Central Otago District Council
Central Otago Heat Pump Home Heating Report

Assessment Report

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1 Executive Summary

Opus International Consultants (Opus) was commissioned to advise the Central Otago District Council on the merit of heat pumps as the sole heating source to replace wood/multifuel burners in an average 1980's Central Otago home, under the Otago Regional Council Air Plan requirements now and in the future.

The construction type for a Central Otago home from that time period consist of timber frame with minimal insulation and single glazed windows. The assessment considered both two and three bedroom homes with varying orientations.

Central Otago has some of the most extreme climate on mainland New Zealand. It is characterised by:

- Hot summers
- Cold dry winters
- A predominantly dry westerly wind flow.
- Low air humidity

The temperatures to be encountered by the sole heating source ranges from

External Conditions

Summer 29.4˚C
Winter -5.3˚C (minimum low temperatures of approximately -12˚C)

Indoor Conditions

Temperature 21°C

Based on Central Otago conditions dwellings require between 5.5 kW and 11 kW of heating during the winter season. Currently, there are several heat pump models available from local retailers which will provide heating in central Otago winter conditions.

There are simple building improvements over the base model which can reduce heat loss and improve the thermal efficiency of houses. These include:

- Installing/upgrading insulation
- Double glazing
- Draft control

Opus makes the following recommendations in order to maximise sole heating source's efficiency:

a) Upgrade roof and wall insulation with wool or fibreglass to reduce heat loss and energy consumption.

b) Upgrade windows to double glazed windows.

2 Introduction

2.1 General

Opus International Consultants (Opus) was commissioned to advise the Central Otago District Council on the merit of heat pumps as the sole heating source to replace wood/multifuel burners in an average 1980's Central Otago home, under the Otago Regional Council Air Plan requirements now and in the future.

This report discusses the assessment of mechanical services, updated from the original report written in 2008.

The report includes some discussion on the various types of modifications that could be made to a home to improve the efficiency of the sole heating source.

2.2 Building Description

The buildings of concern are average single storey Alexandra stock houses of typical 1980s summerhill stone. Based on the New Zealand Standards NZS 3604:1981 used for the homes concerned in this assessment, it is expected that the average Alexandra stock house of the time period mentioned above, would consist of the following:

- Timber frame building
- Single glazed windows
- Wall construction: face brick with inner gypsum wall, separated by a 50 mm gap with no extra insulation
- Carpeted concrete floor

This assessment considers both two and three bedroom homes with a gross floor area of approximately 114 m^2 and 134 m^2.

2.3 Design Conditions

Central Otago has some of the most extreme climate on South Island New Zealand. It is characterised by:

- Hot summers
- Cold dry winters
- A predominantly dry westerly wind flow.
- Low air humidity

The buildings of concern for this assessment are located within Central Otago in Alexandra. The temperatures to be encountered by the sole heating source ranges from

2.3.1 External Conditions

Summer	29.4˚C
Winter	-5.3˚C (peak low temperatures of approximately -12˚C)

2.3.2 Indoor Conditions

Temperature 21°C

3 Mechanical Services

3.1 Design Requirements

Further to Section 2.3, the following applies:

3.1.1 Design Standards

The following design standards and codes will be used in undertaking the assessment:

- AS/NZS 3823:2005 Performance of electrical appliances
- NZS 3604:2006 Timber Framed Buildings
- NZS 4218:2004 Energy Efficiency – Small Building Envelope
- New Zealand Building Code

3.1.2 Objectives

The Central Otago District Council has a set of minimum standards for energy efficiency and sustainability that apply to this assessment. These standards are based on the Minimum Energy Performance Standards (MEPS) and the Energy Efficiency and Conservation Authority (EECA) guidelines for certain products such as heat pumps. Heat pumps must comply with these standards for energy efficiency along with the standards set by Standards New Zealand.

The CODC requirements have been compiled to achieve a high level of electrical energy efficiency and minimal environmental foot print. These are summarised as:

(i) Determine appropriate heat pump system based on economic feasibility.

(ii) Achieve specified design conditions.

(iii) Utilise energy efficient equipment.

(iv) Minimise electricity usage – comply with AS/NZS 3823 and MEPS/EECA recommendations.

Current MEPS requirements for split system heat pumps are an Annualised Coefficient of Performance of 3.66 for heat pumps under 4 kW and 3.22 for heat pumps from 4 to 10 kW. The Coefficient of Performance is a rating of refrigeration equipment efficiency according to the ratio of heat output to electrical power input. The COP varies with seasonal temperatures so the annualised efficiency is its estimated overall performance through the year.

3.2 Design Features

3.2.1 Heating, Ventilation and Air Conditioning (HVAC) Requirements

A series of preliminary simulations of the building, and its environment, was generated in order to better determine the thermal comfort requirements. The building is expected to require approximately 5.5 kW of heating for the common living space for a two bedroom house and approximately 6 kW of heating for the common living space for a three bedroom house to maintain the desired conditions within the building. Should it be desired to heat the entire home, instead of just the common living space, a two bedroom house would then require approximately 9.5 kW of heating compared to approximately 11 kW of heating for a three bedroom home.

3.3 Assessment Discussion

3.3.1 Requirements

As explained in section 3.2.1, an average 1980's Central Otago home would require between approximately 5.5 and 11 kW of heating during the winter season based on the orientation of the house, quality of the construction and the improvements made to the house (e.g. ceiling insulation, wall insulation and floor insulation).

3.3.2 Building Improvements

Although this report focuses on the use of air conditioning units as the sole energy source for Central Otago houses, there are simple improvements over the base model which can reduce heat loss. These improvements include:

- Installing/upgrading insulation
- Double glazing
- Draft control (reduction of outside air infiltration)

According to NZS 4218:2004, the Standard specifies minimum thermal energy performance requirements for buildings to achieve an adequate standard of energy efficiency. The rating of thermal resistance of a building element (e.g. wall, floor or roof) is referred to as the R-value. The minimum R-values required by this Standard will provide economic benefits relative to an uninsulated building. The higher levels of insulation provide a higher R-value which provides further benefits. As part of this assessment, a list was drawn of potential improvements to a typical 1980's Central Otago stock house. These are summarised below:

(i) Ceiling insulation (fibreglass or wool).

(ii) Wall insulation (fibreglass or wool).

(iii) Double glazed windows.

Should these changes be made to a Central Otago home, it is estimated that properly installing wall and ceiling insulation would improve the thermal resistance of the building by 14 to 25%. As a simple lower cost measure, installation of insulation is the best option for improving the thermal efficiency of any building.

Furthermore, should double glazed windows be added in addition to the wall and ceiling insulation, the thermal resistance of the building could improve by 20 to 30%

Both insulation and double glazing improve thermal efficiency. They also reduce the infiltration of outside air.

Infiltration is outside air leaking into the building, which is balanced by inside air leaking out. The heating required for incoming outside air and the loss of warm interior air is a significant building heat load. Therefore reduction of air leakage can significantly improve comfort and reduce heating loads.

3.3.3 Effect of External Conditions on Performance

Air conditioning units use a gas with low boiling point characteristics to transfer energy, based on reversible Rankine thermodynamic cycle. The refrigerant gas employed in these systems changes state as it travels round the circuit between the indoor and outdoor units as a result of the temperature difference between the gas and the environments.

In heating mode, the indoor unit receives hot gas from the outdoor unit. The gas changes state to a liquid in the indoor unit giving up heat to the interior space. The liquid refrigerant returns to the outdoor unit.

In the outdoor unit the liquid refrigerant changes back to a vapour by taking in energy from the external environment. This is possible because the liquid refrigerant is generally colder than the surrounding air. The refrigerant, now a gas, travels to the indoor unit.

As the outdoor conditions get close to the temperature of the refrigerant the efficiency of the cycle reduces. Consequently, in winter extreme cold reduces the amount of heat available to the indoor unit.

The normal operating temperature range of many low cost A/C units is quite high in NZ terms, some as high as 0℃. Some units, sold predominantly in the North Island, are rated for -5℃, which would stop working in the Central South Island winters.

Therefore we have assumed the design condition should be -12℃ for the Central Otago region. There is data demonstrating low temperatures lower than this, as low as -15℃. In this case the indoor units would not be able to achieve the design indoor conditions, but approximately 2-3℃ less, around 18-19℃. For most users this reduction would be acceptable.

3.4 Costs

3.4.1 Capital cost

The cost of a heatpump for domestic use can range from $2,500 to $5,000 depending on its kW rating.

This above does not include installation cost, which is estimated at $500 to $1,600 depending on complexity.

3.4.2 Operating costs

The thermal model was used to estimate the annual energy consumption for the subject houses, then approximate annual heating costs.

Electrical power costs were based on a rate of $0.33 / kW-hr plus a line charge of $1.00 per day. This is based on an 'anytime/24hour' charge rate without prompt payment discount.

Annual energy demand for two- and three-bedroom houses calculated by the thermal model is shown in the table below. Many houses are heated by a single heat pump which heats only the lounge, kitchen and dining areas of the house. This situation is also presented in the table.

Energy consumption and costs for a three-bedroom house, insulated and double-glazed, to show the approximate savings achievable with energy-saving renovations.

House	Whole House heating (kW-hr)	Annual Power costs	Lounge, Kitchen heating (kW-hr)	Annual Power costs
2-Bedroom Standard	9,965	$1,456	5,281	$940
3-Bedroom Standard	14,398	$1,943	7,617	$1,197
3-Bedroom Insulated	6,159	$1,037	3,258	$718

Also for comparison the table below provides costs of heating with firewood and wood pellets and heat pump electrical power costs. The comparison is for lounge-kitchen heating rather than whole-house, since a single wood fire or pellet fire is presumed to be typical. The wood fire is presumed to be a modern clean-burner with 70% efficiency, the pellet fire 80% efficient.

House	Lounge, Kitchen heating (kW-hr)	Annual Power costs	Firewood	Wood Pellets
2-Bedroom Standard	5281	$940	$833	$384
3-Bedroom Standard	7,617	$1,197	$1,202	$554

While the fire wood alternative is significantly cheaper, despite its lower efficiency, it is much less controllable or convenient. For the lower cost, much more input in the form of handling and stockpiling the fire wood, is required of the user.

3.4.3 Availability in Central Otago Region

Both Mitsubishi Electric and Daikin offer domestic heat pump systems able to provide heating at the minimum temperature design of -12°C. Mitsubishi's

Hypercore series demonstrates performance at its rated capacity at -15°C, and continues to provide heating to -25°C. Information on these systems is available on their web sites:

Mitsubishi Electric http://www.mitsubishi-electric.co.nz/heatpump/

Daikin www.daikin.co.nz/home-solutions

Hypercore www.mitsubishi-electric.co.nz/heatpump/group.aspx?cat=7665

When selecting systems for the local region the following must be considered in the information provided by the suppliers:

- External operating conditions
- Internal operating conditions
- Refrigerant gas type, should be R407 or R410
- Outdoor unit power requirements
- Filter type and location
- Condensate drainage requirements for the indoor unit

4 Conclusion

The assessment results suggest that it is possible to install heat pumps in the Central Otago region while keeping a coefficient of performance that is above the requirements set by New Zealand Standards. Though the heating efficiency of heat pumps decreases with lower temperatures, Daikin and Mitsubishi offer solutions that could adequately heat an Alexandra home at temperatures of -12˚C.

Opus also makes the following building recommendations to maximise the heating efficiency:

Upgrade roof and wall insulation with wool or fibreglass to reduce heat loss and energy consumption.

Upgrade windows to double glazed windows.

Appendix A – Two Bedroom House Model

The following table was generated in order to better determine the thermal comfort requirements and represents a series of simulations of the building and its environment. In this model, a house with a single bedroom, a double bedroom, bathroom, living room, dining room and kitchen was modelled. Each alternative represents a different orientation of the house and each column represents different types of improvements that could be made to the house in order to improve its thermal resistance.

2 Bedroom House					
Alternative	**Room**	**Std Heating (kW)**	**Wall Heating (kW)**	**Dbl Glaze Heating (kW)**	**Wall and Dbl Glaze Heating (kW)**
1 - House with Living room, dining room and kitchen facing East					
	Bathroom	1.10	0.83	0.98	0.70
	Double Bdrm	2.13	1.75	1.87	1.48
	Kitchen/Dining	2.73	2.32	2.35	1.93
	Living Room	2.05	1.39	1.79	1.43
	Single Bedroom	1.15	0.73	1.00	0.87
2 - House with Living room, dining room and kitchen facing North					
	Bathroom	1.29	0.98	1.15	0.85
	Double Bdrm	1.98	1.63	1.72	1.36
	Kitchen/Dining	3.00	2.55	2.61	2.16
	Living Room	2.04	1.67	1.76	1.40
	Single Bedroom	0.88	0.78	0.76	0.66
3 - House with Living room, dining room and kitchen facing West					
	Bathroom	1.29	0.98	1.15	0.85
	Double Bdrm	2.00	1.65	1.74	1.39
	Kitchen/Dining	2.76	2.34	2.38	1.94
	Living Room	2.02	1.65	1.75	1.39
	Single Bedroom	1.10	0.97	0.96	0.84
4 - House with Living room, dining room and kitchen facing South					
	Bathroom	1.36	1.03	1.22	0.90
	Double Bdrm	2.09	1.72	1.83	1.45
	Kitchen/Dining	2.62	2.22	2.24	1.83
	Living Room	2.00	1.64	1.74	1.38
	Single Bedroom	1.11	0.98	0.97	0.84

Appendix B – Three Bedroom House Model

The following table was generated in order to better determine the thermal comfort requirements and represents a series of simulations of the building and its environment. In this model, a house with two single bedrooms, a double bedroom, bathroom, living room, dining room and kitchen was modelled. Each alternative represents a different orientation of the house and each column represents different types of improvements that could be made to the house in order to improve its thermal resistance.

3 Bedroom House					
Alternative	**Room**	**Heating (kW)**	**Wall Heating (kW)**	**Dbl Glaze Heating (kW)**	**Wall and Dbl Glaze Heating (kW)**
1 - House with Living room, dining room and kitchen facing East					
	Bathroom	0.79	0.72	0.66	0.66
	Double Bdrm	2.06	1.69	1.80	1.80
	Kitchen/Dining	3.30	2.76	2.92	2.92
	Living Room	2.50	2.14	2.11	2.11
	Single Bedroom 1	1.22	0.95	1.09	1.09
	Single Bedroom 2	0.87	0.77	0.75	0.75
2 - House with Living room, dining room and kitchen facing North					
	Bathroom	0.64	0.58	0.50	0.45
	Double Bdrm	2.18	1.78	1.91	1.52
	Kitchen/Dining	3.09	2.57	2.70	2.19
	Living Room	2.62	2.23	2.21	1.83
	Single Bedroom 1	1.32	1.02	1.18	0.89
	Single Bedroom 2	0.90	0.79	0.77	0.66
3 - House with Living room, dining room and kitchen facing West					
	Bathroom	0.83	0.78	0.68	0.64
	Double Bdrm	2.14	1.81	1.86	1.54
	Kitchen/Dining	3.41	2.60	3.00	2.20
	Living Room	2.35	2.06	1.95	1.66
	Single Bedroom 1	1.11	0.86	0.98	0.74
	Single Bedroom 2	0.92	0.85	0.79	0.71
4 - House with Living room, dining room and kitchen facing South					
	Bathroom	0.81	0.72	0.67	0.59
	Double Bdrm	2.06	1.69	1.81	1.43
	Kitchen/Dining	3.39	2.82	3.00	2.43
	Living Room	2.41	2.05	2.01	1.65
	Single Bedroom 1	1.29	1.00	1.15	0.86
	Single Bedroom 2	0.80	0.70	0.67	0.58