operating expenses in constant 1992 dollars increased steadily from 1990 to 1996 (Table 1[1]). Total operating expenses in nominal dollars were $24.89 billion in 1995. Expenses on direct energy amounted to 8.5% of total operating expenses, whereas expenses on indirect energy amounted to 26.1% (fertilizers 7.8%, pesticides 4.3%, machinery depreciation charges 11.4% and building depreciation charges 2.6%). Expenses for machinery fuel represented 68% of the total expenses of direct energy use (Statistics Canada, 21-603). Figure 1 indicates that Ontario spent the most on farm operations, followed by Alberta, Saskatchewan and Quebec.

Table 1: Total Expenditures on Farm Operations in Canada (in Billions of 1992 dollars)

Expenditures	1990	1991	1992	1993	1994	1995	1996
Operating Expenses after Rebates	20.05	20.37	20.93	21.86	23.40	24.61	25.98
Total Rebates	0.41	0.41	0.30	0.31	0.30	0.28	0.25
Operating Expenses	20.46	20.78	21.23	22.17	23.69	24.89	26.23
* *FIPI (1992=100)	101.80	100.30	100.00	104.90	108.40	112.50	117.70
Operating Expenses	20.11	20.71	21.23	21.14	21.85	22.12	22.28

* Total operating expenses =Total operating expenses after rebates + Total rebates.
* FIPI = Farm Input Price Index.
Source: Statistics Canada.

[1] For example, total nominal farm operating expenses in 1996 was $26.23 billion and the farm inputs price index was 117.7. Therefore total farm operating expenses in constant 1992 dollars was $ 26.23 / 117.7 or $22.28 billion.

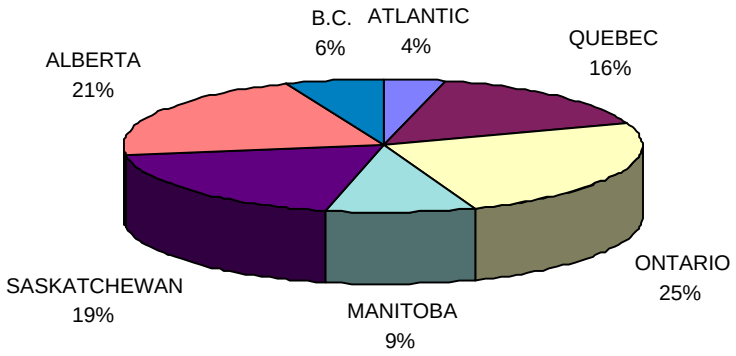

Figure 1: Percentage Distribution of Total Farm Operating Expenses by Province in 1995 (Statistics Canada)

Table 2: Expenditures on Direct and Indirect Energy as a Percent of Total Farm Expenditures

Direct Energy

Region	Total Expenses	Electricity	Heating Fuel	Machinery Fuel	Total
	($ million)				
Nfld.	60	1.9	1.4	2.4	5.7
P. E. I.	258	1.7	0.5	5.1	7.3
N. S.	319	2.3	1.2	3.6	7.1
N.B.	278	2.0	0.7	4.7	7.4
Que.	3830	2.6	0.8	2.7	6.1
Ont.	6090	2.5	1.3	3.9	7.7
Man.	2410	2.0	0.4	6.8	9.2
Sask.	4720	1.5	0.4	9.9	11.8
Alta.	5440	1.4	0.6	6.5	8.5
B. C.	1490	2.1	0.8	3.8	6.7
Canada	24892	2.0	0.8	5.7	8.5

Source: Statistics Canada

The direct energy component of Tables 2 indicates that expenses on direct energy, as a percent of total expenses, were highest in Saskatchewan (11.8%) followed by Manitoba (9.2%), Alberta (8.5%) and Ontario (7.7%).

Indirect Energy

	Fertilizer	Pesticides	Machinery Dep.	Building Dep.	Total
Nfld.	2.7	0.6	5.6	1.6	10.5
P. E. I.	11.5	6.2	8.7	2.4	28.8
N. S.	3.3	1.7	8.2	3.8	17.0
N.B.	6.6	3.7	8.7	2.3	21.3
Que.	4.8	1.3	7.1	2.8	16.0
Ont.	5.8	3.1	9.3	4.0	22.2
Man.	12.5	7.4	12.7	1.2	33.8
Sask.	11.0	7.7	16.1	1.3	36.1
Alta.	8.5	4.2	13.4	2.2	28.3
B. C.	4.0	1.4	6.7	4.4	16.5
Canada	7.8	4.3	11.4	2.6	26.1

The indirect energy component indicates that this type of energy, as a percent of total farm expenses, was also highest in Saskatchewan (36.1%), followed by Manitoba (33.8%), P.E.I (28.8%), Alberta (28.3%) and Ontario (22.2%).

3.2. Direct Energy Used in Farm Production

Table 3 indicates the quantities of energy used on the farm from 1990 to 1996 (in Petajoules). In 1995 and 1996, the energy consumed on farm operations was highest in Saskatchewan, followed by Ontario and Alberta. Table 4 indicates the amount of direct energy consumed on farms by energy type (NG, NGL, Elec., RPP and Steam) and by province in 1995. It can be seen that Saskatchewan, Ontario and Alberta farmers used the most energy in 1995 and that direct energy use was highest in 1992 and 1996.

Table 3: Direct Agricultural Energy Used in Canada and Provinces

	1990	1991	1992	1993	1994	1995	1996
Nfld.	0.5	0.7	2.0	0.9	1.0	1.3	1.2
P.E.I.	1.4	1.4	1.7	1.5	1.4	1.6	1.8
N.S.	2.5	3.5	8.5	3.0	3.2	3.7	3.6
N.B	1.9	2.0	3.6	2.3	2.7	3.1	2.7
Que.	19.8	20.6	31.1	19.8	19.7	17.7	16.8
Ont.	44.0	44.6	54.6	44.2	43.5	50.1	55.2
Man.	20.5	18.6	18.1	19.6	19.5	21.7	22.9
Sask.	50.6	45.9	43.9	45.0	48.4	50.1	55.3
Alta.	53.3	46.5	46.5	49.3	44.3	47.0	52.8
B.C.	10.1	11.3	13.2	12.6	10.8	10.0	11.5
Canada	204.7	195.3	223.6	198.5	194.5	206.5	223.9

Source: Statistics Canada.

Table 4: Direct Energy Consumed on Farms by Energy Type and Region, 1995 (PJ)

	Ng	Ngl	Electricity		RPP	Steam	Total
			Hydro	N & T			
Nfld.	0	0	0.1	0	1.2	0	1.3
P. E. I.	0	0	0	0.3	1.3	0	1.6
N. S.	0	0	0	0.2	3.4	0	3.7
N. B.	0	0	0.1	0.2	2.7	0	3.1
Que.	0.2	1.2	5.9	0.2	10.2	0	17.7
Ont.	10.1	1.8	2.4	7.3	28.4	0.1	50.1
Man.	1	1	4.9	0	16.1	0	21.7
Sask.	5.7	0.3	1.2	3.7	39.2	0	50.1
Alta.	6.1	0.2	0.2	5.7	34.8	0	47
B. C.	0.6	0.2	1.1	0.2	7.8	0	10
Canada	22.9	4.4	15.9	17.9	145	0.1	207

Source: Statistics Canada.

Ng = natural gas, Ngl = natural gas liquids (include LPG), RPP = Refined Petroleum Products.
Electricity is divided into Hydro and Nuclear & Thermal (N & T).
To obtain the estimates of Hydro electricity, it is assumed that the percentage of hydro electricity consumed by province is proportional to the percentage of hydro electricity produced in each province (e.g., in Quebec, hydro = 97%, N & T =3%).

To obtain the estimates of energy consumed for farm business only, the percentages given in the Farm Energy Use Surveys of 1981 and 1997 were used. It was assumed that farm business energy use was linear (Coxworth, 1997). The difference between farm business energy use in 1997 and 1981 was divided by 15 to obtain the average annual rate of change. The annual rate of change was added to each subsequent year. The resulting percentages of energy used for farm business are displayed in Table 5.

Table 5: Percentage Direct Energy Used for Farm Business Activities by Energy Source for Canada

Energy Type	1990	1991	1992	1993	1994	1995	1996
Ng	63.1	62.1	61.1	60.2	59.2	58.3	57.3
Ngl	59.3	57.5	55.6	53.8	52	50.2	48.4
Electricity	66.4	66.3	66.3	66.2	66.2	66.1	66.1
RPP*	85.6	84.9	84.2	83.4	82.7	82	81.3
Steam	100.0	100.0	100.0	100.0	100.0	100.0	100.0

* RPP= Average (% Diesel + % Gasoline).
Ng= natural gas, Ngl= natural gas liquids (include LPG), RPP= Refined petroleum products.
The percentages of farm energy consumed for farm business only, by province are different from those in Table 13. However, provincial percentages were not used because most of them have a large Coefficient of Variation number (CV).

To obtain the estimates of direct energy used for farm business only for the 1990 - 1996 period, the percentages given in Table 5 were multiplied by the total quantity of each energy type consumed on the farm (Table 6). The calculated estimates are shown in Table 7. Energy use was highest in 1992 because of an increase in RPP during 1992.

Table 6: Total Direct Farm Energy Used for Farm Business Activities in Canada (in PJ)

Energy Type	1990	1991	1992	1993	1994	1995	1996
Ng	14.6	14.4	15.4	18.8	14.0	13.3	15.4
Ngl	4.2	3.0	3.8	3.3	2.6	2.2	2.4
Hydro	13.9	13.8	13.7	13.7	13.9	13.5	14.6
N & T	9.1	8.9	8.9	8.9	9.1	8.8	9.5
RPP	119.6	112.5	132.6	105.7	108.4	119.1	126.5
Steam	0.0	0.2	0.1	0.2	0.1	0.1	0.0
Canada	161.4	152.8	174.5	150.6	148.1	157.0	168.4

Note: Electricity = 60.6% Hydro and 39.4% Nuclear and Thermal.

Table 7: Percentage Distribution of Direct Farm Energy Demand by Energy Type for Canada

Energy Type	1990	1991	1992	1993	1994	1995	1996
Ng	11	12	11	16	12	11	12
Ngl	3	3	3	3	3	2	2
Elec.	17	17	15	17	18	16	16
RPP	68	68	70	64	67	70	69
Others	1	1	1	1	1	1	1

The above percentages were derived from total direct farm energy (including personal use). Percentages may not add to 100% due to rounding.

Source: Statistics Canada

Table 7 indicates that Refined Petroleum Products represents about two third of the total direct energy used on the farm. However, these percentages vary among provinces. For example, in the Atlantic Provinces natural gas was not used on farms from 1990 to 1996.

3.3. Indirect Energy

3.3.1. Energy Used in Fertilizers

According to Mudahar et al, (1987), energy used in the production of fertilizers accounts for about 40% of total energy used in agricultural production in developed countries. Most of this energy was consumed in the production of nitrogen, phosphorous and potassium fertilizers.

The Canadian fertilizer consumption, shipments, and trade data[2] consist of the quantities of all fertilizer sold annually in Canada. This includes fertilizer used for purposes other than farming (e.g. fertilizer used on lawns and home gardening). Assuming that the quantities of fertilizer used for purposes other than farming are negligible, Coxworth (1997) estimated the energy consumed in the production and transportation of fertilizer. The method used was based on the report by Bhat et al. (1994). To estimate the energy consumed in fertilizer production, the total quantity of each fertilizer nutrient was multiplied by the corresponding energy used per tonne of nutrient. For example since the production of ammonia required 57.62 GJ of energy per tonne of nutrient, the

[2] Canadian Fertilizer Consumption, Shipments, and Trade data were collected by Maurice Korol and Gina Rattray, on behalf of Agriculture and Agri-Food Canada, Policy Branch. See Korol, M., and Rattray, G. 1996 for further references.

total quantity (in tonnes) of ammonia sold was multiplied by 57.62 Gigajoules (GJ). The quantities of fertilizers sold in Canada from 1990 to 1996 are shown in Table 8.

Table 8: Quantities of Fertilizer Sold in Canada (thousands of tonnes)

	1990	1991	1992	1993	1994	1995	1996
Nitrogen	1196.3	1157.8	1253.3	1305.8	1406.0	1448.4	1576.2
Phosphate	513.5	578.2	592.2	615.9	641.2	628.4	658.4
Potassium	359.8	337.9	310.2	327.8	328.0	309.9	333.2

Source: Agriculture and Agri-Food Canada, 1996.

Table 9: Calculated Quantities of Energy Used in the Production and Transportation of Fertilizer Sold in Canada (in PJ)

Nutrient	1990	1991	1992	1993	1994	1995	1996
Nitrogen	79.5	76.6	83.0	86.8	93.0	96.5	104.4
Phosphate	7.6	7.2	7.4	7.7	7.9	7.8	8.2
Potassium	4.0	3.8	3.5	3.7	3.5	3.5	3.7
Total	91.2	87.6	93.9	98.1	104.5	107.7	116.3

Source: Coxworth (1997).

Table 9 indicates that most of the energy consumed in fertilizer production was consumed in the production of nitrogen fertilizers. According to Statistics Canada (1995), energy use in the chemical manufacturing industry (which includes fertilizer and pesticides industries) declined by about 34.5 % over the past decade. Therefore, the quantities in Table 9 probably over-estimate the amount of energy used in fertilizer production.

Mudahar et al. (1982) estimated the average energy requirement for the production, packaging, transportation and application of fertilizers (Table 10). Since the energy used in fertilizer production has decreased over the past decade, the average energy used in producing fertilizers in Table 10 was reduced by 34.5%. The results are shown in Table 11.

Table 10: Average Energy Used in Fertilizer Production (GJ/thousands tonnes)

Nutrient	Production	PTA	Total
Nitrogen	69.54	8.59	78.13
Phosphate	7.70	9.75	17.45
Potassium	6.38	7.32	13.70

PTA = Packaging, Transportation and Application.

Source: Mudahar et al., 1982.

Table 11: Reduced Average Energy Used in Fertilizer Production (GJ / thousand tonnes)

Nutrient	Production	PTA	Total
Nitrogen	45.55	8.59	54.14
Phosphate	5.04	9.75	14.79
Potassium	4.18	7.32	11.50

The quantities of energy consumed in fertilizer production (Table 12) were obtained by multiplying the total averages in Table 10 by the total quantities of fertilizer sold (Table 11). Figure 2 indicates that Saskatchewan and Alberta were the largest users of fertilizers in Canada in 1995.

Table 12: Estimates of Energy Used in Fertilizer Production in Canada (PJ)

	1990	1991	1992	1993	1994	1995	1996
Nitrogen	64.8	62.9	67.9	70.7	76.1	78.4	85.3
Phosphate	9.7	8.6	8.8	9.1	9.5	9.3	9.7
Potash	4.1	3.9	3.6	3.8	3.8	3.7	3.8
Total	78.6	75.4	80.3	83.6	89.4	91.4	98.8

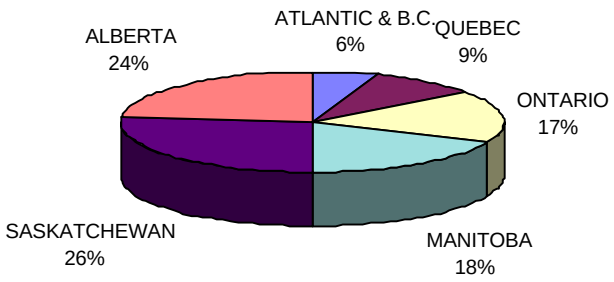

Figure 2: Percentage Distribution of the Quantities of Fertilizer Sold by province in Canada, 1995 (Agriculture and Agri-Food Canada, 1996)

3.3.2. Energy Used in Pesticide Production

The most frequently used pesticides in Canada are herbicides, insecticides, fungicides and fumigants. To estimate the total energy used in the production of farm inputs, the quantities of each type of pesticide needs to be known. Coxworth (1997) asserted that data on the quantities of pesticides used in Canada were difficult to obtain. He therefore used the estimated quantities of a 1991 Pesticides Registrant Survey in his calculations. Green (1987) estimated that the average energy input in the production, transportation and application of pesticides was 6.6% of the total energy used in the production of fertilizers in the United States in 1980 (the energy input in fertilizer production was 518 PJ and the energy input in pesticide production was 34 PJ.) The methods of production, packaging, transportation and application of pesticides were assumed the same in Canada as in the United States. The estimates of energy used in pesticide production in Canada were obtained by taking 6.6% of the data given in Table 12. The results are shown in Table 13. These values are similar to those reported by Coxworth (1997). Because of technological improvements, these estimates should be further reduced by 34.5%, making the amount of energy expended on pesticide production small compared to fertilizer production.

Table 13: Estimated Quantities of Energy Used in Pesticide Production, Packaging, Transportation and Application in Canada (PJ)

	1990	1991	1992	1993	1994	1995	1996
Energy	5.2	5.0	5.3	5.5	5.9	6.0	6.5

There were 149 agricultural chemical establishments in Canada in 1995 (15 chemical fertilizer, 123 mixed fertilizer and 11 other agricultural chemical). These establishments spent

$121.4 million on fuel and electricity. The percentage distribution of energy spending by this industry was as follows: chemical fertilizer establishments 92%, mixed fertilizer establishments 7% and other agricultural chemical establishments 1% (Statistics Canada 32-203).

3.3.3. Energy Sequestered in Farm Machinery and Buildings

The amount of energy consumed in the manufacturing of farm machinery consists of the energy used in extracting, transporting and refining the raw materials and the energy used in the manufacturing, maintaining and repairing processes. Bowers (1992) estimated that the energy sequestered in the manufacturing of farm machinery was only about 2.4 % of the total energy consumed in agricultural production in the United States. Fluck et al. (1980) suggested that one method of measuring the energy requirement in farm machinery was to multiply the cost of the machine by the energy consumption to GDP ratio. Doering et al. (1977) estimated the energy consumed in farm machinery based on value-added. This method excluded the energy sequestered in metals. Table 14 displays the results by Doering et al (1997).

Table 14: Energy Used in Manufacturing Farm Machinery (MJ/kg)

Equipment	Energy Used
Tractor	27.63
Combine	21.65
Plow	12.78
Disc	9.96
Applicator	10.20
Planter	16.90
Rotary Hoe	11.38
Tires	85.80

Source: Doering et al. (1977)

Table 14 indicates that tire manufacturing requires the most energy in its production. The total quantity of energy used in the manufacture of all farm machinery could be estimated if the total number of each equipment type was known. Coxworth (1997) estimated the energy sequestered in farm machinery via the depreciation and repair charges, based on methods used by Stirling and Kun (1995). The depreciation and repair charges were converted to constant 1990 dollars, then multiplied by 69.06 PJ (the estimated amount of energy in farm machinery in 1990 for Canada). Similarly, Coxworth estimated the energy sequestered in farm buildings. The results are shown in Table 15 and Table 16.

Table 15: Energy Sequestered in Farm Machinery in Canada (PJ)

Year	1990	1991	1992	1993	1994	1995	1996
Energy	69.1	66.6	66.2	66.1	66.8	67.0	67.4

Source: Coxworth (1997).

Table 16: Energy Sequestered in Farm Buildings in Canada (PJ)

Year	1990	1991	1992	1993	1994	1995	1996
Energy	35.9	37.2	36.0	34.2	33.2	33.9	35.7

Source: Coxworth (1997).

Tables 15 and 16 indicate that the energy sequestered in farm machinery and buildings is significant. Measuring the energy used in farm machinery and buildings via the depreciation and repair charges involves making a strong assumption since depreciation charges may not be a function of the amount of energy used in the production of farm machinery and buildings.

4. Food and Beverage Processing Energy Use

The food and beverage processing industry is a sub-sector of the manufacturing sector. In 1995, the manufacturing sector spent $9387.8 million on energy and consumed 1788.3 PJ or 26.7 % of the total energy consumed in Canada (Statistics Canada 31-203).

4.1. Expenditures on Energy in Food and Beverage Processing

There were 2965 food processing establishments in Canada in 1995. These establishments spent $693.8 millions on energy (7.4% of the total manufacturing expenses on energy). Table 17 indicates the number of food processing establishments in Canada by region. The distribution of expenses on energy in the industry is shown in Figure 3 and the provincial distribution is shown in Figure 4. The figures indicate that the food industry in Ontario and Quebec spent the most on energy (42% and 22% respectively).

The beverage industry consisted of 225 establishments (103 soft drink industries, 19 distilleries, 68 breweries and 35 wine industries) in 1995, These establishments spent $91.1 million on energy (about 1% of total manufacturing expenses). The distribution of the spending on energy by industry was as follows: Brewery products 48.1%, Soft drinks 31.7%, Distillery products 17.8% and Wine industry 2.4%.

Table 17: Number of Food Processing Establishments by Province in 1995

Province	# of Food Processing Establishments
Nfld.	93
P. E. I	47
N. S.	184
N. B.	120
Que.	826
Ont.	938
Man.	130
Sask.	78
Alta.	258
B. C.	291

Source: Statistics Canada.

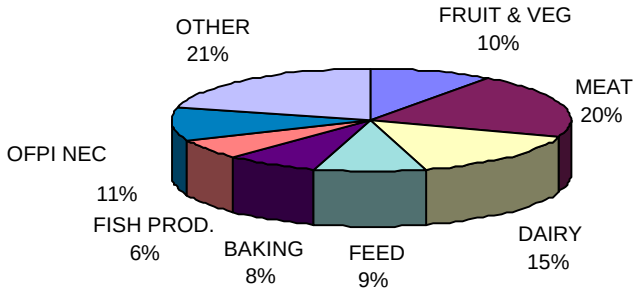

Figure 3: Percentage Distribution of Expenses on Energy by Industry in 1995 (Statistics Canada)

FRUIT & VEG (with 194 establishments) in Figure 6 include: canned, preserved and frozen fruit and vegetable industries. MEAT (557) includes: meat products, and poultry; DAIRY (270) includes liquid milk, and other dairy products; Feed industry (466); BAKING (454) includes bread and other bakery products; FISH products (400); OFPI NEC (Other Food Products Industries NEC, (294)); OTHER (330) includes cereal, flour, tea, coffee, potato chip, pretzel, popcorn, malt, oil, biscuit, sugar and other food product industries, each of these establishments have a share in the energy cost which is less than 5% for this group.

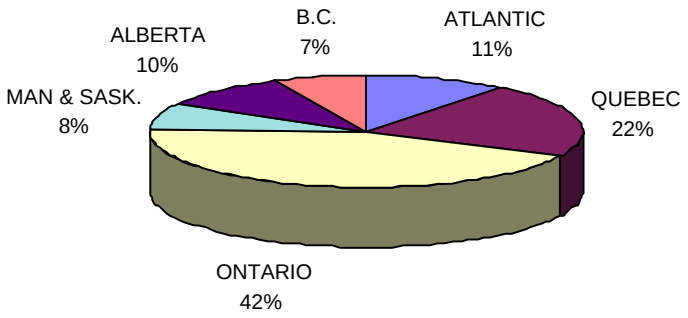

Figure 4: Percentage Distribution of Expenses on Energy for the Processing Food Industry in 1995 (Statistics Canada)

The distribution of the total spending on energy by province was as shown in Figure 5 and reveals that the beverage industry in Ontario, Quebec, Alberta and B. C. spent the most on processing energy.

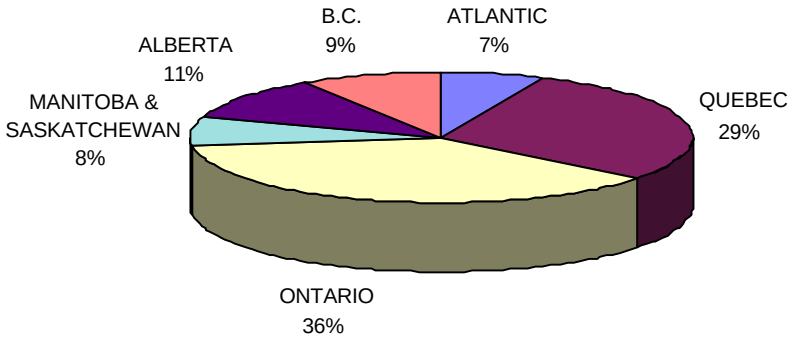

Figure 5: Percentage Distribution of Spending on Energy in the Beverage Industry in 1995 (Statistics Canada)

* The number of beverage establishments by region in 1995 was: Atlantic 19, Quebec 49, Ontario 81, Manitoba and Saskatchewan 18, Alberta 21 and B.C. 37.

4.2. Quantities of Energy Consumed in Food and Beverage Processing

To obtain the quantity of energy used in the food and beverage processing industry, it is assumed that the cost of one unit of energy is the same for all manufacturing industries. Since the food and beverage industry energy expenditures represented 8.4% (7.4% + 1%) of the total manufacturing expenses in 1995, the total quantity of energy used in the manufacturing sector in 1995 (i.e., 1788.3 PJ) was multiplied by 8.4%. The corresponding energy used in food processing amounted to 150.2 PJ (or 2.2% of the total energy consumed in 1995). Similarly, the estimated quantities of energy used in the food and beverage processing industry from 1990 to 1996 were calculated. The results are summarized in Table 18. These quantities represent about 2% of the total energy used in Canada. Table 19 indicates that in the food and beverage processing industry, natural gas was the main source of energy used in 1973.

Table 18: Estimated Quantities of Energy Consumed by the Food and Beverage Processing Industry in Canada (in PJ)

	1990	1991	1992	1993	1994	1995	1996
Energy	146.4	144.5	146.4	147.1	151.2	150.2	150.0

Table 19: Percentage Distribution of Energy Use by Energy Type for Selected Food Processing Industries in the United States in 1973

Industry	Ng	Elec.	RPP	Coal	Others
Meat Packing	46	31	14	9	0
Prepared animal feeds	52	38	10	<1	0
Wet corn milling	43	14	7	36	0
Fluid milk	33	47	17	3	0
Beet sugar processing	65	1	5	25	4
Malt beverages	38	37	18	7	0
Bread and related products	34	28	38	0	0
Frozen fruits and vegetables	41	50	5	4	0
Soybean oil mills	47	28	9	16	0
Canned fruits and vegetables	66	16	15	3	0
Canned sugar refining	66	1	33	0	0
Sausage and other meat	46	38	15	1	0
Animal and marine fats and oils	65	17	17	1	0
Average	49.4	26.6	15.6	8.1	0.3

Source: Unger (1975)

5. Summary

The focus of this report was on estimating the quantities and values of non-renewable energy consumed in farming, food processing, home, restaurants and hotel food preparation.

At the farm level, the estimated total energy consumed is the sum of the values in Table 6, Table 12, Table 13, Table 15 and Table 16. Thus, total energy consumed at the farm level represents about 5% of total Canadian energy used (Table 20). Table 21 indicates that about 20% of total annual farm expenses are spent on energy.

Table 20: Total Energy Used at the Farm Level in Canada (in PJ)

	1990	1991	1992	1993	1994	1995	1996
Ng	14.6	14.4	15.4	18.8	14	13.3	15.4
Ngl	4.2	3 .0	3.8	3.3	2.6	2.2	2.4
Hydro	13.9	13.8	13.7	13.7	13.9	13.5	14.6
N & T	9.1	8.9	8.9	8.9	9.1	8.8	9.5
RPP	119.6	112.5	132.6	105.7	108.4	119.1	126.5
Steam	0	0.2	0.1	0.2	0.1	0.1	0
Nitrogen Fertilizer	64.8	62.9	67.9	70.7	76.1	78.4	85.3
Phosphate Fertilizer	9.7	8.6	8.8	9.1	9.5	9.3	9.7
Potash Fertilizer	4.1	3.9	3.6	3.8	3.8	3.7	3.8
Farm Machinery	69.1	66.2	66.2	66.1	66.8	67	67.4
Farm Buildings	35.9	37.2	36	34.2	33.2	33.9	35.7
Pesticides	5.2	5	5.3	5.5	5.9	6	6.5
Total Farm Business Energy	350.2	336.6	362.3	340	343.4	355.3	376.8
Total Energy Use Canada	6321.2	6221	6328.1	6523	6696.8	6882.5	7129.1
Ag. Energy as % of total Energy Used	5.5	5.4	5.7	5.2	5.1	5.1	5.2

Table 21: Total Expenses on Direct and Indirect Farm Energy in Canada ($ millions)

	1990	1991	1992	1993	1994	1995	1996
Total heating fuel	187.6	193.4	189.0	190.9	203.7	187.1	202.8
Electricity	434.3	448.7	466.6	481.8	497.8	496.2	528.8
Machinery fuel	1210.7	1230.4	1226.7	1307.1	1363.7	1421.5	1504.0
Fertilizer & Lime	1242.0	1260.1	1340.4	1398.6	1659.0	1941.8	2090.1
Pesticides	720.9	658.1	710.4	769.0	954.5	1063.0	1186.9
Total	3795.5	3790.7	3933.1	4147.4	4678.7	5109.6	5512.6
% of Total Farm Operating Expenses	18.5	18.2	18.5	18.7	19.7	20.5	21.0

* Total Expenses = Expenses after Rebates + Rebates. Expenses include personal energy used on the farm.

As noted in Table 17, the majority of foods processing industries are in Ontario and Quebec. Table 22 indicates the total quantities and values of energy used in the food and beverage industry from 1990 to 1996.

Table 22: Quantity and Dollar Value of Energy Used in Food and Beverage Processing in Canada

	1990	1991	1992	1993	1994	1995	1996
Quantity (PJ)	146.4	144.5	146.4	147.1	151.2	150.2	150.0
Values ($)	671.5	685.5	705.8	748.7	804.8	784.9	784.6
% of Total Canadian Energy Use	2.3	2.3	2.3	2.2	2.2	2.2	2.1

Table 23: Quantity of Energy Used in Home, Restaurant, and Hotel Food Preparation in Canada (in PJ)

	1990	1991	1992	1993	1994	1995	1996
Home	161.6	157.4	159.2	169.7	172.4	169.4	183.9
Restaurant and hotel	90.1	90.7	92.0	97.3	95.8	101.0	102.0
Total	251.7	248.1	251.2	267.0	268.2	270.4	285.9
% of Total Canadian Energy Use	4.0	4.0	4.0	4.1	4.0	3.9	4.0

The percentage of total energy used in the Canadian food system (excluding the energy used in farm machinery and buildings) was obtained by adding the percentages in Table 20, 22 and 23 (Table 24). The percentage of energy used including farm machinery and buildings is set out in Table 25.

Table 24: Percentage of the Total Canadian Energy Used by the Canadian Food System, Excluding the Energy in Farm Machinery and Buildings

	1990	1991	1992	1993	1994	1995	1996
Percentage	10.2	10.0	10.4	10.0	9.8	9.8	9.9

Table 25: Percentage of the Total Energy Used by the Canadian Food System, Including Farm Machinery and Buildings, 1990-1996

	1990	1991	1992	1993	1994	1995	1996
Percentage	11.9	11.7	12	11.5	11.3	11.3	11.3

Table 25 showed that the energy consumed in the Canadian Food System is approximately 11% of the total energy demand in Canada. This percentage does not include the energy used in the manufacture of food processing machinery, buildings, transportation vehicles and roads.

The total energy consumed in the farming and food processing sectors and the corresponding GDP are given in Table 26.

Table 26: Farming and Food Processing Energy Consumption (Excluding Energy in Farm Machinery and Buildings) in PJ, the Corresponding GDP (in Billions of Dollars) and Energy to GDP Ratio

	1990	1991	1992	1993	1994	1995	1996
Total Farming and Food Energy	390.9	377.0	406.5	386.3	393.9	403.9	433.0
Corr. GDP (1992=100)	28.0	28.2	27.3	28.2	29.7	29.8	30.7
Energy/GDP	14.0	13.4	14.9	13.7	13.3	13.5	14.1

Corr. GDP = Corresponding GDP.

Canada exports and imports significant agricultural, food and beverage products. If net food export is defined as the difference between total agriculture and food exports and total agriculture and food imports, then the energy used in producing net food exports can be calculated by multiplying net food exports (Table 27) by the energy to GDP ratio in Table 26. The values of total exports and imports in constant 1992 dollars (deflated using the GDP deflator) and the corresponding quantities of energy exported are given in Table 27. In Table 27, it was assumed that the energy consumed per dollar of exports is equivalent to the energy consumed per dollar of imports.

Table 27: Total Exports and Imports of Agriculture and Food Products in Canada

	1990	1991	1992	1993	1994	1995	1996
GDP Deflator	100.8	99.3	100.0	102.5	106.4	108.4	110.1
Real Exports	12053.0	12133.0	14158.0	14270.0	15253.0	16983.0	18841.0
Real Imports	8036.0	8444.0	9127.0	10037.0	11102.0	11449.0	11899.0
Net Food Exports	4017.0	3689.0	5031.0	4233.0	4151.0	5534.0	6942.0
Corresponding Energy Exported	56.2	49.4	75.0	58.0	55.2	74.7	97.9

Real Exports = total exports of live animals, food, feed, beverage and tobacco divided by the GDP deflator. The data are from CANSIM series D399375 and D399376.
Real Imports = Total imports of live animals, food, feed, beverage and tobacco divided by the GDP deflator. The data are from CANSIM series D397917 and D397918.
GDP deflator = (GDP in any given year / GDP in 1992) * 100.

Source: Statistics Canada.

The total energy consumed on nutrition by Canadians (TECN) is equal to the energy used in farming (FE), plus the energy used in food processing (FPE), minus the energy used in net food exports (NFE), plus the energy used in residential (RES), restaurant and hotel (RH) food preparation (i.e., TECN = FE + FPE - NFE + RES + RH). The estimated quantities are given in Table 28.

Table 28: Total Energy Used by Canadians on Nutrition (Excluding the Energy in Farm Machinery and Buildings)

Nutrition Energy	1990	1991	1992	1993	1994	1995	1996
TECN	586×10^9	576×10^9	583×10^9	595×10^9	607×10^9	600×10^9	611×10^9
Per Capita Annual TECN	21.1×10^3	20.5×10^3	20.5×10^3	20.6×10^3	20.8×10^3	$20.3\ 10^3$	$20.4\ 10^3$
Average Daily Per Capita TECN	57.8	56.2	56.0	56.4	57.0	55.6	55.7

Per capita annual TECN = TECN / population.
Average Daily Per Capita TECN = Per Capita Annual TECN / 365 days (366 days in 1992 and 1996).

Table 28 indicates that, on average, every Canadian use over 56 MJ of energy on nutrition per day (or 13,400 Kcal. per day). Brown et al., (1976) estimated that about 22.5 MJ of energy was consumed per ½ kg can of cooked corn. Thus, an individual eating 3 cans of cooked corn per day would consume 57.5 MJ of energy. Green (1978) estimated that the energy consumption per year per person in crop production in the United States was 7600 MJ. That is equivalent to 20.8 MJ of energy per day per person. Singh (1986) reported that the energy required, per kg of processed cheese, was 13.6 MJ. 8.7 MJ of energy was needed per kg of processed canned food and 5.2 MJ / kg of canned fruits and vegetables. 29.1 MJ/kg were required for mashed potato granules and flakes and 8.2 MJ/kg of frozen citrus juice.

The results shown in Table 29 include the energy sequestered in farm machinery and buildings.

Table 29: Total Energy Used by Canadians on Nutrition Including Farm Machinery and Buildings

Nutrition Energy	1990	1991	1992	1993	1994	1995	1996
TECN Per Capita	$691x10^9$	$680x10^9$	$685x10^9$	$696x\ 10^9$	$707x\ 10^9$	$701x\ 10^9$	$714x\ 10^9$
Annual TECN	$24.9x10^3$	$24.2x10^3$	$24.0x10^3$	24.1x103	$24.2x10^3$	$23.7x10^3$	$23.9x10^3$
Average Daily Per Capita TECN	68.2	66.3	65.6	66	66.3	64.9	65.3

* TECN = FE + FPE - NFE + RES + RH + energy used in farm machinery and buildings
Per Capita Annual TECN = TECN / Population.
Average Daily Per Capita TECN = Per Capita Annual TECN / 365 days (366 days in 1992 and 1996).

6. Conclusion

The objective of this study was to estimate the amount of energy consumed in farming, food processing, residential and commercial food preparation. At the farm level, the estimates indicated that Saskatchewan, Manitoba and Alberta farmers spent a higher percentage of their operating expenses on direct and indirect energy than the other provinces (Table 2). In 1996, the quantity of energy consumed by province was highest in Saskatchewan (55.28 PJ), Ontario (55.19 PJ) and Alberta (52.78 PJ). The average distribution of direct energy consumed on the farm by energy type was as follows: Refined Petroleum Products 68%, electricity 16%, natural gas 12%, natural gas liquids 3% and other 1%. About 77% of the total direct energy consumed on farms was used for farm business only. Nitrogen fertilizer production represented greatest energy input, reflecting the high energy cost in the manufacture of nitrogen fertilizer. From 1990 to 1996, direct and indirect energy consumed on the farm represented about 4% of the total energy demand in Canada.

In food processing, Ontario and Quebec had the most establishments with 938 and 826 respectively in 1995. As a result, these two provinces spent more energy on food processing. The meat and dairy processing industries were the biggest consumers of energy in this sector (Fig. 3). Similarly, Ontario and Quebec had the most establishments in beverage processing. Most of the energy in beverage processing was consumed in the brewery and soft drink industries. The quantity of energy used in food and beverage processing represented about 2% of the total final energy used in Canada (Table 18). Natural gas and electricity were the main sources of energy in the food and beverage processing industry (Table 19).

Green (1987) suggested that the amount of energy consumed in food and beverage processing in the USA in 1980 was about 1.5 times the amount of energy used in agricultural production (3086 PJ). Thus, in this report the total amount of energy consumed in the agriculture and food sector may have been under-estimated. For example, the estimates do not include the energy sequestered in food processing machinery and buildings.

Statistics Canada does not publish data on industries with less than five establishments. Consequently, data were not available on energy consumption in most food processing industries in Newfoundland, Prince Edward Island, the Yukon and the North West Territories. However, the non-availability of data from these provinces and territories should not significantly affect our estimates.

From 1990 to 1996, energy consumption in residential food preparation was about 3% of the total final energy demanded in Canada. Ontario and Quebec were the highest consumers of residential energy. Energy use in the commercial sector was also highest in Ontario and Quebec. The commercial sector energy consumption represented approximately 1% of the total energy used in Canada.

The objective of this study was also to estimate the average per capita energy consumed on nutrition per day in Canada. Our findings suggest that every Canadian uses about 66 MJ of energy per day on nutrition. This estimate does not include the energy used by humans and animals for food provisions. Not included in this estimate in renewable energy, wood energy, the energy sequestered in food processing machinery and buildings, and the energy used in waste management. Fluck et al. (1980) suggested that more than 15 MJ of energy per day is required to provide food for one person.

Because Canada exports and imports farm and processed food products, the amount of energy corresponding to net food exports was estimated. Thus, the total energy consumed by Canadians was calculated by subtracting the quantity of energy used in producing net food exports from the total amount of energy used in farming and food processing (Table 27).

Further research is needed in order to estimate the quantities and values of energy used in transporting farm and processed food products. Statistics Canada should report the quantities of fossil fuels and hydro energy used in the processing sector. Better methods are also needed in estimating the energy sequestered in farm machinery and buildings and the energy consumed in the manufacture of farm pesticides.