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Energy Utilization In Vermont Agriculture

Energy consumption in the United States has been increasing at the rate of about 5 percent a year over the last two decades, four times faster than our population growth. Our national energy budget now consumes 35 percent of the world's energy. Such statistics, in themselves significant as indicators of our dominant role as energy consumers, become even more disquieting when our use of this energy is more closely examined.

The food production, processing, and marketing system is today a major energy consumer in the U.S. economy, using 15% to 18% of our total energy budget. This system, marked by the growth of agribusiness and specialization, is dependent on decreasing supplies of fossil fuels. Food production and distribution no longer rests on labor intensive agriculture and traditional storage techniques. The development of highly processed foods and the extensive use of internal combustion engines and electrical power, along with the increase in meat consumption since 1945, have drastically changed food production. These developments have at least one outcome which affects all consumers: the overall energy efficiency of our food system from field to table has fallen.

We are at an end of the era of cheap energy, at least until technological advances lead us to use of other energy sources. Meanwhile, the energy crisis has clearly shown us that production and distribution systems for all goods — including agricultural items — are based on obsolete assumptions concerning the finite nature of natural resources. Contrary to conventional wisdom, the United States and the global community are moving into a new era of production constraints on both our limited, non-renewable and our renewable resources.

This change in focus requires a more critical understanding of how, where and to what ends we use resources, as well as examination of alternative patterns of resource use. Before we can effectively deal with this present and long-lasting problem, however, current energy use patterns must be analyzed and discussed. Such study of the agricultural system can move us toward more efficiency in the use of raw fuels. It may also help us to put environmental, social and economic considerations into the energy equation.

Long-term improvements in agricultural productivity and stability are bound to our definition of **agricultural efficiency**. In the past and even today most societies define efficiency as an economic concept, related to profit maximization. Fuel or electrical energy are, thus, efficient if their use results in higher profits, and are inefficient when they are no longer profitable. This definition does not take other questions into account. What are the amounts and purposes of cultural energy used, items such as human labor, fuel, tractors, fertilizers and other energy subsidies? What is valuable to the quality of life and the ongoing operation of our monetary system? What are, in short, the total costs of production? These considerations require a full energy accounting system for agricultural production, one which describes the real costs of goods and services and guides us toward energy conservation measures.

Full Energy Accounting

Process analysis is one method which can be used to obtain more complete energy accountings. It involves the detailed accounting of the energy inputs involved at all stages of the production process for a particular product, separating cultural from non-cultural energy. This method, one of several ways to gather and analyze data, was used in our study of Vermont Agriculture to determine **net energy.** This concept generally refers to the amount of energy remaining after all energy costs of finding, producing, upgrading, transporting, and all energy used in labor, material and other social inputs have been subtracted. Although net energy does not consider the quality of energy, it can determine the desirability or appropriateness of a particular energy form for a specific use. "High quality" energy like electricity, for example, is less efficient for space heating than solar or wood.

This total accounting uses the kilocalorie (kcal) as a unit of measurement. A calorie is the amount of heat required at a pressure of one atmosphere to raise the temperature of one gram of water one degree centigrade. This approach allows us to make energy efficiency statements which consider cultural and non-cultural energy dimensions, converting available information and data obtained directly from manufacturers and farmers into a uniform analysis.

According to United States Department of Agriculture figures, 95.2% of Vermont's agricultural cash receipts for 1973 fell into four production output categories. Dairy accounted for 88%, apples for 1.9%, eggs and poultry products for 4%, and maple sugar for 1.3%. These categories were expanded to include, in our study, both direct and indirect outputs. In apple production, for example, apples are the food output, but vegetative growth such as wood, leaves and hay, as well as chemical residues, heat and oxygen are also outputs.

Vermont's agricultural system in 1970 produced over 225 million gallons of milk, 17,000 tons of apples, 11 million dozen eggs, and, as of 1974, 321,000 gallons of maple syrup. We have developed summary energy budgets for these four production categories, including inputs and outputs measured in kilocalories (see table at the end of this report).

Our analysis of the energy inputs required for this productive output also considered direct (on-site) and indirect items. A process which appears less energy-intensive on-site can, in fact, be more energy-intensive when total inputs are included in the calculation. In our study of maple production, for example, it was critical not only to include energy calculations for direct inputs such as horse labor or fuel used by tractors, but to look at the energy costs for indirect inputs such as tractor production.

Here is a brief summary of the way we looked at horse labor, fuel for tractors, and tractor production in our study of the maple industry in Vermont. Similar calculations were completed for all inputs in the four major agricultural sectors.

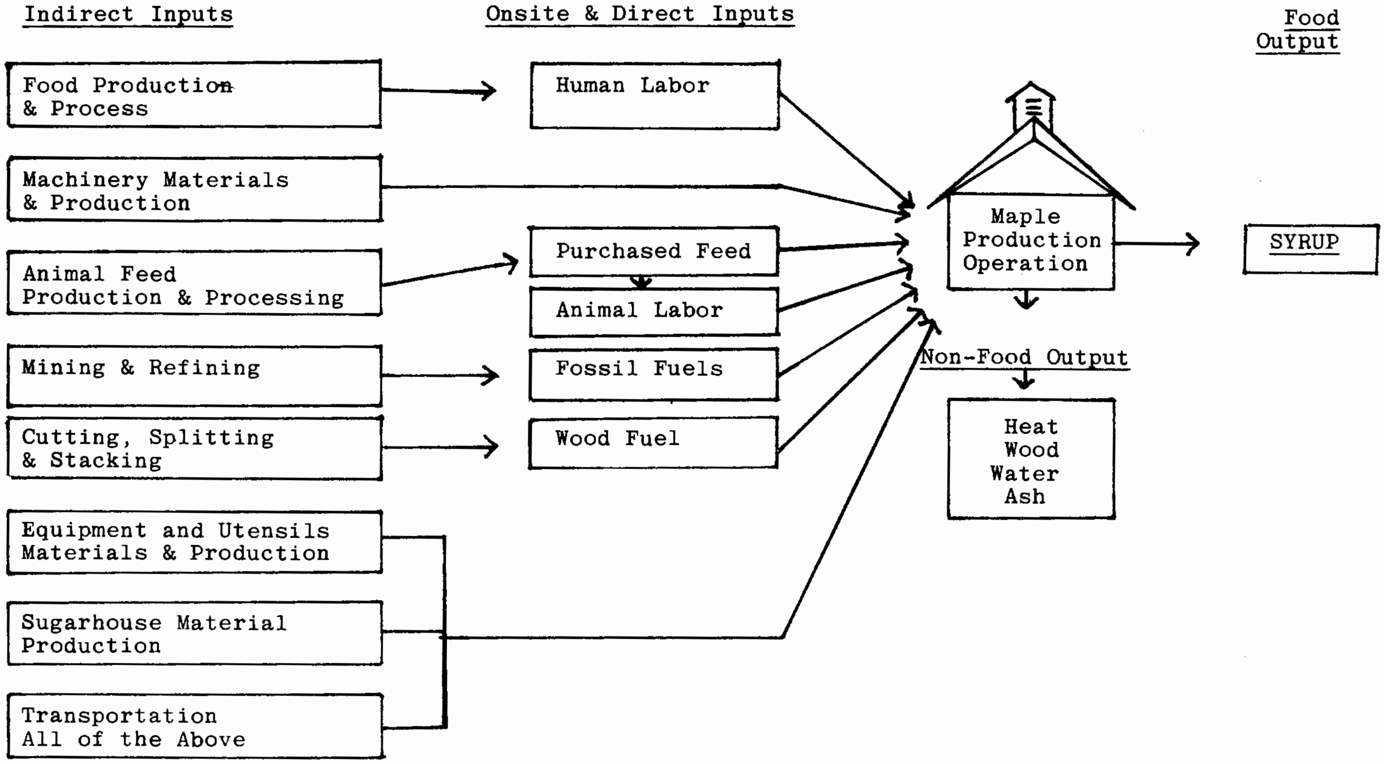
Horse Labor: Input was derived first by multiplying the estimate for horse-gathered taps in Vermont by the average of 0.25 hours of horse labor per tap. That gives 61,000 horse-hours per season. We used feed consumption figures of 0.58 pounds oats per hour and 0.73 pounds hay per hour to derive totals of 17.1 tons of oats and 22.3 tons of hay consumed each season by maple horses. The energy input yearly attributable to horses in this industry was then determined, using figures of 2122.4 gross kcal per pound of oats and 2045.4 gross kcal per pound of hay.

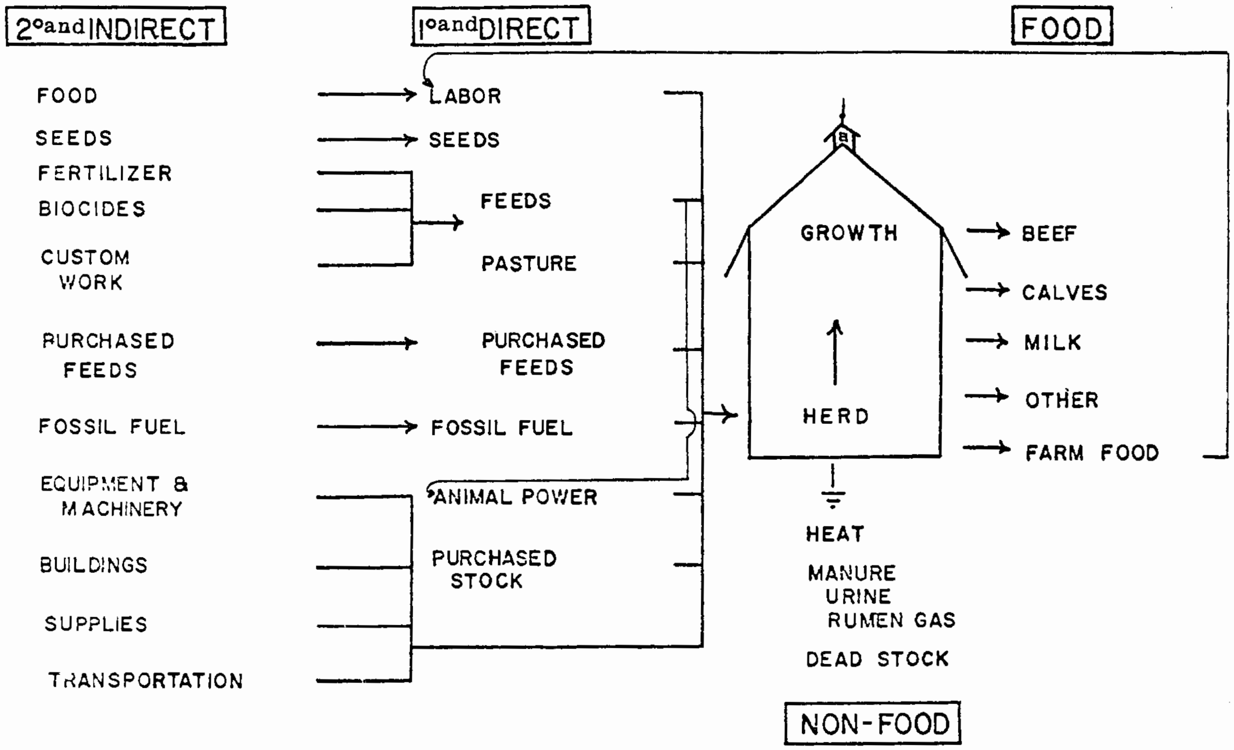
Fossil Fuel for Tractors: Fuel consumption was computed by multiplying the total estimated number of gas-powered tractors in use on maple operations by the average use of 87.34 hours per tractor each season. This total was multiplied by the average consumption of 4.2 gallons of gas per hour, giving a total of 121,787 gallons of gasoline attributed to gas-powered tractors. Assuming that 50% of tractors were deisel, at 87.34 hours per season, we multiplied this figure by 2.9 gallons of fuel per hour for a total of 70,177 gallons of diesel fuel for tractors. Adding total gas and diesel figures gives the total tractor fuel consumption for the season.

Tractor Fabrication: The energy required to manufacture a tractor, an indirect input for maple production, were first determined by calculating the estimated total tractor horsepower based on an average of 43.74 h.p. per tractor, multiplied by the estimated total tractors in use. When taken times the estimated 2.65 x 10^6 kcals per tractor horsepower, this figure gives a total input of 6.43 x 10^{11} kcals. We assumed that maple accounts for 1/6, or 2 months of the tractor's yearly use, and depreciated it over 20 years at 5%.

Tractor Materials: Each tractor also has an energy cost for raw materials, that is, the energy needed to produce and transport its constituent materials. These costs were calculated by assuming that steel comprised 99% of tractor weight, at 3.15 tons per 45 h.p. tractor. The total weight of 554 maple tractors is about 1728 tons. At 108 x 10^7 kcals per ton for steel production, kilocalorie input was determined and depreciated for a yearly figure. Transportation was taken at an estimated 4.43 x 10^5 kcal per ton of agricultural machinery. After depreciation, this produced the value for transport input.

ENERGY FLOW FOR VERMONT MAPLE PRODUCTION





MODEL OF ENERGY FLOWS ON A DAIRY FARM

Vermont Agriculture

MAJOR ENERGY INPUTS

Through a process analysis approach to full energy accounting, we have been able to pinpoint the major energy inputs for each agricultural industry in Vermont. The major items are generally high on the food chain. Both the dairy and egg industry use the products of herbivorous animals. These animals are primary consumers rather than primary producers. High energy inputs are needed for the conversion of maple sap to syrup and for apple orchard tending. Very little Vermont agriculture uses primary production of plants directly as the final output as is the case in grain production.

Feeds and fossil fuels are critical inputs for both the **egg** and **dairy** industry. Grain poultry feeds and the energy needed for their production account for 88% of energy inputs in egg production. Feeds are the major inputs for the dominant dairy sector.

Direct on-site fuel consumption is the major factor in **maple syrup** and **apple** production. Wood and the fossil fuels used in evaporation processes account for 66% of the energy inputs for the maple industry. Fuel use is also the dominant input in apple production, including fossil fuels for ground and aircraft equipment, heating oil, wood, propane, as well as the fuel needed to produce and transform wood, electricity and other fuel that is eventually used on-site.

THE QUESTION OF SIZE

What scale is appropriate or most efficient? Such a question is critical in almost any political, social or economic discussion today. It is also relevant to the discussion of Vermont's productive units in agriculture. In the dairy industry, for example, the average acreage of farms and the number of cows per farm have both significantly increased. In order to understand the effect of different size operations on overall energy efficiency, we compared economy of scale models for each item.

In two sectors, the maple and apple industries, we found relatively little efficiency advantage at any size. The energy efficiency advantage of a 4000 tap maple operation over a 1000 tap operation is less than 10%. The situation in the apple industry is similar, and, given the current approach of ground or air crop spraying, there is little chance that less energy use can be achieved by increasing the size of apple operations. At the moment a 218 acre apple orchard, with 158 producing acres, is not much more efficient than a 35 acre operation.

Commercial egg operations are currently more efficient than homestead operations utilizing purchased feed. Most efficiency differences, we found, depended upon the amount of feed expended to produce each egg. Increased mechanization reduces the waste of feed. Aside from this difference, however, there seems to be no real energy advantage of a large commercial operation over a small one.

In the dairy industry, the smallest farms are the most energy efficient. A dairy farm with between 25 and 42 cows, especially if they use a high proportion of feeds from hay and pasture, is both most efficient and produces a greater total food output per cow. Indirect inputs, such as energy needed to produce seed, fertilizers and herbicides, and food consumed in providing needed human labor, are lower for a larger dairy operation than for a small farm. Direct inputs, however, are generally higher for larger farms.

TECHNOLOGY IN PRODUCTION

Various methods and technologies used in agriculture affect the overall energy intensity of production. In looking at the four major items, we've compared the energy efficiency of different techniques and examined the major energy inputs for specific steps in producing apples, poultry items, maple syrup and dairy items. Some of our comparisons, for example, are the relative efficiency of horses for sap gathering as opposed to gas-powered farm tractors, and the contrast of ground and air spraying of apple orchards.

The use of tractors in maple production, which requires fossil fuels transported from distant places, is far less energy efficient than using horses. A tractor "consumes" 12.5 times the energy that a horse "consumes" in producing a gallon of syrup, and the grain or hay needed for horses can be produced locally.

Apple production provides another comparison. Air or plane spraying is slightly more energy efficient than ground spraying. The difference in efficiency depends on two aspects of air spraying. This technique has an efficiency advantage only if maintenance costs are low and the air time from airfield to orchard is under one-half hour.

The level of mechanization affects efficiency in both the egg and dairy industries. Mechanization which reduces the waste of feed significantly increases overall energy efficiency for chicken farms and homestead operations. When comparing hay with pasture for dairy feed production, both of which have lower energy costs than corn silage, we noticed that mechanized hay handling required the larger energy input. Tractors are used for spreading manure and lime, as well as for harvesting. Tedders, conditioners and hay dryers are now used on many large farms. Nonetheless, the resulting high energy cost may be offset by decreases in energy losses through spoilage.

Dairy production has been marked by a trend toward reduced use of human labor and its replacement with fossil fuel powered equipment. The idea is to increase labor efficiency by spreading overhead over more cows and raising the production level per cow. As a result, however, overall efficiency appears to be declining. Increased use of electricity and fossil fuel shows a law of diminishing returns. Increased energy inputs tend not to lead to increases in calories of milk output. In addition, the technique of breeding animals for large rumens and enormous appetites shows little relation to feed conversion efficiency. Finally, the substitution of machinery for men occurs at a generally high energy cost.

THE USES OF FUEL

Specific sub-processes in the production of each agricultural item account for large energy inputs. Many of these, in turn, require fossil fuels or appropriate alternatives. In the production of maple syrup, for example, either oil or wood can be used as an evaporating fuel. With the current evaporator rigs wood is slightly less efficient. But the inefficiency of wood could be substantially reduced through the addition of a preheater hood to wood evaporators. Wood, of course, is also locally reproducable.

The type of feed used for dairy herds also has a significant affect on overall efficiency. Feed from hay and pasture has a generally lower energy cost than either corn silage or commercial feeds. Pasture, in particular, is a land intensive approach in which energy expenses are limited to fences, liming and occasional improvements. Corn silage and commercial concentrate feeds, in contrast, are both more energy consumptive. Corn requires energy for seed production, land preparation, herbicides and fertilizers, harvesting, storage and feeding. Commercial feeds have an even higher cost, requiring energy for transportation, additive production and mixing.

Another comparative dimension in dairy production is the source of inputs. There has been an historical trend toward increased dependence on inputs originating off the farm. We found, however, that both overall energy efficiency and the caloric value of milk are higher when the proportion of on-farm inputs is higher.

Agricultural production in Vermont is affected by fossil fuels in even more direct ways. In the apple industry, they are currently used for ground and air spraying equipment, and for both production and transportation of fuels, electricity and wood. Heating oil and propane also figure among the total inputs. As a result, increases in energy costs immediately affect consumers. Farmers are faced with the uncomfortable choice: lowered profits or increased cost for the product.

Fuels are also critical for the production of the other items. They are needed by poultry operations to obtain grain yields, to produce constituents such as corn, soybean meal, fish meal and meat scraps and lime, and for their transportation to feed mills. In the maple industry there are large fossil fuel expenses for equipment, materials and fuel transportation. Although efficiency of feed handling for egg production can be improved by technical innovation on the farm, efficiency in oil use cannot be improved by sugarmakers. And as we mentioned previously, the increases in electricity and fossil fuel use among dairy farmers have not been reflected in increases in calories of milk output.

IMPLICATIONS FOR THE FUTURE

Our examination of energy efficiency in agriculture, and its fossil fuel, scale and technological dimensions, has led to a general diagnosis for each industry. Two fall into the specialty food category, another is already in rapid decline, and one — the dairy industry — has only a short-term viability given its current structure and fuel dependence.

Prospects for Vermont egg producers and consumers are not bright. Since the mid 1960s more than half of the commercial poultry producers in the state have gone out of business. The remaining businesses, many of them involving large numbers of chickens, may produce significant environmental problems due to pollution from manure run-off. In the poultry industry, competition is becoming stiff and profits for the farmer are small.

At one time the seasonal flow of sap served as a major sweetening agent in the northeastern United States and southeastern Canada. But the coming of the cane and sugar beets from far-away islands transformed this household Vermont staple into a luxury product. Maple syrup will remain a specialty item at least for the near future. The recent energy crisis saw many sugarmakers affected by oil, metal and plastic shortages, and the escalating prices of these commodities. The maple industry faces energy, economic and internationally-related constraints, and it is unlikely that producers in any item of Vermont agriculture will abandon dollars concerns until economics accurately reflects energy efficiency.

Maple syrup has been a specialty item for some time. Apples may soon become specialty fruits unless new cheap forms of energy are found, and efficient technologies developed. The current approaches, which usually involve substantial use of fertilizers and pesticides, are certain to mean less profit or higher prices. The situation is related to current consumer attitudes. The desire for a perfect fruit during most of the year appears to have led to the energy consumptive technologies we now support.

The current structure of the dairy industry has economic advantages at the moment, but ignores the energy dependency which may soon affect it. Little food and fuel is produced on dairy farms, in fact, less than 50% of feeds used. The increase in fossil fuel use already illustrates the output limitations of this approach. Vermont may soon be unable to compete with the mid-West.

The number of dairy farms has declined to about one seventh the total for 1920. The remaining operations have more average acreage and more cows per farm, but the total number of cows in the state is lower. Farmers have raised the output per cow and decreased the amount of human labor. The harder we push cows to produce, however, the lower becomes the overall energy efficiency of this major agricultural industry.

POSSIBILITIES FOR INCREASED EFFICIENCY

The previous trends can be affected by improved use of resources, changes in scale, and technical innovations. Use of a high percentage of locally-produced, renewable resources could improve the energy efficiency, and ultimately the overall condition of the maple syrup and egg industries. The potential of maple production may rest with increased efficiency in the use of wood for evaporation, and the integration of draft horses into year-round processes such as skidding logs or pulping. Egg production can be enhanced through the use of manure for methane production as either a direct energy source or indirectly as a fertilizer or feed supplement. This development would increase efficiency for any size poultry farm.

The efficiency of dairy production can be improved by an increase in on-farm inputs, things like hay and pasture used as feed. Such a shift, applied in combination with human labor-intensive means and a return to smaller herds, could significantly affect both the energy costs of production and the caloric value of milk.

On-farm innovations could complement these changes in resource use. We have mentioned the possibility of an engineered preheater to increase the efficiency of wood in maple production. Homestead poultry operations can become viable in terms of overall energy use partly by feeding household scraps to chickens and allowing them either full range or fenced yards for scratching. Possible changes in apple production include more efficient natural storage facilities, more efficient cultivation technologies, and decreased use of chemical fertilizers and pesticides. Alternative forms of pest and disease control would, however, still be needed.

Conclusion

The energy efficiency of Vermont's four major agricultural sectors is low. As we indicated earlier, the relatively high place of these items on the food chain and the high energy inputs normally required have contributed to this situation. Vermont's agriculture, which does not use primary production of plants directly, is currently skewed by the dependence of dairy producers on imported feeds. They account for over 60% of the overall energy input for agriculture. Farmers are also vulnerable to rising energy costs and fossil-fuel dependent products which are sometimes in short supply.

The State's low agricultural efficiency and fuel dependency are compounded by an economic system which discourages and prevents farmers from adopting more energy efficient or ecologically-sound practices. As things stand, profit and short-term solutions to problems tend to support one another. If short-term profit is the criteria and the problem is a need to reduce the use of natural gas, for example, then the solution may be increased use of electricity generated by fossil fuel.

Erik Eckholm of Worldwatch Institute has exemplified the situation. The problem of surging world grain prices, he notes, led farmers to convert pastures, woodlands and idle fields to crops in the mid-1970s even though much of the land had inadequate conservation treatment. As a result, the average loss of topsoil to water and wind on those lands rose to double the tolerable level, according to government soil conservation officials. In this case, short-term profit led to soil depletion.

If the criteria, on the other hand, include resource availability and sustained productivity, then the current problems must be matched by long-term solutions. At the moment, these solutions aren't supported by immediate profit. The choice of extending our current economic policies into the future, however, will tend to increase the hardships for most farmers.

Another choice is available, redefinition of the concepts of efficiency, profit and resource exploitation. Our process analysis approach is a tool for such a change in thinking. It acknowledges that food production is dependent on raw fuels and the quality of the water, air and soil. For future generations, we believe, efficiency will mean the protection rather than the depletion of these resources.

The concept of nutrition must also be redefined, with a view of the overall market structure and quality of life. We must begin to consider more than the caloric or protein accounting which currently characterize our nutritional concerns.

In the near future, additional comparative analysis will be needed concerning various modes and sizes of agricultural production. These might include the individual operation which has mixed output, such as meat and forage, fruit and vegetable; the monocultural production unit; cooperative associations which produce a variety of items; and intermediate levels of production on specific items from the individual farm up to the national level.

Such study must place agriculture in a social, biological, and political framework. We have taken a bioregional approach to analysis which considers the state an important political level. The state level provides a perspective for public policy decision-making and individual farmers. On this level, a bioregional view considers the direction of technological development, the environmental costs, short and long run natural resource demands, and the economic impact of changes in energy use or availability. It might be possible, nonetheless, to extend this approach to a multi-state region, for instance, New England or a part of this region and New York.

When farmers consider the installation of production processes that require a large, on-going energy subsidy, the type of energy demanded and the nature of the benefits derived should be carefully reviewed. We recommend a long-term view, especially if alternatives are feasible and available. State and national researchers must look for production options that are economically, socially and environmentally adequate.

Agricultural policy is also made at the local level. Such policy, we conclude from the research summarized previously, will prove most effective if it indicates an awareness of the needed long-term energy resources for a fully efficient agricultural system.

TABLE
SUMMARY OF ENERGY INPUT-OUTPUT FOR VERMONT AGRICULTURE

INPUTS	
Labor	12.4 x 10^9 kcal
Draft animals	0.2 x 10^9 kcal
Feed	7840 x 10^9 kcal
Feed production and transportation	1080 x 10^9 kcal
Fuel and electrical use — on-site	1082 x 10^9 kcal
Fuel processing and transportation	330 x 10^9 kcal
Equipment manufacturing and materials	93.9 x 10^9 kcal
Vehicle manufacturing and maintenance	87.7 x 10^9 kcal
Building fabrication and materials	102 x 10^9 kcal
Transportation of equipment and materials	324 x 10^9 kcal
Product transportation*	7.5 x 10^9 kcal
TOTAL INPUT	13,477 x 10^9 kcal
OUTPUTS	
Apple	10 x 10^9 kcal
Maple	4.6 x 10^9 kcal
Eggs and poultry meat	12 x 10^9 kcal
Dairy (milk & meat & calves)	720 x 10^9 kcal
TOTAL OUTPUT	747 x10^9 kcal

Overall State Agricultural Efficiency = OUTPUT = 5.5%

Overall State Agricultural Efficiency = OUTPUT = 5.5% = 18 cal in/cal out

* Apple and eggs only