THE ENERGY REQUIREMENT OF FARMING IN NEW ZEALAND

W.A.N. Brown

Agricultural Economics Research Unit

and

R.G. Pearson

Joint Centre for Environmental Sciences

Lincoln College, Canterbury

October 1977

Research Report No. 80

THE AGRICULTURAL ECONOMICS RESEARCH UNIT

Lincoln College, Canterbury, N.Z.

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PREFACE

This report presents the findings of a study of the direct and indirect energy use by the New Zealand farming sector on a 'to-farm-gate' basis. Although detailed statistics are available on this sector in financial terms, little data have been collected on inputs to agriculture in physical terms, and this complicates the application of energy analysis. This report therefore provides complete detail on all working calculations and the assumptions made, so that through wide distribution of these findings and the resulting feedback, the study estimates may be more precisely defined and the resulting energy requirement data improved.

Finance for this project was provided by the Ministry of Agriculture & Fisheries. In addition, staff of the Ministry assisted in aspects of the data collation programme, and their assistance is gratefully acknowledged.

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SUMMARY

Process analysis is used to quantify the direct and indirect energy requirements of the farming sector in New Zealand. Average annual energy input, 1971-1976 is estimated at 22,600 TJ, the main components being from petroleum fuel (35.5%), fertiliser (28%) and farm tractors and machinery (16.2%).

The overseas contribution to this total energy use on New Zealand farms is approximately 90 per cent. This means that New Zealand is almost totally currently dependent on overseas energy sources to sustain its present system of farming.

Marked annual variation in energy input to farming has occurred over the five year period studied. Energy use is highly correlated with annual movement in farm income, through changes in the consumption of both petroleum fuel and fertiliser.

New Zealand compares well with the USA, UK and Australia in an analysis of energy input to and output from their respective farming systems - for instance the UK, with an intensive system of agriculture, has an energy output:input ratio of around 0.3, compared with a ratio of approximately 2.3 for the extensive farming practiced in New Zealand.

CHAPTER 1

INTRODUCTION

This report summarises an energy analysis study of New Zealand farming which quantifies the direct and indirect energy requirements of the farming sector.[1] The energy inputs analysed include not only the primary or direct energy forms of fossil fuel, electricity, coal and gas, but also the energy consumed indirectly in the production processes for inputs such as fertilisers, weedicides and farm machinery, and in the transport of these inputs to the farm.

The project extends the initial calculations of Pearson and Corbet (1976) who first estimated the annual energy inputs into New Zealand farming at 20,800 TJ per year,[2,3] made up as shown in Table 1.1.

TABLE 1.1

Energy Inputs to Farms in New Zealand, 1975

	'000TJ per year	%
Direct Energy Requirement		
Fuel	10.1	48.5
Electricity	1.3	6.3
Indirect Energy Requirements		
Fertiliser	4.8	23.1
Lime	0.2	1.0
Farm Chemicals	1.0	4.8
Farm Machinery	3.4	16.3
	20.8	100.0

Source: Pearson & Corbet (1976 : 419).

[1] A detailed description of the development of energy analysis and its potential application in New Zealand is found in Pearson (1976). Energy analysis is defined as "the determination of the energy sequestered in the process of making a good or service".

[2] TJ is a terajoule, equal to 10^{12} joules. (A megajoule, MJ, is 10^6 joules, a gigajoule, GJ, 10^9 joules).

[3] Pearson and Corbet noted that inputs unaccounted for in their calculations could add a further 20 per cent to total energy requirements.

Chapter 2 reviews alternative analytical methods used in overseas studies on energy in agriculture. In Chapter 3, data on the input structure of New Zealand agriculture are used to generate the energy requirement estimates and comparisons are made with similar data from the United Kingdom, U.S.A., and Australia. Current research studies in this field are summarised in Chapter 4, and alternative avenues for further research examined.

CHAPTER 2

ALTERNATIVE ANALYTICAL METHODS

There are basically three techniques that have been employed in evaluating the energy requirements of a particular sector of the economy:

Input - Output Analysis;
Analysis of Industrial Production Statistics; and
Process Analysis

Each of these alternatives is discussed below.

2.1 Input-Output Analysis (I-O)

An input-output transactions table, R, is a square matrix, each row and column representing the sales and purchases respectively of a collection of similar establishments or sectors. All financial transactions in the economy are recorded by the table, any matrix cell, r_{ij}, giving the purchases from industry i required to produce the output of industry j. The output of any sector is either utilised as an input into another sector (an inter-industry transaction) or goes direct to final demand use (as, for example, household consumption or export). The interdependence in the economy is clearly recognised by this format, since a change in the output of any one sector affects the levels of its input purchases which are all in turn the output of other sectors.

Input-output is an attractive tool for energy research. The advantage of its use is that since sectoral interdependencies in production are explicitly accounted for, the system can reflect all the direct and indirect energy transactions in the economy and their inter-relationships. This enables economy-wide implications of alternative energy scenarios at the aggregate level to be fully evaluated or conversely, allows detailed analysis of the direct and indirect energy requirements of a particular industry at the sector level.

Since input-output tables commonly record transactions in money terms, initial analysis will yield the dollar units of direct energy required to produce one dollar of sector output. The sectoral and/or national impacts of alternative energy pricing policies can then be evaluated directly, assuming that the basic technical production relationships in the economy remain unchanged. In addition, if the primary energy rows in the table are converted into physical units the energy requirement per dollar of output can be calculated (MJ/$), and hence energy requirement per kilogram of output (MJ/kg) by evaluating the physical inputs associated with each sector.

To date, applications of input-output analysis in energy research have included:

(i) Calculation of the energy requirements of industries in the UK (Wright, 1974) and the US (Herendeen, 1974).

(ii) Evaluation of the implications of higher energy costs on industrial prices (UK, NEDO, 1975).

(iii) Simulation of the impact of alternative energy scenarios on the US economy (Penn and Irwin, 1977. Combines input-output analysis and linear programming.)

One immediate problem in using the technique of input-output for energy research in an open economy is the treatment of imports. Either the energy content of imports can be neglected, or alternatively, the broad assumption can be made that the manufacturing process for imports is closely parallel to that for equivalent domestic commodities.[4] (UK, NEDO, 1975 ; 10-13)

The crucial question in the use of input-output analysis is the 'realism' of the structure depicted by the transactions matrix, in that normally researchers are using data bases of 1963 and 1968 (UK), or 1963 and 1967 (US).[5] While it is generally accepted that the technological coefficients change only slowly through time[6], the extreme movements in energy prices during the 1970's may mean that the energy - output money ratios have changed markedly from the situation depicted by the I-O tables. This does not detract, however, from the very useful insights which input-output analysis can reveal into the relationships which link direct and indirect energy use and production in the economy.

Appendix I contains a preliminary analysis of direct energy use by the NZ farming sector for 1965-66, using input-output analysis. This indicates that fossil fuels accounted for around 18,000TJ of energy requirement, and electricity and manufactured gas for 3,000TJ. These figures are considerably in excess of the estimates presented later in this report in Chapter 3, mainly due to the definition of 'farming' used in each case. The I-O table sectoral definition includes all farming establishments as well as associated contracting firms, topdressing firms and shearers. It is therefore, a much broader definition than that used in Chapter 3, where 'farming' includes only those establishments actually engaged in agricultural, pastoral or horticultural production.

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[4] A third alternative is to calculate the energy requirement of imports using manufacturing statistics from the country of origin, but usually the data for this is not available.

[5] The latest published New Zealand Table is for 1965-1966.

[6] Carter (1974)

The I-O analysis contained in Appendix I also allows sectoral comparisons of energy use. Although the farming sector is the largest consumer of direct energy in absolute terms, its direct energy consumption per dollar of final demand (FD) is relatively low, being 17th in fossil fuel consumption (at 27MJ/$FD) and 57th in electricity and gas consumption (at 8MJ/$FD).[7]

2.2 Industrial Production Statistics

It is sometimes possible to submit industrial production statistics to energy analysis, either on an individual industry or sector basis. The average energy requirement per unit of output can be derived and compared between industries or interpreted in terms of probable response by that industry to alternative energy scenarios.

An example of this approach is a study by Casper on the 1968 UK Census of Production statistics. This data base was very detailed providing input and output data for 153 industries in financial terms and, in many cases, in physical quantities. The basic procedure involved three steps (Casper *et al*. 1975 : 9):

"(i) Evaluating the total energy requirement input using either the quantities (times their energy requirement/ton etc.,) or the values (times their energy intensities) of all the documented inputs;[8]

(ii) Evaluating the total output of the industry;

(iii) Calculating the energy intensity of the sector by dividing the energy requirement input by the output."

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[7]Petroleum and coal products, and electricity and manufactured gas only. Ranking amongst all 109 sectors in the economy.

[8]The energy intensity is the ratio of energy requirement to financial value.

The procedure used was an iterative approach, analysing first those industries which had high primary fuel consumption (the fuel industries). Third and fourth round iterations generated consistent approximations of the energy intensity of all major inputs. The results therefore incorporated three aspects of the energy requirement for any particular sector:

(i) The direct energy consumption

(ii) The indirect energy consumption of production inputs manufactured in the UK

(iii) The indirect energy consumption of imported production inputs.

While such an approach is useful in analysis of the inter-relationships between industrial establishments for which detailed input statistics are kept, its application is limited in agriculture due to the paucity of physical input data collected.

2.3 Process Analysis

Process analysis in energy research involves (Chapman 1974 : 96):

(i) Identifying the production processes which combine to generate the final product;

(ii) Analysing each of these production processes in terms of their input structure; and

(iii) Assigning an energy value to each input, and to the final product.

This procedure can either be applied on a sectoral or individual product basis at national or regional level, or alternatively at the level of individual industry or farm. Each of these applications is discussed below.

<u>2.3.1 National or regional studies:</u> Examples of research in this area are:

(i) Estimation of energy inputs on a national scale into the US food system, 1940-1970 (Steinhart & Steinhart 1974); the Australian food system (Gifford & Millington 1975); and the UK food system (Leach 1975).

(ii) Calculation of the energy requirement of one crop at the national level (Pimentel et al. 1973).

(iii) Estimation of energy inputs on a regional scale into Californian farming (Cervinka et al. 1974); New York State Agriculture (Gunkel et al. 1974); and Texas Agriculture (Coble 1975).

All of these projects have calculated the energy requirements of agriculture by estimating the physical inputs into agriculture, either from published data sources or farm surveys, and then applying energy values (e.g. MJ/kg) to the various inputs identified. The UK study (Leach 1975) used a variation of this technique in applying energy intensity values (MJ/$) to those inputs which could not be identified in physical terms.

The extent of input information analysed varies with the study, some concentrating on fuel use on farms (e.g. Cervinka et al. 1974; Gunkel et al. 1974) and others tabulating all major inputs such as fuel, fertilisers, equipment, feedstuffs and transport (e.g. Leach 1975; Gifford & Millington 1975). The level of physical input disaggregation in process analysis for these types of studies is to one level - i.e. energy values are applied to the actual inputs themselves (tractors, irrigation equipment) rather than their disaggregated components. The figure used for the energy requirement of a tractor, for instance, includes the energy consumed in the manufacture of the steel, tyres etc., as well as the final assembly of the tractor.

2.3.2 Farm level studies: Examples of this type of energy research are provided by:

(i) Estimates from surveys of the fuel use on farms in California and New York State (Cervinka et al. 1974, Gunkel et al. 1974. Although these authors conducted farm-level surveys, the data obtained is published in aggregate form.)

(ii) Calculation of total direct and indirect energy use on farms in South Australia (Handreck & Martin 1976), and Western Canada (Jensen 1975), and for single production systems such as beef (Lockeretz 1975).

(iii) Estimates of the on-farm effects of energy price increases (cropping systems in the US: Commoner et al. 1974) and comparative analysis of organic and chemical farming (Lockeretz et al. 1975).

Consideration of the implications of use of energy reducing production technology on one crop (Pain & Phipps 1975).

(iv) Comparative analyses of the energy requirements of cereal and forage crops in developed and developing countries (Slesser 1973).

These projects all involve process analysis in that they identify the inputs into the system at the farm level, either directly or indirectly, and apply energy requirement data to the physical information generated. This enables the energy component of the production system to be identified and related to the total system and, in some instances, for the physical and financial effects of energy alternatives to be explored.

2.4 The Alternatives Compared

Each of the alternative techniques discussed in this Chapter for evaluating energy requirements has particular advantages in certain applications. The analysis of direct energy consumption by sectors of the economy can be handled directly through use of data from the Department of Statistics, but questions on sectoral inter-relationships, indirect energy requirements, and imported energy content are probably best approached through input-output analysis. Due to the open nature of the N.Z. economy, however, and the heavy reliance on imports, little information on indirect energy requirements can be generated by this approach. A similar problem occurs with analysis of industrial production statistics.

The application of process analysis can overcome this problem to a large extent. Many overseas studies have calculated the energy inputs into a wide variety of intermediate products, and by addition of overseas transport and local manufacturing components, the indirect energy requirement in New Zealand can be derived. This type of approach, which looks at each sector or commodity in isolation, is the first step to a more comprehensive analysis. Once the data base has been expanded and more energy requirement estimates for both domestically produced goods and imports are available, a more detailed and integrated study of energy flows in the economy, using either input-output analysis or industrial production statistics could be undertaken.

A further development, once a sound data base has been established, is to use linear programming as a means of evaluating the impact of alternative energy scenarios. Examples are found in Dvoskin & Heady (1976) and Penn & Irwin (1977).

The next Chapter uses process analysis to identify the physical inputs into farms in New Zealand, and applies energy requirement information to this data to generate estimates of total direct and indirect energy use.

CHAPTER 3

ENERGETICS OF NEW ZEALAND FARMING

This Chapter estimates the direct and indirect energy inputs into New Zealand farms, using process analysis[9]. Between-country comparisons of the relative magnitude of energy inputs are made, and the energy ratio for New Zealand farming estimated[10].

3.1 Inputs into Agriculture

Little information on the input structure of New Zealand agriculture is collected in physical terms, most of the statistical data being on a financial basis. Table 3.1, for instance, details the inputs into agriculture during 1972-1975, and shows the relative importance of various input categories on a financial ranking. Capital consumption (for instance, new machinery, development expenditure) is the largest input grouping, followed closely by fertiliser, lime and seed, vehicle expenses, and repairs and maintenance. Although this ordering will not duplicate the relative energy requirements of the various inputs, it does identify those that require careful study.

3.2 Direct Energy Inputs

Direct energy inputs into farming derive from the following sources -

* Petroleum and Dieseline (Appendix II)
* Electricity (Appendix III)

There is negligible use of either coal or gas by the farming sector.

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[9] The energy requirement estimates used for much of the analysis depend heavily on the work of Sarah Dawson (1977). Without her base research being available, this project could not have been accomplished.

[10] Energy ratio = $\frac{\text{Energy out}}{\text{Energy in}}$, energy out being in bomb calorimeter units (as opposed to digestible dry matter).

TABLE 3.1

Inputs to Agriculture, 1972-1975

	Year ended March							
	1972		1973		1974		1975	
	$m	%	$m	%	$m	%	$m	%
Animal Health, Weed and Pest (Control)	32	7.2	42	8.2	51	8.6	47	7.3
Shearing expenses	27	6.1	30	5.9	32	5.4	37	5.7
Fertiliser, Lime and Seed	74	16.6	85	16.6	109	18.4	86	13.4
Vehicle expenses	61	13.7	66	12.9	71	12.0	88	13.6
Electricity	10	2.3	11	2.2	11	1.9	11	1.7
Feed and Grazing	57	12.8	75	14.7	91	15.4	104	16.1
Agricultural Services	20	4.5	24	4.7	28	4.7	31	4.8
Repairs and Maintenance	71	16.0	85	16.6	98	16.6	126	19.5
Packing and Containers	6	1.4	7	1.4	8	1.4	10	1.6
Railage and Cartage	24	5.4	28	5.5	31	5.2	39	6.1
Administration and General	40	9.0	34	6.6	36	6.1	40	6.2
Insurances	6	1.4	7	1.4	8	1.4	8	1.2
Rent	16	3.6	17	3.3	17	2.9	18	2.8
Subtotal	444	100.0	512	100.0	590	100.0	644	100.0
Salaries and Wages	136		155		180		200	
Operating Surplus	541		765		707		372	
Capital consumption	110		120		130		134	
Indirect taxes	24		26		30		34	
Subsidies	-25		-13		-5		-8	
Gross Input	1230		1565		1632		1376	

Source: NZ Department of Statistics, <u>New Zealand Official Yearbook 1976</u>, p.372

Total direct energy inputs are estimated to average, 1971-1976, 9365 TJ per year, 85 percent of which is from fossil fuel (Table 3.2). These estimates exclude supply losses, and therefore represent the amount of energy that is directly consumed by farming. The total is probably 15 percent less than the energy which has to be supplied to overcome production and supply losses[11].

3.3 Indirect Energy Inputs

Indirect energy inputs into farming derive from a multitude of items from fertiliser to fencing staples. The major components are analysed in the accompanying appendices, covering the inputs of -

* Fertiliser (Appendix IV)
* Lime (Appendix V)
* Fertiliser and Lime Transport (Appendix VI)
* Fertiliser and Lime Ground Contract Application (Appendix VI)
* Agricultural Aerial Operation (Appendix VII)
* New Tractor Purchases (Appendix VIII)
* Farm Trucks, Machinery and Equipment (Appendix IX)
* Fencing Wire (Appendix X)
* Fence Posts (Appendix XI)
* Drench (Appendix XII)
* Insecticides, Fungicides and Weedkillers (Appendix XIII)
* Commercial Transport not included in the above. (Appendix XIV)

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[11] There is no uniformity between researchers on whether an 'energy requirement of energy' should be included in energy input estimates. On the one hand, actual consumption totals represent the amount of energy that is an input to the production system and therefore the amount needed if alternative energy sources are to be found, and substituted for current energy forms. Alternatively, presentation of consumption figures may tend to disguise the magnitude of the actual primary energy necessary to create this delivered energy at the point of consumption, and overcome production and supply losses.

The average annual indirect energy inputs of 13,225TJ, 1971-1976, are dominated by fertiliser, which accounts for nearly 50 percent of the total (Table 3.2). The next largest indirect energy input is from farm tractors and machinery, which account for 3,650TJ or a further 28 percent. Clearly, however, some items of the input structure of farms will not be accounted for in Table 3.2, but these would probably only represent up to 10 percent in total.[12]

3.4 Total Energy Input

Total energy input into farming is estimated to average 22,600TJ per year (Table 3.2). This is close to the Pearson and Corbet estimate of 20,800TJ per year but the relative input components differ, petroleum fuel being 20 percent less and fertiliser 30 percent greater. The factors causing these divergences are:

* The original data covered a wider sectoral definition than included in this report. The original petroleum fuel deliveries therefore include consumption by contractors and other non-farm activities.
* The data in this report relates to average 1971-1976 inputs, whereas the original figures were for 1971-1972. Annual fluctuations in fertiliser use, for instance, are quite marked and can affect the annual energy requirement estimates significantly.
* Additional inputs to farming are included in this study, viz: fertiliser and lime transport and application, other ground and aerial transport and fencing material.

The largest form of energy input into farming in New Zealand is petroleum fuel, accounting for 35.5 percent of the total. The second largest input item is fertiliser (28%), followed by farm tractors and machinery (16.2%) and

[12] One important input not considered is farm buildings.

TABLE 3.2

Energy Requirement of
Inputs to New Zealand Farming

Year	1971-72	1972-73	1973-74	1974-75	1975-76	Average 1971-1976 TJ	Average 1971-1976 %
	. . . .	. . TJ . .	. . . . . .				
Direct Energy Inputs:[a]							
Motor Spirit and Diesel	7985	8280	8145	7955	7790	8030	35.5
Electricity	1260	1346	1303	1332	1422	1335	5.9
Total Direct[b]	9245	9626	9448	9287	9212	9365	41.5
Indirect Energy Inputs:							
Fertiliser	5451	7413	7923	4926	5861	6315	28.0
Limestone	320	377	388	355	365	360	1.6
Fert. & Lime Transport	461	560	564	432	504	505	2.2
Ground Contract Application[c]	289	353	357	266	314	315	1.4
Ag. Aerial Operations[d]	397	526	569	399	424	465	2.1
New Tractors	1544	1876	1906	1309	1121	1550	6.9
Other Farm Machinery						2100[e]	9.3
Fencing Wire	288	378	434	278	236	325	1.4
Fencing Posts						297[e]	1.3
Drench and Dip						18[e]	0.1
Insecticides, Fungicides & Weedkillers	327	819	544	367	571	525	2.3
Commercial Transport n.e.i.[f]						450[e]	2.0
Total Indirect	11,942	15,167	15550	11,197	12,261	13,225	58.5
TOTAL ENERGY INPUT[g]	21,187	24,793	24,998	20,484	21,473	22,590	100.0

[a]Excludes allowance for supply losses.

[b]Negligible use of coal and gas by farming.

[c]Fertiliser and lime.

[d]Fertiliser, lime, insecticides, fungicides, weedkillers, supply dropping, etc.

[e]Indicative estimate only. Included in column totals.

[f]Half of road transport assumed to be to-farm (Ambler, 1975). Indicative estimate only.

[g]To farm gate. Column totals include items note e. Buildings not included.

transport and contract application of fertiliser, lime, weedicides and pesticides (7.7%).

Marked annual variation occurs in total energy input, the range being from 6% below to 10% above the mean in the five year period, 1971-1976. The main cause of this variation is the difference in fertiliser application between years, although petroleum fuel usage also displays some oscillation. Since studies by the Ministry of Agriculture and Fisheries suggest a high correlation between farm income and fertiliser application, a similar relationship is hypothesised with energy input. Figure 1 graphically compares those and other trend variables, the base data being tabulated in Table 3.3. Clearly, energy input to the New Zealand farming system is highly correlated with farm income, and bears little relationship to costs or volume of output during the 1971-1976 period.

FIGURE 1

Annual Movements in Major Agricultural Indices

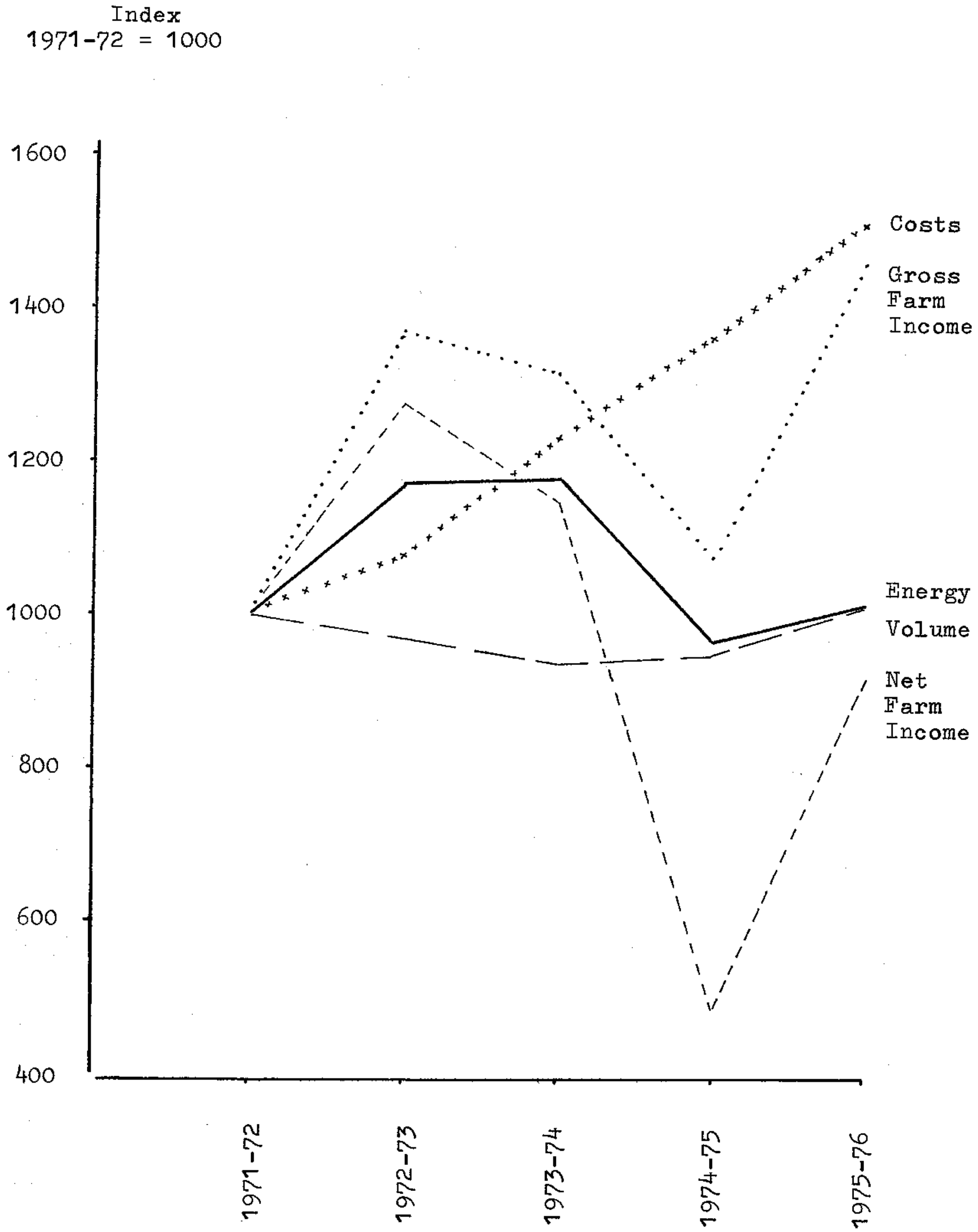

TABLE 3.3

Annual Movements in Agricultural Indicators

Year	Net Farming Income	Gross Farm Income	Volume Index of Agricultural Production	All Farming Costs Price Index
	\$m	\$m	1965-66=1000	1971=1000
1975-76	496p	1641.0p	1138p	1593
1974-75	268	1214.0p	1071p	1439
1973-74	624	1483.0p	1064	1295
1972-73	693	1533.6p	1094	1140
1971-72	542	1125.7	1133	1058
1970-71	324	934.9	1102	1000

Source: Ministry of Agriculture and Fisheries, Economic Review of New Zealand Agriculture (various issues).

Department of Statistics, National Income and Expenditure 1974-75; Monthly Abstract of Statistics (Jan-Feb 1977, Aug. 1977)

The New Zealand component of the indirect energy requirement data has been calculated by Dawson (1977) and is summarised in Table 3.4. A large amount of the indirect energy input into New Zealand farming is imported energy - that already embodied in imported raw materials and goods. For instance, only five percent of the energy requirement of fertiliser utilised by New Zealand farmers is added to the produce from New Zealand direct energy sources, the majority being expended overseas in the mining and transportation operations. Similarly, the NZ component of the energy requirements for farm tractors, drench, dip, insecticides, fungicides and weedkillers is relatively small. Naturally, however, the energy inputs to some activities such as limestone manufacture, aerial and ground application of fertiliser, lime and weedkillers, and commercial

TABLE 3.4

New Zealand and Overseas Energy Requirements for Agricultural Input Items

COMMODITY	UNITS	NEW ZEALAND				OVERSEAS				TOTALS		
		Electricity	Liquid Fuel	Solid Fuel	Gaseous Fuel	Electricity	Liquid Fuel	Gaseous Fuel	Unknown Makeup	New Zealand	Overseas	Total
Fertiliser												
Phosphate Rock	MJ/kg						1.8				1.8	1.8
Sulphur	MJ/kg						2.3	3.0			5.3	5.3
Superphosphate	MJ/kg	0.02	0.04				1.36	0.34		0.06	1.7	1.8
Lime - Wet	MJ/kg	0.01	0.1							0.1		0.1
- Dry		0.01	2.1							2.1		2.1
Machinery												
Tractors (2000 kg)	MJ/tractor	300							3.3×10^5	300	3.3×10^5	3.3×10^5
Combine Harvester (800 kg)	MJ/harvstr.	1200							1.3×10^6	1,200	1.3×10^6	1.3×10^6
Seed Drill (900 kg)	MJ/unit		19,000						48,000	19,000	48,000	67,000
Cultivator (800 kg)	"		17,000						43,000	17,000	43,000	60,000
Harrow	"		900						2,300	900	2,300	3,200
Fencing Material												
Bright Steel Wire	MJ/kg	5.0	0.5	25.5	2.5					34.0		34.0
Galvanised Wire	MJ/kg	5.0	0.5	25.5	2.5				4.0	34.0	4.0	38.0
Concrete Posts	MJ/post	3.5	27.0	36.0						66.5		66.5
Timber Posts	MJ/post	0.7	8.0							8.7		8.7

Source: Dawson (1977)

transport are totally dependent on primary energy from New Zealand energy supplies.

By matching the two tables of indirect energy requirement and sources of energy, it is estimated that approximately 72 percent of the indirect energy requirement for New Zealand farming is imported from overseas, embodied in the physical inputs purchased. The local primary energy input is mainly attached to the transport sector. When allowance is made for the fact that approximately 95 percent of all liquid fuel used in New Zealand is imported, the overseas energy contribution to New Zealand farming is around 90 percent of the total use. Thus New Zealand is almost totally dependent in overseas energy inputs to sustain its current system of farming.

3.5 Comparative Analysis of Energy Inputs

The data on energy inputs into New Zealand farming (Table 3.2) can be compared with similar analyses for the farming systems of the UK (Table 3.5), USA (Table 3.6) and Australia (Table 3.7). Although the methods used for deriving the tables are not exactly analogous,[13] useful insights are possible from the relative weightings attached to the various inputs between countries (Table 3.8).

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[13] For instance, the US analysis excludes fuel losses to end use, while the Australian table includes an additional 11.5% for this component of primary fuel energy requirement.

TABLE 3.5

Energy Inputs to UK Agriculture, 1968

	'000TJ	%
On farm:		
Coal	5.62	1.5
Coke	3.31	0.9
Electricity (non-domestic)	29.75	7.9
Petroleum	69.74	18.4
Fertiliser	81.92	21.8
Machinery	31.77	8.4
Chemicals	8.48	2.2
Buildings	22.77	6.0
Transport services etc.	16.28	4.3
Feedstuffs (incl. imports)	104.5	27.5
Miscellaneous	4.28	1.1
Total	378	100.0
Food Processing[a] (incl. transport and packaging)	476	
Food distribution[a]	139	
	993[b]	

[a]Includes both demestically produced and imported food.

[b]Energy content of the output of UK agriculture for human consumption, 1968, estimated at 130,000 TJ.

Source: Adapted from Leach (1975) and White (1975).

TABLE 3.6

Energy Use in US Food System, 1970

	'000 TJ	%
On farm:		
Fuel (direct use)[a]	971.3	44.1
Electricity	267.1	12.1
Fertiliser	393.6	17.8
Agricultural Steel	8.4	0.4
Farm Machinery; new only	334.9	15.2
Tractors; new only	80.8	3.7
Irrigation[b]	146.5	6.7
Subtotal[c]	2202.6	100.0
Processing Industry[d]	3524.9	
Commercial and home[e]	3366.2	
Total[f]	9093.7	

[a]Excludes fuel losses, wellhead/mineshaft to end use (10-12%).

[b]4.1868 x 10^3MJ per acre irrigated.

[c]Excludes repairs and maintenance, new construction, seed and animal health, research expenditures.

[d]Includes truck transport only.

[e]Refrigeration and cooking only. Neglects automobile use.

[f]Excludes allowances for food exported, thus overstating the energy used in the US food system. Represents 12.8% of total US energy use. Original data in calorific units converted to joules using 1.0 cal = 4.1868 J.

Source: Adapted from Steinhart and Steinhart (1974).

TABLE 3.7

Energy Inputs to Australian Agriculture, 1965-69

	'000TJ	%
On farm:		
Electricity[a]	8.4	9.7
Primary fuel[b]	46.2	53.2
Fertiliser	18.8	21.6
Farm Machinery	6.8	7.8
Agricultural Chemicals	4.4	5.1
Road Transport of Farm Supplies net	1.0	1.2
Farm Labour	1.2	1.4
Sub total[c]	86.8	100.0
Transport to factory	7.4	
Processing and packaging	84.4	
Transport from factory	7.7	
Home (incl. transport from retail)	121	
Total[d]	307.3	

[a]Thermal efficiency of 30% assumed.

[b]Includes 11.5% addition for refining and transportation.

[c]Excludes repairs and maintenance to infrastructure and capital items. Approximately 29% retained for consumption as food in Australia.

[d]Represents 25% of total non-domestic use of energy.

Source: Adapted from Gifford and Millington (1975).

TABLE 3.8

A Comparison of Energy Inputs
Into Farming Between Countries

Input Category	UK	US	Australia	NZ
	. . . percent of total energy input . .			
Direct Inputs				
Petroleum	33	47	55	41
Electricity	14	13	11	7
Total	47	60	66	48
Indirect Inputs				
Fertiliser	38	20	25	33
Machinery	15	20	9	19
Total	53	40	34	52
TOTAL	100	100	100	100

Source: Adapted from Tables 3.2 and 3.5 - 3.7.

Although the energy input associated with fertiliser in New Zealand farming is relatively high at 33 percent, this is because all other inputs are lower than in more intensive agricultural systems as found in the US and UK. Heavy use of nitrogenous fertiliser is usually associated with feedlot farming, which also has a considerable complementary energy investment in buildings, equipment and waste disposal systems.

An indication of the degree of intensiveness of agricultural systems can be obtained by comparing farm energy use and national population. New Zealand farming has an energy input of approximately 7.4 GJ per head of population, which compares with figures of 6.6 for Australia, 6.8 for the UK and 10.3 for the USA (Table 3.9). When adjustments are made for the fact that New Zealand produces enough food for, perhaps, three times the current population level (approximately 66 percent of meat and dairy production is exported) and that the UK imports a substantial quantity of meat and dairy products, the energy input into farming in New Zealand per head of population which could be supported by the output may be around one quarter of the comparable figure for the UK.

Similarly, New Zealand would compare well with the USA and Australia on this basis - allowance for exports would lower the USA figure slightly and the Australian figure substantially, perhaps to around 9 GJ and 3-4 GJ per head of supportable population respectively. The New Zealand farming energy input figure of around 3 GJ per head of supportable population is one third of the USA figure, and slightly less than the Australian situation.[14] These figures, however, require detailed study and are only used here for illustrative purposes as to the kinds of results which might be expected.

TABLE 3.9

Energy Inputs Into Farming Related to Population

Country	Total Energy Input	Population	Energy Input/ head of population	Energy Input/ head of supportable population[a]
	'000TJ	m	GJ	GJ
New Zealand	23	3.1	7.4	≏ 3
Australia	87	13.2	6.6	≏ 3 - 4
UK	378	56	6.8	≏ 11
USA	2203	213	10.3	≏ 9

[a]For general interpretation only. Supportable population defined as the number of people which could be maintained at the same level of food intake as is currently exhibited in these four countries, with existing local farming output.

[14]The marked difference can be attributed to the type of farming predominating in each country -- extensive pastoral farming in Australia and New Zealand, and intensive cropping and feedlot farming in the USA and UK. Constraints on energy supply are thus likely to have a greater impact on British and American agriculture than in New Zealand or Australia, and comparative advantage will shift.

3.6 Energy Input-Output Ratios

Energy input-output ratios can be useful in comparative analysis of agricultural systems. Figure 2 summarises the analysis by Leach (1975) on the ratios for differing systems of food production, and demonstrates the high energy ratios associated with subsistence agriculture which has few inputs except labour, and the lower ratios associated with the more intensive types of agricultural systems. For UK agriculture as a whole, Leach estimates an energy ratio of 0.34 at the farm gate. This figure can be contrasted with that for an extensive system of agriculture in Australia of around 2.5 (Gifford and Millington 1975 : 7).

The gross energy value of the output of New Zealand farming is estimated to average 55,500 TJ per year (Table 3.10) implying an energy ratio of around 2.3, similar to the Australian situation.[15]

From Table 3.10, the average energy requirement per kg of output is around 6 MJ, which can be compared to estimates by Walker (Walker 1975 a and b) of 1.2 MJ/kg for wheat production in Canterbury, and 3.7-11 MJ/kg (incl. labour) for lamb production in Canterbury.[16] The national data is dominated, however, by the large volume of milk produced, over half the total output in weight. If this milk is alternatively analysed in terms of final product (butter, cheese, casein etc.), the average energy requirement doubles to around 13 MJ/kg of output.

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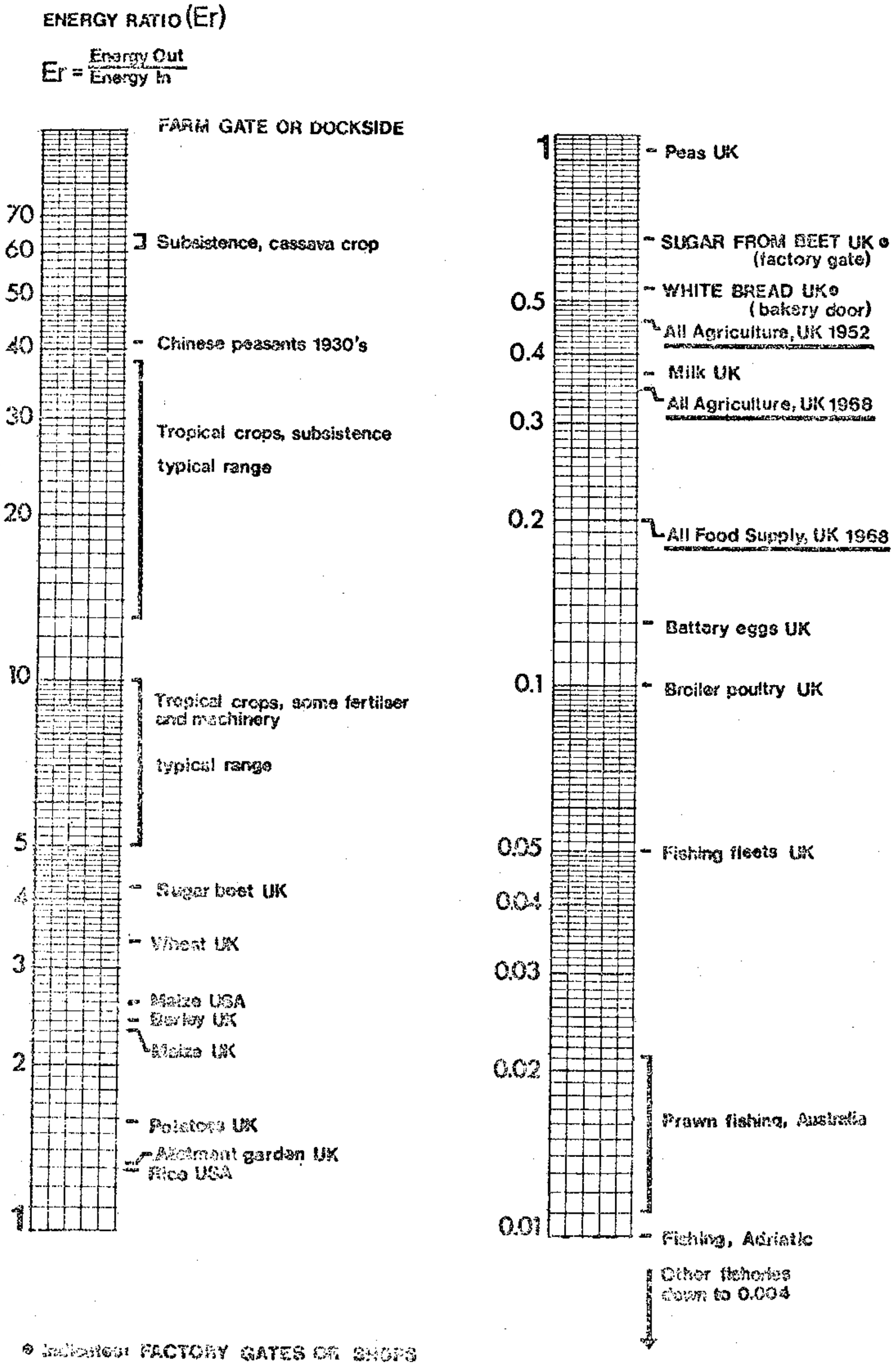
[15] This comparison is biased against the New Zealand farming situation which exhibits a relatively higher ratio of animal to crop products.

[16] These figures closely parallel the preliminary results being obtained by Mr I.G. McChesney of the Joint Centre for Environmental Sciences, who has calculated the average energy requirement of meat production at around 7.5 MJ/kg for 21 mixed cropping farms in mid-Canterbury (McChesney 1977 : pers.comm.).

FIGURE 2

ENERGY RATIOS FOR FOOD PRODUCTION



Source: Leach (1975)

TABLE 3.10

Energy Value of Output of
The New Zealand Farming Sector, 1971-76

Commodity	Average Output[a] 1971-76	Energy Conversion Factor[b]
	'000 tonnes	MJ/kg
Milk[c]	5900	3.08
Meat Products[d]		
Beef	440	11.5
Veal	25	7.8
Mutton	188	15.0
Lamb	345	13.8
Pig Meat	37	23.1*
Edible Offal	57	5.0
Wool	309	23.7*
Crops:		
Wheat	309	16.7*
Barley	274	16.3*
Oats	51	18.3*
Maize	127	16.7*
Peas	54	15.6*
Vegetables[e]	284	3.85*
Potatoes	227	3.85*
Fruit[e]	60	2.55*
Apples and Pears[e]	129	2.55*
Tobacco	3	18.4*
	8816	

Total gross energy value of output estimated at 55,500 TJ.

[a] From Department of Statistics (1976) New Zealand Official Yearbook, 1976 and (1977) Monthly Abstract of Statistics, July 1977

[b] Gross energy values; ie. bomb calorimeter values. Calculated from gross energy values of 38.9MJ/kg for fat, 23.4MJ/kg for protein and 15.9MJ/kg for CHO_5 and the relevant composition of the commodities listed. (A. Nicol, 1977 pers.comm.). Asterisks denote Australian data from Gifford & Millington (1975).

[c] Specific gravity of 1.032 applied to off-farm deliveries averaging 5718 m litres.

[d] Bone-in weights.

[e] 1971-74 average output.

3.7 Energy Ratios Beyond the Farm-Gate

Pearson & Corbet (1976) have collated information on the direct energy inputs into the processing of New Zealand agricultural products, estimating these to be twice the on-farm direct energy use. No analysis has been completed on the retail distribution and food preparation sectors in New Zealand. A brief study of Tables 3.5, 3.6 and 3.7 gives some indication of the relative magnitudes of these components.

The Australian farming sector is a large exporter of farm produce and net domestic food requirements account for 42 percent of food products at the farm gate in energy terms. (Gifford and Millington, 1975:5). The energy requirement of processing and packaging of this domestically consumed food[17] accounts for 2.7 times the energy required to produce it, and for home preparation the multiple approximates 3.3 of the total energy requirement. Of the energy cost of producing and getting food to the household table in Australia, only 14 percent is the to-farm-gate component.

The US farming sector does not export relatively as much of its total output as Australia in energy terms, but even with no allowance for exports, the farm gate energy costs approximate 24 percent of the total energy requirement of food on the household table. It is probable that if exports were excluded from total farm-gate energy costs, the proportion would fall below 20 percent.

Given the lack of more detailed analysis and statistical data, no specific conclusions can be made as to the beyond-farm-gate energy requirements of the New Zealand food system. It is probable, however, that for locally-consumed produce, on-farm energy inputs account for less than one fifth of the total energy input required to put it on the household table.

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[17] Including transport to the retail sector.

CHAPTER 4

RESEARCH RELATED TO ENERGY IN NEW ZEALAND AGRICULTURE

This Chapter outlines a framework for research relating to energy in agriculture. Current and proposed research programmes in this area are then briefly summarised, followed by some comments on possible areas for further research.

4.1 Framework for Research into Energy in Agriculture.

In considering the many possibilities for research in this area, it is important to identify the objective involved - what do we really want to know? The basic interest is impact analysis - what effects will there be on agriculture, and indirectly on New Zealand society, should the present energy use pattern in agriculture be altered by changes in the availability and/or relative price of various energy resources?

To evaluate these impacts, detailed information is needed on:

- the present use pattern;
- the potential for conservation; and
- the potential for alternative energy supply.

Present energy use. The present use pattern can be evaluated at national level, and at a disaggregated level. Agricultural sectors can be classified according to region, geography or production type. Both direct and indirect energy use can be considered. Indirect energy use can be further classified to identify overseas and local inputs. Detailed study can identify the end uses of energy in each farm sector and thus allow an evaluation of the function of energy in that sector by exploring the relationship of energy use to land and labour productivity and human comfort and convenience. For example, there is a close relationship between the use of energy-intensive fertilisers and land productivity, whereas energy-intensive tractors contribute largely to labour productivity.

<u>The potential for conservation</u>. With a full understanding of present use patterns, it is possible to identify areas with potential for energy conservation. The analysis of any conservation strategy is fourfold -- technical, economic, social and environmental. The technical aspect is concerned with the physical change required (e.g. more frequent tuning of tractors, reduced tillage cultivation), the energy savings, the requirements for other resources, and the effect on land productivity. The economic aspect covers the calculation of the dollar cost of a particular conservation action, and also the fiscal measures that could be taken to encourage such an action (e.g. taxes, subsidies). Social factors include the impact on labour utilisation and rural populations, and the social measures required to encourage conservation (e.g. publicity, training). Environmental impacts of a conservation step, if any, also need to be considered.

<u>The potential for alternative energy supply</u>. This area can be divided into the technical, economic, social and environmental aspects, in an identical manner to the conservation study. Alternative supply technology can be separated into two problems -- the production of the energy form (e.g. electricity generation, methanol from natural gas) and the integration of the new supply with the energy demand. With the exception of farm based supply alternatives (solar heat, wind, biomass), the production problem is not of direct concern to agriculture. However, the integration problem is important and needs to be based on the end-use analysis within each farming sector. Factors such as the power requirement, the duration of the activity, the timeliness factor, the location (e.g. moving or stationary) all need to be considered.

The evaluation of the three areas discussed is not restricted to the farm, but is applicable to the transport, processing, marketing and final consumption of agricultural produce.

Given the background on energy use, conservation and alternative supply, it is possible to attempt evaluations of impact analysis, to explore alternative energy scenarios, to forecast future energy demands and supply modes and so on.

4.2 Published Research

The following list summarises the published research reports and papers which examine energy in New Zealand agriculture and related processing industries.

Topic	Author(s)
Energy Use in Agriculture	Pearson & Corbet (1976)
Meat Processing	Pearson & Pilling (1975)
Forestry	Beca, Carter, Hollings & Ferner (1976)
The Production of Ethanol from Farm Crops	Mulcock (1975 a, b c)
Direct Energy Inputs by Farm Type	Pilling (1977)
Textiles	Halliday et al (1977)
Biogas Production	Stewart (1977)
Energy Farming (general)	Troughton & Cave (1975) and other authors in this publication.
Energy Farming from Trees	Uprichard (1975) Cousins (1975) Lowry (1976)

4.3 Current Research Projects

A number of research projects relating to energy in New Zealand agriculture are currently underway. They include -

Farm energy modelling. The New Zealand Energy Research and Development Committee (NZER & DC) is funding a study by the Joint Centre for Environmental Sciences, Lincoln College, into energy use in agriculture. It is aimed at quantifying energy inputs to NZ agriculture to allow the development of a model to be used to evaluate the impact of energy shortages and /or high energy prices in the future and the potential savings possible by the use of new energy sources and by energy conservation. The data collection process has included a detailed study of the technique of energy analysis (Pearson 1977), a survey of industry associated with agriculture to calculate energy requirements of farm inputs (Dawson 1977), a study of energy use in agriculture on a national scale (Pearson & Corbet 1976), and surveys of mixed cropping farms in mid-Canterbury and hill country farms in North Canterbury. Further farm surveying is planned, in order to gain detailed information on energy use in different farming sectors.

Farm fuel conservation. Work is in progress in the Agricultural Engineering departments at Massey and at Lincoln College looking at fuel savings resulting from different cultivation practices such as reduced tillage and multiple implement passes.

Wind Energy Surveys. A major survey of the potential for wind power is being carried out by Lincoln College and the University of Canterbury and University of Otago.

Energy farming. A number of projects on different aspects of energy farming are in progress at various institutions in New Zealand. At the University of Auckland, the Forest Research Institute in Rotorua, and the DSIR Physics and Engineering Laboratory at Lower Hutt, attention is being given to the technologies of energy farming from trees. At Lincoln College, research is underway on the fermentation of farm crops to ethanol, and on the potential for use of macrocarpa as a fuel. At Invermay, work is in progress on the anaerobic digestion of farm wastes and farm crops to form 'biogas', principally methane. The NZER & DC has established a biomass research group to co-ordinate research work in this field and to commission additional research where required.

Fertiliser industry survey. The Joint Centre for Environmental Sciences, Lincoln College, has carried out a survey of energy use in the fertiliser industry in New Zealand as part of its contract with the NZER & DC. A report on this work is expected late in 1977.

Food industry surveys. Vickers of the Dairy Research Institute, Palmerston North, is just completing a report on energy use and potential conservation measures in the New Zealand dairy industry. In addition, the Food Technology Department at Massey University is currently studying methods of saving energy in those parts of the food industry not covered by previous research on the meat and dairy sectors.

4.4 Further Research

The complete study of all aspects of energy in agriculture requires an interdisciplinary approach which is beyond the resources of any one organisation. There are, however, a number of potential areas for useful research by agricultural economists which can be identified, and which could complement research programmes by other organisations.

Possible studies are divided into four groups -- those concerned with present energy use, with energy conservation, with alternative energy forms, and integrated studies.

Energy uses

1. Energy Inputs into Farming: Energy use data related to farming sectors can be obtained from information collected in cost-of-production surveys carried out by the Producer Boards, Meat and Wool Boards' Economic Service, the Statistics Department and the Agricultural Economics Research Unit. Additional questions could be inserted in future surveys to improve the data base for energy analysis. This would be a cheap and simple method of obtaining reliable data on energy use in the major farming sectors.

2. Energy in the total food system: Research could be started aimed at calculating the total energy input into the NZ food system, with particular emphasis on the energy requirements from farm gate to domestic consumption. This could lead to cost-effectiveness analysis of the potential energy savings in sections of the food chain. Much of this work could be based on a collation of existing information from other research groups.

Energy Conservation

1. Energy use in agricultural transport: The most serious energy problem faced by New Zealand is the high levels of imported liquid fuel needed for the transport sector. Farming involves a heavy use of transport, both of inputs to the farm and of products from the farm. Any rationalisation of transport could then have a marked impact on the farming sector. The study envisaged could examine the alternative methods for conservation of fossil fuel energy in transport recommended by Beca Carter Hollings & Ferner (1977), and study their implications for agriculture in New Zealand.

2. On-farm impacts of reduced fertiliser use: The major indirect energy input into farming in New Zealand is fertiliser. This study could investigate the impact of changing input structures on New Zealand farms by studying such parameters as optimal production systems, gross output, net farm income, and export earnings, and the resulting implications for energy saving. This study could be a forerun to the modelling work discussed under 'Integrated Studies'.

Alternative energy forms..

1. Economic evaluation of energy farming - Analysis of the potential of 'energy farming': This could extend the work of Troughton and Cave (1975), Uprichard (1975), Cousins (1975), Lowry (1976) and Stewart (1977), establishing comparative costs and returns from energy farming, and the implications for regional development and the national economy.

2. Economic constraints to alternative energy forms: The development of a technically feasible energy form does not guarantee its implementation. Consideration needs to be given to relative costs, subsidies, taxation factors, etc., to evaluate the farmers' reaction to alternatives to diesel, petrol and electricity. Study also needs to be undertaken into the best forms of distribution and marketing of alternatives (such as liquified petroleum gas).

Integrated studies

1. Energy modelling: A variety of methods have been used overseas to model energy flows in agriculture. A careful evaluation of past work in this field could allow the development of a practical model suited to NZ conditions.

2. Farm impacts of energy price rises: Farmers are shielded by subsidies from the true costs of some inputs, particularly fertiliser. In the light of rising energy prices, a useful study could evaluate the farm response to changing input costs and/or subsidy payments, and the resulting implications for energy use.

4.5 An Assessment of Alternatives

Research priorities change over time, and while certain projects appear to have immediate relevance, new developments in this field can quickly change the rankings. Because of the multi-disciplinary nature of the total research effort required into energy in agriculture, careful planning is necessary to preserve balance and uniformity in objective. It is hoped that the alternatives outlined in this chapter will assist in this overall planning, so that priorities can be established and further research continued.

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APPENDICES

APPENDIX I

Analysis of Direct Energy Use by the NZ Farming Sector, 1965-1966, using Input-Output Analysis

I.1 The Input-Output Tables

The NZ input-output tables analysed are those for the year 1965-66[1]. The 109 sector table is used for the analysis since it provides greater detail than the 44 sector condensation for direct energy requirement information.[2]

I.2 Sectoral Definition

The definitions of the Farming (S_1), Petroleum and Coal (S_{62}) and Electricity and Gas (S_{97}) sectors are briefly outlined below to aid in interpreting the analysis.

S_1 Farming. All establishments engaged in agricultural, pastoral and horticultural activities, as well as the contractors associated with the industry (e.g. topdressing firms, shearers, harvesting and weed control contractors).

S_{62} Petroleum and Coal Products[3]. Establishments engaged in the processing (but not extraction) of petroleum and coal, the main output being lubricating oils, greases, gasoline, diesel and fuel oils, and bitumen[4]. The conversion of coal into gas in included in Sector 97.

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[1] NZ Department of Statistics (1975a and 1975b). Tables for 1971-72 should be published during 1978.

[2] The 'Electricity and Gas' sector is identical in both Tables S_{97} and S_{33} but the 'Petroleum and Coal Products' sector in the larger table S_{67} is amalgamated with six other chemical product sectors in the condensed version S_{22}. Subscripted numbers refer to the sector numbers - e.g. S_1 refers to Sector 1 as used in the input-output table.

[3] Analogous to Industrial Production Code 390.

[4] The 'Mining and Quarrying' Sector (S4) only encompasses activities within the location of the mine or quarry.

S_{97} Electricity and Gas. Establishments which produce and distribute electricity and gas including geothermal steam production and conversion of coal into gas. The majority of these establishments are distributors such as the local power boards.

I.3 Energy Sales via Petroleum and Coal Products

The sales of the petroleum and coal products sector in 1965-66 totalled $54.0m, of which the household sector (S_{111}) was the largest purchaser ($16.8m). The next largest consumer in total was the farming sector ($8.8m) which represented the largest purchaser among the intermediate sectors, in fact nearly double the purchases of the second largest intermediate sector, road transport ($4.5m).

Petroleum production in 1965-66 is estimated to have an energy content of 111,419 TJ, made up as follows:[5]

Motor Spirit	1556m litres at 34.7 MJ/L
Diesel	563m litres at 38.3 MJ/L
Fuel Oil	677m litres at 40.8 MJ/L
Other types	202m litres at 40.8 MJ/L

[5] Petroleum production figures from Department of Statistics (1977:19). Other types consist of bunker fuels and bitumen. Output of Industry 390, 1965-66, totalled 3047m litres, valued at $56.5m, which closely approximates these figures in quantity and value terms. (Department of Statistics. 1968b:200).

This energy estimate closely parallels that of the NDC Fuel and Power Committee which estimated the historical usage of energy from oil products, 1965-66, at 113,518 TJ (107.6 BTU x 10^{12}) or two percent more than the 111,419 TJ derived above.[6]

I.4 Energy Sales via Electricity and Gas

The total output of the electricity and gas sector in 1965-66 was valued at $167.8m, $61.4m of this being the value of bulk sales of high voltage electricity generated by the NZED to power boards and municipal electricity departments[7].

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[6]The Fuel and Power Committee of the NDC estimated historical usage (1965-66), in consumer energy terms as follows:

		TJ
Oil Products		113,518
Coal		47,739
Manufactured Gas		2,954
Electricity		
Primary	36,978	
From Coal	2,585	
From Oil	-	
Total		39,563
Total Consumer Energy		203,773

Consumer energy reflects 'the quantity of each energy form actually supplied to consumers'. A conversion factor of 1.0 BTU = 1.055 x 10^3 J is applied to the original data. (NZ National Development Conference 1969:10-11).

[7]Shown by the intersection of row 97 and column 97 in the input-output table. Bulk and Interchange sales of $60.8m for the year ended 31/3/66 closely approximate this figure (Department of Statistics 1967:558).

The largest consumer was the household sector ($52.4m), but the largest purchaser among the intermediate sectors was farming ($7.9m), exceeding the trade ($7.4m) service ($3.8m) and pulp and paper ($3.5m) sectors by significant amounts.

Electricity and gas sales in 1965-66 are estimated to have an energy content of 41,838 TJ, made up as follows:

Total electricity generated for public supply[8]	38,081 TJ
Total gas generated[9]	3,757 TJ
	41,838 TJ[10]

The NDC estimates (see footnote 6) of 42,517 TJ closely approximates this figure, the difference being less than 2%.

I.5 Energy Sales - Coal: Table I.1 estimates total consumption of coal in New Zealand, 1965-66, at 2.56m tonnes of which 0.7m tonnes was used in gas or electricity generation. The majority of the remainder was consumed directly by industry, 0.9m tonnes, with negligible amounts being purchased by the farming sector.

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[8] Total electricity generated for public supply for the year ended 31/3/66 was 10,578m kWh, of which 9,004m kWh sold retail for $98.7m. Together with 'bulk' and 'other' sales of $62.9m, total sales approximated $161.6m (Department of Statistics 1967:558-559).

[9] Gas generated totalled 5975m ft^3, of which retail sales were 4933m ft^3, for a total revenue of $6.291m, exclusive of subsidy (Department of Statistics, 1968b:270).

[10] Conversion factors applied are:

$1 \text{ kWh} = 3.6 \times 10^6 \text{J}$

Energetic value of coal gas = 22.2 MJ/m^3

Total value of electricity and gas sales from footnotes 8 and 9 above is $167.9m, which is in line with the $167.8m sales depicted by the sector in the input-output table.

TABLE I.1

Coal Consumption in New Zealand, 1965-66

Consumer and Sector	Consumption ('000 tonnes)
Railways S_{101}	128
Gasworks S_{97}	247
Electricity S_{97}	455
Households S_{111}	339*
Factories:	
Meatworks S_5	115
Dairy S_8	307
Pulp and Paper S_{44}	127
Cement S_{66}	221
Other	177
Other Consumers	448*
Total	2,563

*1966 figures

Source: Department of Statistics. N.Z. Yearbook 1970. p.467.

Although the energetic value of coal consumption would need to be incorporated in any overall study of energy flows in the economy, it is not considered further here because it constitutes such a small direct input into the farming sector.

I.6 Direct Energy Inputs Into Farming.

The data generated in the previous sections is summarised in Table I.2. If it is assumed that energy inputs into the farming sector (S_1) reflect the economy average in terms of energetic value per dollar of input, the direct energy requirements of the sector approximates 21,000 TJ in 1965-66, 85 percent of which is from petroleum and coal products. This figure can only be interpreted broadly, however, since differential energy pricing policies between consumers mean that figures on average energy values per dollar (MJ/$) of sector output will exhibit high variations.

TABLE I.2

Direct Energy Input into Farming in New Zealand, 1965-66

Sector Number and Name	Energy Content of Sector Output	Value of Sector Output	Average Energy Content per Dollar of Sector Output[a]	Sales by Energy Sectors to Farming	Energy Content Of Sales to Farming[a]
	TJ	$m	MJ/$	$m	TJ
62. Petroleum & Coal Products	111,419	54.0	2,063	8.8	18,154
97. Electricity & Gas	41,838	107.0[b]	391	7.9	3,089

[a]Energy pricing policies differ markedly between consumers. For instance, average electricity price (1976) varies between 1.202 c/kWh for Domestic consumption and 2.185 c/kWh for Commercial consumption, and fuel oil is generally cheaper for industry than for agriculture. These figures can only therefore be used as broad indicators.

[b]Value of gross output less sales to supply authorities.

I.7 Sectoral Comparisons of Direct Energy Inputs

As mentioned in the previous sections, farming is the largest intermediate sector in terms of total direct energy consumption of petroleum, coal products, electricity and gas[11]. The interesting comparison however, is to study the sectors on a common base, and this is provided by the $(I-A)^{-1}$ matrix in the input-output tables which detail 'the direct and indirect outputs required by each industry from itself and from every other industry in the economy in order to produce one unit of its output for final demand[11,12].' This information can be used to derive the comparative energy requirements if final demand was increased by one unit in various sectors; and this calculation is shown in Table I.3.

It is clear from these figures that farming is one of the lowest users of electricity and gas per unit of output, although its use of petroleum and coal products is comparatively high, ranking 17th among all sectors in the economy.

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[11]Does not include coal.

[12]Department of Statistics (1975a:5).

TABLE I.3

Total Energy Inputs Required for a One Dollar Change in Final Demand 1965-1966[a]

Sector Number and Name	Energy Input Required to produce one Dollar of Final Demand[b]	Ranking over 109 sectors
Petroleum and Coal Products	\$FD	
S_1 Farming	27	17=
S_{63} Bituminous Material	425	1
S_{104} Road Transport	56	2
S_{103} Air Transport	54	3
S_{67} Glass Production	52	4
S_9 Milk Treatment	50	5=
S_{11} Grain Milling	31	14
Electricity and Gas		
S_1 Farming	8	57=
S_{44} Pulp and paper	38	1
S_{66} Cement	30	2
S_{69} Lime	25	3
S_{11} Grain Milling	21	6
S_9 Milk Treatment	20	8=

[a]Excludes coal consumption, except when used in electricity, gas, or coal products production.

[b]$(I-A)^{-1}$ multiplied by the average energetic values per \$ (Table I.2). Calculations therefore assume average energetic values are constant for all sectors.

APPENDIX II

Analysis of Use of Petroleum Products by NZ Farmers

	1971	1972	1973	1974	1975	1976	Average
Deliveries to 'Agriculture & Hunting'[1] ('000 tonnes):							
Gasoline				108.4	113.8	108.2	110.1
Light Diesel Oil				97.3	98.1	98.4	97.9
Total[2]	n.a.	n.a.	n.a.	221.7	228.9	231.1	227.2
(m. litres)[3]							
Gasoline				150.0	157.2	149.3	152.2
Light Diesel Oil				117.8	118.7	119.2	141.4
Gasoline Quantity Claimed for Rebate (m. litres)[4]	79.6	76.4	79.2	62.8	85.1	n.a.	76.6
Estimated Sales to Farmers[5] (m. litres)							
Gasoline	115	120	130	123	132	120	123
Light Diesel Oil	105	107	107	97	95	91	100
Energy Requirement of Sales to Farmers[6] (TJ)	7860	8110	8450	7840	8070	7510	7973
Energy Requirement adjusted to June Year (TJ)		7985	8280	8145	7955	7790	8031

[a] Includes Farming (sheep, beef, crop, dairy, poultry, tobacco, market gardening, orchardists, mixed general); Agricultural Contracting; Commercial Hunting & Trapping; Lime and Fertiliser Spreading; Shearing; Landscape Gardening; Bee Keeping & Honey Production; Livestock & Agricultural Services; Noxious Animal Control; and Game Propagation.

[b] Includes Light Fuel Oil; Avgas; Blended Heating Oil; and other minor fuels. Negligible quantities of these fuels are consumed directly by farmers.

[c] Specific gravity at 10°C of 0.7284 (premium), 0.7022 (regular) and 0.8262 (light diesel oil) Kg/litre.

[d] Data from NZPO. The number of litres claimed for rebate each year may not parallel actual farm use, since farmers have up to two years to claim the rebate allowance although a 3 month 10% penalty applies. The effect of the rebate, raised from 4.0c/litre to 8.7c/litre in 1975 is very marked, considering the small change in sector deliveries.

[e] AERU estimates, based on discussions with the major oil companies. Farming defined as in footnotes and above.

[f] Energetic values of 34.39 (premium), 33.16 (regular) and 37.48 (light diesel oil) MJ/litre.

APPENDIX III

Energy Requirement of Electricity Usage in Farming in New Zealand[a]

Year ended 31 March	Units Consumed	
	million kWh	TJ[b]
1971	331	1192
1972	350	1260
1973	374	1346
1974	362	1303
1975	370	1332
1976	395	1422

[a]Defined as:

> the use of electrical energy for any agricultural, horticultural or stock raising type of activity... The figures in general will be exclusive of supply to farm houses unless there is only one service line or one meter on the property...
> (NZED, 1977 pers.comm.).

[b]At 3.6 MJ/kWh.

Source: (i) Department of Statistics, 1976. New Zealand Official Yearbook 1976. p.530.

(ii) NZED Annual Statistics in relation to Electric Development and Operation (various issues).

APPENDIX IV

Energy Requirement of Fertiliser Manufactured in New Zealand[a]

Type of Material	Energy Requirement[b]	Quantity Manufactured[d]					
		1970-71	1971-72	1972-73	1973-74	1974-75	1975-76
	MJ/kg	. . . .		'000 tonnes	. . . .		
Rock Phosphate	1.8	992.1	1055.3	1299.8	1296.2	913.3	1089.7
Serpentine	0.4	62.9	75.0	115.5	117.5	73.5	100.6
Dry Lime	2.1	80.0	83.3	111.0	125.4	90.8	99.6
Sulphur	5.3	199.4	210.6	251.9	262.6	183.5	215.8
Ammonium Sulphate	15.0	6.0	8.3	11.2	11.5	7.2	9.4
Potassium Chloride	5.1	169.6	186.7	236.7	249.9	187.1	206.7
Dolomite	0.1	1.0	2.1	1.3	2.0	2.3	2.5
Urea	34.0	0.5	0.6	0.8	1.2	0.7	1.6
Other Secondary Mixtures	4.0[c]	7.9	8.9	11.0	13.5	8.1	7.0
Imported: Urea	35.0	5.5	9.0	24.2	30.7	6.9	12.0
Ammonium nitrate	25.3	0.1	0.5	0.2	0.4	0.1	0.2
Ammonium sulphate	16.5	21.1	16.2	26.0	30.1	13.4	15.7
Other	16.3[c]	29.2	30.8	44.9	46.9	31.0	33.4
		. . . .		TJ	. . . .		
TOTAL ENERGY REQUIREMENT		5058.6	5450.5	7413.4	7923.0	4925.6	5861.0

[a] Because of the large amount of energy released in the conversion process of sulphur to sulphuric acid, fertiliser works in New Zealand have negligible additional energy requirement. The data in this table, therefore, only includes the energy requirements of the raw material inputs up to the works gate. Deliveries only deviate slightly from quantities manufactured each year, the average fluctuation during 1970-76 being ± 1.8 percent.

[b] Adapted from Dawson [1977].

[c] AERU estimates

[d] From (i) NZ Department of Statistics. 1973. Imports 1970-71, Part A.
(ii) NZ Ministry of Agriculture. NZ Fertiliser Statistics. Various issues.

APPENDIX V

Energy Requirement of Limestone Used In New Zealand Agriculture

	1970	1971	1972	1973	1974	1975	1976
Limestone Production for Agriculture ('000 tonnes)	1158	1281	1540	1696	1539	1503	1686
Dry Lime used in Fertiliser Mixtures ('000 tonnes)	78	82	97	118	108	95	110[a]
Energy Requirements							
-Calendar Year (TJ)	272	292	348	406	370	340	389
-June Year (TJ)		282	320	377	388	355	365

[a] AERU estimate

Sources: Limestone production, and use of lime in primary and secondary fertilisers from NZ Ministry of Agriculture and Fisheries, 1975. NZ Fertiliser Statistics, 1975, and the Mines Department (pers.comm.) An energy requirement of 0.1 MJ/kg and 2.1 MJ/kg for wet and dry lime respectively is taken from Dawson (1977). It is assumed that all lime used is in the wet form except that incorporated in fertiliser mixtures, which averages 6.6% of annual use.

APPENDIX VI

Energy Requirements of Fertiliser and Lime Transport and Ground Contract Application in New Zealand Agriculture

	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76
Total Fertiliser Distribution ('000 tonnes)	1328.1	2093.2	2634.5	2675.0	1777.2	2239.2
Total Lime Distribution ('000 tonnes)	1140	1321	1511	1505	1420	1492
Total Fertiliser and Lime	2468.1	3414	4146	4180	3197	3731
Distance Travelled in Farm Delivery[a] (m. tonne km)	266.5	368.7	447.8	451.4	345.3	402.9
Energy Requirement of Farm Delivery[b] (TJ)	333	461	560	564	432	504
Energy Requirement of Ground Contract Application[c] (TJ)	204	289	353	357	266	314

[a] At an average delivery distance of 108 km - Analysis of Fertiliser and Lime Transport Subsidy data from MAF (MAF, pers.comm.)

[b] At 50 percent modal split, road : Rail (from MAF analysis; see (a) above), and 1.8 MJ/tonne km for road and 0.7 MJ/tonne km for rail (Dawson 1977 and AERU estimates). No backloading consideration included.

[c] Ground Contract application of 40 percent of fertiliser and 90 percent of lime with an average application rate of 250 kg/ha and 2,500 kg/ha respectively. Eight percent of 1975 bulk spreading charges ($7.50/t and $2.40/t) assumed to be diesel fuel costs, giving a fuel energy requirement of 237 MJ and 76 MJ per tonne applied respectively.

APPENDIX VII

Energy Requirements of Agricultural Aerial Operations in New Zealand 1971-1976

Year Ended 31 March	Revenue Hours Flown: Distribution of Solids[a]	Distribution of Liquids[b]	Other Aerial Work[c]	Fuel Consumed[d]	Fuel Energy Requirement[e]
	....	Hours	....	m litres	TJ
1971	86,369	11,253	2,935	11.5	389
1972	87,706	12,483	2,438	11.7	397
1973	117,556	15,285	3,014	15.5	526
1974	125,971	17,622	3,434	16.8	569
1975	83,923	16,489	3,000[f]	11.8	399
1976	85,359	21,436	3,000[f]	12.5	424

[a] Includes fertiliser, lime, seed, pellets, prills, bait.

[b] Includes fertiliser, insecticide, fungicides, weed killers.

[c] Based on 20 percent of the total hours flown in 'Supply Dropping' and 'Miscellaneous Aerial Work', being directly connected with agriculture - e.g. fencing material, supply dropping, stock spotting, survey work etc.

[d] Fuel consumption estimated as follows: For solids, at 100 litres/hour plus 15% non-revenue flying time; for liquids at 90 litres/hour plus 25% non-revenue flying time; for other work at 80 litres/hour plus 25% non-revenue flying time.

[e] At 33.82 MJ/litre for aviation fuel.(Argas).

[f] AERU estimates.

Source: Revenue hours flown from NZ Department of Statistics (1976), Agricultural Statistics 1973-74, part 6. p. 9 and M.O.T. pers.comm. Remaining calculations based on AERU estimates from discussions with M.O.T. and agricultural aerial contractors.

APPENDIX VIII

Energy Requirement of New Tractors in New Zealand

	1971-72	1972-73	1973-74	1974-75	1975-76
Number of Tractors Registered[a]	4679	5684	5777	3966	3396
Energy Requirement (TJ)[b]	1544	1876	1906	1309	1121

[a]MAF collation of data supplied by the Motor Vehicle Branch of the NZPO.

[b]Assuming an average tractor weighs 2000 kg, with an energy requirement of 3.3×10^5 MJ/tractor from Dawson (1977).

APPENDIX IX

Energy Requirement for Farm Trucks, Machinery and Equipment in NZ Agriculture

The energy requirement for farm trucks, machinery and equipment in NZ agriculture is very difficult to estimate, and only broad estimates are possible. This is because no statistics are currently available on actual sales of different classes of items to agriculture (except tractor registration information). The annual sales figures are therefore estimated indirectly, and an average energy requirement per tonne or per unit applied to classes of machinery. This approach is similar to that adopted overseas -- In the USA, Pimentel used an average life of machinery at 10 years, with an energy requirement of 77.5 MJ/kg (Pimentel et al. 1973), and in Canada, Jensen used an average useful life of 12 years, with an energy requirement of 86.8 MJ/kg (Jensen 1975), both based on the work of Berry and Fels. In an alternative methodology, Steinhart and Steinhart estimated the energy requirement of US farm machinery using an average energy input of 1.1×10^4 MJ/horsepower for tractors. (Steinhart and Steinhart 1974).

The numbers of the principal items of farm machinery on NZ farms is shown in Table IX.1, with data on imports and the manufacture and assembly of farm machinery during 1970-72 in Table IX.2. Assuming that all imports and NZ production are sold (i.e. no changes in stocks during 1970-72), the proportions of machinery replaced each year vary widely with the class of item -- from three percent (once every 36 years) for ploughs to 18 percent (once every six years) for cultivators. This can only be interpreted as broadly indicative of the situation, since manufacturers and retail stock changes mentioned above are not included, and classification of items between the two tables may not be consistent. Until further data is available, however, these tables provide the basis for the energy requirement estimates used in this study[1].

The average annual sales, 1970-72, of farm machinery and equipment (excluding tractors) are estimated by item in Table IX.3. From estimates of the average weight of these items, the energy requirement is estimated at 2,100 TJ/an. Together with tractors (Appendix VIII), the purchase of all items of farm machinery and equipment is estimated to involve an input of indirect energy into farming of approximately 3,650 TJ/an assuming that all components are manufactured from the raw material and no recycling takes place.

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[1] Although data on the capital expenditure on 'transport vehicles' and 'tractors and farm machinery' by the farm sector are available ($65.5m gross and $46.1m gross respectively in 1972-73), this could not be interpreted in physical terms.

TABLE IX.1

Farm Trucks and Machinery in New Zealand Agriculture

Principal Items	Numbers on Occupied Holdings as at June 1974
	No.
Farm Trucks	32,967
Tractors	95,289
Header Harvesters	4,828
Balers	12,994
Rakes	22,223
Mowers	42,720
Conditioners	12,057
Ploughs	33,646
Cultivators	21,483
Harrows	30,288
Drills	14,391
Fertiliser Spreaders	19,946

Source: Machinery numbers from NZ Department of Statistics, Agricultural Statistics 1973-74, Part 6, p.4.

TABLE IX.2

Farm Machinery and Equipment Imported Fully Assembled, Manufactured, or Assembled From Parts in New Zealand

Item	1970-71	1971-72
	No.	
Imported Units		
Tractors:		
Crawler	313	206
Wheel	4116	3868
Headers and Combines	81	155
Seed Drills	117	198
Seed/Fertiliser Distributors	523	701
Forage harvester	41	55
Pick-up balers	781	439
Rakes	1224	401
Mowers	1719	1395
Rotary hoes	350	428
Manufactured/Assembled from parts		
Tractors	1822	2101
Headers and Combines	135	144
Cultivating -		
Ploughs	970	873[a]
Cultivators	4014	3691[a]
Harrows etc.	1826	2106
Seeding and Planting -		
Drills and other planters	679	616
Mowers and hayrakes	2669	3675

[a]AERU estimates

Source: (i) NZ Department of Statistics (1973), Imports 1970-71 Part A, and (1975) Imports 1971-72 Part A (Combination of two, six-month tabulations).

(ii) NZ Department of Statistics, Statistics of Industrial Production, 1972-73, pp.240-241.

TABLE IX.3

Energy Requirement of Farm Machinery (excl. tractors) and Equipment Sold in New Zealand, 1970-72

Item	Estimated No. of Units Sold[a] per year	Average Weight per Unit[b]	Energy Requirement per Unit[c]
		kg	MJ
Crawler Tractors	250	10,000	86.1 MJ/kg
Headers & Combines	260	8,000	1.3×10^6 MJ/unit
Seed Drills	800	900	60,000 MJ/unit
Seed/Fertiliser Distributors	600	700	86.1 MJ/kg
Balers	600	500	86.1 MJ/kg
Rakes	1900	300	86.1 MJ/kg
Mowers	3600	250	86.1 MJ/kg
Ploughs	920	800	63,000 MJ/unit
Cultivators	3850	800	60,000 MJ/knit
Harrows	1950	43 kg/leaf	3,200 MJ/unit
Trucks	4000	2,500	86.1 MJ/kg

[a] AERU estimates based on Appendix II.

[b] AERU estimates together with data from Dawson (1977)

[c] Per unit energy requirement data from Dawson (1977). Remainder allocated on energy requirement of 86.1 MJ/kg based on Berry, Fels & Makino (1974).

Note: The total energy requirement of the farm machinery listed above is 1897 TJ. The energy requirement of plant not included is assumed to add 10 percent to this figure, for a total of 2100 TJ.

APPENDIX X

Energy Requirement of Fencing Wire in New Zealand Agriculture 1971-1976[a]

	1971	1972	1973	1974	1975	1976
	. . . .	. . .	tonnes	. . . .	. . . .	. . . . . .
Ordered:						
No. 8	1,655	2,910	7,156	1,317	1,190	3,364
12½ H/T	2,961	5,813	13,258	162	1,840	6,582
Other Gauges	370	462	1,327	330	213	726
TOTAL	4,987	9,185	21,741	1,809	3,243	10,673
Delivered:	8,132	8,066	13,188	10,570	4,385	8,879
	. . . .	. . .	TJ	. . . .	. . . .	. . . . . .
Energy Requirement[b]	290	286	469	398	157	315
Energy Requirement (year ending June)	288	378	434	278	236	

[a]All deliveries from Wire Distributors Ltd assumed to go to the agricultural sector.

[b]Energy requirements of 34.0 MJ/kg for 12½ H/T and of 38.0 MJ/kg for all other wire taken from Dawson (1977), and applied to wire delivery data.

APPENDIX XI

Energy Requirement of Fence Posts In New Zealand Agriculture

Item	Annual Usage 1969-70	1970-71	Energy Requirement
	.... m		
Posts:			
Wood[a]	5.0	5.6	9.1 MJ/post
Concrete[a]	0.9	0.7	76.2 MJ/post
Steel posts and standards[b]	1.4	1.2	145 MJ/post

[a]Energy requirements for wood and concrete posts assume the ratio of Intermediate posts to strainer posts used is 40:1.

[b]The average weight of a steel post and standard is estimated at 5 kg.

Total average annual energy requirement estimated at 297 TJ.

Source: (i) Posts erected from NZ Department of Statistics, Agricultural Statistics 1969-70, p. 35 and Agricultural Statistics 1970-71, p. 31

(ii) Energy requirement data from Dawson (1977).

APPENDIX XII

Energy Requirement of the NZ Agricultural Drench Market

From market estimates, the volume of drench consumed by agriculture for 1976 is taken at 1.7m litres. Analysis of the proportion of active ingredient of each of the major products in this market indicates a weighted average composition of 7%, or a total amount of active ingredient of 119,000 kg. With an allowance of an additional ten percent for the dip market, the total energy requirement is estimated at 18 TJ (130,900 kg at 136 MJ/kg) using data from Dawson (1977).

APPENDIX XIII

Energy Requirement of the Agricultural Insecticide, Fungicide and Weedkiller Market in New Zealand

	1970-71[a]	1971-72[a]	1972-73[a]	1973-74[b]	1974-75[b]	1975-76[b]
	. . . . tonnes active ingredient					
Insecticides & Fungicides:						
DDT & other chlorinated hydrocarbons	213	94	280	250	200	250
Organo-phosphates & other	545	497	1,378	750	500	950
Weedkillers	2,101	1,829	4,363	3,000	2,000	3,000
	. . . . TJ					
Energy Requirement[c]	389	327	819	544	367	571

[a]Department of Statistics, Industrial Production (various issues). Part of Industry 389, 'Chemical Products n.e.i.'

[b]Market estimates.

[c]At 136 MJ/kg from Dawson (1977).

APPENDIX XIV

Energy Requirement of Commercial Road Transport in New Zealand Agriculture 1972-75

	1972	1973	1974	1975
Expenditure on railage and cartage ($m)[a]	24	28	31	39
Estimated expenditure on road transport ($m)[b]	21.6	25.2	27.9	35.1
Estimated proportion of expenditure on fuel costs (%)[c]	8	8	10	11
Weighted average price of fuel (c/l)[d]	7.2	7.2	12.0	15.8
Consumption of fuel (m litres)	24	28	23.3	24.4
Energy requirement (TJ)[e]	862	1006	837	877

[a]Expenditure on railage and cartage from NZ Department of Statistics, 1976. <u>New Zealand Official Yearbook 1976</u>. p.372.

[b]Ninety percent of total expenditure assumed attributable to road transport (Ambler, 1975).

[c]Proportion of total revenue in commercial rural road transport attributable to fuel expenses estimated from: NZ Ministry of Transport, <u>Annual Report</u> various issues;

(1976). <u>Statistics of the Licensed Road Transport Industry</u>;

(1973). <u>Statistics of the Licensed Road Transport Industry</u>; and

(1972). <u>Car and Truck Operating Costs</u>.

[d]Analysis assumes 50 percent of fuel used is diesel, 50 percent petrol, with an energy requirement of 37.48 MJ/l and 34.39 MJ/l for diesel and petrol respectively.

[e]Estimated energy requirement is lower level estimate, since some farm cartage costs will be indirectly included in other expenditure or revenue figures.

Note: The above table estimates the energy requirement of commercial road transport in New Zealand agriculture as around 900 TJ/an. As indicated in the footnotes to the table, some farm cartage costs are not included in this estimate since they will be incorporated indirectly in the net revenue or cost figures of categories in the agricultural production accounts (e.g. milk; slaughter livestock; fertiliser).

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