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LEAST-COST DOMESTIC HEAT ENERGY INVESTMENTS FOR GREAT BARRIER ISLAND UNDER RESTRICTIONS ON THE HARVESTING OF NATIVE FUELWOOD SPECIES.

A thesis to the value of 75 points presented in partial fulfilment of the requirements of the degree of Master of Agricultural Economics in Natural Resource and Environmental Economics at Massey University.

TONY L. WHARTON

1995

MASSEY UNIVERSITY

Great Barrier Island

Ratepayer Energy Survey

THIS SURVEY SHOULD BE COMPLETED BY THE HEAD OF THE HOUSEHOLD.

Through this survey an understanding is sought about the different uses of land, and the energy sources and appliances used by houses on Great Barrier Island.

Please follow the instructions below, and answer the questions which follow by ticking the boxes or filling in the spaces where appropriate. Where a question does not apply to you, please tick the box marked Not Applicable or N/a.

All of your answers to this survey are strictly confidential and will not be seen by any person other than myself.

SECTION 1: HOUSEHOLD DETAILS.

1) Do you currently own, rent, lease or use any property or land on Great Barrier Island?

☐ YES ☐ NO

If you answered "NO" to the above question, please go straight to page 8. Otherwise, please continue with question 2.

2) What is the TOTAL COMBINED LAND AREA (in EITHER hectares OR acres) of ALL of the property which your household uses, rents or owns on Great Barrier Island?

EITHER: ________ Hectares OR ________ Acres

3) Please tick the box below which best applies to the property which you own, rent or use on Great Barrier.

☐ All of the land is contained within one property lot.

☐ The total land area is made up of more than one property lot
- How many lots in total would you own or use? ____________

☐ The land is less than or part of one whole property lot.
- What percentage of the lot would your household have direct control over? ____________ %

☐ Uncertain / not applicable.

4) Is there a house, bach, hut, caravan or any other dwelling situated on any of the property?

☐ YES ☐ NO

If you answered "NO" to the above question, please go straight to page 8.
Otherwise, please continue with question 5

5) Is this dwelling used by you, or by any other person as a MAIN residence?

☐ YES ☐ NO

If you answered "YES", please go straight to question 6.
Otherwise, please answer part a) below.

a) For how many weeks of each year would somebody usually stay or live in this dwelling ?

Either: ________ weeks; OR: ☐ Dwelling not usually stayed in.

If this dwelling is not usually lived or stayed in, please go straight to page 8.
Otherwise, please continue with question 6).

6) Is any part of your land or property used to earn any type of income? (eg farming, renting it out, or growing vegetables or firewood for sale).

☐ YES ☐ NO

If you answered "NO" to question 6 above, please go on to question 7.
Otherwise, please continue with parts a) and b) below.

a) Please describe the MAIN income-earning activity for the land is used.

Main Activity: ______________________;

b) In an average year, approximately how much money would be earned in total from this land (before tax) ?

Income from land: $__________ per year OR: ☐ Don't know / no answer.

7) **Is any part of the total land area used to grow or produce food, firewood or any other products for use by yourself, or for use by the occupier of the dwelling, ie: not for selling?**

☐ YES ☐ NO

If you answered "NO" to question 7 above, please go on to question 8. Otherwise, please continue with part a) below.

a) How much do you think these products would cost EACH YEAR if they had to be bought, rather than produced on the property?

Approximate yearly value: $ ______________

8) **Please estimate the total percentage of your land area that would be used to produce food, firewood or other products, both for sale AND for use by yourself (or the occupier)**

Total Percentage of Land Used: __________ %

SECTION 2: HOUSEHOLD ENERGY USES.

9) **For both the cooking table below, and the home heating table on the next page, please tick the box which best describes the fuel and the appliance or method that would MOST OFTEN be used in your house on Great Barrier Island**

COOKING:

FUEL	APPLIANCE
☐ Wood	☐ Stove, oven or range
☐ Gas/LPG	☐ Burner or hotplate only
☐ Electricity	☐ Open fire
☐ Coal	☐ Microwave oven
☐ None used	☐ None used
☐ Other, please describe: ______________	☐ Other, please describe: ______________

lease tick the box which bests describes the fuel and appliance or method that you ould MOST OFTEN use for home heating on Great Barrier Island.

IOME HEATING:

FUEL	APPLIANCE
☐ Wood	☐ Single-fuel stove (eg wood fire)
☐ Gas/LPG	☐ Pot-Belly type stove
☐ Electricity	☐ Open fire
☐ Coal	☐ Cooking range or oven
☐ Kerosene	☐ Heater (Gas/electric/kerosene)
☐ None used	☐ None used
☐ Other, please describe: ____________	☐ Other, please describe: ____________

The table below shows a number of alternative fuels and methods which can be used to heat 1ot water. For both the Fuel and Method tables, please tick in the columns labeled "MAIN" the uel and the method that would most often be used as the MAIN method of water heating in your house on Great Barrier.

If, in addition to the main method of water heating you also regularly use another uel or method as a backup, please indicate the BACKUP fuel and method used by ticking the appropriate boxes in the backup fuel and method columns labeled "B / U".

HOT WATER HEATING - MAIN AND BACKUP METHODS

FUEL			METHOD / APPLIANCE		
MAIN	**B/U**		**MAIN**	**B/U**	
☐	☐	Wood	☐	☐	Wetback/water jacket to stove or range
☐	☐	Gas/LPG	☐	☐	Wetback or water jacket to open fire
☐	☐	Electricity	☐	☐	Water heated over open fire
☐	☐	Coal	☐	☐	Water boiled on top of stove or range
☐	☐	Kerosene	☐	☐	Solar-heated hot water cylinder
☐	☐	Sunlight	☐	☐	LPG/Gas fuelled instant water heater
☐	☐	None used	☐	☐	Electric hot water cylinder system.
☐	☐	Other, please describe: ____________	☐	☐	None used
			☐	☐	Other, please describe: ____________

SECTION 3: HOUSEHOLD FUEL USE:

11) Is any type of generated electricity used in your house on Great Barrier?

☐ YES ☐ NO

If you answered "NO" to the above question, please go straight to question 12. Otherwise, please continue with a) and b) below.

a) Which of the following devices would be regularly used for generating electricity? Please tick all that are applicable.

☐ Solar-electic panels
☐ Wind turbine
☐ Other, please describe:____________________
☐ Diesel or petrol powered generator.
☐ Micro-hydro generator

b) Of these, which ONE would you consider to be the main source of the house's electricity? If you consider that two or more of these devices are of equal importance, please tick both boxes.

☐ Solar-electic panels
☐ Wind turbine
☐ Other, please describe:____________________
☐ Diesel or petrol powered generator.
☐ Micro-hydro generator

12) If you use WOOD as a fuel in your household, for either cooking, heating or water-heating, please answer parts a) and b). Otherwise, please go straight to question 13.

a) Of the following types of wood, which one would you MOST OFTEN burn? Please tick:

☐ Pine
☐ Manuka/Kanuka
☐ Don't use wood.
☐ Eucalyptus
☐ Macrocarpa
☐ Other, please describe:________________

b) Which of the following best describes you MAIN source of firewood at the present?

☐ Grown on own section
☐ Collected from elsewhere
eg: Beach, forest scrap, friends.
☐ Purchased.
☐ Other, please describe:________________

SECTION FOUR.

The Auckland City Council has recently introduced restrictions on the amount of native scrub and timber which can be cleared from any property lot on Great Barrier Island. Could you please answer the questions which follow relating to your responses toward the restrictions.

Please be as frank as possible, remembering that your individual answers are totally confidential, and will never be seen by any person other than myself.

3) Are there any substantial areas of native scrub or teatree growing on your land?

☐ YES ☐ NO

If you answered "NO" to question 13 above, go straight to to question 14. Otherwise, please answer question a):

a) As best as you are able to, can you please estimate the OVERALL PERCENTAGE % of your total land area which is covered ONLY by teatree, that is, don't include any areas of your land where teatree grows mixed with other tree types.

Percentage covered: __________ %

14) Have the restrictions on firewood harvesting in any way caused you to modify or change the fuels which you use for cooking, water-heating OR home-heating?

☐ YES ☐ NO

If you answered "NO" to question 14 above, please go straight to question 15

Otherwise, please answer parts a) to d).

a) What was the MAIN fuel which you used for COOKING before the firewood harvesting restrictions? If you have not changed the fuel you use for cooking, tick "No Change".

Cooking fuel: ______________________ ☐ No change

b) Which fuel did you most often use for your MAIN source of HOME HEATING before the restrictions? If you have not changed the fuel you use, please tick "No change".

Home Heating fuel: ____________________ ☐ No change

c) Which fuel did you most often use for your MAIN source of WATER HEATING before th restrictions? If you have not changed the fuel you use, please tick "No Change".

Water Heating fuel: ____________________ ☐ No change

d) Which fuel did you most often use for your BACKUP source of WATER HEATING befor the restrictions? If you have not changed the fuel you use, or you don't use a backup method, please tick "Not applicable".

Backup Water Heating fuel: ____________ ☐ Not Applicable

15) **Have the firewood restrictions caused you to change or modify your firewood sources or collecting methods?**

☐ YES ☐ NO ☐ Not applicable

If you answered "NO" or "Not applicable" to the above question, please go straight to page 8. Otherwise, could you briefly describe how you have changed your firewood sources or methods in reponse to the restrictions?

____

____

____

____

____

Thank you for taking the time to complete this survey form. Your results will be collated along with those of the other respondents, and will be used as the basis for constructing fuel and energy models for Great Barrier Island.

Please place the completed survey form into the free-post envelope provided, and return it as soon as possible.

If you have lost the envelope provided, please post the results to:

Tony Wharton
Department of Agricultural Economics
Massey University
Palmerston North
New Zealand

It is anticipated that the results of this project will be published in "The Barrier Bulletin" early next year. However, if you would like a copy of the results, or of the project findings, please write to me at the above address.

Please feel free to use the remainder of this page if you have any further comments about the Council's restrictions on firewood harvesting.

Any comments you may have on this survey would be very helpful and greatly appreciated.

Once again, thank you for your help with my project.

Tony Wharton.

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ABSTRACT.

The Auckland City Council's 1992 district plan for Great Barrier Island introduced areal restrictions upon the clearance of manuka and kanuka (teatree), which is one of the main sources of energy for domestic heatloads on the island. The restrictions will force many households to change the way in which they allocate their resources to heat energy production, and many households will incur additional compliance costs as a result.

This study addresses the alternative energy investments available to households on the island (including teatree and eucalyptus biomass energy crops; petrol, diesel, solar, and wind generated electricity; LPG; and solar waterheating) and identifies the least-cost energy investments under the restrictions for a number typical island households. Biomass growth rates are derived for a teatree fuelwood crop, and the cost of domestic heat production is modelled for each household through the use of energy expenditure models. The optimal energy investment for each model household, both under restrictions and in the absence of restrictions, is determined, and the total financial cost of compliance for each model household is calculated. The effectiveness of the council's current restrictions and policies is assessed, and alternative energy and environmental conservation policies are evaluated.

The study found that the current policies were not effective, and that 63% of model households would incur additional energy costs from complying with the restrictions. Of all the energy sources compared, teatree fuelwood was found to produce heat at the lowest cost per kW. However the high capital cost of wood-fuelled appliances made LPG the least-cost fuel type where no appliances were owned, and appliance capital costs were found to be the main factor determining the overall economics of a particular energy system. The study also found that rather than promoting the development of eucalyptus fuelwood crops on Great Barrier Island, the promotion of sustainable methods of teatree fuelwood crop management, such as the Swiss method, would both lead to environmental conservation and would satisfy the heat energy needs of island households.

CHAPTER 1. INTRODUCTION

1.1 RESOURCE CONFLICT ON GREAT BARRIER ISLAND.

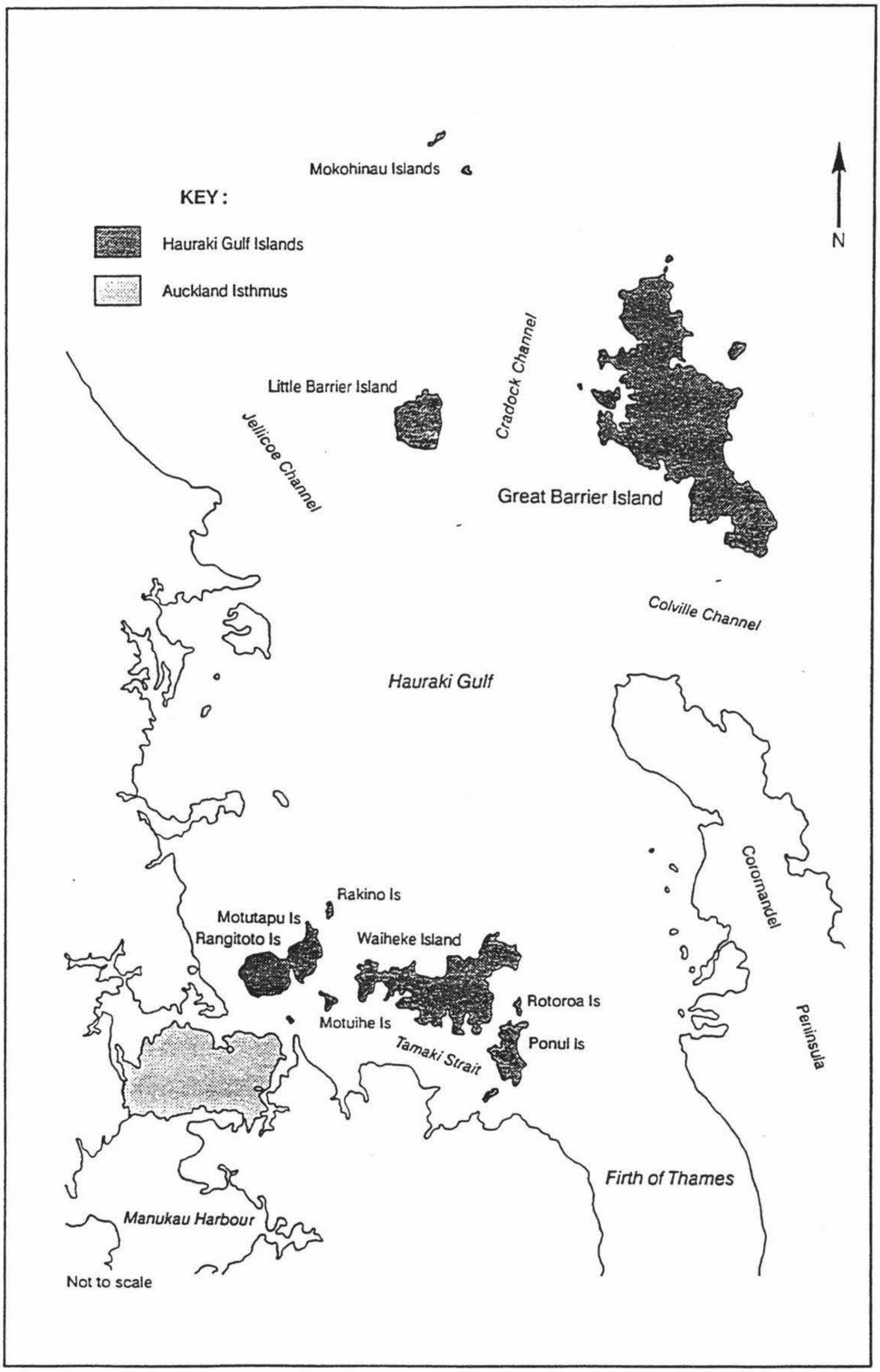
1.1.1 INTRODUCTION.

Humanity's use of energy is one of the characteristics along with culture, literature, religion, and art, which separates us as a species from animals. It was estimated in 1975 that humanity's consumption of energy from woody biomass was greater than the combined total of all of the energy which was consumed from hydroelectricity, nuclear power and geothermal energy (Earl, 1975). Although this situation has no doubt altered over the past 20 years, fuelwood is still a major source of domestic energy for a large proportion of the world's population, not only in less developed countries but also in the remote areas of developed countries (Ibid).

Great Barrier Island is one of such places in New Zealand. Great Barrier Island lies in the Hauraki Gulf 90 kilometres north-east of Auckland City (Figure 1.1) and is the largest island off the coast of the North Island, and the fifth largest island of the New Zealand group after the South, North, Stewart and Chathams Islands. The Island is approximately 285 square kilometres in area and derives it's name from the protection or 'barrier' it affords the Hauraki Gulf as it's north-eastern boundary (Great Barrier Committee of Enquiry, 1975).

One of the significant attractions of Great Barrier Island is it's expansive native forests and scenic natural environment, which were considered by Clunie (1993) to be unique and outstanding. Because of it's extent and pervasive qualities, the native vegetation and communities of the native scrub species manuka and kanuka in particular, are considered to be a key element contributing to the distinctiveness, visual quality and character of Great Barrier Island (Auckland City, 1992; Clunie, 1993).

FIGURE 1.1 GREAT BARRIER ISLAND LOCALITY MAP.



The permanent population of the island is approximately 1,200 people, many of whom are attracted to living on the island by the remoteness and the 'back-to-nature' lifestyle which it offers (Great Barrier Committee of Enquiry, 1975). Indeed, one of the island's unique features which is considered to enhance it's appeal to many visitors and residents is the lack of any public reticulated mains electricity supply, forcing households to adopt alternative sources of energy in order to meet their domestic heat energy needs (Ibid, 1975).

1.1.2 THE ROLES OF MANUKA AND KANUKA.

Leyland *et al* (1986) reported that in the New Zealand the main requirements for domestic energy in order of annual quantity consumed are water heating, space heating, cooking, and lighting/other household appliances. The majority of energy demanded by households is in the form of heat, with up to 78% of a household's total annual energy demand being a demand for heat (Ibid).

One of the principal heat energy sources of Great Barrier Island households is fuelwood from the native scrub species manuka (*Leptospermum scoparium*) and kanuka (*Kunzea ericoides*), each or collectively known as teatree (Auckland City, 1992; Clunie, 1993). Manuka and kanuka are prominent trees or tall shrubs which are found either growing together or growing separately throughout New Zealand, and are often considered to be a plant pest by many farmers and landowners (Allen *et al*, 1992; Grant, 1967). Vegetatively the species are similar, but the main difference between the two is in their flowers and fruit (Burrell, 1965). Both species can vary in habit from a small tree 10 metres high to a compact bush usually less than 4 metres in height. Estler *et al* (1974) reports that most teatree scrubland has developed from bare ground or from short open vegetation, and it's presence on land often indicates the destruction of previous native vegetation by fire.

Teatree stands cover well over half of the land area in the central and southern parts of Great Barrier Island, particularly on private land. The two species dominate the vegetation canopy in a substantial portion of the native vegetation on the island, much of which is regenerating from the past excesses of forestry exploitation and land clearance (Clunie, Ibid). Teatree's predominance in a naturally occurring state throughout the island combined with it's high biomass density and heat content has contributed to it's widespread popularity and usage as a fuel in many households throughout the island.

In addition to being one of the major sources of domestic heat energy on the island, manuka and kanuka are also considered to play a number of important roles in the environment and landscape of Great Barrier Island. In addition to their aesthetic role as the predominant land-cover on the island, both manuka and kanuka also play a significant ecological role as a seral community or 'nurse crop' and are considered to play a key role in the re-establishment of native forests on sites from which they have been displaced through felling and land clearance (Estler *et al*, 1974; Grant, 1967; Clunie, 1993). Almost all teatree communities are transitional, and Clunie (Ibid) considered that the teatree communities on Great Barrier Island were the most important and by far the most extensive of the seral communities regenerating to species rich native forests.

Manuka and kanuka communities are also considered to have other significant roles in protecting and sustaining the natural environment. Teatree stands are considered to have substantial intrinsic value as a major reservoir of natural biodiversity on the islands of the Hauraki Gulf and are home to a diverse range of native plants and animals, many of which are considered to be of international significance (Clunie, Ibid). Clunie also reports that there is a much greater diversity of teatree stands on Great Barrier Island than on the inner islands of the Hauraki Gulf, or on Waiheke Island. Teatree stands on steep slopes are considered to serve an important function in soil conservation, and well established stands of vegetation provide continuous protection of water quality in streams, by regulating runoff and dispersing and filtering erosion products (Clunie, Ibid).

1.1.3 TEATREE CLEARANCE RESTRICTIONS.

Auckland City (formerly the Auckland City Council) is the local-body authority which has territorial jurisdiction over the resources and communities of Great Barrier Island. Under the Resource Management Act 1991, Auckland City has both a mandate and a responsibility to give effect to, and promote, the sustainable management of the natural and physical resources on Great Barrier Island. (Resource Management Act, 1991; Auckland City, 1992). Sustainable management is defined in the act as: "managing the use, development, and protection of natural and physical resources in a way, or at a rate which enables communities to provide for their social, economic and cultural well being, and for their safety and well-being, while:

> a) sustaining the potential of natural and physical resources (excluding minerals) to meet the foreseeable needs of future generations; and
> b) safeguarding the life-supporting capacity of air, water, soil and ecosystems; and
> c) avoiding, remedying or mitigating any adverse effects of activities on the environment" (Resource Management Act, 1991).

The Resource Management Act also requires Auckland City to "recognise and provide for matters of natural importance" (section 6), of which "the protection of areas of significant indigenous vegetation and significant habitats of indigenous fauna" (6c) is one.

The district plan (Hauraki Gulf Islands Section) is the main policy tool by which Auckland City implements and gives effect to the sustainable resource management principles of the Resource Management Act on Great Barrier Island. The district plan presents the rationale for the council's adopted resource management strategies on the island, which are expressed in rules, regulations and restrictions governing the development and use of the island's key resources as perceived by Auckland City. In the district plan Great Barrier Island is separated into 16 strategic management areas, and for each area the key resource issues are identified, and provisions made via policy instruments to ensure their sustainable management and protection.

As the harvesting and clearance of teatree for use as a household fuel has a large potential to detrimentally impact the "life-supporting capacity of soils and ecosystems", and the "protection of areas of significant indigenous vegetation", Auckland City's 1992 district plan for the Hauraki Gulf Islands introduced policies to promote the revegetation of Great Barrier Island through introducing restrictions on the removal of native vegetation (Auckland City, 1992). In particular the district plan introduced the following restrictions governing the clearance of teatree from private land:

- a ban on the clearance of any native vegetation above 3 metres in height, with the exception of teatree where the height restriction is 6 metres in recognition of the widespread use of teatree as a fuel;

- a restriction on the maximum area of any single lot which is able to be cleared of native vegetation (Auckland City, 1992).

The district plan divided the entire land area of Great Barrier Island into a number of land classes, each determined by the character, use and cover of the land area. The maximum area able to be cleared on any lot under the restrictions is dependent on the classification of the land on which the lot is situated. The clearance restrictions for the removal of indigenous vegetation as a permitted activity (permitted by households as of right) were set at three possible levels across all of the land classes: either not permitted, a maximum total clearance of 300 m^2, or a maximum total clearance of 500 m^2 (Auckland City, 1992). The district plan also provided for an increased level of clearance limits for the clearance of teatree as a discretionary activity where a resource consent had been granted. However, this is only permitted for the purposes of commercial firewood harvesting (section 6F1.1.3).

The maximum clearance areas also took account of the area of previously cleared land existing on a section, and were based on a "reasonable minimum area within which a standard dwelling could be located inclusive of an area for an accessway" (*Pers Comm:* Auckland City, 1994). Therefore, on many sections the area which could be cleared as of right is sufficient only to enable a house to be built. It is considered by Auckland City that the vast majority of sections on the island fell into land classes 8 (Regenerating slopes: - 30% of total land area) and 10 (Forest and bush areas: 45% of land) (Ibid). Appendix 1 presents the complete list of land classes for Great Barrier Island and their associated clearance restrictions as a permitted activity.

1.2 THESIS OBJECTIVES AND APPROACH.

1.2.1 OBJECTIVES

The widespread use of teatree as a fuel source in households, combined with the restrictions imposed on the clearance of native vegetation and teatree has resulted in a resource-use conflict on Great Barrier Island. Under the restrictions, many households may be placed in the position of having to modify or change the energy sources and fuels which they use in order to comply with the district plan requirements, possibly at considerable additional expense to the household.

In order to provide an alternative to the harvesting of native teatree on Great Barrier, Auckland City has been considering implementing a policy of encouraging households to provide for their heat energy requirements by growing their own sustainable fuelwood plots utilising exotic hardwoods, particularly eucalypts, by distributing information on the costs and benefits of household's planting their own eucalyptus fuelwood crops (*Pers comm:* Auckland City 1994).

The objective of this thesis is to address this resource use issue by examining and quantifying the impact of the restrictions upon Great Barrier Island households, determine the optimal energy investments for households under the restrictions, and to examine alternative policies to the current restrictions which are available to Auckland City to lowering the rate of teatree clearance toward a socially optimal level and minimise the environmental and ecological effects of teatree clearance. Specifically, the main objectives of the study are fourfold:

i) to determine which energy project investment will be optimal for Great Barrier Island households under the teatree clearance restrictions given their current household resources, energy investments, and energy demands;

ii) to quantify the effects that compliance with the restrictions will have o households in terms of additional energy costs incurred where the household's use of teatree for fuelwood is restricted[1];

iii) to assess the overall effectiveness of the council's current policies, the quantitative levels of the restrictions, and the council's plan to promote eucalyptus fuelwood production regimes on the island; and

iv) to evaluate the economic competitiveness of alternative domestic energy systems and fuels.

1.2.2 OUTLINE OF STUDY.

A number of energy investments are compared in this study to determine which would be the least-cost energy investment for households both in the absence of the teatree clearance restrictions and under compliance with the restrictions. Each energy type was selected on the basis of it's appropriateness for use as an energy investment in remote area households. The energy investments selected for comparison in the study are:

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[1] It is assumed that the main value of teatree to the household is as a fuel.

- Eucalyptus biomass fuelwood crops;
- Teatree biomass fuelwood crops;
- Purchased teatree fuelwood;
- Liquid Petroleum Gas (LPG);
- Diesel generated electricity;
- Petrol generated electricity;
- Wind and solar generated electricity;
- Solar radiation (waterheating only).

A review of the theory and the literature on energy project investment, domestic heat energy economics, and biomass energy crop production economics is presented in Chapter 2, and it's relevance and contribution to the present study are highlighted.

The cost of each energy investment is modelled using a net present cost criteria applied to a series of energy expenditure models which incorporated capital, maintenance and fuel costs as well as appliance efficiencies. The development of each of the expenditure models and the assumptions made in their use and analysis are presented in chapter 3.

Biomass growth functions for eucalyptus and teatree wood are derived for use in the fuelwood energy expenditure models, and the collection and analysis of biomass growth data and the development of the growth functions for both species are presented in chapter 4.

In recognition of the fact that the least-cost investment for a household will depend upon the household's current energy investment and resources, a postal-administered questionnaire was designed and implemented to collect data on household resources and the average annual duration of residence of Great Barrier Island households. From the questionnaire results a series of model households are developed which can be considered to be typical island households in respect of their energy appliance ownership characteristics. The development, implementation and the results of the postal questionnaire and the formulation and characteristics of each of the model households are presented in chapter 5.

The questionnaire results, biomass growth functions, and additional data collected on household heat energy requirements are then used to derive the values of the variables used in the energy expenditure models. The calculation of the expenditure model variable values, together with the results of each of the models are presented in chapter 6.

Each of the model Great Barrier Island households are then analyzed using both the results of the energy expenditure models and the data on the household's land and appliance ownership characteristics. The least-cost investment for each model household by heatload is determined both in the absence of the teatree clearance restrictions and under compliance with the restrictions. Chapter 7 presents the analysis and the least-cost investments for each of the model households.

The financial effects of the clearance restrictions upon the model households are calculated and analyzed in chapter 8, and alternative policy options available to Auckland City are explored. The results of the study are summarised in chapter 9, and conclusions are made on the effects of teatree restrictions on households, on the current clearance restriction policies and eucalyptus proposals, and on the economics of alternative domestic heat energy systems.

CHAPTER 2: REVIEW OF THEORY AND THE LITERATURE

This chapter opens by explaining the economics and justification of teatree clearance restrictions and the effects which they are likely to have both on Great Barrier Island households and on the environment. Next, the energy investment decision facing households will be presented, followed by a review of the relevant literature and prior research on domestic heat energy economics and biomass energy production economics. The chapter will then present the minimum net present value (least-cost) criteria as the appropriate decision criteria for evaluating the optimal energy investment for Great Barrier Island households, and will conclude this study's use of and contribution to existing domestic heat energy economics literature.

2.1 THE ECONOMICS OF CLEARANCE RESTRICTIONS.

2.1.1 BENEFITS OF TEATREE USE AND PRESERVATION.

The physical and natural features of Great Barrier Island were considered by Clunie (1993) to be 'unique and outstanding' and native vegetation is considered one of the main factors contributing to the island's natural and scenic quality. Protecting the environment of Great Barrier Island and limiting the destruction of native vegetation and ecosystems were considered to be the key requirements for promoting the sustainable management of the island's natural resources (Clunie, 1993; Auckland City, 1992).

Just as teatree plays several important roles in the island's ecology (as explained in chapter 1), people also derive a variety of values and benefits from both the preservation of teatree and from it's use. Households on Great Barrier Island value teatree as a source of quality fuelwood, which can be written as B_F - the fuelwood benefit from teatree harvesting. People who derive a utility from the high scenic quality of the island, of which teatree is a major factor, attach a value to the presence of teatree which can be written as B_P, the benefits of teatree preservation. In addition to the scenic value which people may place on teatree, many people may also wish to preserve the option to harvest it in the future if they wish to, or to pass it on to future generations. This option can only be preserved and maintained so long as the current stock of teatree is preserved or sustained, which gives rise to an option value B_O (Worsop, 1991). There is also evidence for a fourth component of total value: existence value (B_E), which arises from people's wish to preserve teatree stocks in their current state for no other reason other than because they value it's existence without actually wishing to use it or even reserve the option to use it. Individuals will place an existence value on teatree when they derive a utility from the knowledge that the resources will continue to be conserved even though current or future use is anticipated (Ibid, 1991). The Resource Management Act also argues the case for 'intrinsic value' (B_I), a concept which while it partially overlaps with existence value also differs from it in the sense that the economic-imperative world view would still acknowledge the existence of value in a world totally devoid of all humans (Ibid, 1991).

2.1.2 COSTS OF TEATREE USE.

In addition to the benefits of teatree use there are also costs, both private and social, incurred from the destructive use of teatree. The total social opportunity cost of use comprises three main components: the direct harvesting/extraction cost (C_H); user cost (C_U), and externality cost (C_E) (Ibid, 1991). User cost refers to a cost imposed on future users as a result of a unit of teatree being consumed in the present rather than in the future. Where teatree is managed to provide a sustainable output user costs will be zero as present consumption will not preclude future consumption. However if the harvest or usage rate of teatree is such that physical production is unsustainable and the current rate of consumption can not be maintained in the long term without degrading the teatree stocks then a user cost will arise (Ibid, 1991).

Externalities are external costs associated with the clearance of teatree for which no compensation is made by households, examples of which include scenic degradation and harmful impacts upon wildlife populations. The imposition of externalities is perhaps the major social cost associated with the harvesting of teatree by households. As there are no incentives for households to internalise user costs and externalities there will be a tendency towards the over-harvesting of teatree stocks (Ibid, 1991).

2.1.3 SOCIALLY OPTIMUM CLEARANCE RATES.

The need for clearance restrictions such as those introduced by Auckland City arises because the optimal private clearance or harvest rate differs from the optimal social harvest level. When the conventional economic rules of efficiency and utility maximisation are applied to the harvesting of teatree the results show that a household will clear successive quantities until the monetary marginal utility obtained from the last unit of heat produced from the teatree biomass is equal to the monetary marginal cost of harvesting that unit, written as $MB_F = MC_H$. Only the household's own derived utility and harvesting costs are considered in the harvesting decision, and there is no compulsion or economic incentive for a household to take into account externalities and the impact of clearance upon non-consumptive users of the resource, such as tourists (Ibid, 1991).

The socially optimal level of teatree harvesting is defined as being that level at which the marginal benefit of the last unit of teatree fuelwood consumed to society (MB_F) is equal to society's opportunity cost of use (the sum of MC_H, MC_U *and* MC_E) plus the benefits which people gain from preserving that unit of teatree, namely their preservation, option, existence, and intrinsic values ($MB_P + MB_O + MB_E + MB_I$). Therefore, the socially optimal equilibrium clearance level for teatree will occur when, for the last unit consumed $MB_F = MC_H + MC_U + MC_E + MB_P + MB_O + MB_E + MB_I$.

2.1.4 MARKET FAILURE AND TEATREE PROPERTY RIGHTS.

As the social equilibrium rule for natural resource use equates total use value to total social opportunity cost plus preservation value and not just to harvesting costs, optimal clearance will take place at a lower level than would occur through using the standard utility maximising rule for an individual (Ibid, 1991). Externalities, user costs, and scenic and environmental degradation arise because the market system takes into account only private costs and benefits, and therefore fails to achieve a socially efficient allocation. Private households gain at the expense of others such as tourists whose enjoyment of the teatree stocks does not result in their depletion and whose costs and benefits are not taken into account (Jacobson, 1991). Additionally, the values of non-human users of the resource such as the wildlife which flourishes in the ecological habitat of the teatree stands (Clunie, Ibid) are not taken into account by the market.

Some features of the environment, such as it's scenic value and it's provision of a habitat for rare plants and animals, have the characteristics of public goods in that they are both non-exclusive in ownership and non-rivaled in consumption (Randall, Ibid). It is not physically possible to prevent people from enjoying the scenery (non-exclusiveness), and one person's enjoyment of the scenery does not detract from the quantity of scenic amenity able to be enjoyed by others (non-rivalled consumption). Randall (Ibid) writes that the non-exclusive and non-rivaled characteristics of public goods will lead to them being undersupplied by the market, as consumers will not be willing to pay for services which they can obtain for free (know as the free-rider effect), and suppliers will not be willing to face the costs of supplying a good if there are no means of preventing free-riders from partaking of the good.

The environment of Great Barrier Island ins a public good which the market system both fails to preserve, and undersupplies. The Government is forced to intervene in the management of the environment through territorial authorities such as Auckland City, to provide for the management of environmental resources in a way which they consider to be socially optimal. Jacobson (1991) writes that the role of resource managers such as Auckland City is to weigh up the costs and benefits of alternative uses of natural resources and the environment, based on what they perceive as society's priorities. The range of values which society places on vegetation needs to be considered in addition to the costs associated with harvesting in order that a socially optimal use of the resources is achieved.

As mentioned in chapter 1 the Resource Management Act (1991) gives Auckland City both a mandate and a responsibility to provide for the sustainable management of Great Barrier Island's natural and physical resources, and to provide for the protection of significant areas of both indigenous vegetation and indigenous fauna. As the clearance of teatree has a large potential to impact upon the life-supporting capacity of soils and ecosystems in a way which is detrimental to their function and integrity, and is clearly in breach of the requirements to protect areas of significant indigenous vegetation and fauna, Auckland City has intervened through the introduction of household clearance quotas to lower harvesting rates to a level which they consider to be socially optimal.

Auckland City's restrictions on the harvesting of teatree from private land is felt by many residents to conflict with their right to determine the optimal usage of their resources (*Pers comm:* Parsons, 1994). The conflict therefore is not only one of private versus social equilibrium harvest levels, but also one of conflicting property rights perceptions.

A common viewpoint among island residents is that as their land contained the stocks of teatree when it was purchased and as teatree forms the main fuel supply of the island's households (*Pers comm:* Auckland City, 1994), that ownership of the land implicitly includes a right to harvest the teatree. Furthermore, Auckland City's regulations are seen to attenuate householder's property rights by making an activity which was once permitted as of right, illegal, for which no compensation is made by the council. The viewpoint of islanders is that Auckland City has eroded the long-standing existing property rights of households to use the teatree on their land to provide for their domestic heat needs.

However, the economic-institutional concept of property rights differs from the layman's understanding of the term in several ways. Randall (1987) defines ownership as a legal device that assigns the right to use, subject to various possible restrictions. Rather than being a licence for the unrestricted use of an object or resource, the concept of ownership carries with it the need to take account of the external effects of resource use upon others parties. Individuals independently expressing their various ownership rights may often come into conflict through externalities, and as in the case of Great Barrier Island, this often include conflicts between the owners of a resource and the non-owners.

To resolve these conflicts Randall (Ibid) states that it is not sufficient merely to specify ownership of the resource concerned, but that the rights that accompany ownership must also be specified. Property rights specify both the proper relationships among people with respect to the use of resources, and also the penalties for violating those proper relationships. One can conceive of many different sets of rights with respect to a particular resource, all of which meet the criteria for non-attenuated property rights of being transferable, exclusive and enforceable, but each of which is specified differently from the others (Randall, Ibid).

Therefore, the role of territorial authorities such as Auckland City in resource management is to "restrict the freedom of individuals by limiting the harm an individual can impose upon others" (Randall, Ibid; pg 161). Essentially institutions such as the teatree clearance restriction prevent households from imposing costs on both the environment and upon non-consumptive users of teatree.

Randall (Ibid) concludes that property rights are part of society's institutional and legal framework, and that the job of governments, as society's elected lawmakers, is to define those activities which are incompatible with the exclusive ownership and private use of resources, to define the "rules of the game" under which people live (Randall, Ibid; pg 161), which is analogous to Jacobson's (Ibid) formation of resource policies based on society's perceived priorities.

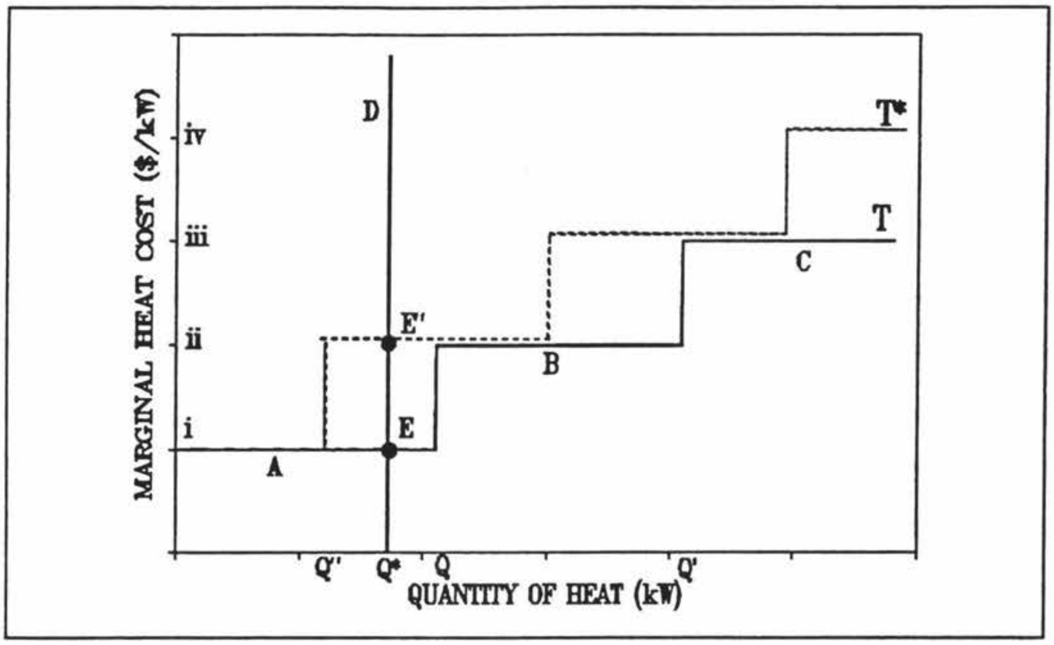
Therefore, the conflict on Great Barrier Island is not only due to the failure of the market to take account of externalities and of the values of non resource owners, but also as a result of a conflict between the landowner's perceived nature of property rights and that of society. Society is the ultimate judge of the rights attributed to ownership, and institutional rights of ownership may be altered over time to reflect a change in society's priorities, for example the introduction of the Resource Management Act. While it is likely that shifting property rights on Great Barrier Island will impose costs on land owners, from society's viewpoint it is justified as households have the potential to impose externalities on others.

2.1.5 GRAPHICAL TREATMENT OF CLEARANCE RESTRICTIONS.

The use of the clearance quotas to decrease teatree clearance can be demonstrated using microeconomic theory, as presented in Figure 2.1. The annual energy supply function (marginal energy cost function) of a hypothetical household in the absence of any clearance restrictions is represented by ***T***, where ***T*** presents the marginal energy cost of a succession of different energy sources arranged and consumed in order of increasing cost.

Figure 2.1 shows that for a cost-minimising household ***A*** is the least-cost single heat production method with a marginal cost of ***$i*** per kW, which is assumed to be the use of teatree fuelwood from the household's land. Using teatree the household can consume up to ***Q*** kW of heat. However, at quantities beyond ***Q***

FIGURE 2.1 HOUSEHOLD ENERGY SUPPLY FUNCTION.



the stocks of teatree are assumed to be depleted, and to produce additional energy the household must switch to the next-best method ***B*** (assumed to be grown eucalyptus fuelwood) with a marginal cost of ***$ii***. Similarly, method ***C*** represents the next-best method after ***B***, with a marginal cost of ***$iii.***

As the household is assumed to be rational and cost-minimising, it will firstly consume heat from source ***A***, the least-cost method, until the supply of teatree is depleted, and then it will switch to source ***B***. Where the household uses both methods ***A*** and ***B*** simultaneously the energy production frontier shows that the household can consume a total of ***Q'*** kW of heat annually, equal to the total energy consumed from grown teatree fuelwood plus the energy consumed from grown eucalyptus fuelwood.

The household's demand curve for heat energy is represented by ***D***, a perfectly inelastic demand curve reflecting the assumption that household annual energy demand is fixed at ***Q**** kW (Leyland *et al* (Ibid)). In the absence of any clearance restrictions the household can satisfy all of their demand for heat energy by using only method ***A*** (teatree), and achieve equilibrium at point ***E*** by consuming ***Q**** kW of heat.

The introduction of teatree clearance restrictions decreases the quantity of teatree fuelwood which the household is able to legally harvest from their land. As the household can now only supply a quantity of heat equal to ***Q"*** from teatree, their energy production frontier shifts from ***T*** to ***T****, with the amount of leftward shift being equal to ***Q - Q"*** (the annual quantity of heat able to be produced from the total amount of teatree on their land less the quantity of heat able to be produced from the harvestable quota of teatree). As the household can only produce ***Q"*** of heat from teatree, to satisfy their demand for heat at ***Q**** they must switch to the next-best method (***B***) to meet their remaining demand. The new level of equilibrium will be at point ***E"*** where the household still consumes ***Q**** kW, but uses a combination of both methods ***A*** and ***B***.

The total cost faced by the household in the absence of the restrictions can be represented by the product of marginal cost of teatree per kW (*$i*) and the quantity produced (*Q**). However, when faced with achieving an optimal investment under harvest restrictions the household will achieve a minimum cost equal to (*$i * Q"*) + (*$ii * (Q* - Q")*). The household will incur an additional compliance cost under the clearance restrictions by an amount represented by (*$ii - $i*) * (*Q* - Q"*).

Clearly the size of the clearance quota will determine by how much the energy production frontier shifts leftward. Where a small quota allowance is introduced, the frontier will shift by a larger amount than where the household has a large quota. Where a household is totally prohibited from clearing any additional teatree, making method ***A*** unavailable (such as is the case for many household's on Great Barrier Island), the household's energy production frontier will shift so that it intersects the Y axis at ***ii*** (the marginal cost of the next-best method ***B***), and the household will face a large compliance cost.

The end result of implementing clearance restrictions is to induce the household to adopt the next-best energy option by making teatree (the least-cost option) unavailable. Under this situation the household's demand for teatree and their harvesting activities will be curtailed, and the teatree stocks will be sustained and preserved.

2.2. THE ENERGY INVESTMENT DECISION.

One of the basic themes of economics is that the resources of individuals are limited in supply, and therefore individuals must make decisions about how best to allocate their scarce resources among a limited set of alternatives in order to satisfy their objectives (Baumol and Blinder, 1988). Similarly, households as a group of consumers have limited resources in terms of the land, money and capital equipment/appliances which they own. In order to satisfy their demand for heat energy they must allocate these resources among numerous different alternative energy 'investments', where the return to the household's investment is a supply of heat energy. For most households in New Zealand the energy investment decision is straightforward, with the vast majority of households choosing to consume heat using reticulated electricity from the national grid due to it being a relatively low-cost, efficient and convenient source of energy for domestic heatloads.

However, households on Great Barrier Island do not have the luxury or convenience of a reticulated electricity supply, and therefore each household must actively allocate their resources between a number of alternative energy investments in a way that will maximise their objectives. Consumption theory assumes that a consumer is assumed to have one of two objectives, either to maximise utility given their budget and resource constraints; or the dual objective: to achieve a given level of utility with the minimum expenditure (Doll and Orazem, 1984).

If we assume that in the case of energy consumption a consumer receives utility directly from the consumption of heat energy, then for energy investment decisions a household will similarly have one of two objectives, either to maximise the heat output derived from the household's allocation of resources to heat consumption; or to achieve a required level of heat output at the least-cost. A household investing resources in energy consumption with either objective will achieve the same optimal investment, but each objective considers the allocation from a slightly different perspective.

Past studies in the field of energy investment (presented in section 2.2.2) assumed that the annual household requirement of heat energy is fixed for an average household in any particular region of New Zealand. While the law of demand shows that this will not be strictly true, as heat energy is something of a necessity in New Zealand life it is considered likely that household demand for generic heat will be relatively inelastic. Furthermore the assumption of a constant annual demand for energy regardless of the fuel source supplying the heatload provides an appropriate benchmark for comparing different energy technologies on the same output basis. Therefore, if it is assumed that the annual requirement of heat energy is both equal for all households and remains constant over time, then the investment decision facing households is to achieve a required level of heat output at least cost.

This conclusion refers to a static solution of minimising cost to satisfy a fixed energy requirement over a particular time period. The situation considered by this study is more complex in that in this particular case a fixed quantity of annual heat is to be supplied from a possible range of energy sources, which involves an investment decision and necessitates the incorporation of the time value and the opportunity cost of money into the analysis.

As investment in energy projects takes place over a substantial time period with both costs incurred and benefits received over numbers of years, the time value of money must also be taken into account if a decision criteria is to reflect the opportunity cost of the household's monetary resources. The significance of the time value of money stems from the ability of money to earn a positive rate of return with the result that a dollar which is spent in one year's time is of less importance to a household than a dollar which is spent in the present, due to the return which could be earned from the money in the interim (Levy and Sarnat, 1990).

Levy and Sarnat (Ibid) write that an intelligent investment decision requires the comparison of alternatives and therefore the stipulation of a decision rule for comparing the available alternatives. The net present value (NPV) method is such a decision rule which takes account of the time value of money through discounting and provides a decision criteria for ranking projects on the basis of the net present value of their annual costs and revenues. The net present value method is defined as follows:

$$NPV=\sum_{t=0}^{n} \frac{S_t}{(1+k)^t} - I_0$$

where:

S_t = net cash receipt at the end of year *t*;

I_o = initial investment outlay in year 0;

k = the discount rate/opportunity cost of household capital;

n = the project's duration in years.

A project's NPV is derived by discounting the net cash receipts at a rate which reflects the opportunity cost of the funds, summing the present value net cash flows over the life of the project, and deducting the initial outlay. For energy projects where only costs are incurred to produce a given quantity of heat the decision criteria will be in terms of a *net present cost* (NPC), where the capital and annual fuel costs incurred by the household are discounted and added.

As the goal of the household is to achieve a given level of heat for the minimum expenditure, where the annual demand for heat is assumed to be constant for all energy sources, the NPC criteria can be used to *rank* the alternative investments. The decision rule will be to select that energy investment which produces the required energy quantity at the lowest net present cost.

2.3 REVIEW OF THE LITERATURE

2.3.1 DOMESTIC HEAT ENERGY ECONOMICS RESEARCH.

The teatree clearance restrictions introduced by Auckland City effectively prohibits many households on Great Barrier Island from harvesting any quantities of teatree (Auckland City, 1992). As shown in figure 2.1, the task facing many households is to reallocate their resources to an alternative energy type in order to provide for their domestic heat requirements. The investment decision facing households is to determine which alternative energy type or combination of types will provide for their heat energy requirements at the least present value cost, taking into account the household's resources and the opportunity cost of the resources currently invested to energy consumption.

A review of the domestic heat energy economics/energy investment decision literature was conducted to determine how past studies had determined the optimal energy investment for domestic heatloads. In New Zealand three main studies had been conducted which compared the cost of producing domestic heat energy from various fuels and appliances. The first two studies: Leyland, Watson and Noble (1986) and Worley Consultants (1989) compared the cost of supplying all three domestic heatloads (cooking, spaceheating and waterheating) with a range of alternative fuels using the least-cost criterion as a basis for selection, while Patterson and Earle (1992) analyzed the annual cooking energy requirements of New Zealand households for both electricity and natural gas.

Leyland *et al's* (1986) research is the most comprehensive study into domestic heat energy economics performed in New Zealand. Leyland *et al* calculated the cost of producing heat energy for waterheating, spaceheating and cooking in households in four regions throughout New Zealand (Auckland, Taupo, Christchurch and Dunedin) from reticulated electricity, coal, fuelwood, LPG, and solar energy (waterheating only). Leyland *et al* considered appliances to be an integral component of the heat production process, and therefore for each fuel/heatload combination data was also collected on representative appliances, appliance prices and appliance efficiencies.

Leyland *et al* assumed that the energy requirement of a 'typical' household in each of the four regions for each heatload was fixed at an annual quantity regardless of the energy type used to supply the heatload. The net cost of each alternative heat system was considered in terms of the national resource cost rather than financial cost. As a consequence the fuel prices used in the analysis were not considered reflective of the actual fuel cost to the consumer in the market place. The analysis took the form of an economic cost/benefit analysis prepared from a national point of view, and considered the opportunity cost of the household's financial resources through using a net present value format, comparing the results at both a 10% and a 5% discount rate.

Worley (1989) calculated the cost to Canterbury households of using 6 different fuels for spaceheating in order to determine the overall least-cost spaceheating method. The costs resulting from the use of electricity (heatpumps), coal, LPG, wood, kerosene and fuel-oil were all modelled by Worley *et al* on the assumption that each combination was required to provide sufficient useful heat energy to meet the spaceheating requirements of a typical Canterbury house. The fuels compared were selected on the basis of their current high rates of usage in Canterbury households.

Their analysis used the payback criterion to estimate the length of time it would take each of the heating systems to recover it's costs from the savings which the household would accrue over using electricity, which was assumed to be the benchmark fuel for spaceheating. The payback method was considered by Worley to be the evaluation criterion most likely to be undertaken by an individual householder considering spaceheating options.

In recognition of the fact that different spaceheating methods and appliances have different combustion efficiencies and heatloss ratios, Worley incorporated appliance efficiency factors into their analysis to compare 'useful' heat outputs rather than potential outputs, and thus provide a more accurate indication of the true cost of spaceheating. The net result of the study was a series of financial models incorporating both capital costs and annual fuel costs which calculated the least-cost spaceheating method from the payback method.

Horgan (1989) used the energy content of a number of commonly used heating fuels combined with appliance efficiencies as a basis for comparing the cost to households of using alternative fuel sources and appliances for spaceheating. While Horgan did not perform any actual analysis, he concluded that as fuel costs are only one component of an overall heating system, to compare alternative systems it is necessary to take both capital costs and appliance efficiencies into account, as well as annual fuel costs.

Patterson and Earle (1992) examined the total energy requirements of the preparation and storage of food in typical New Zealand household by calculating the cooking heat requirements of a range of typical recipes and meals considered representative of the meals prepared in an average New Zealand household. The authors utilised data from an earlier study by Blakely and Cook (1973) which had measured the average annual energy usage of an electric oven. They derived equivalent energy requirements for a gas oven by multiplying the cooking energy requirements of an electric oven by the ratio of the average efficiency of an electric oven to the average efficiency of a gas oven, based on a survey of commonly available ovens. The results of Patterson and Earle's study was an annual total cooking energy requirement representative of the cooking requirements of a typical New Zealand household which cooked with an electric oven each day.

2.3.2 BIOMASS ENERGY CROP ECONOMICS RESEARCH.

In view of Auckland City's proposed policy of encouraging the development of household eucalyptus fuelwood crops a literature review was also conducted on the current state of knowledge and research on biomass energy production economics. The results revealed that the concept of farming biomass specifically for use as an energy source is reported by Henry (1979) to have originated from early experiments with new silvicultural methods which were conducted in an attempt to boost wood yields. The high yields subsequently achieved from intensively managed experimental plots both encouraged and lent credibility to the concept of producing wood exclusively for it's fuel value.

Sims *et al* (1990) reported that in practice the best regimes for the production of a fuelwood from a woody biomass crop were through using the short rotation intensive culture (SRIC) silvicultural management system. The SRIC system is based around short rotations of between 3 and 15 years, high planting densities with either clear-felling or coppicing (depending on the species chosen), and the use of silvicultural management techniques such as fertilisation, irrigation and weed control to maximise biomass yields. In many respects Sims *et al* (Ibid) reports that SRIC management is more akin to traditional agricultural and horticultural cropping than to traditional forestry.

Many articles and papers have been published on the topic of biomass energy farming with most of them concerned primarily with species selection and management techniques. The most relevant single piece of research is Sims *et al* (Ibid), who investigated the potential of SRIC fuelwood and pulpwood production from coppiced eucalyptus biomass plantations. They developed a number of financial models to calculate the cost of producing eucalyptus biomass from a 1ha coppiced plantation. Sims *et al* (Ibid) constructed a total of 9 models based upon 3 different rotation lengths and 3 different end products (fuelwood, pulpwood, and fuelwood/pulpwood). Each of the models incorporated production costs, revenues, physical yields and management assumptions, and calculated the net present value of each biomass production regime for a period equal to three times the regime's particular rotation length[2]. The net present value analysis utilised a discount rate of 7% and included sensitivity analyses to determine break-even input and product prices.

Wallace (1989) conducted a survey of the various sources of fuelwood available to households in Dunedin. Using the heat energy content of each of the wood species as a basis for comparison, Wallace ranked the comparative cost of each fuelwood species on a kiloWatt per dollar expended basis to determine the least-cost fuelwood type.

2.3.3 CONTRIBUTION OF THE LITERATURE TO PRESENT STUDY.

Both Leyland *et al* (1986) and Worley (1989) had developed effective analytical frameworks for modelling domestic heat energy production costs for comparing alternative fuel and appliance combinations. Horgan (Ibid), Leyland *et al* (Ibid) and Worley (Ibid) each developed the concept of modelling whole-system costs incorporating both appliance costs and the concept of useful heat production. It is considered that the approaches of each of these studies in modelling energy costs on a fixed output requirement basis, and incorporating both whole-system costs and appliance efficiencies is the best framework for the present study.

Both Patterson and Earle (1992) and Worley (Ibid) had developed the concept of the energy requirements of the 'typical' home, while both Worley (Ibid) and

[2] Replanting is assumed to occur after the third coppice.

Wallace (Ibid) considered domestic heat energy production from a regional basis. As this study also takes the form of a regional energy investment analysis it is considered that the regional study concept incorporating the use of fuel and appliance costs specific to Great Barrier Island households, combined with the model household concept and current household appliance resource data, will enable results to be attained which will be the most accurate available for evaluating the energy investment decisions faced by Great Barrier Island households.

Sims *et al's* (Ibid) study is the most comprehensive available on the field of biomass energy production economics, and provides much of the methodology and framework to be used for modelling biomass growth and production costs.

2.3.4 CONTRIBUTION OF RESEARCH TO DOMESTIC HEAT ENERGY ECONOMICS AND BIOMASS ENERGY CROP ECONOMICS.

It is intended that this study builds upon and extends the approaches of previous domestic heat energy economic and biomass energy crop economics studies in several ways.

Firstly, both the breadth and depth of the energy sources compared in this study are to be wider than in previous studies. While Leyland *et al* (Ibid), Worley (Ibid), Horgan (Ibid) and Wallace (Ibid) each considered the cost of using fuelwood for heatloads, each assumed that fuelwood was purchased by the household and did not consider the potential of households providing for their own fuelwood requirements through biomass energy crops. Leyland *et al* (Ibid) and Worley (Ibid) only calculated the cost of using one type of fuelwood, and none of the studies considered the feasibility of using wood as an energy source for cooking. While this study also calculates the cost of using purchased fuelwood, it expands upon past studies by also examining the economic potential of producing fuelwood from household energy crops from two different fuelwood species, and for all 3 heatloads.

Secondly, none of the previous studies addressed the issue of supplying energy to domestic heatloads for households in remote areas from generated electricity or from alternative energy technology such as wind turbines, solar-electric panels or solar waterheaters. In addition to fuelwood energy crops this study also analyses three alternative sources of electricity including wind/solar technologies, and examines the feasibility of solar waterheaters.

The work of Sims *et al* (Ibid) is extended through considering the production of eucalyptus biomass for domestic use rather than solely for sale, and by ranking it against other domestic energy sources. Additionally, while they examined production costs under three different rotation lengths, they did not examine the factors which determined the relative present-value cost of differing rotation lengths. This study expands on the work of Sims *et al* (Ibid) by examining the economics of fuelwood production under variable rotation lengths for both eucalyptus and teatree to determine the least cost rotation length for fuelwood production, and the factor which determines which rotation length will always be the least-cost.

Sims *et al* (Ibid) assumed a constant growth rate for eucalyptus biomass production, and past studies on teatree biomass growth had only modelled single aspects of teatree growth, such as height or diameter. This study builds upon past studies both in the area of teatree ecology and biomass energy crop modelling, by empirically deriving a volume growth rate for teatree biomass using a modification of the sectional method and by determining the least-cost rotation length using a sigmoid growth function rather than a linear growth function. Finally, while both Patterson and Earle (Ibid) and Worley (Ibid) had developed the concept of model households, their investment decisions did not consider the opportunity cost of the household's current resource stocks and energy investment. This study extends the concepts developed by Patterson and Earle (Ibid) and Worley (Ibid) by considering the investment decision based upon the household's current resource and appliance investments, and modelling typical households based on empirical household data.

CHAPTER 3. ENERGY EXPENDITURE MODELS.

3.1 EXPENDITURE MODEL METHODOLOGY.

3.1.1 INVESTMENT PERIOD, TIMING AND DISCOUNT RATE

As stated in chapter 1, the objective of this study is to determine the particular investment of household land, appliance and monetary resources which will satisfy the heat energy requirements of Great Barrier Island households at least cost, given the areal restrictions on the clearance of teatree. For each energy source, the cost of supplying a heatload with a specified quantity of **useful** heat energy is calculated using the net present cost criterion applied to a series of energy expenditure models. Each expenditure model is defined for a different heatload/energy source combination which is assumed to supply a quantity of energy sufficient to meet a household's annual heat energy requirements for a 30 year period.

It is considered that 30 years is the most appropriate time frame for comparing the costs incurred from different energy sources given the long rotations associated with teatree's slow growth (Allen *et al*, 1992). Leyland *et al* (Ibid) had used a 20 year time period for their analysis, while Sims *et al* (Ibid) had used a maximum period of 24 years for modelling the costs of eucalyptus biomass production. However, it is considered that 20 years is not long enough for comparing the costs incurred from growing eucalyptus fuelwood (which incurs relatively high costs in some cases beyond the 20 year period), and the costs incurred from using other fuels. It is also considered that 30 years is the maximum time period over which households would conceivably plan for their energy investments.

Each energy expenditure model calculates the net present financial cost incurred by a household for the required quantity of **useful** heat energy produced by each energy source/heatload combination. Annual costs comprise of capital, maintenance, and fuel costs. It is considered that minimum financial cost is the decision criterion on which individual households would be most likely to base their energy investment decisions, as opposed to minimum economic or per kiloWatt energy costs. For each expenditure model a representative appliance was selected which was considered typical of appliances found in Great Barrier Island households for that heatload/fuel combination. The models also incorporate appliance efficiency ratings to calculate the **total** heat requirements of each appliance from the fuel. Each of the models assumes that, where relevant, fuel is purchased by the household at the beginning of a year for consumption throughout the year.

The household discount rate used in the models is taken as the risk-free opportunity cost of the household's capital, selected as the current rate of return on Government stock. In view of the long-term nature of energy investments the discount rate is taken as the current return for government stock with a maturity of 7 years, which was 9%. The rates of return for stock with lower and higher maturity dates ranged very closely around the 9% level.

3.1.2 MODEL VARIABLES.

As Great Barrier Island is a popular holiday destination it is considered that many of the households which used a dwelling on the island will be temporary rather than permanent residents and will therefore only require heatloads for a portion of the year. As the differing annual lengths of residence between resident and non-resident households will affect their relative energy requirements and the levels of cost which they incur, separate NPC analyses are conducted for both household categories, as well as for each of the three heatloads, by defining two variables for use in the models:

i) the annual quantity of **useful** heat required for each heatload, denoted by *HEATyr*; and

ii) the average number of days each year spent in residence by each household category (resident and non-resident), denoted by *DPY*.

HEATyr is assumed to take three possible values, each of which represents the **useful** heat requirements of either cooking, spaceheating or water heating. The study and the models assume that the annual useful heat demand of households for each of the three heatloads is a fixed annual requirement, discussed in chapter 6.

DPY is assumed to take two possible values: either 365 days per year for a resident household, or the value of the average number of days per year spent in residence by non-resident households, discussed in chapter 6.

3.2 FUELWOOD EXPENDITURE MODELS.

3.2.1 INTRODUCTION.

A series of fuelwood expenditure models were developed which calculate the net present cost to a hypothetical household of using fuelwood to supply the heat energy requirements of each heatload. The cost of using the following three alternative fuelwood sources is calculated by the models:

i) eucalyptus fuelwood grown by the household;
i) teatree fuelwood grown by the household; and
iii) teatree fuelwood purchased by the household.

3.2.2 APPLIANCES.

The cost of meeting the heat energy requirements of households from fuelwood is compared for two different appliances:

i) a Wamsler k97a woodstove (for cooking, water and spaceheating);and
ii) a Jayline junior woodfire (spaceheating only).

Both of these appliances are considered to be representative of typical wood-burning appliances used in Great Barrier Island households. Retail and freight prices for each of the appliances were obtained. The manufacturer's product specifications for both appliances gives performance data at both high and a low heat settings. This study will calculate an averaged heat output value for each appliance to represent a medium heat setting.

The cost of using the Wamsler woodstove with each of the three fuelwood sources is calculated separately for three different heatload scenarios:

i) where the woodstove is only used for cooking;
ii) where the woodstove is only used for water heating; and
ii) where the woodstove is used for both cooking and water heating.

As the woodstove radiates space heat to the surrounding airspace during cooking and water heating, spaceheating as a separate heatload is not analyzed. The heat radiated during cooking and water heating is considered to contribute to the household's space heating requirements at a zero marginal cost, and thus to be effectively included in the cooking and/or water heating cost. The expenditure models for the Jayline junior woodfire only derive the cost of spaceheating using each of the three fuelwood sources. The appliance specification and cost data for both the Jayline and Wamsler appliances are presented in appendix 5a.

3.2.3 MODEL ASSUMPTIONS.

Where fuelwood of either species is grown by a household the models assume that the area of the fuelwood crop is divided into multiple individual sub-plots referred to as rotations. Rotations are planted and/or harvested at the rate of one rotation per year, and the total number of individual areal rotations used is equivalent to the length of each rotation, for example a rotation length of 12 years entails the use of 12 rotations, one of which is planted or harvested each year in a 12 year cycle. The models for either wood species assume that both the area of land planted or harvested annually (which is the area of 1 rotation - denoted *ROTarea*), and the volume of wood harvested from each rotation (denoted *YIELD*) are equal for each rotation and for each year.

Fuelwood is harvested from each individual areal rotation when a period equal to one rotation length has elapsed since the planting or coppicing of that particular rotation. The models assume that there is a period equal to one rotation length between the first planting in year 0 and the first harvest of the **first** rotation (referred to as the **initial** rotation) where no fuelwood has yet reached harvest maturity. In this period households are assumed to purchase teatree fuelwood to meet their fuelwood requirements.

Figure 3.1 graphically represents a hypothetical 1ha fuelwood crop of either eucalyptus or teatree with a rotation length of 9 years (denoted *ROTlength*). The crop is planted and harvested in 9 separate annual areal rotations of .11 ha each (represented by the areas I to IX), planted and harvested at the rate of one rotation per year. Rotation I is planted in year 0, and rotation II in year 1, with the cycle continuing until the initial harvest at the end of year 9 where rotation I is harvested and replanted (for a teatree crop), or coppiced (for a eucalyptus crop). Rotation II is harvested/replanted or coppiced in year 10, rotation III in year 11, and so on, until year 18 when rotation I will be harvested for a second time, having grown for 9 years since the previous harvest.

In this way each individual rotation (I through IX) will be harvested once every 9 years, after which the cycle repeats itself. The household will purchase teatree fuelwood in years 0 through 8 as none of the trees will have reached harvesting maturity during this time. The models also assume that teatree crops are resown immediately following a harvest (Grant, 1967), while eucalyptus crops are to be coppiced and replanted following the third coppice (Sims *et al*, Ibid).

FIGURE 3.1 GRAPHICAL REPRESENTATION OF 1HA ROTATIONAL FUELWOOD CROP.

I Plant: yr 0 Harv : yr 9	**II** Plant: yr 1 Harv : yr 10	**III** Plant: yr 2 Harv : yr 11
IV Plant: yr 3 Harv : yr 12	**V** Plant: yr 4 Harv : yr 13	**VI** Plant: yr 5 Harv : yr 14
VII Plant: yr 6 Harv : yr 15	**VIII** Plant: yr 7 Harv : yr 16	**IX** Plant: yr 8 Harv : yr 17

Freshly harvested wood has a moisture content approximately equal to it's oven-dry mass[3], with the result that approximately half of the mass of freshly harvested wood consists of moisture. The models assume that each harvest of grown fuelwood (either species) is reduced to a 25% moisture content through

[3] Oven-dried wood has a 0% moisture content.

air drying in the sun before it is combusted by households[4]. The models also assume that households dry the fuelwood immediately following harvesting for use in the same year, and that as the wood is air-dried using sunlight there is no drying cost incurred.

The models define the quantity and volume of fuelwood in steres, where 1 stere is equal to 1 'thrown' m^3 of fuelwood and contains approximately 65% of the volume of 1 solid m^3 of wood (Earl, Ibid). To enable for the comparison of teatree and eucalyptus fuelwoods which have different wood densities and energy contents, the models determine the annual fuelwood requirements of each heatload (denoted *DEMyr*) for either species in terms of a teatree equivalent (**TE**) stere volume, where eucalyptus **TE** denotes eucalyptus fuelwood expressed as the **energy equivalent volume** of teatree fuelwood[5]. Finally, all of the models assume that the land used for fuelwood production is already owned by the household and does not have to be purchased.

3.2.4 EUCALYPTUS FUELWOOD MODELS.

3.2.4.1 EUCALYPTUS MODEL VARIABLES.

The eucalyptus fuelwood models use the variables *HEATyr* and *DPY*, defined previously, to calculate the values of three additional variables, each of which is specific to a eucalyptus fuelwood crop:

> i) The volume of fuelwood (TE steres) required annually to meet the energy requirements of a heatload which has a useful energy requirement of *HEATyr*, denoted *DEMyr*;

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[4] Air drying maximises the energy which can be obtained from each stere, as a high moisture content reduces the obtainable useful heat through using a high level of heat in the combustion process to evaporate moisture from the wood (Earl, 1975).

[5] 1 stere of eucalyptus fuelwood contains the same quantity of energy in kW as ⅔ of a stere of teatree fuelwood, where ⅔ is the ratio of eucalyptus biomass density to teatree biomass density (Wallace, 1989).

ii) The area of each rotation in hectares, denoted *ROTarea*; and

iii) The fuelwood volume yield (in steres) from one rotation of a eucalyptus crop, denoted $YIELD_{EUCAL}$.

ANNUAL VOLUME OF FUELWOOD REQUIRED - *DEMyr*.

The value of *DEMyr* for each of the three heatloads is calculated as the household's **daily** fuelwood requirement for the heatload in **TE** steres (denoted *DEMday*) multiplied by the average number of days spent in residence by the household per year (*DPY*), discussed in chapter 6.

$$DEMyr = DEMday \times DPY$$

where:

DEMday = Daily fuelwood requirement (**TE** steres).

The value of *DEMday* is calculated as the heatload's daily useful heat requirement (denoted *HEATday*) divided by the appliance's per hour heat output from the combustion of one **TE** stere of fuelwood (denoted as ε), calculated from manufacturer's performance trials. ε is defined as the appliance's **heat conversion efficiency** from chemical potential energy to heat.

$$DEMday = HEATday \,/\, \varepsilon$$

where:

HEATday = Daily requirement of useful heat for heatload (kW);

ε = Appliance heat conversion efficiency.

The value of *HEATday* is calculated by dividing the **annual** useful heat requirement for the heatload (denoted *HEATyr*) by 365 days per year.

$$HEATday = HEATyr/365$$

The appliance's heat conversion efficiency (ε) is calculated from manufacturer's specifications as it's rate of heat output per hour to the heatload (denoted ***Yhr***) divided by the volume of fuelwood combusted by the appliance during that hour (denoted *COMBhr*).

$$\varepsilon = Yhr \,/\, COMBhr$$

where:

Yhr = Output of heat per hour to heatload (kW);

COMBhr = Volume of fuelwood combusted per hour (steres **TE**).

The volume of fuelwood combusted in one hour (*COMBhr*) is equal to the **total TE volume** of wood combusted in the appliance during the trial, divided by the time taken for total biomass combustion (denoted as *TIME*). The total volume of wood combusted is equal to the mass of the wood combusted (*MASS*) divided by the product of teatree biomass density[6] (denoted *DENtea*) and the volume of wood contained in one stere (*VOLstere*). The density of teatree biomass is used in order to covert the mass value of the fuelwood combusted during the trials into a **TE** volume.

$$COMBhr = (MASS \,/\, (DENtea \times VOLstere)) \,/\, TIME$$

where:

MASS = Mass of wood combusted (kg);

DENtea = Density of teatree biomass (kg/m^3);

VOLstere = Actual volume of wood per stere (m^3/stere);

TIME = Hours taken for wood to fully combust.

The heat conversion factors for both the woodstove and the woodfire are derived using values for *MASS*, *Yhr* and *TIME* contained in the manufacturer's specifications.

[6] 680kg/m^3; Source: Nicholas, NZFRI (date unknown).

ROTATIONAL AREA - *ROTarea.*

The area of each rotation of a eucalyptus fuelwood crop (*ROTarea*) is dependent upon the **TE** volume of fuelwood required annually (*DEMyr*), and is calculated as the ratio of the volume of **eucalyptus** fuelwood required annually (*DEMyr* / ⅔; where ⅔ converts the fuelwood requirement from a **TE** stere to a eucalyptus stere) to the volume of air-dried fuelwood able to be harvested from a **1ha** eucalyptus rotation, where all the trees are assumed to be of an equal age.

$$ROTarea = (DEMyr \,/\, \tfrac{2}{3}) \,/\, (BIOMASS_{EUCAL} \,/\, (DENeucal \times VOLstere)) \qquad (1)$$

where:

DEMyr = Heatload annual fuelwood requirement (steres **TE**);

⅔ = Ratio of eucalyptus biomass density to teatree biomass density;

$BIOMASS_{EUCAL}$= Mass of eucalyptus fuelwood harvested from a **1ha** rotation (air dry kg);

DENeucal = Density of eucalyptus biomass (kg/m^3);

VOLstere = Actual volume of wood per stere (m3/stere).

The value of $BIOMASS_{EUCAL}$ is calculated as the annual air-dry biomass growth rate of the eucalyptus trees (denoted *GROWTH*), multiplied by the optimum age of the trees at harvest (*ROTlength*). The value of *GROWTH* represents the growth increment in the air-dried fuelwood mass (assumed to have a moisture content of 25% of it's final mass) rather than total biomass growth which will be larger due to the high moisture content of freshly harvested wood (approximately 110% of final mass; Earl, Ibid).

$$BIOMASS_{EUCAL} = GROWTH \times ROTlength$$

where:

GROWTH = Eucalyptus biomass growth rate (air-dried kg/year).

The values of *GROWTH* and *ROTlength* used are derived in chapter 6.

ANNUAL FUELWOOD YIELD - $YIELD_{TE}$.

$YIELD_{TE}$ represents the teatree equivalent (TE) yield of fuelwood from one rotation of a eucalyptus fuelwood crop **after air drying**, and is equal to the volume of fuelwood harvested in steres (denoted $YIELD_{EUCAL}$) multiplied by ⅔ - the ratio of eucalyptus biomass density to teatree biomass density - to convert the eucalyptus yield to a teatree energy equivalent (TE) yield.

$$YIELD_{TE} = \tfrac{2}{3} \times YIELD_{EUCAL}$$

where:

> $YIELD_{TE}$ = Teatree equivalent volume of fuelwood harvested from one rotation (air dried steres);
>
> $YIELD_{EUCAL}$ = Volume of eucalyptus fuelwood harvested from one rotation (air dried steres).

The value of $YIELD_{EUCAL}$ is calculated as the area of one rotation (*ROTarea*) multiplied by the total volume of air-dried eucalyptus fuelwood harvested from a rotation of size **1ha**. The volume of fuelwood harvested from a 1ha rotation is derived by converting the mass of air dry fuelwood harvested ($BIOMASS_{EUCAL}$) into a stere equivalent, where the conversion factor for kilograms to steres is the product of the eucalyptus biomass density (*DENeucal*[7]) and the volume of one fuelwood stere in m^3 per stere (*VOLstere*).

$$YIELD_{EUCAL} = ROTarea \times (BIOMASS_{EUCAL} / (DENeucal \times VOLstere)) \quad (2)$$

where:

> *ROTarea* = Area of one rotation of teatree fuelwood (ha);
>
> $BIOMASS_{EUCAL}$= Mass of eucalyptus fuelwood harvested from a **1ha** rotation (air dried kg).

From equations *(1)* and *(2)* it follows that for a eucalyptus crop $YIELD_{EUCAL}$ = *DEMyr* / ⅔; and that $YIELD_{TE}$ = *DEMyr*, as expected.

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[7] $450 kg/m^3$, Source: Tombleson, 1985.

3.2.4.2 EUCALYPTUS FUELWOOD EXPENDITURE MODEL.

The net present cost of supplying a heatload using grown eucalyptus fuelwood in either the woodstove **or** the woodfire is calculated from the following model:

$$NPC = APPL + \sum_{Y=0}^{29} PV\ (WOODpur_Y, WOODgrow_Y\ MAINT_Y) - PV(SALV)$$

where:

NPC = Net present cost of heatload ($);

$APPL$ = Appliance purchase cost in year 0 ($);

PV = Present value ($);

$WOODpur_Y$ = Cost of **purchased teatree** fuelwood in year Y ($);

$WOODgrow_Y$ = Cost of **grown eucalyptus** fuelwood in year Y ($);

$MAINT_Y$ = Periodic appliance maintenance cost in year Y ($);

$SALV$= Appliance salvage value in year 29 ($), where $SALV = APPL$ x (LIFE - 30).

ANNUAL COST OF PURCHASED TEATREE FUELWOOD ($WOODpur_Y$).

As previously stated, the fuelwood models assume that there is a period of one rotation length between the first planting in year 0 and the initial harvest where households are assumed to purchase teatree fuelwood to meet their fuelwood requirements.

From year 0 to the year prior to initial harvest ($0 \leq Y < ROTlength$) the fuelwood yield from the crop will be 0 ($YIELD_{TE} = 0$), and therefore the volume of teatree fuelwood that must be purchased will equal *DEMyr*. From the initial harvest onward ($Y \geq ROTlength$) the annual yield of fuelwood from the crop ($YIELD_{TE}$) will equal the household's annual demand (*DEMyr*), and no wood will be purchased.

The total cost of purchased wood is equal to the quantity which must be purchased multiplied by the per stere price of wood on Great Barrier Island, and for all years is calculated from the following equation:

$$WOODpur_Y = (DEMyr - YIELD_{TE}) \times PRICEwood; \qquad (0 \leq Y \leq 29)$$

where:

$DEMyr$ = Annual fuelwood requirement (TE steres);

$YIELD_{TE}$ = Harvestable volume of one rotation of crop (TE steres);

$PRICEwood$ = Price of purchased teatree fuelwood ($/stere, ex GBI).

ANNUAL COST OF GROWN EUCALYPTUS FUELWOOD ($WOODgrow_Y$). To calculate the annual cost of growing the required quantity of eucalyptus fuelwood ($WOODgrow_Y$) a biomass production model was constructed for a fuelwood crop consisting of eucalyptus salignia on inland sites, or eucalyptus botryoides for more coastal locations. The model assumes that the trees are grown and coppiced in rotations using the crop management assumptions developed by Sims *et al* (Ibid), and assumes a 92% conversion from above-ground biomass to fuelwood mass, to allow for harvest debris and the coppice stump (Tombleson, 1992). It is also assumed that the trees were replaced after the third coppice, and that the yield from each coppice was equal.

The total cost in any year of growing the required quantity of eucalyptus fuelwood is equal to the sum of the costs of tree purchasing and planting; land cultivation, crop maintenance and fertilisation; and the labour and machinery cost of harvesting the fuelwood. The annual cost of planting and tree purchase are determined by three factors:

i) the area of land planted in any year, which is the area of one rotation (*ROTarea*);

ii) the optimal planting density of the crop in stems per ha (denoted *PLANTden*); and

iii) the price per tree of the planting labour or tree stocks and freight.

The annual cost of crop maintenance and cultivation is determined by the area of land to be planted, and the per hectare price of maintenance and cultivation.

The 1ha model developed by Sims *et al* (Ibid) is used to calculate the cost of producing eucalyptus fuelwood. In order to calculate the cost of producing fuelwood for a crop with a rotation area of *ROTarea* as opposed to the 1 ha used by Sims *et al* (Ibid), all costs are multiplied by the rotation area in hectares (*ROTarea*).

The cost in any year of growing the required quantity of eucalyptus fuelwood with a rotation area of *ROTarea* is derived by the following model:

$$WOODgrow_Y = PURCH_Y + PLANT_Y + CULT_Y + CMAINT_Y + CHAR_Y$$

where:

$WOODgrow_Y$ = Cost of grown eucalyptus fuelwood in year Y (\$);

$PLANT_Y$ = Labour cost of planting trees in year Y (\$);

= $PLANTden \times ROTarea \times PRICEplant$

$PURCH_Y$ = Purchase cost of trees (including freight) in year Y (\$);

= $PLANTden \times ROTarea \times (PRICEtree + PRICEfrght)$

$CULT_Y$ = Cost of land cultivation in year Y (\$);

= $ROTarea \times PRICEcult$

$CMAINT_Y$ = Crop maintenance & fertilisation cost in year Y (\$);

= $ROTarea \times PRICEcmaint$

$CHAR_Y$ = Cost of fuelwood harvesting in year Y (\$/stere);

where:

PLANTden = Optimal tree planting density (stems/ha);

ROTarea = Area of one rotation (ha);

PRICEplant = Price of planting labour (\$/tree);

PRICEcult = Price of cultivation (\$/ha);

PRICEtree = Price of tree stocks (\$/tree);

PRICEfrght = Price of freight (\$/tree);

PRICEcmaint = Price of crop maintenance (\$/ha/yr).

The specific combination of these costs incurred by the household in any year will change as the state and maturity of the crop changes. For example, if a rotation length of 8 years is assumed, then planting, tree purchase and cultivation costs are only incurred in the first 8 years of the crop's life (years 0 to 7) and after the third coppice of each rotation (starting in year 24); while harvesting costs are incurred annually starting from the initial harvest of the first rotation (year 8). The values of *ROTarea* and *PLANTden* used in the models are calculated in chapter 6.

The annual harvest cost (*CHAR*) is calculated as the volume of eucalyptus fuelwood harvested from one rotation ($YIELD_{EUCAL}$) multiplied by the labour cost to harvest one stere (denoted *Phar*).

$$CHARV_Y = YIELD_{EUCAL} \ x \ Phar$$

where:

$YIELD_{EUCAL}$ = Volume of eucalyptus fuelwood harvested from one rotation (air dry steres);

Phar = Labour and chainsaw cost to harvest one stere ($/stere).

3.2.4.3 ANNUAL COST OF GROWN EUCALYPTUS WITH OPPORTUNITY COST OF LAND USE.

The cost of producing eucalyptus fuelwood was also modelled for a household which had an opportunity cost attached to the use of their land. For these households the cost of wood grown ($WOODgrow_Y$) is calculated using the model developed in section 3.2.4.2, with the exception that the actual opportunity cost incurred in any year by a household growing fuelwood on productive land, in terms of the value of forgone production (denoted as $Copp_Y$) is considered to add to the true cost of fuelwood production. The model assumes that a fuelwood crop will be initially planted on land which is currently unproductive, and that fuelwood will only be planted on productive land when the supply of unused land is depleted.

For the model the monetary opportunity cost of the household's **total** land area is defined as *OPPcst*, and it's value is defined as *OPPcst* = *$X* from the use of *Y%* of the total household land area; where the values for *Y* and *X* were the average percentage of land used (denoted *LANDopp)* and the average opportunity cost from this land over all households whose land had an opportunity cost of use. The values of both *OPPcost* and *LANDopp* are derived separately for both residents and non residents in chapter 6.

The household only incurs an opportunity cost where the total amount of land remaining unplanted in any year, denoted $LANDspare_Y$, is less than the area of household land used for opportunity cost (*LANDopp*), implying that some productive land is covered in eucalyptus. The opportunity cost incurred where fuelwood is grown on productive land is calculated for individual years as the total opportunity cost of the productive land to the household (*OPPcost*) multiplied by the percentage of the household's total productive land planted in eucalyptus. The percentage of total productive land planted in eucalyptus is calculated as the ratio of the area of productive land remaining unplanted in any year ($LANDopp - LANDspare_Y$) to the area of land in opportunity cost (*LANDopp*).

$$Copp_Y = ((LANDopp - LANDspare_Y)/ LANDopp) \times OPPcost; \quad LANDspare_Y < LANDopp$$

where:

$Copp_Y$ = Opportunity cost of land use incurred in year Y ($);
LANDopp = Total amount of land used for other crops/uses (ha);
$LANDspare_Y$ = Household land remaining unplanted in year Y (ha);
OPPcost = Total income/opportunity cost of household land ($/yr).

The area of total household land remaining unplanted in any year (*LANDspare*) is calculated as the household's total land area (*TOTland*) less the total area of land planted in eucalyptus fuelwood at that point in time (denoted $Leucal_Y$).

$$LANDspare_Y = TOTland - Leucal_Y$$

where:

$TOTland$ = Total household land area (ha);

$Leucal_Y$ = Total area covered in eucalyptus at year Y (ha).

The values of *TOTland* for residents and non-residents are derived in chapter 6.

The total area of land covered by the fuelwood crop increases during the initial plantings of each of the rotations, and remains constant once all rotations have been planted. Where the year Y is less than the year of initial harvest ($Y < ROTlength$), the total area covered is calculated as the area of one rotation (*ROTarea*) multiplied by the value of the year plus 1 (to take into account the initial planting in year 0).

$$Leucal_Y = (Y + 1) \times ROTarea; \quad Y < ROTlength$$

Where the year is equal to or past the year of initial harvest ($Y \geq ROTlength$) the land covered by the fuelwood crop will be equal to the area of one rotation (*ROTarea*) multiplied by the rotation length (*ROTlength*).

$$Leucal_Y = ROTarea \times ROTlength; \quad Y \geq ROTlength$$

3.2.5 TEATREE FUELWOOD MODEL I - GROWN TEATREE.

3.2.5.1 TEATREE MODEL VARIABLES.

The teatree fuelwood crop models assume that the teatree crop comprises of a mix of both manuka and kanuka trees. As the two species are vegetatively very similar and differ principally in their flowers and fruit (Burrell, 1965), the models assumed them to have similar growth rates. Therefore the models consider the crop in terms of generic 'teatree' rather than the individual species, and one biomass production function is used to model the growth of the entire crop. This appears reasonable given the vegetative similarities of the two trees, the fact that they often grow intermixed, and that Watson and O'Loughlin (1985) had sampled both manuka and kanuka to derive a root biomass function for manuka.

The cost of growing teatree fuelwood on household land is modelled under two scenarios:

i) where there are assumed to be no restrictions on the clearance of teatree; and:

ii) where there are clearance restrictions which the household complies with.

Under the restriction compliance scenario, the models assume a total areal clearance limit of $300m^2$, taken as a weighted average of the clearance restrictions for all land classes on Great Barrier Island. The models are based on the assumption that the existing cleared area for a house is $300m^2$ (Auckland City, 1994), giving an effective clearance restriction of 0 additional m^2.

The teatree fuelwood models also use the variables *HEATyr* and *DPY* to calculate the values of the variables *DEMyr*, *ROTarea* and $YIELD_{TE}$ for both household categories, where $YIELD_{TE}$ is defined as the yield from one rotation of a teatree fuelwood crop in volume rather than mass. The values of *DEMyr* used in the teatree models are equivalent for each heatload and residency category as used in the eucalyptus models. However, the values of $YIELD_{TE}$ and *ROTarea* are defined specifically for a teatree crop, and differed from those used in the eucalyptus model.

The formula used to calculate *ROTarea* in the teatree models is equivalent to that used for calculating the rotational area of a eucalyptus crop (equation **1**), with the exceptions that as *DEMyr* is already a teatree equivalent value it is not divided by ⅔, $BIOMASS_{TEA}$ replaces $BIOMASS_{EUCAL}$, and as $BIOMASS_{TEA}$ represents fuelwood volume rather than mass, it is not divided by biomass density (used to convert mass to volume) as in the eucalyptus models.

Similarly, the formula used to calculate $YIELD_{TE}$ is equivalent to that used to calculate $YIELD_{EUCAL}$ (equation **1**), with the exceptions that *ROTarea* is specified for a teatree crop (as above), $BIOMASS_{TEA}$ replaces $BIOMASS_{EUCAL}$, and $BIOMASS_{TEA}$ is not divided by biomass density. The total **volume** of the harvested wood is assumed not to change during the drying process: it's volume is assumed to be the same after drying as at the time of harvest. It is considered that while drying decreases the fuelwood's mass through reducing it's moisture content, the volume of the wood will not change.

The derivation of the value of $BIOMASS_{TEA}$ and of the actual values of *ROTarea* both under clearance restrictions and in the absence of the restrictions are discussed in chapter 6.

3.2.5.2 GROWN TEATREE EXPENDITURE FUNCTION.

The net present cost of supplying a heatload using grown teatree fuelwood in either the woodstove **or** the woodfire is calculated from the following model:

$$NPC = APPL + \sum_{Y=0}^{29} PV\ (WOODpur_Y, WOODgrow_Y\ MAINT_Y) - PV(SALV)$$

where:

NPC = Net present cost of heatload ($);

$APPL$ = Appliance purchase cost in year 0 ($);

PV = Present value ($);

$WOODpur_Y$ = Cost of **purchased teatree** fuelwood in year Y ($);

$WOODgrow_Y$ = Cost of **grown teatree** fuelwood in year Y ($);

$MAINT_Y$ = Periodic appliance maintenance cost in year Y ($);

$SALV$= Appliance salvage value in year 29 ($), where $SALV = APPL$ x (LIFE - 30).

The annual cost of purchased teatree fuelwood ($WOODpur_Y$) is equivalent to that calculated in section 3.2.4.2 for the grown eucalyptus model. However, as the rotation length for a teatree crop will be different to that used for a eucalyptus crop, the household will purchase fuelwood for a different number of years until the initial harvest.

ANNUAL COST OF GROWN TEATREE FUELWOOD - $WOODgrow_Y$

The annual cost producing the required volume of fuelwood from a teatree crop is calculated using a teatree biomass production model. As with the eucalyptus models, the teatree crop is assumed to be grown and harvested in individual annual rotations, each of the same area and each giving an equal annual yield at the time of harvest. It is assumed that the teatree crop is unmanaged, with the exception that replanting/resowing takes place after each harvest through the scattering of seed pods and cut branches over the harvested area (Grant, 1967.)

A base teatree production model was developed which assumes that the household did not have an opportunity cost of land use, and that there are no significant areas of teatree currently growing *in situ* on the household's land. Under these assumptions the only cost to the household of producing teatree fuelwood is the cost of harvesting, calculated as:

$$WOODgrow_Y = CHARV_Y$$

where:

$WOODgrow_Y$ = Cost of wood grown in year Y ($);

$CHARV_Y$ = Cost of fuelwood harvest in year Y ($).

The annual cost of harvesting a quantity of fuelwood equal to *DEMyr* is calculated as the cost of harvesting one stere (*Phar*) multiplied by the annual yield of fuelwood in steres ($YIELD_{TE}$).

$$CHARV_Y = YIELD_{TE} \text{ x } Phar$$

where:

$YIELD_{TE}$ = Harvestable volume from one rotation of teatree (steres);

Phar = Labour and chainsaw cost to harvest one stere ($).

3.2.5.3 ANNUAL COST OF TEATREE WITH OPPORTUNITY COST OF HOUSEHOLD LAND.

The assumptions made and the model used where teatree fuelwood which is grown on land with an opportunity cost are identical to those for the eucalyptus model in 3.2.4.3, where the total annual cost of grown fuelwood is equal to the harvest cost ($CHARV_Y$, as calculated in section 3.2.5.2) plus any opportunity cost incurred where fuelwood is grown on productive land, as for the eucalyptus models. The only difference in the models is that the variable for the total area covered in fuelwood used in the eucalyptus models ($Leucal_Y$) is replaced by $Ltea_Y$ in the teatree models. The formula used to calculate $Ltea_Y$ is the same as that used for $Leucal_Y$, but uses the value for *ROTarea* calculated for a teatree crop.

3.2.5.4 ANNUAL COST OF TEATREE WITH EXISTING TEATREE ON HOUSEHOLD LAND.

The cost of growing teatree fuelwood was also modelled where the household is assumed to have substantial stands of teatree growing *in situ* on their property. The variable *LANDtea* is defined as the percentage of household land currently covered in teatree, and is assumed to take the value *Z%*, where *Z* is the average percentage of a household's land covered in teatree calculated over all households who's land contains teatree, derived separately for both residents and non residents in chapter 6.

Where a household's land area contained a substantial stock of teatree growing *in situ* it is assumed that the existing teatree stocks will form the basis of the fuelwood crop, and that extra trees will be planted where the existing stock is less than that required to meet the household's fuelwood requirements on an annual basis. The assumption is made that the existing stock of teatree are harvested in equal annual rotations, with the size of each annual rotation (denoted *ROTexist*) being equal to the total area of the existing block, calculated as the total household land area (*TOTland*) multiplied by the percentage of land covered in teatree(*LANDtea*); divided by the rotation length (*ROTlength*).

$$ROTexist = (TOTland \times LANDtea) \; / \; ROTlength$$

The model assumes that the existing scrub is currently 12 years old. This was chosen as a representative age only, recognising that the actual age of the existing scrub and the area covered will vary between individual households. As with the other teatree models, the only cost to the household for the fuelwood will be the harvest cost, although as teatree stocks already exist, harvesting will take place immediately from year 0, unlike in the base model which assumed harvesting did not begin until after a period of time equal to one rotation had elapsed since the planting of the first rotation.

As with the other models, the total annual fuelwood cost consists of both the cost of wood grown ($WOODgrow_Y$) and the cost of wood purchased ($WOODpur_Y$) where necessary. The annual cost of purchased fuelwood where teatree already exists on household land is calculated using the same formula for $WOODpur_Y$ as in section 3.2.4.2. However, the value of the annual fuelwood yield ($YIELD_{TE\,(Y)}$) used is assumed to take two possible values:

i) either a YIELD from one rotation of the existing stock from year 0 to the year prior to ROTlength ($0 \leq Y < ROTlength$); or
ii) a YIELD from one rotation after supplementary trees have been planted to bring the crop up to full production ($Y \geq ROTlength$).

The volume of fuelwood which can be harvested from the **existing** teatree stocks is determined by the area of one rotation of existing teatree (*ROTexist*), the biomass present per ha at the time of harvest ($BIOMASS_{TEA\ (Y)}$), and the actual volume of biomass per stere of fuelwood (*VOLstere*).

$$YIELD_{TE\ (Y)} = ROTexist \ x \ (BIOMASS_{TEA\ (Y)} \ / \ VOLstere)$$

Where the yield from 1 rotation of the existing crop ($YIELD_{TE\ (Y)}$) is greater than or equal to the household's annual requirements (*DEMyr*) then the existing crop will supply all of the household's fuelwood needs and no wood will need to be purchased in any of the years. However, where the annual yield from the existing block is less than required ($YIELD_{TE\ (Y)} < DEMyr$), the household is assumed to purchase additional teatree fuelwood to supplement the yield in the short term. In this situation the model also assumes that the crop size will be increased through the planting of additional trees from year 0 until the year before the initial harvest ($0 \leq Y < ROTlength$) until the total crop size is such that the annual yield from each rotation is equal to the volume demanded ($YIELD_{TE\ (Y)} = DEMyr$).

The additional area that must be planted in each year until the end of the first rotation (denoted *NEWplant*) is calculated as the required rotation area for an annual sustainable yield of *DEMyr* (given by *ROTarea*), less the area of one rotation of the existing stock (*ROTexist*).

$$NEWplant_Y = (ROTarea - ROTexist); \quad 0 \leq Y < ROTlength$$

where:

$NEWplant_Y$ = Area of new plantings needed in year Y;

ROTexist = Area of 1 rotation of existing teatree (ha).

By the end of the first rotation where $Y = ROTlength$, $DEMyr = YIELD_{TE\ (Y)}$.

The cost of wood grown by the household is derived from the following formula:

$$WOODgrow_Y = CHARV_Y$$

The cost of harvest is calculated as the harvestable volume of teatree fuelwood from one rotation ($YIELD_{TE(Y)}$) as defined above, multiplied by the cost to harvest 1 stere of fuelwood.

$$CHARV_Y = YIELD_{TE(Y)} \times Phar$$

3.2.5.5 ANNUAL FUELWOOD COST WITH BOTH EXISTING TEATREE ON LAND AND OPPORTUNITY COST.

The final teatree cost model assumes that the household both utilised part of their land for earning income or producing goods **and** that the land contained substantial section of teatree *in situ*. This model is an extension of the base model to incorporate **both** the teatree currently on land variation and the opportunity cost of land variation.

3.2.6 TEATREE FUELWOOD MODEL II - PURCHASED TEATREE.

The value of *DEMyr* used in the purchased teatree models is the same for each heatload as defined for the eucalyptus models. The net present cost of supplying a heatload using only purchased teatree fuelwood in either the woodstove **or** the woodfire is calculated from the following model:

$$NPC = APPL + \sum_{Y=0}^{29} PV\ (WOODpur_Y,\ MAINT_Y) - PV(SALV)$$

where:

NPC = Net present cost of heatload ($);

$APPL$ = Appliance purchase cost in year 0 ($);

PV = Present value ($);

$WOODpur_Y$ = Cost of **purchased teatree** fuelwood in year Y ($);

$MAINT_Y$ = Periodic appliance maintenance cost in year Y ($);

SALV= Appliance salvage value in year 29 ($), where $SALV = APPL$ x (LIFE - 30).

The **annual** cost of purchased teatree fuelwood is equivalent to that defined in section 3.2.4.2, with the exception that a quantity of fuelwood equal to *DEMyr* is purchased by the household from year 0 to 29 inclusive, and no wood is grown.

$$WOODpur_Y = DEMyr \times PRICEwood; \quad 0 \leq Y \leq 29$$

where:

DEMyr = Annual fuelwood requirement (TE steres);

PRICEwood = Price of purchased teatree fuelwood ($/stere, ex GBI).

3.3 LPG ENERGY EXPENDITURE MODELS.

3.3.1 INTRODUCTION.

The net present cost of using Liquid Petroleum Gas (LPG) to supply the heat energy requirements of heat loads in Great Barrier Island households was calculated using three LPG energy expenditure models, with each of the three expenditure models defined for a specific heat load.

The appliances chosen for use in the models are considered typical of LPG fuelled appliances likely to be used in households on Great Barrier Island (Figure 3.2).

FIGURE 3.2 LPG APPLIANCES USED IN MODELS.

Heat Load	Appliance used
Cooking	Vulcan Holiday LPG/Propane stove
Water heating	Rinnai REU 58E LPG water heater
Space heating	Goldair GSR 420 Radiant heater

For each appliance, cost and performance specifications were obtained from retailers and manufacturers. The **useful** energy requirement of each heatload (*HEATyr*) is assumed to be the heatload's yearly useful heat energy requirement for a 365-day year, with the exception that the useful heat requirement for water heating assumes that as the water is heated and used immediately there are no standing losses.

3.3.2 LPG ENERGY EXPENDITURE MODEL.

Each of the three LPG energy expenditure models calculates the net present cost to the household of using LPG to produce heat for the heatloads from the following model:

$$NPC = APPL + \sum_{Y=0}^{29} PV\,(\,Cgas_Y,\,MAINT_Y) - PV(SALV)$$

where:

NPC = Net present cost (\$);

$APPL$= Appliance purchase cost in year 0 (\$);

$Cgas_Y$ = Cost of LPG gas used in year Y (\$);

$MAINT_Y$ = Periodic appliance maintenance cost in year Y (\$);

$SALV$ = Appliance salvage value in year 29 (\$), where $SALV = APPL$ x (Life - 30).

The annual cost of LPG fuel for each of the heat loads (*Cgas*) is calculated as the price of LPG per kg to the household (denoted *PRICEgas*) multiplied by the quantity of LPG required annually for the heatload. The household's annual LPG requirement is calculated as the household's yearly requirement of LPG fuel <u>based on a heatload usage of 365 days per year</u> (*DEMgasyr*) multiplied by the proportion of days per year for which the household is in residence (*DPY* / 365).

$$Cgas_Y = (DEMgasyr \times (DPY / 365)) \times PRICEgas$$

where:

DEMgasyr = Yearly requirement of LPG based on usage of 365 days (kg);

DPY = Days in residence per year;

PRICEgas = Price of LPG ($ per kg).

The household's yearly requirement of LPG (*DEMgasyr*) for a heatload is equal to the number of hours for which the appliance is used annually (based on a usage of 365 days/yr, denoted *USEyr*) multiplied by the appliance's hourly LPG consumption rate (denoted *RATE*), derived from the manufacturer's specifications.

$$DEMgasyr = USEyr \times RATE$$

where:

USEyr = Total number of appliance usage hours per year;

RATE = Rated fuel consumption rate of appliance (kg/hr).

The appliance's annual hours of usage (*USEyr*) is calculated as the household's yearly **useful** heat requirements for the heat load (*HEATyr*) divided by the rated heat output of the appliance per hour.

$$USEyr = HEATyr / Y$$

where:

HEATyr = Annual useful heat requirement for heat load (kW);

Y = Rated heat output of appliance (kW/hour).

Where the appliance's LPG consumption rate is not given by the manufacturers (such as for the Vulcan stove) it is calculated from the following formula derived by Worley (1989):

$$RATE = (12.7 \times Y) / \varepsilon$$

where:

12.7 = Energy content of LPG (kWh/kg);

ε = Appliance heat conversion efficiency (%)

The data for appliance purchase and maintenance costs, appliance rated heat output and fuel consumption rates, fuel price, and heat load yearly energy requirements which were used in the expenditure models are presented in appendix 2.

3.4 ELECTRICITY ENERGY EXPENDITURE MODELS.

3.4.1 INTRODUCTION.

The cost of supplying a household's heat requirements from generated electricity is compared for three alternative sources of electricity:

i) a diesel generating system;
ii) a petrol generating system; and
iii) a wind turbine/solar electric panel hybrid system.

An expenditure model is developed for each electricity source, and the cost of supplying electricity for cooking, water heating and space heating calculated for each. The models developed assume that a household's electricity generating system also provides electricity for other household appliances and lighting in addition to heat loads. The capital and maintenance costs of each of the systems are therefore allocated between the heat loads and the other loads on a **proportion of total output basis.** Fuel costs are calculated by the models directly on the heat load appliance's hours of usage.

Information obtained from suppliers and manufacturers of remote area power systems (RAPS) detailed a range of daily household electricity requirements representative of a range of different sized houses, where the size of the house is a proxy for the number of residents and the number and variety of appliances used. The average daily **total** energy requirements of a medium-sized household on RAPS electricity was selected as an estimate of the requirements of an average Great Barrier Island household using generated electricity, where a typical medium sized household is estimated to have a daily electricity requirement of 2.2 kW **in addition** to heat load energy requirements - sufficient to power a number of lights and a limited number of appliances. The information which is used to calculate the energy requirements is presented in appendix 3. The models assume that the house is supplied with 240 volt AC electricity, and that standard AC appliances are used.

For each of the three electricity sources a representative generating system capable of meeting the household's total electricity requirements was selected. It is assumed that the generators and turbines are used to charge batteries rather than supplying the appliances with electricity directly, and that the appliances will be run from the batteries, a standard practice with domestic RAPS electricity systems (*Pers comm:* Power Mate (1994); Mase (1994)).

3.4.2 ELECTRICAL ENERGY EXPENDITURE MODEL.

The net present cost of the heat load, which consists both of the cost of the appliance used and the cost of the electricity generated, is derived from the following model:

$$NPC = NPC_A + NPC_G$$

where:

NPC = Total net present cost of heatload ($);

NPC_A = Net present cost of appliance ($);

NPC_G = Net present cost of electricity generated ($).

The remainder of this section explains how the various costs were calculated for each of the three electricity systems modelled.

3.4.2.1 APPLIANCE COST.

The net present cost of the appliance used for the heatloads is derived from the following model:

$$NPC_A = APPL_A + \sum_{Y=0}^{29} PV\ (MAINT_{Y(A)}) - PV(SALV_A)$$

where:

NPC_A = Net present cost of appliance ($);

$APPL_A$ = Appliance purchase cost in year 0 ($);

PV = Present value ($);

$MAINT_A$ = Periodic appliance maintenance cost in year Y ($/yr);

$SALV_A$ = Appliance salvage value in year 29, where $SALV_A = APPL$ (Useful life - 30) ($).

The three appliances which were selected for inclusion in the expenditure models are presented in figure 3.3, while the performance and cost specifications for each of the three appliances are presented in appendix 3.

FIGURE 3.3 ELECTRICAL APPLIANCES USED IN MODELS:

Heat Load:	Appliance
Cooking	Shacklock 640H basic radiant oven
Space heating	Hanimex sunglow 1000 Watt bar heater
Water heating	135 litre low pressure hot water cylinder

3.4.2.2 ELECTRICITY COST - DIESEL AND PETROL GENERATORS.

Both diesel and petrol generators are available in a range of models and rated Wattage outputs. Figure 3.4 presents the two generators which were selected as being suitable for meeting the electricity requirements of a medium sized house on RAPS electricity, based on information and recommendations from suppliers.

FIGURE 3.4 DIESEL AND PETROL GENERATORS SELECTED.

Fuel	Generator model:
Diesel	MASE easy 4200DM Diesel, continuous output: 3.6 kW
Petrol	MASE FM 4000 Petrol, continuous output: 3.0 kW

Price and performance specifications were obtained for both generators, and are presented in appendix 3.

The total net present cost of the generated electricity (NPC_G) consists of the sum of the generating system capital cost (denoted *GEN*), the present value of the periodic maintenance costs (denoted $MAINT_{Y(G)}$), and the present value of the yearly fuel costs (denoted $Cfuel_Y$), less the salvage value of the system (*SALV*). The capital cost, salvage value and yearly maintenance costs are all multiplied by a factor of ***P***, being the proportion of system capital and maintenance costs directly attributable to the heatload. In addition to the generator, the generating system cost (*GEN*) also includes the cost of rechargeable batteries and an inverter to convert the AC current produced by the generator and used by the appliances to the DC current stored by the batteries.

The net present cost of generating the required quantity of electricity for each of the heat loads is calculated from the following algebraic model:

$$NPC_G = (\mathbf{P}\ x\ (GEN - PV(SALV)) + \sum_{Y=0}^{29} PV\ (MAINT_{Y(G)}\ x\ \mathbf{P}\ ) + \sum_{Y=0}^{29} PV\ (Cfuel_Y)$$

where:

NPC_G = Net present cost of generated electricity ($);

P = Proportion of capital and maintenance costs attributable to heat load;

GEN = Generating system purchase cost in year 0 ($);

$MAINT_{Y(G)}$ = Periodic generating system maintenance cost in year Y ($);

SALV = Generating system salvage value in year 29 ($),
where *SALV* = *GEN* x (Use life - 30);
$Cfuel_Y$ = Cost of generator fuel used in year Y ($).

P is calculated as the ratio of the quantity of electricity required for the heatload to the total household electricity requirements.

$$P = (HEATyr / (HEATyr + 2.2)$$

where:

P = Proportion of system costs attributable to heatload;
HEATyr = Required useful heat for heatload;
HEATyr + 2.2 = Total daily household electricity requirement (kW/day).

The annual fuel cost for either the diesel or petrol systems (*Cfuel*) is calculated as the price of the fuel to the household per litre (denoted *PRICEfuel*) multiplied by the quantity of fuel required annually by the generator to produce the required quantity of electricity for the heat load. The household's annual fuel requirement is calculated as the household's yearly requirement of generator fuel based on a heatload usage of 365 days per year (*DEMfuelyr*) multiplied by the proportion of days per year for which the household is in residence.

$$Cfuel_Y = DEMfuelyr \times PRICEfuel \times (DPY/365)$$

where:

DEMfuelyr = Quantity of generator fuel required per year: 365 day usage (litres);
PRICEfuel = Price of fuel ($/l);
DPY = Variable for number of days in residence per year.

The quantity of fuel required in a 365-day year (*DEMfuelyr*) is calculated as the annual total electricity input required by the appliance over a 365 day year (denoted *DEMappyr*) multiplied by the quantity of electricity generated by the generator from 1 litre of fuel (denoted *RATE*).

$$DEMfuelyr = DEMappyr \times RATE$$

where:

DEMappyr = Annual total electricity input required by appliance (kW);

RATE = Electricity generated from 1 litre of fuel (kW/litre).

The total quantity of electricity required by the appliance in a year (*DEMappyr*) is equal to the total quantity of useful heat required by the heat load (*HEATyr*) divided by the appliance's electricity to heat energy conversion efficiency (ε), derived from the appliance's specifications.

$$DEMappyr = HEATyr \ / \ \varepsilon$$

where:

HEATyr = total quantity of energy required per year (kW);

ε = appliance electricity to heat conversion efficiency (%).

The generator's electricity output per litre of fuel consumed is derived for both generators from information contained in the manufacturer's specifications, and is calculated as the ratio of the generator's electricity production rate in kW/hr (*OUThr*) to it's fuel consumption rate in litres/hr (*CONShr*).

$$RATE = OUThr \ / \ CONShr$$

where:

OUThr = Generator electricity production rate (kW/hr);

CONShr = Generator fuel consumption rate (litres/hr).

3.4.2.3 ELECTRICITY COST - WIND AND SOLAR HYBRID SYSTEM.

The cost of meeting a household's heatload demands from a wind turbine/solar electric panel hybrid system is derived from the following algebraic model, where the capital costs, salvage value and periodic maintenance costs are multiplied by

P - the proportion of systems costs directly attributable to the heatloads, as calculated previously in section 3.4.2.2. As the fuel inputs into the system (wind and solar radiation) are obtained at zero cost, the only costs incurred by the household are the system maintenance and capital costs. The model does not utilise the variable for the number of days in residence per year, as unlike a diesel or petrol generator, no component of the system's cost is affected by the amount of time for which output is required - a wind/solar system produces electricity continuously whether required or not.

$$NPC_G = \boldsymbol{P} \times (GEN - PV(SALV_G)) + \sum_{Y=0}^{29} PV\,(\,\boldsymbol{P} \times MAINT_{Y(G)})$$

where:

NPC_G = Net present cost of generated electricity ($);

GEN = Generating system purchase cost in year 0 ($);

PV = Present value ($);

$MAINT_{Y(G)}$ = Periodic generating system maintenance cost in year Y ($);

$SALV_G$ = Generating system salvage value in year 29, where $SALV_G = GEN$ x (Useful life - 30).

Enquiries to a number of retailers and manufacturers of alternative energy products in the Auckland area revealed that individual systems have a specified maximum daily electricity output, and therefore systems are tailored to meet the energy requirements of individual households (*Pers comm:* Soma (1994), Forgan Jones (1994)).

Industry sources reported that in practice the best results were achieved using a combination of wind and solar technologies (Ibid). A Forgan Jones BP wind/solar hybrid system was chosen as a representative electrical system, with a maximum rated output of 6.8 kW per day - sufficient to meet the electricity needs of a medium sized house with **either** a cooking load **or** a space heating load. This is considered to be a high load by industry standards, and this particular system had the highest possible output rating of those commonly sold by manufacturers.

Enquiries to manufacturers revealed that while systems with higher daily outputs, in order to supply electricity for multiple heatloads or a water heater, are possible, they are not usually installed in households due to their high capital costs. Additionally, wind and solar technologies are not considered by manufacturers to be competitive with fuelwood and LPG systems for heatloads, and as a result, prices for units with higher output ratings are not available.

In order to assess the claims that electrical systems were not competitive with other energy systems for supplying heatloads, and to compare the costs of alternative energy systems with those of conventional diesel/petrol electricity, fuelwood and LPG systems, it was necessary to estimate the prices of wind/solar electricity generating systems which would be capable of producing the required output to supply multiple heat loads. Industry sources reported that alternative energy systems benefited from economies of scale, and a system with double the maximum rated energy output can be obtained for less than double the capital cost (*Pers comm:* Forgan Jones). Approximate system prices were estimated by creating a cost function for wind/solar systems from the available price data given for a range of systems, each with different output ratings (in kW/hrs/day). System prices were regressed against output using least-squares regression to form a cost function which estimated system price where output is the independent variable. The resulting cost curve was best represented by a logarithmic function.

The derived cost function is considered to be the best approximation to the actual cost of higher output systems available. The function is used in the expenditure models to estimate the cost of a system when the daily input required by the appliance (*DEMappyr*/365) is known.

3.5 SOLAR WATER HEATER ENERGY EXPENDITURE MODEL.

The net present cost of using a solar water heating system in Great Barrier Island households is calculated using an energy expenditure model, where the value of *HEATyr* is defined as the daily requirement of heat for a water heating load, including standing losses. A Solarmax solar water heating system was chosen as a representative appliance. The manufacturer's specifications using solar radiation data for the Auckland region showed that on average the system could supply only up to 88% of the household's required daily heat energy, and that in many cases a backup or booster system is needed. The energy expenditure model assumed that either a wood stove, a wood fire, a gas water heating unit or an electric water heating element could be used as a booster. The model therefore calculated the cost of water heating as both the cost of using the solarmax unit, plus the additional cost of either of the four methods as a booster.

With the exception of the LPG water heater backup, it is assumed that the other booster appliances were already owned by the household, as it is considered that due to their high capital costs a household would not purchase any of the appliances specifically for use as a booster, but would use them where they were already owned. The cost of solar heated hot water is calculated from the following model, where the net present cost includes both the cost of the solar water heater, and the appliance and/or fuel cost of the booster.

$$NPC = NPC_S + NPC_B$$

where:

NPC = Total net present cost of water heating ($);

NPC_S = Net present cost of solar system ($);

NPC_B = Net present cost of booster system ($).

$$NPC_S = APPL + \sum_{Y=0}^{29} PV\ (MAINT_Y) - PV(SALV)$$

where:

$APPL$= Water heating appliance cost in year 0 ($);

$MAINT_Y$ = Periodic water heating system maintenance cost in year Y ($);

$SALV$ = System salvage value in year 29, where $SALV = APPL$ x (Useful life - 30).

The net present cost of the booster for each of the four booster systems is calculated from the following models which incorporated the variable $\boldsymbol{R}$ as the percentage of the water heating load to be met from the booster system.

$$NPC_B \text{ for an LPG booster} = APPL\sum_{Y=0}^{29} PV\ (Cgas_Y \ x\ \boldsymbol{R}) - PV(SALV)$$

$$NPC_B \text{ for a woodfire/stove booster} = \sum_{Y=0}^{29} PV\ ((WOODpur_Y + WOODgrow_Y) x\ \boldsymbol{R})$$

$$NPC_B \text{ for a diesel generator} = \sum_{Y=0}^{29} PV\ (Cfuel_Y \ x\ \boldsymbol{R})$$

where:

$\boldsymbol{R}$ = Percentage of heatload to be met from booster system;

$Cgas_Y$ = Cost of LPG fuel in year Y as calculated from LPG water heating models;

$WOODpur_Y$ = Cost of wood purchased in year Y as calculated from fuelwood water heating models;

$WOODgrow_Y$ = Cost of fuelwood grown in year Y as calculated from fuelwood water heating models;

$Cfuel_Y$ = Cost of generator fuel in year Y as calculated from electricity water heating models.

R is calculated as the ratio of the household's daily water heating requirements to be met by a booster (equal to the daily water heating requirement less the contribution made by the Solarmax) to the households total daily water heating energy requirements.

$$\boldsymbol{R} = ((HEATyr/365) - 6.9\ )\ /\ (HEATyr/365)$$

where:

HEATyr = Yearly requirement of water heating (kW);

6.9 = Daily heat contribution from SolarMax unit (kW).

CHAPTER 4. DERIVATION OF FUELWOOD CROP BIOMASS GROWTH FUNCTIONS.

4.1 EUCALYPTUS SALIGNIA/BOTRYOIDES BIOMASS GROWTH RATE.

In this section the value of the biomass growth rate (*GROWTH*) used in the eucalyptus fuelwood models is derived, where biomass growth rate is measured in air-dry kilograms of wood per hectare per year. It is considered that the best data available on the growth rates of various eucalyptus species was that used by Sims *et al* (Ibid), which details stand parameters and wood yields for the eucalyptus species salignia, nitens, fastigata, and regnans from a range of independent studies. This data is presented in appendix 5a.

Sims *et al* (Ibid) wrote that although the biomass models which they constructed utilised the best data available, as short rotation woody biomass production was a relatively new concept in New Zealand at the time of their analysis (1991), there was a shortage of data available on the yields attainable from different species under different stocking rates, management techniques and locations. A search of the relevant literature confirmed this, and only one other eucalypt growth trial, Fredrick (1985), could be found which contained relevant growth data.

From the data collected, Sims *et al* (Ibid) concluded that a mean annual increment (MAI) in above ground biomass of 20 oven-dry tonnes (ODT) per ha/year was feasible from eucalypts, within a certain range of stocking rate/age combinations. While this appears a reasonable assumption given the shortage of data available, a closer analysis of the data found that in general the only eucalyptus species that actually achieved a MAI of 20 ODT/ha/yr or better on the trials was eucalyptus regnans, which attained an average MAI of 24 ODT/ha/yr. An analysis of the data collected by Fredrick (1985), reproduced in appendix 5a, found that eucalyptus regnans achieved an average MAI of 25 ODT/ha/yr in this trial.

A further analysis of the data collected by Sims *et al* (Ibid) showed that the average MAI obtained over all of the other eucalypt species excluding regnans was only 17 ODT/ha/yr. The other species appear to have reasonably similar biomass growth rates, although the one eucalyptus fastigata trial gave a low MAI of only 13 ODT/ha/yr. From the results it appears that eucalyptus regnans produces biomass at a faster rate than any of the other Eucalyptus species. However, this conclusion conflicts with published information which reports that depending on the location, the species which are recommended for fuelwood cropping in New Zealand, based on their high growth rates, are eucalyptus nitens for colder areas, and eucalyptus salignia and botryoides for warmer areas (New Zealand Journal of Forestry Science, 1985).

The significance of the trial results reduces when it is considered that all of the trials were located in the central North Island of New Zealand, whereas it was reported (New Zealand Journal of Forestry Science: 15(2),1985a) that the best plantation successes for eucalyptus salignia have been achieved in the northern part of the North Island. Additionally, the trials had been conducted under a range of soil and climatic conditions, stocking rates and management regimes, which would have strongly affected the results obtained. It was therefore concluded that it would be inappropriate to attach much significance to the results obtained from individual trials or individual species.

In the absence of more accurate data it is assumed that under the favourable climatic growing conditions present on Great Barrier Island, a MAI of 20 oven-dry tonnes per hectare per year is feasible for either eucalyptus salignia and eucalyptus botryoides (Sims *et al*, Ibid). This assumption appears reasonable given that the best plantation successes for eucalyptus salignia have been achieved in the northern part of the North Island, and that the New Zealand Forest Research Institute (symposium #10, 1968) reports that most eucalypt species will grow well on land which is able to grow manuka, or that has in the past grown native forests, both of which are characteristic of the Great Barrier Island land area.

4.2 TEATREE BIOMASS PRODUCTION FUNCTION.

4.2.1 INTRODUCTION.

In this section the biomass growth function used to calculate the value of $BIOMASS_{TEA}$ in the teatree fuelwood models is derived, where teatree biomass growth is measured in cubic metres per hectare per year.

At the time of writing, with the exception of Watson and O'Loughlin (1985) who had derived a production function for the biomass production of manuka roots, there had been no work published in New Zealand which had modelled the biomass production of manuka or kanuka growing under natural conditions. However, several papers had been published which attempted to model single aspects of above-ground teatree biomass growth. The most important of these were Watson and O'Loughlin (Ibid), whose root biomass study had produced data on the diameter at breast height (dbh) of a sample of manuka and kanuka trees at varying ages; and Allen *et al* (1992), who had modelled the relationship between the stem density (number of individual stems) of teatree stands and the average age of the stand.

Data from these two studies was used to model the diameter growth of teatree with age, and the change in the stem density (number of stems per ha) of a teatree plot with age. From here a sample of teatrees was measured using a modification of the sectional method of volume estimation, and this data was used to estimate individual tree volumes. A growth function modelling the relationship between the diameters of teatree and their volumes is constructed from the calculated volumes and the tree measurements. The three derived equations for diameter, density and volume are then combined to form a biomass production function which estimates the total volume of wood present on a 1ha block of land planted in teatree, to define the *BIOMASS* parameter in the teatree energy expenditure models.

4.2.2 DIAMETER AT BREAST HEIGHT GROWTH FUNCTION.

Tree diameter is usually measured as it's diameter at breast height (dbh), where dbh refers to the diameter over bark measured at breast height (1.4 metres) at right angles to the tree's stem (Goulding, 1994). The general growth trend of a tree's diameter at breast height with age is represented by a sigmoid or cubic-type growth curve displaying slow initial growth at the seedling stage, an approximately linear stage which represents the highest rate of marginal physical growth, and a plateau stage as the tree reaches maturity (Carron, 1968).

Watson and O'Loughlin (Ibid) measured the diameters of 10 manuka and kanuka trees from two different teatree blocks aged between 13 and 50 years old. The equivalent diameters of multi-stemmed trees were obtained from summing the cross sectional areas of the individual stems and calculating the corresponding diameters. A scatterplot of the data collected by Watson and O'Loughlin (Ibid) showed that a positive relationship appeared to exist between the age of the recorded trees and their dbhs, with diameter considered to be a function of age.

The data collected by Watson and O'Loughlin (Ibid) was used to derive a growth function between the age of a stand of teatree, and the average diameter of trees of this age. The stem diameters were regressed against tree age using least-squares regression, and a growth function fitted which best appeared to model the physical growth in tree diameter with age.

A cubic function of the type $Y = a + bX + cX^2 + dX^3$ was fitted to the data. The resulting least-squares production function was nearly perfectly linear, with coefficients in the order of 1E-17 for a and 1E-18 for b. The cubic form was rejected as being unsuitable for modelling Watson and O'Loughlin's (Ibid) data.

Two functions of the forms $Y = a + bX + cX^2$ and $Y = a + bLOG(X)$ were fitted to the data as it was anticipated that the relationship may take a logarithmic form. However, the resulting growth function from the data was near-linear and took a very weak exponential growth form rather than logarithmic. It was considered that this was a result of the small quantity of data collected by Watson and O'Loughlin (Ibid), which made variations between individual trees more significant than would have been the case had a larger quantity of data been used.

It was therefore considered that given the limited quantity of data collected by Watson and O'Loughlin (Ibid), the most appropriate form for estimating a relationship between the average dbh of a stand of teatree and the stand age from this data would be a linear equation. The tree dbh data was regressed against age using least squares regression, and a linear function was fitted to the data.

The resulting growth function is as follows (figure 4.1):

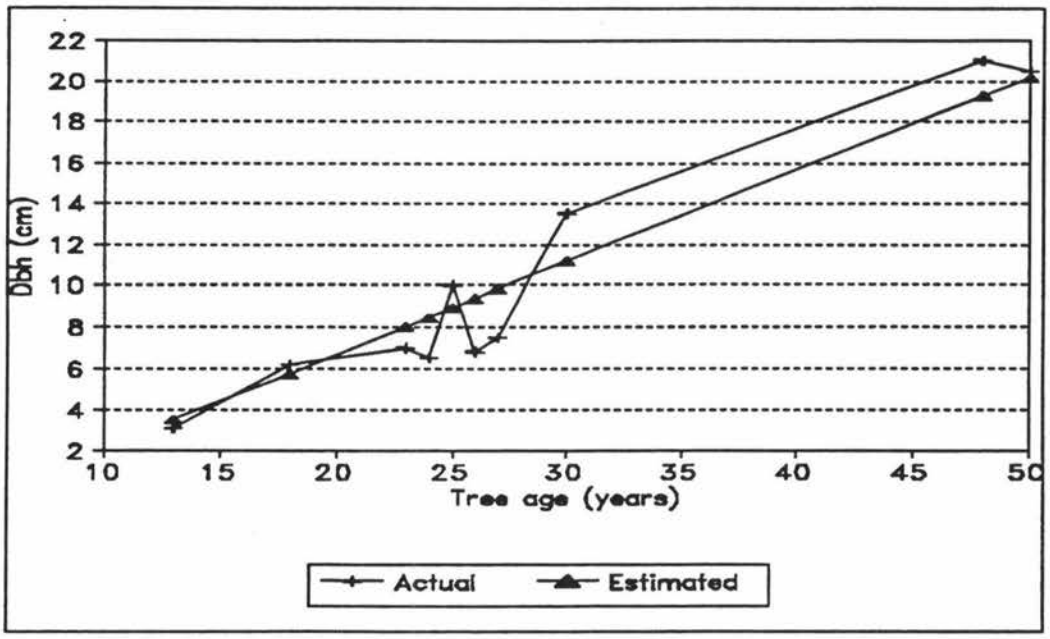
$$dbh = -2.34 + (.450 \times Age)$$

where:

dbh = Average diameter at breast height of trees in stand (cm);

Age = The age of the stand in years.

FIGURE 4.1: TEATREE DBH INCREMENT AS A FUNCTION OF AGE.



This function is considered to provide a good estimate of diameter within the age range of 10 to 50 years old. Ages beyond these limits are considered not to be representatively modelled by the function.

4.2.3 STEM DENSITY GROWTH FUNCTION.

Allen *et al* (1992) recorded the density and average ages of trees from 8 different teatree stand samples, which ranged in average age from 2 to 70 years old (taken as the average age of tree establishment). An analysis of the data showed that a negative logarithmic relationship appeared to exist between the average age of a teatree stand, and the average number of trees per ha within the stand, where the number of trees in a stand was considered to be a function of the stand age (Ibid). This observation was confirmed by Allen *et al* (Ibid), who reported that stems densities decreased markedly over time due to competition and overcrowding.

The data collected by Allen *et al* (Ibid) (presented in appendix 6a) was used to derive a growth function between the age of a stand of trees and the average stem density per ha. The tree density data was regressed against age, and a number of different function types fitted to the data.

The physical relationship between stem density and average tree age appeared to be modelled most closely by the following logarithmic growth function:

$$\bar{D} = 43{,}797 - (22{,}936 \times Log(Age))$$

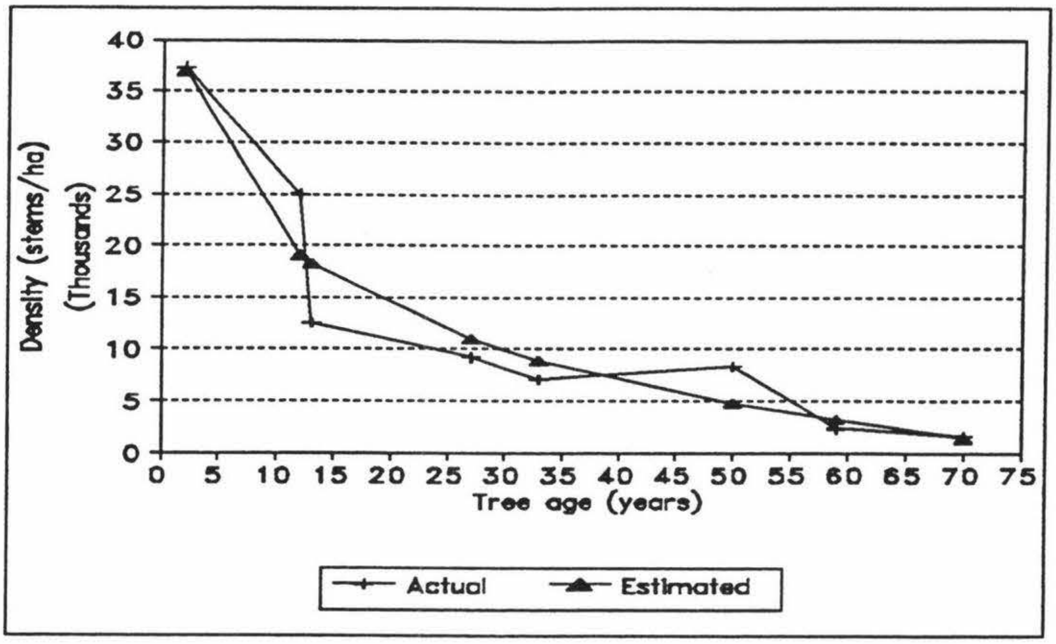
where:

$\bar{D}$ = Tree density (stems per ha);

Age = The average age of the tree stand in years.

The graphical form of the function is shown over the page in figure 4.2. It is considered that the density growth function is appropriate for modelling teatree density within the wide age range of 2 to 70 years old, due to the wide range of ages sampled by Allan et al.

FIGURE 4.2: RELATIONSHIP BETEEN TEATREE AGE AND STEM DENSITY.



4.2.4 TREE VOLUME GROWTH FUNCTION.

4.2 4.1 INTRODUCTION.

No work had previously been published which had attempted to model the relationship between either the age, diameter, or height of a manuka or kanuka tree and the tree's volume. In order to construct a teatree biomass production model, original data on teatree measurements was collected and used to model a growth function for individual tree volume.

As the general trend in volume growth with age for trees usually takes the shape of a sigmoidal or cubic growth curve (Carron, 1968) it was assumed that a tree's volume was dependent on the tree's age. As the relationship between tree age and average dbh had already been derived in section 4.4.2, it was decided that the most appropriate approach to modelling the relationship between the average age of a stand of trees and the average per tree volume of trees within that stand was to model the relationship between average diameter and average tree volume, using average dbh as a proxy for age.

The assumption that tree volume is dependent upon diameter appears reasonable given that conventional tree mensuration techniques derive a tree's volume using it's diameter as one of two variables (height is the second variable), and secondly, that it was considered that diameter was dependent on tree age, where tree age was the major independent factor in biomass volume growth (Carron, 1968).

As the relationship was to be used to model a fuelwood crop, it was decided that only above ground wood volume of a size suitable for use as fuelwood would be measured, and that twigs, leaves and small branches under approximately 1cm in diameter would not be included in the model.

4.2.4.2 SURVEY OF TREE VOLUME ESTIMATION METHODS.

A survey of the literature showed that there are two main methods commonly used in practice to estimate tree volume:

1) Destructive sampling and weighing of the tree; and
2) Mathematical estimation

1) The destructive sampling method.
Destructive sampling involves cutting down and weighing all of the parts of the tree to derive the total biomass weight. When the average density of the wood is known the volume of the tree can be estimated by dividing the total mass of the tree by the wood density. This approach was used by Tombleson (1985), Watson and O'Loughlin (Ibid), Levett *et al* (1985), and Fredrick *et al* (Ibid). While this method yields accurate results for determining the mass and volume of a tree, it is more often used to measure mass rather than volume, and it has the significant drawback in that the tree must be destroyed to obtain the data.

2) Mathematical estimation methods.
The second and more traditional approach to tree volume measurement involves using mathematical formulas to estimate the volume of the tree. Carron (Ibid) reports that in practice, irrespective of where in a tree a log comes from, or of the

type of tree which is being measured, a log or tree stem is almost invariably regarded as a frustum of a second degree paraboloid (the remainder of a cone whose upper part has been cut off parallel to the base), and it volume is usually calculated by one or other of the Huber or Smallen method.

Given the ecological and environmental significance of teatree, and it's protected status on Great Barrier Island, it was considered that destructive sampling would be undesirable and inappropriate. It was therefore decided to use traditional mathematical techniques of volume estimation to model the relationship for tree volume as a function of diameter.

4.2.4.3 SECTIONAL METHOD OF VOLUME ESTIMATION.

The traditional or 'objective' method of measuring tree volume considers the tree as a single log whose branches have been trimmed off at their junction with the stem. However, Carron (Ibid) writes that very few trees represent simple, ideal geometric solids, and most have irregular surfaces due to the episodic growth pattern of the stems. When occurring under natural conditions, teatree displays a non-uniform and uneven growth form, which differs considerably from the standard cylindrical bole of pine and eucalypt trees grown under managed silvicultural regimes. Teatree tends to develop multiple stems and branches of substantial size growing at various angles to the tree. This makes the traditional volume estimation techniques unsuitable for use with teatree.

However, when teatree grows at a high density, as is characteristic of teatree growing on Great Barrier Island, it's shape tends to be more upright and uniform between trees. While it may still produce multiple stems, due to the restricted light access and the close proximity of other trees the overall spread of the tree is significantly reduced with most of the growth occurring upwards, rather than outwards.

To take account of the non-uniform growth form of teatree it was decided to use a modification of the sectional method of volume estimation which estimates whole tree volume as a sum of the volumes of individual sections of the tree (Carron, Ibid). Carron writes that the sectional method is considered to be particularly suitable for estimating both multi-stemmed trees and standing trees, both of which were characteristic of the current application.

The standard sectional method assumes the stem to consist of a number of sections of constant length, with a section of variable length remaining at branch and stem ends. The volumes of the individual sections are estimated using a mathematical volume equation such as Huber's formula, and summed to give a whole tree volume. It was considered that given the uneven branch shape of teatree, which is rarely uniformly straight throughout the entire branch, the most appropriate method of estimating volume would be to use a modification of the sectional method which utilised a variable section length over all sections instead of a constant length.

Under the standard sectional method the fixed sectional length is used to minimise errors which may occur when the same log is measured a number of times by different people. Carron reports that the precision between measurers is reduced, but only slightly, when the positions of measurement are unrepresentative (such as crooked branches) and the measurer uses a different technique to overcome this. Carron also reports that measurement bias from uneven stem form is reduced when shorter sectional lengths are taken in areas of non-uniform shape. In light of this it was considered that more accurate estimates from individual branches would be obtained by using a variable section length which could be adjusted to minimise errors arising from crooked branches.

4.2.4.4 TEATREE VOLUME ESTIMATION.

A suitable stand of teatree of varying ages and heights growing at high densities was located in Tokomaru, 15kms southwest of Palmerston North. Due to the lack of data available about the growth of teatree in different areas around New Zealand the assumption was made that teatree stands growing in the Manawatu were representative in their volume and diameter growth over time of teatree growing on Great Barrier Island and in other areas throughout New Zealand. The stand of teatree in Tokomaru, growing at high densities on land which contained remnants of native forest, was considered to be growing under similar conditions, with the exception of climate, to teatree growing on Great Barrier Island.

A total of 11 trees of various diameters, heights and shapes were sampled from a range of locations within the stand. The diameter at breast height of each tree was measured and recorded, and the equivalent diameters of multi-stemmed trees was derived by summing the cross sectional areas of the individual stems and calculating the diameter corresponding to this cross sectional area (Allen *et al*, Ibid). With the aid of chalk each tree was visually divided up into numerous segments, each of which was approximately uniform in shape through the segment. Individual branches and stems were divided into multiple segments where the branch shape was crooked, to obtain approximately straight branch and stem segments. For each section the sectional length and the circumference of both ends was measured and recorded. Branches smaller than approximately 1cm in diameter and twigs were not included in the volume estimation.

Three main techniques of volume estimation were then used to calculate the volume of each individual tree segment from the data: Huber's formula, Smallan's formula and Whyte's method.

Huber's formula, also known as the cylinder formula (Whyte, 1994) is derived as follows:

$$v = \frac{1}{4} \pi \, x \, d_5 \, x \, L$$

where:

v = volume (cm_3);

d_5 = mid sectional diameter (cm);

L = sectional length (cm);

Smallen's formula is calculated by:

$$v = \tfrac{1}{8}\,\pi\, x\, (D^2 + d^2)\, x\, L$$

where:

D = large end diameter (cm)

d = small end diameter (cm) (Goulding, 1994).

Whyte's formula, a modification of Smallen's, is also often used for estimating sectional volumes. Whyte's formula is calculated by:

$$v = (\pi / 12)\, x\, (D^2 + d^2 - D\, x\, d)\, x\, L \qquad \text{(Ibid).}$$

Carron writes that each method differs chiefly in the assumptions which it makes as to the shape of the log. Huber's method considers the sections to be a perfect cylinder, whereas Whyte's and Smallen's methods assume the sections to have a more conical shape. Each of the three methods were used to estimate the volume of a variety of hypothetical tree sections. The results showed that where the end diameters of the sections were equal, all three methods gave an equal volume. However, when the difference between the two diameters increased, the Smallen method calculated volumes significantly higher than obtained through using wither Huber's or Whyte's method. This observation was confirmed by Carron, who wrote that Smallen's formula gives very little error when the diameters of both ends of the log are similar, but the error increases with an increase in the difference between the two diameters. The results obtained from using Huber's formula and Whyte's method were very similar, with Whyte's formula calculating volumes slightly higher than Huber's. A comparison of the results obtained using the three methods is shown in table 4.1.

TABLE 4.1: COMPARISON OF HUBER, WHYTE AND SMALLEN METHODS OF SECTIONAL VOLUME ESTIMATION.

D =	.5 m	.5 m	.5 m
d =	.5 m	.4 m	.3 m
L =	1 m	1 m	1 m
	Results:		
Huber: vol (m^3) =	*.196*	*.159*	*.126*
Whyte: vol (m^3) =	*.196*	*.160*	*.128*
Smallen: vol (m^3) =	*.196*	*.161*	*.134*

It was considered that Whyte's method gave the most reliable estimation of teatree volume for two main reasons. Firstly, it took account of the differing diameters of the cylinder ends rather than just using a mean diameter as did Huber's formula, and it estimated volumes with considerable less error where the end diameters differed than did Smallen's method, which also took account of the differing diameters of the cylinder ends. Secondly, Whyte's method assumed the tree sections to be of a conical rather than cylindrical shape, which was felt to be more appropriate to the shape and low stature of teatree.

Sectional volumes were calculated from the data using Whyte's method, and summed to give whole tree volumes. These were then regressed against the data collected for tree diameter. A number of growth functions were then fitted to the data to determine which type of function most closely modelled the physical relationship, and growth function was derived which modelled average tree volume as a function of average tree diameter.

The results showed that there appears to be a general sigmoid-type relationship between tree diameter and volume as was expected, although there are significant variations between individual trees which were considered to be to be due to the influence of tree height, which was not measured by the growth function. It was considered that a cubic function most closely and appropriately modelled the relationship. The derived growth function is as follows:

$$V = .0157 - .0089\ dbh + .0017\ dbh^2 - 7.3E\text{-}5\ dbh^3$$

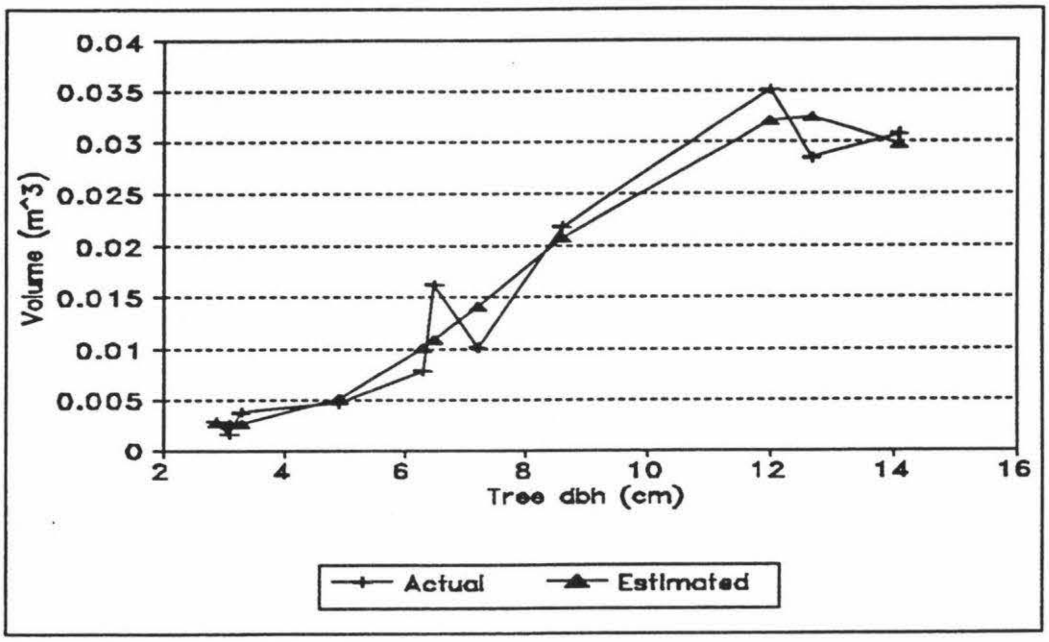
where:

V = Average per tree volume (m^3);

dbh = Average diameter at breast height of trees (cm).

The graphical form of the function is shown in figure 4.3.

FIGURE 4.3: TEATREE VOLUME GROWTH AS A FUNCTION OF DBH.



It was considered that the growth function is appropriate for modelling teatree volume within a dbh range of 3.3cm to 12.8 cms, which are the points of inflection of the cubic function where it's concavity changed from concave to convex and vice versa. Diameters beyond this range are considered not to be representatively modelled by the function. However, within the relevant range the function is considered to provide a good approximation to average teatree volume.

4.2.5 TEATREE BIOMASS PRODUCTION FUNCTION.

The three derived growth functions for diameter, density and volume were consolidated into one production function which modelled the average volume of teatree biomass present on 1ha of land at the time of harvest, where time was defined as the age of the trees at harvest. The mathematical derivation of the biomass production function from the three individual growth functions for dbh, density and volume is presented in appendix 6a.

The average quantity of biomass present on a land area of 1ha at the time of harvest (*Age*) was considered to be a product of the average volume of wood per tree (*V*) and the average density of trees per ha (*D*). The formula for diameter was substituted for the variable *dbh* in the volume function, and the resulting relationship was then multiplied by the density function. The resulting biomass production function giving the volume of teatree harvestable from a 1ha teatree block over time is (Fig 4.4):

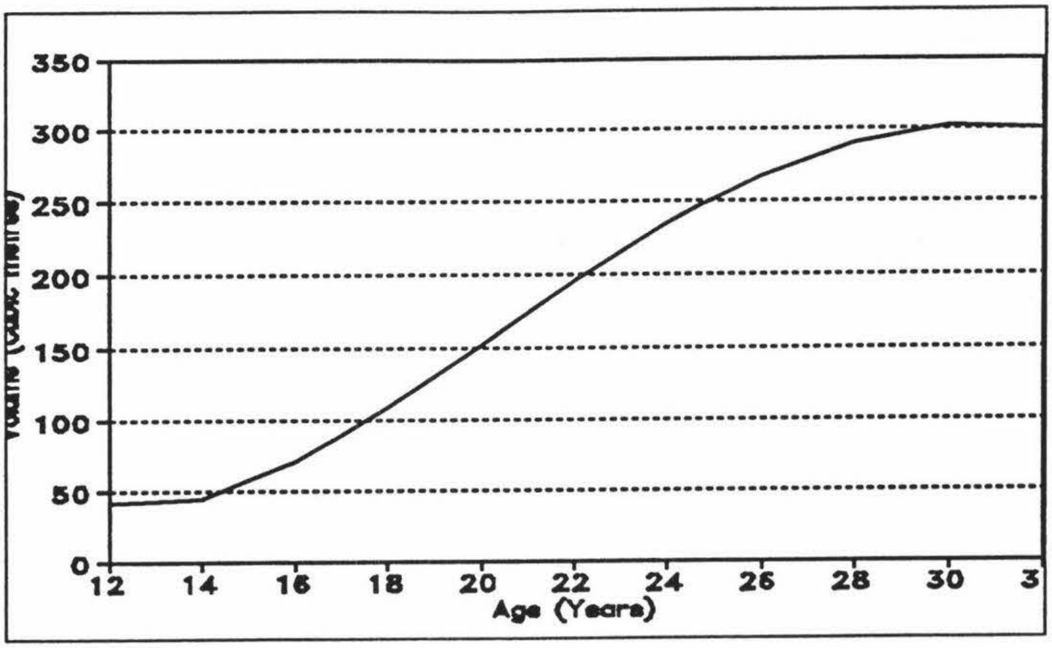
$$BIOMASS_Y = (.0458 - [.0076\ Age] + [.0017 \times \{.4502\ Age\}^2] + [-7E\text{-}05 \times \{-2.3406 + .4502\ Age\}^3]) \times (43{,}797 - [22{,}936 \times LOG\ Age])$$

where:

$BIOMASS_Y$ = Biomass present (m^3) on 1 ha of land at year Y, where Y = *Age*.

Due to the lack of published information available comparing the growth of teatree in different areas around New Zealand, the assumption is made in the derivation and use of the biomass production functions that the tree growth data used to calculate the production functions is representative of teatree growth on Great Barrier Island. A literature search was made of published material on teatree growth. Six articles were found which described or recorded the growth of teatree in a variety of areas throughout New Zealand. The literature search revealed that the major factors considered to affect the growth of teatree were: surrounding

FIGURE 4.4: HARVESTABLE VOLUME AS A FUNCTION OF TREE AGE.



vegetation, density, access to light, topography, and coastal influence (Esler *et al*). The effect of climate on growth was not mentioned in any of the articles.

The biomass function is considered to provide a good estimation of average teatree volume within the relevant range of applicability, taken as the relevant range of the derived volume function, as it has the highest lower age limit (calculated at 12 years) and the lowest upper age limit 30 years) of each of the three functions. Therefore the biomass function's range of relevance was between the ages of 12 and 30 years old. Ages beyond these limits are considered not to be representatively modelled by the biomass function. It was also assumed that the ratio of conversion from tree volume to fuelwood is 100%. This is higher than the ratio used in the eucalyptus energy expenditure model, as the derivation of the teatree volume growth function had not included the above ground biomass such as twigs and small branches that forms the majority of the biomass discarded at the site. Additionally, as the teatree is not coppiced there is no wastage from the stump as with the eucalyptus species. The actual value of $BIOMASS_{TEA}$ used in the teatree expenditure models is derived in chapter 6.

CHAPTER 5. HOUSEHOLD QUESTIONNAIRE AND FIELD TRIP.

5.1 FIELD TRIP.

A field trip to Great Barrier Island was undertaken in late March of 1994. The objectives of the field trip were:

- to view and experience first-hand the growing conditions, proliference, and 'intrinsic scenic importance' (Clunie, 1993) of manuka and kanuka on the island;

- to gain an understanding of the remote lifestyle of the island's residents, which was considered to be a major factor governing their energy use decisions (*Pers.comm:* Earth Energy Systems, 1994);

- to gauge local opinion on Auckland City's teatree clearance restrictions; and

- to collect information on the price of fuels to island households.

An extensive exploration of the island by 4-wheel drive vehicle enabled a large number of sites of naturally growing teatree to be sited, and it's growing form to be observed. Teatree was found to be growing in a natural state on a large proportion of the island, as reported by Clunie (1993), and was considered to be an integral and important part of the Great Barrier Island scenic and natural environment, particularly where it could be observed from roadsides. Teatree was found to predominantly grow in high density plots, and in this state it took a more upright and uniform growth form between trees, with less horizontal spreading of branches, although multiple stems were still common. Isolated teatree plants were common on roadsides, and these tended to take a more bush-like appearance with significant horizontal branch growth.

There were strong feelings among locals against the introduction of reticulated mains electricity, as it was perceived as a threat to the uniqueness of the island. Local opinion toward the teatree restrictions was also very negative, with many reports of continued illegal felling of teatree in spite of the restrictions. There were also reports of native timber being illegally removed from Department of Conservation land with considerable damage to the native bush. There appeared to be little enforcement of the restrictions by Auckland City, which relied to a large extent on information volunteered by other residents on non-compliance and illicit vegetation clearance (*Pers comm*: Auckland City, 1994).

The prices to households of diesel, petrol, LPG, and teatree fuelwood were also collected from a sample of service stations and island fuel suppliers.

5.2 QUESTIONNAIRE DESIGN AND IMPLEMENTATION.

5.2.1 QUESTIONNAIRE SAMPLE.

A postal-administered questionnaire was used to collect information from a sample of households which either owned or used land on Great Barrier Island. The questionnaire was designed primarily to collect information on current household heat energy sources, households' average annual length of stay on Great Barrier, and household land and appliance resources. Questions were asked regarding the use of household land and the percentage of the property covered with teatree, both of which were used as variables in the expenditure models. The questionnaire also asked respondents for their responses to and opinions of Auckland City's teatree clearance restrictions.

It was considered that the postal questionnaire format was the most effective way of collecting the required information as opposed to telephone surveys or personal interviews, as it would allow a larger sample of households to be surveyed at a lower monetary and time cost. It was also felt that a more representative cross section of households could be sampled using a postal approach, as many households on Great Barrier Island were without telephones.

The population for the questionnaire was defined as being: *"all households which regularly use a house or dwelling located on Great Barrier Island"*, where a household was considered to be a group of one or more persons which shared a dwelling. It was considered that this sample population definition encompassed all of the major users of domestic heat energy on Great Barrier Island. The population set included both residents and non-residents, but by definition excluded all households which owned land or dwellings on the island but did not usually use them for accommodation, on the basis that these households were not normally consumers of domestic heat energy on the island. Additionally, the population set did not include people who stayed at motels, guest houses or similar, as it was considered that these people would not make long term energy decisions involving the resources of the motel or guest house.

The most comprehensive source of information available regarding the use of dwellings on Great Barrier Island was the current ratepayer list, a copy of which was obtained from Auckland City. While the ratepayer list contained the names and addresses of all of the people who currently owned land on the island, it did not indicate whether there was a dwelling present on the land, or if the dwelling was regularly used. Additionally the ratepayers list gave no information regarding people who regularly used a dwelling on the island but did not own it, such as tenants of rental properties.

It was decided that despite these shortcomings the ratepayer list was still the best information available, and therefore a sample of households was selected from the list using simple random sampling. The assumption made in using the ratepayer list was that each ratepayer represented a single household. To minimise the shortcomings of the list the questionnaire was designed and worded in such a way as to eliminate those respondents who by definition were not part of the defined population.

To account for the possibility of a house being used as accommodation by a person other than the owner of the house (where the owner was assumed to be the ratepayer), the questions were phrased in such a way that a ratepayer could satisfactorily answer on behalf of their tenants. It was considered that this was the most satisfactory way to overcome the response bias that would have been present had the questionnaire only addressed the ratepayers **own** use of the property. While some degree of response bias may still have been present in the questionnaire, it was considered that most landlords would be able answer the questions with sufficient accuracy, as it was assumed that most houses would be rented complete with energy systems and major appliances such as stoves already in place.

The sample size needed to ensure a representative covering of the population, at a 95% degree of accuracy, was calculated from Cochran (1964) to be 256 households. However, this figure was based on a ratepayer population of 806, whereas the true size of the defined study population taking into account the number of absentee landlords was probably considerably lower than this.

A sample of 370 ratepayers was chosen at random from the list of 806. The sample size that was actually chosen was larger than the required sample size to allow for the effects of ratepayers which owned land without a dwelling and non-replies on the final response rate. Where two people with the same address appeared in the sample such as a husband and wife, they were considered to be part of the same household, only one questionnaire was mailed to them, and another sample member was chosen at random from the list.

5.2.2. METHODOLOGY.

The questionnaires were printed in booklet form on bright yellow A3 paper, two pages to a sheet. The cover of the questionnaire contained an outline map of Great Barrier Island, the questionnaire title, and a large reproduction of the Massey University logo. The logo, coloured paper and booklet form were all used to try and attach a degree of importance, credibility and professionalism to the questionnaire in the respondent's mind, in order to arouse the respondent's interest, to boost response rates, and to draw attention to the questionnaire should it be left lying around. The booklet form, stapled in the centre of the A3 page, was felt to give a more professional look to the questionnaire compared to the standard questionnaire design of A4 sheets stapled together.

Yu and Cooper (1983) report that a response rate of 30% is considered typical for postal questionnaires. To try and maximise the response rate, a pre-questionnaire information letter was used. Emory (1981) reports that response rates are likely to be higher where recipients are familiar with or have a personal interest in the study. To inform ratepayers of the project and to raise their interest and awareness before the questionnaire was mailed out, a newspaper article together with a photo was published in the "Barrier Bulletin" magazine, the local monthly magazine of Great Barrier Island.

The article described the objectives of the study and appealed to readers for help by completing and returning questionnaires should they receive them. It was felt that the magazine article helped to add a further degree of credibility and professionalism to the study through using a medium which would be seen by readers to be objective. The use of the article also enabled a large number of ratepayers to be informed of the forthcoming questionnaire at virtually no cost. A copy of the article is included in appendix 7.

5.2.3 PILOT QUESTIONNAIRE.

A pilot questionnaire was mailed out to 20 households selected from the list of ratepayers to identify any problems in the questionnaire before the main questionnaire was implemented. Each questionnaire was mailed in an A3 envelope and addressed to the ratepayer. A covering letter, reply-paid envelope, and a photocopy of the Barrier Bulletin article was included in the envelope. The covering letter was designed to stress the personal approach of the questionnaire and to inform the recipient that his or her reply, by completing the questionnaire, was very important to the accurate and successful completion of the study.

Both the letter and the questionnaire asked that the questionnaire be completed by the head of the household, who was assumed to be the ratepayer, to ensure that the most accurate information on household incomes and resources was collected. The letter was countersigned by the supervisors of the research, Professor Anton Meister and Dr. Robert Alexander. The covering letter also drew attention to the photocopy of the Barrier Bulletin Article, which was included in the envelope to jog the memories of those recipients who had seen the article, and to provide further information, from an apparently objective source, to those who had not.

The pilot questionnaire package was sent out in early October using standard mail. The questionnaires were individually numbered, and a reminder letter re-asserting the importance of the recipients help in completing the study was mailed out two weeks later to all those from whom replies had not yet been received. A copy of the questionnaire, and initial and reminder letters are contained in appendix 7.

Out of the 20 pilot questionnaires mailed out, 5 were received after the first two weeks. A further 9 replies were received following the mailing of the reminder letter to the 15 non-respondents. None of the pilot questionnaires were returned by the Post Office as "Gone - no address" or similar, and all of the 14 replies which were received were valid and usable. Table 5.1 presents the final response rate to the pilot questionnaire.

Table 5.1 Response rates to Pilot questionnaire.

Total pilot questionnaires mailed:	**20**
Number of complete questionnaires returned:	5
Number returned "wrong address" etc:	0
Valid responses:	**5**
Number of reminder letters mailed:	15
Responses after reminder letter mailed:	9
Total valid responses received.	**14**
Total valid response rate:	**70%**

5.2.4 MAIN QUESTIONNAIRE.

There appeared to be no problems with the wording or format of the pilot questionnaire, with all replies having been valid and usable. It was therefore decided to mail out the main questionnaire to the full sample using the same methodology and covering letter approach as before and without making any modifications.

The same approach was used, with 370 individually numbered questionnaires being mailed out in late October using standard mail. 17 questionnaires were returned by the post office marked as "Gone - no address", and 2 were returned unanswered by people who no longer owned land on Great Barrier Island. These questionnaires were re-posted to another 19 ratepayers whose names were selected from the ratepayers list. One questionnaire was returned unanswered with no explanation. A reminder letter was sent out after approximately 2 weeks to all those from whom no responses had been received. Table 5.2 presents the final response rates to the main questionnaire (not including the results from the pilot questionnaire).

Table 5.2. Response rates to the main questionnaire.

Total questionnaires mailed:	**370**
Questionnaires returned before reminder letter mailed:	88
Number returned "wrong address" etc:	19
Number of invalid responses:	1
Valid responses:	**68**
Number of questionnaires re-mailed	19
Number of reminder letters mailed:	282
Responses after reminder letter mailed:	113
Total valid responses received.	**181**
Total valid response rate:	**49%**

While the response rate from the main questionnaire was higher than normally obtained from the postal questionnaire format, it was considerably lower than the response rate from the pilot questionnaire, considered to be partially due to the small sample size chosen for the pilot sample.

When the results of the pilot questionnaire which had been identical to the main questionnaire were included, a total of 195 usable responses were collected from both mailings of the questionnaire giving an overall response rate of 53%. Although this was less than the number of usable replies needed to attain results representative of the population at a 95% confidence level, it was considered that due to the actual size of the defined population probably being somewhat smaller than 806, the results provided a good and accurate representation of the defined population.

5.3 QUESTIONNAIRE RESULTS.

5.3.1 INTRODUCTION.

The returned questionnaires were processed into two separate categories, residents and non-residents, to enable the responses for both groups to be separately analyzed. A household was considered to be a permanent resident if they answered that their house on Great Barrier Island was their principle residence (question 5). If they had answered no to this question, or owned land on Great Barrier Island but not a dwelling, then they were considered a non-resident.

The responses from each returned questionnaire were analyzed using a spreadsheet package with database capability. The range of fuels and appliances used by households were rated to determine which fuel and which appliance were most often used as the **main** fuel and appliance in households for each particular activity. The **total number** of houses which used a particular fuel or appliance, whether as the main fuel/appliance or not, was also counted.

This section presents the summary of the questionnaire results for all respondents analyzed in separate resident and non-resident categories. The complete table of questionnaire results for both household categories is presented in appendix 8.

5.3.2 HOUSEHOLD LAND HOLDINGS.

Of the total questionnaire respondents, 194 households (99%) owned or used land on Great Barrier Island. Of these 49% considered themselves to be permanent residents of the island. Over all respondents, 85% of households reported having a house or other dwelling on their land. As expected, all resident households had a house on their land, while 71% of non residents had a house or dwelling on their land. The mean annual length of stay on Great Barrier taken over all non-residents with houses was 9 weeks. The mean land area owned for non-residents was .17ha, while for residents it was 4.07ha.

The responses for the remaining sections of the questionnaire were only calculated from those respondents who reported having a house on their land (85% of total respondents), as respondents not owning houses were not considered to be part of the questionnaire population.

5.3.3 HOUSEHOLD LAND USES.

Non-residents:

Only 3% of non-residents reported that they earned some form of income from their land, while 39% reported using land to grow food or produce for the household. Households which used their land for either income or household produce used an average of 31% of their total land area for both activities, and the annual opportunity cost of the land used over all non-residents was $1,055.

Residents:

22% of resident households reported that they earned some form of income from their land, while 75% reported that they used it to grow food or other products. Households which utilised their land used an average of 34% of their total land area for both activities combined and had an average annual opportunity cost for this land of $5,866 for all uses.

5.3.4 COOKING.

COOKING FUELS.

Non-residents:

Among the non-resident households surveyed LPG was the most popular cooking fuel, followed closely by wood. 64% of non resident households regularly used LPG for cooking and 52% considered it to be their main cooking fuel. Wood was used regularly by 55% of non-resident households, and was the main fuel for 43%.

Residents:

Wood was the most popular cooking fuel for residents followed by LPG, with 73% of resident households regularly using wood as a cooking fuel, and 53% considering it to be their main cooking fuel. LPG was used regularly by 64% of households, and was the main fuel for 43%.

The results showed that many households, both resident and non resident, often used more than one fuel for cooking. Further analysis of the data revealed that 42% of non-residents used only LPG for cooking, 33% used only wood, and 25% used both LPG and wood. Of resident households 37% used only wood, 29% used only LPG, and 37% used both wood and LPG.

COOKING APPLIANCES.

Non-residents:

While LPG appliances were the most common by *fuel* type among non-resident households, with 56% of households owning either a LPG stove or an LPG burner/cook-top, the most popular single *appliance* type was a stove (either wood or LPG), owned by 66% of non-resident households surveyed. 67% of all non-resident stoves were wood-fuelled (43% of all non-resident households), while 33% were LPG-fuelled stoves (21% of all non-resident households)[8].

Residents:

94% of resident households used a stove or a range for cooking, while 29% used an LPG burner/cooktop. Stoves and ranges were the main cooking appliance for 77% of resident households, while LPG burners were the main appliance for 16%. From the questionnaire data it was calculated that 64% of all resident households owned a woodstove and 30% owned an LPG stove.

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[8] The percentage of stoves which were woodstoves was found by dividing the total number of woodstoves (defined as total wood users for cooking less the number who cooked in an open fire) by the total number of stoves, on the assumption that wood could only be burned in a stove or open fire. All of the remaining stoves were assumed to be LPG fuelled.

5.3.5 SPACEHEATING.

SPACEHEATING FUELS

Non-residents:

Wood was the preferred heating fuel of the non-resident households sampled, with 70% of households regularly using it as a heating fuel and 64% reporting it to be their main spaceheating fuel. 10% of non-resident households reported that they did not use any form of space heating, possibly due to them being summer visitors.

Residents:

Wood was also the most popular heating fuel for residents, with 88% of homes using it for heating and 80% reporting it to be their main heating fuel. LPG was used for heating by 21% of homes, and as a main source by 15%.

SPACEHEATING APPLIANCES.

Non-resident:

There were a wide variety of appliances used by non-residents for space heating. Foremost among them were woodfires/potbelly stoves, owned by 39% of non-resident households. The cooking range was used for spaceheating by 30% of non-resident households, and as the main source of spaceheating by 26%.

Resident:

The most popular appliance among residents was a woodfire (either a woodfire or a potbelly stove), owned by 60% of households and used by 47% as the main heating appliance. Cooking ranges were used by 32% of houses as a heat source and were considered by 27% to be their main space heating source.

5.3.6 WATER HEATING.

WATER HEATING FUELS.

Non-residents:

Wood was the primary water heating fuel for the majority of non-resident households, used by 56% of all non-resident households surveyed, and as a main source by 54%. LPG was used in 36% of households, and as the primary water heating fuel by 34%. Nearly 60% of non-residents did not use a back-up water heater, while of those who did nearly half used some form of solar water heating device.

Residents:

Wood was the most popular water heating fuel for residents, used in 71% of households surveyed and as a main fuel in 69%. LPG, the next most popular water heating fuel, was only used in 25% of houses. 61% of residents used no form of backup water heating, while 17% used an LPG fuelled backup system.

WATER HEATING APPLIANCES.

Non-residents:

41% of non-residents surveyed used a wetback or waterjacket attached to their wood stove or range as their main form of water heating, while a surprisingly high number (21%) boiled water on top of their stove as their main water heating method. LPG water heaters were used in 28% of non-resident homes, and in 25% of these as a main source of water heating.

Residents:

As with the non-residents the most popular form of water heating among residents was a wetback or water jacket attached to their oven or range, used by 64% of residents and by 62% as the main appliance. LPG water heaters were used in 30% of households and by 21% as their main water heating source.

5.3.7 HOUSEHOLD ELECTRICITY USAGE AND GENERATION.

Non-residents:

64% of non-resident households surveyed used some form of generated electricity. For these households the most popular forms of electricity generation were solar-electric panels, used by 61% of electricity-using households and the main electricity source of 51% of electricity-using households; followed by diesel or petrol generators, used by 57% of electricity-using households, and the main electricity source of 40% of electricity-using households.

Residents:

85% of resident households surveyed generated electricity, with 67% using diesel or petrol powered generators, and 57% using solar-electric panels. However, solar-electric panels were the top rating primary household electricity source for resident households, used as the main source of electricity by 64% of resident households.

5.3.8 HOUSEHOLD FUELWOOD USAGE.

Non-residents:

Teatree was the most popular fuelwood type of the non-resident households surveyed, with 68% of all non-resident households regularly using it, and 62% rating it as their main type of fuelwood. Eucalyptus wood was used by 2% of households surveyed, and 25% reported that they did not use any type of wood. The main source of fuelwood for non-residents was wood growing on their properties, with 52% of wood users reporting this to be one of their regular sources of wood and 48% rating it as their most important source of fuelwood. 38% of wood users also reported collected wood as being a major source of wood, with 31% considering it to be their main source.

Residents:

Teatree was also the main fuelwood type used by residents, with 87% of all resident households using it, and 79% rating it as their main fuelwood type. Only

4% of residents did not use any type of fuelwood. The main source of fuelwood for residents was wood growing on their properties, with 55% of resident wood users reporting this to be their most important source of fuelwood. 23% of wood users reported collected wood as being a major source of wood, with 21% considering it to be their main source.

5.3.9 LAND AREA COVERED IN TEATREE.

Non-residents:

52% of non residents reported that their land contained substantial areas of teatree growing on it, with the mean percentage of their total land area covered being 43%.

Residents:

57% of residents reported their land containing substantial areas of teatree, with the mean percentage of their total land covered being 52%.

5.3.10 RESPONSE TO TEATREE CLEARANCE RESTRICTIONS.

Non-residents

No non-resident households reported changing to alternative fuels as a result of the teatree restrictions, although 8% reported still using the same fuel type, but from a different source.

Residents:

Only 3% of residents had changed their fuel sources as a result of the teatree harvesting restrictions, with 2% changing their cooking fuel from wood to an alternative, and 1% changing their water heating fuel from wood to an alternative. 15% of residents reported modifying their fuel sources, with many indicating a change from using living teatree to using dead teatree or other wood varieties.

Many households in both residency categories volunteered information about their own illicit harvesting activities, and many also commented that as it was their land, they considered that they had a right to use the teatree in any way they wished.

5.3.11 DISCUSSION OF RESULTS.

The questionnaire results showed that with the exception of non-resident cooking loads, wood was the main fuel used for all heatloads by both residents and non-residents. Teatree was the main wood type used by 83% of wood-using households (both resident and non-resident), and was used by 68% of **all** households. Approximately half of all wood users sourced wood from their property, while 25% collected the majority of their wood from other non-specified sources.

Electricity was little used for heat loads, with it's highest reported use being for cooking in 10% of non-resident households, however it was only used as the main cooking fuel in 4%. The low usage rates of electricity partially explains why the main sources of domestic electricity were low-output solar electric panels, rather than higher output expensive diesel and petrol generators.

There was also no reported use of coal on the island, considered to be due to the high cost of purchase and transporting it to the island compared to other cheaper and more readily available fuels (*Pers com:* Parsons, 1994). The survey data also showed a low rate of usage of solar water heaters, with a large proportion of the devices reported under this category being solar showers and plastic bags rather than commercial solar-water heaters like the Solarmax.

Finally, only 22% of residents and 11% of non-residents reported using wind turbines, and they were only used as the main source of electricity by 9% of all households. Their low usage rates may be the result of the hilly terrain of Great Barrier Island, which limits the use of wind turbines to certain coastal and exposed areas.

5.4. DERIVATION OF MODEL HOUSEHOLDS.

5.4.1 ANALYSIS OF NON-RESIDENT HOUSEHOLDS.

From the questionnaire results a number of hypothetical model households were developed which were considered to be typical households in terms of their appliance and land resources. An analysis was done of the questionnaire results of each respondent in both household categories to determine exactly which appliances each household owned for each heatload. The data for individual non-resident households revealed the following major categories of heatload appliance ownership among resident households, ranked in order of the number of households in each category:

- 13% of households owned only a woodstove for all heatloads;
- 11% owned only an LPG stove and water heater;
- 10% owned only an LPG stove or LPG cook-top;
- 9% owned only an LPG stove, cooktop, and a woodfire;
- 7% owned only a woodstove and a woodfire;
- 6% owned only an LPG stove, LPG heater, and an LPG water heater.

The remaining 44% of non-resident households owned a large variety of appliance combinations, none of which were considered to be significant in terms of the proportion of households owing each combination.

5.4.2. ANALYSIS OF RESIDENT HOUSEHOLDS.

The data for individual resident households revealed the following major categories of heatload appliance ownership among resident households, ranked in order of the number of households in each category:

- 13% of households owned only a woodstove and a woodfire;
- 11% owned only an LPG stove and a woodfire;

- 8% owned a only a woodstove;
- 6% owned an LPG-fuelled stove or cook-top, an LPG water heater and an LPG-fuelled water heater;
- 5% owned a woodstove, an LPG stove and a woodfire; and
- 5% owned a woodfire, an LPG stove, an LPG water heater and an LPG spaceheater.

These appliance combinations represented 48% of resident households. The remaining 52% of non-resident households owned a large variety of appliance combinations, none of which were considered to be significant in terms of the proportion of households in each category.

5.4.3. MODEL HOUSEHOLDS.

It was considered that given the large variation in the appliances owned by households, there was no one single model Great Barrier Island household in terms of it's appliance ownership characteristics, but rather that at least 12 different model households could be defined where at least 5% of all households in the particular residency category owed these appliance combinations. The 12 model households and their appliance characteristics were as follows:

Household 1: *Non-resident with only a woodstove fitted with wetback/waterjacket;*

Household 2: *Non-resident with LPG stove/cook-top and LPG water heater;*

Household 3: *Non-resident with LPG-stove and cooktop;*

Household 4: *Non-resident with LPG-stove/cooktop and woodfire;*

Household 5: *Non-resident with a woodstove fitted with wetback/waterjacket and a woodfire;*

Household 6. *Non-resident with LPG stove, water heater and space heater;*

Household 7: *Resident with only a woodstove fitted with a wetback/waterjacket and a woodfire;*

Household 8: *Resident with an LPG-fuelled stove and a woodfire;*

Household 9: *Resident with only a woodstove;*

Household 10: *Resident with an LPG stove, an LPG water heater and an LPG spaceheater;*

Household 11: *Resident with a woodstove, an LPG stove and a woodfire.*

Household 12: *Resident with a woodfire, an LPG stove, an LPG water heater and an LPG spaceheater.*

CHAPTER 6. ANALYSIS AND RESULTS OF ENERGY EXPENDITURE MODELS.

6.1 MODEL VARIABLE VALUES.

6.1.1 HOUSEHOLD HEATLOAD ENERGY REQUIREMENTS (*HEATyr*).

6.1.1.1 SPACEHEATING.

The energy requirement of a typical Auckland house for domestic spaceheating was calculated by Leyland *et al* (1986) using the computer simulation model Micropas 1.2 and weather data for the Auckland region from the New Zealand weather files. Leyland *et al* (Ibid) defined four different 'comfort levels' for spaceheating, and wrote that households which were able to use local direct radiant heat for a large proportion of their spaceheating would be considered to be comfort level 1 households (defined in table 6.1), with minimal spaceheating requirements.

TABLE 6.1 COMFORT LEVEL 1 SPACEHEATING REQUIREMENTS.

House area:	Living area	Bedroom
Temp. required:	20°C from 4pm - 10pm	15°C from 4pm - 10pm

The **useful** spaceheating energy requirement of a comfort level 1 house located in Auckland was calculated to be 1,336 kWh per year for an un-insulated house, and 341 kWh per year where the house was fully insulated. It was considered that due to Great Barrier Island's warm climate, the majority of houses on the island would fit into the comfort level 1 category. It was therefore assumed that the space heating requirements of households on Great Barrier Island were comparable to those of comfort level 1 households in Auckland. To take into account varying household insulation levels, this study assumed an averaged useful spaceheating requirement of 835.5 kWh/yr for all houses.

6.1.1.2 WATER HEATING.

Cook and Blakely (1980) investigated the total energy requirements of domestic water heating in New Zealand households, which were found to average 3,985 kWh per year for an electric water heating system. Leyland *et al* (Ibid) assumed that this figure had risen since Cook and Blakely's (Ibid) study, and estimated a total heat requirement of 4,000 kWh per year. This value represents the total energy input into an electric hot-water cylinder rather than the useful energy supplied to the heatload, which is considerably less due to standing heat losses from the storage cylinder. Leyland *et al* (Ibid) assumed that standing losses were at the maximum level permitted by the New Zealand code NZS4602, which for a 136 litre cylinder amounted to a loss of 2.8 kWh per day (1,022 kWh per year).

The annual **useful** heat requirement of an average household for domestic waterheating was taken for this study to be 2,978 kWh for all waterheating sources. Where standing losses from a cylinder were incurred from using electricity or fuelwood as a waterheating fuel, the heat losses were considered to add to the total useful energy input requirement of the heatload. Due to it's nearly instantaneous transfer of heat to water on demand, the LPG instant water heating unit was assumed to incur no standing losses.

6.1.1.3 COOKING.

The most reliable data available for household cooking energy requirements was Patterson and Earle (1992) who calculated an average **total** yearly energy requirement of 1,300 kWh where an electric stove was used. The **useful** energy requirement for cooking was estimated by both Patterson and Earl (Ibid) and Leyland *et al* (Ibid) to be 910 kWh per year, where the efficiency of an electric stove was estimated as 70%. Both Patterson and Earl (Ibid) and Leyland *et al* (Ibid) assumed an equivalent useful energy requirement for both electrical and LPG-fuelled stoves.

6.1.1.4 DEFINITION OF *HEATyr* VALUES.

For each heatload the present value cost of each alternative fuel option was separately calculated by using three values of *HEATyr* in the expenditure models. The values of *HEATyr* used are summarised in table 6.2, based on a household residency of 365 days per year.

TABLE 6.2 ANNUAL USEFUL HEATLOAD ENERGY REQUIREMENTS.

Heat load:	**Useful energy requirement *(HEATyr)***
Space heating	835.5 kWh/yr
Water heating	2,978 kWh/yr
Cooking	910 kWh/yr

Where a household was assumed to use one appliance for multiple heatloads *HEATyr* was defined as the sum of the useful energy requirements of both or all of the heatloads. The assumption was made in using these values that the energy requirements of Great Barrier Island households did not differ from those of the average New Zealand household (or Auckland household for spaceheating). It was also assumed that the useful energy requirement of each heatload remained constant where different sources of heat were used, as assumed by Leyland *et al* (Ibid) and Patterson and Earle (Ibid).

6.1.2 DAYS IN RESIDENCE PER YEAR (*DPY*).

The average number of days in residence per year for a typical resident household (*DPY*) was taken to be 365. For non-residents the average annual length of stay on Great Barrier Island over all non-resident households was calculated from the questionnaire results to be 9 weeks per year. The value of *DPY* used in the models for non-resident households was 63 days per year (9 weeks/year x 7 days/week).

6.1.3 ANNUAL FUELWOOD DEMAND (*DEMyr*).

Based on manufacturer's performance trials the heat conversion efficiency (ε) of the Wamsler woodstove operating at a medium heat setting was calculated to be 44%, while for the Jayline Junior woodfire the value of ε was calculated at 83%. The range of values for *DEMyr* calculated by the fuelwood models are presented in table 6.3, where fuelwood volumes are expressed as the number of teatree (**TE**) steres required to produce *HEATyr* useful heat annually for the heatload.

TABLE 6.3 TEATREE STERES DEMANDED ANNUALLY *(DEMyr)*.

	HEAYyr kWh/year	**TEATREE STERES:** *Non-resident*	*Resident*
Wamsler woodstove:			
Cooking	910	0.3	2.0
Waterheating	2,978	1.1	6.1
Total	4,723.5[9]	1.4	8.1
Jayline junior:			
Spaceheating	835.5	0.1	0.7

The energy equivalent volumes of eucalyptus fuelwood required by the household as derived in the eucalyptus fuelwood models are presented in table 6.4.

6.1.4 EUCALYPTUS FUELWOOD CROP VARIABLES.

6.1.4.1 ANNUAL BIOMASS GROWTH RATE (*GROWTH*).

The annual growth rate of eucalyptus biomass in air dried kilograms per hectare (*GROWTH*) was calculated as the annual rate of **harvestable** biomass growth in oven dry kilograms (ODkg) divided by the fuelwood's final moisture content, estimated as 25% of it's final weight (Earl, 1965).

[9] Includes radient spaceheat produced during cooking and waterheating.

TABLE 6.4 EUCALYPTUS STERES DEMANDED ANNUALLY.

	EUCALYPTUS STERES:	
	Non-resident	*Resident*
Wamsler woodstove:		
Cooking	0.5	3.0
Waterheating	1.6	9.2
Total	2.1	12.2
Jayline junior:		
Spaceheating	0.2	1.1

The annual growth rate of harvestable biomass was equal to the total annual biomass growth rate multiplied by the proportion of above ground biomass able to be converted to fuelwood, to allow for slash and the coppiced stump remaining at the harvest site following coppicing.

$$GROWTH = (DRYgrowth \times HARVconv) / (1 - MOISTURE)$$

where:

GROWTH = Annual increment in eucalyptus biomass (air dried kg/hectare);

DRYgrowth = Annual eucalyptus biomass growth in oven-dried kilograms;

HARVconv = Proportion of total above-ground biomass converted to fuelwood;

MOISTURE = Moisture content of fuelwood as a proportion of final biomass weight.

The harvest conversion ratio of a eucalyptus fuelwood crop was estimated by Tombleson (1992) to be approximately 92%, while the annual growth rate of eucalyptus biomass was estimated in chapter 4 at 20,000 ODkg per year. The derived value for *GROWTH* used in the fuelwood expenditure models was 25,000 kg of air-dried biomass per hectare per year.

6.1.4.2 OPTIMAL ROTATION LENGTH (*ROTlength*).

It was considered that the optimal rotation length for a eucalyptus fuelwood crop was the one which would enable the required quantity of fuelwood to be produced for the minimum cost. Sims *et al* (Ibid) reported that for a eucalyptus crop a biomass production rate of 20 ODT/ha was feasible under a number of different planting density and rotation length combinations (table 6.5).

TABLE 6.5 OPTIMAL PLANTING DENSITIES AND ROTATION LENGTHS.

Optimal planting density (stems/ha):	Rotation length:
5,000	3 years
4,000	5 years
2,500	8 years.

An analysis of the data in table 6.5 revealed that the relationship between planting densities and rotation lengths was perfectly linear. An equation which derived the optimal planting densities for rotation lengths between 3 and 8 years was calculated by regressing rotation lengths against planting densities using least squares regression. The resulting formula was:

$$D = 6{,}500 - (500 \times ROTlength); \quad 3 \leq ROTlength \leq 8$$

where:

D = Optimal planting density (stems/ha);

ROTlength = Length of rotation / age of trees at harvest (years).

The least-cost rotation length was determined for both household categories by developing 12 eucalyptus fuelwood production cost models - 6 for residents and 6 for non-residents. Each of the 6 models used a different rotation length from 3 to 8 years, with the optimal planting density for each rotation length being derived using the above optimum density formula.

Each model was based on an assumed plot size of 1 ha, and used the value for *GROWTH* and the crop management assumptions developed by Sims *et al* (Ibid) to calculate the present value cost of producing a quantity of eucalyptus fuelwood equivalent in energy content to *DEMyr* for the Wamsler woodstove (multiple heatloads) for a period of 30 years. The cost and yield assumptions used in the models are presented in appendix 4.

The results of the models revealed that for both household categories the least-cost rotation length was 8 years. The net present cost of fuelwood production declined as the rotation length increased, due to the high initial costs of crop establishment which for longer rotation lengths were spread over a greater number of years and were therefore more heavily discounted than were the establishment costs of shorter rotations.

It was considered that an 8 year rotation length was also least-cost for producing fuelwood for use in the Jayline woodfire for both household categories, as the results for the Wamsler woodstove showed that the least-cost rotation length was not dependent on the quantity of fuelwood required, but rather on the timing of establishment and planting costs, which were a function of the rotation length and rotation area. Based on the above results, the value of *ROTlength* was defined as 8 years for all of the eucalyptus fuelwood energy expenditure models.

The summary of net present costs for each of the 12 models, and the 8-year rotation models for the Wamsler woodstove are presented in appendixes 4 (non-residents) and 5 (residents). The 8-year production cost models for the Jayline woodfire are presented in appendixes 6 (non-residents) and 7 (residents).

6.1.5 TEATREE FUELWOOD CROP VARIABLES.

6.1.5.1 ANNUAL BIOMASS GROWTH RATE (*BIOMASS*).

As calculated in chapter 4, the volume of harvestable biomass from a 1ha teatree crop in any year *Y* is derived from the following growth function:

$$BIOMASS_Y = (.0458 - [.0076\ Y] + [.0017 \times \{.4502\ Y\}^2] + [-7E\text{-}05 \times \{-2.3406 + .4502\ Y\}^3]) \times (43{,}797 - [22{,}936 \times LOG\ Y]); \qquad 13 \leq Y \leq 30$$

where:

$BIOMASS_Y$ = Harvestable volume in year *Y* (steres/ha);

Y = Year of harvest (*ROTlength*).

6.1.5.2 OPTIMAL ROTATION LENGTH.

As with the eucalyptus fuelwood crop, the optimal rotation length for teatree was considered to be one which enabled *DEMyr* to be grown on the available household land at the least cost. To determine the least-cost rotation lengths for both household categories a production model was developed which calculated the present value cost of growing *DEMyr* annually for 30 years for use in the Wamsler woodstove under a range of rotation lengths from 13 years (the minimum range of the biomass production function) to 22 years.

The cost of each rotation was calculated as the net present value of the annual purchased fuelwood cost (*WOODpur*) from year 0 to the year before the first harvest ($0 \leq Y < ROTlength$); **plus** the present value of the grown teatree cost annuities (*WOODgrow*) from the year of initial harvest to the end of year 29 ($ROTlength \leq Y \leq 29$), calculated using the model in chapter 3. The models also calculated the total land area required to produce *DEMyr* under each of the rotation lengths, where the total land required was equal to the value of *ROTarea* (calculated using the formula in chapter 3) multiplied by *ROTlength*.

The results for both household categories, presented graphically for non-residents and residents in figures 6.1 and 6.2 respectively, revealed that the cost of teatree production increased as the rotation length increased, while the total area required decreased with increases in rotation length, due to the sigmoid growth function used.

FIGURE 6.1 NON-RESIDENT PRODUCTION MODEL RESULTS.

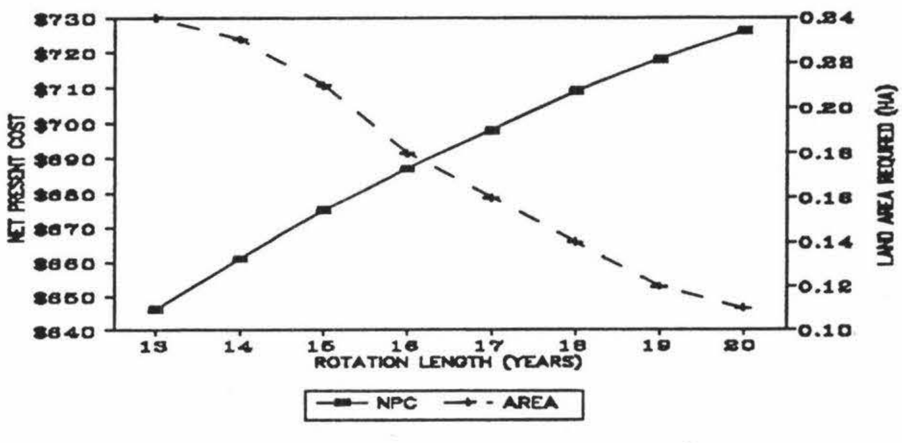
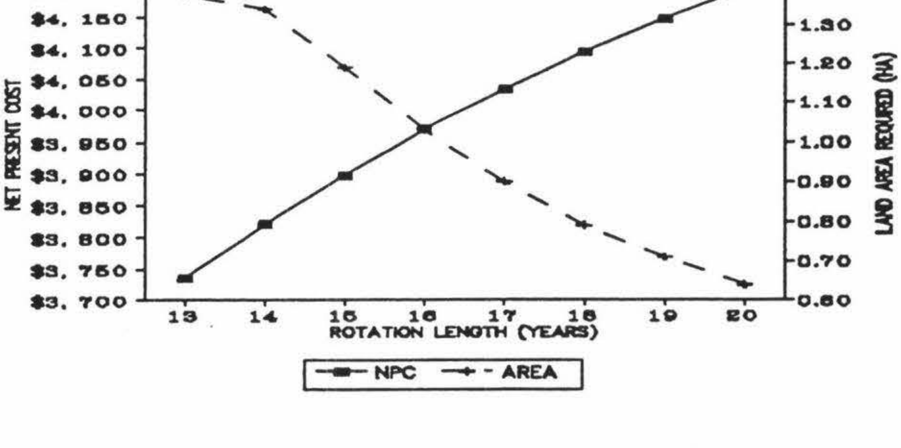


FIGURE 6.2 RESIDENT PRODUCTION MODEL RESULTS.



As the teatree expenditure models were used to calculate the cost of fuelwood production both under compliance with the teatree clearance restrictions and in the absence of any restrictions, it was considered necessary to use the same values of *ROTlength* (and therefore *ROTarea*) for both scenarios, to enable a *ceteris paribus* calculation of the additional cost imposed on the household by the restrictions.

Esler (Ibid) reported that under normal growing conditions teatree reaches a height of 4m in 15 years and 7m in approximately 20 years. It was therefore considered that 17 years was the **maximum** rotation length that could legally be used by a household in order to comply with the 6m height restriction on teatree clearance. In view of the results of the production models it was considered that the optimal rotation length for modelling teatree production would be the one which enabled the majority of households in each category to produce the required quantity of fuelwood on the available land area at the lowest cost.

The household land area data was analyzed for both household categories to determine the percentage of households in each category which had sufficient land available to grow *DEMyr* annually under each of the rotation lengths, where the available land area of each household was considered to be the total household section area less the $300m^2$ residential allowance used by Auckland City.

The teatree production model showed that a rotation length of 17 years - the maximum possible - had a required area which was less than or equal to the available land areas of 54% of non-resident households and 61% of resident households. Shorter rotation lengths had a lower production cost, but had required land areas greater than the available areas owned by the majority of households. Therefore the value of *ROTlength* was defined as 17 years for all of the teatree fuelwood energy expenditure models. The land area data showing the cumulative frequencies of the household land areas for both household categories are presented in appendix 3.

6.1.5.3 TEATREE CROP UNDER HARVEST RESTRICTIONS.

The areal clearance limit for a teatree fuelwood crop harvested as a permitted activity was assumed to be $300m^2$. When coupled with the assumption that the existing cleared area for a residential property was also $300m^2$, the additional clearance of teatree from any property was effectively prohibited. Therefore, it was assumed that where the household complied with the areal clearance limits, that no teatree was able to be harvested.

6.1.6 LAND-USE VARIABLES.

The values for the land-use variables *TOTland* (total household land area), *LANDopp* (% of *TOTland* with an opportunity cost), *OPPcost* (opportunity cost of *LANDopp*), and *LANDtea* (% of *TOTland* covered in teatree) derived from the questionnaire results for use in the expenditure models are shown in table 6.6.

TABLE 6.6 LAND-USE VARIABLE VALUES.

	Non-residents	**Residents**
TOTland (ha)	.17	4.07
LANDopp (% of *TOTland*)	31%	34%
OPPcost ($)	$1,055	$4,158
LANDtea (% of *TOTland*)	43%	52%

The value of *TOTland* for each household category was calculated as the median total household land area over all respondents in each category with houses. The median was considered more representative than the mean as there were a small number of very large properties in both categories which were considered to be outliers.

The values used for *LANDopp* and *OPPcost* were calculated as the mean land area used and the mean total opportunity cost of this land, calculated over all households in each category which had an opportunity cost attached to the use of their land. *LANDtea* was calculated for each category as the mean percentage of land covered, taken over all households in each category which reported having teatree as a land cover on their section.

6.2 EXPENDITURE MODEL RESULTS BY FUEL TYPE.

6.2.1 INTRODUCTION.

The results of the expenditure models for each energy source under all of the household land-use and clearance restriction assumptions are presented in tables 6.7 and 6.8 for non-residents and residents respectively. For each heatload and fuel the tables present the heatload costs under two scenarios:

i) where the appliances are assumed to be already owned by the household and purchase costs are not included in the total cost (*WITH*); and

ii) where the appliances (and generators) are not already owned by the household, and purchase costs are included in the total cost (*WITHOUT*).

6.2.2 FUELWOOD EXPENDITURE MODELS.

6.2.2.1 NO CLEARANCE RESTRICTIONS.

The results of the fuelwood expenditure models where it is assumed that there are no clearance restrictions, excluding appliance purchase costs (*WITH*) and assuming a nil opportunity cost of land use are presented by heat load in figures 6.3 for non-residents and 6.4 for residents. The graphs display the present value cost incurred by a 'typical' resident or non-resident household for producing heat from the following wood types:

- Eucalyptus fuelwood (*EUCAL*);
- Teatree, where the land contains no existing teatree (*T-TREE*),
- Teatree where the land contains existing teatree (*PREVIOUS*); and
- Purchased teatree (*PURCH T*).

The cost of cooking, water heating and multiple heatloads are based on the woodstove, while spaceheating is based only on the Jayline Junior woodfire.

TABLE 6.7 NON-RESIDENT EXPENDITURE MODEL RESULTS.

NET PRESENT COST OF HEAT LOAD FOR 30 YEARS

	COOKING		SPACE HEATING		WATER HEATING		COMBINATION	
APPLIANCE STATUS:	WITH	W/O	WITH	W/O	WITH	W/O	WITH	W/O
TEATREE FUELWOOD:								
LAND-USE ASSUMPTIONS:								
NO PREV / NO OPP CST	$219	$7,062	$601	$2,446	$561	$7,404	$748	$7,591
NO PREV / OPP CST	$219	$7,062	$601	$2,446	$561	$7,404	$2,596	$9,439
PURCHASE	$240	$7,083	$614	$2,459	$625	$7,468	$832	$7,675
PREV / NO OPP CST	$102	$6,945	$560	$2,405	$335	$7,178	$404	$7,247
PREV / OPP CST	$102	$6,945	$560	$2,405	$335	$7,178	$2,629	$9,472
EUCALYPTUS FUELWOOD:								
NO OPP CST	$240	$7,083	$618	$2,463	$579	$7,422	$787	$7,630
OPP COST.	$240	$7,083	$618	$2,463	$579	$7,422	$787	$7,630
DIESEL ELECTRICITY:								
WITHOUT GENERATOR	$8,983	$10,062	$7,136	$7,186	$13,866	$14,445	$16,470	$18,178
WITH GENERATOR	$2,597	$3,676	$1,796	$1,846	$5,176	$5,755	$6,628	$8,336
PETROL ELECTRICITY:								
WITHOUT GENERATOR	$8,433	$9,512	$6,374	$6,424	$16,641	$17,220	$21,740	$23,448
WITH GENERATOR	$3,449	$4,528	$2,207	$2,257	$9,860	$10,439	$14,060	$15,768
SOLAR/WIND ELECTRICITY:	$15,511	$16,590	$12,740	$12,790	$33,169	$33,748	$46,430	$48,138
LPG:	$446	$1,765	$307	$427	$882	$1,531	$1,635	$3,723
SOLAR MAX: WITH LPG UNIT					$4,515	$5,834	-	
SOLAR MAX: WITH WOOD FIRE					$4,068	$6,165		
SOLAR MAX: WITH WOOD STOVE					$4,060	$11,134		
SOLAR MAX: WITH PETROL ELECT.					$4,484	$13,253		

TABLE 6.8 RESIDENT EXPENDITURE MODEL RESULTS.

NET PRESENT COST OF HEAT LOAD FOR 30 YEARS

	COOKING		SPACE HEATING		WATER HEATING		COMBINATION	
APPLIANCE STATUS:	WITH	W/O	WITH	W/O	WITH	W/O	WITH	W/O
TEATREE FUELWOOD (NO RESTRICTIONS):								
LAND-USE ASSUMPTIONS:								
NO TEA / NO OPP CST	$1,110	$7,953	$923	$2,768	$3,086	$9,929	$4,164	$11,007
NO TEA WITH OPP CST	$1,110	$7,953	$923	$2,768	$3,086	$9,929	$4,164	$11,007
PURCHASE TEA	$1,229	$8,072	$997	$2,842	$3,455	$10,298	$4,651	$11,494
TEA / NO OPP CST	$428	$7,271	$687	$2,532	$1,337	$8,180	$1,660	$8,503
TEA WITH OPP CST	$428	$7,271	$687	$2,532	$1,337	$8,180	$1,660	$8,503
EUCALYPTUS FUELWOOD:								
NO OPP CST	$1,232	$8,075	$988	$2,833	$3,080	$9,923	$4,279	$11,122
OPP COST.	$1,232	$8,075	$988	$2,833	$3,080	$9,923	$4,279	$11,122
DIESEL ELECTRICITY:								
WITHOUT GENERATOR	$14,443	$15,522	$10,343	$10,393	$29,165	$29,744	$42,940	$44,648
WITH GENERATOR	$8,056	$9,135	$5,003	$5,053	$20,475	$21,054	$33,098	$34,806
PETROL ELECTRICITY:								
WITHOUT GENERATOR	$19,108	$20,187	$12,644	$12,694	$46,555	$47,134	$70,516	$72,224
WITH GENERATOR	$14,124	$15,203	$8,477	$8,527	$39,774	$40,353	$62,836	$64,544
SOLAR/WIND ELECTRICITY:	$15,511	$16,590	$12,740	$12,790	$33,169	$33,748	$46,430	$48,138
LPG:	$2,342	$3,661	$1,461	$1,581	$4,089	$4,738	$7,892	$9,980
SOLAR MAX: WITH LPG UNIT					$4,802	$6,121		
SOLAR MAX: WITH WOOD FIRE					$4,289	$6,386		
SOLAR MAX: WITH WOOD STOVE					$4,243	$11,317		
SOLAR MAX: WITH PETROL ELECT.					$6,700	$15,469		

FIGURE 6.3 COMPARISON OF FUELWOOD COSTS: NON-RESIDENT.

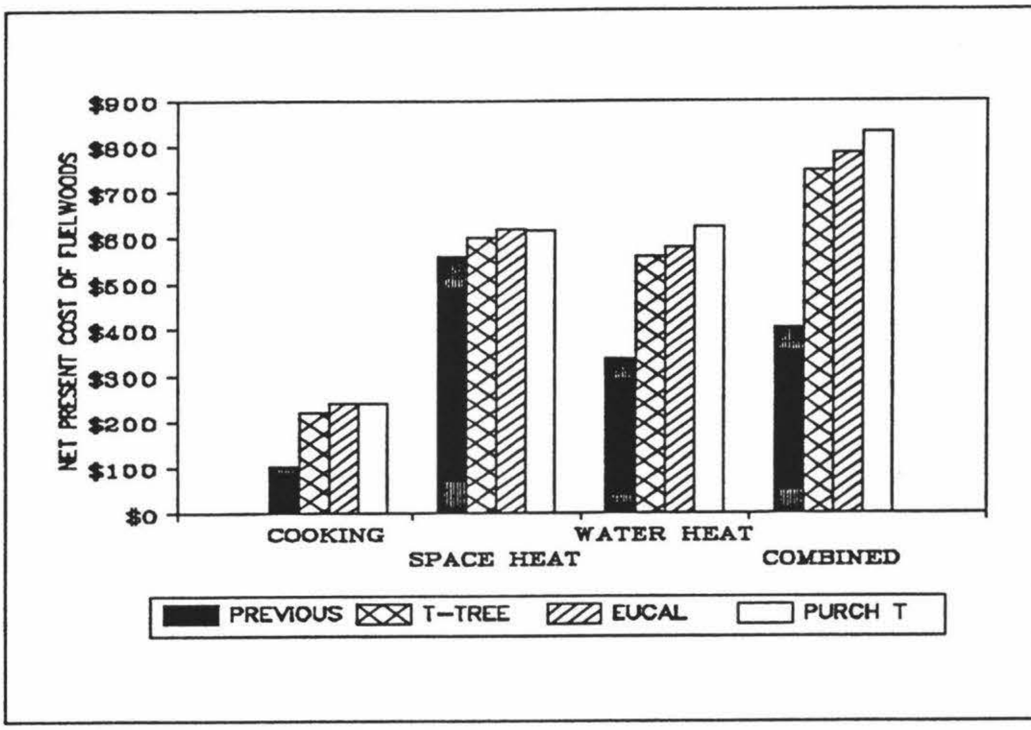
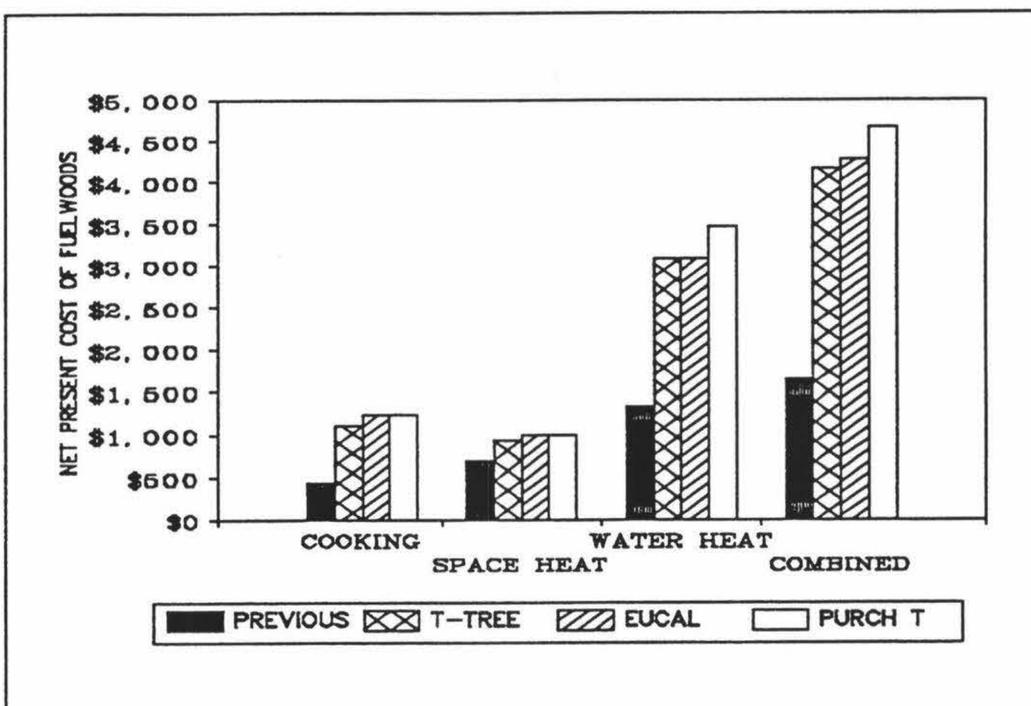


FIGURE 6.4 COMPARISON OF FUELWOOD COSTS: RESIDENTS.



The model results showed that with the exception of water heating loads in resident households where eucalyptus was least-cost, grown teatree was predominantly the least-cost fuelwood source for all other heatloads in both household categories. With the exception of non-resident combined heatloads, the opportunity-cost model results were identical to those obtained where fuelwood was grown on land with no opportunity cost. Additionally, where a household had teatree already growing on their land the results showed that the cost of supplying their heatload energy requirements was considerably smaller than where no teatree previously existed. For all heatloads except resident water heating, eucalyptus was the second-best fuelwood source after grown teatree. However eucalyptus was only slightly less expensive than purchased teatree for space heating and cooking in both household categories.

Given that a eucalyptus crop was significantly more expensive to produce on an annual basis than a teatree crop due to it's high labour and chemical/fertiliser requirements, the cost of producing teatree fuelwood appeared unusually high relative to the eucalyptus fuelwood cost. A closer analysis of the expenditure models revealed that this was due to the large difference in rotation lengths between the two crops, which necessitated the household purchasing fuelwood for an **additional** 7 years under the teatree option before the initial harvest.

The relative rankings of each fuelwood source did not change where it was assumed that household's had to purchase the appliances (*WITHOUT*), although the total net present cost increased dramatically for each heatload and wood type.

6.2.2.1 CLEARANCE RESTRICTIONS.

Where the household complied with teatree clearance restrictions as a permitted activity it was assumed that no teatree could be harvested. Therefore the least-cost fuelwood source for each heatload was either purchased teatree (resident cooking, and non-resident spaceheating) or grown eucalyptus fuelwood (all other heatloads). The full range and results of each fuelwood production, cost and expenditure model are presented in the appendices, arranged in the following order:

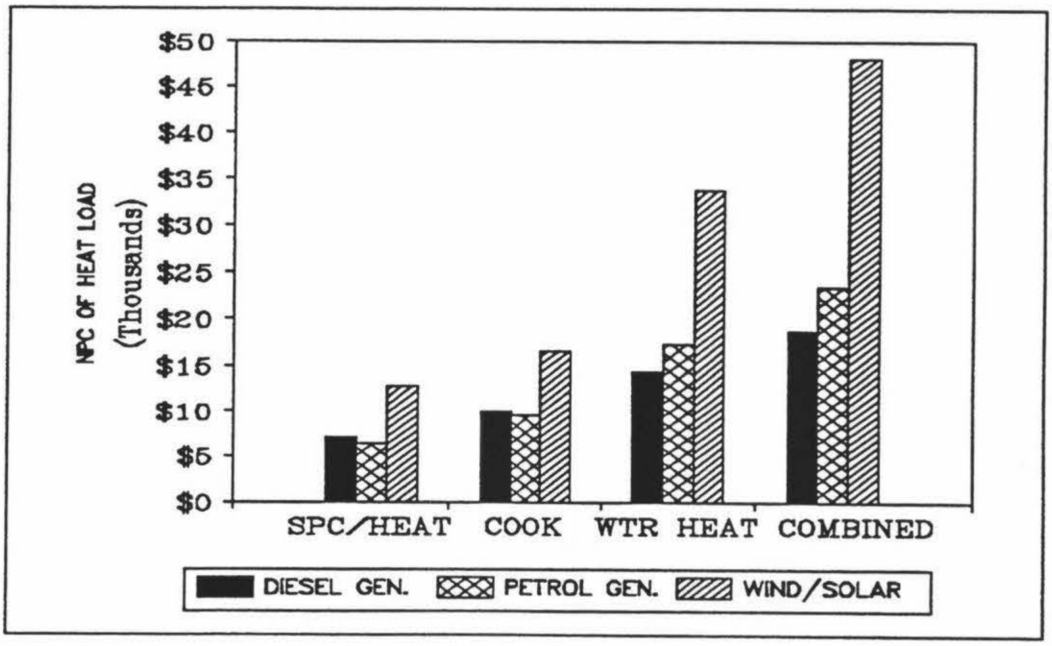
Appendix	Fuelwood	Household type	Appliance
4	Eucalyptus	Non-resident	Wamsler
5	Eucalyptus	Resident	Wamsler
6	Eucalyptus	Non-resident	Jayline
7	Eucalyptus	Resident	Jayline
8	Teatree	Non-resident	Wamsler
9	Teatree	Resident	Wamsler
10	Teatree	Non-resident	Jayline
11	Teatree	Resident	Jayline

6.2.3 ELECTRICAL EXPENDITURE MODELS.

NON-RESIDENTS:

Where appliance purchase costs were not included the diesel generator was the least-cost electricity source for all non-resident heatloads. However when appliance purchase costs were included, and where total energy requirements were low (such as for space heating and cooking) the petrol generator was least-cost (figure 6.5).

FIGURE 6.5 ELECTRICITY MODEL RESULTS: NON-RESIDENTS.

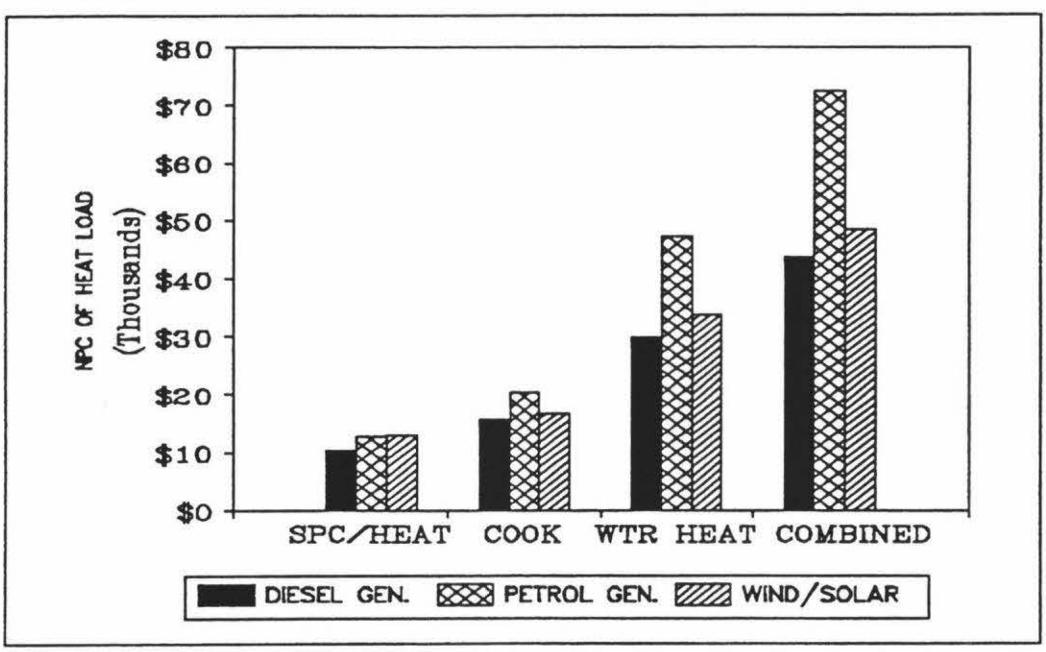


The petrol generator had a lower capital cost than the diesel system, but a much higher fuel cost per litre (both generators gave approximately equal energy outputs per litre of fuel). For low annual energy requirements the lower capital cost of the petrol generator offset the lower fuel cost of the diesel system, resulting in the petrol generator being the least-cost investment. As the required output increased fuel cost became a more significant proportion of total cost, and the petrol generator became increasingly more expensive relative to the diesel generator. The results also revealed that despite having virtually no running costs, the high capital costs of the wind and solar hybrid system made it a very expensive energy investment for heat loads.

RESIDENTS.

For resident households the diesel generator was the least-cost electricity source for all heat loads, both where appliance costs were included (figure 6.6) and where they were excluded.

FIGURE 6.6 ELECTRICITY MODEL RESULTS: RESIDENTS.



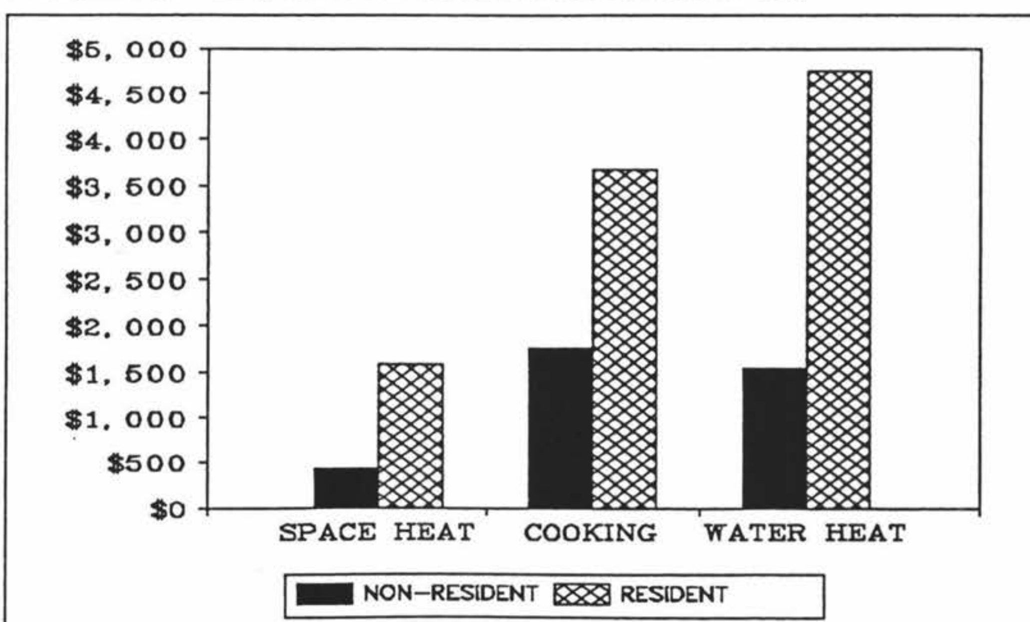
The observations made previously regarding the tradeoffs between petrol and diesel costs did not apply to residents as their energy requirements for each heat load were above the threshold of the petrol system's least-cost range. As the heat load energy requirements increased (eg: from space heating to cooking) the petrol system became proportionately more expensive in comparison to the diesel system. The wind and solar electricity system became more competitive under the higher energy demands of residents, but were still more expensive than the diesel system.

The total cost of producing electricity from the wind and solar system was exactly the same for residents as for non-residents, despite residents having a much higher annual energy demand. This was due to the fact that wind/ solar systems were rated on a daily output basis, with the same unit being used whether the household was resident for 9 weeks per year or 52 weeks. The electrical energy model results for both household categories are presented in appendix 5.

6.2.4 LPG EXPENDITURE MODEL RESULTS.

Figure 6.7 presents the results of the LPG expenditure models (including appliance capital costs).

FIGURE 6.7 LPG EXPENDITURE MODEL RESULTS.



The main observation which can be made is that the cost of water heating for non-residents was lower than their cooking cost, even though water heating consumed nearly 3 times as much LPG per day as did cooking. This was due to the lower appliance cost of the LPG water heater compared to the gas stove (approximately half the cost), which made LPG water heating less expensive per day than LPG cooking for low usage rates. However, under daily use such as experienced by residents the low capital cost of water heating was offset by the high fuel consumption rate and the LPG water heater was the most expensive heat load. The complete range of LPG energy expenditure models are presented in appendix 5 and 4 for residents and non-residents respectively.

6.3 RESULTS BY HEAT-LOAD.

6.3.1 COOKING.

The expenditure model results for both household categories revealed that where the household was assumed to already own each of the appliances (*WITH*), growing fuelwood for use in the wood stove was the least-cost cooking investment, followed by purchasing LPG for use in the LPG stove. In the absence of restrictions teatree was the least-cost fuelwood for both categories, while where there were assumed to be restrictions purchased teatree and eucalyptus were least costs for residents and non-residents respectively.

Where the appliances were not already owned by the household (*WITHOUT*) the LPG-fuelled stove was the least-cost cooking investment for both household categories, followed by the woodstove. Electricity was a very expensive source of energy for cooking, particularly for resident households which had a higher annual heat requirement. The results of each of the expenditure models for cooking (including appliance purchase costs) are presented in figures 6.8 for non-residents and in 6.9 for residents.

FIGURE 6.8 COOKING COSTS (*WITHOUT*): NON-RESIDENTS.

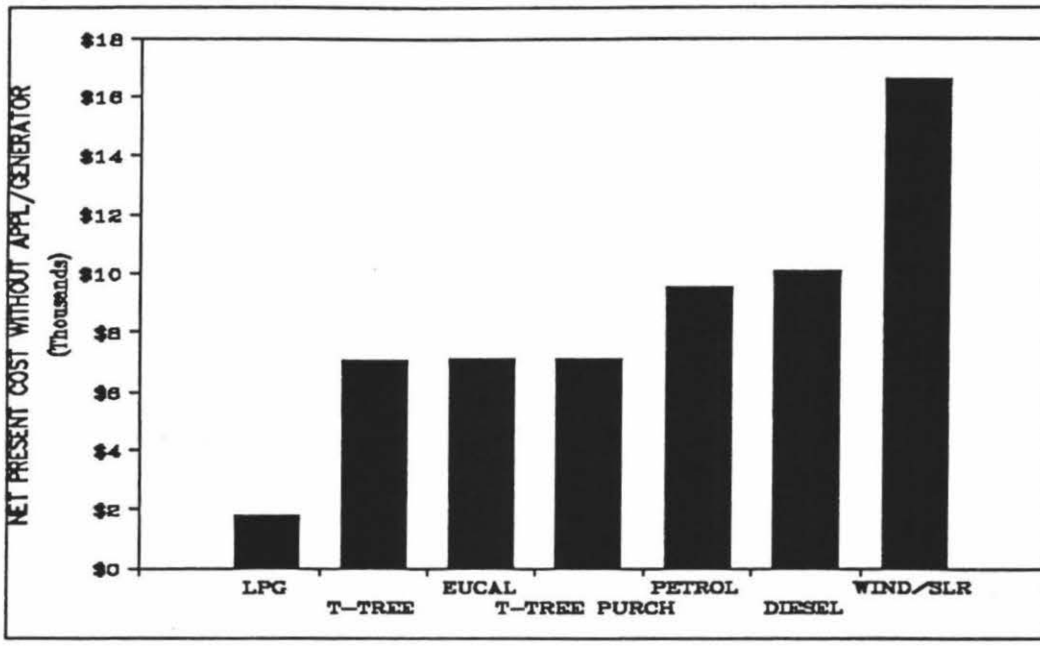
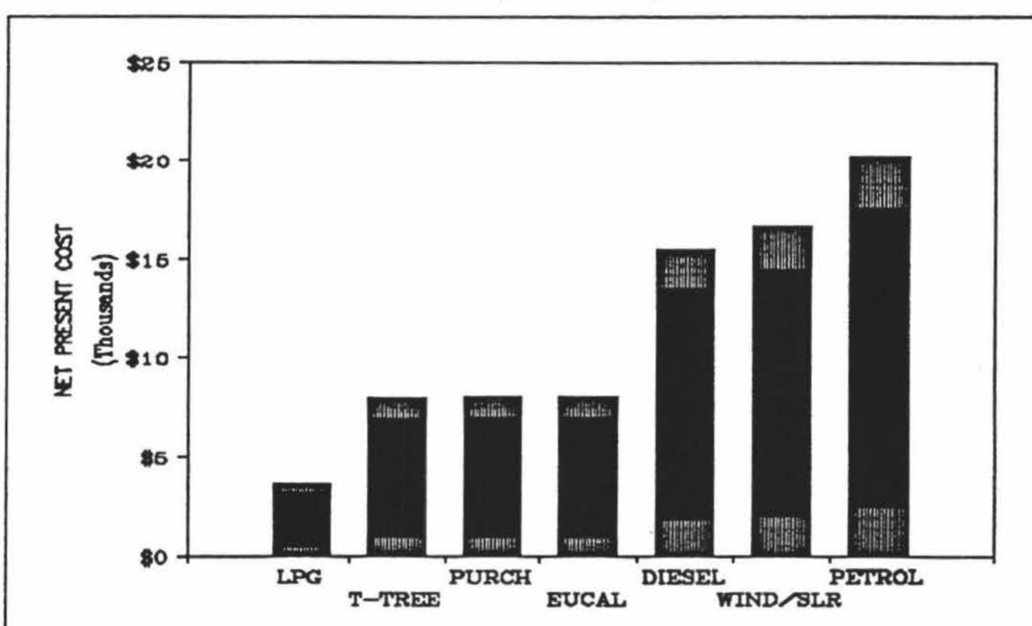


FIGURE 6.9 COOKING COSTS (*WITHOUT*): RESIDENTS.



The results revealed that the appliance capital cost, which comprised up to 96% of the net present cost in the fuelwood models, was the major factor determining the relative rankings of the different cooking methods where the appliances were not already owned. While fuelwood was the least-cost fuel on a heat energy produced per dollar expended basis, the much lower cost of LPG-fuelled appliances resulted in the LPG stove being the least-cost cooking investment.

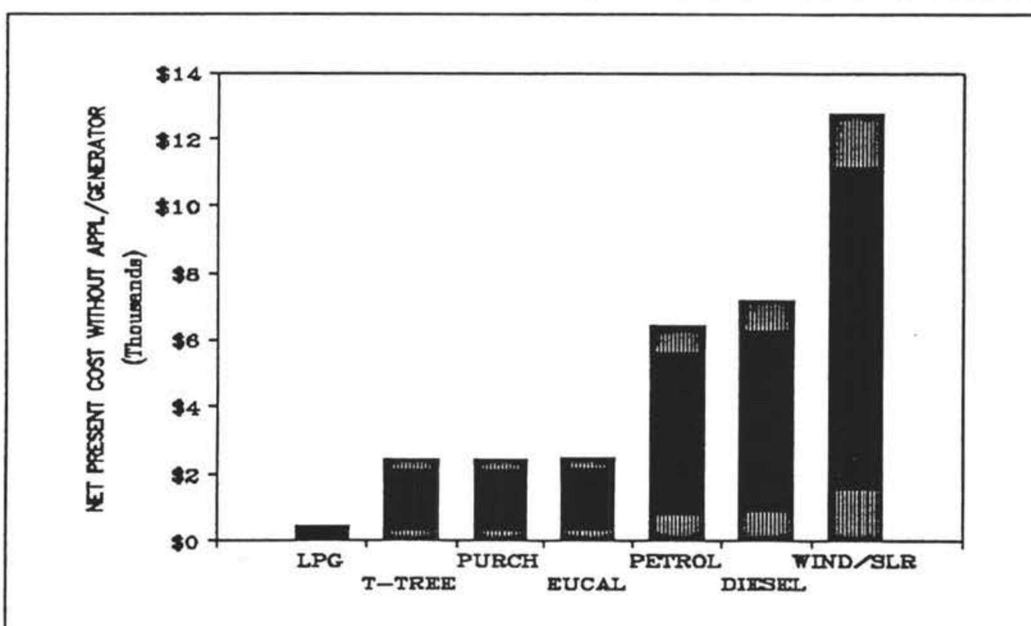
It was considered that even where a household was able to substantially reduce their capital outlay by purchasing a less expensive or second-hand woodstove, that they would not be able to achieve a least-cost cooking investment using fuelwood given the large divergence in the relative prices of wood and LPG cooking appliances (the gas oven was approximately one sixth the price of the woodstove).

6.3.2 SPACE HEATING.

NON-RESIDENTS:

Figure 6.10 compares the spaceheating costs for non-resident households (including appliance costs), where fuelwood costs are based on the Jayline woodfire. Where a household had a woodstove for cooking and/or water heating, spaceheat was produced at zero marginal cost, making the woodstove was the least-cost heating source.

FIGURE 6.10 SPACEHEATING COSTS (*WITHOUT*): NON-RESIDENTS.

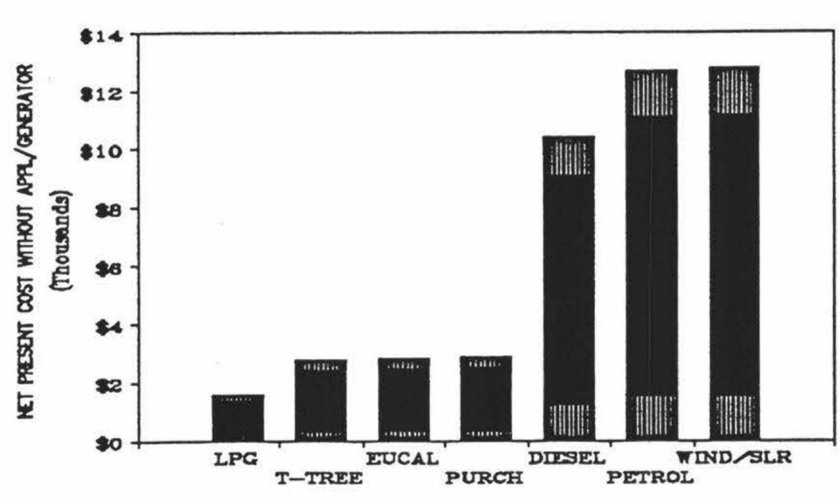


For a non-resident household under both appliance ownership conditions (*WITH* and *WITHOUT*) the LPG-fuelled heater was the least-cost space heating method followed by the Jayline woodfire. As with the cooking models, even though wood was actually the least-cost fuel on a heat output per dollar spent on fuel basis, LPG was the least-cost spaceheating investment (on a heat energy produced per total dollar expended basis) due to the higher capital and appliance replacement costs inherent with the woodfire system.

RESIDENTS:

Figure 6.11, which compares the spaceheating costs for a resident household (including appliance costs (*WITHOUT*)) shows that the LPG-fuelled heater was also the least-cost spaceheating investment for resident households, with the next-best alternative being producing fuelwood for use in a woodfire. However where the appliance was already owned (*WITH*) growing fuelwood (teatree in the absence of restrictions and eucalyptus where restrictions are in force) for use in the woodstove was the least cost investment for resident spaceheating.

FIGURE 6.11 SPACEHEATING COSTS (*WITHOUT*): RESIDENTS.

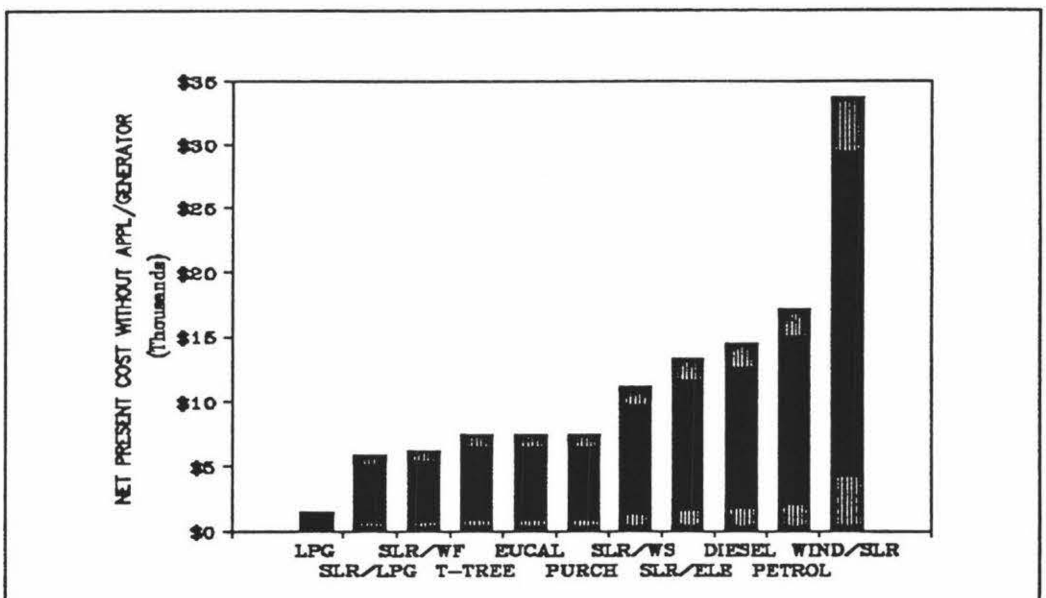


The higher rate of appliance usage by resident households resulted in fuel costs constituting a higher proportion of total cost than for non-residents. Under resident usage the lower cost of wood relative to LPG on a heat output per dollar spent basis became more significant, and the lower fuel costs outweighed the effect of the higher capital costs which had made the woodstove relatively expensive for non-residents. For both household categories electricity was uncompetitive with the other spaceheating investments under both appliance ownership conditions.

6.3.3 WATER HEATING.

Figures 6.12 and 6.13 present the results of the waterheating investments for non-resident and resident households respectively, where appliance costs are included (*WITHOUT*)[10].

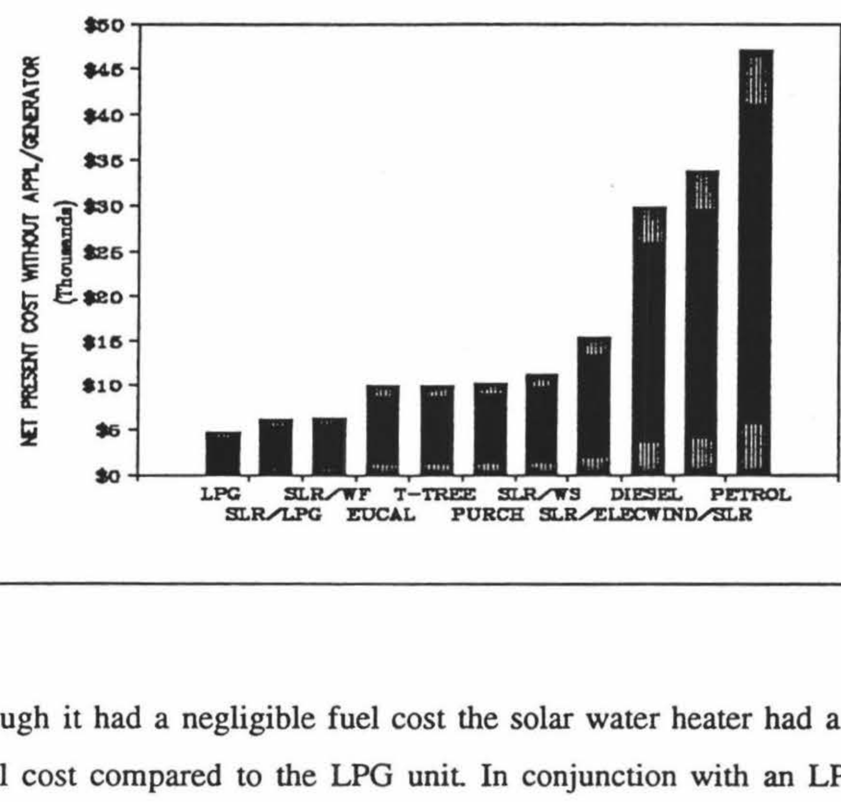
FIGURE 6.12 WATERHEATING COSTS (*WITHOUT*): NON-RESIDENTS.



[10] SLR/LPG, SLR/WF, SLR/WS, and SLR/ELEC refer to the costs of using the Solarmax water heater with the LPG water heater, wood fire, wood stove and electric water cylinder respectively.

Where the household currently owns no appliances LPG was the least-cost waterheating investment for both household categories followed by the Solarmax water heater/LPG water heating combination. Where the household owns each of the appliances, growing fuelwood for use in the Wamsler woodfire was the least cost waterheating investment, followed by the LPG water heater. Again, where appliance costs are included the high relative cost of wood-burning appliances made them uncompetitive with gas appliances, despite wood burning appliances having the lower fuel cost.

FIGURE 6.13 WATERHEATING COSTS (*WITHOUT*): RESIDENTS.



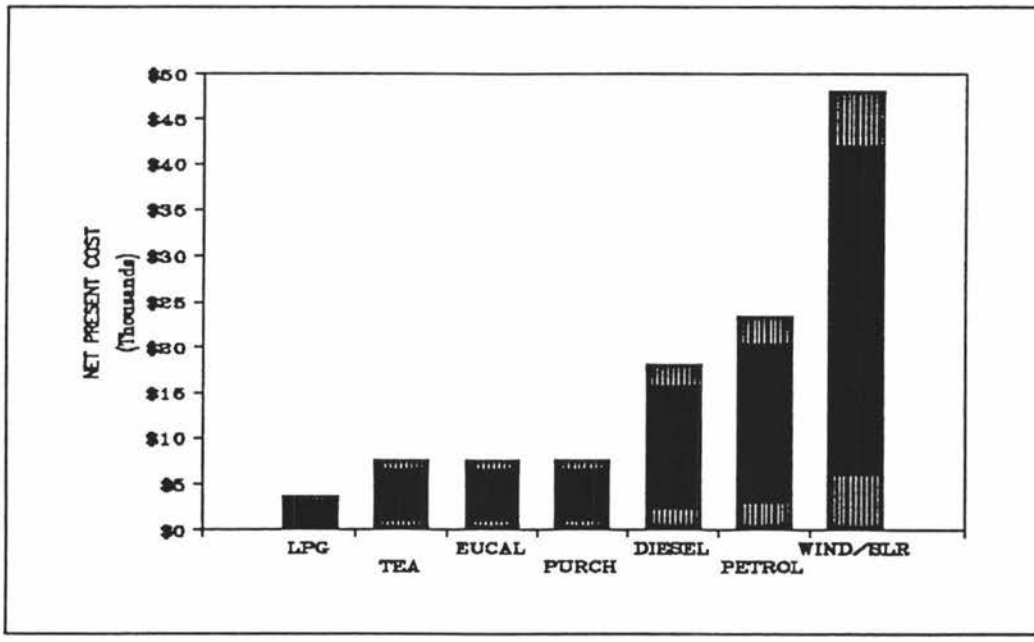
Even though it had a negligible fuel cost the solar water heater had a relatively high total cost compared to the LPG unit. In conjunction with an LPG fuelled booster the cost was approximately double that of using LPG alone, due to the high capital costs of having to use two appliances. Finally, the cost of using electricity for heat loads was once again the most expensive method.

6.3.4 COMBINED HEATLOADS.

Figures 6.14 and 6.15 present the cost of each investment including appliance purchase costs (*WITHOUT*) when used to supply heat for all three heat loads[11]. The graphs do not include either the Jayline woodfire or the Solarmax water heater, as neither were least-cost investments for their particular heat loads and would not be elements of the overall least-cost solution to meet the aggregate heat load requirements of a household.

For non-resident households where no appliances were owned (*WITHOUT*) LPG was the least cost investment for all heatloads. Where the appliances were owned (*WITH*) however, producing fuelwood (either eucalyptus of teatree depending on land use variables and restriction assumptions) was the least-cost investment.

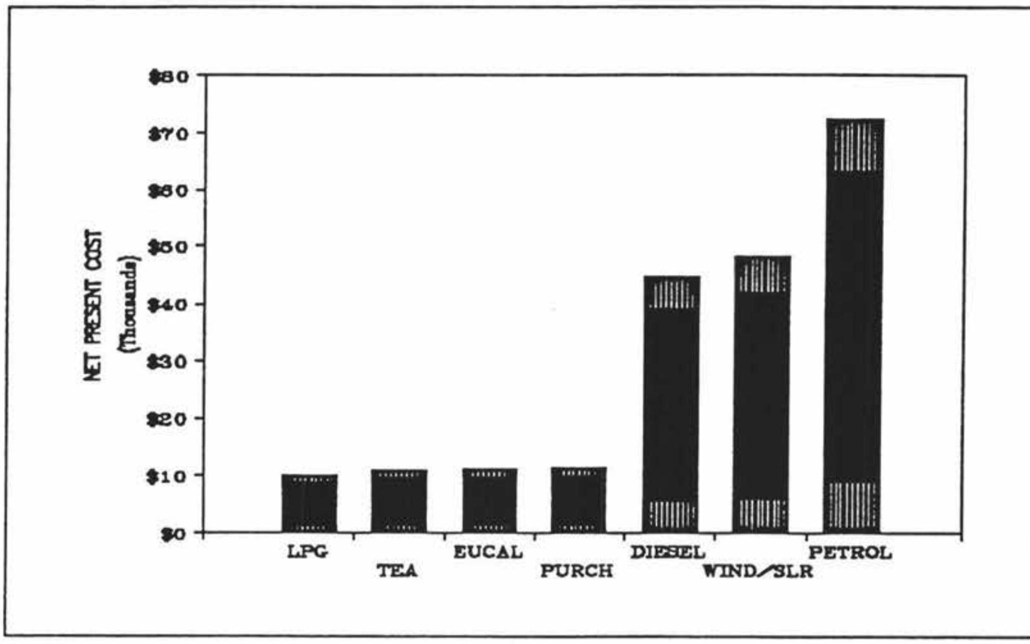
FIGURE 6.14 MULTIPLE HEATLOADS (*WITHOUT*): NON-RESIDENT.



11 Fuelwood results are based on the Wamsler woodstove.

Where no appliances were owned in resident households, LPG was the least cost investment, except where there was existing teatree on the household's land. Where each appliance was owned fuelwood was the least-cost investment under all land use conditions. Electricity was predictably the highest cost energy investment for multiple heatloads in both household categories.

FIGURE 6.15 MULTIPLE HEATLOADS (*WITHOUT*): RESIDENTS.



6.3.5 DISCUSSION OF RESULTS.

For the combined heatloads the results revealed that while using fuelwood was nearly twice as expensive as using LPG for non-resident households where no appliances were owned (*WITHOUT*), for resident households where there was no teatree previously on the land it was only slightly more expensive (10%). This raised the possibility that if Great Barrier Island householders had an opportunity cost of labour less than that assumed by the fuelwood models ($10 per hour), or if cheaper or second hand appliances could be purchased, that fuelwood may supersede LPG as the least-cost investment for multiple heatloads in many resident households. It was considered reasonable to assume that given the remoteness and the lack of industry and employment opportunities on the island[12], that many householders on Great Barrier Island may have a lower opportunity cost of labour, with many possibly having a nil labour opportunity cost. In order to test the hypothesis that a lower opportunity cost of labour would result in fuelwood being the least-cost investment, each of the fuelwood expenditure models was altered to use a zero opportunity cost of labour assumption for planting and harvesting, and a zero harvesting cost on the assumption that fuelwood was now harvested using an axe as oppose to the chainsaw assumed in the original models. The new models also assumed that the household purchased second-hand or cheaper appliances, both for wood fuel and for LPG, and that the appliance price was now 66% of the price of a new appliance.

RESULTS FOR NON-RESIDENTS:

The results for non-residents showed that due to the harvest labour cost comprising a higher proportion of total cost for a eucalyptus crop (harvested from year 8) than for a teatree crop (first harvested in year 17), the cost of using eucalyptus fuelwood in woodstoves and woodfires decreased proportionately more than did the cost of using teatree in the same appliances. However, despite the lower fuelwood costs, LPG remained the least-cost heat investment for multiple heat loads in non-resident households.

RESULTS FOR RESIDENTS:

LPG remained the least-cost investment for residents **individual** heatloads (figure 6.16) when appliance costs were included. However, for multiple heatloads growing fuelwood for use in the Wamsler woodstove was now the least-cost investment, due to the fact that the Wamsler woodstove supplied the household's space heating requirements at a zero marginal cost. Therefore the aggregate cost

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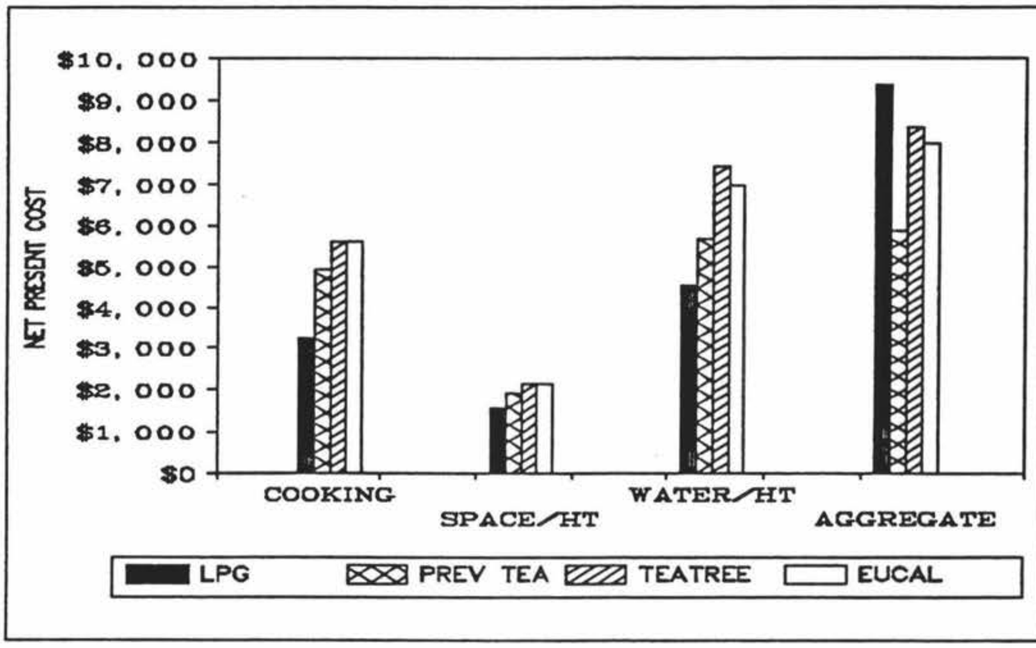
[12] Until recently the unemployment benefit could not be received by the island's residents as the employment prospects on the island were so remote that unemployed people could not be considered to be 'actively seeking employment' while on the island.

of using wood for all three heatloads was only the sum of the cooking and waterheating costs. Additionally, if the opportunity cost of labour remained at zero, the Wamsler woodstove would remain the least-cost investment even if purchased at full price.

FIGURE 6.16 FUELWOOD COSTS WITH LOW-COST APPLIANCES AND NIL LABOUR COST (RESIDENTS).



CHAPTER 7. MODEL HOUSEHOLD LEAST-COST ENERGY INVESTMENTS.

This chapter presents the least-cost heat energy investments for each of the 12 model Great Barrier Island households. Where the resulting least-cost investment is fuelwood, the results are presented under both of the following scenarios:

i) where there are assumed to be no teatree clearance restrictions; and

ii) where the household is assumed to comply with teatree clearance restrictions as a permitted activity - an effective limit of $0m^2$.

For each model household class the percentage of households in that particular residency category which the model household was representative of (in terms of appliance ownership characteristics) is presented in brackets.

7.1 MODEL HOUSEHOLD CLASS 1.

NON-RESIDENT WITH A WOODSTOVE AND WETBACK (13%).

7.1.1 NO RESTRICTIONS.

Under all land-use conditions class 1 model households will achieve a least-cost heat investment for all heatloads by producing fuelwood for use in their existing woodstove. While wood is the generic least-cost fuel, the least-cost wood type for each individual class 1 household is dependent upon the land-use characteristics of individual households. The questionnaire data revealed that 78% of class 1 households have teatree growing on their land, and 55% have an opportunity cost attached to the use of their land. The resulting least-cost fuelwood types are presented in table 7.1, where the proportion of class 1 households displaying each combination of land use characteristic is calculated from the questionnaire data.

Under a zero opportunity cost of labour assumption all class 1 households will still achieve a least-cost investment using the fuelwood types in figure 7.1 with the exception of households which have neither teatree currently growing on their land nor an opportunity cost of land use. For these households the least-cost fuelwood type is now eucalyptus, with a cost of $630. The next-best investment for all class 1 households after growing fuelwood is purchasing an LPG-fuelled stove, heater and waterheater at a cost of $3,723.

TABLE 7.1 LEAST-COST FUELWOOD: CLASS 1 MODEL HOUSEHOLDS.

	No teatree on land	**Teatree on land**
No opportunity cost	Grown teatree (10%)	Grown teatree (35%)
Opportunity cost	Eucalyptus (12%)	Eucalyptus (43%)

7.1.2 CLEARANCE AS A PERMITTED ACTIVITY.

Where the harvesting of teatree was restricted, the least-cost investment for all heatloads in class 1 households is growing eucalyptus fuelwood for use in the woodstove at a cost of $787.

7.2 MODEL HOUSEHOLD CLASS 2.

NON-RESIDENT WITH LPG-FUELLED STOVE AND WATERHEATER (11%).

All class 2 model households would achieve least-cost cooking and waterheating by purchasing LPG for use in the existing LPG-fuelled appliances. It was assumed that as these households do not own any spaceheating appliances that either they do not require spaceheating or that they use the LPG oven for spaceheating. The questionnaire results revealed that 42% of class 2 households do not use any form of spaceheating at all, while 29% use an electric heater and 29% reported using other non-specified methods.

To determine the least-cost spaceheating investment for those class 2 households which do require spaceheating, the cost of using a purchased LPG-fuelled spaceheater (which was least-cost where no appliances are owned by a household) was compared against the cost of using the LPG-fuelled oven and the cost of using a purchased electric heater (diesel generated electricity) where it was assumed that the generator is already owned by the household. The cost of spaceheating from an LPG-fuelled oven was calculated using the expenditure model for the oven combined with the useful heat output requirements for spaceheating.

When spaceheating is only required for a short period of time each year, the use of the existing LPG-fuelled stove is the least-cost spaceheating option ($416) compared to either purchasing an LPG spaceheater ($427) or using the electric heater ($1,796). Enerco natural gas suppliers reported that long periods of space-heating using an LPG-fuelled stove at high temperatures could damage the stove, and produce poisonous gasses if used in a small enclosed space, as with an LPG-fuelled spaceheater. However, when used for relatively short periods of time at a low to medium heat setting in a medium sized room an LPG stove was considered by Enerco to make an economical space-heater (*Pers. comm:* Enerco).

As no class 2 households would achieve a least-cost investment using fuelwood, the teatree clearance restrictions have no impact upon their heat investments. The next-best investment for all heatloads is producing fuelwood with a cost of $7591 where teatree is grown or $7,360 where eucalyptus is grown.

7.3 MODEL HOUSEHOLD CLASS 3.

NON-RESIDENT WITH LPG STOVE/BURNER (10%).

The least-cost cooking investment for class 3 model households is purchasing LPG for use in the existing stove at a cost of $446. The questionnaire data revealed that 63% of class 3 model households do not use any form of spaceheating, while 50% do not use any type of waterheating. Of the 50% that do require waterheating, one-half boil water on their stoves while the remaining households use 'other' non-specified methods. To determine the least-cost waterheating investment for those households which do require waterheating, the cost of boiling water on the LPG stove/burner was compared against the cost of investing in an LPG-fuelled waterheater. The net present cost of boiling water on the stove for 30 years was calculated using the LPG cooking expenditure model, where the cooking heat requirement is replaced by the useful heat requirement for waterheating. The efficiency of the burner/cooktop is assumed to be equivalent to that of the stove - 70%. Where waterheating is only required for a few weeks each year, the least-cost investment is purchasing LPG for use in the existing stove at a cost of $1,268, compared to $1,531 for the LPG-fuelled waterheater.

As with class 2 model households the least-cost spaceheating source for the 37% of households which do require spaceheating is the use of the existing LPG stove. The next-best investment of the household's resources for spaceheating and waterheating is purchasing an LPG fuelled heater and waterheater. As none of the households in this class would achieve a least-cost investment from using fuelwood, the teatree clearance restrictions have no impact upon their heat production investments.

7.4 MODEL HOUSEHOLD CLASS 4.

NON-RESIDENT WITH LPG STOVE/BURNER AND WOODFIRE (9%).

7.4.1 NO RESTRICTIONS.

For class 4 households the least-cost cooking investment is purchasing LPG for use in the existing appliance at a cost of $446. Where the woodfire is of sufficient power to heat water, producing fuelwood for use in the existing woodfire is the least-cost waterheating investment with a maximum cost of $579 where grown eucalyptus fuelwood is used. Where the woodfire is not powerful enough for waterheating, the least-cost waterheating investment is purchasing LPG to boil water over the stove, at a cost of $1,268.

The use of the LPG-fuelled oven is the least-cost spaceheating method for class 4 households ($415) rather than the use of the existing woodfire which has a minimum cost of $560 (where teatree fuelwood was currently growing). However it is considered that the woodfire provides the household with aesthetic benefits that the use of the LPG stove does not provide, and it was assumed that households are willing to incur additional costs to obtain these benefits. Under these assumptions, producing teatree for use in the woodstove is the best investment for class 4 model households under all-land use conditions.

7.4.2 CLEARANCE AS A PERMITTED ACTIVITY.

Where the harvesting of teatree fuelwood is restricted and the household prefers using the woodfire to the LPG stove for spaceheating, the least-cost fuel for both waterheating and spaceheating is eucalyptus fuelwood. The least-cost investment for cooking is not affected by the teatree clearance restrictions.

7.5 MODEL HOUSEHOLD CLASS 5.

NON-RESIDENTS WITH WOODSTOVE AND WOODFIRE (7%).

7.5.1 NO RESTRICTIONS.

The questionnaire results for class 5 model households revealed that in addition to the space heat produced from the woodstove, an extra heating appliance is required to produce spaceheat at times other than when the woodstove is in operation. The least-cost spaceheating investment for a class 5 model household is actually the purchase of an LPG-fuelled spaceheater ($427) rather than the use of the existing woodfire, which has a minimum cost of $560 where there is teatree currently growing on the household's land.

Producing fuelwood for use in the woodstove is the least-cost cooking and waterheating investment for class 5 households. While wood is the generic least-cost fuel, the least-cost wood type for each individual class 1 household is dependent upon the land-use characteristics of individual households. The questionnaire results revealed that 60% of class 5 households currently have teatree growing on their land, while 60% have an opportunity cost attached to the use of their land. The least-cost fuelwood sources for individual class 5 households based on their land-usage characteristics are presented in table 7.2, where the proportion of class 5 households displaying each combination is calculated from the questionnaire data.

TABLE 7.2 LEAST-COST FUELWOOD - CLASS 5 MODEL HOUSEHOLDS.

	No teatree on land	**Teatree on land**
No opportunity cost	Grown Teatree (16%)	Grown teatree (24%)
Opportunity cost	Eucalyptus (24%)	Eucalyptus (36%)

The next-best investment for all heatloads is a combination of the LPG-fuelled stove and waterheater and the woodstove, at a cost of $3,910.

7.5.2 CLEARANCE AS A PERMITTED ACTIVITY.

The least-cost cooking and waterheating investment where teatree harvesting is restricted is growing eucalyptus fuelwood at a cost of $787. The least-cost spaceheating investment is not affected by the teatree clearance restrictions.

7.6 MODEL HOUSEHOLD CLASS 6.

NON-RESIDENT WITH LPG STOVE, WATERHEATER & SPACEHEATER (6%).

For class 6 model households the least-cost investment for all heatloads is purchasing LPG for use in the existing appliances. The teatree clearance restrictions have no effect upon these households.

7.7 MODEL HOUSEHOLD CLASS 7.

RESIDENT WITH WOODSTOVE WITH WETBACK AND WOODFIRE (13%).

7.7.1 NO RESTRICTIONS.

The observation was made for these households that in addition to the space heat produced from the woodstove, an extra heating appliance was required to produce spaceheat at times other than when the woodstove was in operation. The least-cost investment for all heatloads in these households is producing fuelwood for use in the existing wood-fuelled appliances. It was considered that the quantity of fuelwood required annually by a class 7 model household is equal to the quantity of wood required for cooking and waterheating in the woodstove **plus** the quantity of fuelwood required for spaceheating in the woodfire.

As the questionnaire results revealed that no class 7 households had an opportunity cost of land use, the least-cost fuelwood source for individual households is only dependent upon whether on not there is teatree currently growing on the household's land. The questionnaire data revealed that 7 out of the 12 class 7 households have significant areas of household land covered in teatree. The least-cost fuelwood for both the woodstove and the woodfire is grown teatree at a combined cost of $2,347 where there is currently teatree growing on the land, and $5,087 where there is no teatree.

Where the household's opportunity cost of labour is 0, eucalyptus is the least-cost fuelwood for households which do not have teatree currently growing on the land. However, where houses do have teatree growing on their land teatree remains the least-cost investment. The next-best investment for class 7 households is investing in LPG-fuelled appliances for all three heatloads at a cost of $9,980.

7.7.2 CLEARANCE AS A PERMITTED ACTIVITY.

The least-cost investment where teatree harvesting is restricted is growing eucalyptus fuelwood for all three heatloads at a total cost of $5,267 (for both appliances).

7.8 MODEL HOUSEHOLD CLASS 8.

RESIDENT WITH LPG-FUELLED STOVE AND A WOODFIRE (11%).

7.8.1 NO RESTRICTIONS.

The existing LPG-fuelled stove is the least-cost cooking investment at a cost of $2,342, while for spaceheating growing fuelwood for use in the household's existing woodfire is least-cost with a maximum cost of $923 where there are no current stocks of teatree on the land. Grown teatree is the least-cost fuelwood under all land-use conditions, with eucalyptus fuelwood being the next-best alternative.

As these households do not own waterheating appliances it was assumed that they either heated water on their LPG stoves, or that they had a powerful woodstove capable of waterheating. The questionnaire results revealed that 5 of the 12 class 8 model households use the woodfire for waterheating, although 2 of these use it in conjunction with other methods. A further 2 households boil water on their stove as their main waterheating method and another 3 households use an electric hot water cylinder. For class 8 households the least-cost waterheating investment is growing eucalyptus fuelwood for use in the woodfire (where the woodfire is assumed to be of sufficient power to heat water) at a cost of $3,080, which was taken as the equivalent cost of growing eucalyptus fuelwood for waterheating in the Wamsler woodstove. For houses which either do not own a wetback/woodfire, or whose woodfire is not powerful enough for heating water, the least-cost alternative is purchasing an LPG waterheater at a cost of $4,738.

7.8.2 CLEARANCE AS A PERMITTED ACTIVITY.

Where the harvesting of teatree fuelwood is restricted the least-cost spaceheating investment is growing eucalyptus fuelwood for use in the existing woodfire ($988), while the least-cost investments for cooking and waterheating remained unchanged.

7.9 MODEL HOUSEHOLD CLASS 9.

RESIDENT WITH WOODSTOVE (8%).

7.9.1 NO RESTRICTIONS.

The least-cost investment for all heatloads in class 9 households in the absence of restrictions is growing teatree fuelwood for use in the existing woodstove. 5 of the 8 class 9 households reported having teatree currently growing on their land, resulting in a per household energy expenditure of $1,660. For the remaining households with no current teatree stocks the total energy cost is $4,164.

Where there is assumed to be a zero opportunity cost of labour, eucalyptus is the least-cost fuel for those households which do not have teatree growing on their land.

7.9.2 CLEARANCE AS A PERMITTED ACTIVITY.

Where the harvesting of teatree is restricted the least-cost investment for all heatloads is growing eucalyptus fuelwood for use in the existing woodstove ($4,279).

7.10 MODEL HOUSEHOLD CLASS 10.

RESIDENT WITH LPG STOVE, WATERHEATER AND SPACEHEATER (6%).

For class 10 model households the least-cost investment for all heatloads is purchasing LPG for use in the existing appliances. The teatree clearance restrictions have no effect upon these households.

7.11 MODEL HOUSEHOLD CLASS 11

RESIDENT WITH WOODSTOVE, LPG STOVE AND WOODFIRE (5%).

7.11.1 NO RESTRICTIONS.

For cooking and waterheating the least-cost investment is growing teatree fuelwood for use in the woodstove, at a maximum cost of $4,164 where there was no teatree growing on the household's land. The least-cost spaceheating investment is growing teatree for the woodfire at a maximum cost of $923 (no teatree on the household's land).

7.11.2 CLEARANCE AS A PERMITTED ACTIVITY.

Where the harvesting of teatree fuelwood is restricted the least-cost investment for all heatloads is growing eucalyptus fuelwood for use in the existing appliances at a total cost of $5,257.

7.12 MODEL HOUSEHOLD CLASS 12.

RESIDENT WITH WOODFIRE, LPG STOVE, LPG WATERHEATER AND LPG SPACEHEATER (5%).

7.12.1 NO RESTRICTIONS.

The least-cost cooking investment for class 12 model households is purchasing LPG for use in the existing LPG-fuelled appliances. For spaceheating the least-cost investment is growing teatree fuelwood for use in the woodfire at a maximum cost of $923 where there was no teatree growing on the household's land.

Where the heat output of the household's woodfire is sufficient to provide for the household's waterheating requirements, the least-cost waterheating investment will be growing eucalyptus fuelwood for use in the woodfire at a cost of $3,080 - taken as the equivalent eucalyptus fuelwood waterheating cost for the woodstove. Where the woodfire's output is not sufficient to meet the household's waterheating requirements, the least-cost investment is the use of the LPG-fuelled waterheater at a cost of $4,089.

7.12.2 CLEARANCE AS A PERMITTED ACTIVITY.

Where the harvesting of teatree fuelwood is restricted the least-cost investments for all heatloads does not alter, with the exception of spaceheating where the least-cost investment is now grown eucalyptus fuelwood ($988).

CHAPTER 8. ANALYSIS OF TEATREE PROTECTION POLICIES.

8.1 EFFECTS ON MODEL HOUSEHOLDS.

The financial effects of the teatree clearance restrictions upon each of the model households was calculated as the difference between the household's net heat expenditure using a least-cost solution in the absence of restrictions and the household's expenditure using a least-cost solution under compliance with the restrictions as a permitted activity.[13]

The results revealed that eight of the twelve model household classes (65% of modelled households) would incur additional 'compliance costs' as a result of complying with the teatree clearance restrictions (figure 8.1)[14]. The calculation of the compliance cost for each model household is presented in appendix 12. Of these, household classes 7, 9, and 11 (25% of modelled households) would incur net present compliance costs in excess of $1,500. The appliance ownership characteristics of these three model households revealed that each household in these classes used wood-fuelled appliances almost exclusively for all three heatloads, and therefore each would achieve a least-cost investment for all heatloads, in the absence of restrictions, growing teatree fuelwood. For these three households the least-cost investment where teatree clearance restrictions were in place was growing eucalyptus fuelwood.

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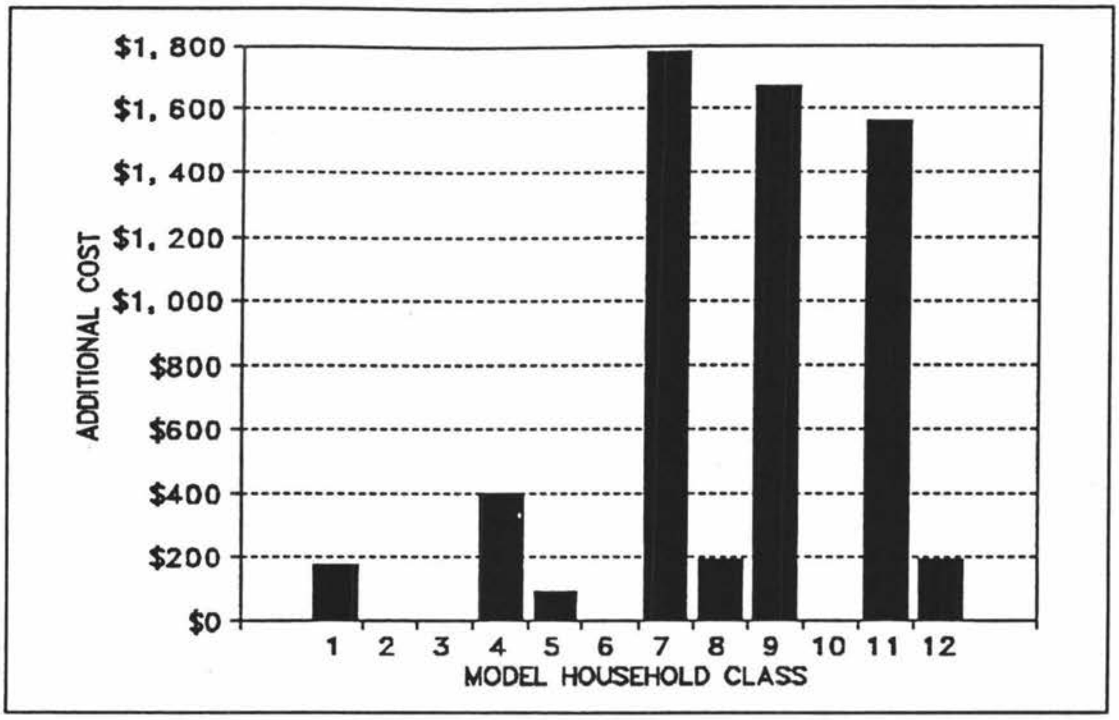
[13] Where individual households in each class would achieve differing least-cost solutions for a heatload as a result of differing land-use characteristics, the total cost for that model household was calculated as a weighted average cost over all households in that class.

[14] For households 4 and 12 it was assumed that 50% of the woodfires owned were able to be used for water-heating.

FIGURE 8.1 COMPLIANCE COST BY MODEL HOUSEHOLD CLASS.



The six model household classes which would incur lower levels of cost from compliance would also each achieve a least-cost investment in the absence of restrictions from growing teatree fuelwood for either one or two heatloads. However, as the appliance ownership characteristics of each of these households revealed that as they did not use fuelwood for all three heatloads, the cost of compliance was not as high as it would have been had they relied completely on wood for all three heatloads, as the restrictions had no effect on their non-fuelwood heatload. The four households which would not incur compliance costs were those which would achieve a least-cost investment from using LPG for all three heatloads, calculated to be 29% of model households.

As was expected, the results showed that where a household predominantly used fuelwood for most or all of their heatloads the cost of compliance was much higher than for those households which did not use wood-fuelled appliances or which used them for only one heatload. The results also showed that the restrictions would have a greater financial impact upon residents than on non-residents, due to the higher annual energy requirements of residents.

The proportion of model households which would achieve a least-cost investment for at least one heatload from growing either eucalyptus fuelwood or teatree fuelwood under either of the clearance restriction scenarios was calculated from the least-cost investment results (table 8.1). In the absence of any clearance restrictions a teatree fuelwood crop would form part of a least-cost energy investment portfolio for the majority of model households, while eucalyptus fuelwood would only be produced by a small minority of households. However, under the current restrictions a eucalyptus fuelwood crop would form part of a least-cost investment portfolio for the majority of model households.

TABLE 8.1 PROPORTION OF MODEL HOUSEHOLDS ACHIEVING LEAST-COST INVESTMENT FOR AT LEAST ONE HEATLOAD FROM FUELWOOD PRODUCTION.

	Eucalyptus	**Teatree**
No restrictions	16%	64%
Permitted activity	66%	0%

8.2 ALTERNATIVES TO CURRENT RESTRICTIONS.

8.2.1 INTRODUCTION.

While compliance with the teatree clearance restrictions would impose additional costs on many Great Barrier Island households, Auckland City had a statutory responsibility under the Resource Management Act to manage the vegetation resources of the island in such a way that the integrity and values of the landscape and natural environment are not adversely affected. However, it was considered that several possibilities existed for the financial impacts of the clearance restrictions upon households to be reduced through modifications to the council's policies while still complying with both the requirements and principles of the Resource Management Act. They were:

i) Allowing teatree harvesting as a **discretionary** activity (at the discretion of Auckland City) under certain provisions (currently only permitted for the commercial production of fuelwood) (Auckland City, 1992); and

ii) Controlled teatree crop management using the 'Swiss' method.

8.2.2 CLEARANCE AS A DISCRETIONARY ACTIVITY.

Section 6F.1.1.3 of the district plan allowed for the clearance of up to 5000m^2 of manuka and kanuka for the sole purpose of commercial fuelwood sale. To obtain a resource consent for teatree clearance as a discretionary activity fuelwood merchants were required to prepare a management plan of the affected area, incorporating the following aspects:

- An assessment of the impact of the proposal on natural habitats and ecological values of the locality, and how they will be managed for protection;

- details of an appropriate rehabilitation programme for any area cleared including either a revegetation programme or the planting of appropriate timber species to secure sustainable use and management; and

- Details on the time periods over which harvesting will take place.

It was considered that the district plan regulations acted in favour of commercial enterprises and to the detriment of ratepayers by denying households the opportunity of providing for their own fuelwood needs through the implementation of sustainable teatree management regimes under the same provisions and requirements used for commercial firewood harvesters. Where households had the opportunity to apply for a resource consent and prepare a management plan, it was considered that environmental damage could be kept to an acceptable minimum whilst still allowing household's to manage the resources on their land under council supervision.

An investigation was carried out to determine if model households would be able to reduce or eliminate their compliance costs if they were able to harvest teatree as a discretionary activity under the same district plan guidelines used for commercial harvesters. The investigation assumed a total areal clearance restriction of $600m^2$ for households, giving an effective restriction of $300m^2$. While this was only double that of the current restriction levels and substantially less than the limit allowed for commercial harvesters, $600m^2$ was estimated to be that level of restriction which would enable the **majority** of households to provide for their fuelwood needs, while still minimising environmental impacts where fuelwood was managed under the sustainable management plan required for the resource consent.

The analysis used a modification of the teatree expenditure models adjusted for the new clearance limit to calculate the total cost of producing fuelwood for 30 years for each of the relevant appliances in each of the 8 model households which used fuelwood. The analysis was based on the assumption that the replanting of teatree on land which had been previously cleared would be considered by Auckland City to reduce the amount of cleared land on any lot. In this way any area harvested would be immediately re-sown. A fuelwood crop could therefore utilise an annual rotational area (*ROTarea*) of $300m^2$, as this would be the maximum area that would ever be cleared at any one time. The analysis also assumed that any land which had previously been cleared by the household (excluding the residential area) would also be incorporated into the fuelwood plot and replanted.

The model for teatree production as a discretionary activity used the same values for *DEMyr* and *ROTlength* as in the original teatree model, but imposed the constraint that *ROTarea* was not greater than $300m^2$. Where a particular household was unable to grow the required amount under the areal constraint, for example where they used fuelwood for all three heatloads, they were assumed to either purchase teatree or to grow eucalyptus fuelwood to supplement the grown teatree, depending on which was least-cost for that particular household.

8.2.3 SWISS TEATREE MANAGEMENT.

The second possibility for reducing the financial cost of the teatree clearance restrictions on households while still safeguarding the environment was a silvicultural management technique known as the 'Swiss' method, discovered during the course of this study. Under the Swiss method the fuelwood crop is not divided into separate annual areal rotations as with the rotational system (although the same rotation length is used), but rather individual trees are selected for harvest each year from throughout the crop at regular distance or tree count intervals.

Figure 8.2 graphically represents a hypothetical fuelwood crop of 18 trees managed and harvested under the Swiss method with a rotation length of 6 years. In the year of initial harvest (year 7) trees **A, K** and **O** are harvested and then resown; in year 8 trees **B, L** and **P** are harvested and resown; and so on until year 14 when the cycle repeats. As figure 8.2 shows, under the Swiss method only 3 trees are felled at each harvest from a stand of 18 trees.

The advantage of the Swiss method for producing teatree fuelwood where a 17 year rotation length is used is that as only one tree from a cluster of 17 is removed each year at regular spacings throughout the crop, the visual, environmental and ecological effects of clearance will be significantly reduced compared to the annual clearfelling of whole areas of teatree, whilst still allowing the household to provide for their needs fuelwood needs at a sustainable rate.

FIGURE 8.2 FUELWOOD CROP MANAGED UNDER THE SWISS METHOD.

A 7	**B** 8	**C** 9	**D** 10	**E** 11	**F** 12
G 9	**H** 10	**I** 11	**J** 12	**K** 7	**L** 8
M 11	**N** 12	**O** 7	**P** 8	**Q** 9	**R** 10

An second investigation was carried out to determine if the model households would be able to reduce or eliminate their compliance costs were they able to manage a teatree crop using the Swiss method, whilst still fulfilling the ecological and planning requirements for a discretionary activity. The investigation was based on the assumption that method assumed that the household was still faced with the current clearance restrictions, but that they were required to complete a management plan, and that as only one tree out of 17 would be harvested per year and immediately replaced, that the land would not be considered to be cleared.

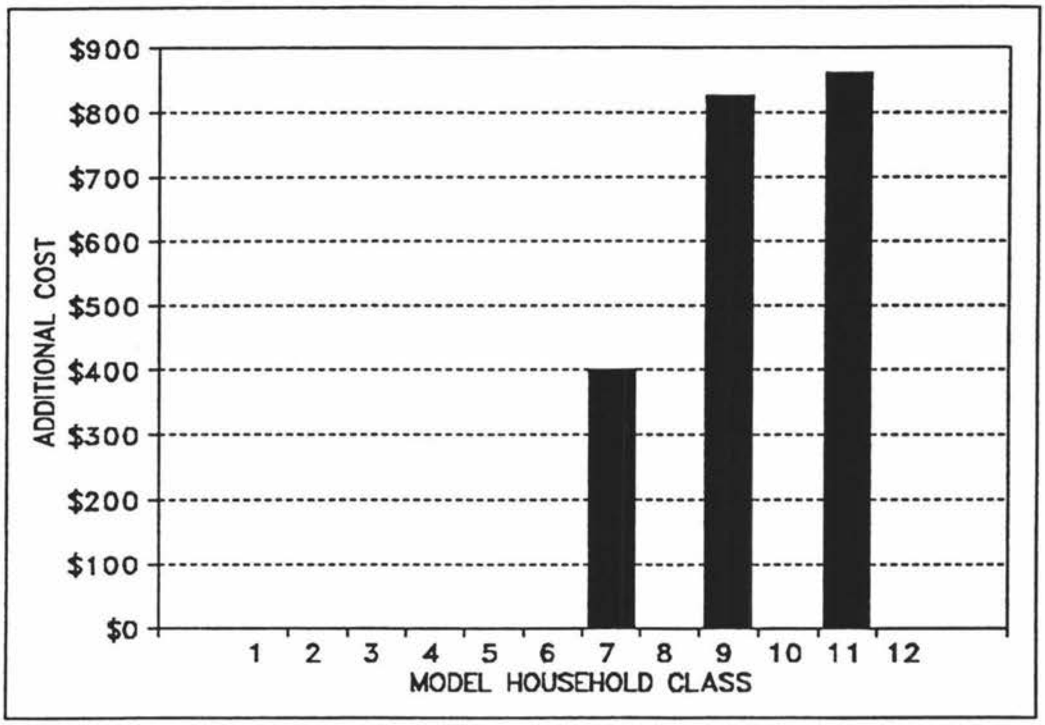
The analysis used the same values for *DEMyr*, *ROTarea* and *ROTlength* as used in the original teatree model, and effectively only differed from the original model in the management assumptions.

8.2.4 RESULTS.

8.2.4.1 CLEARANCE AS A DISCRETIONARY ACTIVITY.

The results of the analysis showed that where households were given the opportunity to manage teatree crops as a discretionary activity, only three of the 12 model household categories (household classes 7, 9 and 11) would incur compliance costs. Furthermore the level of cost incurred by these households would be significantly reduced (figure 8.3). As expected, the three model households incurring compliance costs as a discretionary activity were the three households which used wood-fuelled appliances for all three heatloads and which would incur the highest levels of compliance costs under the current restrictions as a permitted activity (from section 8.1).

FIGURE 8.3 COMPLIANCE COSTS AS A DISCRETIONARY ACTIVITY.



8.2.4.2 SWISS TEATREE MANAGEMENT

As the model for Swiss teatree management differed only from the original teatree expenditure model in chapter 3 in it's management and harvesting assumptions, the results were identical to those achieved in the absence of any restrictions (presented in chapter 6). However it was considered that using the Swiss method would allow the household to provide for their fuelwood needs under the current clearance restrictions with negligible to minimal visual, environmental and ecological effects.

CHAPTER 9: DISCUSSION OF RESULTS AND CONCLUSIONS.

9.1 ALTERNATIVE ENERGY INVESTMENT EVALUATION.

9.1.1 THE EFFECT OF CAPITAL COSTS.

For all heatloads with the exception of non-resident spaceheating, the energy expenditure models revealed that fuelwood was the least-cost energy investment on a dollar per kW of useful heat produced basis. However, the high capital costs of wood-fuelled appliances compared to LPG-fuelled appliances resulted in fuelwood being the more expensive investment of the two where capital costs were included, even though the fuel cost of using wood was lower. Where capital costs were not considered, such as where it was assumed that households already owned the appliances, wood was the less expensive fuel investment.

The expenditure model results showed that heat production was subject to 'economies of production', as for each of the energy systems modelled the non-discounted annual cost was higher in year 0 than in the remaining years of the investment, due to high capital costs. For each of the model households the optimal allocation was also a corner solution where the least-cost investment was always the use of only one fuel and appliance, even where combinations of appliances were analyzed such as for the Solarmax waterheater.

The conclusion can be drawn from the study that the least-cost allocation for a household will be attained from using only one appliance and only one fuel type. The results also indicate that the dominant factor which will determine which of the investments will be least cost for a household is the choice and cost of the appliance used, rather than the fuel type, particularly when energy requirements are low. This conclusion is supported by the study results which showed that in each case where the expenditure models assumed that no appliances were owned, purchasing and using LPG-fuelled appliances was less expensive for all households than purchasing a woodstove and producing fuelwood.

Finally, all but three of the Great Barrier Island model households would achieve a least-cost resource allocation to heatloads from using the appliances which they already owned, rather than from purchasing new appliances.

9.1.2. THE ECONOMICS OF ALTERNATIVE ENERGY TECHNOLOGIES.

The results of the study also revealed that wind and solar electricity generation systems, which are often perceived to be 'the energy sources of the future', were uncompetitive for supplying energy for heatloads compared to fuelwood and LPG. This finding was representative of the study's wider findings on the competitiveness of individual households generating electricity for supplying heatloads.

The study showed that solar water heating systems have the potential to be the least-cost waterheating investment for households which are willing to reduce their hot water consumption. For resident households which are willing to reduce their daily hot-water demands by approximately 20%, the installation of a solar waterheater will be the least-cost investment, even when other appliances are already owned.

However, where a backup or booster system is required to boost the water temperature or as a safeguard against periods of low solar radiation the cost advantage of solar waterheaters is removed. Where households already own LPG or wood-fuelled waterheating appliances the continued use of the existing appliance was found to be the least-cost investment in the long-term compared to the installation of a solar waterheater. Solar waterheaters were found to be economically uncompetitive for non-resident households due to their low annual demand for waterheating energy.

9.1.3 THE ECONOMICS OF RENEWABLE ENERGY RESOURCES.

While renewable wind and solar electricity and solar waterheating systems were not economically competitive for supplying heatloads, sustainable fuelwood systems were considered to be very competitive as a fuel source on a dollar per kiloWatt of useful heat produced basis where appliance costs were not included. However as previously mentioned the high capital costs of fuelwood appliances made the use of non-renewable LPG the least-cost total investment for domestic heatloads when appliance costs were included.

A sensitivity analysis was conducted on the LPG energy expenditure models using an optimizing routine to determine the per kilogram price at which LPG would be superseded by eucalyptus fuelwood as the least-cost energy source over 30 years for all heatloads where appliance capital costs were included. The results showed that at a price of $2.30 per kg (15% above the current market price) a household would be indifferent between purchasing and operating LPG-fuelled appliances for all heatloads and a combination of a purchased woodstove and grown eucalyptus fuelwood. Furthermore, when the sensitivity analysis was repeated under the assumptions that a cheaper woodstove was purchased and that the household had a nil opportunity cost of labour, the results showed that market price of LPG to island residents would only have to increase by 3.5% for the eucalyptus fuelwood option to be cheaper in the long term.

The results suggest that on a wider scale as New Zealand's supply of natural gas resources diminish into the next century and as the price of LPG increases, the economic viability of investing in sustainable fuelwood crops and wood-fuelled appliances for domestic heatloads will increase for areas such as Great Barrier Island which are dependent on remote area power supplies. This conclusion can also be extended to apply to rural localities in New Zealand which are forced to adopt remote area power supplies when faced with the cost of installing electricity cables to their households under an increasing 'user pays' system.

9.2 EVALUATION OF TEATREE RESTRICTIONS AND COUNCIL POLICIES.

9.2.1 SUMMARY OF STUDY RESULTS.

The study results showed that 64% of all model households would achieve a least-cost investment to at least one heatload in the absence of clearance restrictions from producing teatree fuelwood (table 8.1). In order to comply with the teatree clearance restrictions each of these households must re-allocate their household resources away from the harvest and use of teatree fuelwood and invest in an alternative fuel source, incurring additional compliance costs in the process. Where households are unable to clear vegetation as a permitted activity the study showed that 72% of model households would achieve a least-cost investment for at least one heatload from growing eucalyptus fuelwood.

9.2.2 DEFICIENCIES OF THE CURRENT POLICY.

Given the relatively low levels of compliance reported from the questionnaire responses it would appear that the current vegetation conservation policies have not had a significant effect in inducing households to alter their behaviour away from using teatree fuelwood and toward investing in alternative fuelwood sources such as eucalyptus. Many households wrote that they resented the imposition of restrictions on what they perceived as their right to harvest teatree growing on their own land, and many households reported actively defying the restrictions.

The current clearance restrictions were considered to be typical of many regulations introduced by city and regional councils under the Resource Management Act which were deemed by Auckland barrister Alan Dormer to "demand unrealistically high environmental standards seeking zero effects rather than sustainable management"[15]. Specifically, there were considered to be four

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[15] National Business Review, July 8th 1994.

main deficiencies with the current clearance restriction policies:

i) Auckland City relied heavily on information volunteered from other residents to detect illicit scrub clearance (*Pers comm:* Auckland City);

ii) There was a lack of enforcement of the restrictions by Auckland City (*Pers comm:* Auckland City);

iii) 64% of model household had an economic incentive to illegally harvest teatree, as they would incur additional costs from investing in eucalyptus fuelwood;

iv) As the district plan regulations denied households the opportunity of providing for their own fuelwood needs through the implementation of sustainable teatree management regimes under the same provisions and requirements used for commercial firewood harvesters, ratepayers had no opportunity and therefore no incentive to sustainably manage their own teatree fuelwood crops.

9.2.3 RECOMMENDATIONS.

Economic theory suggests that a quota scheme via clearance restrictions is an appropriate economic instrument to ensure that a socially efficient level of teatree harvesting is attained on Great Barrier Island. However such instruments will only work where there are high penalties for infringement and a strong level of enforcement to induce people to alter their behaviour away from the undesirable activity, both of which appear to be lacking in the present case.

While the promotion and adoption of eucalyptus fuelwood management regimes on the island would enable the majority of model households to minimise their energy costs under the constraints of the present clearance restrictions, it was considered unlikely that this policy would be adopted by households when there is no economic inducement (such as infringement penalties) for them to reduce their usage of teatree and shift to a more expensive energy source.

It was considered that there were three possible policy options open to Auckland City to protect Great Barrier Island's native vegetation resources:

i) retain the current restrictions but introduce heavier penalties and stronger enforcement;

ii) allow clearance as a discretionary activity as for commercial harvesters;

iii) alter the current restrictions to allow for and promote the use of the Swiss method.

9.2.3.1 RETAIN CURRENT RESTRICTIONS.

The first option open to Auckland city is to maintain the current restriction levels but increase the levels of surveillance, enforcement, and the use of economic instruments such as financial penalties for non-compliance to provide an economic incentive for households to shift away from the use of teatree. Where households have an economic incentive to shift to an alternative fuelwood source the promotion of eucalyptus fuelwood regimes was considered to be an appropriate policy given the proportion of model households which would achieve a least-cost investment under the constraints of the clearance restrictions from adopting them.

However, given the low incomes of many households, the relatively high costs of compliance, and the prevalent strong feelings among residents against the clearance restrictions it was considered likely that many households would continue to illegally harvest teatree despite the introduction of heavier penalties. In the words of Federated Farmers High Country chairman Bob Brown speaking at a recent sustainable land management conference: "if farmers (or households) can not afford to use sustainable land-management practices, then it simply will not happen" (Straight Furrow, May 9th 1994).

9.2.3.2 ALLOW CLEARANCE AS A DISCRETIONARY ACTIVITY.

The second option open to Auckland City is to amend the current regulations to allow households the opportunity of applying for resource consents to clear teatree as a discretionary activity. To receive a resource consent households would have to prepare sustainable management plans for their teatree blocks and satisfy the same environmental and ecological criteria as commercial harvesters.

To be effective this policy would also require an increase in the levels of surveillance, enforcement, and the use of economic instruments for non-compliance to induce households to take steps towards owning the goal of sustainable management of the teatree resources on their land. This was echoed by speakers at a recent land management conference who stated that "there is no greater incentive to care for land than ownership" (Straight Furrow, May 9th 1994). It was considered that a sense of ownership, both of the resource itself and of the need for conservation and preservation is vital if households are to take steps to conserve and protect Great Barrier Island's teatree resources. Where households did not apply for resource consents, or were refused one, the current zero-base restrictions should continue to apply.

While this second solution goes further towards encouraging households to manage their own resources in a sustainable manner and minimising the costs of household compliance, it was considered that clearfelling large areas of land even where they would be immediately replanted would still have some undesirable environmental and visual effects on the ecosystems and natural landscape of the island.

9.2.3.3 ALTER CURRENT RESTRICTIONS TO ALLOW SWISS METHOD.

The third solution available to the council is to promote the use of the Swiss method for teatree fuelwood crop management, and to alter the current regulations to allow households to apply for a resource consent to manage teatree as a discretionary activity under the Swiss method. Under this proposal households would be required to prepare teatree crop management plans and to satisfy the same environmental and ecological criteria as used for teatree clearance as a discretionary activity for commercial harvesters. This policy would also require an increase in the levels of surveillance, enforcement, and the use of economic instruments for non-compliance to induce households to take steps towards managing their teatree resources in a manner that is both physically and ecologically sustainable.

9.2.4 CONCLUSIONS.

As well as protecting and preserving natural and environmental resources, it was considered that sustainable land management also involved the "wise and conservative use of land and resources to ensure households remain viable and financially strong". (Straight Furrow, May 9th 1994). While the current teatree clearance restrictions were introduced to preserve natural and environmental resources on Great Barrier Island, they had not been effective in achieving this aim, had weak enforcement, and would result in households incurring additional levels of costs.

It was considered that the optimal policy for preservation of the teatree resources of Great Barrier Island would be one which allowed households to sustainably use the teatree resources to provide for their energy needs which would have a minimal to negligible level of environmental and ecological impact, and at the same time ensured that households remained financially strong by minimising avoidable compliance costs.

The results of the study showed that requiring households to adopt the Swiss method in order to harvest teatree through amending the current policies would enable households to provide for their fuelwood needs without incurring compliance costs beyond those required to apply for a resource consent, would result in negligible visual, environmental and ecological effects, and would allow households to take ownership of both the teatree stocks and the sustainable management ideal. It was therefore considered that altering the current regulations to allow households to apply for a resource consent permit to manage teatree under the Swiss method as a discretionary activity is the most appropriate course of action available to Auckland City.

While amending the current policy to incorporate discretionary clearance under the Swiss method was seen to be more equitable than the current policy, it would require Auckland City to incur additional levels of cost, particularly for administration, surveillance and enforcement. However, it was considered that these would have to be increased no matter which policy option the council chose, if the policy was to be effective. Before implementing such a policy it is necessary firstly to weigh up the additional social benefits that would be gained from the policy amendment (in terms increased environmental, ecological and landscape preservation) with the additional costs which would be incurred. In addition, the net social benefit of the new policy must be greater than the net social benefit of the current policy (which includes the household compliance costs measured in chapter 8) for there to be an increase in social welfare from introducing the new policy. This evaluation should be performed through the use of cost benefit-analysis, and where the new policy results in a higher level of net social benefit than the current clearance policy, then there will be a net increase in social welfare from implementation. and the new policy should be introduced.

In conclusion, if it is found that the net social benefit of the Swiss teatree management proposal (defined as social benefits less social costs) is greater the net social benefit of the current policy, social welfare will be increased from implementation of the new policy, and it should therefore be introduced.

REFERENCES.

Allen, R, *et al.* (1992). Ecology of *Kunzea ericoides* (A.Rich) (Kanuka) in East Otago, New Zealand. New Zealand Journal of Botany, Vol 30.

Auckland City, (1992). Proposed District Plan: Hauraki Gulf Islands Section. Auckland City, Auckland.

Baumol, K., and Blinder, A. (1994). Economics: Principle and policy. 7th ed. Dryden press, Fort Worth.

Blakeley and Cook, (1974). Household electricity consumption in New Zealand. World energy conference, Detroit.

Burrell, Juliet (1965). Ecology of Leptospermum in Otago. New Zealand Journal of Botany, Vol 3, No.1.

Carron, L. (1968). Outline of forest mensuration techniques, with special reference to Australia. Australian National University Press, Canberra.

Clunie & Associates (1993). Controls on the Clearance of Manuka and Kanuka in the proposed district plan for the Hauraki Gulf islands. Unpublished report for the Auckland City Council.

Cochran, W. (1964). Sampling Techniques. Wiley, New York.

Doll, J., and Orazem, F. (1984). Production Economics. Wiley, New York.

Earl, D. (1975). Forest energy and economic development. Clarendon, Oxford.

Emory, (1981). Business Research Methods, 3rd ed. Irwin, Illinois.

Esler, A.E. and Astridge, Sandra, J. (1974) Tea Tree (Leptospermum) communities of the Waitakere Range. New Zealand Journal of Botany 12: 485-501.

Fredrick *et al* (1985). Dry matter content and nutrient distribution in an age series of Eucalyptus regnans plantations in New Zealand. New Zealand Journal of Forestry Science 15(2).

Goulding, (1994). Tree measurement techniques article. Sourced from New Zealand Forestry Research Institute, Rotorua.

Grant, D. (1967). Factors affecting the establishment of manuka. Proceedings of the 20th annual weed and pest conference.

Great Barrier Island Committee of Enquiry (1975). Great Barrier Island: the report of the Great Barrier Island Committee of Enquiry. Town and Country Planning, Wellington.

Henry, J.F. (1979). The silvicultural energy farm in perspective.
Contained in Progress in Biomass Conversion, Academic press, New York.

Horgan, G. (1989). The cost of energy from wood compared with it's cost from other fuels. Contained in 'The firewood venture', Ministry of forestry.

Jacobson, V. (1991). Property rights, prices and sustainability. Contained in Regional Resource Futures (conference proceedings), University of Waikato, 1991.

Levy, H., and Sarnat, M. (1990). Capital investment and financial decisions. Prentice Hall, New York.

Leyland, Watson and Noble. (1986). Domestic Heat Energy Economics - a comparison based on resource costs. New Zealand Energy research and development committee, Auckland.

Nicholas, I. (1989). Wood as a fuel. Contained in 'Growing Firewood', Ministry of Forestry, Wellington.

Patterson, M., and Earle, M. (1982). Total energy requirements of household preparation and storage of food. New Zealand Energy Research and development committee.

Randall, Allan. (1987). Resource Economics: An economic approach to natural resource and environmental policy. Wiley, New York

Resource Management Act (1991). Government Printer, Wellington.

Sims, R.E.H., Handford, P., Bell, T. (1990). Wood fuel supply and utilisation from short-rotation energy crops. Massey University, Palmerston North.

Tombleson, J. (1986). Eucalyptus nitens firewood belt - 'Goudies'. New Zealand Tree Grower magazine, August 1986.

Wallace, I. (1989). Firewood Supply in Dunedin. Contained in 'Growing Firewood', Ministry of Forestry, Wellington.

Watson, A. and O'Loughlin, C. (1985). Morphology, strength and biomass of manuka roots and their influence on slope stability. New Zealand Journal of Forestry Science 15(3).

Worley Consultants Ltd. (1989). Comparative Costs of Useful Energy from Fuels and Heating Appliances in the Canterbury region. Ministry of Energy, Wellington.

Worsop, M.A. (1991). A sustainable plan for Agriculture. Contained in Regional Resource Futures (conference proceedings), University of Waikato, 1991.

APPENDICES.

1) **TEATREE CLEARANCE RESTRICTIONS BY LAND UNIT.**

2) **LPG ENERGY EXPENDITURE MODELS:**

- Non-residents;
- Residents.

3) **ELECTRICAL ENERGY EXPENDITURE MODELS:**

- Load assumptions;
- Appliances and generators;
- Non-resident cooking and spaceheating;
- Non-resident waterheating and combined heatloads;
- Resident cooking and spaceheating;
- Resident waterheating and combined heatloads.

4) **SOLAR WATER HEATER ENERGY EXPENDITURE MODELS:**

- Non-residents;
- Residents.

5) **EUCALYPTUS FUELWOOD ENERGY EXPENDITURE MODELS:**

5A)
- Appliance and heatload assumptions;
- Eucalyptus stand growth parameters.

5B) NON-RESIDENT WAMSLER WOODSTOVE MODELS:

- Model/load variables;
- Comparison of rotation length costs;
- Eucalyptus crop production model;
- 8-year rotation length cost model;
- Energy expenditure model;
- Opportunity cost model.

5C) RESIDENT WAMSLER WOODSTOVE MODELS:

- Model/load variables;
- Comparison of rotation length costs;
- Eucalyptus crop production model;
- 8-year rotation length cost model;
- Energy expenditure model;
- Opportunity cost model.

5D) NON-RESIDENT JAYLINE WOODFIRE MODELS:

- Model/load variables, crop production model;
- 8-year rotation length cost model;
- Energy expenditure model;

5E) RESIDENT JAYLINE WOODFIRE MODELS:

- Model/load variables, crop production model;
- 8-year rotation length cost model;
- Energy expenditure model;

6) TEATREE FUELWOOD ENERGY EXPENDITURE MODELS:

6A) BIOMASS GROWTH RATES:

- Dbh/Age, Density/Age;
- Volume/Age, Biomass/Age.

6B) NON-RESIDENT WAMSLER WOODSTOVE MODELS:

- Fuelwood crop production model;
- Energy expenditure model - No teatree on land;
- Opportunity cost model - No teatree on land;
- Energy expenditure model - Purchased fuelwood;
- Crop production model - Teatree on land;
- Energy expenditure model - Teatree on land;
- Opportunity cost model - No teatree on land;

6C) RESIDENT WAMSLER WOODSTOVE MODELS:

- Fuelwood crop production model;
- Energy expenditure model - No teatree on land;
- Opportunity cost model - No teatree on land;
- Energy expenditure model - Purchased fuelwood;
- Crop production model - Teatree on land;
- Energy expenditure model - Teatree on land;
- Opportunity cost model - No teatree on land;

6D) NON-RESIDENT JAYLINE WOODFIRE MODELS:

- Teatree crop production model;
- Energy expenditure model - No teatree on land;
- Opportunity cost model - No teatree on land;
- Energy expenditure model - Teatree on land;
- Opportunity cost model - No teatree on land;

6E) RESIDENT JAYLINE WOODFIRE MODELS:

- Teatree crop production model;
- Energy expenditure model - No teatree on land;
- Opportunity cost model - No teatree on land;
- Energy expenditure model - Teatree on land;
- Opportunity cost model - No teatree on land;

7) QUESTIONNAIRE.

- Barrier Bulletin Article
- Covering Letter
- Questionnaire
- Follow-up letter.

8) QUESTIONNAIRE RESULTS.

8A) NON-RESIDENTS

8B) RESIDENTS

8C) LAND AREAS BY RESIDENCY

9) TEATREE PRODUCTION UNDER CLEARANCE RESTRICTIONS

- Production cost model
- Energy Expenditure Model - No teatree on land;
- Energy Expenditure Model - Teatree on land;
- Results.

10) ZERO OPPORTUNITY COST OF LABOUR ANALYSIS.

10A) NON-RESIDENTS.

- Eucalyptus, Wamsler 8 year production cost model;
- Energy expenditure model;
- Eucalyptus, Jayline 8 year production cost model;
- Energy expenditure model;
- Teatree, Wamsler, - no teatree on land;
- Jayline, energy expenditure model - no teatree on land.
- Results.

10B) RESIDENTS.

- Eucalyptus, Wamsler 8 year production cost model;
- Energy expenditure model;
- Eucalyptus, Jayline 8 year production cost model;
- Energy expenditure model;
- Teatree, Wamsler, no teatree on land;
- Jayline, energy expenditure model - no teatree on land.
- Results.

11) SENSITIVITY ANALYSES - MODEL HOUSEHOLD 2.

- Spaceheating analysis;
- Waterheating analysis.

12) CALCULATION OF COMPLIANCE COSTS

APPENDIX 1.

Teatree clearance restrictions as a permitted activity (by land unit)

Land unit and description.		Restriction
1)	Coastal cliffs	NP
2)	Dune systems and sand flats	300 m^2
3)	Alluvial flats	300 m^2
4)	Wetland systems	NP
5)	Foothills and lower slopes	300 m^2
6)	Steep pastured slopes	300 m^2
7)	Steep infertile coastal slopes	NP
8)	Regenerating slopes	500 m^2
9)	Low fertility hills	NP
10)	Forest and bush areas	NP
11)	Traditional residential	300 m^2
12)	Bush residential	300 m^2
13)	Retailing	300 m^2
14)	Visitor Facilities	300 m^2
15)	Industrial	300 m^2
16)	Extractive industry	N/A
17)	Landscape amenity	300 m^2
18)	Outdoor activities	300 m^2
19)	Community facilities	300 m^2
20)	Landscape protection	300 m^2

NP = Not Permitted

APPENDIX 2.

LPG ENERGY EXPENDITURE MODELS:

- Non-residents;
- Residents.

LPG ENERGY EXPENDITURE MODELS.
COOKING, WATER HEATING AND SPACE HEATING

NON-RESIDENT*

DAILY ENERGY REQUIREMENTS (kW Hrs):

Cooking:	2.5
Water heating	7.7
Space heating:	2.3

APPLIANCES USED:

- COOKING:	*Vulcan Holiday LPG/Propane gas fuelled Oven*		
Fuel:	LPG	Exp.Life	30 yrs
Cost:	$1,319	Maint:	30 every 5 yrs
Avg.Rating:	10 kW		
Efficiency:	70% (Source: Leyland et al)		
- SPACE HEATING:	*Goldair GSR420 Radient LPG heater*		
Fuel:	LPG	Life	15 yrs
Cost:	$120	Maint:	20 every 5 yrs
Avg.Rating:	1.4 kW		
- WATER HEATING:	*Rinnai REU68E LPG water heater*		
Fuel:	LPG	Life	15 yrs
Installed Cost:	$649	Maint:	20 every 5 yrs
Avg.Rating:	9.52 kW		

APPLIANCE PERFORMANCE DATA:

	WATER HEATER		SPACE HEATER		COOKING	
Rating:	Consump. kg/hour	Output Kw	Consump. kg/hour	Output Kw	Consump. kg/hour	Output Kw
Medium	0.59	9.52	0.10	1.40	0.67	6.00

DERIVED FUEL USAGE RATES:

Annual hours of use	50.8	103.7	26.3
Kg fuel used/year:	30.0	10.8	17.7

MODEL VARIABLES:

FUEL PRICE/KG	$2.00	DISCOUNT RATE	9%
		ANNUITY RATE	10.2 TO YEAR 29

		WATER HEAT		SPACE HEATING		COOKING	
		ACT	PV	ACT	PV	ACT	PV
Purchase Cost:	Appliance	649	649	120	120	1319	1319
Fuel Costs:	Yearly Fuel cost:	60		22		35	
	Cost for 30 yrs:		671		241		397
Replace/Maint. Costs:							
Yr 5:	Maint:	20	13	20	13	30	19
Yr 10:	Maint:	20	8	20	8	30	13
Yr 15:	Replace	649	178	120	33	0	0
	Maint:	20	5	20	5	30	8
Yr 20	Maint:	20	4	20	4	30	5
Yr 25:	Maint:	20	2	20	2	30	3
Yr 30:	Salvage	0	0	0	0	0	0

Net Present Cost :	$1,531	$427	$1,765

LPG ENERGY EXPENDITURE MODELS.
COOKING, WATER HEATING AND SPACE HEATING

RESIDENT

DAILY ENERGY REQUIREMENTS (kW Hrs):

Cooking:	2.5
Water heating	7.7
Space heating:	2.3

APPLIANCES USED:

- COOKING: *Vulcan Holiday LPG/Propane gas fuelled Oven*
  - Fuel: LPG — Exp.Life: 30 yrs
  - Cost: $1,319 — Maint: 30 every 5 yrs
  - Avg.Rating: 10 kW
  - Efficiency: 70% (Source: Leyland et al)

- SPACE HEATING: *Goldair GSR420 Radient LPG heater*
  - Fuel: LPG — Life: 15 yrs
  - Cost: $120 — Maint: 20 every 5 yrs
  - Avg.Rating: 1.4 kW

- WATER HEATING: *Rinnai REU68E LPG water heater*
  - Fuel: LPG — Life: 15 yrs
  - Installed Cost: $649 — Maint: 20 every 5 yrs
  - Avg.Rating: 9.52 kW

APPLIANCE PERFORMANCE DATA:

	WATER HEATER		SPACE HEATER		COOKING	
Rating:	Consump. kg/hour	Output Kw	Consump. kg/hour	Output Kw	Consump. kg/hour	Output Kw
Medium	0.59	9.52	0.10	1.40	0.67	6.00

DERIVED FUEL USAGE RATES:

Annual hours of use	293.5	598.9	151.7
Kg fuel used/year:	173.2	62.3	102.4

MODEL VARIABLES:

FUEL PRICE/KG	$2.00	DISCOUNT RATE	9%
		ANNUITY RATE	10.2 TO YEAR 29

		WATER HEAT		SPACE HEATING		COOKING	
		ACT	PV	ACT	PV	ACT	PV
Purchase Cost:	Appliance	649	649	120	120	1319	1319
Fuel Costs:	Yearly Fuel cost:	346		125		205	
	Cost for 30 yrs:		3878		1395		2293
Replace/Maint. Costs:							
Yr 5:	Maint:	20	13	20	13	30	19
Yr 10:	Maint:	20	8	20	8	30	13
Yr 15:	Replace	649	178	120	33	0	0
	Maint:	20	5	20	5	30	8
Yr 20	Maint:	20	4	20	4	30	5
Yr 25:	Maint:	20	2	20	2	30	3
Yr 30:	Salvage	0	0	0	0	0	0
Net Present Cost :			$4,738		$1,581		$3,661

APPENDIX 3.

ELECTRICAL ENERGY EXPENDITURE MODELS:

- Load assumptions;
- Appliances and generators;
- Non-resident cooking and spaceheating;
- Non-resident waterheating and combined heatloads;
- Resident cooking and spaceheating;
- Resident waterheating and combined heatloads.

TOTAL ELECTRICITY LOAD ASSUMPTIONS

HEAT LOAD DAILY ELECTRICAL ENERGY REQUIREMENTS

HEAT LOAD	APPLIANCE EFFICIENCY	PER YEAR kW Useful	PER YEAR kW Total	PER DAY (W) Total
Cooking	70%	910	1,300	3,562
Heating	100%	839	839	2,297
Water Heating*	74%	2,978	4,000	10,959

(Total electricity requirement = heat load requirement/appliance efficency)
(*Waterheating Total kW includes standing heat losses)

TYPICAL DAILY ELECTRICITY REQUIREMENTS OF MEDIUM-SIZED HOUSEHOLD.

(Source: BP Alternative energy Product catalog)

APPLIANCE	#	WATTS	HRS/DAY	WHRS/DA
Flouro. Light	3	20	4	240
	2	8	1	16
Stereo	1	20	3	60
TV	1	60	3	180
Water Pump	1	375	0.5	187.5
Vacuum cleaner	1	600	0.2	120
Washing machine	1	700	0.2	140
microwave	1	1200	0.2	240
170L DC fridge/freezer	1	54	7	378
220L DC freezer	1	54	7	378
PLUS:				
Electric Jug:	1	1500	0.2	300
TOTAL KW/H PER DAY:				2240

TOTAL ELECTRICAL SYSTEM OUTPUT REQUIRED (W/HR/DAY)

	HEAT LOAD	OTHER	BATTERY LOSSES	TOTAL
Cooking	3,562	2,240	1,024	6,825
Heating	2,297	2,240	801	5,338
Water Heating	10,959	2,240	2,329	15,528

(Battery losses = 15%. Source :Bp alternative energy catalog)

ELECTRICAL ENERGY EXPENDITURE MODELS:
APPLIANCES AND GENERATING SYSTEMS USED.

DIESEL AND PETROL GENERATORS:

Diesel system:	Mase Easy 4200DM Diesel, 3.6 kW cont.	
System cost:	Generator:	$4,770
	4 * L16 (6 volt, 350 AH) US batteries	$2,250
	1 * Ebbett inverter with charger	$3,450
	Total System Cost:	$10,470
Petrol system:	Mase FM 4000M Petrol, 3.0 kW cont.	
System cost:	Generator:	$2,430
	4 * L16 (6 volt, 350 AH) US batteries	$2,250
	1 * Ebbett inverter with charger	$3,450
	Total System Cost:	$8,130

PERFORMANCE SPECIFICATIONS:

Model	Fuel	Output (W)	Fuel use l/hour
Easy 4200 DM	Diesel	3600	1.9
FM4000M	Petrol	3000	2
Generator life:	20 years		
Batt/Invert. Life:	15 years		
Maint cost:	$30 every 5 yrs		

WIND/SOLAR HYBRID GENERATING SYSTEM:

FORGAN JONES BP Sample system 8:	
RATED OUTPUT:	6,880 Watts/day
COMPONENTS:	1 * SOMA 1000 wind turbine 4 * BP275 Solar modules 1 * BPR2-40 Regulator 24 * 2p779 PVSTOR Batteries 1 * 2524 Trace inverter
Quoted price:	$23,617

APPLIANCES USED:

- COOKING:	*Shacklock 640H Basic Radient Oven*		
Fuel:	240V AC electricity	Exp.Life	30 yrs
Cost:	$1,079	Maint:	30 every 10 yrs
Max. rating:	11.4 kW		
Efficiency:	70%(Source: Leyland et al)		
- SPACE HEATING:	*Hanimex Sunglow 1000 electric radiant bar heater.*		
Fuel:	240V AC electricity	Life	15 yrs
Cost:	$50	Maint:	13.5 in year 8
Max. rating:	1 kW		
Efficiency:	100%(Source: Leyland et al)		
- WATER HEATING:	*Electric Water heater, 135 Litre - Low Pressure*		
Fuel:	240V AC electricity	Life	15 yrs
Installed Cost:	$529	Maint:	40 in year 10
Max. rating:	2 kW		
Heat losses:	74%(Source: Leyland et al)		

ELECTRIC ENERGY EXPENDITURE MODEL.
NON-RESIDENT: COOKING.

Model Variables:

Diesel Price: $/l	$0.73	Discount rate	9%
Petrol price: $/l	$1.13	Annuity rate	10.2
Days/yr	63		

		DIESEL		PETROL		WIND/SOLAR	
		ACT	PV	ACT	PV	ACT	PV
Purchase Cost:	System:	10,470	$10,470	8,130	$8,130	23,617	$23,617
	Appliance:	1,079	$1,079	1,079	$1,079	1,079	$1,079
Fuel costs:	$/Yr	166		324		0	
	Fuel to yr 30:	4,970	$1,855	9,718	$3,628	0	0
Replace/Maint. Costs:							
Yr 5:	Maint:	30	$19	30	$19	40	$26
Yr 10:	Maint:	60	$25	60	$25	70	$30
Yr 15:	Btry/Invert	5,700	$1,565	5,700	$1,565	5700	$1,565
	Maint:	30	$8	30	$8	40	$11
Yr 20:	Generator	4770	$851	2,430	$434	0	$0
	Maint:	60	$11	60	$11	70	$12
Yr 25:	Maint:	30	$3	30	$3	40	$5
Yr 30:	Salvage	(2,325)	($175)	(1,155)	($87)	0	$0

	Diesel	Petrol	Wind/Solar
Present Value System cost*	$14,633	$13,736	$25,266
% of system output used for cooking:	61%	61%	61%
Net Present Cost (Cooking) (inc appliance cost)	$10,062	$9,512	$16,590

(System cost excludes appliance cost)

ELECTRIC ENERGY EXPENDITURE MODEL.
NON-RESIDENT: SPACE HEATING.

		DIESEL		PETROL		WIND/SOLAR	
		ACT	PV	ACT	PV	ACT	PV
Purchase Cost:	System:	10,470	$10,470	8,130	$8,130	23,617	$23,617
	Appliance:	50	$50	50	$50	50	$50
Fuel costs:	$/Yr	130		253		0	
	Fuel to yr 30:	3,887	$1,321	7,600	$2,584	0	
Replace/Maint. Costs:							
Yr 5	Maint:	30	$19	30	$19	40	$26
Yr 8:	Htr Maint:	14	$7	14	$7	14	$7
Yr 10:	Maint:	30	$13	30	$13	40	$17
Yr 15:	Btry/Invert	5,700	$1,565	5,700	$1,565	5700	$1,565
	Htr replace	50	$14	50	$14	60	$16
Yr 20:	Generator	4,770	$851	2,430	$434	0	$0
	Maint:	30	$5	30	$5	40	$7
Yr 23:	Htr Maint:	14	$2	14	$2	14	$2
Yr 25:	Maint:	30	$3	30	$3	40	$5
Yr 30:	Salvage	(2,342)	($176)	(1,172)	($88)	0	$0

	Diesel	Petrol	Wind/Solar
Present Value System cost*	$14,094	$12,687	$25,262
% of system output used for cooking:	51%	51%	51%
Net Present Cost (Heating) (inc appliance cost)	$7,186	$6,424	$12,790

(*System cost excludes appliance cost)

ELECTRIC ENERGY EXPENDITURE MODEL.
NON-RESIDENT: WATER HEATING.

		DIESEL		PETROL		WIND/SOLAR	
		ACT	PV	ACT	PV	ACT	PV
Purchase Cost:	System:	10,470	$10,470	10,470	$10,470	38,223	$38,223
	Appliance:	529	$529	529	$529	529	$529
Fuel costs:	$/Yr	377		737		0	
	Fuel to yr 30:	11,307	$3,844	22,109	$7,516	0	
Replace/Maint. Costs:							
Yr 5:	Maint:	30	$19	30	$19	40	$26
Yr 10:	Maint:	30	$13	30	$13	40	$17
	W/H Maint:	40	$17	40	$17	40	$17
Yr 15:	Bttry/Invert	5,700	$1,565	5,700	$1,565	5700	$1,565
	W/H replace	529	$145	529	$145	529	$145
Yr 20:	Generator	4,770	$851	2,430	$434	0	$0
	Maint:	30	$5	30	$5	40	$7
Yr 25:	Maint:	30	$3	30	$3	40	$5
	W/H Maint:	40	$5	40	$5	40	$5
Yr 30:	Salvage	(2,355)	($177)	(1,185)	($89)	0	$0

	DIESEL	PETROL	WIND/SOLAR
Present Value System cost*	$16,760	$20,103	$40,009
% of system output used for waterheating:	83%	83%	83%
Net Present Cost (Waterheating) (inc appliance cost)	$14,445	$17,220	$33,748

(*System cost excludes appliance cost)

ELECTRIC ENERGY EXPENDITURE MODEL.
NON-RESIDENT: COOKING, WATER AND SPACE HEATING.

Total System output necessary (W/day): 22,421

		DIESEL		PETROL		WIND/SOLAR	
		ACT	PV	ACT	PV	ACT	PV
Purchase Cost:	System:	10,470	$10,470	10,470	$10,470	47,893	$47,893
	Appliance:	1,658	$1,658	1,658	$1,658	1,658	$1,658
Fuel costs:	$/Yr	544		1,064		0	
	Fuel to yr 30:	16,326	$5,550	31,923	$10,852	0	$0
Total Replace/Maint. Costs:			2,336		2,007		1,679
	Tot. Salvages:		(177)		(89)		0

	DIESEL	PETROL	WIND/SOLAR
Present Value System cost*	$18,178	$23,239	$49,572
% of system output used for waterheatin	94%	94%	94%
Net Present Cost (Combination): (inc appliance cost)	$18,703	$23,448	$48,138

(*System cost excludes appliance cost)

ELECTRIC ENERGY EXPENDITURE MODEL.
RESIDENT: COOKING.

Model Variables:

Diesel Price: $/l	$0.73	Discount rate	9%
Petrol price: $/l	$1.13	Annuity rate	10.2
Days/yr	365		

		DIESEL		PETROL		WIND/SOLAR	
		ACT	PV	ACT	PV	ACT	PV
Purchase Cost:	System:	10,470	$10,470	8,130	$8,130	23,617	$23,617
	Appliance:	1,079	$1,079	1,079	$1,079	1,079	$1,079
Fuel costs:	$/Yr	960		1,877		0	
	Fuel to yr 30:	28,795	$10,749	56,303	$21,017	0	0
Replace/Maint. Costs:							
Yr 5:	Maint:	30	$19	30	$19	40	$26
Yr 10:	Maint:	60	$25	60	$25	70	$30
Yr 15:	Bury/Invert	5,700	$1,565	5,700	$1,565	5700	$1,565
	Maint:	30	$8	30	$8	40	$11
Yr 20:	Generator	4770	$851	2,430	$434	0	$0
	Maint:	60	$11	60	$11	70	$12
Yr 25:	Maint:	30	$3	30	$3	40	$5
Yr 30:	Salvage	(2,325)	($175)	(1,155)	($87)	0	$0

	DIESEL	PETROL	WIND/SOLAR
Present Value System cost*	$23,527	$31,125	$25,266
% of system output used for cooking:	61%	61%	61%
Net Present Cost (Cooking) (inc appliance cost)	$15,522	$20,187	$16,590

(System cost excludes appliance cost)

ELECTRIC ENERGY EXPENDITURE MODEL.
RESIDENT: SPACE HEATING.

		DIESEL		PETROL		WIND/SOLAR	
		ACT	PV	ACT	PV	ACT	PV
Purchase Cost:	System:	10,470	$10,470	8,130	$8,130	23,617	$23,617
	Appliance:	50	$50	50	$50	50	$50
Fuel costs:	$/Yr	751		1,468		0	
	Fuel to yr 30:	22,520	$7,655	44,033	$14,969	0	
Replace/Maint. Costs:							
Yr 5	Maint:	30	$19	30	$19	40	$26
Yr 8:	Htr Maint:	14	$7	14	$7	14	$7
Yr 10:	Maint:	30	$13	30	$13	40	$17
Yr 15:	Bury/Invert	5,700	$1,565	5,700	$1,565	5700	$1,565
	Htr replace	50	$14	50	$14	60	$16
Yr 20:	Generator	4,770	$851	2,430	$434	0	$0
	Maint:	30	$5	30	$5	40	$7
Yr 23:	Htr Maint:	14	$2	14	$2	14	$2
Yr 25:	Maint:	30	$3	30	$3	40	$5
Yr 30:	Salvage	(2,342)	($176)	(1,172)	($88)	0	$0

	DIESEL	PETROL	WIND/SOLAR
Present Value System cost*	$20,428	$25,072	$25,262
% of system output used for heating:	51%	51%	51%
Net Present Cost (Heating) (inc appliance cost)	$10,393	$12,694	$12,790

(*System cost excludes appliance cost)

ELECTRIC ENERGY EXPENDITURE MODEL.
RESIDENT: WATER HEATING.

		DIESEL		PETROL		WIND/SOLAR	
		ACT	PV	ACT	PV	ACT	PV
Purchase Cost:	System:	10,470	$10,470	10,470	$10,470	38,223	$38,223
	Appliance:	529	$529	529	$529	529	$529
Fuel costs:	$/Yr	2,184		4,270		0	
	Fuel to yr 30:	65,510	$22,270	128,091	$43,544	0	
Replace/Maint. Costs:							
Yr 5:	Maint:	30	$19	30	$19	40	$26
Yr 10:	Maint:	30	$13	30	$13	40	$17
	W/H Maint:	40	$17	40	$17	40	$17
Yr 15:	Btry/Invert	5,700	$1,565	5,700	$1,565	5700	$1,565
	W/H replace	529	$145	529	$145	529	$145
Yr 20:	Generator	4,770	$851	2,430	$434	0	$0
	Maint:	30	$5	30	$5	40	$7
Yr 25:	Maint:	30	$3	30	$3	40	$5
	W/H Maint:	40	$5	40	$5	40	$5
Yr 30:	Salvage	(2,355)	($177)	(1,185)	($89)	0	$0

	Diesel	Petrol	Wind/Solar
Present Value System cost*	$35,186	$56,131	$40,009
% of system output used for waterheating:	83%	83%	83%
Net Present Cost (Waterheating) (inc appliance cost)	$29,744	$47,134	$33,748

(*System cost excludes appliance cost)

ELECTRIC ENERGY EXPENDITURE MODEL.
RESIDENT: COOKING, WATER AND SPACE HEATING.

Total System output necessary (W/day): 22,421

		DIESEL		PETROL		WIND/SOLAR	
		ACT	PV	ACT	PV	ACT	PV
Purchase Cost:	System:	10,470	$10,470	10,470	$10,470	47,893	$47,893
	Appliance:	1,658	$1,658	1,658	$1,658	1,658	$1,658
Fuel costs:	$/Yr	3,153		6,165		0	
	Fuel to yr 30:	94,590	$32,155	184,951	$62,873	0	$0
Total Replace/Maint. Costs:			2,336		2,007		1,679
	Tot. Salvages:		(177)		(89)		0

	Diesel	Petrol	Wind/Solar
Present Value System cost*	$44,783	$75,260	$49,572
% of system output used for waterheating:	94%	94%	94%
Net Present Cost (Combination): (inc appliance cost)	$43,648	$72,224	$48,138

(*System cost excludes appliance cost)

APPENDIX 4.

SOLAR WATER HEATER ENERGY EXPENDITURE MODELS:

- Non-residents;
- Residents.

SOLAR WATER HEATER ENERGY EXPENDITURE MODEL
NON-RESIDENT

Appliance:	*SolarMax solar water heater.*		
Fuel:	Solar radiation.	**Exp.Life**	15 yrs
Purchase cost:	2600	**Maint:**	20 every 5 yrs
Freight and Installation	250		

MODEL VARIABLES:

Days/yr	63	Discount Rate:	9%
		Annuity Rate:	10.20
Total Required Energy (kW/day):	7.77		
Solar Contribution: (kW):	6.90	LPG price ($/l)	$2.00
% :	89%	Petrol price ($/l)	$1.13
From other source (kW/day):	0.87	Wood price	$50.00 /stere

	SOLAR MAX		LPG		WOOD FIRE		WOOD STOVE		ELECTRICITY (PETROL)	
	ACT	PV	ACT	PV	ACT	PV	ACT	PV	ACT	PV
Appliance purchase	3099	$3,099	1319	$1,319	0	$0	0	$0	0	$0
Annual fuel cost	0		5.34		4.12		3.41		41	
For 29 years:		$0		$60		$46		$38		$462
Replace/Maint. Costs:										
Yr 5: Maint:	20	$13	20	$13						
Yr 10: Maint:	20	$8	20	$8						
Yr 15: Replace	3099	$851	1319	$362						
Maint:	0	$0	0	$0						
Yr 20 Maint:	20	$4	20	$4						
Replace	249	$44	249	$44						
Yr 25: Maint:	20	$2	20	$2						
Yr 30: Salvage	0	$0	0	$0						
NET PRESENT COST (INC SOLAR MAX):				**$5,834**		**$4,068**		**$4,060**		**$4,484**

NOTE:
Model assumes that where woodstove, woodfire or petrol electricity are used as a backup, that they are already owned by household.

SOLAR WATER HEATER ENERGY EXPENDITURE MODEL
RESIDENT

Appliance:	*SolarMax solar water heater.*		
Fuel:	Solar radiation.	Exp.Life	15 yrs
Purchase cost:	2600	Maint:	20 every 5 yrs
Freight and installation	250		

MODEL VARIABLES:

Days/yr	365	Discount Rate:	9%
		Annuity Rate:	10.20
Total Required Energy (kW/day):	7.77		
Solar Contribution: (kW):	6.90	LPG price ($/l)	$2.00
% :	89%	Petrol price ($/l)	$1.13
From other source (kW/day):	0.87	Wood price	$50.00 /stere

		SOLAR MAX		LPG		WOOD FIRE		WOOD STOVE		ELECTRICITY (PETROL)	
		ACT	PV	ACT	PV	ACT	PV	ACT	PV	ACT	PV
Appliance purchase		3099	$3,099	1319	$1,319	0	$0	0	$0	0	$0
Annual fuel cost For 29 years:		0	$0	30.95	$347	23.86	$267	19.78	$222	239	$2,679
Replace/Maint. Costs:											
Yr 5:	Maint:	20	$13	20	$13						
Yr 10:	Maint:	20	$8	20	$8						
Yr 15:	Replace	3099	$851	1319	$362						
	Maint:	0	$0	0	$0						
Yr 20	Maint:	20	$4	20	$4						
	Replace	249	$44	249	$44						
Yr 25:	Maint:	20	$2	20	$2						
Yr 30:	Salvage	0	$0	0	$0						

NET PRESENT COST (INC SOLAR MAX): LPG $6,121; WOOD FIRE $4,289; WOOD STOVE $4,243; ELECTRICITY (PETROL) $6,700

NOTE:
Model assumes that where woodstove, woodfire or petrol electricity are used as a backup, that they are already owned by household.

APPENDIX 5.

EUCALYPTUS FUELWOOD ENERGY EXPENDITURE MODELS:

5A) - Appliance and heatload assumptions;
- Eucalyptus stand growth parameters.

5B) NON-RESIDENT WOODSTOVE MODELS:
- Model/load variables;
- Comparison of rotation length costs;
- Eucalyptus crop production model;
- 8-year rotation length cost model;
- Energy expenditure model;
- Opportunity cost model.

5C) RESIDENT WOODSTOVE MODELS:
- Model/load variables;
- Comparison of rotation length costs;
- Eucalyptus crop production model;
- 8-year rotation length cost model;
- Energy expenditure model;
- Opportunity cost model.

5D) NON-RESIDENT WOODFIRE MODELS:
- Model variables, crop production model;
- 8-year rotation length cost model;
- Energy expenditure model;

5E) RESIDENT WOODFIRE MODELS:
- Model variables, crop production model;
- 8-year rotation length cost model;
- Energy expenditure model;

APPLIANCE AND HEAT LOAD ASSUMPTIONS.

WAMSLER K97a WOODSTOVE

Purch. Price:	$6,625	
Freight & Installation:	$449	
Expect. Life:	50	yrs
Maintenence:	$20	every 5 years

APPLIANCE PERFORMANCE:

Setting:	Fuel load kg	m^3	Time Hrs	H/W or Cooking	Room	Total Efficiency:
High	10	0.03	1	10	7	40%
Low	10	0.03	2	4	6	47%
Medium	10	0.03	1.5	7	6.5	44%

JAYLINE JUNIOR WOODSTOVE

Purch. Price:	$1,645	
Freight & Installation:	$200	
Expect. Life:	15	yrs
Maintenence:	$20	every 5 years

APPLIANCE PERFORMANCE:

Setting:	Fuel load kg	m^3	Time Hrs	H/W	Room	Total Efficiency:
Medium	2	0.01	1	2	5	83%

ENERGY REQUIREMENTS:

Usefull cooking load:	910	kWh/year.
Usefull Water heating:	2794	kWh/year.
Total Water heating:	2794	kWh/year (inc heat loss)
Usefull space heating:	839	kWh/year.

STAND PARAMETERS AND WOOD YIELDS
FROM INDEPENDENT EUCALYPTUS TRIALS

Data source: Sims et al, 1990.

SPECIES	AGE @ HARVEST (YRS)	STOCK RATE (STEM/ha)	DBH (cm)	TOTAL BIOMASS (ODT/ha)	MAI ODT/ha/yr
Salignia	3	6960	5.3	51	17
Nitens	4	6470	3.9	71	18
Fastigata	4	7250	3	51	13
Nitens	5	1675	13.5	82	16
Nitens	7	1675	15.2	133	19
Salignia	2.6	5000	7.2	55	21
Salignia	3.2	6013	5.8	48	15
Salignia	8	829	9.8	127	16
Regnans	4	2050	10.5	69	17
Regnans	7	1850	17.1	187	27
Regnans	10	1075	25	319	32
Regnans	8	2150	14.5	163	20

MEAN MAI OVER ALL SPECIES (ODT/HA/YR)	**20.0**
MEAN MAI OVER E. REGNANS (ODT/HA/YR)	**24**
MEAN MAI OVER OTHER SPECIES (ODT/HA/YR)	**16.9**

STAND PARAMETERS AND WOOD YIELDS
EUCALYPTUS REGNANS

Data source: "Dry matter content and nutrient distribution in an age series of Eucalypts regnans in New Zealand". - NZ Journal of Forestry Science # 15, 1985.
Trials located at Mangakino, cental North Island.

AGE @ HARVEST (YRS)	STOCK RATE (STEM/ha)	DBH (cm)	TOTAL BIOMASS (ODT/ha)	MAI ODT/ha/yr
4	1400	10.5	68.5	17
7	1575	17.1	198	28
10	1400	25	319	32
13	1250	21.6	294	23
17	1680	24.1	460	27

MEAN MAI (ODT/HA/YR)	**25.4**

NON RESIDENT: ENERGY REQUIREMENTS:
EUCALYPTUS FUELWOOD

MODEL VARIABLES:		
Weeks per year:	9	
Usefull cooking load:	158	kWh/year.
Usefull Water heating:	484	kWh/year.
Total Water heating:	491	kWh/year (inc heat loss)
Usefull space heating:	145	kWh/year.

COOKING AND SPACE HEATING:

		DAILY	YEARLY
Avg cooking Load (W):		2,493	157.5 kW
Time Used		21 Min	22.5 Hours
Fuel requirements (kg):		2.37	150.0
(Stere):		0.01	0.5
Space Heat Produced:		2,315 W	146.3 kW
% of total heating needs:	Summer:	444%	
	Winter	40%	

WATER/SPACE HEATING:

		DAILY	YEARLY
Avg W/h Load (W):		7,772	491.0 kW
Time Used (inc waste):		67 Min	70.1 Hours
Fuel requirements (kg):		7.40	467.6
(Stere):		0.03	1.6
Space Heat Produced:		7,217 W	65.0 kW
% of total heating needs:	Summer:	1383%	
	Winter	123%	

ANALYSIS OF EUCALYPTUS ROTATION COSTS - NON RESIDENT

FUELWOOD REQUIREMENTS (STERE/YR)	EUCAL	TEATREE
COOK	0.5	0.3
WATER	1.6	1.1
TOTAL	2.1	1.4

DISCOUNT RATE	9%
TEATREE PRICE	$50 /STERE
PURCHASE COST/YR	$69

ROTATION LENGTH

	3			4			5			6			7			8		
YEAR	GROW	BUY	PV	GROW	BUY	PV	GROW	BUY	PV	GROW	BUY	PV	GROW	BUY	PV	GROW	BUY	PV
0	76	$69	145	51	$69	121	37	$69	106	27	$69	96	20	$69	89	15	$69	84
1	77	$69	134	52	$69	112	37	$69	98	27	$69	89	20	$69	82	15	$69	78
2	78	$69	125	53	$69	103	38	$69	91	28	$69	82	21	$69	76	16	$69	72
3	32		24	54	$69	96	39	$69	84	29	$69	76	22	$69	70	16	$69	66
4	32		22	32		22	40	$69	77	30	$69	70	22	$69	65	17	$69	61
5	32		21	32		21	32		21	30	$69	65	23	$69	60	17	$69	56
6	32		19	32		19	32		19	32		19	23	$69	55	18	$69	52
7	32		17	32		17	32		17	32		17	32		17	18	$69	48
8	32		16	32		16	32		16	32		16	32		16	32		16
9	107		49	32		15	32		15	32		15	32		15	32		15
10	107		45	32		13	32		13	32		13	32		13	32		13
11	107		42	32		12	32		12	32		12	32		12	32		12
12	32		11	83		29	32		11	32		11	32		11	32		11
13	32		10	83		27	32		10	32		10	32		10	32		10
14	32		9	83		25	32		9	32		9	32		9	32		9
15	32		9	83		23	68		19	32		9	32		9	32		9
16	32		8	32		8	68		17	32		8	32		8	32		8
17	32		7	32		7	68		16	32		7	32		7	32		7
18	107		23	32		7	68		14	58		12	32		7	32		7
19	107		21	32		6	68		13	58		11	32		6	32		6
20	107		19	32		6	32		6	58		10	32		6	32		6
21	32		5	32		5	32		5	58		10	51		8	32		5
22	32		5	32		5	32		5	58		9	51		8	32		5
23	32		4	32		4	32		4	58		8	51		7	32		4
24	32		4	83		10	32		4	32		4	51		6	46		6
25	32		4	83		10	32		4	32		4	51		6	46		5
26	32		3	83		9	32		3	32		3	51		5	46		5
27	107		10	83		8	32		3	32		3	51		5	46		5
28	107		10	32		3	32		3	32		3	32		3	46		4
29	107		9	32		3	32		3	32		3	32		3	46		4
NPV:			$832			$761			$719			$706			$697			$689

EUCALYPTUS ENERGY CROP PRODUCTION MODEL:
EUCALYPTUS SALIGNIA & BOTRYOIDES

BASE MODEL:

MODEL ASSUMPTIONS:

Land area: (ha)	1
Wood density kg/m3	450
Actual vol. of wood/stere	0.65

CROP PRODUCTION DATA:

Age at harvest	8
Planting density (s/ha)	2500
Trees per km (single)	500
Tree spacing (m)	2.00

BIOMASS PRODUCTION FROM 1 HA:

Biomass : Tonne/ha	200
Stere / ha after 8 years	629.1
For 8 year cycle rotation:	
Area per rotation (ha)	0.13
Harvest per year, .1 ha rotatio	78.6

RESULTS FOR NON-RESIDENTS:

MODEL VARIABLES:

Weeks per year:	9
Total land (ha)	5.4
Mean Gross Margin	$1,055
Land used for income (%)	31%
(ha)	1.7
Available land (ha):	3.7

ENERGY REQUIREMENTS:
STERES PER YEAR:

Cooking	0.5
Water Heating	1.6
Total:	2.1

PRODUCTION MODEL RESULTS:

Fuelwood needed per year:	2.1 steres
For 8 year cycle rotation:	
Area per rotation (ha)	0.003
(m^2)	33.6
Total area Required (ha)	0.03
(m^2)	268.5

FUELWOOD PRODUCTION COST ANALYSIS - NON-RESIDENT

EUCALYPTUS SALIGNIA & BOTRYOIDES: 8 YEAR ROTATION CYCLE.

BASED ON 1HA ASSUMPTION:

PRODUCTION COSTS:

Tree cost	$1.00	Harvesting:	$13	/stere
Freight	$0.40	Cultivation	$200	/ha
Planting	$0.25	Maint.	$157	/ha/yr

YEAR	# TREES ON PLOT	PLANT COST	TREE COST	CULTV.	MAINT.	BIOMASS (STERES)	HARVEST COST	TOTAL (68 STERE/YR)	ACTUAL COSTS: 2.1 STERE/YR
0	313	78.1	437.5	25.0		0	0.0	540.6	$14.5
1	625	78.1	437.5	25.0	19.6	0	0.0	560.2	$15.0
2	938	78.1	437.5	25.0	39.2	0	0.0	579.8	$15.6
3	1250	78.1	437.5	25.0	58.8	0	0.0	599.4	$16.1
4	1563	78.1	437.5	25.0	78.3	0	0.0	619.0	$16.6
5	1875	78.1	437.5	25.0	97.9	0	0.0	638.5	$17.1
6	2188	78.1	437.5	25.0	117.5	0	0.0	658.1	$17.7
7	2500	78.1	437.5	25.0	137.1	0	0.0	677.7	$18.2
8	2500				156.7	78.63	1022.2	1178.9	$31.7
9	2500				156.7	78.63	1022.2	1178.9	$31.7
10	2500				156.7	78.63	1022.2	1178.9	$31.7
11	2500				156.7	78.63	1022.2	1178.9	$31.7
TO YR 23					1880.0	943.6	12266.7	14146.7	$379.8
24	2500	78.1	437.5	25.0	156.7	78.6	1022.2	1719.5	$46.2
25	2500	78.1	437.5	25.0	156.7	78.6	1022.2	1719.5	$46.2
26	2500	78.1	437.5	25.0	156.7	78.6	1022.2	1719.5	$46.2
27	2500	78.1	437.5	25.0	156.7	78.6	1022.2	1719.5	$46.2
28	2500	78.1	437.5	25.0	156.7	78.6	1022.2	1719.5	$46.2
29	2500	78.1	437.5	25.0	156.7	78.6	1022.2	1719.5	$46.2
								$34,053	$914

EUCALYPTUS FUELWOOD ENERGY EXPENDITURE ANALYSIS: NON- RESIDENT.

APPLIANCE: WAMSLER WOODSTOVE

TOTAL LAND (HA)	0.17	
LAND USED FOR OPP. COST	0.05	HA
INCOME FROM LAND	$1,055	
DISCOUNT RATE:	9%	
ROTATION LENGTH (YRS):	8	

			COOKING:				WATER HEATING				
YEAR	Appliance	Maint.	WOOD COST Purch	Grow	TOTAL	P.V.	WOOD COST Purch	Grow	TOTAL	P.V.	COMBINED
0	$7,074		$17	$4	$7,115	$7,115	$53	$11	$7,138	$7,138	$7,179
1			$17	$4	$41	$38	$53	$11	$64	$59	$97
2			$17	$4	$21	$17	$53	$12	$65	$54	$72
3			$17	$4	$21	$16	$53	$12	$65	$50	$66
4			$17	$4	$21	$15	$53	$13	$85	$61	$75
5		$20	$17	$4	$41	$27	$53	$13	$86	$56	$70
6			$17	$4	$21	$13	$53	$13	$66	$40	$52
7			$17	$4	$21	$12	$53	$14	$67	$36	$48
8				$8	$8	$4		$24	$24	$12	$16
9				$8	$8	$4		$24	$44	$20	$24
10		$20		$8	$28	$12		$24	$44	$19	$22
11				$8	$8	$3		$24	$24	$9	$12
12				$8	$8	$3		$24	$24	$9	$11
13				$8	$8	$3		$24	$24	$8	$10
14				$8	$8	$2		$24	$24	$7	$9
15		$20		$8	$28	$8		$24	$44	$12	$14
16				$8	$8	$2		$24	$24	$6	$8
17				$8	$8	$2		$24	$24	$6	$7
18				$8	$8	$2		$24	$24	$5	$7
19				$8	$8	$1		$24	$24	$5	$6
20		$20		$8	$28	$5		$24	$44	$8	$9
21				$8	$8	$1		$24	$24	$4	$5
22				$8	$8	$1		$24	$24	$4	$5
23				$8	$8	$1		$24	$24	$3	$4
24				$11	$11	$1		$35	$35	$4	$6
25		$20		$11	$31	$4		$35	$55	$6	$8
26				$11	$11	$1		$35	$35	$4	$5
27				$11	$11	$1		$35	$35	$3	$5
28				$11	$11	$1		$35	$35	$3	$4
29	($2,814)			$11	($2,802)	($230)		$35	($2,779)	($228)	($227)
NET PRESENT COST:						$7,083				$7,422	$7,630
WITH OPPORTUNITY COST:						$7,083				$7,422	$7,630

EUCALYPTUS FUELWOOD ENERGY EXPENDITURE ANALYSIS: NON- RESIDENT.

APPLIANCE: WAMSLER WOODSTOVE

TOTAL LAND (HA)	0.17
LAND USED FOR OPP. COST	0.05 HA
INCOME FROM LAND	$1,055
DISCOUNT RATE:	9%
ROTATION LENGTH (YRS):	8

			COOKING:				WATER HEATING				
YEAR	Appliance	Maint.	WOOD COST Purch	Grow	TOTAL	P.V.	WOOD COST Purch	Grow	TOTAL	P.V.	COMBINED
0	$7,074		$17	$4	$7,115	$7,115	$53	$11	$7,138	$7,138	$7,179
1			$17	$4	$41	$38	$53	$11	$64	$59	$97
2			$17	$4	$21	$17	$53	$12	$65	$54	$72
3			$17	$4	$21	$16	$53	$12	$65	$50	$66
4			$17	$4	$21	$15	$53	$13	$85	$61	$75
5		$20	$17	$4	$41	$27	$53	$13	$86	$56	$70
6			$17	$4	$21	$13	$53	$13	$66	$40	$52
7			$17	$4	$21	$12	$53	$14	$67	$36	$48
8				$8	$8	$4		$24	$24	$12	$16
9				$8	$8	$4		$24	$44	$20	$24
10		$20		$8	$28	$12		$24	$44	$19	$22
11				$8	$8	$3		$24	$24	$9	$12
12				$8	$8	$3		$24	$24	$9	$11
13				$8	$8	$3		$24	$24	$8	$10
14				$8	$8	$2		$24	$24	$7	$9
15		$20		$8	$28	$8		$24	$44	$12	$14
16				$8	$8	$2		$24	$24	$6	$8
17				$8	$8	$2		$24	$24	$6	$7
18				$8	$8	$2		$24	$24	$5	$7
19				$8	$8	$1		$24	$24	$5	$6
20		$20		$8	$28	$5		$24	$44	$8	$9
21				$8	$8	$1		$24	$24	$4	$5
22				$8	$8	$1		$24	$24	$4	$5
23				$8	$8	$1		$24	$24	$3	$4
24				$11	$11	$1		$35	$35	$4	$6
25		$20		$11	$31	$4		$35	$55	$6	$8
26				$11	$11	$1		$35	$35	$4	$5
27				$11	$11	$1		$35	$35	$3	$5
28				$11	$11	$1		$35	$35	$3	$4
29	($2,814)			$11	($2,802)	($230)		$35	($2,779)	($228)	($227)
NET PRESENT COST:						$7,083				$7,422	$7,630
WITH OPPORTUNITY COST:						$7,083				$7,422	$7,630

OPPORTUNITY COST ANALYSIS
EUCALYPTUS FUELWOOD, NON - RESIDENT,

AND IN OPP COST (m^2): 378.2 TOTAL LAND AREA (M^2): 1239
OT. INCOME FROM LAND: 1055

OTAL PLOT SIZE (M^2)

65 203 269

IZE OF YEARLY ROTATIONS (M^2):

8 **25** **34**

Opportunity cost only occurs when the land remaining unplanted (SPARE) < land with opportunity cost.

COOKING		WATER HEATING:				COMBINED			
SED ^2	SPARE M^2	LAND US M^2	SPARE	COST	PV	LAND US M^2	SPARE	COST	PV
8	1231	25	1214		$0	34	1205		$0
16	1223	51	1188		$0	67	1172		$0
24	1215	76	1163		$0	101	1138		$0
33	1206	102	1137		$0	134	1105		$0
41	1198	127	1112		$0	168	1071		$0
49	1190	152	1087		$0	201	1038		$0
57	1182	178	1061		$0	235	1004		$0
65	1174	203	1036		$0	269	970		$0
65	1174	203	1036		$0	269	970		$0
65	1174	203	1036		$0	269	970		$0
65	1174	203	1036		$0	269	970		$0
65	1174	203	1036		$0	269	970		$0
65	1174	203	1036		$0	269	970		$0
65	1174	203	1036		$0	269	970		$0
65	1174	203	1036		$0	269	970		$0
65	1174	203	1036		$0	269	970		$0
65	1174	203	1036		$0	269	970		$0
65	1174	203	1036		$0	269	970		$0
65	1174	203	1036		$0	269	970		$0
65	1174	203	1036		$0	269	970		$0
65	1174	203	1036		$0	269	970		$0
65	1174	203	1036		$0	269	970		$0
65	1174	203	1036		$0	269	970		$0
65	1174	203	1036		$0	269	970		$0
65	1174	203	1036		$0	269	970		$0
65	1174	203	1036		$0	269	970		$0
65	1174	203	1036		$0	269	970		$0
65	1174	203	1036		$0	269	970		$0
65	1174	203	1036		$0	269	970		$0
65	1174	203	1036		$0	269	970		$0
			NPV OPP COST		$0		NPV OPP COST		$0

RESIDENT ENERGY REQUIREMENTS:
EUCALYPTUS FUELWOOD

MODEL VARIABLES:

Weeks per year:	52	
Usefull cooking load:	910	kWh/year.
Usefull Water heating:	2794	kWh/year.
Total Water heating:	2837	kWh/year (inc heat loss)
Usefull space heating:	839	kWh/year.

COOKING AND SPACE HEATING:

		DAILY	YEARLY
Avg cooking Load (W):		2,493	910.0 kW
Time Used		21 Min	130.0 Hours
Fuel requirements (kg):		2.37	866.7
(Stere):		0.01	3.0
Space Heat Produced:		2,315 W	845.0 kW
% of total heating needs:	Summer:	444%	
	Winter	40%	

WATER/SPACE HEATING:

		DAILY	YEARLY
Avg W/h Load (W):		7,771	2836.6 kW
Time Used (inc waste):		67 Min	405.2 Hours
Fuel requirements (kg):		7.40	2701.5
(Stere):		0.03	9.2
Space Heat Produced:		7,216 W	375.3 kW
% of total heating needs:			
	Summer:	1383%	
	Winter	123%	

ANALYSIS OF EUCALYPTUS ROTATION COSTS - RESIDENT

FUELWOOD REQUIREMENTS (STERE/YR)

	EUCAL	TEATREE
COOK	3.0	2.0
WATER	9.2	6.1
TOTAL	12.2	8.1

DISCOUNT RATE	9%
TEATREE PRICE	$50 /STERE
PURCHASE COST/YR	$404

ROTATION LENGTH

	3			4			5			6			7			8		
YEAR	GROW	BUY	PV	GROW	BUY	PV	GROW	BUY	PV	GROW	BUY	PV	GROW	BUY	PV	GROW	BUY	PV
0	437	$404	841	296	$404	699	211	$404	615	155	$404	558	114	$404	518	84	$404	488
1	445	$404	779	302	$404	647	216	$404	568	159	$404	516	118	$404	478	87	$404	450
2	453	$404	721	308	$404	599	221	$404	526	163	$404	477	121	$404	442	90	$404	415
3	183		141	314	$404	554	226	$404	486	167	$404	440	125	$404	408	93	$404	384
4	183		130	183		130	230	$404	449	171	$404	407	128	$404	377	96	$404	354
5	183		119	183		119	183		119	175	$404	376	131	$404	348	99	$404	327
6	183		109	183		109	183		109	183		109	135	$404	321	102	$404	302
7	183		100	183		100	183		100	183		100	183		100	105	$404	278
8	183		92	183		92	183		92	183		92	183		92	183		92
9	620		285	183		84	183		84	183		84	183		84	183		84
10	620		262	183		77	183		77	183		77	183		77	183		77
11	620		240	183		71	183		71	183		71	183		71	183		71
12	183		65	479		170	183		65	183		65	183		65	183		65
13	183		60	479		156	183		60	183		60	183		60	183		60
14	183		55	479		143	183		55	183		55	183		55	183		55
15	183		50	479		131	394		108	183		50	183		50	183		50
16	183		46	183		46	394		99	183		46	183		46	183		46
17	183		42	183		42	394		91	183		42	183		42	183		42
18	620		131	183		39	394		83	337		72	183		39	183		39
19	620		121	183		36	394		77	337		66	183		36	183		36
20	620		111	183		33	183		33	337		60	183		33	183		33
21	183		30	183		30	183		30	337		55	297		49	183		30
22	183		27	183		27	183		27	337		51	297		45	183		27
23	183		25	183		25	183		25	337		46	297		41	183		25
24	183		23	479		61	183		23	183		23	297		38	267		34
25	183		21	479		56	183		21	183		21	297		34	267		31
26	183		19	479		51	183		19	183		19	297		32	267		28
27	620		61	479		47	183		18	183		18	297		29	267		26
28	620		56	183		16	183		16	183		16	183		16	267		24
29	620		51	183		15	183		15	183		15	183		15	267		22
NPV:			$4,812			$4,405			$4,162			$4,088			$4,039			$3,994

EUCALYPTUS ENERGY CROP PRODUCTION MODEL: EUCALYPTUS SALIGNIA & BOTRYOIDES

BASE MODEL:

MODEL ASSUMPTIONS:

Land area: (ha)	1
Wood density kg/m3	450
Actual vol. of wood/stere	0.65
Fuelwood conversion	92%

CROP PRODUCTION DATA:

Age at harvest	8
Planting density (s/ha)	2500
Trees per km (single)	500
Tree spacing (m)	2.00

BIOMASS PRODUCTION FROM 1 HA:

Biomass : Tonne/ha after 8 yrs:	200
Stere / ha after 8 years	629.1
For 8 year cycle rotation:	
Area per rotation (ha)	0.13
Harvest per year (stere):	78.6

RESULTS FOR RESIDENTS:

MODEL VARIABLES:

Weeks per year:	52
Total land (ha)	4.1

ENERGY REQUIREMENTS:

STERES PER YEAR:

Cooking	3.0
Water Heating	9.2
Total:	12.2

PRODUCTION MODEL RESULTS:

Fuelwood needed per year:	12.2 steres
For 8 year cycle rotation:	
Area per rotation (ha)	0.019
(m^2)	193.9
Total area Required (ha)	0.16
(m^2)	1551.4

FUELWOOD PRODUCTION COST ANALYSIS - RESIDENT

EUCALYPTUS SALIGNIA & BOTRYOIDES: 8 YEAR ROTATION CYCLE.

BASED ON 1HA ASSUMPTION:

PRODUCTION COSTS:

Tree cost	$1.00	Harvesting:	$13	/stere
Freight	$0.40	Cultivation	$200	/ha
Planting	$0.25	Maint.	$157	/ha/yr

YEAR	# TREES ON PLOT	PLANT COST	TREE COST	CULTV.	MAINT.	BIOMASS (STERES)	HARVEST COST	TOTAL (68 STERE/YR)	ACTUAL COSTS: 12.2 STERE/YR
0	313	78.1	437.5	25.0		0	0.0	540.6	$83.9
1	625	78.1	437.5	25.0	19.6	0	0.0	560.2	$86.9
2	938	78.1	437.5	25.0	39.2	0	0.0	579.8	$89.9
3	1250	78.1	437.5	25.0	58.8	0	0.0	599.4	$93.0
4	1563	78.1	437.5	25.0	78.3	0	0.0	619.0	$96.0
5	1875	78.1	437.5	25.0	97.9	0	0.0	638.5	$99.1
6	2188	78.1	437.5	25.0	117.5	0	0.0	658.1	$102.1
7	2500	78.1	437.5	25.0	137.1	0	0.0	677.7	$105.1
8	2500				156.7	78.63	1022.2	1178.9	$182.9
9	2500				156.7	78.63	1022.2	1178.9	$182.9
10	2500				156.7	78.63	1022.2	1178.9	$182.9
11	2500				156.7	78.63	1022.2	1178.9	$182.9
TO YR 23					1880.0	943.6	12266.7	14146.7	$2,194.7
24	2500	78.1	437.5	25.0	156.7	78.6	1022.2	1719.5	$266.8
25	2500	78.1	437.5	25.0	156.7	78.6	1022.2	1719.5	$266.8
26	2500	78.1	437.5	25.0	156.7	78.6	1022.2	1719.5	$266.8
27	2500	78.1	437.5	25.0	156.7	78.6	1022.2	1719.5	$266.8
28	2500	78.1	437.5	25.0	156.7	78.6	1022.2	1719.5	$266.8
29	2500	78.1	437.5	25.0	156.7	78.6	1022.2	1719.5	$266.8
								$34,053	$5,283

EUCALYPTUS FUELWOOD ENERGY EXPENDITURE ANALYSIS: RESIDENT.

APPLIANCE: WAMSLER WOODSTOVE

TOTAL LAND (HA)	4.02
LAND USED FOR OPP. COST	1.41 HA
INCOME FROM LAND	$5,866
DISCOUNT RATE:	9%
ROTATION LENGTH (YRS):	8

			COOKING:				WATER HEATING				
YEAR	Appliance	Maint.	WOOD COST Purch	Grow	TOTAL	P.V.	WOOD COST Purch	Grow	TOTAL	P.V.	COMBINED
0	$7,074		$98	$20	$7,312	$7,312	$306	$64	$7,443	$7,443	$7,681
1			$98	$21	$239	$219	$306	$66	$371	$341	$560
2			$98	$22	$120	$101	$306	$68	$374	$315	$415
3			$98	$23	$121	$93	$306	$70	$376	$290	$383
4			$98	$23	$121	$86	$306	$73	$398	$282	$368
5		$20	$98	$24	$142	$92	$306	$75	$401	$260	$340
6			$98	$25	$123	$73	$306	$77	$383	$228	$302
7			$98	$26	$124	$68	$306	$80	$385	$211	$278
8				$44	$44	$22		$138	$138	$69	$92
9				$44	$44	$20		$138	$158	$73	$93
10		$20		$44	$64	$27		$138	$158	$67	$86
11				$44	$44	$17		$138	$138	$54	$71
12				$44	$44	$16		$138	$138	$49	$65
13				$44	$44	$14		$138	$138	$45	$60
14				$44	$44	$13		$138	$138	$41	$55
15		$20		$44	$64	$18		$138	$158	$44	$56
16				$44	$44	$11		$138	$138	$35	$46
17				$44	$44	$10		$138	$138	$32	$42
18				$44	$44	$9		$138	$138	$29	$39
19				$44	$44	$9		$138	$138	$27	$36
20		$20		$44	$64	$11		$138	$158	$28	$36
21				$44	$44	$7		$138	$138	$23	$30
22				$44	$44	$7		$138	$138	$21	$27
23				$44	$44	$6		$138	$138	$19	$25
24				$65	$65	$8		$202	$202	$26	$34
25		$20		$65	$85	$10		$202	$222	$26	$33
26				$65	$65	$7		$202	$202	$21	$28
27				$65	$65	$6		$202	$202	$20	$26
28				$65	$65	$6		$202	$202	$18	$24
29	($2,814)			$65	($2,749)	($226)		$202	($2,612)	($215)	($209)
NET PRESENT COST:						$8,075				$9,923	$11,122
WITH OPPORTUNITY COST:						$8,075				$9,923	$11,122

EUCALYPTUS FUELWOOD - RESIDENT OPPORTUNITY COST.

LAND IN OPP COST (m^2): 14,070 **TOTAL LAND AREA (M^2):** 40,200
TOT. INCOME FROM LAND: $5,866

TOTAL PLOT SIZE (M^2)

377 1,175 1,551

SIZE OF YEARLY ROTATIONS (M^2):

47 147 194

Opportunity cost only occurs when the land remaining unplanted (SPARE) < land with opportunity cost.

COOKING		WATER HEATING:				COMBINED			
USED M^2	SPARE M^2	LAND USED M^2	SPARE	COST	PV	LAND USED M^2	SPARE	COST	PV
47	40153	147	40053		$0	194	40006		$0
94	40106	294	39906		$0	388	39812		$0
141	40059	440	39760		$0	582	39618		$0
188	40012	587	39613		$0	776	39424		$0
236	39964	734	39466		$0	970	39230		$0
283	39917	881	39319		$0	1164	39036		$0
330	39870	1028	39172		$0	1357	38843		$0
377	39823	1175	39025		$0	1551	38649		$0
377	39823	1175	39025		$0	1551	38649		$0
377	39823	1175	39025		$0	1551	38649		$0
377	39823	1175	39025		$0	1551	38649		$0
377	39823	1175	39025		$0	1551	38649		$0
377	39823	1175	39025		$0	1551	38649		$0
377	39823	1175	39025		$0	1551	38649		$0
377	39823	1175	39025		$0	1551	38649		$0
377	39823	1175	39025		$0	1551	38649		$0
377	39823	1175	39025		$0	1551	38649		$0
377	39823	1175	39025		$0	1551	38649		$0
377	39823	1175	39025		$0	1551	38649		$0
377	39823	1175	39025		$0	1551	38649		$0
377	39823	1175	39025		$0	1551	38649		$0
377	39823	1175	39025		$0	1551	38649		$0
377	39823	1175	39025		$0	1551	38649		$0
377	39823	1175	39025		$0	1551	38649		$0
377	39823	1175	39025		$0	1551	38649		$0
377	39823	1175	39025		$0	1551	38649		$0
377	39823	1175	39025		$0	1551	38649		$0
377	39823	1175	39025		$0	1551	38649		$0
377	39823	1175	39025		$0	1551	38649		$0
377	39823	1175	39025		$0	1551	38649		$0
		NPV OPP COST			$0	NPV OPP COST			$0

NON-RESIDENT ENERGY REQUIREMENTS:
EUCALYPTUS FUELWOOD: JAYLINE JUNIOR

MODEL VARIABLES:

Weeks per year:	9	
Usefull space heating:	145	kWh/year.

SPACE HEATING:

	DAILY	YEARLY
Avg Heating Load (W):	2,297	145.1 kW
Time Used	28 Min	29.0 Hours
Fuel requirements (kg):	0.92	58.1
(Stere):	0.00	0.2

EUCALYPTUS ENERGY CROP PRODUCTION MODEL:
EUCALYPTUS SALIGNIA & BOTRYOIDES

BASE MODEL:

MODEL ASSUMPTIONS:

Land area: (ha)	1
Wood density kg/m3	450
Actual vol. of wood/stere	0.65

CROP PRODUCTION DATA:

Age at harvest	8
Planting density (s/ha)	2500
Trees per km (single)	500
Tree spacing (m)	2.00

BIOMASS PRODUCTION FROM 1 HA:

Biomass : Tonne/ha	200
Stere / ha after 8 years	629.1
For 8 year cycle rotation:	
Area per rotation (ha)	0.13
Harvest per year, .1 ha rotation	78.6

RESULTS FOR NON-RESIDENTS:

MODEL VARIABLES:

Weeks per year:	9

ENERGY REQUIREMENTS:

STERES PER YEAR:

Space heating	0.2
Total:	0.2

PRODUCTION MODEL RESULTS:

Fuelwood needed per year:	0.2 steres
For 8 year cycle rotation:	
Area per rotation (ha)	0.000
(m^2)	3.2
Total area Required (ha)	0.00
(m^2)	25.2

JAYLINE JUNIOR WOODFIRE

EUCALYPTUS SALIGNIA & BOTRYOIDES: 8 YEAR ROTATION CYCLE.

BASED ON 1HA ASSUMPTION:

PRODUCTION COSTS:

Tree cost	$1.00	Harvesting:	$13	/stere
Freight	$0.40	Cultivation	$200	/ha
Planting	$0.25	Maint.	$157	/ha/yr

YEAR	# TREES ON PLOT	PLANT COST	TREE COST	CULTV.	MAINT.	BIOMASS (STERES)	HARVEST COST	TOTAL (68 STERE/YR)	ACTUAL COSTS: 0.2 STERE/YR
0	313	78.1	437.5	25.0		0	0.0	540.6	$1.4
1	625	78.1	437.5	25.0	19.6	0	0.0	560.2	$1.4
2	938	78.1	437.5	25.0	39.2	0	0.0	579.8	$1.5
3	1250	78.1	437.5	25.0	58.8	0	0.0	599.4	$1.5
4	1563	78.1	437.5	25.0	78.3	0	0.0	619.0	$1.6
5	1875	78.1	437.5	25.0	97.9	0	0.0	638.5	$1.6
6	2188	78.1	437.5	25.0	117.5	0	0.0	658.1	$1.7
7	2500	78.1	437.5	25.0	137.1	0	0.0	677.7	$1.7
8	2500				156.7	78.63	1022.2	1178.9	$3.0
9	2500				156.7	78.63	1022.2	1178.9	$3.0
10	2500				156.7	78.63	1022.2	1178.9	$3.0
11	2500				156.7	78.63	1022.2	1178.9	$3.0
TO YR 23					1880.0	943.6	12266.7	14146.7	$36.0
24	2500	78.1	437.5	25.0	156.7	78.6	1022.2	1719.5	$4.4
25	2500	78.1	437.5	25.0	156.7	78.6	1022.2	1719.5	$4.4
26	2500	78.1	437.5	25.0	156.7	78.6	1022.2	1719.5	$4.4
27	2500	78.1	437.5	25.0	156.7	78.6	1022.2	1719.5	$4.4
28	2500	78.1	437.5	25.0	156.7	78.6	1022.2	1719.5	$4.4
29	2500	78.1	437.5	25.0	156.7	78.6	1022.2	1719.5	$4.4
								$34,053	$87

EUCALYPTUS FUELWOOD ENERGY EXPENDITURE ANALYSIS: NON-RESIDENT

APPLIANCE: JAYLINE WOODFIRE

DISCOUNT RATE: 9%
ROTATION LENGTH (YRS): 8

SPACE HEATING

YEAR	Appliance	Maint.	WOOD COST Purch	Grow	TOTAL	P.V.
0	$1,845		$7	$1	$1,862	$1,862
1			$7	$1	$17	$16
2			$7	$1	$8	$7
3			$7	$2	$9	$7
4			$7	$2	$9	$6
5		$20	$7	$2	$29	$19
6			$7	$2	$9	$5
7			$7	$2	$9	$5
8				$3	$3	$2
9				$3	$3	$1
10		$20		$3	$23	$10
11				$3	$3	$1
12				$3	$3	$1
13				$3	$3	$1
14				$3	$3	$1
15	$1,845			$3	$1,848	$507
16				$3	$3	$1
17				$3	$3	$1
18				$3	$3	$1
19				$3	$3	$1
20		$20		$3	$23	$4
21				$3	$3	$0
22				$3	$3	$0
23				$3	$3	$0
24				$4	$4	$1
25		$20		$4	$24	$3
26				$4	$4	$0
27				$4	$4	$0
28				$4	$4	$0
29				$4	$4	$0

NET PRESENT COST: $2,463

WITH OPPORTUNITY COST: $2,463

RESIDENT ENERGY REQUIREMENTS:
EUCALYPTUS FUELWOOD: JAYLINE JUNIOR

MODEL VARIABLES:

Weeks per year:	52
Usefull space heating:	839 kWh/year.

SPACE HEATING:

	DAILY	YEARLY
Avg Heating Load (W):	2,297	838.5 kW
Time Used	28 Min	167.7 Hours
Fuel requirements (kg):	0.92	335.4
(Stere):	0.00	1.1

EUCALYPTUS ENERGY CROP PRODUCTION MODEL:
EUCALYPTUS SALIGNIA & BOTRYOIDES

BASE MODEL:

MODEL ASSUMPTIONS:

Land area: (ha)	1
Wood density kg/m3	450
Actual vol. of wood/stere	0.65

CROP PRODUCTION DATA:

Age at harvest	8
Planting density (s/ha)	2500
Trees per km (single)	500
Tree spacing (m)	2.00

BIOMASS PRODUCTION FROM 1 HA:

Biomass : Tonne/ha	200
Stere / ha after 8 years	629.1
For 8 year cycle rotation:	
Area per rotation (ha)	0.13
Harvest per year, .1 ha rotation	78.6

RESULTS FOR RESIDENTS:

MODEL VARIABLES:

Weeks per year:	52

ENERGY REQUIREMENTS:
STERES PER YEAR:

Space heating	1.1
Total:	1.1

PRODUCTION MODEL RESULTS:

Fuelwood needed per year:	1.1 steres
For 8 year cycle rotation:	
Area per rotation (ha)	0.002
(m^2)	18.2
Total area Required (ha)	0.01
(m^2)	145.8

FUELWOOD PRODUCTION COST ANALYSIS - RESIDENT
JAYLINE JUNIOR WOODFIRE

EUCALYPTUS SALIGNIA & BOTRYOIDES: 8 YEAR ROTATION CYCLE.
BASED ON 1HA ASSUMPTION:

PRODUCTION COSTS:

Tree cost	$1.00	Harvesting:	$13 /stere
Freight	$0.40	Cultivation	$200 /ha
Planting	$0.25	Maint.	$157 /ha/yr

YEAR	# TREES ON PLOT	PLANT COST	TREE COST	CULTV.	MAINT.	BIOMASS (STERES)	HARVEST COST	TOTAL (68 STERE/YR)	ACTUAL COSTS: 1.1 STERE/YR
0	313	78.1	437.5	25.0		0	0.0	540.6	$7.6
1	625	78.1	437.5	25.0	19.6	0	0.0	560.2	$7.8
2	938	78.1	437.5	25.0	39.2	0	0.0	579.8	$8.1
3	1250	78.1	437.5	25.0	58.8	0	0.0	599.4	$8.4
4	1563	78.1	437.5	25.0	78.3	0	0.0	619.0	$8.7
5	1875	78.1	437.5	25.0	97.9	0	0.0	638.5	$8.9
6	2188	78.1	437.5	25.0	117.5	0	0.0	658.1	$9.2
7	2500	78.1	437.5	25.0	137.1	0	0.0	677.7	$9.5
8	2500				156.7	78.63	1022.2	1178.9	$16.5
9	2500				156.7	78.63	1022.2	1178.9	$16.5
10	2500				156.7	78.63	1022.2	1178.9	$16.5
11	2500				156.7	78.63	1022.2	1178.9	$16.5
TO YR 23					1880.0	943.6	12266.7	14146.7	$197.9
24	2500	78.1	437.5	25.0	156.7	78.6	1022.2	1719.5	$24.1
25	2500	78.1	437.5	25.0	156.7	78.6	1022.2	1719.5	$24.1
26	2500	78.1	437.5	25.0	156.7	78.6	1022.2	1719.5	$24.1
27	2500	78.1	437.5	25.0	156.7	78.6	1022.2	1719.5	$24.1
28	2500	78.1	437.5	25.0	156.7	78.6	1022.2	1719.5	$24.1
29	2500	78.1	437.5	25.0	156.7	78.6	1022.2	1719.5	$24.1
								$34,053	$476

EUCALYPTUS FUELWOOD ENERGY EXPENDITURE ANALYSIS: RESIDENT

APPLIANCE: JAYLINE WOODFIRE

DISCOUNT RATE: 9%
ROTATION LENGTH (YRS): 8

			SPACE HEATING			
			WOOD COST			
YEAR	Appliance	Maint.	Purch	Grow	TOTAL	P.V.
0	$1,845		$38	$8	$1,936	$1,936
1			$38	$8	$92	$84
2			$38	$8	$46	$39
3			$38	$8	$46	$36
4			$38	$9	$47	$33
5		$20	$38	$9	$67	$44
6			$38	$9	$47	$28
7			$38	$9	$47	$26
8				$16	$16	$8
9				$16	$16	$8
10		$20		$16	$36	$15
11				$16	$16	$6
12				$16	$16	$6
13				$16	$16	$5
14				$16	$16	$5
15	$1,845			$16	$1,861	$511
16				$16	$16	$4
17				$16	$16	$4
18				$16	$16	$3
19				$16	$16	$3
20		$20		$16	$36	$7
21				$16	$16	$3
22				$16	$16	$2
23				$16	$16	$2
24				$24	$24	$3
25		$20		$24	$44	$5
26				$24	$24	$3
27				$24	$24	$2
28				$24	$24	$2
29				$24	$24	$2

NET PRESENT COST: $2,837

WITH OPPORTUNITY COST: $2,837

APPENDIX 6.

TEATREE FUELWOOD ENERGY EXPENDITURE MODELS:

6A) BIOMASS GROWTH RATES:

- Dbh/Age, Density/Age;
- Volume/Age, Biomass/Age.

6B) NON-RESIDENT WOODSTOVE MODELS:

- Fuelwood crop production model;
- Energy expenditure model - No teatree on land;
- Opportunity cost model - No teatree on land;
- Energy expenditure model - Purchased fuelwood;
- Crop production model - Teatree on land;
- Energy expenditure model - Teatree on land;
- Opportunity cost model - No teatree on land;

6C) RESIDENT WOODSTOVE MODELS:

- Fuelwood crop production model;
- Energy expenditure model - No teatree on land;
- Opportunity cost model - No teatree on land;
- Energy expenditure model - Purchased fuelwood;
- Crop production model - Teatree on land;
- Energy expenditure model - Teatree on land;
- Opportunity cost model - No teatree on land;

6D) NON-RESIDENT WOODFIRE MODELS:

- Teatree crop production model;
- Energy expenditure model - No teatree on land;
- Opportunity cost model - No teatree on land;
- Energy expenditure model - Teatree on land;
- Opportunity cost model - No teatree on land;

6E) RESIDENT WOODFIRE MODELS:

- Teatree crop production model;
- Energy expenditure model - No teatree on land;
- Opportunity cost model - No teatree on land;
- Energy expenditure model - Teatree on land;
- Opportunity cost model - No teatree on land;

DERIVATION OF TEATREE BIOMASS PRODUCTION FUNCTION

DIAMETER AT BREAST HEIGHT (DBH) AS A FUNCTION OF AGE:

Data Source: Watson and O'Loughlin

ACTUAL DATA Age	Dbh (cm)	ESTIMATED: Dbh (cm)
0	0.0	-2.3
13	3.1	3.5
18	6.2	5.8
23	7.0	8.0
24	6.5	8.5
25	10.0	8.9
26	6.8	9.4
27	7.5	9.8
30	13.5	11.2
48	21.0	19.3
50	20.5	20.2

REGRESSION OUTPUT

Constant		-2.34059
Std Err of Y Est		1.897232
R Squared		0.925973
No. of Observations		11
Degrees of Freedom		9
X Coefficient(s)	0.450164	
Std Err of Coef.	0.042427	

Dbh = -2.341 + .450 x Age

DENSITY (STEMS/HA) AS A FUNCTION OF AGE

Data source: Allan et al.

ACTUAL DATA Age	LOG(age)	Stems/ha	ESTIMATED Stems/ha
2	0.30	37200	36892
12	1.08	25000	19044
13	1.11	12500	18247
27	1.43	9300	10966
33	1.52	7100	8967
50	1.70	8400	4828
59	1.77	2400	3179
70	1.85	1700	1476

REGRESSION OUTPUT

Constant		43797.09
Std Err of Y Est		3835.6
R Squared		0.91509
No. of Observations		8
Degrees of Freedom		6
X Coefficient(s)	-22936.9	
Std Err of Coef.	2852.375	

D = 43797 - (22936 x LOG (Age))

TREE VOLUME AS A FUNCTION OF DBH

Data source: measured trees

ACTUAL DATA				ESTIMATED	REGRESSION OUTPUT			
Dbh (cm)	Dbh^2	Dbh^3	Tree Vol. M^3	Tree Vol. M^3				
2.9	8.4	24.4	0.0029	0.0027	Constant		0.015693	
3.1	9.6	29.8	0.0016	0.0026	Std Err of Y Est		0.003331	
3.3	10.9	35.9	0.0038	0.0026	R Squared		0.948684	
4.9	24.0	117.6	0.0047	0.0051	No. of Observations		11	
6.3	39.7	250.0	0.0078	0.0101	Degrees of Freedom		7	
6.5	42.3	274.6	0.0162	0.0110	Degrees of Freedom		9	
7.2	51.8	373.2	0.0102	0.0141	X Coefficient(s)	-0.00885	0.001722	-7.3E-05
8.6	74.0	636.1	0.0218	0.0208	Std Err of Coef.	0.00585	0.000806	3.3E-05
12.0	144.0	1728.0	0.0351	0.0320	Std Err of Coef.	0.000305		
12.7	161.3	2048.4	0.0285	0.0323				
14.1	198.8	2803.2	0.0307	0.0298	V = .0157 - .0089Dbh + .0017Dbh^2 - (7.3E-5 Dbh^3)			

DERIVATION OF BIOMASS PRODUCTION FUNCTION:

Dbh = a + b.Age
D = c - d.(LOG(Age))
V = e + f.Dbh + g.dbh^2 + h.dbh^3

where:

a =	-2.341	e =	0.016
b =	0.450	f =	-0.009
c =	43797	g =	0.002
d =	-22937	h =	-7E-05

The quantity of biomass present on 1ha at the time of harvest (Age) will be a product of the per tree volume (V) and the density of trees per ha (D).

BM = V x D
= (e + f.(Dbh) + g.(Dbh^2) + h.(Dbh^3)) x (c + d.LOG(Age))
= (e + f.(a + b.Age) +g.(a + b.Age)^2 + h.(a+b.Age)^3) x (c + d.LOG(Age))
= (e. + f.a + f.b.Age + g.a^2 + 2.g.a.b.Age + g.(b.age)^2 + h.(a+b.Age)^3) * (c + d.LOG (Age))
= ((e + f.a + g.a^2) + f.b.Age + (2.g.a.b.Age) + g.(b.Age)^2 + h.(a+b.Age)^3) * (c + d.(LOG(Age)))

= (.0458 - (.0076 Age) + (.0017 x (.4502 Age)^2) + (-7E-05 x (-2.3406 + .4502 Age)^3)) * (43, 797 - (22,936 LOG (Age)))

where:

BM =Quantity of biomass present (m^3)on 1ha of land at Age

WORKING:

e	0.0157	e + fa +ga^	0.0458
f.a	0.0207		
g.a^2	0.0094	f.b.	-0.0040
		2.g.a.b	-0.0036
		g	0.0017
		b	0.4502
		h	-7.3E-05
		a	-2.341
		b	0.4502
		c	43797
		d	-22937

TEATREE FUELWOOD CROP PRODUCTION MODEL:
NON RESIDENT, - WAMSLER WOODSTOVE

MODEL ASSUMPTIONS:

Wood density kg/m3	680
Actual vol wood/stere	0.65
Wood cost (bought):	$50 / stere
Harvesting cost/stere:	$18
Harvest constraint (m^2):	300
Harvest constraint (yrs)	18
Discount Rate:	9%

FUEL REQUIREMENTS (STERE/YEAR)

Cooking	0.3
Water Heating	1.1
TOTAL	1.4

	BASE MODEL: 1HA			RESULTS FOR NON-RESIDENTS:						
YEAR	WOOD/HA M^3	PLOT SIZE M^2	STERES/YR PER ROT	ACTUAL ROT. SIZE (M^2)	TOT. LAND (Ha)	M^2	% NON-RES WITH AREA	PRES. VAL WOOD CST	PRES VAL HARVEST CST	NPV
13	49	769	5.8	184	0.24	2,396	39%	$570	$76	$647
14	55	714	6.0	165	0.23	2,314	39%	$593	$68	$661
15	66	667	6.8	138	0.21	2,063	39%	$614	$61	$674
16	81	625	7.8	112	0.18	1,789	39%	$633	$54	$687
17	99	588	9.0	91	0.16	1,553	54%	$651	$47	$698
18	120	556	10.2	76	0.14	1,366	54%	$667	$42	$708
19	141	526	11.4	64	0.12	1,222	54%	$682	$36	$718
20	163	500	12.5	56	0.11	1,113	54%	$695	$31	$727
21	185	476	13.5	49	0.10	1,031	56%	$708	$27	$734
22	206	455	14.4	44	0.10	970	56%	$719	$23	$742

TEATREE ENERGY EXPENDITURE ANALYSIS: NON-RESIDENT.

MODEL ASSUMPTION : No teatree previously on land. **APPLIANCE:** Wamsler woodstove

Total land avb:	0.17 HA	Opportunity cost options:	
Land needed:	0.16 HA	Land used for other:	31%
		Opp. cost of land:	$1,055
Discount rate	9%		
Rotation length:	17 yrs		

			COOKING:				WATER HEATING				
YEAR	Appliance	Maint.	WOOD COST PURCH	GROW	TOTAL	P.V.	WOOD COST PURCH	GROW	TOTAL	P.V.	COMBINED
0	$7,074		$17		$7,108	$7,108	$53		$7,127	$7,127	$7,161
1			$17		$17	$16	$53		$53	$49	$64
2			$17		$17	$14	$53		$53	$45	$59
3			$17		$17	$13	$53		$53	$41	$54
4			$17		$17	$12	$53		$53	$37	$49
5		$20	$17		$37	$24	$53		$73	$47	$58
6			$17		$17	$10	$53		$53	$32	$42
7			$17		$17	$9	$53		$53	$29	$38
8			$17		$17	$9	$53		$53	$27	$35
9			$17		$17	$8	$53		$53	$24	$32
10		$20	$17		$37	$16	$53		$73	$31	$38
11			$17		$17	$7	$53		$53	$20	$27
12			$17		$17	$6	$53		$53	$19	$25
13			$17		$17	$6	$53		$53	$17	$23
14			$17		$17	$5	$53		$53	$16	$21
15		$20	$17		$37	$10	$53		$73	$20	$25
16			$17		$17	$4	$53		$53	$13	$18
17				$6	$6	$1		$19	$19	$4	$6
18				$6	$6	$1		$19	$19	$4	$5
19				$6	$6	$1		$19	$19	$4	$5
20		$20		$6	$26	$5		$19	$39	$7	$8
21				$6	$6	$1		$19	$19	$3	$4
22				$6	$6	$1		$19	$19	$3	$4
23				$6	$6	$1		$19	$19	$3	$3
24				$6	$6	$1		$19	$19	$2	$3
25		$20		$6	$26	$3		$19	$39	$5	$5
26				$6	$6	$1		$19	$19	$2	$3
27				$6	$6	$1		$19	$19	$2	$2
28				$6	$6	$1		$19	$19	$2	$2
29	($2,814)			$6	($2,807)	($231)		$19	($2,795)	($230)	($229)
NET PRESENT COST:						$7,062				$7,404	$7,591
WITH OPPORTUNITY COST:						$7,062				$7,404	$9,439

TEATREE EXPENDITURE MODEL - OPPORTUNITY COST ANALYSIS

NON-RESIDENT, NO EXISTING TEATREE ON LAND

LAND IN OPP COST (M^2): 534.3 **TOTAL LAND AREA (M^2):** 1723.5

TOT. INCOME FROM LAND: $1,055

TOTAL PLOT SIZE (M^2)

377 1176 1,553

SIZE OF YEARLY ROTATIONS (M^2):

22 69 91

Opportunity cost only occurs when the land remaining unplanted (SPARE) < land with opportunity cost.

First planting occurs end of year 1.

YEAR	COOKING		WATER HEATING:				COMBINED			
	USED M^2	SPARE M^2	LAND USED M^2	SPARE	COST	PV	LAND USED M^2	SPARE	COST	PV
0	0	1701	0	1654	$0	$0	0	1632	$0	$0
1	22	1679	69	1585	$0	$0	91	1541	$0	$0
2	44	1657	138	1516	$0	$0	183	1449	$0	$0
3	67	1635	207	1447	$0	$0	274	1358	$0	$0
4	89	1613	277	1378	$0	$0	365	1267	$0	$0
5	111	1590	346	1308	$0	$0	457	1175	$0	$0
6	133	1568	415	1239	$0	$0	548	1084	$0	$0
7	155	1546	484	1170	$0	$0	639	993	$0	$0
8	178	1524	553	1101	$0	$0	731	901	$0	$0
9	200	1502	622	1032	$0	$0	822	810	$0	$0
10	222	1479	692	963	$0	$0	914	719	$0	$0
11	244	1457	761	893	$0	$0	1005	627	$0	$0
12	266	1435	830	824	$0	$0	1096	536	$0	$0
13	288	1413	899	755	$0	$0	1188	445	$177	$58
14	311	1391	968	686	$0	$0	1279	353	$358	$107
15	333	1368	1037	617	$0	$0	1370	262	$538	$148
16	355	1346	1107	548	$0	$0	1462	170	$718	$181
17	377	1346	1176	548	$0	$0	1553	170	$718	$166
18	377	1346	1176	548	$0	$0	1553	170	$718	$152
19	377	1346	1176	548	$0	$0	1553	170	$718	$140
20	377	1346	1176	548	$0	$0	1553	170	$718	$128
21	377	1346	1176	617	$0	$0	1553	170	$718	$118
22	377	1346	1107	617	$0	$0	1553	170	$718	$108
23	377	1346	1107	617	$0	$0	1553	170	$718	$99
24	377	1346	1107	617	$0	$0	1553	170	$718	$91
25	377	1346	1107	617	$0	$0	1553	170	$718	$83
26	377	1346	1107	617	$0	$0	1553	170	$718	$76
27	377	1346	1107	617	$0	$0	1553	170	$718	$70
28	377	1346	1107	617	$0	$0	1553	170	$718	$64
29	377	1723	1107	617	$0	$0	1553	170	$719	$59
NPV OPP COST		$0	NPV OPP COST			$0	NPV OPP COST			$1,848

TEATREE ENERGY EXPENDITURE ANALYSIS: NON-RESIDENT.

WOOD PURCHASE OPTION: WAMSLER WOODSTOVE

FUEL: Teatree (Purchased)

Discount Rate: 9%

Wood price/stere $50

YEAR	Appliance	Maint.	COOKING: WOOD COST PURCH	COOKING: GROW	COOKING: TOTAL	COOKING: P.V.	WATER HEATING: WOOD COST PURCH	WATER HEATING: GROW	WATER HEATING: TOTAL	WATER HEATING: P.V.	COMBINED
0	$7,074		$17		$7,108	$7,108	$53		$7,127	$7,127	$7,161
1			$17		$17	$16	$53		$53	$49	$64
2			$17		$17	$14	$53		$53	$45	$59
3			$17		$17	$13	$53		$53	$41	$54
4			$17		$17	$12	$53		$53	$37	$49
5		$20	$17		$37	$24	$53		$73	$47	$58
6			$17		$17	$10	$53		$53	$32	$42
7			$17		$17	$9	$53		$53	$29	$38
8			$17		$17	$9	$53		$53	$27	$35
9			$17		$17	$8	$53		$53	$24	$32
10		$20	$17		$37	$16	$53		$73	$31	$38
11			$17		$17	$7	$53		$53	$20	$27
12			$17		$17	$6	$53		$53	$19	$25
13			$17		$17	$6	$53		$53	$17	$23
14			$17		$17	$5	$53		$53	$16	$21
15		$20	$17		$37	$10	$53		$73	$20	$25
16			$17		$17	$4	$53		$53	$13	$18
17			$17		$17	$4	$53		$53	$12	$16
18			$17		$17	$4	$53		$53	$11	$15
19			$17		$17	$3	$53		$53	$10	$14
20		$20	$17		$37	$7	$53		$73	$13	$16
21			$17		$17	$3	$53		$53	$9	$11
22			$17		$17	$3	$53		$53	$8	$10
23			$17		$17	$2	$53		$53	$7	$10
24			$17		$17	$2	$53		$53	$7	$9
25		$20	$17		$37	$4	$53		$73	$8	$10
26			$17		$17	$2	$53		$53	$6	$7
27			$17		$17	$2	$53		$53	$5	$7
28			$17		$17	$2	$53		$53	$5	$6
29	($2,814)		$17		($2,797)	($230)	$53		($2,761)	($227)	($225)
NET PRESENT COST:						$7,083				$7,468	$7,675

TEATREE ENERGY EXPENDITURE ANALYSIS: NON-RESIDENT.

EXISTING TEATREE ON LAND OPTION: WAMSLER WOODSTOVE

MODEL ASSUMPTIONS:

Total land area (ha)	0.17
% of Land covered	43%
Initial age of scrub (yrs):	13
Rotation length (years):	15
Wood cost (bought):	$50
Harvesting cost/stere:	$18
Discount Rate:	9%

FUEL REQUIREMENTS (STERE/YEAR

Cooking	0.3
Water Heating	1.1
TOTAL	1.4

YEAR	WOOD/HA M^3	EXISTING PLOT SIZE M^2	STERES/YR / ROTATN.	COOK STERES TO BUY	COOK TOTAL COST	W/H STERES TO BUY	W/H TOTAL COST	COMBINED
0	49	44	0.33	0.01	$7	0.73	$42	$49
1	55	44	0.37	0.00	$6	0.69	$41	$47
2	66	44	0.44	0.00	$6	0.62	$39	$45
3	81	44	0.54	0.00	$6	0.51	$35	$42
4	99	44	0.67	0.00	$6	0.39	$32	$38
5	120	44	0.80	0.00	$6	0.26	$27	$33
6	141	44	0.95	0.00	$6	0.11	$23	$29
7	163	44	1.09	0.00	$6	0.00	$19	$25
8	185	44	1.24	0.00	$6	0.00	$19	$25
9	206	44	1.38	0.00	$6	0.00	$19	$25
10	226	44	1.40	0.00	$6	0.00	$19	$25
11	244	44	1.40	0.00	$6	0.00	$19	$25
12	261	44	1.40	0.00	$6	0.00	$19	$25
13	274	44	1.40	0.00	$6	0.00	$19	$25
14	286	44	1.40	0.00	$6	0.00	$19	$25
15	294	44	1.40	0.00	$6	0.00	$19	$25

TEATREE ENERGY EXPENDITURE ANALYSIS: NON-RESIDENT.

MODEL ASSUMPTION : Teatree previously on land. **APPLIANCE:** Wamsler woodstove

Total land (Ha): 0.17 HA
Land needed 0.16 HA

Opportunity cost options:

Land used for other: 31%
Opp. cost of land: $1,055

Discount Rate: 9%
Rotation Length: 17 yrs

			COOKING:				WATER HEATING				
YEAR	Appliance	Maint.	WOOD COST PURCH	GROW	TOTAL	P.V.	WOOD COST PURCH	GROW	TOTAL	P.V.	COMBINED
0	$7,074		$0	$6	$7,081	$7,081	$36	$6	$7,116	$7,116	$7,123
1				$6	$6	$6	$34	$7	$41	$38	$43
2				$6	$6	$5	$31	$8	$39	$33	$38
3				$6	$6	$5	$26	$10	$35	$27	$32
4				$6	$6	$4	$20	$12	$32	$22	$27
5		$20		$6	$26	$17	$13	$14	$47	$31	$35
6				$6	$6	$4	$6	$17	$23	$13	$17
7				$6	$6	$3	$0	$19	$19	$10	$14
8				$6	$6	$3		$19	$19	$10	$13
9				$6	$6	$3		$19	$19	$9	$12
10		$20		$6	$26	$11		$19	$39	$16	$19
11				$6	$6	$2		$19	$19	$7	$10
12				$6	$6	$2		$19	$19	$7	$9
13				$6	$6	$2		$19	$19	$6	$8
14				$6	$6	$2		$19	$19	$6	$8
15		$20		$6	$26	$7		$19	$39	$11	$12
16				$6	$6	$2		$19	$19	$5	$6
17				$6	$6	$1		$19	$19	$4	$6
18				$6	$6	$1		$19	$19	$4	$5
19				$6	$6	$1		$19	$19	$4	$5
20		$20		$6	$26	$5		$19	$39	$7	$8
21				$6	$6	$1		$19	$19	$3	$4
22				$6	$6	$1		$19	$19	$3	$4
23				$6	$6	$1		$19	$19	$3	$3
24				$6	$6	$1		$19	$19	$2	$3
25		$20		$6	$26	$3		$19	$39	$5	$5
26				$6	$6	$1		$19	$19	$2	$3
27				$6	$6	$1		$19	$19	$2	$2
28				$6	$6	$1		$19	$19	$2	$2
29	($2,814)			$6	($2,807)	($231)		$19	($2,795)	($230)	($229)
NET PRESENT COST:						$6,945				$7,178	$7,247
WITH OPPORTUNITY COST:						$6,945				$7,178	$9,472

TEATREE EXPENDITURE MODEL - OPPORTUNITY COST ANALYSIS

NON-RESIDENT, TEATREE ON LAND

TOTAL LAND AREA (M^2): 1700

LAND IN OPP COST (M^2):	534	**LAND IN TEATREE (M^2)**	741
TOT. INCOME FROM LAND:	$1,055		
INDIVIDUAL PLOT SIZE (M^2)	69		91
NEW PLANTING/YR	0		48

Opportunity cost only occurs when the land remaining unplanted (SPARE) < land with opportunity cost. New plantings occur at end of year.

YEAR	WATER HEATING:				COMBINED			
	LAND USED M^2	SPARE	COST	PV	LAND USED M^2	SPARE	COST	PV
0	0	982	$0	$0	0	935		$0
1	0	982	$0	$0	48	887		$0
2	0	982	$0	$0	96	839		$0
3	0	982	$0	$0	143	791		$0
4	0	982	$0	$0	191	744		$0
5	0	982	$0	$0	239	696		$0
6	0	982	$0	$0	287	648		$0
7	0	982	$0	$0	334	600		$0
8	0	982	$0	$0	382	553		$0
9	0	982	$0	$0	430	505		$0
10	0	982	$0	$0	478	457		$0
11	0	982	$0	$0	525	409	$247	$96
12	0	982	$0	$0	573	361	$341	$121
13	0	982	$0	$0	621	314	$436	$142
14	0	982	$0	$0	669	266	$530	$159
15	0	982	$0	$0	716	218	$624	$171
16	0	982	$0	$0	764	170	$718	$181
17	0	982	$0	$0	812	170	$718	$166
18	0	982	$0	$0	812	170	$718	$152
19	0	982	$0	$0	812	170	$718	$140
20	0	982	$0	$0	812	170	$718	$128
21	0	982	$0	$0	812	170	$718	$118
22	0	982	$0	$0	812	170	$718	$108
23	0	982	$0	$0	812	170	$718	$99
24	0	982	$0	$0	812	170	$718	$91
25	0	982	$0	$0	812	170	$718	$83
26	0	982	$0	$0	812	170	$718	$76
27	0	982	$0	$0	812	170	$718	$70
28	0	982	$0	$0	812	170	$718	$64
29	0	982	$0	$0	812	170	$718	$59
	NPV OPP COST			$0	NPV OPP COST			$2,225

TEATREE FUELWOOD CROP PRODUCTION MODEL:
RESIDENT: WAMSLER WOODSTOVE

MODEL ASSUMPTIONS:

Wood density kg/m3	680	
Actual vol wood/stere	0.65	
Wood cost (bought):	$50	/ stere
Harvesting cost/stere:	$18	
Harvest constraint (m^2):	300	
Harvest constraint (yrs)	18	
Discount Rate:	9%	

FUEL REQUIREMENTS (STERE/YEAR)

Cooking	2.0
Water Heating	6.1
TOTAL	8.1

	BASE MODEL: 1HA			RESULTS FOR NON-RESIDENTS:						
YEAR	WOOD/HA M^3	PLOT SIZE M^2	STERES/YR PER ROT	ACTUAL ROT. SIZE (M^2)	TOT. LAND (Ha)	M^2	% RES WITH AREA	PRES. VAL WOOD CST	PRES VAL HARVEST CST	NPV
13	49	769	5.8	1065	1.38	13,842	57%	$3,294	$441	$3,735
14	55	714	6.0	955	1.34	13,368	57%	$3,426	$394	$3,820
15	66	667	6.8	795	1.19	11,922	57%	$3,546	$351	$3,897
16	81	625	7.8	646	1.03	10,339	57%	$3,657	$311	$3,968
17	99	588	9.0	528	0.90	8,973	60%	$3,759	$274	$4,033
18	120	556	10.2	438	0.79	7,892	60%	$3,852	$240	$4,093
19	141	526	11.4	372	0.71	7,063	60%	$3,938	$210	$4,147
20	163	500	12.5	322	0.64	6,433	60%	$4,016	$181	$4,198

TEATREE ENERGY EXPENDITURE ANALYSIS: RESIDENT.

MODEL ASSUMPTION : No teatree previously on land. **APPLIANCE:** Wamsler woodstove

Total land avb:	4.02 HA	Opportunity cost options:	Land used for other:	35%
Land needed:	0.90 HA		Opp. cost of land:	$5,866
Discount rate	9%			
Rotation length:	17 yrs			

YEAR	Appliance	Maint.	COOKING: WOOD COST PURCH	GROW	TOTAL	P.V.	WATER HEATING: WOOD COST PURCH	GROW	TOTAL	P.V.	COMBINED
0	$7,074		$98		$7,270	$7,270	$306		$7,380	$7,380	$7,576
1			$98		$98	$90	$306		$306	$280	$370
2			$98		$98	$83	$306		$306	$257	$340
3			$98		$98	$76	$306		$306	$236	$312
4			$98		$98	$69	$306		$306	$216	$286
5		$20	$98		$118	$77	$306		$326	$212	$275
6			$98		$98	$58	$306		$306	$182	$241
7			$98		$98	$54	$306		$306	$167	$221
8			$98		$98	$49	$306		$306	$153	$203
9			$98		$98	$45	$306		$306	$141	$186
10		$20	$98		$118	$50	$306		$326	$138	$179
11			$98		$98	$38	$306		$306	$118	$156
12			$98		$98	$35	$306		$306	$109	$144
13			$98		$98	$32	$306		$306	$100	$132
14			$98		$98	$29	$306		$306	$91	$121
15		$20	$98		$118	$32	$306		$326	$89	$116
16			$98		$98	$25	$306		$306	$77	$102
17				$35	$35	$8		$110	$110	$25	$34
18				$35	$35	$7		$110	$110	$23	$31
19				$35	$35	$7		$110	$110	$21	$28
20		$20		$35	$55	$10		$110	$130	$23	$29
21				$35	$35	$6		$110	$110	$18	$24
22				$35	$35	$5		$110	$110	$17	$22
23				$35	$35	$5		$110	$110	$15	$20
24				$35	$35	$4		$110	$110	$14	$18
25		$20		$35	$55	$6		$110	$130	$15	$19
26				$35	$35	$4		$110	$110	$12	$15
27				$35	$35	$3		$110	$110	$11	$14
28				$35	$35	$3		$110	$110	$10	$13
29	($2,814)			$35	($2,778)	($228)		$110	($2,704)	($222)	($219)
NET PRESENT COST:						$7,953				$9,929	$11,007
WITH OPPORTUNITY COST:						$7,953				$9,929	$11,007

TEATREE EXPENDITURE MODEL - OPPORTUNITY COST ANALYSIS

RESIDENT, NO EXISTING TEATREE ON LAND

LAND IN OPP COST (M^2): 14,070 **TOTAL LAND AREA (M^2):** 40,200

TOT. INCOME FROM LAND: $5,866

TOTAL PLOT SIZE (M^2)

2179 6794 8,973

SIZE OF YEARLY ROTATIONS (M^2):

128 400 528

Opportunity cost only occurs when the land remaining unplanted (SPARE) < land with opportunity cost.
First planting occurs end of year 1.

YEAR	COOKING		WATER HEATING:				COMBINED			
	USED M^2	SPARE M^2	LAND USED M^2	SPARE	COST	PV	LAND USED M^2	SPARE	COST	PV
0	0	40200	0	40200	$0	$0	0	40200	$0	$0
1	128	40200	400	40200	$0	$0	528	40200	$0	$0
2	256	40072	799	39800	$0	$0	1056	39672	$0	$0
3	385	39944	1199	39401	$0	$0	1583	39144	$0	$0
4	513	39815	1599	39001	$0	$0	2111	38617	$0	$0
5	641	39687	1998	38601	$0	$0	2639	38089	$0	$0
6	769	39559	2398	38202	$0	$0	3167	37561	$0	$0
7	897	39431	2797	37802	$0	$0	3695	37033	$0	$0
8	1026	39303	3197	37403	$0	$0	4223	36505	$0	$0
9	1154	39174	3597	37003	$0	$0	4750	35977	$0	$0
10	1282	39046	3996	36603	$0	$0	5278	35450	$0	$0
11	1410	38918	4396	36204	$0	$0	5806	34922	$0	$0
12	1538	38790	4796	35804	$0	$0	6334	34394	$0	$0
13	1667	38662	5195	35404	$0	$0	6862	33866	$0	$0
14	1795	38533	5595	35005	$0	$0	7390	33338	$0	$0
15	1923	38405	5994	34605	$0	$0	7917	32810	$0	$0
16	2051	38277	6394	34206	$0	$0	8445	32283	$0	$0
17	2179	38149	6794	33806	$0	$0	8973	31755	$0	$0
18	2179	38021	6794	33406	$0	$0	8973	31227	$0	$0
19	2179	38021	6794	33406	$0	$0	8973	31227	$0	$0
20	2179	38021	6794	33406	$0	$0	8973	31227	$0	$0
21	2179	38021	6794	33406	$0	$0	8973	31227	$0	$0
22	2179	38021	6394	33406	$0	$0	8973	31227	$0	$0
23	2179	38021	6394	33806	$0	$0	8973	31227	$0	$0
24	2179	38021	6394	33806	$0	$0	8973	31227	$0	$0
25	2179	38021	6394	33806	$0	$0	8973	31227	$0	$0
26	2179	38021	6394	33806	$0	$0	8973	31227	$0	$0
27	2179	38021	6394	33806	$0	$0	8973	31227	$0	$0
28	2179	38021	6394	33806	$0	$0	8973	31227	$0	$0
29	2179	38021	6394	33806	$0	$0	8973	31227	$0	$0
NPV OPP COST		$0	NPV OPP COST			$0	NPV OPP COST			$0

TEATREE ENERGY EXPENDITURE ANALYSIS: RESIDENT.

WOOD PURCHASE OPTION: WAMSLER WOODSTOVE

FUEL: Teatree (Purchased)

Discount Rate: 9%

Wood price/stere $50

			COOKING:				WATER HEATING				
YEAR	Appliance	Maint.	WOOD COST PURCH	GROW	TOTAL	P.V.	WOOD COST PURCH	GROW	TOTAL	P.V.	COMBINED
0	$7,074		$98		$7,270	$7,270	$306		$7,380	$7,380	$7,576
1			$98		$98	$90	$306		$306	$280	$370
2			$98		$98	$83	$306		$306	$257	$340
3			$98		$98	$76	$306		$306	$236	$312
4			$98		$98	$69	$306		$306	$216	$286
5		$20	$98		$118	$77	$306		$326	$212	$275
6			$98		$98	$58	$306		$306	$182	$241
7			$98		$98	$54	$306		$306	$167	$221
8			$98		$98	$49	$306		$306	$153	$203
9			$98		$98	$45	$306		$306	$141	$186
10		$20	$98		$118	$50	$306		$326	$138	$179
11			$98		$98	$38	$306		$306	$118	$156
12			$98		$98	$35	$306		$306	$109	$144
13			$98		$98	$32	$306		$306	$100	$132
14			$98		$98	$29	$306		$306	$91	$121
15		$20	$98		$118	$32	$306		$326	$89	$116
16			$98		$98	$25	$306		$306	$77	$102
17			$98		$98	$23	$306		$306	$71	$93
18			$98		$98	$21	$306		$306	$65	$86
19			$98		$98	$19	$306		$306	$59	$79
20		$20	$98		$118	$21	$306		$326	$58	$76
21			$98		$98	$16	$306		$306	$50	$66
22			$98		$98	$15	$306		$306	$46	$61
23			$98		$98	$14	$306		$306	$42	$56
24			$98		$98	$12	$306		$306	$39	$51
25		$20	$98		$118	$14	$306		$326	$38	$49
26			$98		$98	$10	$306		$306	$33	$43
27			$98		$98	$10	$306		$306	$30	$39
28			$98		$98	$9	$306		$306	$27	$36
29	($2,814)		$98		($2,716)	($223)	$306		($2,508)	($206)	($198)
NET PRESENT COST:						$8,072				$10,298	$11,494

TEATREE ENERGY EXPENDITURE ANALYSIS: RESIDENT.

EXISTING TEATREE ON LAND OPTION: WAMSLER WOODSTOVE

MODEL ASSUMPTIONS:

Total land area (ha)	4.02
% of Land covered	52%
Initial age of scrub (yrs):	13
Rotation length (years):	17
Wood cost (bought):	$50
Harvesting cost/stere:	$18
Discount Rate:	9%

FUEL REQUIREMENTS (STERE/YEAR)

Cooking	2.0
Water Heating	6.1
TOTAL	8.1

YEAR	WOOD/HA M^3	EXISTING PLOT SIZE M^2	STERES/YR / ROTATN.	COOK STERES TO BUY	COOK TOTAL COST	W/H STERES TO BUY	W/H TOTAL COST	COMBINED STERES TO BUY	TOTAL COST
0	49	1230	9.32	0.00	$35	0.00	$110	0.00	$145
1	55	1230	10.40	0.00	$35	0.00	$110	0.00	$145
2	66	1230	12.49	0.00	$35	0.00	$110	0.00	$145
3	81	1230	15.36	0.00	$35	0.00	$110	0.00	$145
4	99	1230	18.81	0.00	$35	0.00	$110	0.00	$145
5	120	1230	22.64	0.00	$35	0.00	$110	0.00	$145
6	141	1230	26.70	0.00	$35	0.00	$110	0.00	$145
7	163	1230	30.86	0.00	$35	0.00	$110	0.00	$145
8	185	1230	34.99	0.00	$35	0.00	$110	0.00	$145
9	206	1230	38.98	0.00	$35	0.00	$110	0.00	$145
10	226	1230	42.75	0.00	$35	0.00	$110	0.00	$145
11	244	1230	46.20	0.00	$35	0.00	$110	0.00	$145
12	261	1230	49.28	0.00	$35	0.00	$110	0.00	$145
13	274	1230	51.93	0.00	$35	0.00	$110	0.00	$145
14	286	1230	54.08	0.00	$35	0.00	$110	0.00	$145
15	294	1230	55.70	0.00	$35	0.00	$110	0.00	$145

TEATREE ENERGY EXPENDITURE ANALYSIS: RESIDENT.

MODEL ASSUMPTION : Teatree previously on land. **APPLIANCE:** Wamsler woodstove

Total land (Ha): 4.02 HA
Land needed 0.90 HA

Opportunity cost options:

Land used for other: 35%
Opp. cost of land: $5,866

Discount Rate: 9%
Rotation Length: 17 yrs

			COOKING:				WATER HEATING				
YEAR	Appliance	Maint.	WOOD COST PURCH	GROW	TOTAL	P.V.	WOOD COST PURCH	GROW	TOTAL	P.V.	COMBINED
0	$7,074		$0	$35	$7,109	$7,109	$0	$110	$7,184	$7,184	$7,219
1				$35	$35	$32	$0	$110	$110	$101	$133
2				$35	$35	$30	$0	$110	$110	$93	$122
3				$35	$35	$27	$0	$110	$110	$85	$112
4				$35	$35	$25	$0	$110	$110	$78	$103
5		$20		$35	$55	$36	$0	$110	$130	$85	$107
6				$35	$35	$21	$0	$110	$110	$66	$87
7				$35	$35	$19	$0	$110	$110	$60	$79
8				$35	$35	$18		$110	$110	$55	$73
9				$35	$35	$16		$110	$110	$51	$67
10		$20		$35	$55	$23		$110	$130	$55	$70
11				$35	$35	$14		$110	$110	$43	$56
12				$35	$35	$13		$110	$110	$39	$52
13				$35	$35	$12		$110	$110	$36	$47
14				$35	$35	$11		$110	$110	$33	$43
15		$20		$35	$55	$15		$110	$130	$36	$45
16				$35	$35	$9		$110	$110	$28	$37
17				$35	$35	$8		$110	$110	$25	$34
18				$35	$35	$7		$110	$110	$23	$31
19				$35	$35	$7		$110	$110	$21	$28
20		$20		$35	$55	$10		$110	$130	$23	$29
21				$35	$35	$6		$110	$110	$18	$24
22				$35	$35	$5		$110	$110	$17	$22
23				$35	$35	$5		$110	$110	$15	$20
24				$35	$35	$4		$110	$110	$14	$18
25		$20		$35	$55	$6		$110	$130	$15	$19
26				$35	$35	$4		$110	$110	$12	$15
27				$35	$35	$3		$110	$110	$11	$14
28				$35	$35	$3		$110	$110	$10	$13
29	($2,814)			$35	($2,778)	($228)		$110	($2,704)	($222)	($219)
NET PRESENT COST:						$7,271				$8,108	$8,503
WITH OPPORTUNITY COST:						$7,271				$8,108	$8,503

TEATREE EXPENDITURE MODEL - OPPORTUNITY COST ANALYSIS
RESIDENT, TEATREE ON LAND

TOTAL LAND AREA (M^2): 40200

LAND IN OPP COST (M^2):	14070	LAND IN TEATREE (M^2)	20904
TOT. INCOME FROM LAND:	$5,866		
INDIVIDUAL PLOT SIZE (M^2)	400		528
NEW PLANTING/YR	0		0

Opportunity cost only occurs when the land remaining unplanted (SPARE) < land with opportunity cost. New plantings occur at end of year.

YEAR	WATER HEATING:				COMBINED			
	LAND USED M^2	SPARE	COST	PV	LAND USED M^2	SPARE	COST	PV
0	0	19296	$0	$0	0	19296		$0
1	0	19296	$0	$0	0	19296		$0
2	0	19296	$0	$0	0	19296		$0
3	0	19296	$0	$0	0	19296		$0
4	0	19296	$0	$0	0	19296		$0
5	0	19296	$0	$0	0	19296		$0
6	0	19296	$0	$0	0	19296		$0
7	0	19296	$0	$0	0	19296		$0
8	0	19296	$0	$0	0	19296		$0
9	0	19296	$0	$0	0	19296		$0
10	0	19296	$0	$0	0	19296		$0
11	0	19296	$0	$0	0	19296		$0
12	0	19296	$0	$0	0	19296		$0
13	0	19296	$0	$0	0	19296		$0
14	0	19296	$0	$0	0	19296		$0
15	0	19296	$0	$0	0	19296		$0
16	0	19296	$0	$0	0	19296		$0
17	0	19296	$0	$0	0	19296		$0
18	0	19296	$0	$0	0	19296		$0
19	0	19296	$0	$0	0	19296		$0
20	0	19296	$0	$0	0	19296		$0
21	0	19296	$0	$0	0	19296		$0
22	0	19296	$0	$0	0	19296		$0
23	0	19296	$0	$0	0	19296		$0
24	0	19296	$0	$0	0	19296		$0
25	0	19296	$0	$0	0	19296		$0
26	0	19296	$0	$0	0	19296		$0
27	0	19296	$0	$0	0	19296		$0
28	0	19296	$0	$0	0	19296		$0
29	0	19296	$0	$0	0	19296		$0
		NPV OPP COST		$0		NPV OPP COST		$0

TEATREE FUELWOOD CROP PRODUCTION MODEL:
NON-RESIDENT: JAYLINE JUNIOR WOODFIRE

MODEL ASSUMPTIONS:

Wood density kg/m3	680
Actual vol wood/stere	0.65
Wood cost (bought):	$50 / stere
Harvesting cost/stere:	$18
Harvest constraint (m^2):	300
Harvest constraint (yrs)	18
Discount Rate:	9%

FUEL REQUIREMENTS (STERE/YEAR)

Space heating	0.1
TOTAL	0.1

YEAR	BASE MODEL: 1HA			RESULTS FOR NON-RESIDENTS:						
	WOOD/HA M^3	PLOT SIZE M^2	STERES/YR PER ROT	ACTUAL ROT. SIZE (M^2)	TOT. LAND (Ha)	M^2	% RES WITH AREA	PRES. VAL WOOD CST	PRES VAL HARVEST CST	NPV
13	49	769	5.8	17	0.02	225	82%	$54	$7	$61
14	55	714	6.0	16	0.02	218	82%	$56	$6	$62
15	66	667	6.8	13	0.02	194	82%	$58	$6	$63
16	81	625	7.8	11	0.02	168	82%	$60	$5	$65
17	99	588	9.0	9	0.01	146	84%	$61	$4	$66
18	120	556	10.2	7	0.01	128	94%	$63	$4	$67
19	141	526	11.4	6	0.01	115	94%	$64	$3	$68
20	163	500	12.5	5	0.01	105	97%	$65	$3	$68

TEATREE ENERGY EXPENDITURE ANALYSIS: NON-RESIDENT.

MODEL ASSUMPTION : No teatree previously on land.

APPLIANCE: Jayline Junior

Opportunity cost options:

Total land avb:	0.17 HA	Land used for other: 31%
Land needed:	0.01 HA	Opp. cost of land: $1,055
Discount rate	9%	
Rotation length:	13 yrs	

SPACE HEATING

YEAR	Appliance	Maint.	WOOD COST PURCH	GROW	TOTAL	P.V.
0	$1,845		$7		$1,858	$1,858
1			$7		$7	$6
2			$7		$7	$6
3			$7		$7	$5
4			$7		$7	$5
5		$20	$7		$27	$17
6			$7		$7	$4
7			$7		$7	$4
8			$7		$7	$3
9			$7		$7	$3
10		$20	$7		$27	$11
11			$7		$7	$3
12			$7		$7	$2
13				$2	$2	$1
14				$2	$2	$1
15	$1,845			$2	$1,847	$507
16				$2	$2	$1
17				$2	$2	$1
18				$2	$2	$1
19				$2	$2	$0
20		$20		$2	$22	$4
21				$2	$2	$0
22				$2	$2	$0
23				$2	$2	$0
24				$2	$2	$0
25		$20		$2	$22	$3
26				$2	$2	$0
27				$2	$2	$0
28				$2	$2	$0
29	$0			$2	$2	$0

NET PRESENT COST: $2,446

WITH OPPORTUNITY COST: $2,446

TEATREE EXPENDITURE MODEL - OPPORTUNITY COST ANALYSIS

NON-RESIDENT, NO EXISTING TEATREE ON LAND

LAND IN OPP COST (M^2): 527 **TOTAL LAND AREA (M^2):** 1,700

TOT. INCOME FROM LAND: $1,055

TOTAL PLOT SIZE (M^2)
218

SIZE OF YEARLY ROTATIONS (M^2):
17

Opportunity cost only occurs when the land remaining unplanted (SPARE) < land with opportunity cost.
First planting occurs end of year 1.

YEAR	SPACE HEATING:			
	LAND USED M^2	SPARE	COST	PV
0	0	1700	$0	$0
1	17	1700	$0	$0
2	33	1683	$0	$0
3	50	1667	$0	$0
4	67	1650	$0	$0
5	84	1633	$0	$0
6	100	1616	$0	$0
7	117	1600	$0	$0
8	134	1583	$0	$0
9	151	1566	$0	$0
10	167	1549	$0	$0
11	184	1533	$0	$0
12	201	1516	$0	$0
13	218	1499	$0	$0
14	218	1482	$0	$0
15	218	1482	$0	$0
16	218	1482	$0	$0
17	218	1482	$0	$0
18	218	1482	$0	$0
19	218	1482	$0	$0
20	218	1482	$0	$0
21	218	1482	$0	$0
22	218	1482	$0	$0
23	218	1482	$0	$0
24	218	1482	$0	$0
25	218	1482	$0	$0
26	218	1482	$0	$0
27	218	1482	$0	$0
28	218	1482	$0	$0
29	218	1482	$0	$0
	NPV OPP COST			$0

TEATREE ENERGY EXPENDITURE ANALYSIS: NON-RESIDENT.

EXISTING TEATREE ON LAND OPTION: JAYLINE JUNIOR

MODEL ASSUMPTIONS:

Total land area (ha)	4.02
% of Land covered	52%
Initial age of scrub (yrs):	13
Rotation length (years):	13
Wood cost (bought):	$50
Harvesting cost/stere:	$18
Discount Rate:	9%

FUEL REQUIREMENTS (STERE/YEAR)

Space heating	0.1
TOTAL	0.1

YEAR	WOOD/HA M^3	EXISTING PLOT SIZE M^2	STERES/YR / ROTATN.	SPACE HEATING STERES TO BUY	SPACE HEATING TOTAL COST
0	49	1608	12.19	0.00	$2
1	55	1608	13.59	0.00	$2
2	66	1608	16.33	0.00	$2
3	81	1608	20.09	0.00	$2
4	99	1608	24.59	0.00	$2
5	120	1608	29.61	0.00	$2
6	141	1608	34.92	0.00	$2
7	163	1608	40.36	0.00	$2
8	185	1608	45.76	0.00	$2
9	206	1608	50.98	0.00	$2
10	226	1608	55.90	0.00	$2
11	244	1608	60.42	0.00	$2
12	261	1608	64.45	0.00	$2
13	274	1608	67.90	0.00	$2
14	286	1608	70.72	0.00	$2
15	294	1608	72.84	0.00	$2

TEATREE ENERGY EXPENDITURE ANALYSIS: NON-RESIDENT.

APPLIANCE: JAYLINE JUNIOR

MODEL ASSUMPTION : Teatree previously on land.

Total land (Ha):	0.17 HA	Opportunity cost options:	
Land needed	0.02 HA	Land used for other:	31%
		Opp. cost of land:	$1,055
Discount Rate:	9%		
Rotation Length:	13 yrs		

SPACE HEATING

YEAR	Appliance	Maint.	WOOD COST PURCH	GROW	TOTAL	P.V.
0	$1,845		$0	$2	$1,847	$1,847
1				$2	$2	$2
2				$2	$2	$2
3				$2	$2	$2
4				$2	$2	$2
5		$20		$2	$22	$15
6				$2	$2	$1
7				$2	$2	$1
8				$2	$2	$1
9				$2	$2	$1
10		$20		$2	$22	$9
11				$2	$2	$1
12				$2	$2	$1
13				$2	$2	$1
14				$2	$2	$1
15	$1,845			$2	$1,847	$507
16				$2	$2	$1
17				$2	$2	$1
18				$2	$2	$1
19				$2	$2	$0
20		$20		$2	$22	$4
21				$2	$2	$0
22				$2	$2	$0
23				$2	$2	$0
24				$2	$2	$0
25		$20		$2	$22	$3
26				$2	$2	$0
27				$2	$2	$0
28				$2	$2	$0
29				$2	$2	$0

NET PRESENT COST: $2,405

WITH OPPORTUNITY COST: $2,405

TEATREE FUELWOOD CROP PRODUCTION MODEL:
RESIDENT: JAYLINE JUNIOR WOODFIRE

MODEL ASSUMPTIONS:

Wood density kg/m3	680
Actual vol wood/stere	0.65
Wood cost (bought):	$50 / stere
Harvesting cost/stere:	$18
Harvest constraint (m^2):	300
Harvest constraint (yrs)	18
Discount Rate:	9%

FUEL REQUIREMENTS (STERE/YEAR)

Space heating	0.8
TOTAL	0.8

YEAR	BASE MODEL: 1HA			RESULTS FOR NON-RESIDENTS:						NPV
	WOOD/HA M^3	PLOT SIZE M^2	STERES/YR PER ROT	ACTUAL ROT. SIZE (M^2)	TOT. LAND (Ha)	M^2	% RES WITH AREA	PRES. VAL WOOD CST	PRES VAL HARVEST CST	
13	**49**	769	5.8	100	0.13	1,302	82%	$310	$42	$351
14	**55**	714	6.0	90	0.13	1,257	82%	$322	$37	$359
15	**66**	667	6.8	75	0.11	1,121	82%	$334	$33	$367
16	**81**	625	7.8	61	0.10	972	82%	$344	$29	$373
17	**99**	588	9.0	50	0.08	844	84%	$354	$26	$379
18	**120**	556	10.2	41	0.07	742	94%	$362	$23	$385
19	**141**	526	11.4	35	0.07	664	94%	$370	$20	$390
20	**163**	500	12.5	30	0.06	605	97%	$378	$17	$395

TEATREE ENERGY EXPENDITURE ANALYSIS: RESIDENT.

MODEL ASSUMPTION : No teatree previously on land.

APPLIANCE: Jayline Junior

Total land avb:	4.02 HA		Land used for other:	35%
Land needed:	0.08 HA		Opp. cost of land:	$5,866
Discount rate	9%			
Rotation length:	13 yrs			

Opportunity cost options:

SPACE HEATING

YEAR	Appliance	Maint.	WOOD COST PURCH	GROW	TOTAL	P.V.
0	$1,845		$38		$1,921	$1,921
1			$38		$38	$35
2			$38		$38	$32
3			$38		$38	$29
4			$38		$38	$27
5		$20	$38		$58	$38
6			$38		$38	$23
7			$38		$38	$21
8			$38		$38	$19
9			$38		$38	$17
10		$20	$38		$58	$24
11			$38		$38	$15
12			$38		$38	$13
13				$14	$14	$4
14				$14	$14	$4
15	$1,845			$14	$1,859	$510
16				$14	$14	$3
17				$14	$14	$3
18				$14	$14	$3
19				$14	$14	$3
20		$20		$14	$34	$6
21				$14	$14	$2
22				$14	$14	$2
23				$14	$14	$2
24				$14	$14	$2
25		$20		$14	$34	$4
26				$14	$14	$1
27				$14	$14	$1
28				$14	$14	$1
29	$0			$14	$14	$1

NET PRESENT COST: $2,768

WITH OPPORTUNITY COST: $2,768

TEATREE EXPENDITURE MODEL - OPPORTUNITY COST ANALYSIS
RESIDENT, NO EXISTING TEATREE ON LAND

LAND IN OPP COST (M^2): 14,070 **TOTAL LAND AREA (M^2):** 40,200
TOT. INCOME FROM LAND: $5,866

TOTAL PLOT SIZE (M^2)
1257

SIZE OF YEARLY ROTATIONS (M^2):
97

Opportunity cost only occurs when the land remaining unplanted (SPARE) < land with opportunity cost.
First planting occurs end of year 1.

YEAR	SPACE HEATING:			
	LAND USED M^2	SPARE	COST	PV
0	0	40200	$0	$0
1	97	40200	$0	$0
2	193	40103	$0	$0
3	290	40007	$0	$0
4	387	39910	$0	$0
5	484	39813	$0	$0
6	580	39716	$0	$0
7	677	39620	$0	$0
8	774	39523	$0	$0
9	870	39426	$0	$0
10	967	39330	$0	$0
11	1064	39233	$0	$0
12	1161	39136	$0	$0
13	1257	39039	$0	$0
14	1257	38943	$0	$0
15	1257	38943	$0	$0
16	1257	38943	$0	$0
17	1257	38943	$0	$0
18	1257	38943	$0	$0
19	1257	38943	$0	$0
20	1257	38943	$0	$0
21	1257	38943	$0	$0
22	1257	38943	$0	$0
23	1257	38943	$0	$0
24	1257	38943	$0	$0
25	1257	38943	$0	$0
26	1257	38943	$0	$0
27	1257	38943	$0	$0
28	1257	38943	$0	$0
29	1257	38943	$0	$0
		NPV OPP COST		$0

TEATREE ENERGY EXPENDITURE ANALYSIS: RESIDENT.

EXISTING TEATREE ON LAND OPTION: JAYLINE JUNIOR

MODEL ASSUMPTIONS:

Total land area (ha)	4.02
% of Land covered	52%
Initial age of scrub (yrs):	13
Rotation length (years):	13
Wood cost (bought):	$50
Harvesting cost/stere:	$18
Discount Rate:	9%

FUEL REQUIREMENTS (STERE/YEAR)

Space heating	0.8
TOTAL	0.8

YEAR	WOOD/HA M^3	EXISTING PLOT SIZE M^2	STERES/YR / ROTATN.	SPACE HEATING STERES TO BUY	SPACE HEATING TOTAL COST
0	49	1608	12.19	0.00	$14
1	55	1608	13.59	0.00	$14
2	66	1608	16.33	0.00	$14
3	81	1608	20.09	0.00	$14
4	99	1608	24.59	0.00	$14
5	120	1608	29.61	0.00	$14
6	141	1608	34.92	0.00	$14
7	163	1608	40.36	0.00	$14
8	185	1608	45.76	0.00	$14
9	206	1608	50.98	0.00	$14
10	226	1608	55.90	0.00	$14
11	244	1608	60.42	0.00	$14
12	261	1608	64.45	0.00	$14
13	274	1608	67.90	0.00	$14
14	286	1608	70.72	0.00	$14
15	294	1608	72.84	0.00	$14

TEATREE ENERGY EXPENDITURE ANALYSIS: RESIDENT.

APPLIANCE: JAYLINE JUNIOR

MODEL ASSUMPTION : Teatree previously on land.

Total land (Ha): 4.02 HA
Land needed 0.13 HA

Discount Rate: 9%

Rotation Length: 13 yrs

Opportunity cost options:
Land used for other: 35%
Opp. cost of land: $5,866

SPACE HEATING

YEAR	Appliance	Maint.	WOOD COST PURCH	GROW	TOTAL	P.V.
0	$1,845		$0	$14	$1,859	$1,859
1				$14	$14	$13
2				$14	$14	$12
3				$14	$14	$11
4				$14	$14	$10
5		$20		$14	$34	$22
6				$14	$14	$8
7				$14	$14	$7
8				$14	$14	$7
9				$14	$14	$6
10		$20		$14	$34	$14
11				$14	$14	$5
12				$14	$14	$5
13				$14	$14	$4
14				$14	$14	$4
15	$1,845			$14	$1,859	$510
16				$14	$14	$3
17				$14	$14	$3
18				$14	$14	$3
19				$14	$14	$3
20		$20		$14	$34	$6
21				$14	$14	$2
22				$14	$14	$2
23				$14	$14	$2
24				$14	$14	$2
25		$20		$14	$34	$4
26				$14	$14	$1
27				$14	$14	$1
28				$14	$14	$1
29				$14	$14	$1

NET PRESENT COST: $2,532

WITH OPPORTUNITY COST: $2,532

APPENDIX 7.

QUESTIONNAIRE:

- Barrier Bulletin Article
- Covering Letter
- Questionnaire
- Follow-up letter.

SCHOOL OF
APPLIED AND
INTERNATIONAL
ECONOMICS

MASSEY
UNIVERSITY

Dear Sir/Madam.

GREAT BARRIER ISLAND ENERGY SURVEY

Good afternoon. I am writing to ask you for a small amount of your time to help me with a project I am doing for my Masters degree at Massey University. I am conducting a study into the current and potential sources of household energy available to houses on Great Barrier Island. An article on my project appeared recently in The Barrier Bulletin magazine. I have enclosed a copy of the article with this letter for your interest and information.

The aim of my study is both to evaluate the effect that the Auckland City Council's restrictions on the clearance of native timber from private land on Great Barrier has had on you, as a ratepayer of the island. Also, my project aims to determine which energy sources will meet your domestic energy needs on Great Barrier under these restrictions for the lowest overall cost. To do so requires gathering first-hand information from people like yourself.

Enclosed with this letter you will find a questionnaire form which should take you no longer than around 10 minutes to complete. Your name was chosen at random from a list of Great Barrier Island ratepayers. As questionnaire forms have only been mailed out to a small sample of ratepayers, your help with my study by filling out the enclosed survey form would be greatly appreciated.

While your participation in this survey is completely voluntary, your answers and contributions to this study would be extremely important to me, and will greatly increase the accuracy of my study.

You can be assured that your individual responses will be held in complete confidence, and will never be seen by any person other than myself. The results which I will use will be of statistical totals only. Your names are known only by myself, and this is for mailing purposes only. While the top of this survey form has been marked with a number, this is used ONLY for mailing purposes, to facilitate the sending of a reminder letter to those people who have not yet replied. I promise you that your name will never be written on the survey form. Once all the completed forms have been received, the list of survey numbers and corresponding names will be destroyed, and your survey form will be totally anonymous and untraceable to you.

A post-paid self-addressed envelope is enclosed for your convenience in returning the questionnaire. *Additionally, your comments about this survey form would be very welcome.* Thank you for your help.

Yours sincerely

Tony Wharton
Student Researcher

Professor Anton Meister
Professor of Resource &
Environmental Economics

Dr Robert Alexander
Lecturer in Resource &
Environmental Economics

Department of Agricult
Economics and Busines
Massey University
Private Bag 11222
Palmerston North
New Zealand

Telephone 0-6-356 9099
Facsimile 0-6-350 5642

Department of Agricultural Economics
Massey University
Private Bag
PALMERSTON NORTH

SCHOOL OF
APPLIED AND
INTERNATIONAL
ECONOMICS

MASSEY
UNIVERSITY

Thursday 6th October, 1994

Dear Sir / Madam,

Good afternoon. A short time ago I sent you a questionnaire form for the Great Barrier Island ratepayer energy survey which I am doing for my masters thesis at Massey University.

As of today I have not yet received a reply from you. If you have recently returned the questionnaire, please ignore this letter, and accept my sincere thanks for your help with my project.

As questionnaire forms have only been mailed out to a small sample of ratepayers, your contribution to my study by filling out the survey would be extremely helpful to me, and will greatly increase the accuracy of my study.

Thank you for your time and help in this matter,

Yours sincerely

Tony Wharton.

Department of Agricultur
Economics and Business
Massey University
Private Bag 11222
Palmerston North
New Zealand

Telephone 0-6-356 9099
Facsimile 0-6-350 5642

APPENDIX 8.

QUESTIONNAIRE RESULTS:

8A) NON-RESIDENTS

8B) RESIDENTS

8C) LAND AREAS BY RESIDENCY

NON-RESIDENT'S SURVEY RESULTS

		TOTAL	% OF NON RESIDENTS
1)	*USE LAND ON G.B.I?*	98	
	USE	1	
	NO USE		
2)	*COMBINED LAND AREA (HA)*	474	
3)	*LOT STATUS?*		
	ONE	76	78%
	MORE THAN 1	15	15%
	NUMBER OF LOTS	40	
	LESS THAN 1	0	0%
	N/A	8	8%
	TOTAL NO. OF LOTS SURVEYED:	116	
4)	*HOUSE ON LAND?*		
	YES	69	71%
	NO	28	29%
5)	*MAIN RESIDENCE?*		
	YES	0	0%
	NO	68	100%
a)	*OF NO'S: LENGTH OF STAY*		
	TOTAL WEEKS/YR	618.5	
	NO STAY	3	
	MEAN OVER ALL NON RESIDENTS	9	
6)	*INCOME FROM LAND?*		
	YES	2	3%
	NO	60	97%
b)	*TOTAL INCOME FROM LAND?*	$650	
	# OF YES'S NOT STATING INC	1	
	MEAN INCOME OVER YES'S	$650	
	MEAN INCOME OVER ALL	$21	
7)	*GROW FOOD/PRODUCE ON LAND?*		
	YES	24	39%
	NO	38	61%
a)	*OF YES REPLIES:*		
	TOTAL COST	$9,730	
	# OF YES'S NOT STATING COST	0	
	MEAN OVER ALL YES RESPONDENTS	$405	
	MEAN COST OVER ALL RESPOND.	$157	
8)	*TOTAL LAND % USED?*	838.05	
	MEAN % OVER ALL YES RESPONDENTS	31.0%	
	MEAN % OVER ALL RESPOND.	12.6%	

		RATING	%	#USERS	%
9)	*COOKING FUEL?*				
	WOOD	28.7	43%	36	55%
	GAS	34.3	52%	42	64%
	ELEC	0	0%	0	0%
	COAL	0	0%	0	0%
	NONE	0	0%	0	0%
	OTHER	3	5%	3	5%
	COOKING APPLIANCE?				
	STOVE	39.7	61%	43	66%
	BURNR	18.8	29%	23	35%
	FIRE	6.5	10%	7	11%
	MWAVE	0	0%	0	0%
	NONE	0	0%	0	0%
	OTHER	0	0%	0	0%

HEATING FUEL?				
WOOD	42.5	64%	46	70%
GAS	9	14%	12	18%
ELEC	2	3%	2	3%
COAL	0	0%	0	0%
KERO	3.5	5%	4	6%
NONE	9	14%	9	14%
OTHER	0	0%	0	0%
HEATING APPLIANCE?				
STOVE	10.33	16%	12	19%
POTB	12	19%	13	20%
FIRE	4	6%	4	6%
CKRNG	16.33	26%	19	30%
HETR	12.33	19%	14	22%
NONE	9	14%	9	14%
OTHER	0	0%	0	0%

10) ***WATER HEATING -MAIN FUEL?***

WOOD	34.5	54%	36	56%
GAS	21.5	34%	23	36%
ELEC	0	0%	0	0%
COAL	0	0%	0	0%
KERO	2	3%	2	3%
SUN	1	2%	1	2%
NONE	5	8%	5	8%
OTHER	0	0%	0	0%
BACK UP FUEL?				
WOOD	4	6%	5	8%
GAS	8.5	13%	9	14%
ELEC	2.5	4%	3	5%
COAL	0	0%	0	0%
KERO	1.5	2%	2	3%
SUN	10.5	16%	13	20%
NONE	38	58%	38	58%
OTHER	0	0%	0	0%
WATER HEATING MAIN APPL?				
WBRNG	25.3	40%	26	41%
WBFIR	0.0	0%	0	0%
FIRE	2.5	4%	3	5%
BOIL	13.3	21%	15	24%
SOLAR	1.0	2%	1	2%
GAS	14.8	24%	16	25%
ELEC	1.0	2%	1	2%
NONE	5.0	8%	5	8%
OTHER	0.0	0%	0	0%
BACK UP APPLIANCE?				
WBRNG	2.5	4%	3	5%
WBFIR	0	0%	0	0%
FIRE	2	3%	2	3%
BOIL	8.5	14%	9	15%
SOLAR	9.5	16%	11	18%
GAS	2	3%	2	3%
ELEC	0.5	1%	1	2%
NONE	35	57%	35	57%
OTHER	1	2%	1	2%

11)	*USE ELECTRICITY?*			
	YES	42	64%	34%
	NO	24	36%	63%
a)	*USE WHICH OF FOLLOWING?*			
	SOLAR	27	61%	33%
	WIND	5	11%	19%
	OTHER	1	2%	100%
	DIESL	25	57%	28%
	HYDRO	0	0%	0%

		RATING	%	#USERS	%
b)	*MAIN SOURCE?*				
	SOLAR	22.5	51%	24	55%
	WIND	3.5	8%	4	9%
	OTHER	0.5	1%	1	2%
	DIESL	17.5	40%	19	43%
	HYDRO	0	0%	0	0%
12) a)	*WOOD USED?*				
	PINE	2.5	4%	4	6%
	MANUKA	40.5	62%	44	68%
	NO WOOD USE	16	25%	16	25%
	EUCALYPTUS	0.5	1%	1	2%
	MACROCARPA	1	2%	2	3%
	OTHER	4.5	7%	7	11%
b)	*MAIN SOURCE?*				
	GROW	23	48%	25	52%
	COLLECT	15	31%	18	38%
	PURCHASE	10	21%	11	23%
	OTHER	0	0%	0	0%

			TOTAL	% OF NON RESIDENTS	% OF TOTAL RESPONDENTS
13)	*MANUKA/KANUKA ON LAND?*				
	YES		38	52%	41%
	NO		35	48%	46%
a)	*TOTAL LAND %?*		1641%		38%
	NO ANSWER		2		
	AVG PERCENTAGE - YES'S		43%		
	AVG PERCENTAGE - ALL		23%		
14)	*CHANGE FUEL SINCE RESTRICT?*				
	YES		0	0%	0%
	NO		66	100%	42%
a)	*COOK FUEL:*	NC	0		
		WOOD	0		
		GAS	0		
		ELEC	0		
		COAL	0		
		OTHER	0		
b)	*HEAT FUEL:*	NC	0		
		WOOD	0		
		GAS	0		
		ELEC	0		
		COAL	0		
		KERO	0		
		OTHER	0		
c)	*MAIN W/H:*	WOOD	0		
		GAS	0		
		ELEC	0		
		COAL	0		
		KERO	0		
		SUN	0		
		OTHER	0		
d)	*B/U WH:*	WOOD	0		
		GAS	0		
		ELEC	0		
		COAL	0		
		KERO	0		
		SUN	0		
		OTHER	0		
15)	*MODIFIED FUEL SOURCES?*				
	YES		5	8%	26%
	NO		48	74%	38%
	NOT APPLICABLE		12	18%	86%

RESIDENTS SURVEY RESULTS

		TOTAL	% OF RESIDENTS
1)	*USE LAND ON G.B.I?*		
	USE	96	
	NO USE	0	
2)	*COMBINED LAND AREA (HA)*	2030.2	
3)	*LOT STATUS?*		
	ONE	65	68%
	MORE THAN 1	24	25%
	NUMBER OF LOTS	68	
	LESS THAN 1	0	0%
	N/A	6	6%
	TOTAL NO. OF LOTS SURVEYED:	133	
4)	*HOUSE ON LAND?*		
	YES	96	100%
	NO	0	0%
	AVG LOT SIZE (HA)	14.2	
	AVG LOT/RP/HOUSE	1.4	
	AVG LAND/HOUSE (HA)	19.6	
5)	*MAIN RESIDENCE?*		
	YES	96	100%
	NO	0	0%
6)	*INCOME FROM LAND?*		
	YES	21	22%
	NO	74	78%
b)	*TOTAL INCOME FROM LAND?*	$87,322	
	# OF YES'S NOT STATING INC	7	
	MEAN INCOME OVER YES'S	$4,158	
	MEAN INCOME OVER ALL	$1,379	
7)	*GROW FOOD/PRODUCE ON LAND?*		
	YES	70	75%
	NO	23	25%
a)	*OF YES REPLIES:*		
	TOTAL COST	$111,000	
	# OF YES'S NOT STATING COST	5	
	MEAN OVER ALL YES RESPONDENTS	$1,708	
	MEAN COST OVER ALL RESPOND.	$1,285.4	
8)	*TOTAL LAND % USED?*	2323.0836538462	
	MEAN % OVER ALL YES RESPONDENTS	34.7%	
	MEAN % OVER ALL RESPOND.	26.7%	

		RATING	%	#USERS	%
9)	*COOKING FUEL?*				
	WOOD	51.0	53%	70	73%
	GAS	41.5	43%	61	64%
	ELEC	3.5	4%	10	10%
	COAL	0.0	0%	0	0%
	NONE	0.0	0%	0	0%
	OTHER	0.0	0%	0	0%
	COOKING APPLIANCE?				
	STOVE	72.7	77%	88	94%
	BURNR	15.4	16%	27	29%
	FIRE	3.8	4%	9	10%
	MWAVE	1.6	2%	4	4%
	NONE	0.0	0%	0	0%
	OTHER	0.5	1%	1	1%

HEATING FUEL?				
WOOD	77.0	80%	84	88%
GAS	14.0	15%	20	21%
ELEC	2.0	2%	3	3%
COAL	0.0	0%	0	0%
KERO	1.0	1%	1	1%
NONE	2.0	2%	2	2%
OTHER	0.0	0%	0	0%
HEATING APPLIANCE?				
STOVE	26.1	28%	34	37%
POTB	17.6	19%	21	23%
FIRE	8.1	9%	10	11%
CKRNG	24.5	27%	29	32%
HETR	13.7	15%	19	21%
NONE	2.0	2%	2	2%
OTHER	0.0	0%	0	0%
10) *WATER HEATING -MAIN FUEL?*				
WOOD	66.0	69%	68	71%
GAS	22.5	23%	24	25%
ELEC	4.0	4%	4	4%
COAL	0.0	0%	0	0%
KERO	0.0	0%	0	0%
SUN	3.5	4%	4	4%
NONE	0.0	0%	0	0%
OTHER	0.0	0%	0	0%
BACK UP FUEL?				
WOOD	8.5	9%	10	11%
GAS	15.0	16%	16	17%
ELEC	6.5	7%	8	9%
COAL	0.0	0%	0	0%
KERO	0.0	0%	0	0%
SUN	6.0	6%	7	8%
NONE	57.0	61%	57	61%
OTHER	0.0	0%	0	0%
WATER HEATING MAIN APPL.?				
WBRNG	59.0	62%	61	64%
WBFIR	0.0	0%	0	0%
FIRE	2.5	3%	3	3%
BOIL	3.5	4%	4	4%
SOLAR	4.5	5%	5	5%
GAS	18.5	19%	20	21%
ELEC	4.0	4%	4	4%
NONE	2.0	2%	2	2%
OTHER	1.0	1%	1	1%
BACK UP APPLIANCE?				
WBRNG	7.0	8%	8	9%
WBFIR	1.5	2%	2	2%
FIRE	0.0	0%	0	0%
BOIL	9.0	10%	9	10%
SOLAR	9.0	10%	10	11%
GAS	7.0	8%	8	9%
ELEC	7.5	8%	9	10%
NONE	51.0	55%	51	55%
OTHER	0.0	0%	0	0%

		TOTAL	% OF RESIDENTS		
11)	***USE ELECTRICITY?***				
	YES	82.0	85%		
	NO	14.0	15%		
a)	***USE WHICH OF FOLLOWING?***				
	SOLAR	54.0	38%		
	WIND	21.0	15%		
	OTHER	0.0	0%		
	DIESL	64.0	45%		
	HYDRO	3.0	2%		
		RATING	**%**	**#USERS**	**%**
b)	***MAIN SOURCE?***				
	SOLAR	43.5	46%	49	52%
	WIND	10.5	11%	12	13%
	OTHER	0.0	0%	0	0%
	DIESL	39.0	41%	42	44%
	HYDRO	2.0	2%	3	3%
12) a)	***WOOD USED?***				
	PINE	8.0	8%	13	11%
	MANUKA	75.6	79%	84	72%
	NO WOOD USE	5.0	5%	5	4%
	EUCALYPTS	0.9	1%	3	3%
	MACROCARPA	4.9	5%	9	8%
	OTHER	1.5	2%	2	2%
b)	***MAIN SOURCE?***				
	GROW	50.5	55%	53	55%
	COLLECT	19.5	21%	22	23%
	PURCHASE	21.0	23%	22	23%
	OTHER	0.0	0%	0	0%

			TOTAL	% OF RESIDENTS
13)	***MANUKA/KANUKA ON LAND?***			
	YES		55.0	57%
	NO		41.0	43%
a)	***TOTAL LAND %?***		2732%	
	NO ANSWER		2	
	AVG PERCENTAGE - YES'S		52%	
	AVG PERCENTAGE - ALL		30%	
14)	***CHANGE FUEL SINCE RESTRICT?***			
	YES		3.0	
	NO		92.0	
a)	***COOK FUEL:***	NC	4.0	
		WOOD	2.0	
		GAS	0.0	
		ELEC	0.0	
		COAL	0.0	
		OTHER	0.0	
b)	***HEAT FUEL:***	NC	4.0	
		WOOD	1.0	
		GAS	0.0	
		ELEC	0.0	
		COAL	0.0	
		KERO	0.0	
		OTHER	0.0	
c)	***MAIN WH:***	WOOD	1.0	
		GAS	0.0	
		ELEC	0.0	
		COAL	0.0	
		KERO	0.0	
		SUN	0.0	
		OTHER	0.0	
d)	***B/U WH:***	WOOD	3.0	
		GAS	0.0	
		ELEC	0.0	
		COAL	0.0	
		KERO	0.0	
		SUN	0.0	
		OTHER	0.0	

			TOTAL	% OF RESIDENTS
15)	***MODIFIED FUEL SOURCES?***			
		YES	14.0	15%
		NO	80.0	83%
		NOT APPLICABLE	2.0	2%

HOUSEHOLD LAND AREA BY RESIDENCY CATAGORY.

RESIDENTS:			
AREA (HA)	#	%	% WITH LAND BELOW THIS
0.05	3	3%	0%
0.06	2	2%	3%
0.07	9	10%	6%
0.08	2	2%	16%
0.13	5	6%	18%
0.17	7	8%	23%
0.24	1	1%	31%
0.27	3	3%	32%
0.37	1	1%	36%
0.48	2	2%	37%
0.58	1	1%	39%
1.00	3	3%	40%
1.79	1	1%	43%
1.97	1	1%	44%
2.80	2	2%	46%
3.59	1	1%	48%
3.81	1	1%	49%
4.02	3	3%	50%
4.07	1	1%	53%
4.11	1	1%	54%
4.12	1	1%	56%
4.22	1	1%	57%
4.42	1	1%	58%
4.47	2	2%	59%
4.62	1	1%	61%
4.77	1	1%	62%
4.97	1	1%	63%
4.97	1	1%	64%
5.03	1	1%	66%
5.17	1	1%	67%
5.47	1	1%	68%
8.06	1	1%	69%
8.87	1	1%	70%
9.48	1	1%	71%
9.97	1	1%	72%
10.49	1	1%	73%
10.90	1	1%	74%
12.52	1	1%	76%
12.97	1	1%	77%
14.94	1	1%	78%
16.16	1	1%	79%
23.27	1	1%	80%
24.25	1	1%	81%
28.10	1	1%	82%
28.97	1	1%	83%
35.97	1	1%	84%
44.97	1	1%	86%
46.51	1	1%	87%
48.53	1	1%	88%
49.34	1	1%	89%
49.97	1	1%	90%
51.77	1	1%	91%
64.72	1	1%	92%
65.94	1	1%	93%
76.86	1	1%	94%
137.57	1	1%	96%
141.61	1	1%	97%
242.79	2	2%	98%

NON-RESIDENTS:			
AREA (HA)	#	%	% WITH LAND BELOW THIS
0.05	11	19%	0%
0.06	1	2%	19%
0.07	10	17%	20%
0.09	1	2%	37%
0.10	3	5%	39%
0.12	1	2%	44%
0.17	9	15%	46%
0.37	5	8%	61%
0.46	1	2%	69%
0.47	1	2%	71%
0.48	1	2%	73%
0.50	1	2%	75%
0.78	1	2%	76%
0.84	1	2%	78%
0.98	1	2%	80%
2.56	1	2%	81%
3.97	1	2%	83%
4.02	2	3%	85%
4.07	1	2%	88%
4.22	1	2%	90%
4.47	1	2%	92%
6.04	1	2%	93%
6.45	1	2%	95%
7.25	2	3%	97%

NOTES:

HOUSEHOLD LAND WAS DEFINED AS TOTAL LAND AREA LESS 300 M^2 HOUSING AREA (AUCKLAND CITY STANDARD ALLOWANCE).

DATA SOURCE:

QUESTIONNAIRE RESULTS.

APPENDIX 9.

TEATREE PRODUCTION UNDER CLEARANCE RESTRICTIONS

- Production cost model
- Energy Expenditure Model - No teatree on land;
- Energy Expenditure Model - Teatree on land;
- Results.

TEATREE ENERGY EXPENDITURE ANALYSIS: RESIDENT.
UNDER CLEARANCE RESTRICTIONS

EXISTING TEATREE ON LAND OPTION: WAMSLER WOODSTOVE

MODEL ASSUMPTIONS:

Total land area (ha)	4.02
% of Land covered	52%
Initial age of scrub (yrs):	13
Rotation length (years):	17
Wood cost (bought):	$50
Harvesting cost/stere:	$18
Discount Rate:	9%

FUEL REQUIREMENTS (STERE/YEAR)

Cooking	2.0
Water Heating	6.1
TOTAL	8.1
WITH RESTRICT:	4.58

YEAR	WOOD/HA M^3	EXISTING PLOT SIZE M^2	STERES/YR / ROTATN.	STERES/YR / ROTATN.	COOK STERES TO BUY	COOK TOTAL COST	W/H STERES TO BUY	W/H TOTAL COST	COMBINED STERES TO BUY	TOTAL COST
0	49	1230	9.32	4.58	0.00	$35	1.53	$159	3.49	$257
1	55	1230	10.40	4.58	0.00	$35	1.53	$159	3.49	$257
2	66	1230	12.49	4.58	0.00	$35	1.53	$159	3.49	$257
3	81	1230	15.36	4.58	0.00	$35	1.53	$159	3.49	$257
4	99	1230	18.81	4.58	0.00	$35	1.53	$159	3.49	$257
5	120	1230	22.64	4.58	0.00	$35	1.53	$159	3.49	$257
6	141	1230	26.70	4.58	0.00	$35	1.53	$159	3.49	$257
7	163	1230	30.86	4.58	0.00	$35	1.53	$159	3.49	$257
8	185	1230	34.99	4.58	0.00	$35	1.53	$159	3.49	$257
9	206	1230	38.98	4.58	0.00	$35	1.53	$159	3.49	$257
10	226	1230	42.75	4.58	0.00	$35	1.53	$159	3.49	$257
11	244	1230	46.20	4.58	0.00	$35	1.53	$159	3.49	$257
12	261	1230	49.28	4.58	0.00	$35	1.53	$159	3.49	$257
13	274	1230	51.93	4.58	0.00	$35	1.53	$159	3.49	$257
14	286	1230	54.08	4.58	0.00	$35	1.53	$159	3.49	$257
15	294	1230	55.70	4.58	0.00	$35	1.53	$159	3.49	$257

TEATREE ENERGY EXPENDITURE ANALYSIS: RESIDENT.

MODEL ASSUMPTION : No teatree previously on land. **APPLIANCE:** Wamsler woodstove

Total land avb:	4.02 HA	Opportunity cost options:	Land used for other:	35%
Land needed:	0.51 HA		Opp. cost of land:	$5,866
Discount rate	9%			
Rotation length:	17 yrs			

YEAR	Appliance	Maint.	COOKING: WOOD COST PURCH	GROW	TOTAL	P.V.	WATER HEATING: WOOD COST PURCH	GROW	TOTAL	P.V.	COMBINED PURCH	GROW	TOTAL	P.V.
0	$7,074		$98		$7,270	$7,270	$229		$7,303	$7,303	$405		$7,479	$7,479
1			$98		$98	$90	$229		$229	$210	$405		$405	$372
2			$98		$98	$83	$229		$229	$193	$405		$405	$341
3			$98		$98	$76	$229		$229	$177	$405		$405	$313
4			$98		$98	$69	$229		$229	$163	$405		$405	$287
5		$20	$98		$118	$77	$229		$249	$162	$405		$425	$276
6			$98		$98	$58	$229		$229	$137	$405		$405	$241
7			$98		$98	$54	$229		$229	$125	$405		$405	$222
8			$98		$98	$49	$229		$229	$115	$405		$405	$203
9			$98		$98	$45	$229		$229	$106	$405		$405	$186
10		$20	$98		$118	$50	$229		$249	$105	$405		$425	$180
11			$98		$98	$38	$229		$229	$89	$405		$405	$157
12			$98		$98	$35	$229		$229	$82	$405		$405	$144
13			$98		$98	$32	$229		$229	$75	$405		$405	$132
14			$98		$98	$29	$229		$229	$69	$405		$405	$121
15		$20	$98		$118	$32	$229		$249	$68	$405		$425	$117
16			$98		$98	$25	$229		$229	$58	$405		$405	$102
17				$35	$35	$8	$76	$83	$158	$37	$175	$83	$258	$60
18				$35	$35	$7	$76	$83	$158	$34	$175	$83	$258	$55
19				$35	$35	$7	$76	$83	$158	$31	$175	$83	$258	$50
20		$20		$35	$55	$10	$76	$83	$178	$32	$175	$83	$278	$50
21				$35	$35	$6	$76	$83	$158	$26	$175	$83	$258	$42
22				$35	$35	$5	$76	$83	$158	$24	$175	$83	$258	$39
23				$35	$35	$5	$76	$83	$158	$22	$175	$83	$258	$35
24				$35	$35	$4	$76	$83	$158	$20	$175	$83	$258	$33
25		$20		$35	$55	$6	$76	$83	$178	$21	$175	$83	$278	$32
26				$35	$35	$4	$76	$83	$158	$17	$175	$83	$258	$27
27				$35	$35	$3	$76	$83	$158	$15	$175	$83	$258	$25
28				$35	$35	$3	$76	$83	$158	$14	$175	$83	$258	$23
29	($2,814)			$35	($2,778)	($228)	$76	$83	($2,655)	($218)	$175	$83	($2,556)	($210)
NET PRESENT COST:						$7,953				$9,310				$11,133
WITH OPPORTUNITY COST:						$7,953				$9,310				$11,133

TEATREE ENERGY EXPENDITURE ANALYSIS: RESIDENT.

MODEL ASSUMPTION : Teatree previously on land. **APPLIANCE:** Wamsler woodstove

Total land (Ha):	4.02 HA	Opportunity cost options:	Land used for other:	35%
Land needed	0.51 HA		Opp. cost of land:	$5,866
Discount Rate:	9%			
Rotation Length:	17 yrs			

YEAR	Appliance	Maint.	COOKING: WOOD COST PURCH	GROW	TOTAL	P.V.	WATER HEATING: WOOD COST PURCH	GROW	TOTAL	P.V.	COMBINED: PURCH	GROW	TOTAL	P.V.
0	$7,074		$0	$35	$7,109	$7,109	$77	$82	$7,233	$7,233	$175	$82	$7,331	$7,331
1				$35	$35	$32	$77	$82	$159	$146	$175	$82	$257	$236
2				$35	$35	$30	$77	$82	$159	$134	$175	$82	$257	$216
3				$35	$35	$27	$77	$82	$159	$123	$175	$82	$257	$199
4				$35	$35	$25	$77	$82	$159	$113	$175	$82	$257	$182
5		$20		$35	$55	$36	$77	$82	$179	$116	$175	$82	$277	$180
6				$35	$35	$21	$77	$82	$159	$95	$175	$82	$257	$153
7				$35	$35	$19	$77	$82	$159	$87	$175	$82	$257	$141
8				$35	$35	$18	$77	$82	$159	$80	$175	$82	$257	$129
9				$35	$35	$16	$77	$82	$159	$73	$175	$82	$257	$118
10		$20		$35	$55	$23	$77	$82	$179	$76	$175	$82	$277	$117
11				$35	$35	$14	$77	$82	$159	$62	$175	$82	$257	$100
12				$35	$35	$13	$77	$82	$159	$57	$175	$82	$257	$91
13				$35	$35	$12	$77	$82	$159	$52	$175	$82	$257	$84
14				$35	$35	$11	$77	$82	$159	$48	$175	$82	$257	$77
15		$20		$35	$55	$15	$77	$82	$179	$49	$175	$82	$277	$76
16				$35	$35	$9	$77	$82	$159	$40	$175	$82	$257	$65
17				$35	$35	$8	$77	$82	$159	$37	$175	$82	$257	$59
18				$35	$35	$7	$77	$82	$159	$34	$175	$82	$257	$54
19				$35	$35	$7	$77	$82	$159	$31	$175	$82	$257	$50
20		$20		$35	$55	$10	$77	$82	$179	$32	$175	$82	$277	$49
21				$35	$35	$6	$77	$82	$159	$26	$175	$82	$257	$42
22				$35	$35	$5	$77	$82	$159	$24	$175	$82	$257	$39
23				$35	$35	$5	$77	$82	$159	$22	$175	$82	$257	$35
24				$35	$35	$4	$77	$82	$159	$20	$175	$82	$257	$32
25		$20		$35	$55	$6	$77	$82	$179	$21	$175	$82	$277	$32
26				$35	$35	$4	$77	$82	$159	$17	$175	$82	$257	$27
27				$35	$35	$3	$77	$82	$159	$16	$175	$82	$257	$25
28				$35	$35	$3	$77	$82	$159	$14	$175	$82	$257	$23
29	($2,814)			$35	($2,778)	($228)	$77	$82	($2,655)	($218)	$175	$82	($2,557)	($210)
NET PRESENT COST:						$7,271				$8,657				$9,755
WITH OPPORTUNITY COST:						$7,271				$8,657				$9,755

Expenditure model results under clearance restrictions.

	ASSUMPTION:	NET PRESENT COST OF HEAT LOAD FOR 29 YEARS COOKING WITH	COOKING W/O	SPACE HEATING WITH	SPACE HEATING W/O	WATER HEATING WITH	WATER HEATING W/O	COMBINATION WITH	COMBINATION W/O
TEATREE FUELWOOD:	NO PREV / NO OPP CST	$1,110	$7,953	$923	$2,768	$3,179	$10,022	$4,276	$11,119
(UNDER RESTRICTIONS)	NO PREV / OPP CST	$1,110	$7,953	$923	$2,768	$3,179	$10,022	$4,276	$11,119
	PREV / NO OPP CST	$428	$7,271	$687	$2,532	$1,814	$8,657	$2,912	$9,755
	PREV / OPP CST	$428	$7,271	$687	$2,532	$1,814	$8,657	$2,912	$9,755

APPENDIX 10.

ZERO OPPORTUNITY COST OF LABOUR ANALYSIS.

10A) NON-RESIDENTS.

- Eucalyptus, Wamsler 8 year production cost model;
- Energy expenditure model;
- Eucalyptus, Jayline 8 year production cost model;
- Energy expenditure model;
- Teatree, Wamsler, energy expenditure model - no teatree on land;
- Jayline, energy expenditure model - no teatree on land.
- Results.

10B) RESIDENTS.

- Eucalyptus, Wamsler 8 year production cost model;
- Energy expenditure model;
- Eucalyptus, Jayline 8 year production cost model;
- Energy expenditure model;
- Teatree, Wamsler expenditure model - no teatree on land;
- Jayline, energy expenditure model - no teatree on land.
- Results.

FUELWOOD PRODUCTION COST ANALYSIS - NON-RESIDENT
WAMSLER WOODSTOVE

0 OPPORTUNITY COST OF LABOUR OPTION

EUCALYPTUS SALIGNIA & BOTRYOIDES: 8 YEAR ROTATION CYCLE.
BASED ON 1HA ASSUMPTION:

PRODUCTION COSTS:

Tree cost	$1.00	Harvesting:	$0	/stere
Freight	$0.40	Cultivation	$200	/ha
Planting	$0.00	Maint.	$157	/ha/yr

YEAR	# TREES ON PLOT	PLANT COST	TREE COST	CULTV.	MAINT.	BIOMASS (STERES)	HARVEST COST	TOTAL (68 STERE/YR)	ACTUAL COSTS: 2.1 STERE/YR
0	313	0.0	437.5	25.0		0	0.0	462.5	$12.4
1	625	0.0	437.5	25.0	19.6	0	0.0	482.1	$12.9
2	938	0.0	437.5	25.0	39.2	0	0.0	501.7	$13.5
3	1250	0.0	437.5	25.0	58.8	0	0.0	521.3	$14.0
4	1563	0.0	437.5	25.0	78.3	0	0.0	540.8	$14.5
5	1875	0.0	437.5	25.0	97.9	0	0.0	560.4	$15.0
6	2188	0.0	437.5	25.0	117.5	0	0.0	580.0	$15.6
7	2500	0.0	437.5	25.0	137.1	0	0.0	599.6	$16.1
8	2500				156.7	78.63	0.0	156.7	$4.2
9	2500				156.7	78.63	0.0	156.7	$4.2
10	2500				156.7	78.63	0.0	156.7	$4.2
11	2500				156.7	78.63	0.0	156.7	$4.2
TO YR 23					1880.0	943.6	0.0	1880.0	$50.5
24	2500	0.0	437.5	25.0	156.7	78.6	0.0	619.2	$16.6
25	2500	0.0	437.5	25.0	156.7	78.6	0.0	619.2	$16.6
26	2500	0.0	437.5	25.0	156.7	78.6	0.0	619.2	$16.6
27	2500	0.0	437.5	25.0	156.7	78.6	0.0	619.2	$16.6
28	2500	0.0	437.5	25.0	156.7	78.6	0.0	619.2	$16.6
29	2500	0.0	437.5	25.0	156.7	78.6	0.0	619.2	$16.6
								$10,470	$281

EUCALYPTUS FUELWOOD ENERGY EXPENDITURE ANALYSIS:
NONRESIDENT

APPLIANCE: WAMSLER WOODSTOVE, 0 OPPORTUNITY COST OF LABOUR

DISCOUNT RATE: 9%
ROTATION LENGTH (YRS): 8

			COOKING				WATER HEATING				
YEAR	Appliance	Maint.	WOOD COST Purch	Grow	TOTAL	P.V.	WOOD COST Purch	Grow	TOTAL	P.V.	COMBINED
0	$7,074		$17	$3	$7,114	$7,114	$53	$9	$7,136	$7,136	$7,176
1			$17	$3	$40	$37	$53	$10	$63	$58	$95
2			$17	$3	$20	$17	$53	$10	$63	$53	$70
3			$17	$3	$20	$16	$53	$11	$63	$49	$65
4			$17	$4	$20	$15	$53	$11	$84	$59	$74
5		$20	$17	$4	$41	$26	$53	$11	$84	$55	$68
6			$17	$4	$21	$12	$53	$12	$65	$39	$51
7			$17	$4	$21	$11	$53	$12	$65	$36	$47
8				$1	$1	$1		$3	$3	$2	$2
9				$1	$1	$0		$3	$23	$11	$11
10		$20		$1	$21	$9		$3	$23	$10	$10
11				$1	$1	$0		$3	$3	$1	$2
12				$1	$1	$0		$3	$3	$1	$1
13				$1	$1	$0		$3	$3	$1	$1
14				$1	$1	$0		$3	$3	$1	$1
15		$20		$1	$21	$6		$3	$23	$6	$7
16				$1	$1	$0		$3	$3	$1	$1
17				$1	$1	$0		$3	$3	$1	$1
18				$1	$1	$0		$3	$3	$1	$1
19				$1	$1	$0		$3	$3	$1	$1
20		$20		$1	$21	$4		$3	$23	$4	$4
21				$1	$1	$0		$3	$3	$1	$1
22				$1	$1	$0		$3	$3	$0	$1
23				$1	$1	$0		$3	$3	$0	$1
24				$17	$17	$2		$13	$13	$2	$4
25		$20		$17	$37	$4		$13	$33	$4	$6
26				$17	$17	$2		$13	$13	$1	$3
27				$17	$17	$2		$13	$13	$1	$3
28				$17	$17	$1		$13	$13	$1	$3
29	($2,814)			$17	($2,797)	($230)		$13	($2,801)	($230)	($229)
NET PRESENT COST:						$7,052				$7,304	$7,481
WITH OPPORTUNITY COST:						$7,052				$7,304	$7,481

FUELWOOD PRODUCTION COST ANALYSIS - NON-RESIDENT
JAYLINE JUNIOR WOODFIRE

0 OPPORTUNITY COST OF LABOUR OPTION

EUCALYPTUS SALIGNIA & BOTRYOIDES: 8 YEAR ROTATION CYCLE.
BASED ON 1HA ASSUMPTION:

PRODUCTION COSTS:

Tree cost	$1.00	Harvesting:	$0	/stere
Freight	$0.40	Cultivation	$200	/ha
Planting	$0.00	Maint.	$157	/ha/yr

YEAR	# TREES ON PLOT	PLANT COST	TREE COST	CULTV.	MAINT.	BIOMASS (STERES)	HARVEST COST	TOTAL (68 STERE/YR)	ACTUAL COSTS: 0.2 STERE/YR
0	313	0.0	437.5	25.0		0	0.0	462.5	$1.2
1	625	0.0	437.5	25.0	19.6	0	0.0	482.1	$1.2
2	938	0.0	437.5	25.0	39.2	0	0.0	501.7	$1.3
3	1250	0.0	437.5	25.0	58.8	0	0.0	521.3	$1.3
4	1563	0.0	437.5	25.0	78.3	0	0.0	540.8	$1.4
5	1875	0.0	437.5	25.0	97.9	0	0.0	560.4	$1.4
6	2188	0.0	437.5	25.0	117.5	0	0.0	580.0	$1.5
7	2500	0.0	437.5	25.0	137.1	0	0.0	599.6	$1.5
8	2500				156.7	78.63	0.0	156.7	$0.4
9	2500				156.7	78.63	0.0	156.7	$0.4
10	2500				156.7	78.63	0.0	156.7	$0.4
11	2500				156.7	78.63	0.0	156.7	$0.4
TO YR 23					1880.0	943.6	0.0	1880.0	$4.8
24	2500	0.0	437.5	25.0	156.7	78.6	0.0	619.2	$1.6
25	2500	0.0	437.5	25.0	156.7	78.6	0.0	619.2	$1.6
26	2500	0.0	437.5	25.0	156.7	78.6	0.0	619.2	$1.6
27	2500	0.0	437.5	25.0	156.7	78.6	0.0	619.2	$1.6
28	2500	0.0	437.5	25.0	156.7	78.6	0.0	619.2	$1.6
29	2500	0.0	437.5	25.0	156.7	78.6	0.0	619.2	$1.6
								$10,470	$27

EUCALYPTUS FUELWOOD ENERGY EXPENDITURE ANALYSIS: NON-RESIDENT

APPLIANCE: JAYLINE WOODFIRE

DISCOUNT RATE: 9%
ROTATION LENGTH (YRS): 8

SPACE HEATING

YEAR	Appliance	Maint.	WOOD COST Purch	Grow	TOTAL	P.V.
0	$1,845		$7	$1.18	$1,861	$1,861
1			$7	$1.23	$17	$15
2			$7	$1.28	$8	$7
3			$7	$1.33	$8	$6
4			$7	$1.38	$8	$6
5		$20	$7	$1.43	$28	$18
6			$7	$1.48	$8	$5
7			$7	$1.53	$9	$5
8				$0.40	$0	$0
9				$0.40	$0	$0
10		$20		$0.40	$20	$9
11				$0.40	$0	$0
12				$0.40	$0	$0
13				$0.40	$0	$0
14				$0.40	$0	$0
15	$1,845			$0.40	$1,845	$507
16				$0.40	$0	$0
17				$0.40	$0	$0
18				$0.40	$0	$0
19				$0.40	$0	$0
20		$20		$0.40	$20	$4
21				$0.40	$0	$0
22				$0.40	$0	$0
23				$0.40	$0	$0
24				$1.57	$2	$0
25		$20		$1.57	$22	$3
26				$1.57	$2	$0
27				$1.57	$2	$0
28				$1.57	$2	$0
29				$1.57	$2	$0

NET PRESENT COST: $2,448

WITH OPPORTUNITY COST: $2,448

TEATREE ENERGY EXPENDITURE ANALYSIS: NON-RESIDENT.

MODEL ASSUMPTION : No teatree previously on land. **APPLIANCE:** Wamsler woodstove

0 OPPORTUNITY COST OF LABOUR

Opportunity cost options: Land used for other: 35%

Opp. cost of land: $5,866

Discount rate 9%

Rotation length: 17 yrs

			COOKING:				WATER HEATING				COMBINED			
YEAR	Appliance	Maint.	WOOD COST PURCH	GROW	TOTAL	P.V.	WOOD COST PURCH	GROW	TOTAL	P.V.	PURCH	GROW	TOTAL	P.V.
0	$7,074		$17		$7,108	$7,108	$53		$7,127	$7,127	$70		$7,144	$7,144
1			$17		$17	$16	$53		$53	$49	$70		$70	$64
2			$17		$17	$14	$53		$53	$45	$70		$70	$59
3			$17		$17	$13	$53		$53	$41	$70		$70	$54
4			$17		$17	$12	$53		$53	$37	$70		$70	$49
5		$20	$17		$37	$24	$53		$73	$47	$70		$90	$58
6			$17		$17	$10	$53		$53	$32	$70		$70	$42
7			$17		$17	$9	$53		$53	$29	$70		$70	$38
8			$17		$17	$9	$53		$53	$27	$70		$70	$35
9			$17		$17	$8	$53		$53	$24	$70		$70	$32
10		$20	$17		$37	$16	$53		$73	$31	$70		$90	$38
11			$17		$17	$7	$53		$53	$20	$70		$70	$27
12			$17		$17	$6	$53		$53	$19	$70		$70	$25
13			$17		$17	$6	$53		$53	$17	$70		$70	$23
14			$17		$17	$5	$53		$53	$16	$70		$70	$21
15		$20	$17		$37	$10	$53		$73	$20	$70		$90	$25
16			$17		$17	$4	$53		$53	$13	$70		$70	$18
17				$0	$0	$0		$0	$0	$0		$0	$0	$0
18				$0	$0	$0		$0	$0	$0		$0	$0	$0
19				$0	$0	$0		$0	$0	$0		$0	$0	$0
20		$20		$0	$20	$4		$0	$20	$4		$0	$20	$4
21				$0	$0	$0		$0	$0	$0		$0	$0	$0
22				$0	$0	$0		$0	$0	$0		$0	$0	$0
23				$0	$0	$0		$0	$0	$0		$0	$0	$0
24				$0	$0	$0		$0	$0	$0		$0	$0	$0
25		$20		$0	$20	$2		$0	$20	$2		$0	$20	$2
26				$0	$0	$0		$0	$0	$0		$0	$0	$0
27				$0	$0	$0		$0	$0	$0		$0	$0	$0
28				$0	$0	$0		$0	$0	$0		$0	$0	$0
29	($2,814)			$0	($2,814)	($231)		$0	($2,814)	($231)		$0	($2,814)	($231)
NET PRESENT COST:						$7,051				$7,368				$7,526
WITH OPPORTUNITY COST:						$7,051				$7,368				$7,526

TEATREE ENERGY EXPENDITURE ANALYSIS: NON-RESIDENT.

MODEL ASSUMPTION : No teatree previously on land.

0 OPPORTUNITY COST OF LABOUR

APPLIANCE: JAYLINE WOODFIRE

Discount rate	9%						
Rotation length:	17 yrs		**SPACEHEATING**				
YEAR	**Appliance**	**Maint.**	**WOOD COST PURCH**	**GROW**	**TOTAL**	**P.V.**	
0	$1,845		$7		$1,859	$1,859	
1			$7		$7	$6	
2			$7		$7	$6	
3			$7		$7	$5	
4			$7		$7	$5	
5		$20	$7		$27	$18	
6			$7		$7	$4	
7			$7		$7	$4	
8			$7		$7	$4	
9			$7		$7	$3	
10		$20	$7		$27	$11	
11			$7		$7	$3	
12			$7		$7	$2	
13			$7		$7	$2	
14			$7		$7	$2	
15	1845		$7		$1,852	$508	
16			$7		$7	$2	
17				$0	$0	$0	
18				$0	$0	$0	
19				$0	$0	$0	
20		$20		$0	$20	$4	
21				$0	$0	$0	
22				$0	$0	$0	
23				$0	$0	$0	
24				$0	$0	$0	
25		$20		$0	$20	$2	
26				$0	$0	$0	
27				$0	$0	$0	
28				$0	$0	$0	
29				$0	$0	$0	
NET PRESENT COST:						$2,451	
WITH OPPORTUNITY COST:						$2,451	

NON-RESIDENT FUELWOOD MODEL RESULTS.
WITH NO OPPORTUNITY COST OF LABOUR:

NET PRESENT COST OF HEAT LOAD FOR 30 YEARS

	COOKING		SPACE HEATING		WATER HEATING		COMBINATION	
APPLIANCE STATUS:	**WITH**	**W/O**	**WITH**	**W/O**	**WITH**	**W/O**	**WITH**	**W/O**
TEATREE FUELWOOD:								
NO PREV / NO OPP CST	$208	$7,051	$601	$2,446	$525	$7,368	$683	$7,526
NO PREV / OPP CST	$208	$7,051	$601	$2,446	$525	$7,368	$683	$7,526
PREV / NO OPP CST	$177	$7,020	$275	$2,120	$473	$7,316	$647	$7,490
PREV / OPP CST	$177	$7,020	$275	$2,120	$473	$7,316	$647	$7,490
EUCALYPTUS FUELWOOD:								
NO OPP CST	$201	$7,044	$603	$2,448	$461	$7,304	$630	$7,473
OPP COST.	$201	$7,044	$603	$2,448	$461	$7,304	$630	$7,473

FUELWOOD PRODUCTION COST ANALYSIS - RESIDENT
WAMSLER WOODSTOVE

0 OPPORTUNITY COST OF LABOUR OPTION

EUCALYPTUS SALIGNIA & BOTRYOIDES: 8 YEAR ROTATION CYCLE.
BASED ON 1HA ASSUMPTION:

PRODUCTION COSTS:

Tree cost	$1.00	Harvesting:	$0	/stere
Freight	$0.40	Cultivation	$200	/ha
Planting	$0.00	Maint.	$157	/ha/yr

YEAR	# TREES ON PLOT	PLANT COST	TREE COST	CULTV.	MAINT.	BIOMASS (STERES)	HARVEST COST	TOTAL (68 STERE/YR)	ACTUAL COSTS: 12.2 STERE/YR
0	313	0.0	437.5	25.0		0	0.0	462.5	$71.8
1	625	0.0	437.5	25.0	19.6	0	0.0	482.1	$74.8
2	938	0.0	437.5	25.0	39.2	0	0.0	501.7	$77.8
3	1250	0.0	437.5	25.0	58.8	0	0.0	521.3	$80.9
4	1563	0.0	437.5	25.0	78.3	0	0.0	540.8	$83.9
5	1875	0.0	437.5	25.0	97.9	0	0.0	560.4	$86.9
6	2188	0.0	437.5	25.0	117.5	0	0.0	580.0	$90.0
7	2500	0.0	437.5	25.0	137.1	0	0.0	599.6	$93.0
8	2500				156.7	78.63	0.0	156.7	$24.3
9	2500				156.7	78.63	0.0	156.7	$24.3
10	2500				156.7	78.63	0.0	156.7	$24.3
11	2500				156.7	78.63	0.0	156.7	$24.3
TO YR 23					1880.0	943.6	0.0	1880.0	$291.7
24	2500	0.0	437.5	25.0	156.7	78.6	0.0	619.2	$96.1
25	2500	0.0	437.5	25.0	156.7	78.6	0.0	619.2	$96.1
26	2500	0.0	437.5	25.0	156.7	78.6	0.0	619.2	$96.1
27	2500	0.0	437.5	25.0	156.7	78.6	0.0	619.2	$96.1
28	2500	0.0	437.5	25.0	156.7	78.6	0.0	619.2	$96.1
29	2500	0.0	437.5	25.0	156.7	78.6	0.0	619.2	$96.1
								$10,470	$1,624

EUCALYPTUS FUELWOOD ENERGY EXPENDITURE ANALYSIS: RESIDENT

APPLIANCE: WAMSLER WOODSTOVE, 0 OPPORTUNITY COST OF LABOUR

DISCOUNT RATE: 9%
ROTATION LENGTH (YRS): 8

			COOKING				WATER HEATING				
			WOOD COST				WOOD COST				
YEAR	Appliance	Maint.	Purch	Grow	TOTAL	P.V.	Purch	Grow	TOTAL	P.V.	COMBINED
0	$7,074		$98	$17	$7,306	$7,306	$306	$54	$7,434	$7,434	$7,666
1			$98	$18	$233	$214	$306	$57	$362	$332	$546
2			$98	$19	$117	$98	$306	$59	$365	$307	$405
3			$98	$20	$118	$91	$306	$61	$367	$283	$374
4			$98	$20	$118	$84	$306	$64	$389	$276	$360
5		$20	$98	$21	$139	$90	$306	$66	$391	$254	$332
6			$98	$22	$120	$71	$306	$68	$374	$223	$294
7			$98	$23	$121	$66	$306	$70	$376	$206	$272
8				$6	$6	$3		$18	$18	$9	$12
9				$6	$6	$3		$18	$38	$18	$20
10		$20		$6	$26	$11		$18	$38	$16	$19
11				$6	$6	$2		$18	$18	$7	$9
12				$6	$6	$2		$18	$18	$7	$9
13				$6	$6	$2		$18	$18	$6	$8
14				$6	$6	$2		$18	$18	$6	$7
15		$20		$6	$26	$7		$18	$38	$11	$12
16				$6	$6	$1		$18	$18	$5	$6
17				$6	$6	$1		$18	$18	$4	$6
18				$6	$6	$1		$18	$18	$4	$5
19				$6	$6	$1		$18	$18	$4	$5
20		$20		$6	$26	$5		$18	$38	$7	$8
21				$6	$6	$1		$18	$18	$3	$4
22				$6	$6	$1		$18	$18	$3	$4
23				$6	$6	$1		$18	$18	$3	$3
24				$96	$96	$12		$73	$73	$9	$21
25		$20		$96	$116	$13		$73	$93	$11	$22
26				$96	$96	$10		$73	$73	$8	$18
27				$96	$96	$9		$73	$73	$7	$16
28				$96	$96	$9		$73	$73	$7	$15
29	($2,814)			$96	($2,718)	($223)		$73	($2,741)	($225)	($217)
NET PRESENT COST:						$7,896				$9,241	$10,261
WITH OPPORTUNITY COST:						$7,896				$9,241	$10,261

FUELWOOD PRODUCTION COST ANALYSIS - RESIDENT
JAYLINE JUNIOR WOODFIRE

0 OPPORTUNITY COST OF LABOUR OPTION

EUCALYPTUS SALIGNIA & BOTRYOIDES: 8 YEAR ROTATION CYCLE.
BASED ON 1HA ASSUMPTION:

PRODUCTION COSTS:

Tree cost	$1.00	Harvesting:	$0 /stere
Freight	$0.40	Cultivation	$200 /ha
Planting	$0.00	Maint.	$157 /ha/yr

YEAR	# TREES ON PLOT	PLANT COST	TREE COST	CULTV.	MAINT.	BIOMASS (STERES)	HARVEST COST	TOTAL (68 STERE/YR)	ACTUAL COSTS: 1.1 STERE/YR
0	313	0.0	437.5	25.0		0	0.0	462.5	$6.5
1	625	0.0	437.5	25.0	19.6	0	0.0	482.1	$6.7
2	938	0.0	437.5	25.0	39.2	0	0.0	501.7	$7.0
3	1250	0.0	437.5	25.0	58.8	0	0.0	521.3	$7.3
4	1563	0.0	437.5	25.0	78.3	0	0.0	540.8	$7.6
5	1875	0.0	437.5	25.0	97.9	0	0.0	560.4	$7.8
6	2188	0.0	437.5	25.0	117.5	0	0.0	580.0	$8.1
7	2500	0.0	437.5	25.0	137.1	0	0.0	599.6	$8.4
8	2500				156.7	78.63	0.0	156.7	$2.2
9	2500				156.7	78.63	0.0	156.7	$2.2
10	2500				156.7	78.63	0.0	156.7	$2.2
11	2500				156.7	78.63	0.0	156.7	$2.2
TO YR 23					1880.0	943.6	0.0	1880.0	$26.3
24	2500	0.0	437.5	25.0	156.7	78.6	0.0	619.2	$8.7
25	2500	0.0	437.5	25.0	156.7	78.6	0.0	619.2	$8.7
26	2500	0.0	437.5	25.0	156.7	78.6	0.0	619.2	$8.7
27	2500	0.0	437.5	25.0	156.7	78.6	0.0	619.2	$8.7
28	2500	0.0	437.5	25.0	156.7	78.6	0.0	619.2	$8.7
29	2500	0.0	437.5	25.0	156.7	78.6	0.0	619.2	$8.7
								$10,470	$146

EUCALYPTUS FUELWOOD ENERGY EXPENDITURE ANALYSIS: RESIDENT

APPLIANCE: JAYLINE WOODFIRE

DISCOUNT RATE: 9%
ROTATION LENGTH (YRS): 8

SPACE HEATING

YEAR	Appliance	Maint.	WOOD COST Purch	Grow	TOTAL	P.V.
0	$1,845		$38	$6	$1,934	$1,934
1			$38	$7	$90	$82
2			$38	$7	$45	$38
3			$38	$7	$45	$35
4			$38	$8	$46	$32
5		$20	$38	$8	$66	$43
6			$38	$8	$46	$27
7			$38	$8	$46	$25
8				$2	$2	$1
9				$2	$2	$1
10		$20		$2	$22	$9
11				$2	$2	$1
12				$2	$2	$1
13				$2	$2	$1
14				$2	$2	$1
15	$1,845			$2	$1,847	$507
16				$2	$2	$1
17				$2	$2	$1
18				$2	$2	$0
19				$2	$2	$0
20		$20		$2	$22	$4
21				$2	$2	$0
22				$2	$2	$0
23				$2	$2	$0
24				$9	$9	$1
25		$20		$9	$29	$3
26				$9	$9	$1
27				$9	$9	$1
28				$9	$9	$1
29				$9	$9	$1

NET PRESENT COST: $2,754

WITH OPPORTUNITY COST: $2,754

TEATREE ENERGY EXPENDITURE ANALYSIS: RESIDENT.

MODEL ASSUMPTION : No teatree previously on land.
0 OPPORTUNITY COST OF LABOUR

APPLIANCE: Wamsler woodstove

Opportunity cost options:

Land used for other:	35%
Opp. cost of land:	$5,866

Discount rate	9%
Rotation length:	17 yrs

			COOKING:				WATER HEATING				COMBINED			
YEAR	Appliance	Maint.	WOOD COST PURCH	GROW	TOTAL	P.V.	WOOD COST PURCH	GROW	TOTAL	P.V.	PURCH	GROW	TOTAL	P.V.
0	$7,074		$98		$7,270	$7,270	$306		$7,380	$7,380	$404		$7,478	$7,478
1			$98		$98	$90	$306		$306	$280	$404		$404	$370
2			$98		$98	$83	$306		$306	$257	$404		$404	$340
3			$98		$98	$76	$306		$306	$236	$404		$404	$312
4			$98		$98	$69	$306		$306	$216	$404		$404	$286
5		$20	$98		$118	$77	$306		$326	$212	$404		$424	$275
6			$98		$98	$58	$306		$306	$182	$404		$404	$241
7			$98		$98	$54	$306		$306	$167	$404		$404	$221
8			$98		$98	$49	$306		$306	$153	$404		$404	$203
9			$98		$98	$45	$306		$306	$141	$404		$404	$186
10		$20	$98		$118	$50	$306		$326	$138	$404		$424	$179
11			$98		$98	$38	$306		$306	$118	$404		$404	$156
12			$98		$98	$35	$306		$306	$109	$404		$404	$144
13			$98		$98	$32	$306		$306	$100	$404		$404	$132
14			$98		$98	$29	$306		$306	$91	$404		$404	$121
15		$20	$98		$118	$32	$306		$326	$89	$404		$424	$116
16			$98		$98	$25	$306		$306	$77	$404		$404	$102
17				$0	$0	$0		$0	$0	$0		$0	$0	$0
18				$0	$0	$0		$0	$0	$0		$0	$0	$0
19				$0	$0	$0		$0	$0	$0		$0	$0	$0
20		$20		$0	$20	$4		$0	$20	$4		$0	$20	$4
21				$0	$0	$0		$0	$0	$0		$0	$0	$0
22				$0	$0	$0		$0	$0	$0		$0	$0	$0
23				$0	$0	$0		$0	$0	$0		$0	$0	$0
24				$0	$0	$0		$0	$0	$0		$0	$0	$0
25		$20		$0	$20	$2		$0	$20	$2		$0	$20	$2
26				$0	$0	$0		$0	$0	$0		$0	$0	$0
27				$0	$0	$0		$0	$0	$0		$0	$0	$0
28				$0	$0	$0		$0	$0	$0		$0	$0	$0
29	($2,814)			$0	($2,814)	($231)		$0	($2,814)	($231)		$0	($2,814)	($231)
NET PRESENT COST:						$7,887				$9,722				$10,635
WITH OPPORTUNITY COST:						$7,887				$9,722				$10,635

TEATREE ENERGY EXPENDITURE ANALYSIS: RESIDENT.

MODEL ASSUMPTION : No teatree previously on land.

0 OPPORTUNITY COST OF LABOUR

APPLIANCE: JAYLINE WOODFIRE

Discount rate	9%		**SPACEHEATING**			
Rotation length:	17 yrs					

YEAR	Appliance	Maint.	WOOD COST PURCH	GROW	TOTAL	P.V.
0	$1,845		$38		$1,921	$1,921
1			$38		$38	$35
2			$38		$38	$32
3			$38		$38	$29
4			$38		$38	$27
5		$20	$38		$58	$38
6			$38		$38	$23
7			$38		$38	$21
8			$38		$38	$19
9			$38		$38	$17
10		$20	$38		$58	$24
11			$38		$38	$15
12			$38		$38	$14
13			$38		$38	$12
14			$38		$38	$11
15	1845		$38		$1,883	$517
16			$38		$38	$10
17				$0	$0	$0
18				$0	$0	$0
19				$0	$0	$0
20		$20		$0	$20	$4
21				$0	$0	$0
22				$0	$0	$0
23				$0	$0	$0
24				$0	$0	$0
25		$20		$0	$20	$2
26				$0	$0	$0
27				$0	$0	$0
28				$0	$0	$0
29				$0	$0	$0

NET PRESENT COST: $2,771

WITH OPPORTUNITY COST: $2,771

RESIDENT FUELWOOD MODEL RESULTS.

WITH NO OPPORTUNITY COST OF LABOUR:

NET PRESENT COST OF HEAT LOAD FOR 30 YEARS

	COOKING		SPACE HEATING		WATER HEATING		COMBINATION	
APPLIANCE STATUS:	**WITH**	**W/O**	**WITH**	**W/O**	**WITH**	**W/O**	**WITH**	**W/O**
TEATREE FUELWOOD:								
NO PREV / NO OPP CST	$1,044	$7,887	$926	$2,771	$2,879	$9,722	$3,792	$10,635
NO PREV / OPP CST	$1,044	$7,887	$926	$2,771	$2,879	$9,722	$3,792	$10,635
PREV / NO OPP CST	$362	$7,205	$690	$2,535	$1,130	$7,973	$1,288	$8,131
PREV / OPP CST	$362	$7,205	$690	$2,535	$1,130	$7,973	$1,288	$8,131
EUCALYPTUS FUELWOOD:								
NO OPP CST	$1,053	$7,896	$909	$2,754	$2,398	$9,241	$3,418	$10,261
OPP COST.	$1,053	$7,896	$909	$2,754	$2,398	$9,241	$3,418	$10,261

APPENDIX 11.

SENSITIVITY ANALYSES - MODEL HOUSEHOLD 2.

- Spaceheating analysis;
- Waterheating analysis.

HOUSEHOLD 2 SPACEHEATING ANALYSIS
LPG HEATER VS LPG STOVE

APPLIANCE PERFORMANCE DATA:

Rating:	SPACE HEATER Consump. kg/hour	SPACE HEATER Output Kw	STOVE Consump. kg/hour	STOVE Output Kw
Medium	0.10	1.40	0.67	6.00

DERIVED FUEL USAGE RATES:

Annual hours of use	103.7	24.2
Kg fuel used/year:	10.8	16.3

MODEL VARIABLES:

FUEL PRICE/KG $2.00

DISCOUNT RATE 9%
ANNUITY RATE 10.2 TO YEAR 29

		SPACE HEATER ACT	SPACE HEATER PV	COOKER ACT	COOKER PV
Purchase Cost:	Appliance	120	120	0	0
Fuel Costs:	Yearly Fuel cost:	22		33	
	Cost for 30 yrs:		241		366
Replace/Maint. Costs:					
Yr 5:	Maint:	20	13	30	19
Yr 10:	Maint:	20	8	30	13
Yr 15:	Replace	120	33	0	0
	Maint:	20	5	30	8
Yr 20	Maint:	20	4	30	5
Yr 25:	Maint:	20	2	30	3
Yr 30:	Salvage	0	0	0	0
Net Present Cost :			$427		$415

HOUSEHOLD 2: WATERHEATING ANALYSIS
LPG WATER HEATER VS WATER BOILED ON LPG STOVE

APPLIANCE PERFORMANCE DATA:

Rating:	WATER HEATER Consump. kg/hour	WATER HEATER Output Kw	COOK TOP Consump. kg/hour	COOK TOP Output Kw
Medium	0.59	9.52	0.67	6.00

DERIVED FUEL USAGE RATES:

Annual hours of use	50.8	80.6
Kg fuel used/year:	30.0	54.4

MODEL VARIABLES:

FUEL PRICE/KG $2.00

DISCOUNT RATE 9%

ANNUITY RATE 10.2 TO YEAR 29

		WATER HEATER ACT	WATER HEATER PV	COOK TOP ACT	COOK TOP PV
Purchase Cost:	Appliance	649	649	0	0
Fuel Costs:	Yearly Fuel cost:	60		109	
	Cost for 30 yrs:		671		1218
Replace/Maint. Costs:					
Yr 5:	Maint:	20	13	30	19
Yr 10:	Maint:	20	8	30	13
Yr 15:	Replace	649	178	0	0
	Maint:	20	5	30	8
Yr 20	Maint:	20	4	30	5
Yr 25:	Maint:	20	2	30	3
Yr 30:	Salvage	0	0	0	0

Net Present Cost : **$1,531** **$1,268**

APPENDIX 12.

CLASS	% OF ALL RESPOND	HEATLOAD	% OF CLASS	CLEARANCE RESTRICTION SCENARIO NO RESTRICTIONS APPL	FUEL	COST	CLEARANCE AS A PERMITTED ACTIVITY APPL	FUEL	COST	COST OF COMPLY	CLEARANCE AS A DISCRETIONARY ACTIVITY	FUEL	COST	COST OF COMPLY
1	7%	ALL	45%	EXIST	TEATREE	$216	) EXIST	EUCAL	$787	$138	-	-	-	
			55%	EXIST	EUCAL	$433	)							
2	6%	COOK		EXIST	LPG	$446	-	-	-		-	-	-	
		S/HEAT	58%	EXIST	LPG	$241	-	-	-		-	-	-	
		W/HEAT		EXIST	LPG	$882	-	-	-		-	-	-	
3	5%	COOK		EXIST	LPG	$446	-	-	-		-	-	-	
		S/HEAT		NONE	NONE	$0	-	-	-		-	-	-	
		W/HEAT		EXIST	LPG	$1,268	-	-	-		-	-	-	
4	5%	COOK		EXIST	LPG	$446	-	-	-		-	-	-	
		S/HEAT		EXIST	TEATREE	$581	EXIST	EUCAL	$618		-	-	-	
		W/HEAT	50%	EXIST	LPG	$631	-	-	-		-	-	-	
			50%	EXIST	TEATREE	$224	EXIST	EUCAL	$579	$392	-	-	-	
5	4%	COOK & (	40%	EXIST	TEATREE	$217	EXIST	EUCAL	$315	$98	-	-	-	
		W/HEAT(	60%	EXIST	EUCAL	$472	-	-	-		-	-	-	
		S/HEAT		NEW	LPG	$427	-	-	-		-	-	-	
6	3%	ALL		EXIST	LPG	$1,635	-	-	-		-	-	-	
7	6%	ALL	58%	EXIST	TEATREE	$1,361	EXIST	EUCAL	$3,055	$1,769		PURCHTEA/GROW EU	$2,262	$402
			42%	EXIST	TEATREE	$2,137	EXIST	EUCAL	$2,212			PURCHTEA/GROW EU	$1,638	
8	5%	COOK		EXIST	LPG	$2,342	-	-	-		-	-	-	
		S/HEAT		EXIST	TEATREE	$805	EXIST	EUCAL	$988	$183	-	-	-	
		W/HEAT	45%	EXIST	EUCAL	$1,386	-	-	-		-	-	-	
			55%	NEW	LPG	$2,606	-	-	-		-	-	-	
9	4%	ALL	63%	EXIST	TEATREE	$1,038	EXIST	EUCAL	$2,674	$1,679		PURCHTEA/GROW EU	$1,820	$824
			37%	EXIST	TEATREE	$1,562	EXIST	EUCAL	$1,605			PURCHTEA/GROW EU	$1,604	
10	3%	ALL		EXIST LPG		$7,892	EXIST LPG		$7,892					
11	2%	COOK &												
		W/HEAT(		EXIST	TEATREE	$2,912	EXIST	EUCAL	$4,279			PURCHTEA/GROW EU	$3,339	$854
		S/HEAT		EXIST	TEATREE	$805	EXIST	EUCAL	$988			PURCHTEA/GROW EU	$1,232	
12	2%	COOK		EXIST	LPG	$2,342	-	-	-		-	-	-	
		S/HEAT		EXIST	TEATREE	$805	EXIST	EUCAL	$988					
		W/HEAT	50%	EXIST	LPG	$2,045	-	-	-		-	-	-	
			50%	EXIST	EUCAL	$1,540	-	-	-		-	-	-	