ENERGY FARMING IN NEW ZEALAND

G. S. HARRIS*

INTRODUCTION

The concept of energy farming was first mooted as a serious option for New Zealand in 1974 by research workers with an interest in the processing of biomass to liquid fuel, and laboratory research commenced at that time. The overall concept of energy farming was studied during the formulation of energy scenarios for New Zealand (Harris *et al.*, 1977), this work being undertaken mostly in 1975 and 1976. Work undertaken in early 1977 was published subsequently (Harris *et al.*, 1978). DSIR and Massey University held seminars on energy farming in 1975 (DSIR, 1976) and 1978, respectively.

The energy scenario research clearly identified transport and the supply of liquid fuels for transport as being the most important energy supply problem facing New Zealand. It also pointed out the potential for energy farming, but drew attention to the many unknowns related to this technology.

Since 1974 there has been a considerable amount of research in universities and government departments on the processing of crops to fuels, but only recently have significant results started to become available. There has been a good deal of interest in the private sector in this concept, after some considerable misgivings when the idea was first put forward. In 1977 the New Zealand Energy Research and Development Committee, which was already funding a substantial proportion of the research on energy farming, decided to set up a group to study the technology as a whole—that is, a systems study of energy farming. The main objective of the study is to answer the question "What is the potential of energy farming in New Zealand?" This research commenced with a Workshop in September 1977 attended by research workers from the government, industry and the universities.

The research has been completed and the final report is now being written for publication early in 1979. This paper discusses some of the issues raised in the final report of the Energy Farming Research Group.

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*New Zealand Energy Research and Development Committee, c/- University of Auckland, Private Bag, Auckland. This paper was prepared for a meeting of ANZAAS in Auckland in January 1979.

OBJECTIVES OF THE ENERGY FARMING STUDY

The group has been studying all aspects of energy farming, using data which are fairly readily available, in order to determine the potential of energy farming for New Zealand. The study is being undertaken from the national point of view. If the concept of energy farming is eventually accepted for implementation, feasibility studies will be required for particular processing plants based on areas of land dedicated to supply biomass for that plant.

The study has the following principal components:

(1) Evaluation of land suitable and available for various crops.

(2) Technical, economic and environmental evaluation of agricultural crops as a source of biomass (sugar beet, fodder beet, maize, lucerne, oats, pasture).

(3) Technical, economic and environmental evaluation of forestry based on radiata pine.

(4) Evaluation of other crops on which there is less information than on the crops mentioned above.

(5) Technical and economic study of ten processing routes to produce liquid or gas.

(6) Study of distribution and use of alternative fuels.

(7) Environmental and social implications of energy farming.

Since the start of the study there has been considerable work undertaken on distribution and use of alternative transport fuels; and much more is planned as a result of the formation, in November 1978, of the Liquid Fuels Trust Board. Since this work is incomplete, and since it is beyond the resources of the Energy Farming Research Group to effectively study this topic, the group has concentrated on the remaining six study components.

LAND USE

The concept of terrestrial energy farming involves using land to produce an agricultural or forest crop. The land so used needs to be both "suitable" for the crop and "available". While criteria for "suitability" can be written in terms of soil type, climate and topography, the criteria for availability depend on definition of an energy farming processing plant in a particular locality. For instance, only if farmers have an idea of the price to be paid for a crop will they say that some or all of their farm is "available". Hence, the study concentrated on land suitability. The results for maize, beet (sugar and fodder), lucerne and radiata pine are given in Table 1. For the first three crops, most of the suitable land is presently high-value agricultural land. This same land is suitable for radiata pine, but in addition there is much marginal farm land, scrub and cut-over native forest, which could conceivably be used for a new, more profitable activity such as energy farming.

TABLE 1: LAND SUITABILITY (HECTARES) FOR ENERGY CROPS

Total area considered	25 668 900
Total areas suitable for crops:	
Maize	2 447 000
Beet	3 089 700
Lucerne	4 373 000
Radiata pine	7 057 500
Areas suitable for crops in common:	
Maize/Beets	1 908 300
Maize/Lucerne	1 600 200
Maize/Radiata pine	1 937 300
Beets/Lucerne	2 232 300
Beets/Radiata pine	2 577 300
Lucerne/Radiata pine	3 498 000
Area suitable for radiata pine alone:	3 144 000

The table was compiled from soil maps at a scale of 4 miles to 1 inch using a minimum plot size of 80 hectares. While these maps were checked with Ministry of Agriculture and Fisheries district officers and Forest Service conservancy officers, it will be necessary to undertake more detailed studies both at the regional and the local level to determine what is the ultimate land potential for energy farming. In general terms it can be stated that the area of land which is potentially available for energy farming using any of the crops—fodder beet, maize, lucerne or radiata pine—is well in excess of the land area which would be required to supply 100% of New Zealand's liquid fuel requirements in 2000 (Ministry of Energy projections of transport demand).

AGRICULTURAL CROPS

The study of agricultural crops has proceeded with the philosophy that any crop which is used for energy farming should be integrated into the existing farming situation. If energy farming were to proceed with agricultural products, then the existing farmers with their knowledge of particular crops and farming techniques would be required to change their method of management in only a comparatively small way in order to produce the energy crops. In many cases it is quite possible that stocking rates could be held at existing levels. In this way energy farming would be more likely to succeed.

The second point of philosophy in the study has been to minimise the energy inputs used in growing the energy crop. Generally, conventional technology and practice have been used, and no attempt has been made to minimise energy inputs through such new practices as low tillage cropping.

A range of crops has been studied and the energy ratios, energy yield and production costs for some are presented in Table 2. It is readily apparent that fodder beet is the best of the crops studied, and this crop is the one which has been mainly considered in the remainder of the study.

There are a number of unknowns concerning beet, particularly the yield of fermentable sugars and the storing qualities in various parts of the country, especially the North Island.

TABLE 2: ENERGY RATIOS AND PRODUCTION COSTS FOR FOREST AND AGRICULTURAL CROPS

Crop	*Average Collection Distance (km)*	*Net Energy Yield at Factory (GJ/ha/yr)*	*Energy Ratio*	*Production Cost ($/ha)*	*($/ODT)*
Fodder beet (grown in 5-yr rotation with pasture)	16	366	24	864	40
Maize (grown in a continuous maize system)	16	270	17	744	96
Maize (rotational pattern with pasture)	16	273	20	612	79
Pasture	16	193	19	939	87
Lucerne	16	192	26	726	66
Gorse		192	90	118	11
Radiata pine (grown as energy forest 18-yr rotation)	20	194	21	†	50
Radiata pine (30-yr rotation)	20	160	32	†	32*

*This amount is the cost for low grade logs in a conventional forest the bulk of which would be for sawn timber—*i.e.*, only low quantities at that cost.

†These amounts are not relevant since the trees take many years to reach maturity.

It is highly desirable that extensive trials of fodder beet be undertaken in order to obtain a better understanding of the qualities of fodder beet and desirable agronomic practices for energy farming.

FORESTRY

Radiata pine is a resource which could be used for energy farming. Current planting rate exceeds 40 000 hectares per year and the total exotic forest area exceeds 700 000 hectares. While the existing mature forest is almost entirely committed to providing feedstock for existing processing plants and for export and domestic demand, the fate of the forest now being planted has by no means been determined. Thus in the early 1990s a considerable quantity of wood could become available for energy farming. A decision at the present time to implement energy farms based on forest crops would mean that such crops probably could not be available until well into the 1990s because of the growing time required for any species.

The energy ratios and production costs for radiata pine are given in Table 2. Two different forest planting schemes have been considered:

(a) energy forest, 18-year rotation;

(b) conventional forest, 30-year rotation.

It should be noted that for both forest and agricultural crops the opportunity costs are included in the production cost, and that for agricultural crops this is a major proportion of the total cost while for radiata pine it is small.

The energy ratios for radiata pine are high, showing that there is an adequate energy return. Transport is an important item—the processing plant should be sited close to the forest.

Studies have been made of the use of forest residues and wood wastes, but it is not possible to obtain sufficient quantities of these to manufacture large amounts of liquid fuels. It is acknowledged, however, that these may well be the feedstock of the first processing plants because they are much cheaper than whole-tree feedstock.

OTHER SPECIES

A wide variety of other species has been suggested as being more suitable for energy farming than "conventional" species —for instance, gorse, macrocarpa, sugar cane, eucalyptus, potatoes, artichokes, willows, etc. For many of these there is only limited information available on growing conditions and on the yield of crop per hectare per year; hence any evaluation of them must be of a lower order of accuracy

TABLE 3: COST OF TRANSPORT FUEL

Feedstock and Fuel	*Feedstock Cost ODt/d*	*Processing Plant Size (ODt/d)*	*Production Cost*[2]			*Feedstock Cost / Total Cost*
			c/l[3] *in 15% blend*	*c/l*[3] *pure*	*$/GJ*	
Gasoline ex refinery	—	—	—	12.8[1]	3.7	—
Fodder beet to ethanol	40	1000	13.0	17.5	5.7	0.72
Radiata pine to methanol	30	2500	12.0	19.0	6.8	0.34
Radiata pine to methanol	50	2500	16.5	25.5	9.0	0.5
Radiata pine to ethanol	30	1000	20.0	27.0	9.3	0.62
Forage to methane	87	200	N.A.	33.5	13.7	0.80
Maize to ethanol	96	1000	33.0	44.0	19.6	0.70

[1] Gasoline cost is at December 1978.

[2] Other costs are at June 1977.

[3] Costs are quoted in cents per litre of gasoline equivalent; *ie.,* since alcohol burns more efficiently in engines, a lower amount of energy is required for the same distance travelled when compared with gasoline.

than for the species mentioned earlier. In addition, substantial farming of a different species may involve farmers or foresters in significant changes in their management techniques. For this reason, any alternative energy crop would need to be significantly better than "conventional" crops in order to succeed at least in the initial period. Over the longer term, a different energy crop could well become important.

PROCESSING TO TRANSPORT FUEL

The following process routes have been considered:

Beet to ethanol
Wood to ethanol
Maize to ethanol
Forage to methane
Forage to ethanol and methane
Wood to methane
Wood to hydrogen
Wood to methanol
Wood to synthetic gasoline
Wood to electricity

There are basically two processing routes which can be used to transform the biomass into a fuel for use in vehicles. The first of these, fermentation, is biological in character and operates at normal temperatures and pressures. The study has shown that small-scale plants processing feedstock at the rate of 200 to 1000 oven-dried tonnes per day could be economic. There is considerable experience in New Zealand on fermentation plants of various types (*e.g.*, brewing, wine making, sewage treatment), so that they may well be favoured in the initial stages of any energy farming programme. This study has shown, however, that the fermentation plants, to be economic, require crops from highly productive land, some of which is currently used for intensive cropping and livestock production.

The second processing route is gasification, which uses high temperatures and pressures. The gasification routes tend to be economic at a larger scale, *i.e.*, from 500 to 2500 oven-dried tonnes of feedstock per day. There is little experience in New Zealand with this type of plant, and indeed it is the subject of much overseas research and development. It does, however, have the advantage over fermentation plants that it should operate well using a woody feedstock such as radiata pine, straw residue or gorse, and hence an energy farming process using this route would either use land which is not of great value for other more intensive activities, or, in the case of straw residues, use a feedstock with little alternative use.

In Table 3 the costs of fuel produced for some of the various routes studied are presented. The cost of feedstock is shown, together with the proportion it represents of the total cost. In all cases this is a high proportion. It should be noted that since the energy ratios are high (Table 2), cost is by far the most important criterion; so if energy farming is to succeed, the cost must be low enough. The current cost of gasoline is also given, and it will be noted that for the best routes the cost of ethanol or methanol is not greatly above the current cost of gasoline.

The processing of forest products in New Zealand is conventionally through a highly integrated forest-industrial system. For conventional agricultural products the degree of integration is considerably less. For energy farming it would be essential to develop a fully integrated agro-industrial system for efficient production of transport fuel. The cost of transporting feedstock to the processing plant is a significant proportion of the cost of production. There are economies of scale in the various process routes; *e.g.*, a large gasification plant processing 2500 ODT of wood per day is more economic than a 1000 ODT per day plant. However, a larger processing plant intake means a larger area of land which is required to supply the plant, and hence a larger average and more costly feed-stock collection system. When feasibility studies for plants in particular regions are undertaken, there will be a need to strike a careful balance between land suitability and availability, transport distance, including relation of the transport network to land availability, and processing plant size and location.

ENVIRONMENTAL AND SOCIAL

In all of the above studies, environmental factors have been considered. For instance, allowance is made in design of the processing plants to recycle the waste materials to farms, where this is appropriate. Cropping systems have been designed to interfere as little as possible with the existing farm environment, and for most the use of fertiliser has been minimised.

A small survey of the maize industry in the Waikato was undertaken. This shows that a diversification into an energy farming crop will have its main effect at the farm level, with other consequences likely as repercussions run out from that point. There is, however, some uncertainty as to the degree of the effects on farmer farm operations and beyond until further details on the energy farming operations are known. Farmers and people associated with the farming industry are very receptive to the idea of energy farming, but it is apparent that some additional incentive may be required in the initial phases. This will be sensitive to the scale of operation in the locality.

CONCLUSIONS

The answer to the question "What is the potential for energy farming in New Zealand?" is clear. There is adequate land area to supply New Zealand's transport fuel requirements in the year 2000 by processing agricultural or forest crops specially grown for that purpose. The net energy is high and the cost not greatly above the ex-refinery cost of gasoline at present.

The two most economic process routes are fodder beet to ethanol and radiata pine to methanol.

Because of the large amounts of Maui natural gas which are becoming available shortly, it is unlikely that energy farming will be used in a major way for transport fuel until at least the 1990s when the Maui field is starting to be depleted. Because of the long lead times, however, it would be highly desirable for New Zealand to undertake a development and demonstration programme in the 1980s with the objective of having one or two commercial plants operating by 1990. An imaginative decision to fund such a programme of implementation at a modest level should have widespread popular appeal. Compared with current expenditure on liquid fuels and the potential for widespread social and economic disruption because of expensive imported oil, such an investment in our future could be termed wise insurance.

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