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TOWARDS AN ENERGY BALANCE SHEET FOR THE NOVA SCOTIAN AGRICULTURAL FOOD SYSTEM

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Measures are made of the Nova Scotian energy exchanges as the broad dilute field of incident light becomes concentrated into mature plant and animal food crops. The net distribution of the on-farm energy inputs (excluding solar energy) are: 60% fertilizer (which is 60% lime, 40% NPK); 30% fuel and machinery; 10% remainder. There are also post-farm inputs of factory processing, transport, wholesale and retail handling, and home preparation. The on-farm part of the total energy cost varies from less than 10% (for processed potatoes) to 40% (for apple juice). The total annual energy costs to supply human food and animal fodder from the region are of the order of 2000 kcal x 10^9. The most efficient products are grains, which have a food value of 900% of input energy; the least efficient are poultry, whose food value is only 10% of the energy required to produce it.

Introduction

For agricultural prospects as for so many of our other activities, energy costs have become a substantial concern. Before the oil price rises which began in the early 1970's, the direct ends, or derivatives of agricultural investigations had such concerns as the following:

1. Biological and technological. Which plants and animals can be most suitably and efficiently grown in our region and what new varieties can be introduced?

2. Economic. What is the financial future of the farmer and the processing and handling industries in the face of changing monetary prospects?

3. Sociological. Is increased farming to be encouraged as compared with other natural-resource industries? How many workers are to be placed on the land?

4. Political policy. Decisions on the use of land, whether for agriculture, forests, roads, urban intrusions. Policy towards home-grown versus imported products.

During the last decade a new consideration has arisen which deals with energy receipts and expenditures and how their balance can be improved, or how they are likely to be altered outside our area in ways which might benefit Nova Scotian agriculture. The transport of Californian fresh products to our market offers an example. As fuel costs increase, the balance may shift in favor of locally produced food. The energy costs associated with food production, distribution and processing should be understood in order to determine where energy conservation measures are likely to have maximum impact; where measures intended to enhance or regulate agriculture may have high energy costs; and how energy consideration may influence decisions and prosperity of individual farmers and processors.

What we are attempting here is to develop a Nova Scotian energy balance sheet for the agricultural sector. It is hoped that this may be used to examine changes and offer recommendations about the future course of our agriculture. The point of view of the present analysis is that of Odum (1971) who is concerned with the applications of power, which in turn is defined and measured as the rate of flow of useful energy. In agriculture the essential aim is to bring about a change from a broad dilute field of incoming light into the concentrated energy of food which is needed by man; the approach we use to examine the process is by measurement of the energy exchanges as the crops mature. The flow is measured in time units; in this paper the selected energy units are G or gigaCalories or billions of kilocalories, as used in the Nova Scotian agricultural system annually.

Table I. Variation in energy distribution to bring a fixed quantity (say, 1 kg) of food to use. To facilitate comparisons, the on-farm costs have been called 100. Actual on-farm costs in kcal kg^{-1} are 752 for potatoes and 516 for apples. (Whittlesay & Lee, cited from Agriculture Canada 1977.)

	Potatoes			Apples			
	Fresh	Frozen	Dehydrated	Fresh	Dried	Juice	Sauce
On-farm production	100	100	100	100	100	100	100
Processing	–	591	836	–	97	32	159
Transportation	241	154	44	219	33	77	168
Wholesale and retail trade	10	140	19	17	6	11	28
Home storage	–	51	–	53	–	37	–
Home preparation	390	128	112	–	–	–	–
Relative totals	741	1164	1111	389	236	257	455
Absolute totals (kcal kg^{-1})	5560	8730	8335	2015	1225	1330	2360

Limitations on the energy flow approach are acknowledged. The estimates of energy transfer and dissipation are, at this stage, rough approximations. Consideration of calories alone is not relevant to certain issues, such as nutritional quality of food. There is also the perplexing matter of money-energy relationships. Money has been described as a feedback loop which joins some parts of the system, in which it moves in the opposite direction to energy; we obtain food by dispensing money and receive money in return for dispensing our energy as work. Thus money provides a means for organizing the directions of energy movements. Money circulates, whereas the flow of energy is undirectional since energy is continually running down until the sun rebuilds it again into plant life.

As an example of the energy-money relationship we may consider the production of a kilogram of potatoes which when eaten furnishes the body with some 900 kcal, a value that has no corresponding monetary unit. To produce the crop the main source of energy is the sun of which the small fraction (less than 0.1%) which is utilized is also unrelated to money. To augment the sun the farmer adds fuel, pesticides, fertilizers, etc. which cost 750 kcal, a group of costs which could, if desired, be converted to the fluctuating dollars of the moment. Between harvesting and eating, the potatoes require processing, packaging, shipping, marketing, and cooking which cost on the average an additional 700 kcal. For the whole sequence then, it is clear that while a balance sheet can be drawn up in terms of energy, and that some items have a current exchange value into money, it is not feasible to make the whole equation realistic in terms of dollars.

The difficulties of comparing different kinds of energy inputs (solar energy, fossil fuels, animal power) cannot be completely overcome by conversion to common calorific values. Energy consumption at each of the producer, processing, and distribution stages has its own distinctive economic characteristics which influence its potential for altering energy. The energy complexities associated with product type are also significant. Table I illustrates the variation in both total energy cost and its distribution for different potato and apple products.

Despite these various limitations to the energy balance approach, we feel it offers potential to stimulate a renewed interest in traditional forms of Nova Scotian agriculture as well as a more critical review of various provincial and federal agricultural support programs. To such, an energy overview provides an organizing focus for many of the ecological studies which should be undertaken if we are to improve, in any major fashion, our agricultural production. Certain suggestions will be made for changed use of the Nova Scotian energy now being consumed in the food system. Above all, however, it is intended to stimulate further research. The unevenness of the information presented is indicative of the need.

Energy Inputs and Outputs

Average input costs which are necessary to produce, process, and distribute Nova Scotia farm products have been derived from several references (Agriculture Canada 1976; Downing 1975; Henig & Schoen 1975; Hirst 1974; Jensen & Stephanson 1975; Lovering & McIsaac 1976; Ontario Institute for Agrologists 1975; Pimentel et al. 1973; Timbers 1977). In the home and in commercial outlets the storage and cooking of food uses about one-third of the energy required by the system. Transporting and selling the products account together for one-quarter, and processing for another one-quarter of the cost. Only 20% of the energy is used to produce the crop on the farm. Over much of Canada the dominant on-farm input is fuel for machinery, but Nova Scotia, like Prince Edward Island and parts of Ontario, uses a much higher proportion (60%) for fertilizer (Downing & Feldman 1974; Tables III, IV).

Individual products show wide variability from the foregoing averages; for example, animal products may require very high on-farm inputs (Table V). The processes preparatory to consumption also vary widely, as the examples in Table I show. With fresh potatoes the dominant costs lie in home preparation and transport, while the handling of "fast food" preparations adds large processing costs which bring up the total energy to more than 10 times the on-farm input. For fresh apples, more than half the energy goes for transportation; for the dried product on-farm and processing make up over four-fifths of the costs; for juice the chief inputs are on-farm and transport; while processing and delivery make apple sauce the most costly energy user of the family of apple products.

Figure 1 represents energy flow in the Nova Scotia food system. It is adapted from Downing's (1975) picture of the energy flow in the Canadian food system. Downing's divisions and percentage breakdowns were used for the most part. For example, in the original energy breakdown (first left vertical set) Downing suggests that 20% goes into fodder, and 60% into feed, food, and fiber. Downing's proportions were retained throughout Figure 1 with a few exceptions where Nova Scotia was thought to differ from the Canadian average. Nova Scotia Agricultural Statistics (1975) show that exports are lower and imports higher than the national average. They show that at least 50% of animal feed is imported, and for human food we have placed imports at 60% (470/790 at extreme right of Fig 1). In Figure 1, a few totals and some key intermediate numbers have been entered to help provide the thread of the energy chain from fertilizer to food. The numbers are derived from the input in which we had most confidence, namely fertilizer. Details of the energy calculation for fertilizer are shown in Table II in which column 1 and column 2 come from Tables 70 and 71 of Nova Scotia Agricultural Statistics (1975); column 3, which in-

Table II. Annual use of fertilizer on Nova Scotia farms.

	Annual N.S. use (5-yr avg. tonnes x 10^3)	Nutrients (% of wt)	Energy (kcal/kg)	Annual N.S. cost (kcal x 10^9)
	1	2	3	4
Nitrogen as ammonium nitrate. Energy as kcal/kg N	3.94	43	21,650	37
Phosphate as triple super phosphate. Energy as kcal/kg P_2O_5	4.82	43	4,842	10
Potassium as muriate of potash. Energy as kcal/kg K_2O	4.85	43	3,519	7
Lime. Manufacturing and transport costs as kcal/kg	54.81	-	1,512	83
TOTAL				137

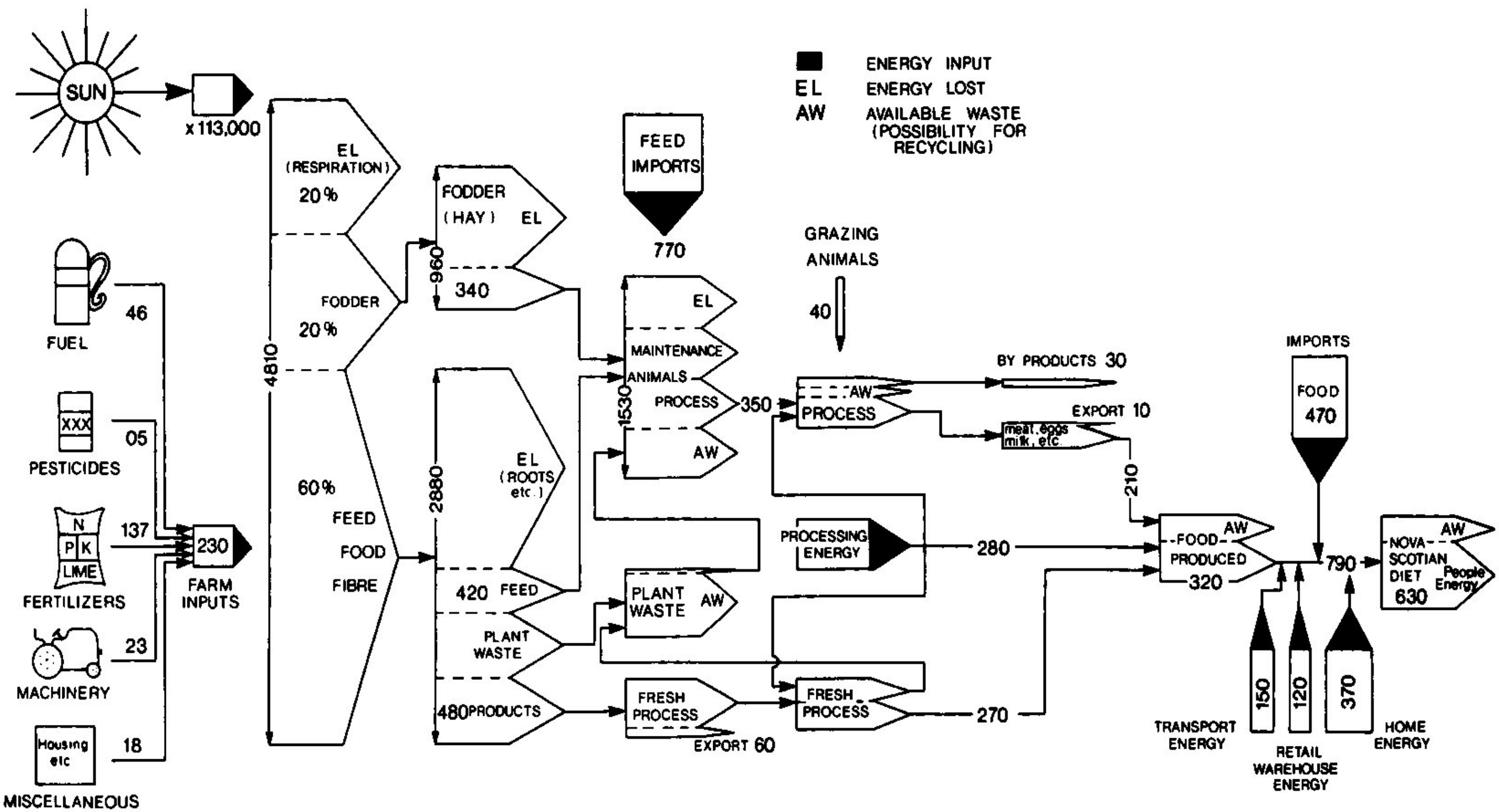

Fig 1. Energy flows in the Nova Scotian food system per annum. Width of arrow base indicates relative amounts of energy. Numbers are kcal x 10^9.

cludes production energy cost of the fertilizers, including fuel, transport, etc., came from Southwell and Rothwell (1976) and Leach (1975, cited from Jensen 1977). Column 4 calculates the total kcal value for fertilizer of 137, which was entered as the initial number on the large chart, Figure 1.

In the absence of direct Nova Scotian values, the remaining inputs shown in Figure 1, for fuel (46), pesticides (5), machinery (23), and miscellaneous (18) were adopted after comparing numbers in the literature. Some of the numbers, as percentages, are given in Tables III and IV, and those accepted for Nova Scotia are in Table III, column 9.

The total farm energy input of 229 x 10^9 kcal is in close agreement with the corresponding number of 248, adjusted by us for Nova Scotia from the Prince Edward Island estimate of Lovering and McIsaac (1976) which was based on Prince Edward Island acreages.

As the tables show, there is across Canada a good deal of variability in the reported distribution of inputs, which differ according to regions, soil conditions, moisture, type of crop, and treatment during growth and after harvest. Any single high input will distort the percentage tables. For instance, in Prince Edward Island the curing of tobacco is reported to use half the total input energy; also their seed for potatoes is unusually costly. In Table III some Prince Edward Island crops are compared to show how their percentage distributions are affected by the energy totals required. However, they average out quite similarly (Table III, columns 7 & 8) whether direct means are used or those weighted for total demand.

In Nova Scotia as Table II (column 4) shows, the exceptional cost is for lime whose annual use is increasing with the subsidy program (vide infra). To show how lime contributes to making up the Nova Scotian list, compare Table III (column 9; the actual adopted figures) with Table IV (column 1), which gives figures as they would have been if Nova Scotian soil had not required lime; even omitting lime, fertilizer is still high. Several authors have suggested that, as our tables indicate, fertilizer accounts for a high proportion of on-farm input in agricultural systems similar to Nova Scotia (e.g. Prince Edward Island, parts of Ontario): (Downing 1975; Hirst 1974; Ontario Institute for Agrologists 1975, cited from Agriculture Canada 1976; Steinhart & Steinhart 1974; Whittlesay & Lee 1976). In the western provinces on the other hand, and for Canada as a whole which is strongly affected by the prairies, the dominant energy input is for fuel (Timbers 1977).

To sum up: after a careful, even though not statistically quantifiable, study of the records, we have adopted for Nova Scotia the relative values shown in Table III (column 9) which, when put into absolute numbers, are the quoted farm inputs listed on Figure 1.

The next step was to establish a number which would place on-farm inputs as a percentage of the total food system costs. Literature estimates vary from 15 to 24 and were rounded to 20% for this study (references cited above). Similarly, other components of the food system had probable input percentages which have been entered on Figure 1.

The annual energy input applicable to Nova Scotia production, as shown on Figure 1 is about 1600 x 10^9 kcal or, in the more usual weight-watcher's terminology, 1600 billion Calories. The total is derived by adding up the black arrow numbers on the large diagram (excluding sun energy) but using for the final 3 (transport, warehouse and home energies) only 40%, which is the part applicable to Nova Scotia products. If full market and home costs are included, the total input becomes about 2000, and with imported food, it goes up to 2400 billion Calories.

Table III. Prince Edward Island percentage farm energy costs for several crops, based on acreages, showing direct averages and averages adjusted for total inputs (Lovering & McIsaac 1976[1]). The accepted Nova Scotian inputs are also shown, although they were derived from comparisons with Table V as well as with Prince Edward Island.

	1 Potatoes	2 Other vegetables	3 Silage corn	4 Cereals	5 Hay	6 Pasture	7 Mean	8 Mean weighted for total energy inputs	9 Nova Scotian values as used
Relative total energy inputs, Potatoes as 100	100	78	50	32	11	7			
Fertilizer	48	74	61	55	53	92	64	60	60
Fuel	25	18	29	25	40	8	24	24	20
Machinery	4	2	4	4	6	-	3	3	10
Pesticides	7	5	4	2	-	-	3	5	2
Other, e.g. drying grain, curing tobacco, etc.	16	1	2	14	1	-	6	8	8
TOTALS	100	100	100	100	100	100	100	100	100

[1]The absolute values in this paper are too high by a factor of 10. Comparisons of percentages are acceptable.

The whole growth system is set in motion by the sun, whose input is several orders of magnitude greater than that provided by farmers (Table VIII). The sun's energy, being a given constant, has not been subject to further analysis here.

Comparison may be made between the initial farm energy cost of 230 and the useful harvest. (It is unnecessary to consider human and animal labour which are quite inconsiderable parts of the energy system). The plant harvest for human use is valued at 480 x 10^9 kcal to which the animal feed and fodder adds 420 + 340. The total of 1240 is 540% of the on-farm input, a strong energy profit.

At this first stage the primary on-the-land investment has been parlayed into a more than 5-fold energy gain. From here on it is downhill all the way as further in-

Table IV. Hypothetical Nova Scotian energy inputs as they would compare with other regions where less lime or no lime is used as fertilizer (cf. Table III, col. 9).

	1	2	3	4	5
	What the accepted Nova Scotian inputs would become if lime were omitted	Ontario (Downing 1975)	Ontario (Ont. Inst. Agrologists, cited from Agriculture Canada 1976)	Saskatchewan (Downing 1975)	All Canada (Timbers 1977)
Fertilizer	35	31	57	4	15
Fuel	33	44		71	68
Machinery	16	8		8	5
(Fuel plus machinery)	(49)	(52)	33	(79)	(73)
Pesticides	3	?	2	?	1
Other	13	17	8	17	11
TOTAL	100	100	100	100	100

vestments are made to get the food into more valuable forms, get it to market, and get it into use by consumers. The 1240 x 10^9 kcal at this initial stage are in the form of fodder, feed or plant products to be further refined. The larger portion, 60% of the initial energy available, is cycled into animal food. The remaining 480 x 10^9 kcal (40%) is further processed into feed energy which is still available for consumption. At this point, plant food for humans is ready for processing, with a final efficiency of 56%. Animal feed requires further inputs and there are also maintenance costs before processing, with consequent reductions in farm efficiency.

The upper half of Figure 1 as well as Table XI, deals with the energy relations for beef, hogs, poultry, eggs, dairy products, and their sustaining feed plants. The calorific values of fodder and feed are derived from standard measurements of animal calorimetry, where maintenance is a balance between assimilated inputs and absolute loss as CO_2, plus available waste as manure and urine.

Processing energy (280 x 10^9 kcal) acts on food which comes from the farm, while the post-farm outputs include industrial power and machinery (60% on the average), together with such commercial items as steel and aluminum cans (24%), glass containers (9%), and paper packaging (7%) (Steinhart & Steinhart 1974).

It is assumed that the food produced as plant and animal products (270 + 210) should have the processing and handling costs prorated to 180 plant output and 140 as animal food (see chart of derivative outputs, Table V). Processing costs will be respectively 160 and 120 for the total of 280 on the chart. Finally, there are large energy inputs required to get the food transported and handled and onto the Nova Scotian table. As mentioned previously, 40% of these final inputs or 256 kcal (plants 140, animals 110) are used up by Nova Scotia-produced food. The foregoing chain of energy events is summed up in a later section.

Direct Measurements

In the previous section, the averages of Canadian farm energy inputs have been taken as a base, and modified to make them applicable to Nova Scotian conditions. The numbers were then recalculated to correspond to the area under cultivation in Nova Scotia with results as illustrated in Figure 1. We turn now for comparison to an independent source of information, namely the annual presentation of data for individual crops as published by the Provincial Government (Nova Scotia Agricultural Statistics 1975). Production is listed in English units which have been converted to metric weights and calorific energy values. Detailed results are given in Tables X and XI of the appendix (with assumed or interpolated numbers in brackets). The derivation of input energies makes use of information from Heichel (1976), Jensen and Stephanson (1975), Southwell and Rothwell (1976), and Whittlesay and Lee (1976). The nutritional values given by these authors were supplemented by the Geigy tables (1956), for human food (Table XII). All sources were compared to secure an accepted value, although there are still many information gaps. Table V is a summary of the direct observations.

Of the 3 columns of figures in Table V, the left one gives the annual energy production cost for the Nova Scotian farming area in kcal x 10^9. The centre column gives the food or fodder value of the product in the same units. In the right column, the food value is expressed as a percentage of the energy input. From the percentage column, it is evident that great variability exists among farm crops. Those with the highest yields are wheat for humans, and pasture, hay, silage, and grains for animals. These have output values reaching 750% of the energy-inputs, which is almost 6-fold that for vegetables and fruit, whose average comes to only 135%.

The second section of Table V deals with post-farm energy costs for food plants.

Table V. Summary of direct observations on food destined for human consumption. Numbers are Nova Scotia annual totals taken from Tables X and XI of the Appendix, where their detailed derivations are given. Outputs are calorific food values from standard sources, for which a list is assembled in Appendix Table XII. Numbers are rounded and not necessarily in complete agreement in different places.

HUMAN FOOD PLANTS	kcal x 10^9		Food energy as % of input energy
	Input cost	Output	
1. FROM THE FARM			
Wheat	2.1	15.1	720
Potatoes	20.3	23.0	112
Carrots	5.5	4.9	90
Other vegetables	4.0	2.5	65
Apples	21.6	24.1	110
Blueberries	1.4	2.8	200
Other fruit	0.6	1.0	150
Total	55.5	73.4	132
2. POST-FARM. Processing, Commercial handling, and home preparation			
Wheat: proc. 2.0; com. hand. 0.7; home 3.5.	6.2	15.1	245
Potatoes: proc. 72.5; com. hand. 43.7; home 54.4.	170.6	23.0	14
Other vegetables: proc. nil; com. hand. 23.8; home 37.1.	60.9	7.4	12
Fruit (82% Apples): proc. 8.2; com. hand. 33.9; home 11.7.	53.8	27.9	52
Total processing & handling	291.5	73.4	25
Total plants	347.0	73.4	20

ANIMAL FOOD

3. ON-THE-FARM FODDER

Pasture, hay, silage	154	1214	790
Grains	16	122	760
Imported feed	766		
Total	936		

4. PROCESSING AND HANDLING OF HUMAN FOOD FROM ANIMALS

Numbers refer to edible portions after processing losses.

Beef	179	23	13
Hogs	119	30	25
Poultry (including 5 to 10% for eggs)	232	20	9
Dairy products	244	100	41
Total	774	173	22
Total animal feed	1710	173	10
Grand total: Human food, plant plus animal	2059	246	12

The input cost has been subdivided into the parts for: (a) commercial or factory processing; (b) transportation plus wholesale and retail handling; and (c) home costs of refrigeration, preparation, cooking, and loss at the table. The superior efficiency of wheat is even more striking here than on the farm. The post-farm yield of wheat per input energy unit is from 5 to 20 times that of other plant food products. The major Nova Scotian plant crops are potatoes and apples. Apples are the only fruit crop for which valid in-and-out costs are available. (Heichel 1976). Blueberries, most of which are exported, make up less than 4% of the edible plants.

Section 3 of Table V deals with combined pasture, hay and silage, plus grains, all of which are among the highest level producers. Pasture is difficult to compare because of its seasonal and qualitative variability. The positive output ratio of on-farm plants is largely cancelled out by imported feed which we have placed as an energy debit.

As to processing-handling (Section 4, centre column) dairy products have maximal food value (100) and efficiency (41%), while poultry is the lowest (20 and 9%). The latter numbers are attributed to the low calorific values of young birds (see food values in Table XI, column 4). On an evicerated dressed-weight basis 90% of our poultry produce is chicken and fowl, of which 90% is chicken (Nova Scotia Agricultural Statistics 1978). Much of the chicken is further processed for the fast food trade.

In Table V and in the Appendix Tables, no allowances have been made for product losses which may occur during post-farm processing-handling and household operations. For fresh meats, fruits, and vegetables, losses may be considerable, while for packaged commodities rejections are probably negligible. According to Copping (1976), the wastage factor for household food may include cooking, domestic loss of nutrient, inedible bones, outside skins and leaves of fruits and vegetables, and plate waste. Obviously, societies will differ in their food rejections; in Britain annual lists have been compiled of food categories, each with its special nutrient conversion factor. British wastage in the household is taken at an inclusive figure of 10%, we omit Nova Scotian factoring as premature.

In addition to the crops listed in Table V, the published statistics show several minor fruits and vegetables, honey, greenhouse operations, etc. There are also non-food items including wool, tobacco, and pelts. Forest products such as Christmas trees and maple products may also be included. None of the foregoing impinges importantly on energy considerations.

Direct and Indirect Production Estimates Compared

In this section, the values derived above from the energy flow chart, (Fig 1) are compared with those which come from direct Nova Scotia Agricultural Statistics (1975). As a first step, both sets of values (Table VI) have been related to their final output calculations as human food. We begin with the bottom line which is an approximation of expected human consumption. Assume that each of the 800,000 Nova Scotians consumes 3000 kcal for 365 days. This gives an annual food use of 880 x 10^9 kcal. Provincial agricultural production as 40% of food eaten, comes to 350 x 10^9 kcal (bottom line of Table V, a figure which is not far from the 320 calculated from Figure 1 for food sent to market) or 248 (food supply as added up from Nova Scotian statistics on individual products; see total outputs on Table VI).

The second row from the bottom of Table VI refers to the extreme right of Figure 1 in which it is noted that 20% of the food prepared for the table is discarded so that only 252 of the 320 x 10^9 kcal produced in Nova Scotia are finally eaten. As calculated in a previous section dealing with Figure 1, final plant product energy output at 180 is higher than final animal product energy output at 140. The direct Nova Scotian statistics show animal food output to be greater (74 and 174 respectively; see Table V). The low value of 74 for plants is probably correct and may reflect the negligible cultivation of wheat for bread in Nova Scotia. Our major grain crop other than hay, is oats for animal consumption. Figure 1, which shows plant production dominant, probably reflects the western Canadian average where grains dominate. (Downing 1975).

According to Table VI, input costs on the farm are quite small for plant products (90 and 56 by the 2 methods) being some 4 times exceeded by processing and handling costs (ca. 300) on the route to the human digestive system. The more important place to seek energy-saving economies would evidently be in post-farm operations.

Animal products have the opposite relationship, with on-farm costs being greater than those for processing and handling. As derived from Figure 1, the ratio is 7 while

Table VI. Relation between food consumed by Nova Scotians and agricultural production. Numbers in the left section are from Figure 1 with on-farm values adjusted to omit exports. Numbers in the right section are from Nova Scotia Agricultural Statistics (1975), average of 1971-1975.

	CHART DERIVATIVES			DIRECT PRODUCT OBSERVATIONS		
	kcal x 10^9			kcal x 10^9		
	Input cost	Output	Output as % of cost	Input cost	Output	Output as % of cost
PLANT PRODUCTS						
1. From the farm	90	180	200	56	74	132
2. Processing, handling and home	300	180	60	294	74	25
Total	390	180	46	350	74	20
ANIMAL PRODUCTS						
1. From the farm	1710	140	9	935	174	19
2. Processing, handling and home	230	140	61	775	174	22
Total	1940	140	7	1710	174	10
Total plant plus animal	2330	320	14	2060	248	12
Kitchen to body, 790 & 630 of which 40% raised in Nova Scotia (Fig 1)	316	252	80			
Rough guess of Nova Scotian consumption is 900 of which 40% is locally produced		350				

the difference as seen from direct observations is only 1.2, a discrepancy not explicable now. Input costs for animal feed are especially high in Nova Scotia because of feed imports of grain, which count as outputs on the prairies but as imports here.

The processing and handling costs, whether for plant or animal products, are greater than the energy value of the food delivered to the consumer. Expressed as a percentage, the food value is only some 60% of the post-farm cost (chart derivatives) or 20 to 25% (direct observations). Stated otherwise, the processing-handling costs use up perhaps 2 to 5 times as much energy as the food they deliver.

For the individual product observations on the right half of Table VI, we did not have a breakdown into factory, selling, and home costs, but calculated them from figures of Whittlesay and Lee (1976). The calculations on the direct or recorded Nova Scotian data may be found in Appendix A.

The 2 right-hand columns in Table VI express the energy output from the plants and animals as percentages of inputs. Plant products on the farm have maximum yields of 200% of input from Figure 1, a value which is elevated by grain (see the first lines of Table V comparing wheat with other plants). Direct Nova Scotia values on the right side of Table VI show 132% gain, because wheat is not very important. As to animal food, we get, by the 2 methods, 9 and 19% of the energy that the farm puts in. Farm energy, then, is between 7 and 22 times as effective for plant production as for human food of animal origin.

For the combined operations of on-farm and processing-handling we can expect to get back 20 to 45% of the plant costs as food, while animal food represents only 7 or 10% of its costs.

Discussion

Canada as a whole uses 10% of its total energy for the food system, a number which is derived from Downing's tables (Agriculture Canada 1977). Downing gives on-farm totals, to which he states there should be added almost 3.5 times as much energy which is utilized to process and handle the crops. In the United States, the food system uses 16.5% of the total national energy output (Agriculture Canada 1977, Table 6).

For Nova Scotia, the total energy consumption (average for 1978 & 1979) is about 65,000 kcal x 10^9 (Nova Scotia Energy Update 1979). The agricultural input costs (bottom lines of our Table VI) average a little over 2000 kcal x 10^9 which gives 3.4% of the provincial total; about the same as the contribution of hydro power to the Province. Nova Scotia's low percentage figure reflects the smaller place of agriculture here, compared with the central growing areas of the continent. In Nova Scotia, depending on the crop, from 10% to 40% of the energy of the system is used on the farm, and the rest goes into processing and handling. Of the initial farm inputs the largest is for lime followed by fuel and machinery, NPK fertilizers, etc. In addition to the foregoing and more than 3 times as great are the imported feed grains. Taken together, the Nova Scotia on-farm costs from outside come to some 10^{12} kcal, a sum which is nearly doubled when we include the feed and fodder grown on the farm for the animals. The food value from human edible carbohydrate may be twice the farm input cost, while for the available protein-fat complex from animal stock the output is only about one-fifth to one-tenth of the cost.

Processing and Handling

Processing costs for plant products (examples in Table I), are usually several times as great as the initial farm inputs. Major processing contributions include industrial power and machinery as well as metal, glass, and paper containers. On the animal side, the dominant energy costs associated with processing are for dairy products and poultry and the slaughtering of meat. Plant and animal products are about equally demanding for refrigeration and storage, followed by the familiar retail activities, then by home storage and preparation. For products grown in Nova Scotia, the approximate annual processing and handling costs for plants total 300 and for animals 350 x 10^9 kcal. The energy importance of post-farm operations can be further underscored by consideration of a so-called agriculture-related component not developed in the present study. Conspicuous components in Nova Scotia would include alcoholic and soft drink bottlers, bakers, and confectioners. Elsewhere in Canada the list would include as well, rubber products, sugar refiners, flour and breakfast cereal producers, and shoe and leather workers. We do not have figures with which to construct a quantitative breakdown of the Nova Scotian component of processing and handling which would correspond to the on-farm portion of the story as illustrated in Figure 1. The development of individual industry costs for dealing with food and related products together with recommendations for energy economies must be considered a matter of high priority.

Tables VI and X show the post-farm division of plant energy inputs into processing, commercial handling including transportation, and home preparation (Agriculture Canada 1977, Tables 32 et seq.). We lack the information necessary for a similar treatment for human foods of animal origin. As so much of the energy associated with food systems is tied to post-farm operations, it is tempting to focus studies and energy conservation programs off the farm. In fact, we concentrate the remaining discussions towards on-farm topics for 3 reasons. First, there is a definite need to consider how vulnerable individual farmers are to energy imperatives. Secondly, it is of interest to consider not only present-day patterns, but also future stages of development when processing, etc. may be much more efficient while primary producers are called upon for dramatically increased yields. Thirdly, the problems of farm-level energy conservation appear to be more complex to deal with as they involve ecological, social and political complexity, in addition to the shared problem of economic feasibility.

Savings on Farm Inputs

Energy improvements in farm machinery are likely to follow patterns developed in the United States. An example is the conversion to diesel-powered farm tractors which now make up more than 85% of new purchases there. Diesel machines use 27% less fuel than those powered by gasoline to do the same amount of work and their fuel is generally less costly. Diesel tractors, however, cost 11% more to buy than those powered by gasoline. Here we have an increased initial cost to be compensated by later monetary as well as energy savings. Other farm machinery shows corresponding fuel relationships. Additionally, a more critical use of farm machinery with energy savings in mind can effect some 15 to 20% reduction (Friedrich 1978). For conversion of the above to Nova Scotian savings, a look at the left end of Figure 1 shows that the change to diesel fuel would save some 125×10^9 kcal annually and other savings in machinery would add another 40×10^9 kcal. These are not inconsiderable quantities and they make a good case for financial incentives, demonstrations, and educational programs.

Over the manufacturing costs of fertilizer the farmer has, of course, no control; his only place to look for economies there lies in diminished use. Taylor (1976) offers a table of energy-saving tips, beginning with an annual soil analysis. We may first mention lime which makes up 60% of our calorie costs (Table II). Since the Province is helping to finance an increasing use of lime, it is doubtful whether significant savings in its use are yet to be achieved. Incidentally, the costs of lime production are expended in Nova Scotia which is a socio-economic consideration. The other 40% of fertilizer energy, mainly nitrogen, has more complicated and shorter term relations than lime. Here research and development are needed to establish the best dates of application as compared to dates of planting and to rates of growth and applicable to various major crops. Taylor also observes that the application of starter fertilizer through the planter or drill is more efficient than broadcasting. Another observation (Friedrich 1978) is that the effectiveness of fertilizer declines with increase in the quantities used, which means that there is an optimal economic rate for the farmer which depends on a comparison of crop production with dollar costs. The savings outlined might together be expected to reduce use of NPK by 25% which would amount in Nova Scotia to 13.5×10^9 kcal.

In recent years, strong objections have been raised about the undesirable side effects which accompany the use of pesticides to control crop losses. An evaluation of the debate would be outside the scope of this paper. In any case, local use amounts to only 2% of farm inputs (Table III) out of which any proposed energy savings would be minor and would be greeted with scepticism by many farmers. We might guess at a saving in the order of a mere 100 kcal.

The bottom line of Table III, 'Miscellaneous' or 'Other', takes in a variety of items including labor, the use of energy in the home, seeds for planting, the drying of cereal crops and tobacco, etc. Its total value is only 18 x 10^9 kcal and obvious potential savings are too small to warrant an estimate now.

To sum up: the savings above come to 179 x 10^9 kcal, of which more than 90% is in fuel and machinery. As a contribution towards solving the national energy problem, it is a rather small item, some might say scarcely worth the effort. However, as a contribution to farmers of the province, it may be essential or vital to their economic survival. Domestic farming has such a high social priority that the level of effort required to secure these savings is fully justifiable.

Any energy-saving changes in farming procedures will be complex compromises between competitive interests. One set of conflicts is national, advocating all-out production of what each region does best and an uninterrupted supply of food, both of which demand extravagant energy. By contrast, the maintenance of environmental fitness demands energy restraint. Then there are the provincial socio-economic objectives of variety and self-sufficiency and there is the demand of consumers for reasonable prices. Added to all these are the necessity of the farmer to receive a reasonable living and the limits of available federal and provincial resources to implement and supervise proposed programs. Clearly the obstacles to energy conservation are formidable.

Energy problems might be divided into macro (survival of the nation) or micro (physical or economic survival of each individual). The farmer, in his production of a continually consumed renewable resource, is a major factor in the national problem. As an individual, the increasing energy costs on his farm offer a threat to his personal economic survival. His continued or increased success is thus doubly important.

Non-food Products

There are some half-dozen such items listed (Nova Scotia Agricultural Statistics 1978), led by two luxury products. Energy values are not available so we mention farm receipts in dollars as percentages of the Nova Scotian totals for 1978, which are: greenhouse flowers, 5%; mink and fox pelts, 2%; all others together, less than 0.5%. Shorn wool is only 0.05%. We have not given any special treatment to these products either in processing or marketing energy allowances.

Size and Diversity of Production Units

From historical settlement patterns, Nova Scotia has inherited a small mixed-farming unit of production. There has been a noticeable trend toward farm consolidation and more capital-intensive production processes. Thus in a quarter-century since the war (1951-78) Nova Scotian farms declined by consolidation to 25% of their earlier number, and at the same time, the average size increased from 50 to 90 hectares while the improved land on the farms went up from 20 to 25% (Nova Scotia Agricultural Statistics 1978). Nonetheless, in Nova Scotia the family farm, part-time farming, and smaller, less capital-intensive units of production, still exert an important influence over Nova Scotia agriculture. Although the average size of our farms is about the same as in Ontario (Geno & Geno 1976), the number of hectares improved by active cultivation has, until recently, only been one-third the

Table VII. Relation of farm size to income (McMahon 1976).

	Up to $2500	$2500 to $5000	$5000 to $10,000	$10,000 and over ($25,000 median)
Number of farms	3400	747	621	1200
Average number of improved hectares	15	25	35	60
Dollars/improved hectare	100	150	200	400

Ontario level. Since about 1960, the amount of improved hectarage per farm has been rising in Nova Scotia and now approaches one-half the Ontario level.

Table VII is a breakdown of some 6000 Nova Scotia farms into improved hectarage and gross income. Data are from the 1970 census. The figure for dollars per hectare (bottom line of Table VII) is subject to considerable individual variation as well as inflation. Included under each farm income category are some producers who specialize in animal production, certain types of which (e.g. chickens, hogs) are grown on limited plots of land, often utilizing imported feed. Hence, the yield per hectare for such operations will be considerably greater than for a farmer who specializes in cash crop production. As well, the relatively low dollar yield per hectare in the $2500-or-less category of farm income is partially attributable to large numbers of part-time farmers, some of whom underutilize their land. Nonetheless, it is abundantly evident that larger farms yield more dollars per hectare than small ones. In the past, high income per hectare would have been the measure of success. Today, however, the enquiry is whether the gain in extra dollars per hectare is at the expense of importing petrochemical energy, and whether acceptable financial returns may not be achieved by practices which require less extravagant use of fuel. Any definitive presentation of aggregate energy flows or possible sources of energy savings should take into account the size, diversity, and scale of production units. The trend of contemporary farming is towards highly mechanized, capital-intensive operations, with a parallel reduction in human and animal labor, which have today become negligible energy costs on the farm. The replacement of labor with capital has reduced the number of farmers to such an extent that currently the outside workers who produce the agricultural inputs outnumber those on the farms by about 2 to 1. It is estimated that in the United States one man can take care of: 60,000-75,000 chickens; 5000 head of cattle; 50-60 milk cows (Friedrich 1978).

Land Use and Crop Choices

The whole system is set in motion by the sun's energy, which may be compared with other inputs. From the sun, 2.6×10^{15} kcal falls annually on the farms. Other inputs are given in Table VIII and show a range from 0.01 to 0.2% of the solar level. In general, photosynthetic efficiency will vary according to the region, the kind of crop selected, and the soil treatment. When considering Nova Scotia, we take the average climate and sunshine as constants, while the soil shows, of course, regional differences which are further adjusted for each desired crop by the primary and special additives, fertilizer, lime, pesticides, etc. The numbers set down in Figure 1, 4810, 230, 1240, etc., represent mean efficiencies; later studies will be required in order to characterize individual crops and regions of the province.

Table VIII. Other energy inputs compared to the sun.

	kcal X 10^9	Percent uptake of sun's energy
Farm inputs.	230	0.01
Total harvest, including respiration which represents the portion of the crop used up during the summer. Unused portions are also included.	4810	0.20
Ongoing or useful harvest, i.e. hay, feed, fruit, and vegetable products (340 + 420 + 480 at left of Fig 1).	1240	0.05

Wheat is much the most productive commodity to grow, with an on-farm efficiency almost 6-fold that for vegetables and fruit. In post-farm operations, wheat is more than 10-fold better than the rest. The difference is presumably because there is little cost associated with the use of baker's bread in the home (and the good old days when the "bread man" labored to deliver it to the home are remembered only by senior citizens). Grains, moreover (Table XII) are given a much higher nutritive rating than vegetables, wheat being about 4000, potatoes 750-900, cauliflower 300, and pumpkins 150 kcal kg^{-1}. We do not grow much of our own wheat, whose production is greatly exceeded by apples and potatoes. Our major grain crop is oats which are for animal feed. In early days when the settlers lived largely on locally grown oatmeal, the efficiency of food distribution would have been much higher.

There is a necessity to determine for specified areas, what kinds of land use will offer the greatest yields of useful energy. Of our unimproved or marginally developed land, some is potentially competitive as farms, perhaps to grow crops for industrial alcohol while some forest land may be competitive with pulp uses for the same purpose. Clearly the distinction between agriculture and forestry is becoming a thing of the past.

Photosynthetic efficiency is a factor in deciding which crops are to be tried or sustained, or whether agriculture can compete with the pulpwood industry. For world or national planners, photosynthesis might be decisive. Such thinkers would perhaps judge that the best crops to pursue in Nova Scotia would be blueberries or balsam fir trees. Some of our other crops like corn are at the northern limits of their range and do not compete with those of sunnier zones. However, the sun's efficiency declines in relative importance as provincial and local interests intrude on those of national planners. Socio-economic factors take over, such as keeping people at work on the land, feeding ourselves, supplying fodder for our stock rather than relying on imports, and generally maintaining agriculture as a going concern. Later studies will be needed to compare the scientific interpretation of efficiencies of individual crops with economic and political imperatives.

Table IX. Agricultural commodity balance sheet, expressed as percentages, Nova Scotia 1973. For absolute values see Tables X and XI of Appendix.

		Relative Nova Scotian production (total per section equals 100)	Percent of required commodity imported from outside Nova Scotia
	CROPS	Based on areas	
	Hay (60,000 hectares) Silage corn (5,000)	74.6	-
	Potatoes (1.500)	1.7	71
	Vegetables (725)	0.8	67
	Grain (15,000)	17.0	80
	Fruit trees (5,000)	5.6	-
	Strawberries (275)	0.3	40
II	ANIMALS	Based on edible yields	
	Pork	26	63
	Beef and veal	29	73
	Mutton & lamb	1	66
	Chicken & turkey	44	17
III	DAIRY PRODUCTS		
	Fluid milk	70	0
	Butter, cheese, etc. calculated as fluid milk equivalents.	30	72

Possibilities for Import Reduction

On the product side, Nova Scotia is a net importing agricultural area (Table IX). The only commodities which are exported outside the province are eggs (10%), blueberries (90%), and apples (50%). Nova Scotia produces only 40% of the food consumed by its small population (Fig 1), a quantity which is clearly too small to influence product prices throughout North America. Hence, prices are set externally, and Nova Scotian producers must meet the production plus transportation costs from other areas in order to retain local markets. Any proposed energy alternatives must take into account the already low Nova Scotian farm incomes. The imposition of higher dollar production costs to facilitate energy savings may be unacceptable in the short run.

Imports, of course, are of numerous classes:

— There are goods from warmer climates such as coffee or oranges or prepared fruit and condiments, a class which does not merit further consideration here.

— There are many of our own summer products brought to us out of season, to which we have become accustomed, and any loss of which we shall accept only under economic stress. There is the beginning of local alleviation of potential shortage by a minor development of greenhouses near sources of waste heat, but it is still mostly only in the talking stage and offers a fruitful field for technology.

— There are products formerly local but now imported from elsewhere in Canada, notably food imports which make up half the farm inputs shown in Figure 1 and which are heavily subsidized. Most of our meat comes from outside, as does nearly all the flour for our bread. In pioneer times, the oatmeal for our food was locally produced and it is today a product much favoured by health enthusiasts. Probably effective advertising, coupled with rising wheat costs, could restore oatmeal to a more prominent position.

— Finally, there are so-called imports which circulate within our own region of the Maritimes and Quebec. Whether these should be called imports in the sense of the classes listed above is a political question related to the degree of provincialism prevalent in our area and subject to discussion in The Atlantic Provinces Economic Council (APEC).

We have not seen published figures with which to quantify the foregoing list, which indicates a large field for research into the ways in which the energy situation will affect economic decisions about imports. The increasing energy shortages will allow new methods for agricultural products to become viable. For instance, transport costs from California will, as they increase, allow local farm costs to become competitive. To cite an example: the largest Nova Scotian foreign import (by weight) is lettuce which increased by 30% between 1973 and 1978. During the same period the local product (by hectarage) declined to the same degree (Nova Scotia Agricultural Statistics 1978). Another example is feed imports which account for one-half the animal requirements, and which could be grown locally if economic considerations so dictated.

Support Programs

The rise of government-sanctioned marketing boards has paralleled the rise of capital-intensive agriculture. Unquestionably, the attainment of a stabilized level of prices and production in important commodities such as milk, eggs, and poultry, has important effects throughout the agricultural sector. Just what the implications of these effects are for energy utilization remains to be clarified. For example, do marketing boards, by ensuring a given level of production, encourage investment in energy-intensive methods and, by perpetuating the status quo, encourage energy inefficiency? If more energy-efficient crops can be discovered, how is the farmer to be induced to grow these crops and the consumer encouraged to buy them?

In Nova Scotia, the agricultural industry also receives subsidies and grants from provincial and federal sources. The Nova Scotia Department of Agriculture's financial assistance to the farmers is largely in the form of capital grants rather than operating grants. Exceptions to this general direction would be the provincial Agricultural Limestone Assistance Policy ($850,000 in 1979) and the federal Feed-Freight Assistance Policy (currently almost $2 million annually).

A major thrust of government-funded support programs is to encourage the development and modernization of farm units and where possible encourage the adoption of new or improved technology. Most of the policies fall into 1 of 3 general categories: (1) land improvement, (2) feed grain and protein crop production, and (3) livestock policies designed to lessen Nova Scotia's dependence on imported meat. Increased energy costs involved in promoting all 3 could be very significant. Typical policies of this nature would be the Fertilizer Assistance Program, the Capital Grants Policy and the Land Improvement Policy (Agriculture Assistance Program).

Eligibility for many of these support programs depends on a commitment of the farmer, who must gross $10,000 or more per year to qualify.

The jointly funded Agricultural Development Agreement policies have the objective of increasing the province's agricultural production. These programs operate on a cost-share basis with 20% of the costs from the Province and the remainder from the Federal government.

The total dollar value of grants and other forms of economic assistance paid to Nova Scotia agriculture in 1975-1976 was $7.2 million, which was some 5% of the gross value for agricultural production in the province.

Little available information exists concerning the effects which the grants and subsidies offered to local farmers have had on agricultural patterns in Nova Scotia. Consequently, the long-term impacts, including ecological and socio-economic, of government economic support programs on agricultural trends in Nova Scotia are presently unknown. The short-term impact appears to be the perpetuation of an energy-intensive and capital-intensive status quo. None of the financial incentives in force at present has the object of persuading farmers to alter their patterns of energy consumption. An offer of incentives could reduce the costs and risks of investment in energy-saving equipment and techniques. Information transfer programs, demonstrations, and technical assistance would be a natural accompaniment to financial aid.

Possible sources of energy savings must take into account the size, diversity, and scale of production units. Other strong imprints on our agricultural industry are made by the marketing boards, which tend to perpetuate the status quo, and by provincial and federal support programs with the intent of introducing new technology. None of the financial incentives in force at the present time has the object of reducing the costs and risks of investment in energy-saving equipment and techniques, which might be accompanied by technical assistance.

We people of the West can get back 25% of what plants cost us as food energy. Animal food yields us only 10% of the input energy. It is not surprising, therefore, that the contemporary world scarcity is especially related to animal protein and that the special effort of the times is to seek more protein from plants.

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References

Agriculture Canada. 1976. *Energy and the Food System*. Food Systems Branch, Agriculture Canada, Ottawa.

Agriculture Canada. 1977. *Energy and the Food System*. Food Systems Branch, Agriculture Canada, Ottawa.

Copping, A. 1976. Household consumption and human nutrition. In *Food Production and Consumption* (ed. A.N. Duckham, J.G.W. Jones and E.H. Roberts) North Holland Publ. Co., Amsterdam, pp. 283-284.

Downing, C.G.E. 1975. *Energy and Agricultural Biomass Production and Utilization in Canada*. (Paper presented at Energy, Agriculture and Waste Management Conference, Syracuse). Engineering Research Service, Agriculture Canada, Contrib. 512, Ottawa.

Downing, C.G.E. and **Feldman, M.** 1974. *Energy and Agriculture*. Research Branch, Agriculture Canada, Ottawa.

Friedrich, R.A. 1978. *Energy Conservation for American Agriculture*. Ballinger Publ. Co., Cambridge.

Geigy Scientific Tables. 1956. 5th Ed. J.R. Geigy, Basle.

Geno, B.J. and **Geno, L.M.** 1976. *Food Production in the Canadian Environment. Perceptions 3*. Science Council of Canada, Ottawa.

Heichel, G.H. 1976. Agricultural production and energy resources. *Am. Sci.* 64: 64-72.

Henig, Y.S. and **Schoen, H.M.** 1975. *Energy Consumption in the Total Production Cycle of Various Food Products*. (Paper presented at 68th Annual Meeting, American Institute of Chemical Engineering, Los Angeles).

Hirst, E. 1974. Food-related energy requirements. *Science* 184: 134-138.

Jensen, N.E. 1977. *Total Energy Budgets for Selected Farms in Western Canada*. Engineering Research Service, Agriculture Canada, Ottawa. Contract No. OSW5-0517, pp. 1-7, 65-87.

Jensen, N.E. and **Stephanson, B.T.** 1975. *Energy Budgets for Crops Grown in Western Canada*. Engineering Research Service, Agriculture Canada, Ottawa.

Lovering, J. and **McIsaac, J.A.** 1976. Energy use in crop production in Prince Edward Island. *Can. Farm Econ.* 11: 1-5.

McMahon, J. 1976. Farming on the margin. Compilation of statistics from federal and provincial sources. (unpubl. manuscr.)

Nova Scotia Energy Update. 1979. N.S. Dept. Mines and Energy, Halifax.

Nova Scotia Agricultural Statistics. 1975. Publ. 100. N.S. Dept. Agriculture and Marketing, Halifax.

Nova Scotia Agricultural Statistics. 1978. Vol. 14. N.S. Dept. Agriculture and Marketing, Halifax.

Odum, H.T. 1971. *Environment, Power and Society.* Wiley-Interscience, New York.

Pimentel, D., Hurd, L.E., Belloti, A.C., Forster, M.J., Oka, I.N., Sholes, O.D., and **Whitman, R.J.** 1973. Food production and the energy crisis. *Science* 182: 443-448.

Southwell, P.H. and **Rothwell, T.M.** 1976. *Analysis of Input/Output Energy Ratios of Crop Production in Ontario.* School of Engineering, Univ. of Guelph, Guelph.

Steinhart, J.S. and **Steinhart, C.E.** 1974. Energy use in the U.S. food system. *Science* 184: 307-316.

Stutt, R.A. 1973. *Energy Balance in Canadian Agriculture.* Farm Management, Economics Branch, Agriculture Canada, Ottawa.

Taylor, G.B. 1976. Agricultural energy use. In *Efficient Electricity Use* (ed. C.B. Smith) Pergamon Press, New York, p. 402. (Cited from Friedrich, 1978.)

Timbers, G.E. 1977. *Present Use of Energy on Canadian Farms.* Research Branch, Agriculture Canada, Ottawa.

Whittlesay, N.K. and **Lee, C.** 1976. *Impacts of Energy Price Changes on Food Costs.* Coll. of Agric. Res. Center, Washington State Univ., Pullman.

Appendices

A. Detailed Source Tables

This section gives the primary source tables which have been summed up as Tables V and VI. Table X is concerned with the plants destined for human consumption and Table XI with animal products. The source is Nova Scotia Agricultural Statistics (1975) and the entries represent 5-year averages from 1971-1975. The first entry is the annual Nova Scotian edible yield (column 1) as millions of kilograms. Sometimes column 1 is a multiple of rate of yield and area under cultivation, sometimes a direct value, and it may originate as bushels, quarts or tons. Some numbers are from general sources recalculated or extrapolated to make them applicable to Nova Scotia. Bracketed numbers are assumed by analogy.

Reference sources for columns 2 and 4 which give unit input and output costs are given in the text. From them come the final annual totals for Nova Scotia in columns 3 and 5 which lead to the easily compared percentage numbers of column 6.

The notes on individual crops are intended to be self-explanatory and the gaps and assumptions shown will enable a reader to form a personal estimate of the probable level of accuracy.

Table X. Detailed relations of plants destined for human consumption, from direct observations. Annual yields are 1971-1975 averages from Nova Scotia Agriculture Statistics (1975).

INDIVIDUAL OBSERVATIONS	1 Annual N.S. edible yield (kg x 10^6)	2 Input (kcal/kg of edible product)	3 Annual N.S. input (kcal x 10^9) (1 x 2)	4 Food value (kcal/kg) (Table XII)	5 Annual total for N.S. (kcal/ x 10^9) (1 x 4)	6 Food energy as % of input energy
I. ON THE FARM						
				Dried		
Wheat. 36 bu/acre x 68 gives kg/ha	3.6	547	2.1	4200	15.1	720
VEGETABLES						
Potatoes	27.0	752	20.3	850	23.0	112
Carrots	11.7	463	5.5	420	4.9	89
Remainder as detailed below.	6.5	606	4.0	380	2.5	63
Beans. Col. 1 was reported dried as 0.1, converted to fresh as 1.0. Col. 4. was similarly changed from 3400 dried to 340 fresh.	1.0			340	0.3	

Cabbage	2.6			240	0.6	
Corn	1.0			960	0.9	
Tomatoes	0.6			220	0.2	
Other: beets, cauliflower, cucumbers, lettuce, parsnips, total.	1.3			363	0.5	
TOTAL VEGETABLES	45.2		29.8		30.4	100
FRUITS						
Fruit trees						
Apples. One bushel taken as 18 kg. Fresh sales make up 35% of crop.	41.6	516	21.6	580	24.1	110
Blueberries	4.1	(331)	1.4	680	2.8	200
Strawberries	0.8		0.6	410	0.3	
Information insufficient for residual fruit calc. Say	(0.5)	(440)		250	1.0	(150)
Total fruit	47.0		23.6		28.2	119
GRAND ON-FARM TOTAL	95.8		55.5		73.7	135
II. POST-FARM. Processing, commercial handling including transportation, and home preparation. (After Whittlesay & Lee 1976; cited from Agriculture Canada 1977, Tables 32 *et seq.*)						
Wheat (col. 4 at 4200): proc. 2.0; com. hand. 0.7; home 3.5.			6.2		15.2	245
Potatoes (assume 1/2 fresh and 1/2 prepared): proc. 72.5; com. hand. 43.7; home 54.4.			170.6		23.2	14
Carrots (assume all fresh): proc. nil; com. hand. 13.8; home 21.5.			35.3		5.0	14
Other vegetables (assume fresh & av. of other veg.): proc. nil; com. hand. 10.0; home 15.6.			25.6		2.5	10
Apples (N.S. Agric. Stat. give 65% processed & 35% fresh): proc. 4.6; com. hand. 30.1; home 9.2.			43.9		24.3	56

Blueberries (assume canned & same as green peas. Assume food value same as bilberries): proc. 3.6; com. hand. 2.3; home 2.2.	8.1	2.8	35
Other fruit (assume fresh & same prep. costs as for vegs.): proc. nil; com. hand. 1.5; home 2.3.	3.8	0.9	24
TOTAL	293.5	73.9	25
GRAND TOTAL, PLANT FOOD	349.0	73.8	21

Table XI. Detailed relations for livestock, dairy products, poultry and eggs. (Nova Scotia Agricultural Statistics 1975, 1978.)

INDIVIDUAL OBSERVATIONS	1 Annual edible yield (kg x 10^6)	2 Input (kcal/kg of edible product)	3 Annual input (kcal x 10^9) (1 x 2)	4 Food value (Kcal/kg)	5 Food value annual N.S. total (kcal x 10^9) (1x4)	6 Food energy as % of input energy (100 col. 5/col. 3)
I. ON THE FARM						
FODDER						
Pasture	190.8	192	36.7	2400	458.0	1250
Hay	267.3	335	89.5	2400	651.5	728
Corn for silage. Ann. yield increasing; av. for '75 & '76 taken.	127.3	220	28.0	812	104.1	372
TOTAL			154.2		1213.6	787
GRAINS						
Barley. 39 bu/acre x 56 gives kg/ha.	4.8	(556)	2.7	Dried 4200	20.1	753
Mixed Grain. 44 bu/acre x 49 gives kg/ha.	6.4	(556)	3.5	4200	26.9	751

Oats. 44 bu/acre x 49 (est.) gives kg/ha.	17.9	(556)	10.0	4200	75.1	754
TOTAL	29.1	(556)	16.2	4200	122.1	754
IMPORTED FEED (as on chart)			766.0			
TOTAL ON-FARM FEED & FODDER			936.4		1335.7	143
II. PROCESSING & HANDLING						
BEEF						
Cattle production from Statistics Canada, probably omits local use.	1.94					
Alternate N.S. Dept. Agriculture Statistics. More probable. Accepted beef, 94%; veal, 6%; total 59,000. Cattle av. 132 kg usable yield.	7.79	23,000	179.1	3,000	23.4	13
HOGS						
N.S. Agric. Stat. (1975) annual numbers are 110,000 each with 63 kg usable yield. Statistics Canada figures are in agreement.	7.00	16,500	116.0	4,000	28.0	24
TOTAL LIVESTOCK			295.1		51.5	17
POULTRY						
Production in N.S., 5-yr average. Dressed weight of fowl, chicken, turkey, geese and ducks.	12.2	18,000				
Broiler output.				1,500		
Suggested ratio. Back calculation.			(220.0)		(18.3)	8

(Some Geigy values)						
Broilers				1,110		
Raw Chicken				1,790		
Duck				3,210		
Goose				3,490		
Turkey				2,620		
EGGS						
Production in N.S., 5-yr average. Dozens.	1.3			1,580	2.0	
Suggested ratio. Back calculation.		(9,200)	(12.0)			17
TOTAL POULTRY PRODUCTS			232.0		20.3	9
DAIRY PRODUCTS						
Total milk. 5-yr average is 160 x 10^6 kg of which 95% is consumable.	152.1	1,270	194.7	650	99.7	51
ADDED COSTS TO PROCESS MILK PRODUCTS. Milk equivalents, 18% for butter.	27.0	7,190	10.0	7,160	10.0	100
17% for other factory products, dehydrated milk, cheese, ice cream. No breakdown available.	26.0	(1,270)	33.0	650	27.2	82
TOTAL DAIRY PRODUCTS			237.7		99.7	42
TOTAL PROCESSING & HANDLING			764.8		171.4	22
GRAND TOTAL ANIMAL FOOD FOR HUMANS			1701.2		171.4	10

B. *Constancy of Energy in Dried Fruits and Vegetables*

When calorific values are stated for fresh food products there is a wide variability; thus cucumbers, lettuce and pumpkins average 140, while corn, parsnips and potatoes average about 850 kcal/kg (Table XII). When products are dried a good deal of the difference disappears; the first three products mentioned average 1336, the second group 1712, so that the 6-fold difference in the fresh vegetables is reduced to a 28% difference when they are dried. The so-called "local" values were the ones used in our own calculations and came from several reference sources. They differ little from the Geigy numbers and probably have the same real variability depending on the time of harvesting and kind of season.

The mean calorific value for the 15 Geigy vegetables was 1533, while for the three fruits it was 1785. The number of fruits is too small to say whether the difference is real.

As regards water content, most fresh fruits and vegetables have 80-90% while commercially dried beans and peas have 5-10%. We do not have a water content figure for dried grains.

Table XII. Comparison of energy ratings of commercial products with those for totally dried products. General source is the Geigy tables (1956). "Local" items as used in our calculations had several sources. There are also some numbers from Stutt (1973). All figures are in kcal/kg.

	Commercial product	Totally dried product
DRIED GRAINS (Stutt 1973)		
Soybeans	4700	
Sunflower seed	4500	
Wheat, oats, barley, corn	4170	
DRIED VEGETABLES		
Haricot beans	3510	3690
Local beans	3400	3574
Peas	3540	3934
FRESH VEGETABLES		
Green beans	351	3217
Beets	331	2668
Cabbage	249	3038
Local cabbage	240	2930
Carrots	400	3502
Local carrots	420	3676
Cauliflower	311	3746
Fodder corn (Stutt 1973)	1151	
Local corn	961	3846
Local silage corn	221	3380
Cucumber	130	2957
Lettuce	150	2884

Parsnip	781	3647
Peas	800	3202
Potatoes (Stutt 1973)	944	
Potatoes	851	3834
Local potatoes	759	3418
Pumpkins	150	2999
Tomatoes	230	3887
Local tomatoes	221	3737
Turnips	320	3513

FRUIT

Apples	580	3616
Bilberries (like blueberries)	679	4090
Strawberries	410	4100