# DAIRY FARM

## Pateoroa Ranfurly Road

## Ranfurly

# FEASIBILITY STUDY FOR WOOD CHIP BOILER PURCHASE

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**Prepared by**

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building services design & commissioning

# FEASIBILITY STUDY FOR WOOD CHIP BOILER PURCHASE

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# 1 EXECUTIVE SUMMARY

This report has been commissioned by Murray Cowan of Bio-Energy Equipment Ltd to ascertain the viability of using a highly automated purpose-built wood chip type Low Temperature Hot Water (LTHW) boiler to provide hot water heating for a dairy shed wash down along with space heating and Domestic Hot Water (DHW) for nearby farm houses.

The dairy farm used in this case study is located on Pateoroa Ranfurly Road outside of Ranfurly in Central Otago. This farm is a new dairy conversion with a new shed proposed (referred to as 'new dairy shed') and two existing houses (referred to as 'homestead' and 'cottage') providing workers' accommodation. The homestead and cottage are located approximately 230 m and 100 m from the new dairy shed respectively. It is proposed that the LTHW boiler will be located in the old dairy shed (referred to as 'new boiler house') which is located between the new dairy shed, homestead and cottage.

The peak heat load for the dairy farm is 59 kW and the annual heating energy consumption is 98 MWh. The investment costs as well as the annual demand related costs (mainly fuel costs) and operation related costs for the different heating systems are shown in Table 1. When the boiler systems have been compared with the direct electricity heating system option there is no payback time for any boiler related heating system. Over a 15 year period, the cheapest boiler related system is the wood chip boiler when subsidised and the diesel boiler when not subsidised. The carbon tax (potential in future) at \$50/tonne$CO_2$ does not change the result.

***Table 1 Investment costs as well as demand and operation related costs for the different heating systems***

| ***Costs*** | **Unit** | **Wood chip** | **Pellet** | **Diesel** | **Electricity** |
|---|---|---|---|---|---|
| Investment costs excluding subsidy | [$] | 168,562 | 168,562 | 112,900 | 36,900 |
| Investment costs including subsidy | [$] | 142,062 | 142,062 | 112,900 | 36,900 |
| Annual demand and operation related costs | [$/year] | 8,798 | 15,216 | 13,825 | 15,076 |

For the new dairy shed, the annual energy consumption is too low to justify a boiler type heating system. Other options could be considered for the new dairy shed, e.g. a solar heating system and/or heat recovery from the milk storage cooling system.

For the homestead and cottage it is worth considering a pellet boiler system for house heating with a domestic type boiler for each house. Given the current market situation, a minimum annual energy consumption of approximately 200 MWh or a smaller investment cost of approximately $70,000 would be required to make this kind of wood chip boiler system feasible.

# 2 INTRODUCTION

This report has been commissioned by Murray Cowan of Bio-Energy Equipment Ltd to ascertain the viability of using a highly automated purpose-built wood chip type Low Temperature Hot Water (LTHW) boiler to provide hot water heating for dairy shed wash down along with space heating and Domestic Hot Water (DHW) for nearby farm houses.

The dairy farm used in this case study is located on Pateoroa Ranfurly Road outside of Ranfurly in Central Otago. This farm is a new dairy conversion with a new shed proposed (referred to as 'new dairy shed') and two existing houses (referred to as 'homestead' and 'cottage') providing workers' accommodation. The homestead and cottage are located approximately 230 m and 100 m from the new dairy shed respectively. It is proposed that the LTHW boiler will be located in the old dairy shed (referred to as 'new boiler house') which is located between the new dairy shed, homestead and cottage.

# 3 DAIRY FARM BUILDINGS

## 3.1 NEW DAIRY SHED

The new dairy shed is to be constructed shortly. It will require DHW for wash down every day from 15th of September to 31st of May each year. It is proposed the DHW will be heated via the boiler system. It is suggested that the new dairy shed be located 120 meters from the new boiler house.

## 3.2 HOMESTEAD

One accommodation building is a large old homestead of approximately 350 m² which is undergoing renovation. For this study, it is assumed the homestead is used for the farm owner's family accommodation. It is proposed the homestead would be heated via LTHW radiators. The DHW would also be heated via the boiler system. The homestead is located 110 meters from the new boiler house.

## 3.3 COTTAGE

The other accommodation building is a small cottage of approximately 120 m² which is also undergoing renovation. For this study, it is assumed the cottage is used as workers' accommodation for a couple, both of whom would be working on the farm during the day but would return at breakfast and lunch times for meals. It is proposed the cottage would be heated via LTHW radiators. The DHW would also be heated via the boiler system. The cottage is located 70 meters from the new boiler house.

# 4 PEAK HEAT LOAD

## 4.1 NEW DAIRY SHED

The total heat load demand for the new dairy shed is a combination of the heat load required to heat the water in the DHW tanks and the heat losses from the LTHW and DHW piping and storage systems. The DHW requirement for the new dairy shed is 1200 litres of water per day at 80 ºC from 15th of September to 31st of May each year. It is proposed that there will be four DHW tanks each with a capacity of 300 litres and a 6 kW heating coil inside, making the required heat load 24 kW. The heat loss throughout the LTHW and DHW systems is assumed to be accounted for by adding on a margin of 5% of the required heat load. Thus the total heat load requirement for the new dairy shed will be 25 kW.

## 4.2 HOMESTEAD AND COTTAGE

The total heat load demand for the homestead and cottage is a combination of the heat loss through the building thermal envelope (including outside air infiltration), the DHW heat load and the heat losses from the LTHW and DHW piping and storage systems. For the calculation of the peak heat load to the homestead and cottage, it is assumed that the maximum indoor temperature during heating is 21°C and the minimum outdoor temperature -9 °C (Table 2). For the calculation of the heat loss through the thermal envelope, it is assumed that after renovation the homestead and cottage will comply with the building code. Thus the new Clause H1 requirements using the minimum required R-values for the building elements have been used although the windows were assumed to be single glazed as it is unlikely these would be replaced (Table 3).

***Table 2 Assumed maximum indoor and minimum outdoor temperatures during heating***

| ***Temperatures*** | **Unit** | **Homestead** | **Cottage** |
|---|---|---|---|
| Maximum indoor temperature | [°C] | 21 | 21 |
| Minimum outdoor temperature | [°C] | -9 | -9 |
| **Difference** | **[°C]** | **30** | **30** |

*Table 3 R-values for the building elements*

| Thermal resistance (R-values) | Unit | Homestead | Cottage |
|---|---|---|---|
| 1 External roof [1] | [m²·°C/W] | 3.30 | 3.30 |
| 2 Skylights [1] | [m²·°C/W] | 0.34 | 0.34 |
| 3 External wall [1] | [m²·°C/W] | 2.00 | 2.00 |
| 4 External glazing | [m²·°C/W] | 0.15 | 0.15 |
| 5 Floor [1] | [m²·°C/W] | 1.30 | 1.30 |

[1] From reference [1]

The dimensions of the buildings and the areas of the building elements are shown in Table 4 and Table 5.

*Table 4 Building dimensions*

| Building dimensions | Unit | Homestead | Cottage |
|---|---|---|---|
| Perimeter of external walls | [m] | 100.0 | 48.0 |
| Space height | [m] | 3.0 | 3.0 |

*Table 5 Areas of the building elements*

| Areas of building elements | Unit | Homestead | Cottage |
|---|---|---|---|
| 1 External roof | [m²] | 350 | 120 |
| 2 Skylights | [m²] | 0 | 0 |
| 3 External wall | [m²] | 225 | 108 |
| 4 External glazing | [m²] | 75 | 36 |
| 5 Floor | [m²] | 350 | 120 |

For the air change of the homestead, it is assumed that the building air volume will be replaced every second hour through infiltration, kitchen and bathroom extracts. For the air change of the cottage, it is assumed that the building air volume will be replaced every hour through infiltration, kitchen and bathroom extracts. The air change rates are designed such that, even in mid-winter, a healthy indoor climate is achieved. The building volumes and air change rates for the homestead and cottage are shown in Table 6.

*Table 6 Building volumes and air change rates for the homestead and cottage*

| Specifications for air change | Unit | Homestead | Cottage |
|---|---|---|---|
| Space volume | [m³] | 1050 | 360 |
| Air change rate | [1/h] | 0.5 | 1 |

For the DHW, it is assumed that there is one DHW tank in the homestead and one in the cottage. The homestead and cottage DHW tank will have a capacity of 300 litres and a 6 kW heating coil inside. The peak heat load requirement for the coil is assumed to be 2.5 kW.

The heat loss throughout the LTHW and DHW piping and storage systems is assumed to be accounted for by adding on a margin of 5% of the required heat load. Thus the total heat load requirement with an outdoor temperature of -9 °C for the homestead and cottage will be 59 kW (Table 7).

*Table 7 Total heat load with an outdoor temperature of -9 °C for the homestead and cottage*

| ***Heat load requirement*** | **Unit** | **Homestead** | **Cottage** |
|---|---|---|---|
| Thermal envelope | [kW] | 29.6 | 12.7 |
| Air change | [kW] | 5.3 | 3.6 |
| Domestic hot water | [kW] | 2.5 | 2.5 |
| **Heat load** | **[kW]** | **37** | **19** |
| Margin | [%] | 5 | 5 |
| **Total heat load** | **[kW]** | **39** | **20** |

### 4.3 TOTAL HEAT LOAD FOR THE DAIRY FARM

The new dairy shed load does not need to be added to the peak heat load, because the new dairy shed does not operate in winter months when the house heating load is at its peak and the new dairy shed heat load can be controlled to occur during the day when the house heating load has dropped off. The new dairy shed DHW usage is greatest in the morning after milking. Therefore, we can assume the DHW heating load be controlled to take place between 10.30am and 3.30pm. Thus the total heat load for the dairy farm is 59 kW.

## 5 ANNUAL HEAT ENERGY CONSUMPTION

### 5.1 DESCRIPTION OF OPERATION CONTROLS

The new dairy shed DHW heating would be controlled to occur between 10.30am and 3.30pm when the house heat load has dropped off. The homestead and cottage DHW heating would be as and when required.

It is assumed the homestead heating would be controlled via a heating controller set up to heat to 21ºC from 4:00am to 10:00pm. Outside of these times the heating system should maintain a minimum set back temperature of 16ºC of the controller (centrally located).

It is assumed the cottage heating would be via a heating controller set up to heat to 21ºC from 4:00am to 8:00am and 11:00am to 1:00pm as well as from 4:00pm to 10:00pm. Outside of these times the heating system should maintain a minimum set back temperature of 16ºC of the controller (centrally located).

## 5.2 Energy Consumption

The DHW energy consumption for the dairy farm buildings is shown in Table 8. It is assumed that the homestead will be home to a five member family. The average daily DHW consumption per person is assumed to be 60 litres per day [2]. The total DHW energy consumption for the dairy farm in this case study is 34 MWh.

***Table 8 DHW energy consumption for the homestead, cottage and dairy shed***

| DHW energy consumption | Unit | Homestead | Cottage | Dairy shed | Total |
|---|---|---|---|---|---|
| Number of occupiers | | 5 | 2 | 0 | **7** |
| Average DHW consumption | [L/day] | 300 | 120 | 1200 | **1620** |
| DHW temperature | [°C] | 60 | 60 | 80 | N/A |
| Average cold water temperature | [°C] | 10 | 10 | 10 | N/A |
| **Annual DHW consumption** | **[MWh]** | **6.4** | **2.6** | **25.3** | **34** |

To determine the heat energy consumption of the homestead and cottage we need to define the following values:

- total heat loss per degree Celsius excluding DHW as well as solar and internal gains
- average annual indoor temperature
- average monthly outdoor temperature
- correction factor that takes into account the effect of solar and internal gains

For the homestead the total heat loss per degree Celsius excluding DHW as well as solar and internal gains is 1221 W/°C as Table 9 shows. For the cottage the total heat loss per degree Celsius excluding DHW as well as solar and internal gains is 570 W/°C as Table 9 shows.

***Table 9 Total heat loss per degree Celsius excluding DHW as well as solar and internal gains for the homestead and cottage***

| Heat loss | Unit | Homestead | Cottage |
|---|---|---|---|
| Thermal envelope | [W/°C] | 988 | 423 |
| Air change | [W/°C] | 175 | 120 |
| **Heat loss** | **[W/°C]** | **1163** | **543** |
| Margin | [%] | 5 | 5 |
| **Total heat loss** | **[W/°C]** | **1221** | **570** |

Table 10 shows the indoor average temperatures (when heating is required) that are calculated based on the controls described for the homestead and cottage heating.

***Table 10 Average indoor temperatures (when heating is required) for the homestead and cottage***

| Indoor temperature | Unit | Homestead | Cottage |
|---|---|---|---|
| Indoor average temperature | [°C] | 19.8 | 18.5 |

The calculated monthly DHW and space heating energy consumption for the dairy shed, homestead and cottage are shown in Table 11. The average monthly outdoor temperatures in Table 11 have come from the National Climate Database of NIWA [3]. The monthly temperatures are average temperatures from 2002 to 2007. The period represents the total hours in each month. The correction factor in Table 11 is used to allow for the reduction in peak heating load due to the effect of solar gains, heat gains from occupants and appliances, additional insulation at night with curtains pulled, lower set back temperature at night and some areas or rooms that would have heating turned off when not in use. The correction factor is based on experience with other houses. The heating season is anticipated to run from March to December for this study. Figure 1 shows the monthly energy consumption for the dairy farm.

*Table 11 Monthly heat energy consumption for the homestead, cottage and dairy shed and equivalent costs for direct electric heating at 15¢/kWh*

| **Description** | **Unit** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** | **Nov** | **Dec** | **Annual** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average outdoor temperature | [°C] | 14.9 | 14.1 | 12.4 | 8.7 | 5.7 | 3.1 | 2.3 | 4.0 | 7.3 | 8.3 | 10.7 | 13.0 | 8.7 |
| Period | [h] | 744 | 672 | 744 | 720 | 744 | 720 | 744 | 744 | 720 | 744 | 720 | 744 | 8760 |
| Correction factor | | 0.00 | 0.00 | 0.20 | 0.40 | 0.50 | 0.60 | 0.60 | 0.50 | 0.40 | 0.30 | 0.20 | 0.15 | N/A |
| ***Energy consumption of dairy shed and equivalant cost for direct electric heating at 15¢/kWh*** | | | | | | | | | | | | | | |
| **DHW of dairy shed** | **[MWh]** | **3.0** | **2.7** | **3.0** | **2.9** | **3.0** | | | | **1.5** | **3.0** | **2.9** | **3.0** | **25** |
| DHW of dairy shed | [$] | 456 | 412 | 456 | 441 | 456 | | | | 221 | 456 | 441 | 456 | 3,793 |
| ***Energy consumption of homestead and equivalant cost for direct electric heating at 15¢/kWh*** | | | | | | | | | | | | | | |
| Space heating of homestead | [MWh] | 0.0 | 0.0 | 1.3 | 3.7 | 6.1 | 8.4 | 9.1 | 6.8 | 4.2 | 3.0 | 1.5 | 0.9 | 45 |
| DHW of homestead | [MWh] | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 6 |
| **Total of homestead** | **[MWh]** | **0.5** | **0.5** | **1.8** | **4.2** | **6.6** | **8.9** | **9.6** | **7.3** | **4.7** | **3.5** | **2.1** | **1.4** | **51** |
| Total of homestead | [$] | 80 | 80 | 270 | 635 | 991 | 1,334 | 1,441 | 1,100 | 706 | 525 | 308 | 212 | 7,681 |
| ***Energy consumption of cottage and equivalant cost for direct electric heating at 15¢/kWh*** | | | | | | | | | | | | | | |
| Space heating of cottage | [MWh] | 0.0 | 0.0 | 0.5 | 1.5 | 2.6 | 3.6 | 3.9 | 2.9 | 1.8 | 1.2 | 0.6 | 0.3 | 19 |
| DHW of cottage | [MWh] | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 3 |
| **Total of cottage** | **[MWh]** | **0.2** | **0.2** | **0.7** | **1.7** | **2.8** | **3.8** | **4.1** | **3.1** | **2.0** | **1.4** | **0.8** | **0.5** | **22** |
| Total of cottage | [$] | 32 | 32 | 106 | 262 | 419 | 573 | 622 | 470 | 295 | 217 | 124 | 82 | 3,233 |
| ***Total energy consumption of dairy farm and equivalant cost for direct electric heating at 15¢/kWh*** | | | | | | | | | | | | | | |
| **Total of dairy farm** | **[MWh]** | **3.8** | **3.5** | **5.5** | **8.9** | **12.4** | **12.7** | **13.7** | **10.5** | **8.1** | **8.0** | **5.8** | **5.0** | **98** |
| Total of dairy farm | [$] | 567 | 523 | 832 | 1,338 | 1,865 | 1,908 | 2,062 | 1,570 | 1,221 | 1,198 | 872 | 750 | 14,707 |

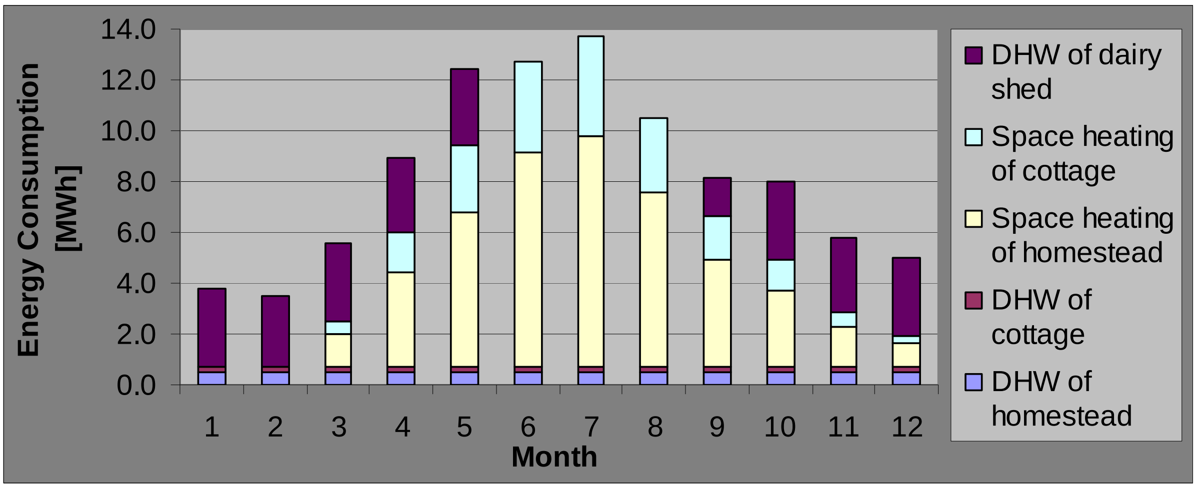


*Figure 1 Monthly energy consumption*

A summary of the heating energy consumption for the homestead, cottage and new dairy shed are shown in Table 19. The total heating energy consumption for the dairy farm is 98 MWh.

*Table 12 Annual heat energy consumptions for the homestead, cottage and dairy shed*

| ***Annual heating energy consumption*** | **Unit** | **Homestead** | **Cottage** | **Dairy shed** | **Total** |
|---|---|---|---|---|---|
| Domestic hot water | [MWh] | 6.4 | 2.6 | 25.3 | 34 |
| Space heating | [MWh] | 44.8 | 19.0 | 0.0 | 64 |
| **Total** | **[MWh]** | **51.2** | **21.6** | **25.3** | **98** |

# 6 ENERGY SOURCE

## 6.1 CHOICE OF ENERGY SOURCE

For this case study the energy source options are wood chips, pellets, diesel and electricity. In Table 13 the energy source densities and specific emissions are described. The specific emissions for the wood chips, pellets and diesel come from the Ministry for the Environment [4]. For the wood chips and pellets it is assumed that there are no $CO_2$ emissions because of the assumption that the $CO_2$ that is emitted from burning the wood is offset by the consumption of $CO_2$ by newly planted trees. The specific emissions for electricity generation were provided by Contact Energy.

*Table 13 Energy source specifications*

| **Description** | **Unit** | **Wood chip** | **Pellet** | **Diesel** | **Electricity** |
|---|---|---|---|---|---|
| Density | [kg/m³] | 200 | 650 | 850 | N/A |
| Specific emissions [1] | [T CO2/TJ] | 104 | 104 | 69 | 28 |
| Specific emissions | [tonne$CO_2$/MWh] | 0 | 0 | 0.247 | 0.100 |

[1] From reference [4]

For the electricity option, it is assumed electric elements would be need in DHW cylinders and electric heating would be used in place of radiators. The electric heating would be controlled via time switch system, each would be provided with thermostatic control.

## 6.2 NET CALORIFIC VALUE FOR WET FUEL

From the heat energy production point of view, the most important property of the fuel is the calorific value, which describes how many units of heat energy will be created when one unit of fuel is burned. The calorific value is possible to measure with a calorimeter. A calorimeter is a system in which a small amount of fuel with a defined weight is burned inside a closed heat conducting container which is immersed in water. Heat generated in the container is conducted into the water. The heat energy released into the water is measured and used to calculate the calorific value of the fuel.

When the fuel is burned in a calorimeter, water vapour is produced and condensates on the internal surface of the container in the calorimeter, which leads to further release of heat energy. For this reason, the calorimeter measures artificially high calorific values for fuels. For dry fuels (containing no water), water vapour is produced from the reaction combining hydrogen from the fuel and oxygen from the atmosphere. For wet fuels, water vapour is produced not only from this reaction but also from evaporation of residual water in the fuel. In real life, when fuel is burned in a heating boiler the resulting water vapour leaves through the chimney and does not contribute to the production of heat energy.[5]

The net calorific value is the best value to use, because it does not include the 'artificial' heat energy due to water vapour. The net calorific value is calculated by considering both the hydrogen and water content of the fuel, as follows:

$$NCV_{dry} = GCV_{dry} - 8.939 \cdot l_{H_2O} \cdot \frac{h}{100}, \text{ where} \qquad (1)$$

$NCV_{dry}$ = net calorific value for dry fuel, MJ/kg
$GCV_{dry}$ = gross calorific value for dry fuel, MJ/kg
$l_{H2O}$ = specific latent heat of vaporization of water at 25 ºC (2.443 MJ/kg)
h = concentration of hydrogen as percentage of weight (dry fuel).

$$NCV_{wet} = NCV_{dry} \cdot \left(1 - \frac{w}{100}\right) - l_{H_2O} \cdot \frac{w}{100}, \text{ where} \qquad (2)$$

$NCV_{wet}$ = net calorific value for wet fuel, MJ/kg
$CV_{dry}$ = net calorific value for dry fuel, MJ/kg
w = concentration of water as percentage of weight
$l_{H2O}$ = specific latent heat of vaporization of water at 25 ºC (2.443 MJ/kg). [5]

The hydrogen and water contents of wood chips and pellets are shown in Table 14. The gross calorific values for the wood chips and pellets come from the test report of CRL Energy Ltd [6]. The net calorific value for dry fuel is calculated using Equation 1 and the net calorific value for wet fuel using Equation 2.

*Table 14 Hydrogen and water content of the fuels as well as calorific values for different fuels*

| Description | Unit | Wood chip | Pellet | Diesel | Electricity |
|---|---|---|---|---|---|
| Hydrogen content [1] | [%] | 6.0 | 6.0 | N/A | N/A |
| Water content [1] | [%] | 30.0 | 8.0 | N/A | N/A |
| Gross calorific value for dry fuel [2] | [MJ/kg] | 20.4 | 20.4 | N/A | N/A |
| Net calorific value for dry fuel | [MJ/kg] | 19.1 | 19.1 | 45.0 | N/A |
| Net calorific value for wet fuel | [MJ/kg] | 12.6 | 17.3 | 43.1 | N/A |
| Net calorific value for wet fuel | [kWh/kg] | 3.5 | 4.8 | 12.0 | N/A |

[1] From reference [7]
[2] From reference [6]

### 6.3 FUEL CONSUMPTION

The annual wood chip, pellet and diesel boiler as well as electricity heater efficiencies and fuel consumptions are presented in Table 15. The table also contains the outputs for the wood chip, pellet and diesel boilers. The output for the boilers are 16 kW higher than the required peak heat load of the dairy farm. This excess is to allow for boiler heat up enough capacity for heating the homestead and cottage from a cold start. The annual volume of woodchips consumed is higher for wood chips than for pellets and especially diesel. This is because the wood chips have the lowest density and energy content (net calorific value for wet fuel), while these properties are the highest for diesel.

*Table 15 Outputs, annual average efficiencies and annual fuel consumptions for the wood chip, pellet and diesel boilers as well as electricity heaters*

| Description | Unit | Wood chip boiler | Pellet boiler | Diesel boiler | Electricity load |
|---|---|---|---|---|---|
| Output | [kW] | 75 | 75 | 75 | 59 |
| Annual average efficiency [1] | [%] | 80.0% | 80.0% | 89.0% | 100.0% |
| Annual fuel consumption | [MWh] | 123 | 123 | 110 | 98 |
| Annual fuel consumption | [$m^3$] | 175 | 39 | 11 | N/A |

[1] From reference [2]

## 7 COSTS

### 7.1 ENERGY SOURCE PRICES

The energy source prices are shown in Table 16. The water content of wood chips and pellets are based on Table 14 (the water content of the wood chips and pellets are 30% and 8%). The wood chips will come from Naseby because it is the closest wood chip supplier for the dairy farm.

*Table 16 Energy source prices excluding GST*

| Description | Unit | Wood chip [1] | Pellet [1] | Diesel [2] | Electricity [3] |
|---|---|---|---|---|---|
| Month price checked | | Dec 2008 | Dec 2008 | Dec 2008 | Dec 2008 |
| Price per volume | [$/m³] | 25 | 282 | 1039 | N/A |
| Price per mass | [$/tonne] | 126 | 434 | 1222 | N/A |
| Price per liter | [$/L] | N/A | N/A | 1.039 | N/A |
| Price per energy unit | [$/GJ] | 10.0 | 25.0 | 28.4 | 41.7 |
| Price per energy unit | [¢/kWh] | 3.6 | 9.0 | 10.2 | 15.0 |
| **Price** | **[$/MWh]** | **36** | **90** | **102** | **150** |

[1] From reference [8]
[2] From reference [9]
[3] From reference [10]

## 7.2 INVESTMENT COSTS

For this case study, an interest rate of 10% and an exhange rate of €0.40 for NZ$1 is used. The operating life is 15 years for the materials and installation and 30 years for the building. The capital recovery factor is used to calculate the annual capital costs from the investment costs. This is the same principle as for bank loans when the same amount is paid back each year. The annual repair costs of the investment costs are based on the Bioheat Final Report [11]. It is assumed that in New Zealand conditions the material annual repair costs are 1% of the total material investment costs. The installation repair costs are assumed to be 1% of the total intallation costs. The building annual repair costs are given as 0.5% of the total building work investment costs. The operating life, capital recovery factor and annual repair costs as a percentage of investment costs are shown in Table 17.

*Table 17 Operating life, capital recovery factor and annual repair costs on investment costs for the materials, installation and building*

| Description | Unit | Materials | Installation | Building |
|---|---|---|---|---|
| Operating life | [years] | 15 | 15 | 30 |
| Capital recovery factor [1] | [%] | 13.1 | 13.1 | 10.6 |
| Annual repair costs [1] | [%] | 1.0 | 1.0 | 0.5 |

[1] From reference [11]

The investment costs for the different heating systems are divided into the costs of the materials, installation (labour) and building work as Table 18 shows. Furthermore, the subsidy has been included for pellets and wood chips.

For the wood chip and pellet boiler systems the highest material costs are the boiler at $54,250 (based on a highly automated purpose-built wood chip type LTHW boiler) and the pipes under the ground between the buildings at $33,712. Together these costs total $87,962 (52% of the investment costs) and the total investment cost is $168,562 without subsidy. All costs exclude GST.

The heating pipes between buildings are based on Flexalen twin pipes (insulated flow and return inside same casing).

*Table 18 Investment costs for the different heating systems excluding GST*

| ***Materials*** | Unit | Wood chip | Pellet | Diesel | Electricity |
|---|---|---|---|---|---|
| New boiler price * | [$] | 54,250 | 54,250 | 5,888 | |
| Fuel handling system * (included in boiler price) | [$] | 0 | 0 | 2,800 | |
| Controls, etc. | [$] | 1,800 | 1,800 | 1,800 | 1,200 |
| Pumps, pipes, insulation materials, etc. | [$] | 4,000 | 4,000 | 4,000 | |
| Chimney | [$] | 1,500 | 1,500 | 1,000 | |
| Pipes DN40 at 2x110 m | [$] | 14,847 | 14,847 | 14,847 | |
| Pipes DN32 at 2x120 m | [$] | 13,444 | 13,444 | 13,444 | |
| Pipes DN25 at 2x70 m | [$] | 5,421 | 5,421 | 5,421 | |
| Radiator systems / electric heaters | [$] | 20,000 | 20,000 | 20,000 | 16,200 |
| DHW tank systems for houses (2x300L) | [$] | 5,000 | 5,000 | 5,000 | 3,200 |
| DHW tank systems in dairy shed (4x300L) | [$] | 10,000 | 10,000 | 10,000 | 6,400 |
| **Total material costs** | **[$]** | **130,262** | **130,262** | **84,200** | **27,000** |
| ***Installation (labour)*** | | | | | |
| New boiler * | [$] | 1,600 | 1,600 | 1,000 | |
| Fuel handling system * | [$] | 2,400 | 2,400 | 1,200 | |
| Controls, wiring, etc. | [$] | 1,200 | 1,200 | 800 | 800 |
| Pumps, pipes, insulation, etc. | [$] | 4,000 | 4,000 | 4,000 | |
| Chimney | [$] | 500 | 500 | 500 | |
| Pipes DN40 at 2x110 m | [$] | 2,200 | 2,200 | 2,200 | |
| Pipes DN32 at 2x120 m | [$] | 2,400 | 2,400 | 2,400 | |
| Pipes DN25 at 2x70 m | [$] | 1,400 | 1,400 | 1,400 | |
| Radiator systems / electric heaters | [$] | 8,000 | 8,000 | 8,000 | 6,000 |
| DHW tank systems for houses | [$] | 400 | 400 | 400 | 400 |
| DHW tank systemi for dairy shed | [$] | 600 | 600 | 600 | 600 |
| Fees | [$] | 4,000 | 4,000 | 3,000 | 1,500 |
| Commissioning | [$] | 1,600 | 1,600 | 1,400 | 600 |
| **Total installation (labour) costs** | **[$]** | **30,300** | **30,300** | **26,900** | **9,900** |
| ***Building work*** | | | | | |
| Boiler room modification * | [$] | 2,000 | 2,000 | 1,000 | |
| Fuel bunker * | [$] | 6,000 | 6,000 | 800 | |
| **Total building work costs** | **[$]** | **8,000** | **8,000** | **1,800** | **0** |
| | | | | | |
| **Total investment** | **[$]** | **168,562** | **168,562** | **112,900** | **36,900** |
| * = applicable for subsidy | [%] | 39 | 39 | 0 | 0 |
| Subsidy | [%] | 40 | 40 | 0 | 0 |
| **Total investment minus subsidy** | **[$]** | **142,062** | **142,062** | **112,900** | **36,900** |

## 7.3 Annual Costs

The annual costs are divided into the capital, demand related and operation related costs. The investment costs presented in Table 18 are converted into capital costs in Table 19 using the capital recovery factors from Table 17. For the demand related costs, the electricity costs include the pumps and electricity usage of the boiler. The repair costs of the material, installation and building in Table 19 are calculated using the annual repair cost percentages of the investment costs from Table 17. The cleaning cost of the chimney and boiler in Table 19 are calculated on the basis that the wood chip boiler needs to be cleaned 8 times per year, the pellet boiler 6 times per year and the diesel boiler once per year. It is assumed that the one boiler cleaning session takes 2 hours at $50/hr. For all boiler systems it is assumed that the chimney cleaning is undertaken once per year a rate of $400/clean. It is assumed the boiler maintenance takes place once per year. For the wood chip and pellet boiler the maintenance is more expensive because the fuel feeding and boiler cleaning systems include more parts that need maintenance.

*Table 19 Annual costs for the heating systems*

| ***Capital costs (interest + depreciation)*** | Unit | Wood chip | Pellet | Diesel | Electricity |
|---|---|---|---|---|---|
| Materials | [$/year] | 14,434 | 14,434 | 11,070 | 3,550 |
| Installation (labour) | [$/year] | 3,357 | 3,357 | 3,537 | 1,302 |
| Building work | [$/year] | 886 | 886 | 237 | 0 |
| **Total capital costs** | **[$/year]** | **18,677** | **18,677** | **14,843** | **4,851** |
| ***Demand related costs*** | | | | | |
| Annual fuel costs today | [$/year] | 4,412 | 11,030 | 11,246 | 14,707 |
| Electricity costs | [$/year] | 400 | 400 | 350 | N/A |
| **Total demand releted costs** | **[$/year]** | **4,812** | **11,430** | **11,596** | **14,707** |
| ***Operation related costs*** | | | | | |
| Repair cost of materials | [$/year] | 1,303 | 1,303 | 842 | 270 |
| Repair cost of installation | [$/year] | 303 | 303 | 269 | 99 |
| Repair cost of building | [$/year] | 80 | 80 | 18 | 0 |
| Cleaning cost of chimney and boiler | [$/year] | 1,200 | 1,000 | 500 | |
| Maintanence cost | [$/year] | 800 | 800 | 400 | |
| Insurance and other costs | [$/year] | 300 | 300 | 200 | |
| **Total operation related costs** | **[$/year]** | **3,986** | **3,786** | **2,229** | **369** |
| | | | | | |
| **Total annual costs** | **[$/a]** | **27,475** | **33,893** | **28,668** | **19,927** |
| **COSTS PER ENERGY UNIT** | **[$/MWh]** | **280** | **346** | **292** | **203** |
| **COST PER ENERGY UNIT** | **[¢/kWh]** | **28.0** | **34.6** | **29.2** | **20.3** |

# 8 SENSITIVITY ANALYSIS

The purpose of the sensitivity analysis is to find out which variables most affect the feasibility calculation. The different options of the sensitivity analysis are shown in Table 20.

*Table 20 Different options for the sensitivity analysis with energy consumption, subsidy for biomass (wood chip and pellet) boiler and carbon tax as variables*

| ***Variables*** | **Unit** | **Option 1 - base option** | **Option 2 - no subsidy** | **Option 3 - with carbon tax** | **Option 4 - +20% energy consumption** | **Option 5 - +100% energy consumption** |
|---|---|---|---|---|---|---|
| Energy consumption | [MWh] | 98 | 98 | 98 | 118 | 196 |
| Subsidy for biomass boiler | [%] | 40 | 0 | 40 | 40 | 40 |
| Carbon tax | [$/tonne$CO_2$] | 0 | 0 | 50 | 0 | 0 |

The sensitivity analysis is performed with reference to the direct electricity heating system. The investment costs for the wood chip, pellet and diesel heating systems are subtracted from the investment cost of the direct electricity heating system. The demand and operation related costs for the wood chip, pellet and diesel heating systems are subtracted from the demand and operation related costs of the direct electricity heating system. The differences between the investment costs for each boiler system and the direct electricity heating system for the different options are shown in Table 21. The annual savings in the energy and operating costs for the wood chip, pellet and diesel boiler heating systems compared to the electricity heating system are shown in Table 22.

***Table 21 Differences between the investment costs for each boiler system and the direct electricity heating system for the different options***

| Heating system | Unit | Option 1 - base option | Option 2 - no subsidy | Option 3 - with carbon tax | Option 4 - +20% energy consumption | Option 5 - +100% energy consumption |
|---|---|---|---|---|---|---|
| Wood chip boiler | [$] | -105,162 | -131,662 | -105,162 | -105,162 | -105,162 |
| Pellet boiler | [$] | -105,162 | -131,662 | -105,162 | -105,162 | -105,162 |
| Diesel boiler | [$] | -76,000 | -76,000 | -76,000 | -76,000 | -76,000 |
| Electricity load | [$] | 0 | 0 | 0 | 0 | 0 |

***Table 22 Annual savings in energy and operating costs for the wood chip, pellet and diesel boiler heating systems compared to the electricity heating system for the different options***

| Heating system | Unit | Option 1 - base option | Option 2 - no subsidy | Option 3 - with carbon tax | Option 4 - +20% energy consumption | Option 5 - +100% energy consumption |
|---|---|---|---|---|---|---|
| Wood chip boiler | [$/years] | 6,278 | 6,278 | 6,769 | 8,337 | 16,573 |
| Pellet boiler | [$/years] | -140 | -140 | 351 | 595 | 3,537 |
| Diesel boiler | [$/years] | 1,251 | 1,251 | 379 | 1,943 | 4,711 |

In this case study, based on a 10% interest rate and 15 year period, the project is feasible if the net present value is positive after 15 years. The net present values over 15 years for the different options are shown in Figures 2 to 6. These figures show that there is no positive net present values over the 15 years for any boiler related heating system when compared to the direct electricity heating system in options 1 to 4. For a reasonable payback time for the wood chip boiler heating system to be achieved, the energy consumption for the dairy farm should be approximately 200 MWh, as Figure 6 shows.


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*Figure 2 Net present values over 15 years for the Option 1*

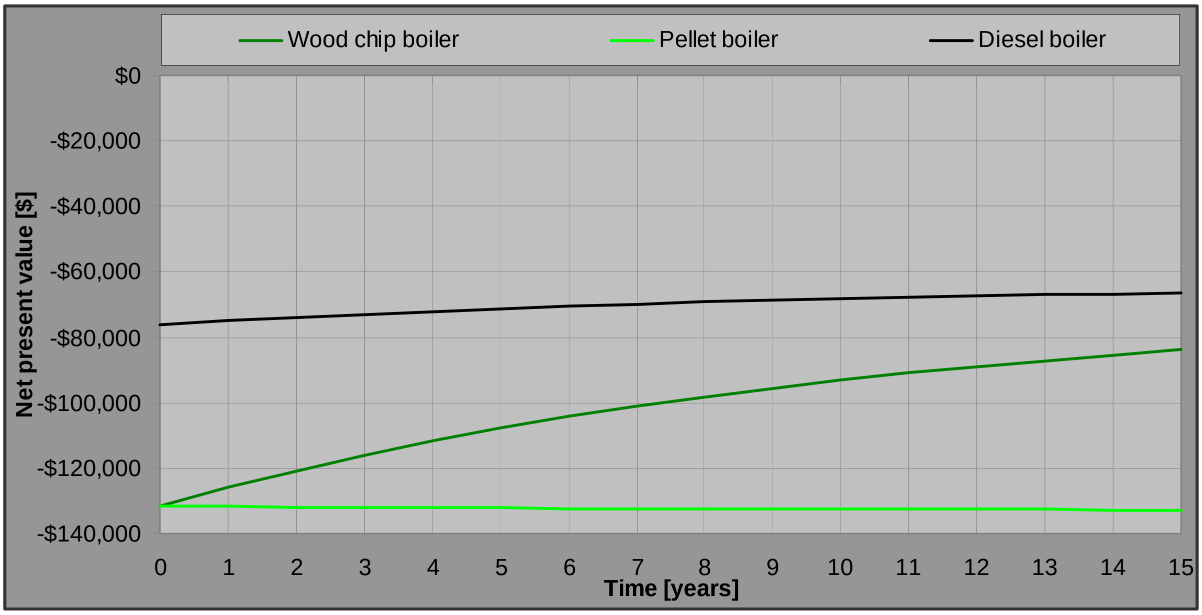


*Figure 3 Net present values over 15 years for the Option 2*


***Figure 4 Net present values over 15 years for the Option 3***


***Figure 5 Net present values over 15 years for the Option 4***

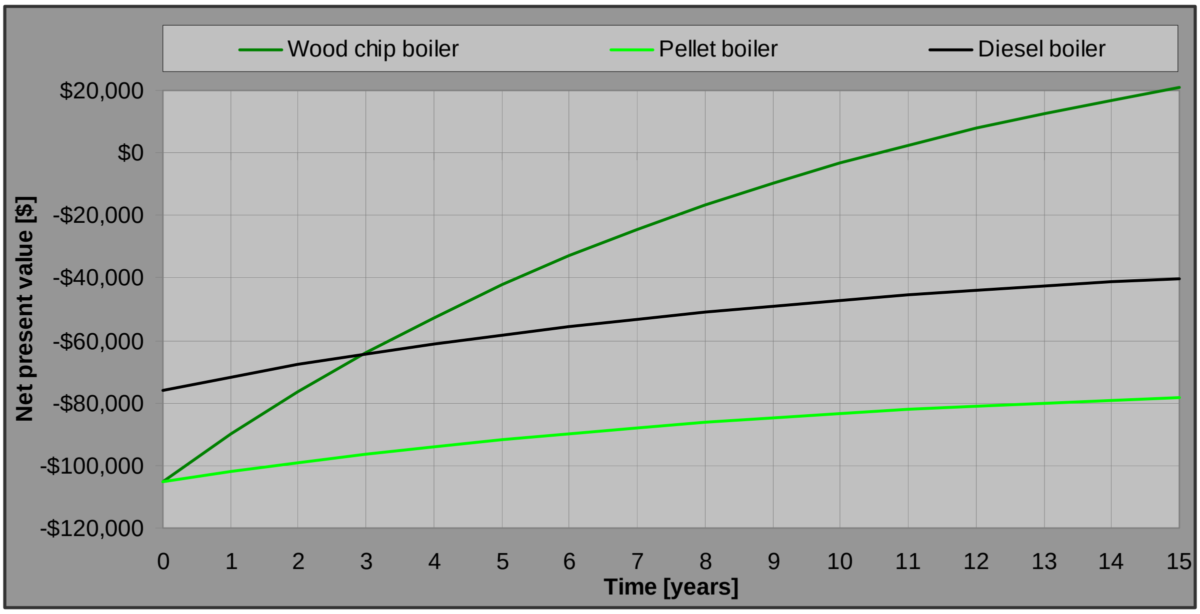


***Figure 6 Net present values over 15 years for the Option 5***

# 9 CONCLUSIONS

The investment cost for the highly automated purpose-built wood chip boiler system is too high for the size of this dairy farm. For a reasonable payback time for the wood chip boiler heating system to be achieved, the energy consumption for the dairy farm should be approximately 200 MWh (twice the estimated energy consumption in this case) or the investment costs should be approximately $70,000 smaller. Furthermore, the currently weak New Zealand currency does not encourage implementing the use of the almost fully automated high efficiency European biomass boilers.

For the new dairy shed, the annual energy consumption is too low to justify a boiler type heating system. Other options should be considered for the new dairy shed, e.g. a solar heating system and/or heat recovery from the milk storage cooling system. For the homestead and cottage it is still worth considering pellets for house heating with a domestic type boiler for each house. The small wood chip boilers are too expensive for the group of small buildings.

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## APPENDIX 1 NET PRESENT VALUES FOR OPTION 1

| **Option 1 - base option** | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Investment and annual savings for the boiler systems compared with direct electricity system without 10% interest over 15 years*** | | | | | | | | | | | | | | | | |
| Wood chip boiler | -$105,162 | $6,278 | $6,278 | $6,278 | $6,278 | $6,278 | $6,278 | $6,278 | $6,278 | $6,278 | $6,278 | $6,278 | $6,278 | $6,278 | $6,278 | $6,278 |
| Pellet boiler | -$105,162 | -$140 | -$140 | -$140 | -$140 | -$140 | -$140 | -$140 | -$140 | -$140 | -$140 | -$140 | -$140 | -$140 | -$140 | -$140 |
| Diesel boiler | -$76,000 | $1,251 | $1,251 | $1,251 | $1,251 | $1,251 | $1,251 | $1,251 | $1,251 | $1,251 | $1,251 | $1,251 | $1,251 | $1,251 | $1,251 | $1,251 |
| ***Investment and annual savings for the boiler systems compared with direct electricity system with 10% interest over 15 years*** | | | | | | | | | | | | | | | | |
| Wood chip boiler | -$105,162 | $5,707 | $5,188 | $4,717 | $4,288 | $3,898 | $3,544 | $3,222 | $2,929 | $2,662 | $2,420 | $2,200 | $2,000 | $1,819 | $1,653 | $1,503 |
| Pellet boiler | -$105,162 | -$127 | -$116 | -$105 | -$96 | -$87 | -$79 | -$72 | -$65 | -$59 | -$54 | -$49 | -$45 | -$41 | -$37 | -$34 |
| Diesel boiler | -$76,000 | $1,137 | $1,034 | $940 | $854 | $777 | $706 | $642 | $583 | $530 | $482 | $438 | $398 | $362 | $329 | $299 |
| ***Cumulative investment and annual savings for the boiler systems compared with direct electricity system without 10% interest over 15 years*** | | | | | | | | | | | | | | | | |
| Wood chip boiler | -$105,162 | -$98,884 | -$92,606 | -$86,328 | -$80,049 | -$73,771 | -$67,493 | -$61,215 | -$54,937 | -$48,659 | -$42,381 | -$36,103 | -$29,825 | -$23,547 | -$17,269 | -$10,991 |
| Pellet boiler | -$105,162 | -$105,302 | -$105,442 | -$105,581 | -$105,721 | -$105,861 | -$106,001 | -$106,141 | -$106,281 | -$106,421 | -$106,561 | -$106,701 | -$106,841 | -$106,981 | -$107,121 | -$107,261 |
| Diesel boiler | -$76,000 | -$74,749 | -$73,498 | -$72,248 | -$70,997 | -$69,747 | -$68,496 | -$67,245 | -$65,995 | -$64,744 | -$63,494 | -$62,243 | -$60,992 | -$59,742 | -$58,491 | -$57,241 |
| ***Net present values for the boiler systems compared with direct electricity system with 10% interest over 15 years*** | | | | | | | | | | | | | | | | |
| Wood chip boiler | -$105,162 | -$99,454 | -$94,266 | -$89,549 | -$85,261 | -$81,363 | -$77,819 | -$74,598 | -$71,669 | -$69,006 | -$66,586 | -$64,385 | -$62,385 | -$60,567 | -$58,913 | -$57,410 |
| Pellet boiler | -$105,162 | -$105,289 | -$105,405 | -$105,510 | -$105,605 | -$105,692 | -$105,771 | -$105,843 | -$105,908 | -$105,968 | -$106,022 | -$106,071 | -$106,115 | -$106,156 | -$106,193 | -$106,226 |
| Diesel boiler | -$76,000 | -$74,863 | -$73,829 | -$72,890 | -$72,035 | -$71,259 | -$70,553 | -$69,911 | -$69,328 | -$68,797 | -$68,315 | -$67,877 | -$67,478 | -$67,116 | -$66,787 | -$66,487 |

## APPENDIX 2 NET PRESENT VALUES FOR OPTION 2

| **Option 2 - no subsidy** | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Investment and annual savings for the boiler systems compared with direct electricity system without 10% interest over 15 years*** | | | | | | | | | | | | | | | | |
| Wood chip boiler | -$131,662 | $6,278 | $6,278 | $6,278 | $6,278 | $6,278 | $6,278 | $6,278 | $6,278 | $6,278 | $6,278 | $6,278 | $6,278 | $6,278 | $6,278 | $6,278 |
| Pellet boiler | -$131,662 | -$140 | -$140 | -$140 | -$140 | -$140 | -$140 | -$140 | -$140 | -$140 | -$140 | -$140 | -$140 | -$140 | -$140 | -$140 |
| Diesel boiler | -$76,000 | $1,251 | $1,251 | $1,251 | $1,251 | $1,251 | $1,251 | $1,251 | $1,251 | $1,251 | $1,251 | $1,251 | $1,251 | $1,251 | $1,251 | $1,251 |
| ***Investment and annual savings for the boiler systems compared with direct electricity system with 10% interest over 15 years*** | | | | | | | | | | | | | | | | |
| Wood chip boiler | -$131,662 | $5,707 | $5,188 | $4,717 | $4,288 | $3,898 | $3,544 | $3,222 | $2,929 | $2,662 | $2,420 | $2,200 | $2,000 | $1,819 | $1,653 | $1,503 |
| Pellet boiler | -$131,662 | -$127 | -$116 | -$105 | -$96 | -$87 | -$79 | -$72 | -$65 | -$59 | -$54 | -$49 | -$45 | -$41 | -$37 | -$34 |
| Diesel boiler | -$76,000 | $1,137 | $1,034 | $940 | $854 | $777 | $706 | $642 | $583 | $530 | $482 | $438 | $398 | $362 | $329 | $299 |
| ***Cumulative investment and annual savings for the boiler systems compared with direct electricity system without 10% interest over 15 years*** | | | | | | | | | | | | | | | | |
| Wood chip boiler | -$131,662 | -$125,384 | -$119,106 | -$112,828 | -$106,549 | -$100,271 | -$93,993 | -$87,715 | -$81,437 | -$75,159 | -$68,881 | -$62,603 | -$56,325 | -$50,047 | -$43,769 | -$37,491 |
| Pellet boiler | -$131,662 | -$131,802 | -$131,942 | -$132,081 | -$132,221 | -$132,361 | -$132,501 | -$132,641 | -$132,781 | -$132,921 | -$133,061 | -$133,201 | -$133,341 | -$133,481 | -$133,621 | -$133,761 |
| Diesel boiler | -$76,000 | -$74,749 | -$73,498 | -$72,248 | -$70,997 | -$69,747 | -$68,496 | -$67,245 | -$65,995 | -$64,744 | -$63,494 | -$62,243 | -$60,992 | -$59,742 | -$58,491 | -$57,241 |
| ***Net present values for the boiler systems compared with direct electricity system with 10% interest over 15 years*** | | | | | | | | | | | | | | | | |
| Wood chip boiler | -$131,662 | -$125,954 | -$120,766 | -$116,049 | -$111,761 | -$107,863 | -$104,319 | -$101,098 | -$98,169 | -$95,506 | -$93,086 | -$90,885 | -$88,885 | -$87,067 | -$85,413 | -$83,910 |
| Pellet boiler | -$131,662 | -$131,789 | -$131,905 | -$132,010 | -$132,105 | -$132,192 | -$132,271 | -$132,343 | -$132,408 | -$132,468 | -$132,522 | -$132,571 | -$132,615 | -$132,656 | -$132,693 | -$132,726 |
| Diesel boiler | -$76,000 | -$74,863 | -$73,829 | -$72,890 | -$72,035 | -$71,259 | -$70,553 | -$69,911 | -$69,328 | -$68,797 | -$68,315 | -$67,877 | -$67,478 | -$67,116 | -$66,787 | -$66,487 |

## APPENDIX 3 NET PRESENT VALUES FOR OPTION 3

| **Option 3 - with carbon tax** | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Investment and annual savings for the boiler systems compared with direct electricity system without 10% interest over 15 years*** | | | | | | | | | | | | | | | | |
| Wood chip boiler | -$105,162 | $6,769 | $6,769 | $6,769 | $6,769 | $6,769 | $6,769 | $6,769 | $6,769 | $6,769 | $6,769 | $6,769 | $6,769 | $6,769 | $6,769 | $6,769 |
| Pellet boiler | -$105,162 | $351 | $351 | $351 | $351 | $351 | $351 | $351 | $351 | $351 | $351 | $351 | $351 | $351 | $351 | $351 |
| Diesel boiler | -$76,000 | $379 | $379 | $379 | $379 | $379 | $379 | $379 | $379 | $379 | $379 | $379 | $379 | $379 | $379 | $379 |
| ***Investment and annual savings for the boiler systems compared with direct electricity system with 10% interest over 15 years*** | | | | | | | | | | | | | | | | |
| Wood chip boiler | -$105,162 | $6,153 | $5,594 | $5,085 | $4,623 | $4,203 | $3,821 | $3,473 | $3,158 | $2,871 | $2,610 | $2,372 | $2,157 | $1,961 | $1,782 | $1,620 |
| Pellet boiler | -$105,162 | $319 | $290 | $263 | $240 | $218 | $198 | $180 | $164 | $149 | $135 | $123 | $112 | $102 | $92 | $84 |
| Diesel boiler | -$76,000 | $344 | $313 | $285 | $259 | $235 | $214 | $194 | $177 | $161 | $146 | $133 | $121 | $110 | $100 | $91 |
| ***Cumulative investment and annual savings for the boiler systems compared with direct electricity system without 10% interest over 15 years*** | | | | | | | | | | | | | | | | |
| Wood chip boiler | -$105,162 | -$98,393 | -$91,624 | -$84,856 | -$78,087 | -$71,318 | -$64,550 | -$57,781 | -$51,012 | -$44,244 | -$37,475 | -$30,707 | -$23,938 | -$17,169 | -$10,401 | -$3,632 |
| Pellet boiler | -$105,162 | -$104,811 | -$104,460 | -$104,110 | -$103,759 | -$103,408 | -$103,058 | -$102,707 | -$102,356 | -$102,006 | -$101,655 | -$101,304 | -$100,954 | -$100,603 | -$100,252 | -$99,902 |
| Diesel boiler | -$76,000 | -$75,621 | -$75,242 | -$74,863 | -$74,484 | -$74,105 | -$73,726 | -$73,347 | -$72,968 | -$72,589 | -$72,210 | -$71,831 | -$71,452 | -$71,073 | -$70,694 | -$70,315 |
| ***Net present values for the boiler systems compared with direct electricity system with 10% interest over 15 years*** | | | | | | | | | | | | | | | | |
| Wood chip boiler | -$105,162 | -$99,008 | -$93,414 | -$88,329 | -$83,706 | -$79,503 | -$75,682 | -$72,209 | -$69,051 | -$66,181 | -$63,571 | -$61,199 | -$59,042 | -$57,082 | -$55,299 | -$53,679 |
| Pellet boiler | -$105,162 | -$104,843 | -$104,553 | -$104,290 | -$104,050 | -$103,832 | -$103,634 | -$103,454 | -$103,291 | -$103,142 | -$103,007 | -$102,884 | -$102,772 | -$102,671 | -$102,578 | -$102,494 |
| Diesel boiler | -$76,000 | -$75,655 | -$75,342 | -$75,057 | -$74,798 | -$74,563 | -$74,349 | -$74,155 | -$73,978 | -$73,817 | -$73,671 | -$73,538 | -$73,418 | -$73,308 | -$73,208 | -$73,117 |

## APPENDIX 4 NET PRESENT VALUES FOR OPTION 4

| **Option 4 - +20% energy consumption** | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Investment and annual savings for the boiler systems compared with direct electricity system without 10% interest over 15 years*** | | | | | | | | | | | | | | | | |
| Wood chip boiler | -$105,162 | $8,337 | $8,337 | $8,337 | $8,337 | $8,337 | $8,337 | $8,337 | $8,337 | $8,337 | $8,337 | $8,337 | $8,337 | $8,337 | $8,337 | $8,337 |
| Pellet boiler | -$105,162 | $595 | $595 | $595 | $595 | $595 | $595 | $595 | $595 | $595 | $595 | $595 | $595 | $595 | $595 | $595 |
| Diesel boiler | -$76,000 | $1,943 | $1,943 | $1,943 | $1,943 | $1,943 | $1,943 | $1,943 | $1,943 | $1,943 | $1,943 | $1,943 | $1,943 | $1,943 | $1,943 | $1,943 |
| ***Investment and annual savings for the boiler systems compared with direct electricity system with 10% interest over 15 years*** | | | | | | | | | | | | | | | | |
| Wood chip boiler | -$105,162 | $7,579 | $6,890 | $6,264 | $5,694 | $5,177 | $4,706 | $4,278 | $3,889 | $3,536 | $3,214 | $2,922 | $2,656 | $2,415 | $2,195 | $1,996 |
| Pellet boiler | -$105,162 | $541 | $492 | $447 | $407 | $370 | $336 | $306 | $278 | $252 | $230 | $209 | $190 | $172 | $157 | $143 |
| Diesel boiler | -$76,000 | $1,766 | $1,606 | $1,460 | $1,327 | $1,206 | $1,097 | $997 | $906 | $824 | $749 | $681 | $619 | $563 | $512 | $465 |
| ***Cumulative investment and annual savings for the boiler systems compared with direct electricity system without 10% interest over 15 years*** | | | | | | | | | | | | | | | | |
| Wood chip boiler | -$105,162 | -$96,825 | -$88,488 | -$80,151 | -$71,814 | -$63,477 | -$55,140 | -$46,803 | -$38,466 | -$30,129 | -$21,792 | -$13,455 | -$5,118 | $3,219 | $11,556 | $19,893 |
| Pellet boiler | -$105,162 | -$104,566 | -$103,971 | -$103,375 | -$102,780 | -$102,185 | -$101,589 | -$100,994 | -$100,399 | -$99,803 | -$99,208 | -$98,612 | -$98,017 | -$97,422 | -$96,826 | -$96,231 |
| Diesel boiler | -$76,000 | -$74,057 | -$72,114 | -$70,171 | -$68,229 | -$66,286 | -$64,343 | -$62,401 | -$60,458 | -$58,515 | -$56,572 | -$54,630 | -$52,687 | -$50,744 | -$48,802 | -$46,859 |
| ***Net present values for the boiler systems compared with direct electricity system with 10% interest over 15 years*** | | | | | | | | | | | | | | | | |
| Wood chip boiler | -$105,162 | -$97,583 | -$90,692 | -$84,429 | -$78,735 | -$73,558 | -$68,852 | -$64,574 | -$60,685 | -$57,149 | -$53,935 | -$51,013 | -$48,356 | -$45,941 | -$43,746 | -$41,750 |
| Pellet boiler | -$105,162 | -$104,620 | -$104,128 | -$103,681 | -$103,274 | -$102,905 | -$102,569 | -$102,263 | -$101,985 | -$101,733 | -$101,503 | -$101,295 | -$101,105 | -$100,932 | -$100,776 | -$100,633 |
| Diesel boiler | -$76,000 | -$74,233 | -$72,628 | -$71,168 | -$69,841 | -$68,635 | -$67,539 | -$66,542 | -$65,635 | -$64,811 | -$64,062 | -$63,382 | -$62,763 | -$62,200 | -$61,688 | -$61,223 |

# APPENDIX 5 NET PRESENT VALUES FOR OPTION 5

| Option 5 - +100% energy consumption | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Investment and annual savings for the boiler systems compared with direct electricity system without 10% interest over 15 years*** | | | | | | | | | | | | | | | | |
| Wood chip boiler | -$105,162 | $16,573 | $16,573 | $16,573 | $16,573 | $16,573 | $16,573 | $16,573 | $16,573 | $16,573 | $16,573 | $16,573 | $16,573 | $16,573 | $16,573 | $16,573 |
| Pellet boiler | -$105,162 | $3,537 | $3,537 | $3,537 | $3,537 | $3,537 | $3,537 | $3,537 | $3,537 | $3,537 | $3,537 | $3,537 | $3,537 | $3,537 | $3,537 | $3,537 |
| Diesel boiler | -$76,000 | $4,711 | $4,711 | $4,711 | $4,711 | $4,711 | $4,711 | $4,711 | $4,711 | $4,711 | $4,711 | $4,711 | $4,711 | $4,711 | $4,711 | $4,711 |
| ***Investment and annual savings for the boiler systems compared with direct electricity system with 10% interest over 15 years*** | | | | | | | | | | | | | | | | |
| Wood chip boiler | -$105,162 | $15,066 | $13,696 | $12,451 | $11,319 | $10,290 | $9,355 | $8,504 | $7,731 | $7,028 | $6,389 | $5,809 | $5,281 | $4,801 | $4,364 | $3,967 |
| Pellet boiler | -$105,162 | $3,215 | $2,923 | $2,657 | $2,416 | $2,196 | $1,996 | $1,815 | $1,650 | $1,500 | $1,364 | $1,240 | $1,127 | $1,024 | $931 | $847 |
| Diesel boiler | -$76,000 | $4,283 | $3,894 | $3,540 | $3,218 | $2,925 | $2,659 | $2,418 | $2,198 | $1,998 | $1,816 | $1,651 | $1,501 | $1,365 | $1,241 | $1,128 |
| ***Cumulative investment and annual savings for the boiler systems compared with direct electricity system without 10% interest over 15 years*** | | | | | | | | | | | | | | | | |
| Wood chip boiler | -$105,162 | -$88,589 | -$72,016 | -$55,444 | -$38,871 | -$22,298 | -$5,726 | $10,847 | $27,420 | $43,992 | $60,565 | $77,138 | $93,710 | $110,283 | $126,856 | $143,429 |
| Pellet boiler | -$105,162 | -$101,625 | -$98,088 | -$94,551 | -$91,015 | -$87,478 | -$83,941 | -$80,405 | -$76,868 | -$73,331 | -$69,795 | -$66,258 | -$62,721 | -$59,184 | -$55,648 | -$52,111 |
| Diesel boiler | -$76,000 | -$71,288 | -$66,577 | -$61,866 | -$57,155 | -$52,444 | -$47,732 | -$43,021 | -$38,310 | -$33,599 | -$28,888 | -$24,176 | -$19,465 | -$14,754 | -$10,043 | -$5,332 |
| ***Net present values for the boiler systems compared with direct electricity system with 10% interest over 15 years*** | | | | | | | | | | | | | | | | |
| Wood chip boiler | -$105,162 | -$90,096 | -$76,399 | -$63,948 | -$52,628 | -$42,338 | -$32,983 | -$24,479 | -$16,748 | -$9,719 | -$3,330 | $2,479 | $7,759 | $12,560 | $16,924 | $20,891 |
| Pellet boiler | -$105,162 | -$101,946 | -$99,024 | -$96,366 | -$93,951 | -$91,755 | -$89,758 | -$87,943 | -$86,294 | -$84,794 | -$83,430 | -$82,191 | -$81,064 | -$80,039 | -$79,108 | -$78,261 |
| Diesel boiler | -$76,000 | -$71,717 | -$67,823 | -$64,284 | -$61,066 | -$58,140 | -$55,481 | -$53,064 | -$50,866 | -$48,868 | -$47,051 | -$45,400 | -$43,899 | -$42,534 | -$41,294 | -$40,166 |