Energy Consumption

in the

Canadian Agricultural and Food Sector

Final Report

For

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Submitted

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1. Introduction

1.1 The Canadian Agriculture and Food Sector

The Canadian agriculture and food sector (CAFS) forms an integral and significant part of the Canadian economy. Since 1990, this sector has contributed approximately five percent to the total Canadian Gross Domestic Product (Statistics Canada).

Industrialized agricultural production uses machinery, fertilizers, pesticides and petroleum products as inputs. All these are produced by other sectors of the economy. The output from agricultural production includes grain, dairy products and livestock which are used as input in the food-processing sectors. All these products, whether as input or output, are at some stage transported by rail or truck from producers to processors or from producers to grocery stores.

The equipment and inputs used in the production, transportation, retail and home preparation of food require a form of energy input. Various example include the following: transportation equipment requires gasoline or diesel fuel; fertilizer production uses natural gas; food processing uses electricity, natural gas and heavy oil; in-home and restaurant food preparation uses natural gas and electricity as sources of energy.

1.2 Greenhouse Gas

In the 1980's, greenhouse gas (GHG) emissions from human activity became a worldwide concern since they are a possible cause of climatic changes. Policy makers are now trying to find methods to reduce GHG emissions.

The three main greenhouse gases are: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) (Bonneau et al., 1998). Carbon dioxide emissions accounted for about 81% of total GHG emissions in Canada in 1995 (Natural Resources Canada, 1997).

Energy may be produced from non-renewable sources such as fossil fuels (e.g. oil, natural gas, coal and peat) and nuclear energy or from renewable energy sources such as sunlight, wind, hydroelectricity, photosynthesis, tidal and geothermal (Fluck et al., 1980). The consumption of non-renewable energy, excluding nuclear energy, at the primary and secondary levels is responsible for the majority of CO_2 emissions. In 1995, energy consumption at the secondary level (residential, commercial, industrial, transportation and agriculture) accounted for 63.1% of the total CO_2 emissions (Natural Resources Canada, 1997).

2. Focus of the Report

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.

3. 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.

3.1 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 as 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).

3.2 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 and;
- Transportation of processed products.

3.3 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.

3.4 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.

3.5 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).

3.6 Fossil Fuels Energy and Hydro Energy

Estimates of fossil fuels energy and hydro energy were separated where possible. In the processing industry, Statistics Canada does not separate the amount of energy consumed into these energy forms and reports only the dollar value of the costs of electricity and fuels. In this report, costs of electricity and fuels were used to estimate the quantity of energy used in the food and beverage industry by assuming the cost of one unit of energy is equal for all manufacturing industries.

Electricity can be generated from hydro energy or from fossil fuels (e.g., coal, uranium (nuclear) and natural gas). Consequently, the energy reported by some processing industries as electricity may have come from fossil fuels.

In this report, portions of electricity produced using hydro, nuclear or thermal energy have been estimated by province from Natural Resources Canada (NRCan) data.

4. Economic Indicators

Fluctuations of energy use in the agriculture and food sector may be better understood by studying various economic indicators. Several economic indicators were collected from 1990 to 1996 from Statistics Canada's CANSIM database[1]. These include Gross Domestic Product (GDP), consumer price indices (CPI), population total energy demands by province and by sector (agriculture, manufacturing, residential and commercial) and some Census of Agriculture data. In the next section, data on economic indicators and energy consumption at the farm, food processing, residential and commercial levels are presented. These data sources are compared between energy used in farming and in food processing. A geographic distribution of food processing energy expenditures is reported and the agriculture and food sector energy consumption is compared to that of total Canadian energy consumption.

4.1 Selected Economic Indicators

Energy use in an economy is related directly to the general level of economic activity. The higher the level of economic activity, as measured by the Gross Domestic Product (GDP), the more energy required to sustain these activities. The GDP contributions of various industries appears in Table 1.

The data reveals that from 1990 to 1996, the agriculture and related services sector contributed

[1] The Canadian Socio-economic Information and Management Database.

2% to Canadian GDP, the food and beverage industries contributed 2.5% and the tobacco products industries contributed 1%. The data also indicates that the level of economic activity in most industries was lower in 1991 and 1992 than in 1990 and increased steadily from 1993 to 1996. From 1990 to 1996, the level of activity in the energy and food industries did not decline. This may be attributed to a rise in energy consumption due to an increase in population or higher consumer prices as indicated in the consumer price index (CPI).

Table 1: Canadian GDP (Billions of 1992 dollars)

	1990	1991	1992	1993	1994	1995	1996
Business Sector	485.1	473.8	474.5	488.1	512.6	525.4	538
Non Business Sector	123.3	126.1	129.8	131.1	130.4	129.6	127.3
Good Producing Industries	205.6	196.5	194	200.8	212	216.7	220.5
Service Producing industries	402.6	403.1	410.2	418.4	431.1	438.4	444.7
Agriculture & Services		11.4	10.3	11.1	11.7	11.8	12.3
Livestock Farms	3	3.1	3.4	3.4	3.4	3.5	3.6
Field Crop Farms	7.5	7.5	6.1	7.1	7.6	7.6	7.9
Related Ag. Services	0.8	0.7	0.7	0.7	0.7	0.7	0.7
Manufacturing industries	102.6	95	96.1	101.9	108.4	113.7	114.9
Food industries	12	12.3	12.5	12.5	13	13.2	13.7
Beverage industries	3.1	3	3.1	3.2	3.3	3.2	3.2
Agricultural chemical industry	0.4	0.4	0.4	0.5	0.6	0.6	0.5
Tobacco products industries	1.1	1.1	1	0.9	1.1	1	1
Energy	33.4	34.6	35.3	37.4	39.7	40.5	41.6
Total economy	609.2	600	604.3	619.2	643.1	655.1	665.3

Source: Statistics Canada

Higher demand of a good usually leads to a rise in its CPI. Data on consumer price indexes and the total Canadian population from 1990 to 1996 are shown in Table 2 and Table 3 respectively. It is evident from Table 2 that, in general, price levels have increased since 1990. Table 3 indicates that Ontario is the most populated province followed by Quebec, British Columbia and Alberta respectively. If energy consumption had been based on population, these provinces should be the largest energy consumers.

Table 2: Canadian Consumer Price Index for Selected Items (1992 = 100)

	1990	1991	1992	1993	1994	1995	1996
Food	95.8	100.4	100	101.7	102.1	104.5	105.9
Goods	94.5	99.2	100	101.6	100.5	102.4	104.0
Services	92.0	97.8	100	102.1	103.8	106.4	108.1
Food & Energy	95.6	100.2	100	101.6	102.1	104.2	106.0
Electricity	82.1	93.9	100	104.2	104.9	104.4	105.6
Piped Gas	87.8	96.3	100	103.8	112.5	105.6	104.4
Fuel Oil & Others	96.0	103.8	100	101.7	100.4	99.0	105.8
Gasoline	105.3	103.7	100	98.5	97.3	101.9	106.4
Transportation	96.3	98.0	100	101.3	107.8	113.4	117.8
All Energy	95.1	99.7	100	101.3	101.8	103.2	106.2
All Items	93.3	98.5	100	101.8	102	104.2	105.9

Source: Statistics Canada

Table 3: Population by Region ('000)

	1990	1991	1992	1993	1994	1995	1996
Nfld.	578	580	582	584	581	576	570
P. E. I.	131	131	131	133	134	135	136
N. S.	912	917	922	929	933	937	941
N. B.	742	748	751	754	756	758	760
Que.	7,010	7,077	7,156	7,229	7,290	7,342	7,391
Ont.	10,313	10,462	10,639	10,790	10,942	11,100	11,252
Man.	1,107	1,109	1,114	1,119	1,125	1,131	1,136
Sask.	1,011	1,005	1,004	1,006	1,009	1,012	1,017
Alta.	2,549	2,595	2,634	2,672	2,706	2,741	2,781
B. C.	3,291	3,372	3,455	3,549	3,649	3,744	3,834
Yukon.	28	29	30	30	30	30	31
N. W. T.	59	61	62	63	65	66	67
Canada	27,733	28,088	28,481	28,858	29,219	29,573	29,917

Source: Statistics Canada

5. Canadian Energy Demand

The types of energy used in this report are:

- Refined petroleum products (RPP) including gasoline, diesel fuel, kerosene, light fuel oil, heavy fuel, still gas, lubricants and greases;
- Natural gas (NG);
- Gas plants (NGL) including liquid petroleum gas and natural gas liquid;

- Coal, coke and coke oven gas;
- Steam and;
- Electricity.

Wood, solar and wind energy are not included due to their low use levels.

The percentage distribution of primary and secondary energy demand in 1995 by energy type is displayed in Figure 1.

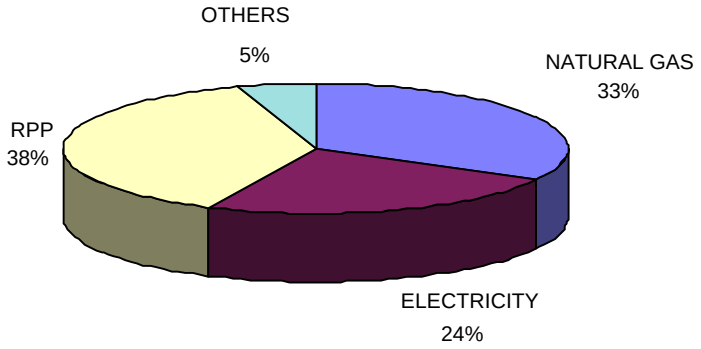

Figure 1: Percentage Distribution of Total Final Energy Demand by Energy Type for Canada in 1995 (Statistics Canada)

The data indicates that Refined Petroleum Products (RPP) were the main source of energy, followed by natural gas and electricity.

The percentage distribution of primary and secondary energy demanded in 1995 by energy type and by province is shown in Table 4 below. It is evident from Table 4 that in 1995 Refined Petroleum Products were the primary source of energy in the Atlantic provinces (Newfoundland, Prince Edward Island, Nova Scotia, and New Brunswick), the Yukon and the North West Territory (NWT). The natural gas consumption percentage was highest in Saskatchewan, followed by Alberta, Manitoba and Ontario. Electricity consumption percentage was highest in Quebec, followed by Newfoundland, New Brunswick, British Columbia and Manitoba.

The method of production of electricity varies from province to province. The percentages of gross electricity generated in 1995 by production type (hydro, thermal, and nuclear) and by province are given in Table 5.

Table 4: Percentage Distribution of Energy Demand by Energy Type in 1995

	Natural Gas	Electricity	RPP	Other
Nfld.	0	32	65	3
P. E. I.	0	14	85	1
N. S.	0	21	77	2
N. B.	0	31	64	5
Que.	16	42	40	2
Ont.	39	20	33	8
Man.	39	22	37	2
Sask.	53	14	32	1
Alta.	48	15	32	5
B. C.	33	24	40	3
Yukon & NWT	11	13	72	4
Canada	33	24	38	5

Source: Statistics Canada

The data indicates that New Brunswick, Quebec and Ontario are the only provinces where nuclear technology is used to produce electricity. According to NRCan, there were 21 nuclear reactors in Canada in 1996, down from 22 the previous year. Thermal electricity generation is highest in Prince Edward Island, Nova Scotia, New Brunswick, Saskatchewan and Alberta whereas in Newfoundland, Quebec, Manitoba and British Columbia, hydro electricity generation is the main form of electricity production. Inter-provincial electricity trade allows provinces to consume electricity from other provinces.

Table 5: Percentage of Indigenous Electricity Generated by Method of Production

	Hydro	Thermal	Nuclear
Nfld.	95	5	0
P. E. I.	0	100	0
N. S.	9	91	0
N. B.	20	67	13
Que.	97	0	3
Ont.	25	16	59
Man.	99	1	0
Sask.	24	76	0
Alta.	4	96	0
B. C.	85	15	0
Yukon & N. W. T.	56	44	0
Canada	60.6	21.7	17.7

Source: NRCan

During the 1990 - 1996 period, energy consumption was the highest in Ontario, Quebec, Alberta, and British Columbia respectively and energy consumption in these provinces increased steadily. The energy consumption in the rest of Canada remained low and steady over the same period. The daily per capita energy demand in Canada (Table 6) indicates that from 1990 to 1996, each Canadian consumed, on average, over 600 MJ of energy per day. In 1995, the total energy demand in Canada was 6882 PJ. Figure 3 below shows graphically a distribution of this amount amongst the regions of Canada.

Table 6: Per Capita Daily Energy Demand in Canada (MJ)

	1990	1991	1992	1993	1994	1995	1996
Total Energy Demand	632×10^9	622×10^9	6328×10^9	6523×10^9	6697×10^9	6882×10^9	7129×10^9
Per Capita Yearly Demand	228×10^3	221×10^3	222×10^3	226×10^3	229×10^3	233×10^3	238×10^3
Per Capita Daily Demand	624	607	607	619	628	638	651

Source: Statistics Canada

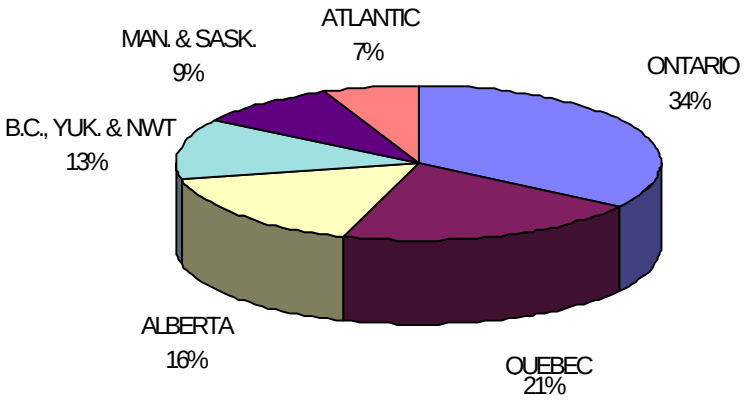

Figure 2: Percentage Distribution of Total Energy Demand by Region in 1995 (Statistics Canada)

Final Demand

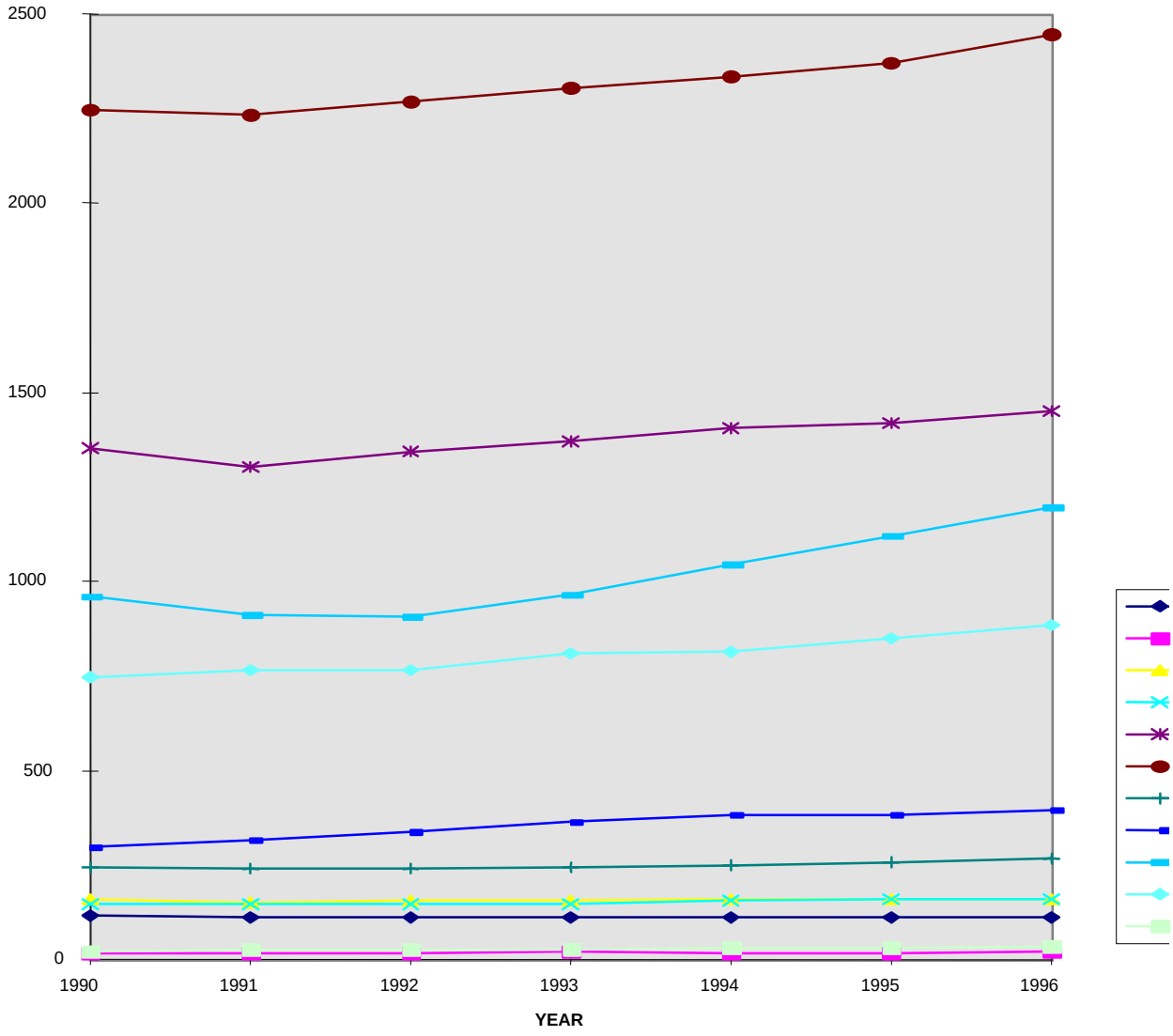

Figure 3: Total Energy Demand by Province from 1990 to 1996 (Statistics Canada)

6. 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.

6.1 Expenditures on Farm Energy

Total farm operating expenses in constant 1992 dollars increased steadily from 1990 to 1996 (Table 7[2]). 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 4 indicates that Ontario spent the most on farm operations, followed by Alberta, Saskatchewan and Quebec.

Table 7: Total Expenditures on Farm Operations in Canada (in Billions of 1992 dollars)

	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.

[2] 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.

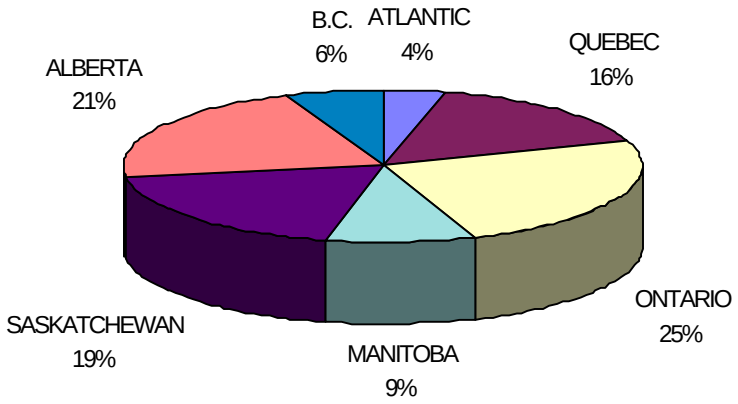

Figure 4: Percentage Distribution of Total Farm Operating Expenses by Province in 1995 (Statistics Canada)

Table 8: Expenditures on Direct and Indirect Energy as a Percent of Total Farm Expenditures

Direct Energy

	Total Expenses ($ million)	Electricity	Heating Fuel	Machinery Fuel	Total
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 8 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

Source: Statistics Canada

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%).

Table 9: Number of Farms and Average Size of Farms in Canada and Provinces

	1991 # of Farms	1991 Average Farm Size (acres)	1996 # of Farms	1996 Average Farm Size (acres)
Nfld.	725	161	731	147
P. E. I.	2361	271	2200	297
N. S.	3980	247	4021	241
N. B.	3252	285	3206	290
Que.	38076	223	35716	237
Ont.	68633	196	67118	206
Man.	25706	743	24341	785
Sask.	60840	1091	56979	1152
Alta.	57245	898	58990	881
B. C.	19225	307	21653	288
Canada	280043	598	274955	611

* Excluding Christmas tree only farms.

Source: Statistics Canada

Table 9 indicates that Saskatchewan utilized more land for agricultural purposes than any other province. This may explain why Saskatchewan farm operators used more direct and indirect energy in farm production activities.

6.2 Direct Energy Used in Farm Production

Table 10 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 11 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 10: Direct Farm Energy Used in Farm Operations by Province and in Canada (PJ)

	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 11: 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 and Thermal energy (N & T) in Table 11. 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%. See Table 5 above)

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 12.

Table 12: Percentage Direct Energy Used for Farm Business Activities by Energy Source for Canada

	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 12 were multiplied by the total quantity of each energy type consumed on the farm (Table 13). The calculated estimates are shown in Table 14. Energy use was highest in 1992 because of an increase in RPP during 1992.

Table 13: Total Direct Farm Energy Used for Farm Business Activities in Canada (PJ)

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

	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 14 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.

6.3 Indirect Energy

6.3.1 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[3] 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 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 15.

Table 15: 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 16: Calculated Quantities of Energy Used in the Production and Transportation of Fertilizer Sold in Canada (PJ)

	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 16 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 16 probably over-estimate the amount of energy used in fertilizer production.

[3] M. Korol and G. Rattray on behalf of Agriculture and Agri-Food Canada, Policy Branch collected Canadian Fertilizer Consumption, Shipments and Trade data.

Mudahar et al. (1982) estimated the average energy requirement for the production, packaging, transportation and application of fertilizers (Table 17). Since the energy used in fertilizer production has decreased over the past decade, the average energy used in producing fertilizers in Table 17 was reduced by 34.5%. The results are shown in Table 18.

Table 17: Average Energy Used in Fertilizer Production (GJ/thousands tonnes)

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

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

Table 19: 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

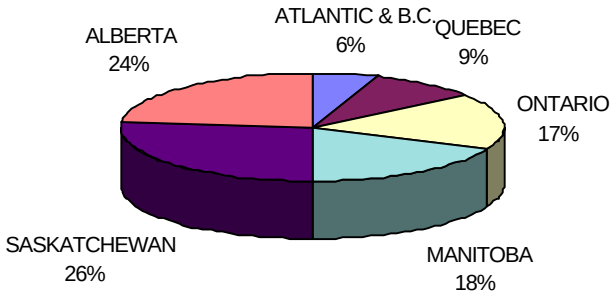

Figure 5: Percentage Distribution of the Quantities of Fertilizer Sold by province in Canada, 1995 (Agriculture and Agri-Food Canada, 1996)

The quantities of energy consumed in fertilizer production (Table 19) were obtained by multiplying the total averages in Table 17 by the total quantities of fertilizer sold (Table 18). Figure 5 indicates that Saskatchewan and Alberta were the largest users of fertilizers in Canada in 1995.

6.3.2 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 19. The results are shown in Table 20. 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 20: 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.)

6.3.3 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 21 displays the results by Doering et al (1997).

Table 21: 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 21 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 22 and Table 23.

Table 22: Energy Sequestered in Farm Machinery in Canada (PJ)

	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 23: Energy Sequestered in Farm Buildings in Canada (PJ)

	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 22 and 23 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.

7. 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).

7.1. 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 24 indicates the number of food processing establishments in Canada by region. The distribution of

expenses on energy in the industry is shown in Figure 6 and the provincial distribution is shown in Figure 7. 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 24: Number of Food Processing Establishments by Province in 1995

	# 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.

7.2 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 25. These quantities represent about 2% of the total energy used in Canada. Table 26 indicates that in the food and beverage processing industry, natural gas was the main source of energy used in 1973.

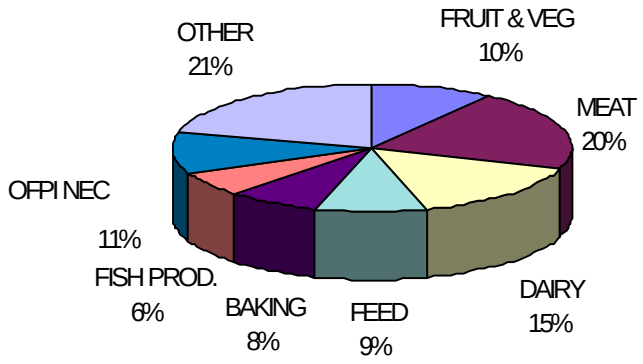

Figure 6: Percentage Distribution of Expenses on Energy by Industry in 1995 (Statistics Canada)

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.

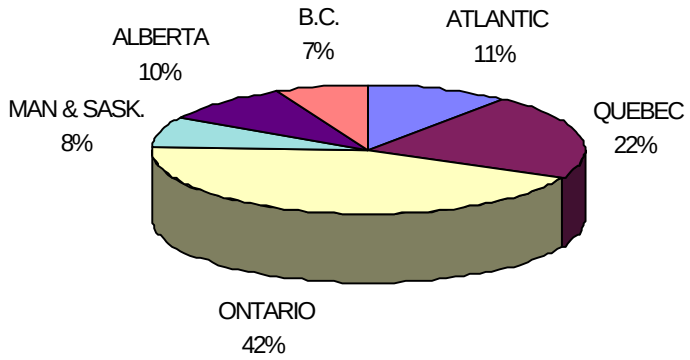

Figure 7: Percentage Distribution of Expenses on Energy for the Processing Food Industry in 1995 (Statistics Canada)

The distribution of the total spending on energy by province was as shown in Figure 8 and reveals that the beverage industry in Ontario, Quebec, Alberta and B. C. spent the most on processing energy.

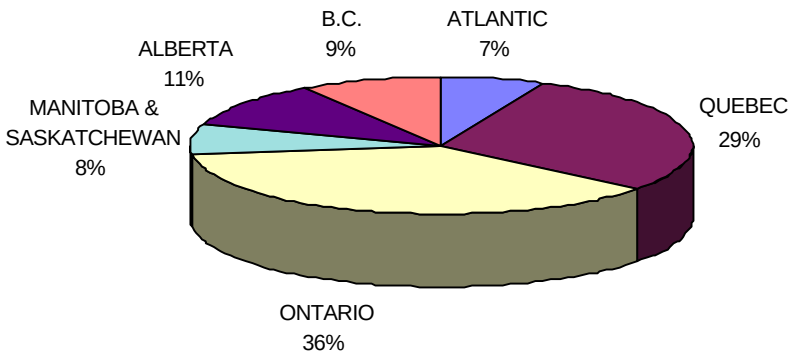

Figure 8: Percentage Distribution of Spending on Energy in the Beverage Industry in 1995 (Statistics Canada)

* 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.

Table 25: Estimated Quantities of Energy Consumed by the Food and Beverage Processing Industry in Canada (PJ)

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

8. Residential Energy Use

Total residential energy use amounted to 1254.9 PJ in 1995. This is equivalent to 18% of total energy expended in Canada. The percentage distribution of residential energy use by energy type was as follows: Natural Gas 47.7%, Electricity 34.6%, Refined Petroleum Products 10.1% and Others[4] 7.6%. Residential energy used by end use was distributed as follows: space heating 61.1%, water heating 20.8%, appliances 13.5%, lighting 4.1% and space cooling 0.5% (Natural Resources Canada, 1997).

[4] Others: include Coal, Steam, and liquid petroleum gases.

Table 26: Percentage Distribution of Energy Use by Energy Type for Selected Food Processing Industries in the United States in 1973

	Ng	Elec.	RPP	Coal	Other
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)

From 1990 to 1996, residential energy use increased from 1197.1 PJ to 1362.2 PJ, an increase of 165.1 PJ. The main factors influencing the increase in residential energy demand were the levels of activity (measured by the number of households), the use of appliances and the weather (Natural Resources Canada, 1997). Table 3 indicates that from 1990 to 1996, Ontario was the most populated province, followed by Quebec, British Columbia and Alberta. Consequently, these provinces should have the highest level of residential energy use. Figure 9 shows that residential energy demanded was the highest in Ontario, followed by Quebec, Alberta and B.C. respectively in 1995. The fact that residential energy demand in Alberta was higher than that of B.C. may be attributed to the difference in weather patterns and relative energy prices.

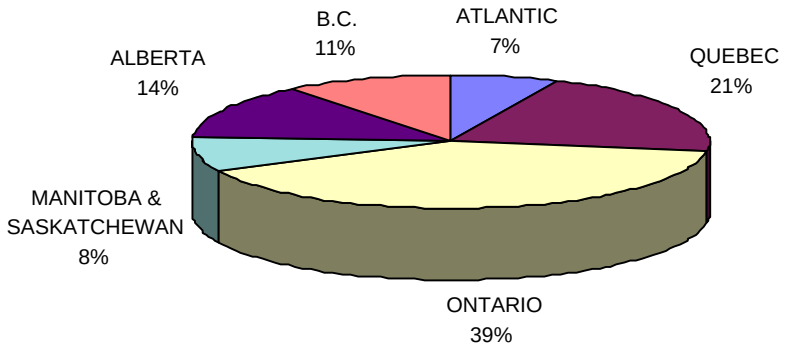

Figure 9: Percentage Distribution of Residential Energy Demand by Region of Canada in 1995 (Statistics Canada)

It was assumed that the percentage of energy used for home preparation was 13.5% (i.e., the percentage of residential energy consumed by home appliances in 1995). Natural Resources Canada (1997) reported that the quantity of energy used by home appliances increased by six PJ from 1990 to 1995. This increase was considered negligible. Thus, 13.5% of the total residential energy was taken as the quantity of energy used for home preparation (i.e. energy used in home preparation = total residential energy multiplied by 13.5%). The resulting quantities are presented in Table 27 and represent about 3% of the total Canadian energy used. The 13.5% factor includes the energy consumed by all equipment used in the home for purposes other than lighting, air conditioning and centralized water heating. The results in Table 27 probably therefore over-estimate the quantities of energy used for home cooking.

Table 27: Home Preparation Energy Consumption in Canada (PJ)

	1990	1991	1992	1993	1994	1995	1996
Energy	161.6	157.4	159.2	169.7	172.4	169.4	183.9

Source: Statistics Canada

9. Commercial Energy Use

The commercial sector defined by Statistics Canada includes: service industries related to mining, transportation, warehousing, communication, wholesale trade, retail trade, finance, insurance, real estate, accommodation, food, beverage, business service, education, health, social services and

other service industries. For this study, the total quantity of energy used by restaurants, hotels and grocery stores is the desired amount of energy estimated in the commercial sector. However data on the quantities and values of energy used by grocery stores were not available.

In 1995, the total final energy demanded by the commercial sector was 1030.3 PJ. This was equivalent to 15% of the total energy use in Canada. The percentage distribution of the total energy demand by energy type is in Figure 10 and the percentage distribution of commercial energy used by region is in Figure 11. Ontario followed by Quebec and Alberta were the greatest consumers of commercial energy.

Natural Resources Canada (1997) reported that restaurants and hotels consumed 9.9% of total commercial energy used (Table 28).

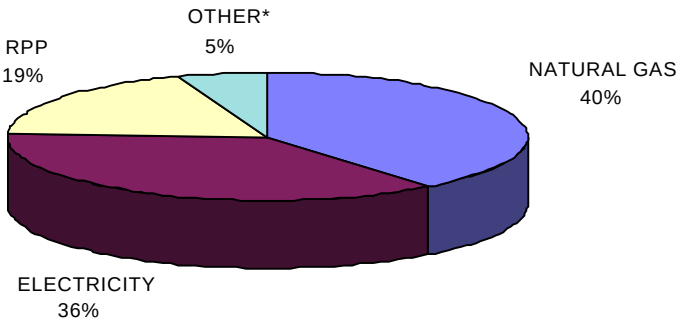

Figure 10: Percentage Distribution of Commercial Energy Demand by Energy Type in 1995 (Statistics Canada)

*Other includes steam, liquid petroleum gases and natural gas liquids.

The estimates of food energy consumed in the commercial sector (Table 28) are small when compared to the estimates of energy consumed in residential food preparation (Table 27). However, this does not mean that eating out saves energy. It indicates only that more food is prepared in the home than restaurants and hotels.

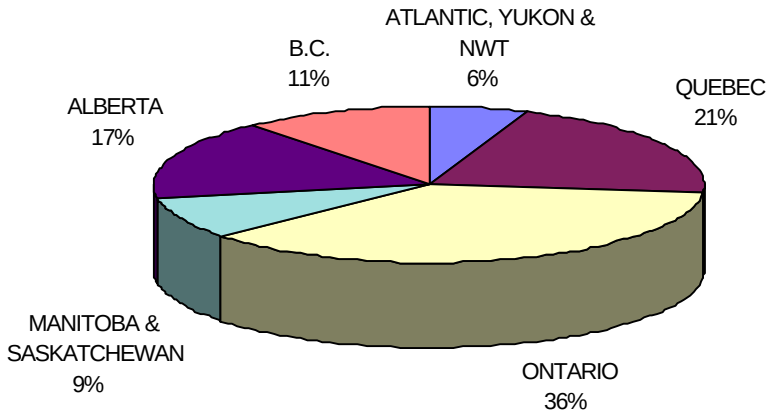

Figure 11: Percentage Distribution of Commercial Energy Demand by Region of Canada in 1995 (Statistics Canada)

Table 28: Estimated Quantities of Energy Consumed in Restaurants and Hotels Food Preparation in Canada (PJ)

	1990	1991	1992	1993	1994	1995	1996
Energy	90.1	90.7	92.0	97.3	95.8	101.0	102.0

10. 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 13, Table 19, Table 20, Table 22 and Table 23. Thus, total energy consumed at the farm level represents about 5% of total Canadian energy used (Table 29). Table 30 indicates that about 20% of total annual farm expenses are spent on energy.

Table 29: Total Energy Used at the Farm Level in Canada (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 30: 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 24, the majority of foods processing industries are in Ontario and Quebec. Table 31 indicates the total quantities and values of energy used in the food and beverage industry from 1990 to 1996.

Table 31: 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 32: Quantity of Energy Used in Home, Restaurant, and Hotel Food Preparation in Canada (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 29, 31 and 32 (Table 33). The percentage of energy used including farm machinery and buildings is set out in Table 34.

Table 33: 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
Energy	10.2	10.0	10.4	10.0	9.8	9.8	9.9

Table 34: 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
Energy	11.9	11.7	12	11.5	11.3	11.3	11.3

Table 34 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 35.

Table 35: 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. It is the sum of the GDP portion from the agricultural, food, beverage, agricultural chemical and tobacco products industries from Table 3.1.

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 36) by the energy to GDP ratio in Table 35. 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 36. In Table 36, it was assumed that the energy consumed per dollar of exports is equivalent to the energy consumed per dollar of imports.

Table 36: 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 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 37.

Table 37: Total Energy Used by Canadians on Nutrition (Excluding the Energy in Farm Machinery and Buildings)

	1990	1991	1992	1993	1994	1995	1996
TECN	586x 10^9	576x 10^9	583x 10^9	595x 10^9	607x 10^9	600x 10^9	611x 10^9
Per Capita Annual TECN	21.1x 10^3	20.5x 10^3	20.5x 10^3	20.6x 10^3	20.8x 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 37 indicates that, on average, every Canadian uses over 56 MJ of energy on nutrition per day (or 13,400 Kcal. per day). This amount of energy consumption is small compared to the total per capita energy demand (Table 6). 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 38 include the energy sequestered in farm machinery and buildings.

Table 38: Total Energy Used by Canadians on Nutrition Including Farm Machinery and Buildings

	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).

11. 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 8). The 1996 Census of Agriculture data show that the average farm size in these three provinces was larger than in other provinces (Table 9). 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. 6). 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 25). Natural gas and electricity were the main sources of energy in the food and beverage processing industry (Table 26).

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. Table 3 indicated that these two provinces were the most populated provinces. 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 36).

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.

12. Appendix 1

Conversion Factors

Acre = 0.404686 ha

m^3 = cubic meter = 1000 litres = 220 gallons

BTU = British Thermal Unit = 1054.615 Joules

Calorie = 4.1868 Joules

KJ = Kilojoule = 103 Joules = 0.948213 BTU ‘s

MJ = Megajoule = 10^6 Joules

GJ = Gigajoule = 10^9Joules

TJ = Terajoule = 10^{12}Joules

PJ = Petajoule = 10^{15}Joules

1 Ton Oil Equivalent (MTOE) = 41.9 TJ

1 Ton Coal Equivalent (TCE) = 29.3 TJ

1 TJ = 28 852.7 Litres of Motor Gasoline

To convert metric units to TJ,		multiply by
Anthracite	Kilotonnes	27.7
Imported Bituminous	Kilotonnes	29.0
Canadian Bituminous	Kilotonnes	30.3
Sub - Bituminous	Kilotonnes	18.3
Lignite	Kilotonnes	15.0
Coke	Kilotonnes	28.8
Coke Oven Gas	Kilotonnes	18.6

To convert metric units to TJ,		multiply by:
Natural Gas		
(150c & 101.325 KPA)	$106m^3$	38.55
Natural Gas Liquids (NGL)		
Ethane	$103m^3$	18.36
Propane	$103m^3$	25.53
Butane	$103m^3$	28.62
Crude		
Crude Oil	$103m^3$	38.76
Light and Medium	$103m^3$	38.51
Heavy	$103m^3$	40.90
Pentanes Plus	$103m^3$	35.17
Refined Petroleum Products		
Motor Gasoline	$103m^3$	34.66
Kerosene	$103m^3$	37.68
Diesel	$103m^3$	38.68
Light Fuel Oil	$103m^3$	38.68
Lubes & Greases	$103m^3$	39.16
Heavy Fuel	$103m^3$	41.73
Still Gas	$103m^3$	41.73
Electricity	GW.h	3.6

A complete Table of conversion factors can be found in Statistics Canada, Energy Statistics Handbook.

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