EVH3 - Impact of Housing on Health in Dunedin NZ

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Authors: Sarah Shannon, Bob Lloyd, Jacob Roos and Jan Kohlmeyer

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1. Aim of the study

There is a large body of evidence that suggests a link between poor housing and ill health. The primary objective of this study is to assess the condition of the housing stock in the Dunedin City Council area with regard to the health of its occupants and to identify areas which may benefit from improvement. A general profile of housing in Dunedin City is presented. This profile examines the age and cost of Dunedin housing in comparison to other cities in New Zealand. Specific areas in Dunedin which are particularly sun-deprived are identified. A further in-depth survey of 91 student houses and flats is carried out in order to establish a base-line of thermal conditions in this generally considered poor housing sector. In addition the seasonal variation of mortality data for Dunedin is compared with the national average.

2. Health affects of poor housing and inadequate energy supplies

The main function of a residential house is to shield the interior environment from the vagaries of the local weather conditions and to provide the inhabitants with a generally safer and more pleasant environment than may exist outside. Specific factors that affect health include the integrity of the building fabric itself, water and air supply and the energy use within the building. This report will concentrate on the aspects surrounding energy supply and thermal comfort of the interior of residential housing as applicable to Dunedin, New Zealand. Water supply and waste removal also have energy implications but these are largely external to the building itself and so will not be considered.

Specific areas where energy supply impinges on health issues (Healthabitat, 1993) are:

- Temperature control (space heating/ air conditioning)
- Washing people (hot water supply)
- Washing clothes and bedding (hot water supply)
- Removing waste (building integrity /external energy supply)
- Adequate water supply (building integrity/external energy supply)
- Nutrition - ability to cook healthy food (stoves, ovens and refrigerators)
- Reducing trauma - safety issues with energy supplies (gas, electricity, coal & wood)
- Ensuring adequate air quality (building fabric integrity and thermal conditions i.e. mould)

The World Health Organization suggests three different thermal zones that are significant for health. Around 18°C is believed to be a comfortable temperature while 16°C or below increases the risk of respiratory diseases. Below 12 °C the risk of cardiovascular strain is increased (World Health Organization, 1987).

Considerable research has looked at the thermal conditions of housing relating to health of the occupants, with much of the research being conducted in Europe and the US. In Britain around 40,000 more deaths are reported in the winter months than at other times of the year. A study by Wilkinson et al. (2001) investigated whether this large winter excess of deaths could be ascribed to poorly insulated housing. The results of the study found that the magnitude of excess winter deaths was greater for people living in poorly heated dwellings. The deaths were also associated with the age of the residential property, the risk being greatest in dwellings built before 1850, and lowest in the more energy-efficient dwellings built after 1980. The most common cause of death was heart attacks and strokes, occurring predominately in the over 65 age group category.

In NZ, Issacs and Donn looked at the seasonal dependence of mortality in NZ in a 1993 study. Their conclusions were that NZ had relatively greater seasonality of mortality than the more extreme climates of the UK, US, Japan or Sweden. This work, together with later work by Issacs and others at the Building Research Association of New Zealand (BRANZ) as part of their Housing Energy Efficiency Project (HEEP) has laid the foundations for understanding indoor temperatures in NZ. Unfortunately data for the South Island has not yet been reported on by these investigators. Current research is underway at Otago University by the Energy Management Group to look at indoor temperatures in a sample of public housing (Shen and Lloyd, 2003).

Indoor air quality is reduced in poorly ventilated housing and has been shown to be linked with respiratory problems such as asthma. Tobacco smoke, cooking and dust mites contribute to the total amount of airborne particles found in the house. Because of their small size these particles are readily inhaled by the lungs and may induce an allergic reaction in some people. Inadequate heating produces damp conditions which promotes the growth of mould and fungi spores. This type of living condition has been linked to respiratory problems such as asthma and bronchitis. Children are more susceptible to these symptoms than adults. A study carried out in Glasgow, Scotland investigated the health of children in low damp, moderately damp and high damp housing. The highest number of symptoms such as wheezing, sore throat, tiredness, and coughing experienced per child occurred in the dampest houses (The Scottish Office Central Research Unit, 1999).

A study by Kock et al. (2002) investigated the relationship between the occurrence of respiratory problems such as wheezing and asthma in relation to housing. The participants were asked whether they had experienced wheezing, shortness of breath or asthma attacks in the past year. Information on housing characterises was gathered such as the age of dwelling, floor covering, heating type and weather they had experienced any water damage to the home that would encourage the growth of mould. The study sampled the populations of 38 different countries including New Zealand. A significant association between mould exposure and adult asthma was found which was consistent across all the countries sampled.

The effects of cold damp housing may be made worse for people on incomes so low that they cannot afford to heat their homes to an adequate level. This situation, sometimes known as fuel poverty, is thought likely to be similar to the case study of student flats i.e. low income and old damp housing stock in the student quarter of Dunedin. The difference in the present case study is that the population is largely young and not in the aged risk categories. In the UK the definition of fuel poverty has been quantified. A household is in fuel poverty if, in order to maintain a satisfactory heating regime, it would be required to spend more than 10% of its income on all household fuel use. In this definition, a 'satisfactory heating regime' is defined as one that achieves 21° C in the living room, and 18° C in the other occupied rooms.

The majority of research in this area has been focused on the impact of poor housing on physical well being. However, inadequate housing may also contribute to mental health problems. A study by Kearns et al., (1991) investigated the association between housing difficulty and mental health in New Zealand. State housing in two major cities, Auckland and Christchurch was considered. Housing difficulty was characterized in various different ways. The income of the occupants and the number of children in the house was considered together with the level of satisfaction with the housing. A questionnaire also asked the participations about the state of repair of the house and problems they considered hazardous to their health. All these factors were combined into a single figure index representing housing difficulty. Psychological stress in the participants was identified using standard health questionnaires. The findings revealed a relationship between housing difficulty and psychological stress. However, it is noted that the relationship was not clear cut and that may other issues lead to psychological stress. Colds, flu and asthma were also correlated with housing difficulty in both cities.

The impact of poor housing comes with a financial cost to the economy. The immediate effect of this impact is the cost to the health services for medical treatment. The number of days spent out of work due to sickness is also increased. A study by Ambrose, (2002) investigated the heath of residents in an area of London before and after a housing regeneration project. Two surveys were carried out, the first in 1996 before a regeneration project and the second in 2000 after. Prior to the regeneration, about half of the rooms were damp and almost three quarters of the population reported that the heating system did not heat the house to a comfortable level. One in three people experienced days when they were ill to a degree requiring a visit to the GP or medication. After the regeneration only one in twenty people reported illness days; a seven-fold improvement. In terms of hospital expenses, it was estimated that the annual healthcare cost was £515 per household prior to the upgrade, in contrast to £72 for the 'control group' households.

As mentioned previously, an adequate clean water supply is crucial for maintaining good health. The water supply in New Zealand is graded by the Public Health Service using the Ministry of Health Drinking Water Standards, however, compliance with these standards is not mandatory. Dunedin City has a water grade of 'Ed' where E means that the source and treatment are completely unsatisfactory and d represents the distribution mechanism, which is also unsatisfactory. Nevertheless, there does not seem to be a high level of microbiological illness that would be expected with this grading. Waste water is disposed of by a system of sewer pipes that were originally built in 1860 and have since been developed and expanded. This report will not further investigate the health problems associated with water supply and wastewater disposal.

3. Housing and Energy Use in NZ

A recent IEA report (Schipper, et al, 2000) suggested that: "By 1995 New Zealand had the lowest space heating intensity (measured as energy per square meter per degree day) of all the countries studied, even including Japan and was about half of Australian levels." The report continued: "It seems unlikely in practice that comfort levels are so low in New Zealand. Possible data problems with wood may partly explain this apparent discrepancy". The data they used was correct. Residential energy use in New Zealand for 1995 was around 17 GJ/capita/annum compared to around 35 GJ/capita/annum in Australia, 30 GJ/capita/annum in Europe and 54 GJ/capita/annum in the US. The low values for NZ residential energy use reflect low levels of space heating. Houses in NZ are energy efficient, in the respect that they use little energy, but poorly heated. In addition with the population being mostly located in the north of the North Island the national average does not reflect conditions in the south, which has considerably greater house heating needs. For example, Auckland has around 1,150 heating degree days compared to Christchurch at 2,400, Dunedin at 2,500 and Invercargill at 3,000 degree days (the base temperature used is 18 $^{\circ}$C).

Several energy efficiency programs are currently underway or at research stage in New Zealand in order to remedy the situation in terms of providing healthy housing and at the same time reducing greenhouse gas emissions. The Government of New Zealand is currently pursuing a national program to improve the energy efficiency of public housing. This housing upgrade project, undertaken by Housing New Zealand, involves placing insulation in the roof, floor and around the hot water cylinder and decreasing unwanted air circulation in the target houses. The Otago University Energy Studies Program in Dunedin is undertaking a project to investigate the efficacy of this upgrade project as it applies to houses in the south of the South Island. Some of the preliminary findings will be reported later in this present paper.

The energy efficiency retrofit program undertaken by Housing New Zealand started in July 2001 to improve the thermal performance of the un-insulated houses nation wide. Around $4 million per annum has been invested on this project with an average of $1,500 being spent per house. Some 500 houses have been scheduled to be upgraded each year out of the housing stock comprising some 3,256 dwellings in the southern regions from 2001 afterwards. The complete retrofit of this stock will take about 6.5 years.

Another project is currently underway to investigate the impact on occupant health of fitting insulation into housing in New Zealand. The research is being carried out by the Housing and Health Research Program, at the Wellington School of Medicine, in conjunction with several locally-based organizations. 1400 households were selected in 2001 and baseline interviews were carried out after the winter of 2001. Households were interviewed about the status of their health. Energy usage data was obtained from electricity and gas companies. Records from GPs and hospitals were also gathered. The researchers then randomly assigned half the houses to be insulated. Community retrofit teams insulated these 700 homes over the summer and then, after the winter of 2002, everyone was interviewed again. The remaining 700 houses constituted the control group and were not insulated. However, at the end of the study, the remaining 700 houses were also insulated. The preliminary results of the study indicate:

- Energy use exhibited a small but statistically significant decrease after the insulation retrofit
- The insulated houses were drier showing a reduction in relative humidity and a slight increase in temperature.
- The participants in the insulated houses reported that their homes were significantly warmer.

- There was a significant improvement in the self-reported health of adults and children living in the houses that were insulated, compared to those whose houses were not yet insulated.

- In the insulated houses there was a reduction in the number of adults and children that reported visiting the GP. The decrease in the number of visits was significant for the adults.

- Adults and children in the insulated houses reported that they were admitted to hospital less often for respiratory conditions.

- There was a reduction in the number of sick days taken by adults and days off school taken by children living in the insulated houses.

- Dust samples were analyzed for allergens and mounds. Insulated houses did not appear to have a marked reduction in mould, however the occupants reported less visible mound.

In addition the NZ Government has set up a program aimed at council participation in energy efficiency measures, this program, Energywise Councils Partnership Program aims to get local Councils to collaborate on energy management issues and to improve awareness of energy efficiency matters and promote sustainable development at the council level. Dunedin city council has recently joined the Energywise project.

4. Dunedin City

Dunedin is situated on the east coast of New Zealand's South Island. The city's southerly location (at latitude 46 degrees South) means that winters are often colder than elsewhere in New Zealand. In winter the mean monthly temperature can drop to 6.5^{o}C in July. Wellington in contrast has a mean July temperature of 8.8^{o}C and Auckland with 10.8^{o}C. Table 1 shows the mean monthly temperatures for locations in New Zealand measured by various NIWA metrological stations.

Table 1 - Mean monthly temperatures for various NIWA meteorological stations around New Zealand for the period 1971 to 2000

LOCATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
AUCKLAND	19.3	19.8	18.5	16.2	13.7	11.6	10.8	11.3	12.6	14.1	15.8	17.8	15.1
WELLINGTON	16.9	17.1	15.8	13.8	11.5	9.5	8.8	9.2	10.6	12	13.4	15.3	12.8
CHRISTCHURCH	17.4	17.1	15.5	12.8	9.6	6.9	6.6	7.7	10	12.3	14	16	12.1
DUNEDIN	15.2	15.1	13.7	11.9	9.2	7	6.5	7.5	9.3	10.9	12.4	13.9	11

The geographical area to be studied in this project is that which is under the territorial authority of Dunedin City council. This area extends from North of Waikouaiti to the Taieri River in the south. Dunedin has a population of 114,342 people and ranks 4th largest in terms of urban size in NZ. The number of residences in Dunedin over the age of 65 is higher than the national average. Until recently the population of Dunedin City has actually declined since 1971 by around 0.1% per annum, while the population of New Zealand as a whole has grown at around 1% per annum during the same time period. This declining population in Dunedin has meant a low demand for new housing and a corresponding low rate of new houses being built. Figure 1 show the populations of Dunedin City and New Zealand from the Census data over the period 1971 to 2001. Dunedin is also different for other NZ cities in that it is a “University town”. The student population, which also includes students from a polytechnic, teachers college and smaller educational establishments, makes up a total of around 20,000 giving a very high proportion of the total population (18%).

The first Europeans to settle in Dunedin were the Scottish in 1848. The population underwent substantial growth during the Otago gold rush in 1861 which helped to make Dunedin a relatively affluent commercial centre.

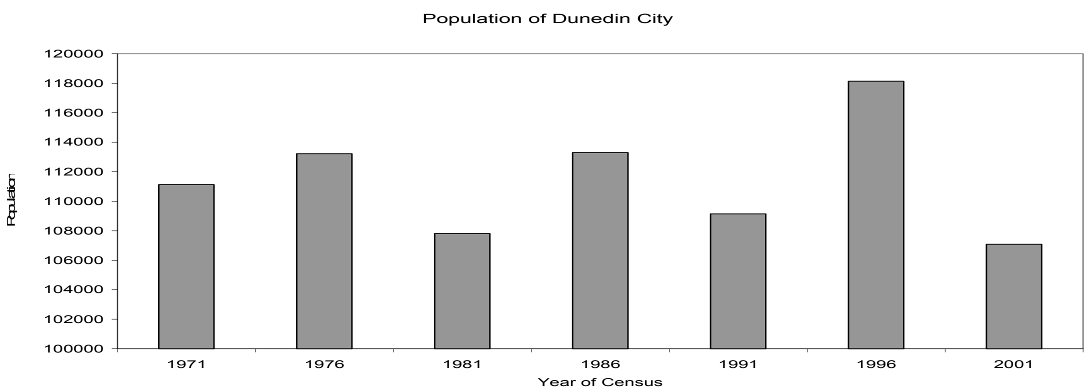

Figure 1 - Population of Dunedin City and New Zealand for 1971 to 2001 (Data is obtained from Statistics New Zealand census data).

4.1. Dunedin population age distribution compared to NZ

The median age of people in Dunedin City is 34.4 years, which is similar to the national average of 34.8 years. However, Dunedin shows a pronounced hump in the student age group between 15 and 24 years as can be seen in figure 2. Another difference is that 13.3% of people (15,231) in Dunedin City are aged 65 and over, compared with all of New Zealand which has only 12.1% of people aged 65 and over. The elderly group would be even more pronounced if allowance was made for the excess at student age.

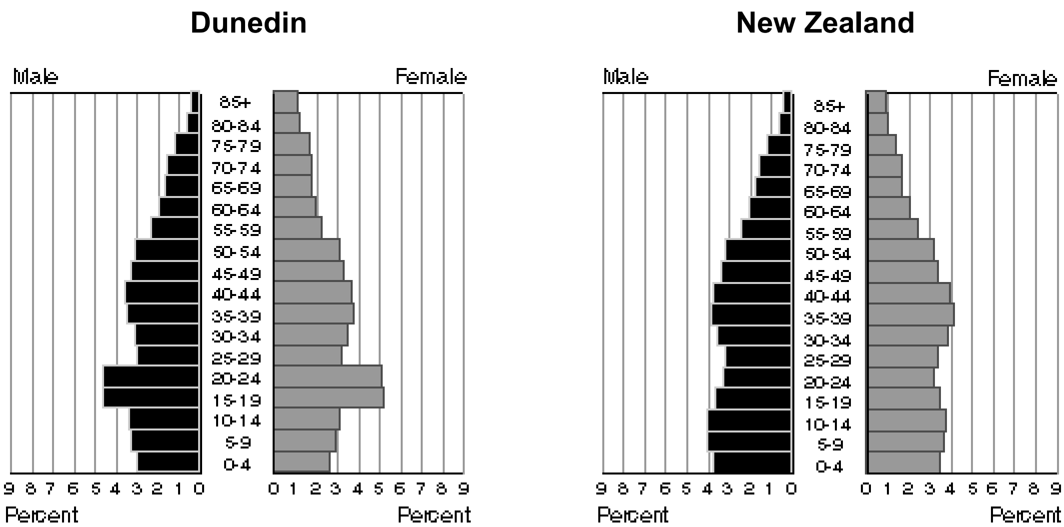

Figure 2 – Age distribution of Dunedin population compared to distribution for all New Zealand.

4.2. Profile of Dunedin Housing Stock

Early housing in Dunedin City was influenced by the Scottish settlers. From 1860 up until 1920, Victorian style “villas” were commonly built. These often featured double bay windows which were intentionally designed to promote ventilation through the house. This means of air ventilation was believed be a healthy means of reducing mould. The villas often had a characteristic double pitched roof, as the maximum length of timber available at the time did not allow for very large span roofs. This particular trait is specific to the Otago area and was thought to reflect the preference of the Presbyterian settlers for formality and symmetry. Figure 4 shows photograph of a typical Dunedin villa house.

In all there are around 40,000 residential dwellings in Dunedin City. Residential dwellings refer to all types of accommodation such as flats, houses and apartments. A large portion of these are Victorian style villas which were built between prior to 1910.

Figure 3 shows the age distribution of houses in Dunedin City with data provided by “Quotable Value” New Zealand**.**

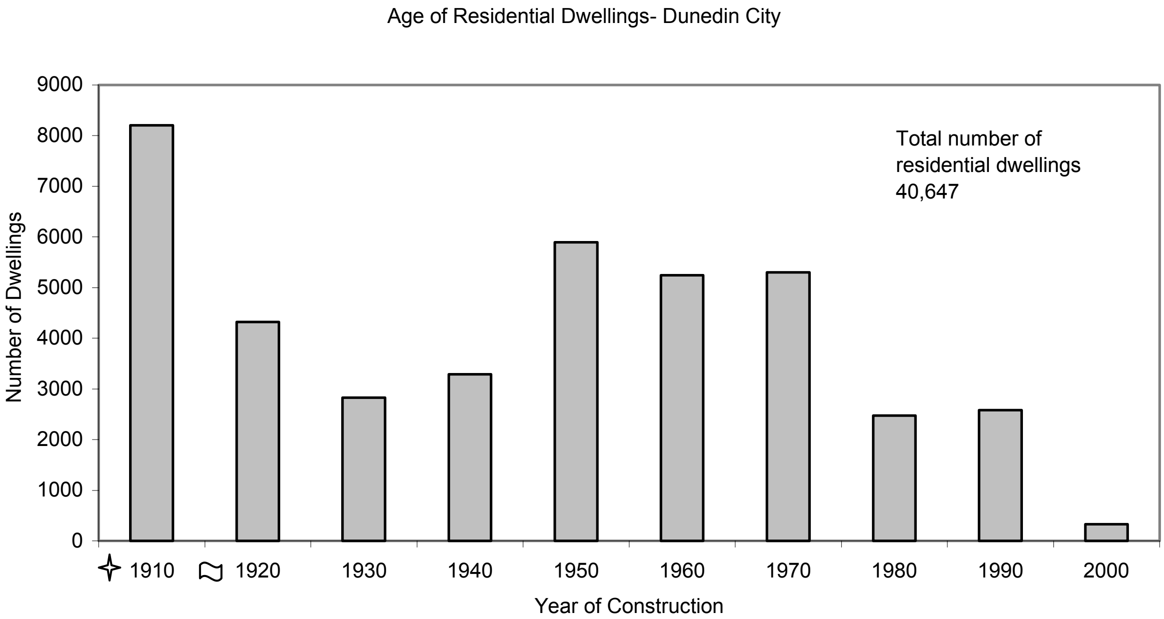

Figure 3 - Distribution of residential dwelling ages for Dunedin City. 1910 corresponds to all the dwelling built on or before 1915. Dwellings built from 1915-1919 are in 1920 category. Thereafter, dwellings built from 1920-1929 are in the 1930 category. The most recent data for 2000-2009 is of course incomplete.

During the postwar era of the 1950's the style of private housing in Dunedin changed somewhat. In addition to privately owned housing State-owned housing was introduced. A typical state house from this period is shown in figure 5. In contrast to earlier homes, State housing attempted to provide affordable and comfortable housing for families as the country underwent a post WWII baby boom. The State owned houses were generally smaller than privately owned housing. A peak spanning 1950 to 1970 in the number of houses built during this period can be seen from the age distribution graph in figure 3. The majority of the state houses were constructed with an external cladding of weatherboard. Corrugated steel was a common roofing material and there was little or

Figure 4 - A typical Dunedin Villa featuring a double pitched roof.

no insulation originally provided in walls or ceilings. A suspended floor with no under floor insulation and large window areas also featured in much of the State housing. These characteristics made the residences draughty and notoriously difficult to heat.

Internationally a shift in attitudes took place during the late 1970's when people became more aware of energy efficiency issues, due to rising oil prices caused by the oil price shocks of the mid and late 1970's. With the 70's also came the popularization of utilizing passive solar heating rather than using fossil fueled heating. Housing started to be designed with orientation to the sun in mind. These international changes also coincided with the introduction of the New Zealand building code to provide minimum standards for thermal insulation.

These regulations were introduced by the Building Industry Authority (BIA) in 1977. The BIA is an independent government organization which manages building industry regulations in New Zealand. The initial New Zealand building code [NZ Standard 4218:1977] specified minimum R-values for walls, roofs and floors where an R-value relates to the thermal resistance of the material. A subsequent update to the code in 1996 recognized the variation in climatic conditions within New Zealand and subdivided the country into three climate zones (New Zealand Standard 4218:1996). The update to the code also included R-values for window areas.

Figure 5 - Weatherboard state house in Dunedin

Compliance with the building standards is monitored by local councils and was not made mandatory until the year 2000. Due to the slowdown in building applications from the late 1970s onwards changes in the national and international arena were not generally apparent in residential buildings in Dunedin. Of the total number of houses in Dunedin City, 86% were built prior to 1977 in which no insulation is expected unless the residences have undergone privately funded refurbishment or sponsored upgrades.

The 2003 mean age for residential dwellings in Dunedin is 53 years (i.e. the average home is "built in 1950"). This makes houses significantly older than other parts of the country with the mean age of residential dwellings in Auckland at 40 years and Wellington at 48 years.

A more detailed age distribution for house construction from 1970 to the present is given in figure 6 (Data from "Quotable Value" NZ). The type of construction materials used for residential buildings in Dunedin is also given in figures 7 and 8 with the data again from "Quotable Value" NZ. Here it can be seen that profiled steel is the most common roofing material with nearly two thirds of all houses using this material and the balance being mostly tiles. Bricks are the most common wall material followed by weatherboard, roughcast and concrete.

Housing price data has been obtained from the Real Estate Institute of New Zealand. This data gives us an estimate of the median value of residential dwellings in Dunedin. The median price of residential housing in Dunedin (2003) is $97,000 which is significantly lower than other cities in New Zealand. In contrast the median price of residential dwellings in Auckland is $298,000. A distribution of the ratable values for residential dwellings in Dunedin City is shown in figure 9. The mean age of dwellings and ratable values for houses in Dunedin, Christchurch and Auckland are tabulated in table 2.

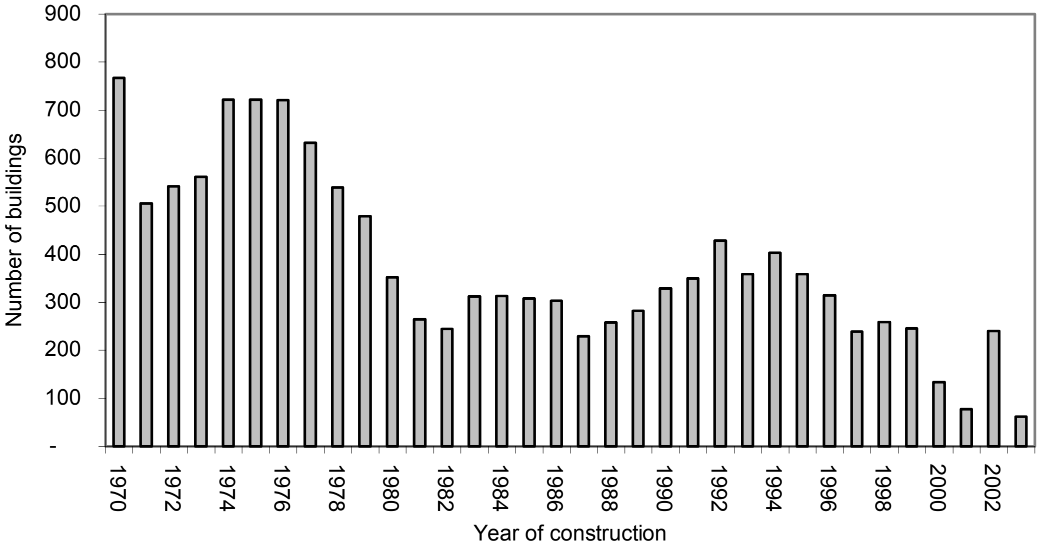

Figure 6: The number of residential dwellings built in Dunedin City from 1970 to the present day. In some cases a decadal estimate of the building age was only available- in this case the data was assumed to be evenly distributed throughout the ten year interval.

Table 2 - Median capital value for residential properties for various cities in New Zealand. The value is calculated for the period July 2002 to July 2003. Data was obtained from The Real Estate Institute of New Zealand, public housing statistics.

LOCATION	AVERAGE YEAR BUILT	AVERAGE AGE	MEDIAN CAPITAL VALUE
Auckland City	1963	40	$298,000
Dunedin City	1950	53	$97,000
Wellington City	1955	48	$237,000

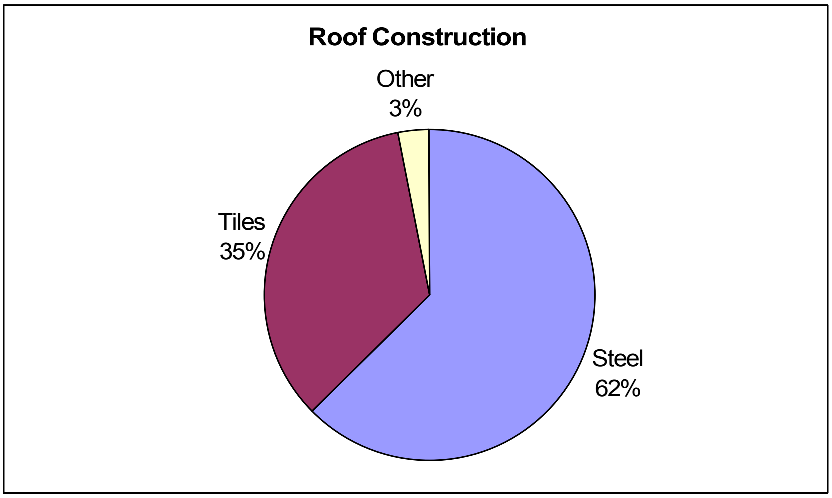

Figure 7- Construction Material used for roofs in residential dwellings Otago region

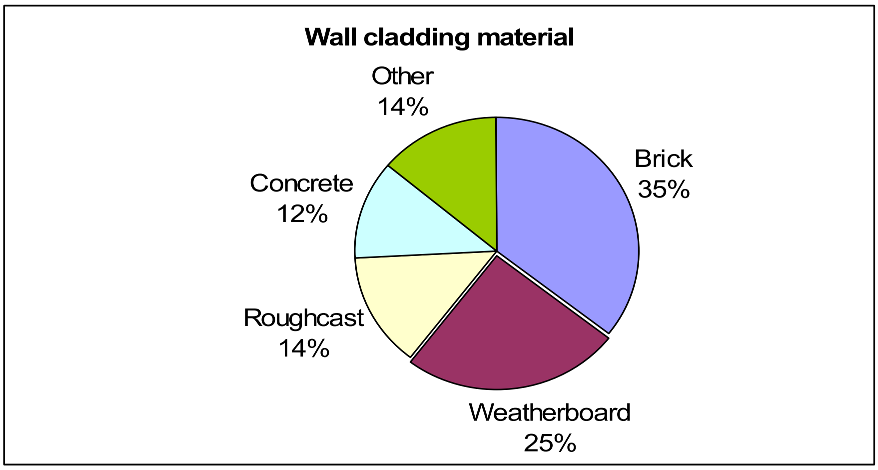

Figure 8 - Construction material used in walls for residential dwellings in Otago region.

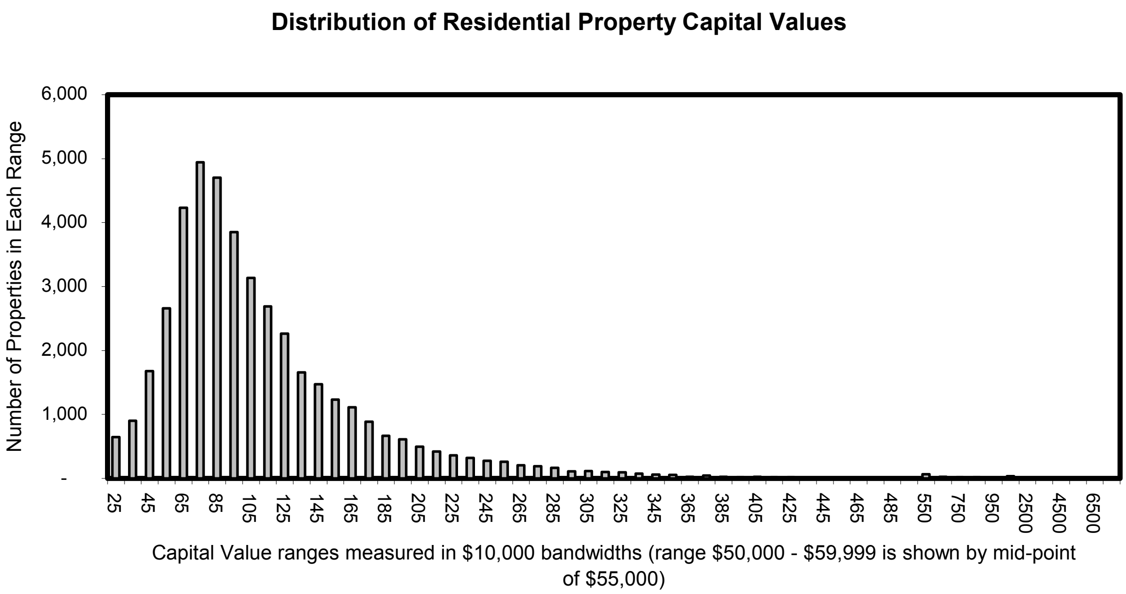

Figure 9 - Capital values of residential dwellings in Dunedin City (2003). Data provided by Dunedin City Council.

4.3. Profile of Dunedin City Council Housing Stock

Dunedin City Council has a small portfolio of its own housing stock with some 939 tenants housed in 89 residential unit blocks (DCC 2003). The average age of the council housing stock is somewhat younger than the city average (of 53) years at 35 years but nonetheless many were built before the national thermal regulations came into force in 1977/78. Figure 10 shows an age distribution of the Council housing stock. The council has made modest progress in upgrading a portion of the houses. Approximately one third of the council units have ceiling insulation in the form of fiberglass batts. To reduce condensation in the bathrooms, heaters have been installed in three quarters of all the units. Hot water cylinder wraps have been fitted into 108 dwellings but because this removes valuable warmed airing space in hot-water closets, it is not frequently done. Table 3 lists the number of insulation upgrades applied to the Council housing stock. The council intends to continue upgrading its housing stock as funds permit.

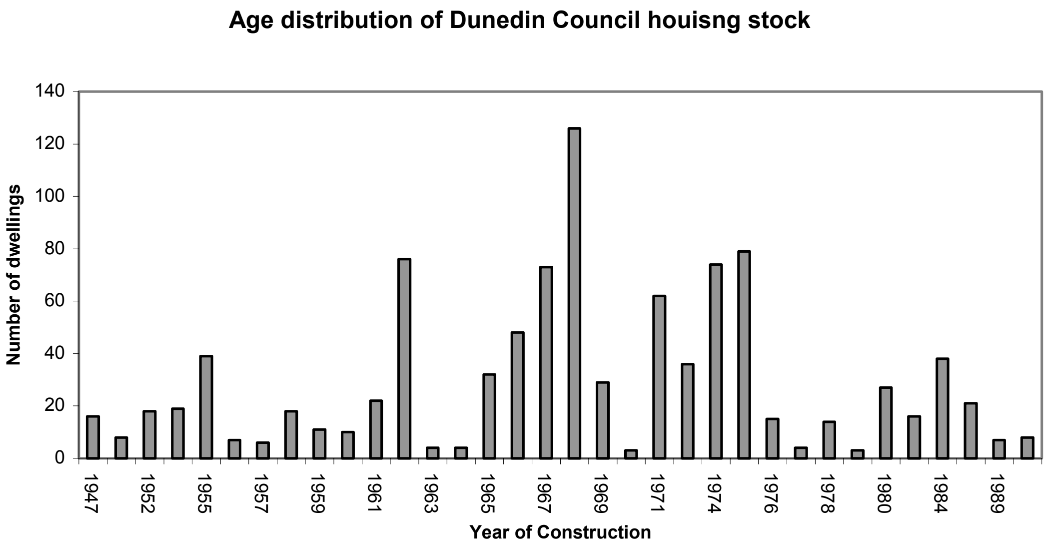

Figure 10 - Age distribution of Dunedin City Council housing stock.

Table 3 - Types of insulation installed in Dunedin Council Stock

Upgrades to Dwellings	Yes	No
Ceiling Insulation	30%	70%
Hot Water Cylinder Wraps	6%	94%
Bathroom Heating	70%	30%

4.4. Areas with Poor Solar Aspect

Dunedin is a very hilly city with the possible dubious distinction of having the steepest street in the world (Baldwin Street). Certain areas of the city are considerably disadvantaged in the amount of solar radiation they receive because of the surrounding topography. To investigate this problem, the Dunedin City Council was asked to use its existing Geographical Information System (GIS) to produce a map of areas of poor solar aspect. Poor solar aspect in this instance is broadly defined as the areas that have long periods of shade either in the morning or afternoon. Poor solar aspect was calculated for a winter day in July at 9:00 in the morning and at 15.30 in the afternoon. Figures 11 and 12 show areas in Dunedin City that have poor solar aspect in the morning and afternoon respectively on this particular day. Each defined region on the map corresponds to an individual census area unit. To quantify the area affected by poor solar aspect the shaded area on the maps are expressed as percentage of the total area of the census area unit. The average percentage shading for the morning and afternoon is computed and listed in table 4 for different residential areas in Dunedin city. This table also lists an estimate of the number of people affected by poor solar aspect in the morning and the afternoon. This estimate is found by relating the population of each area unit to the percentage area with poor solar aspect.

The population for each census area was obtained from the 2001 New Zealand Census. The solar aspect estimate is approximate as it has assumed that the population distribution is uniform within the area unit. Within this limitation the data does give a good indication of the areas most affected. Figure 13 shows the percentage area with poor solar aspect averaged for the morning and the afternoon. Figure 14 shows the number of people affected per residential area in the morning and the afternoon. Vauxhall, North East Valley, Pine Hill and Belleknowes are the worst affected with regards to lacking morning sun. This may be important for residents that are in the home during the day such as pensioners, nightshift workers and parents of young children. Caversham, Brockville, Mornington and the north side of Otago Harbour are the worst affected areas with regards to a lack of afternoon sun. The combined affects of low morning and afternoon sunshine give Caversham, Mornington, North East Valley and Brockville as area of low sunshine exposure. These estimates only account for shading caused by the surrounding topography and do not incorporate shading from other buildings and trees. In addition the analyses are for the areas in general with a wide variation on exposure expected for particular houses within areas. The housing in inner city areas and in the student quarter in North Dunedin are particularly affected by shading from adjacent residences due to the propensity of narrow terrace house style housing facing the street.

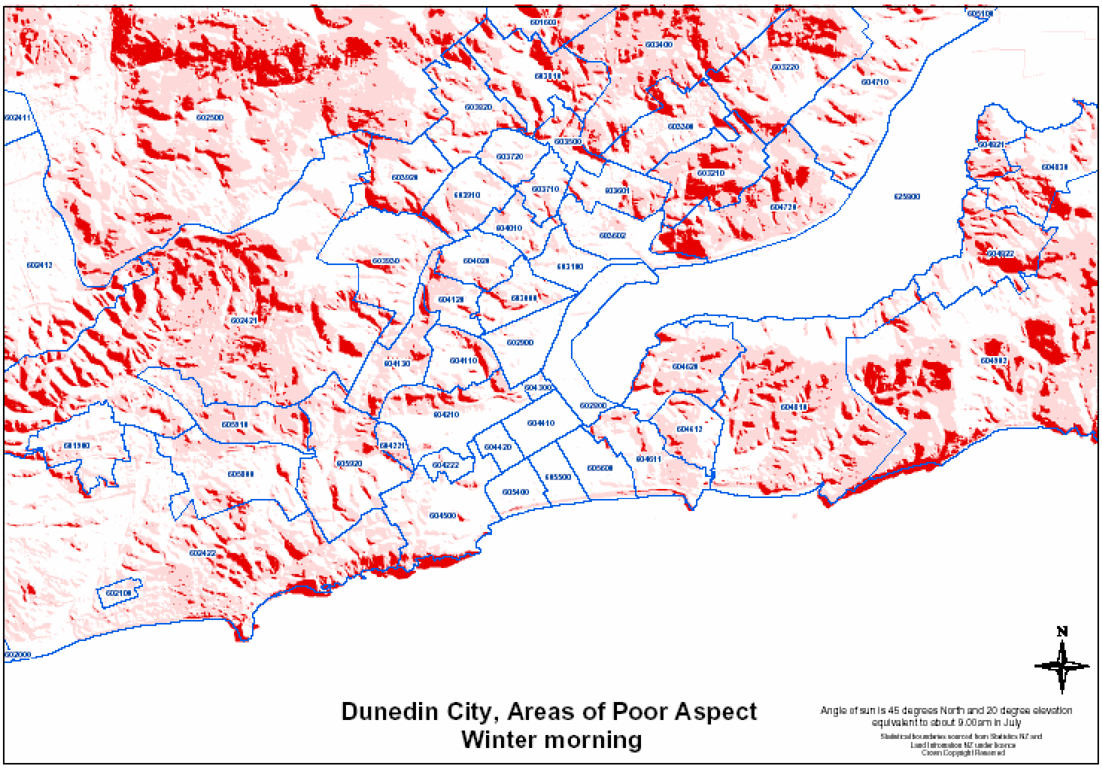

Figure 11 - Areas with poor solar aspect on a winter morning.

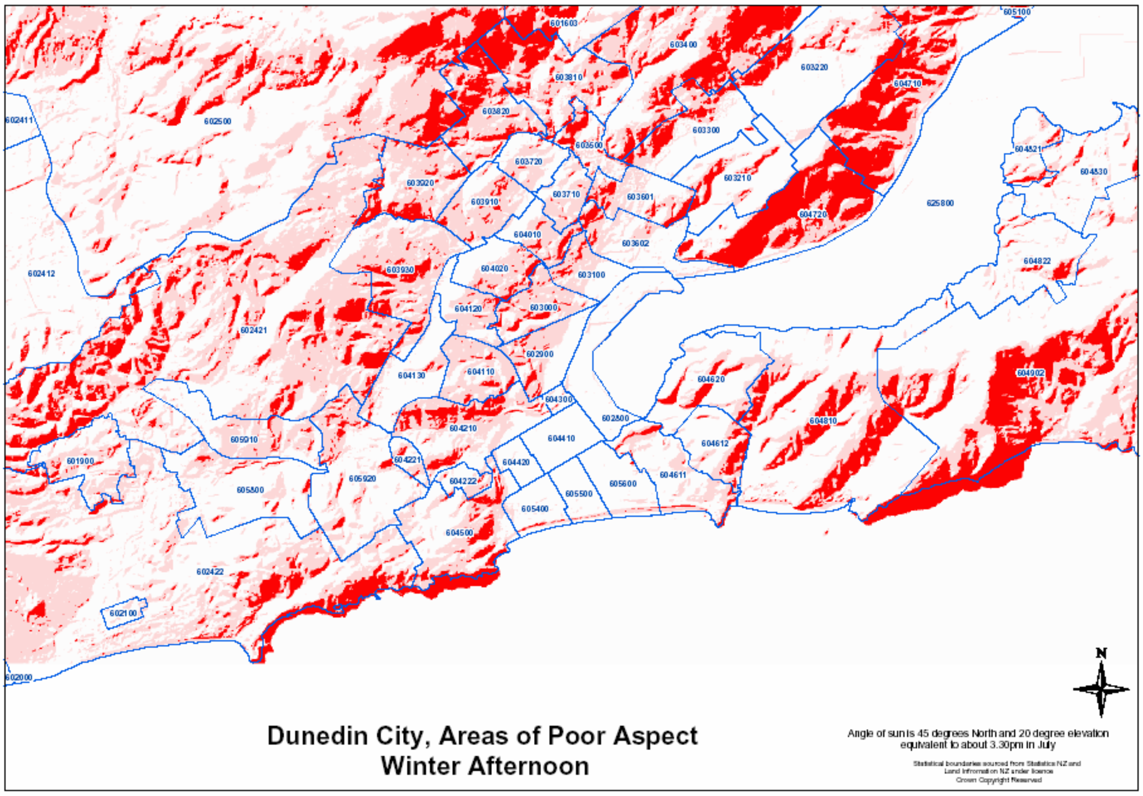

Figure 12 - Areas with poor solar aspect on a winter afternoon.

Table 4 - This table lists the residential areas affected by poor solar aspect in Dunedin City. The average shading corresponds to the average percentage of the area covered by shading for a morning and afternoon on a winter day in July. The number of people in the area affected is an estimated from the population of each area.

Area Unit	*Area Name*	*Area (Ha)*	*Average shading(%)*	*Population*	*No. of people effected*
605910	*Abbotsford*	186	57	1725	979
604612	*Andersons Bay*	120	45	2487	1120
601500	*Aramoana*	-	na	219	na
603720	*Balmacewen*	85	33	795	266
604120	*Belleknowes*	91	54	1800	978
602000	*Brighton*	-	na	1419	na
604830	*Broad Bay-Portobello*	259	22	1074	231
603930	*Brockville*	283	49	3804	1867
606300	*Bush Road*	-	na	2322	na
604300	*Caledonian*	17	18	12	2
604210	*Caversham*	247	50	4998	2479
605920	*Concord*	335	40	2166	860
604222	*Corstorphine East*	37	24	924	221
604221	*Corstorphine West*	32	54	639	344
606220	*East Taieri*	-	na	1071	na
601603	*Evansdale*	-	na	1257	na
601900	*Fairfield*	157	37	2058	765
604420	*Forbury*	44	2	939	17
603220	*Forrester Park*	319	40	777	307
602800	*Fryatt*	176	4	189	8
603810	*Glenleith*	277	62	513	320
605800	*Green Island Central*	289	29	2472	723
603920	*Halfway Bush*	187	61	2346	1440
603820	*Helensburgh*	208	61	1011	619
603000	*High St-Stuart St*	114	52	2535	1309
602900	*High St-The Oval*	124	32	1623	517
601302	*Hyde*	-	na	90	na
604810	*Inner Peninsula*	887	46	867	401
602421	*Kaikorai Hill*	1225	63	291	182
602422	*Kaikorai Lagoon*	162	25	264	65
601604	*Karitane*	-	na	423	na
604130	*Kenmure*	156	40	1848	746
604822	*Macandrew Bay*	260	35	1176	415
603710	*Maori Hill*	75	47	2211	1039
602300	*Middlemarch*	-	na	198	na
602500	*Momona*	335	0	2100	2
604110	*Mornington*	117	56	3462	1924
606100	*Mosgiel East*	-		3210	
606210	*Mosgiel South*	-		2517	
604611	*Musselburgh*	179	43	2835	1215
603601	*North Dunedin*	122	49	2541	1240
603300	*North-East Valley*	204	43	4395	1909
603210	*Opoho*	225	47	1257	596

603602	*Otago University*	164	31	4164	1278
602200	*Outram*	-		576	
603400	*Pine Hill*	405	71	2409	1721
605200	*Port Chalmers*	-		1545	
604720	*Ravensbourne*	377	73	1392	1016
604821	*Raynbirds Bay*	89	1	153	1
604010	*Roslyn North*	82	49	1935	955
604020	*Roslyn South*	111	43	2388	1022
604902	*Sandymount*	1010	0	156	0
605100	*Sawyers Bay*	-		1287	
602600	*Silverpeaks*	-		477	
604410	*South Dunedin*	96	0	2412	1
604500	*St Clair*	273	40	4164	1652
605500	*St Kilda Central*	68	7	1695	114
605600	*St Kilda East*	115	11	2493	274
605400	*St Kilda West*	79	10	1833	190
604710	*St Leonards-Blanket Bay*	323	51	672	346
603100	*Stuart St-Frederick St*	93	33	2427	793
604901	*Taiaroa-Cape Saunders*	-		468	
604620	*Vauxhall*	227	45	3837	1718
601400	*Waikouaiti*	-		972	
601602	*Waitati*	-		549	
603910	*Wakari*	139	54	3222	1735
602100	*Waldronville*	25	31	594	182
601605	*Warrington*	-		369	
602412	*Wingatui*	-		888	
603500	*Woodhaugh*	79	51	783	403
602411	*Wyllies Crossing*	-		252	

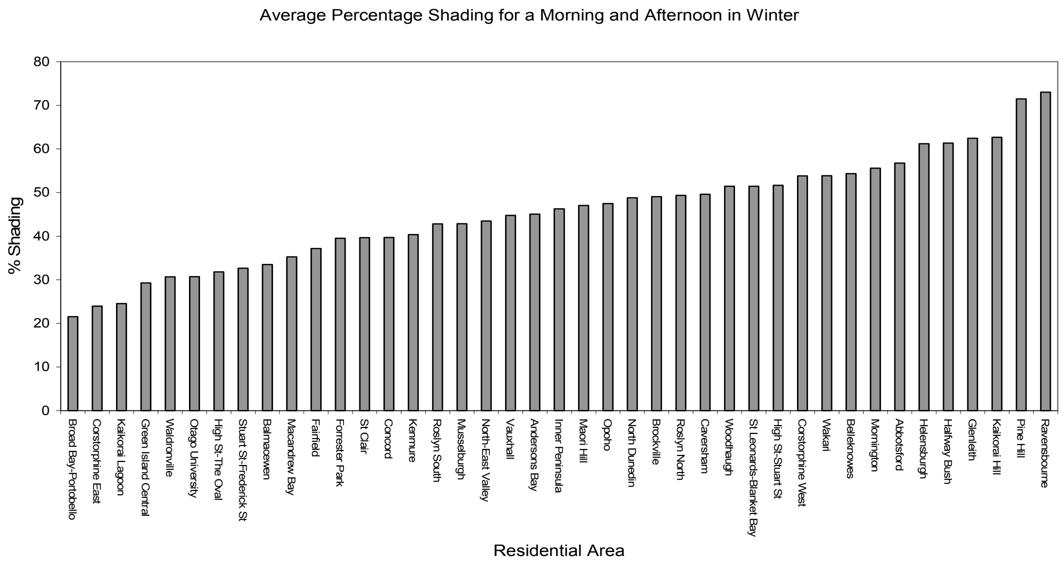

Figure 13 - The average percentage area covered by shading on a winter morning in July at 9:00 and winter afternoon at 15.30.

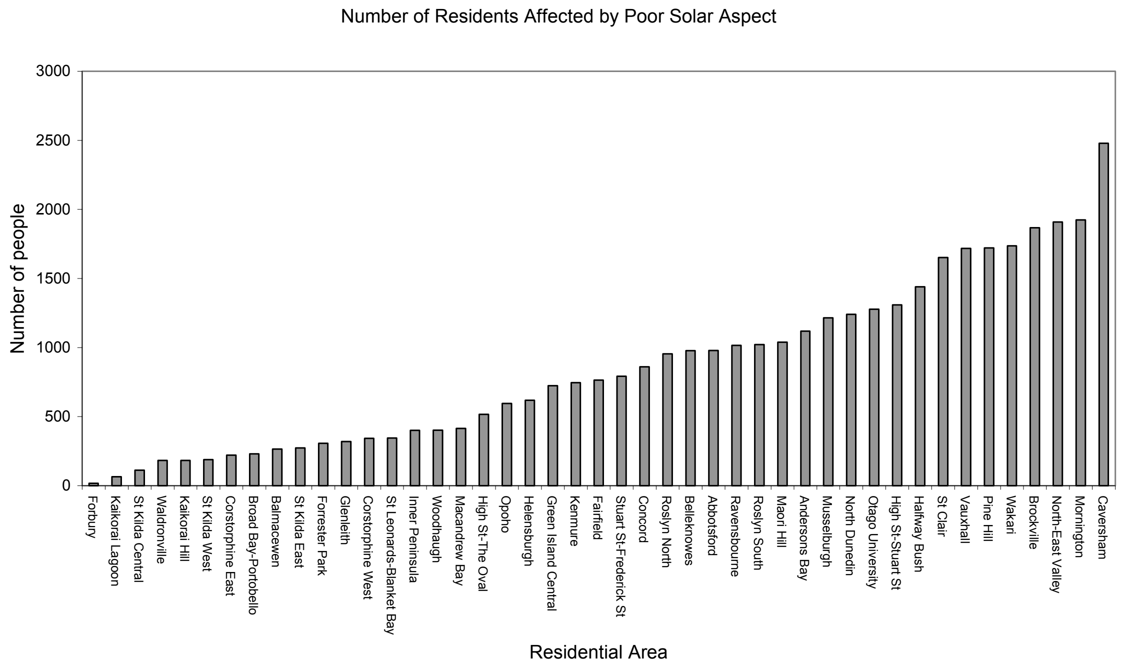

Figure 14 - The average number of people affected by poor solar aspect on a Winter morning and a Winter afternoon in July.

4.5. Energy Use in Dunedin – Is there fuel poverty?

Data from the 1996 and 2001 census provides an outline of the fuel types used for domestic heating. Although there has been a slight decrease in the number of houses using electricity from 1996 to 2001 it is still the major means of home heating. In contrast the use of bottled gas has increased slightly from 1996 to 2001 while wood consumption has remained relatively stable. Figure 16 shows the fuel type use data obtained from Statistics New Zealand.

The average consumption of electricity for a Dunedin house is 9417kWh per annum. This is based on data from 9664 houses in Dunedin City over the period of June 2002 to May 2003 and has been provided by one of the electricity power supply companies (Trust Power 2003). BRANZ from their HEEP study has found that around 30-40% of electricity goes to house heating, meaning some 3800 kWh/annum is used on average for house heating. At an average cost of $0.14 per kWh this would cost some $530 per annum. Other forms of heating including gas, wood and coal are also commonly used.

An extra 3.8 MWh of other heating energy might be expected perhaps costing another $500 per annum. These values then would suggest a range from a few hundred dollars to around $1000 per annum would be spent per household on heating. Then using the definition of being in fuel poverty if a satisfactory heating regime would cost more than 10% of its income on all household fuel use we can calculate the % of households affected once we know the income distribution for Dunedin households.

Here a 'satisfactory heating regime' is defined as one that achieves 21° C in the living room, and 18° C in the other occupied rooms. The trouble is that in Dunedin one might rarely find living rooms heated to 21 °C.

The average income of people in Dunedin is considerably lower than the national average; that is an average income of $14,500 per person compared to $18,500 per person nationally. (Otago $15,700 per person: 2001 data, source Statistics NZ). In terms of households, figure 15 gives the breakdown for Dunedin as compared to the whole of NZ. It might be noted, however, that in this context one of the reasons for the relatively low income of people in the city is due to the high proportion of a low earning student population.

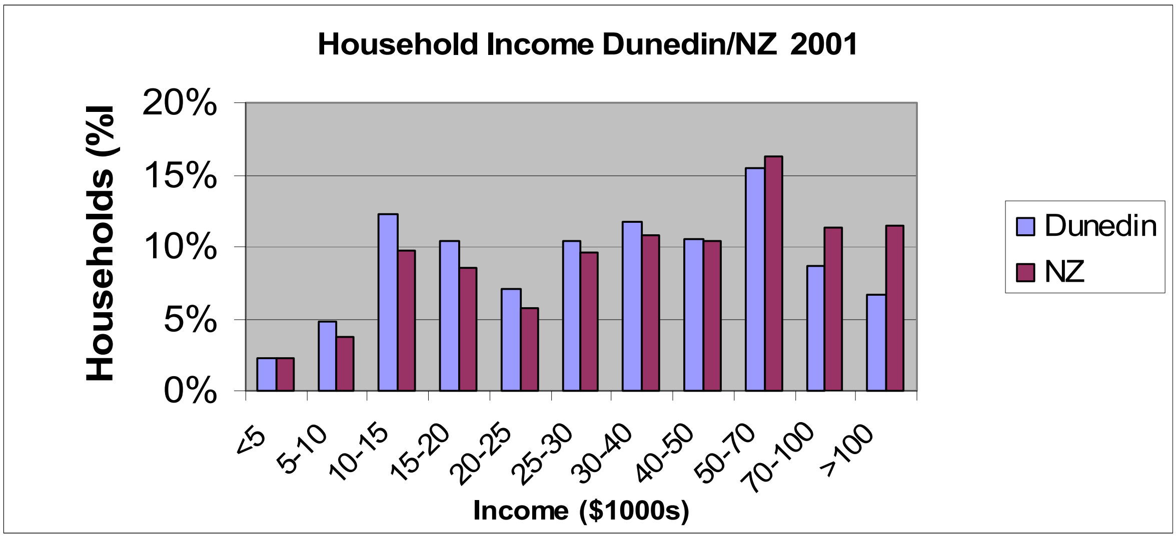

Figure 15: Household income levels for Dunedin and NZ (obtained from Statistics NZ as part of the 2001 census).

Thus all 2% of households in Dunedin generating less than $5,000 income per annum would be highly likely to be in fuel poverty and the 7% of households generating less than $10,000 income per annum are probably in fuel poverty.

However, if we examine what households would have to spend to obtain comfortable living room temperatures of around 21 °C, a different story emerges. A concurrent economic study of public housing in NZ (Taylor and Lloyd 2003) suggested that a basic un-insulated home may need as much as 20 MWh/annum to heat living areas to 20 °C. This level of heating would cost around $2,800 per annum and would consign all of the 36% of households in Dunedin earning less than $25,000 per annum into fuel poverty.

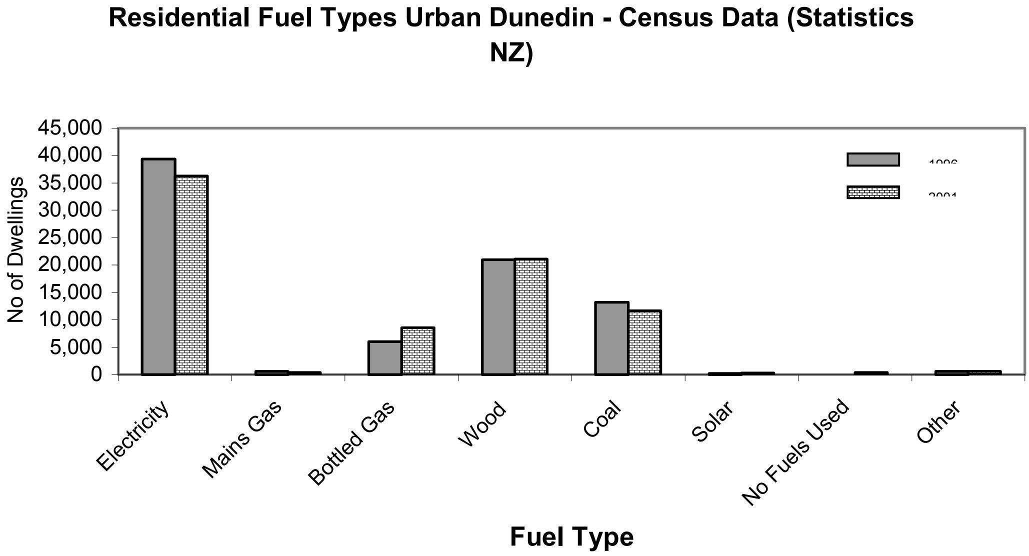

Figure 16 - Means of heating residential dwellings for Dunedin City. Data obtained from Statistics New Zealand

5. Household thermal conditions in Dunedin

Before we look at the health aspects of low home heating we will examine measured household temperatures in two situations, namely student housing and public housing. The student situation was researched specifically for this paper. The public housing situation was researched as a separate exercise funded by the NZ Government (Lloyd and Mill 2003).

5.1. Student accommodation

A survey of 91 student houses located in or around the Otago University area was carried out as part of this research program in order get a feel for household temperatures in the city and to see if the tenants were exposed to temperatures lower than that recommended as healthy by the World Health Organization. This research was carried out as part of the practical assessment for one of the Energy Management 300 level courses on energy efficient building design (EMAN 306) and was funded specifically by the WHO/Dunedin City Council. The sample of houses was self-selected, as participants were solicited through various media and registered on a ‘first-come, first-served’ basis, provided they fitted the criteria; which were that houses surveyed were rented or leased accommodation and were occupied by at least one full time tertiary student. No pretence of a random survey was maintained and it is likely that the flats were representative of the “low end” of the student accommodation market.

The research involved placing two temperature sensors, one in the bedroom and one in the living room, in each of the student houses. The temperature sensors used in the survey were ‘iButtons’, manufactured by the Maxim/Dallas Semiconductor Corporation. These devices are small, robust digital thermometers that measure temperature to an accuracy of ± 0.5°C (as verified by a calibration exercise). The iButtons were set to monitor temperature every hour over a period of approximately 2 months after which the data was downloaded for analysis. The sampling period started in early August 2003 and ended in mid October of the same year and thus covered the winter to spring transition period. Information was also gathered about the house and the inhabitants via a questionnaire.

5.2. Building Fabric

Details regarding the size of the house and the construction fabric of the roof, windows, walls and floor were obtained by the students by physical inspection. A list of the data gathered is summarised in table 5. The approximate age of each house was obtained from “Quotable Value” NZ, and is shown in figure 17.

It can be seen from table 5 that the most common building fabric within the houses surveyed were timber frame weatherboard walls, suspended (wooden) floors, corrugated iron roofs, single glazed windows with wooden frames, and no insulation. Furthermore, the data shows that the majority of student houses were built pre-1914. A physical inspection of such houses suggested that they would be difficult to heat to a comfortable temperature, were likely to have high air leakage around the window frames and through the floors, and would have condensation/moisture control problems due to cold surfaces, particularly the windows. It can be seen by comparison to figure 3 that the sample had a higher proportion of older houses compared to Dunedin as a whole, further suggesting that the survey was of the “lower end” of the student housing market.

Table 5 – Break down of building fabric types, surveyed student houses.

Walls		**Windows**	
Timber frame, weatherboard exterior	49%	Single glazed, wooden frame	77%
Timber frame, brick exterior	22%	Single glazed, aluminium frame	15%
Timber frame, plaster exterior	11%	Single glazed, plastic frame	1%
Concrete block or tilt slab	7%	No data	7%
Mixed types	2%		
No data	9%	**Insulation**	
		No insulation	68%
Floor		Roof insulation	7%
Suspended	59%	Roof and wall insulation	5%
Concrete Slab	32%	No data	20%
Mixed types	1%		
No data	8%	**Roof**	
		Corrugated iron	58%
		Tiled	10%
		No data	32%

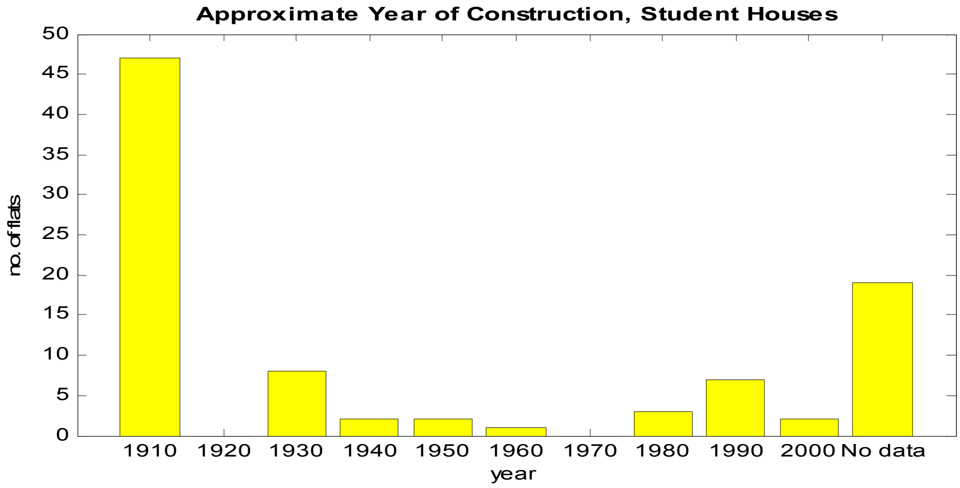

Figure 17 – Age of surveyed student houses. Note that the 1910 category includes all houses built pre-1914, and the 1930 category also includes all houses built in 1929.

5.3. Temperature Analysis

The indoor temperature of the student houses was compared to the prevailing ambient temperature. Outdoor ambient temperature data was measured continuously via an automated weather station on the roof of one of the University buildings. Over the measurement period, a minimum average hourly outdoor dry-bulb temperature of -0.5 °C was recorded on at 6:00 am on 13th August. The minimum indoor temperature of 2.0 °C inside a student house also occurred at this time (in a living room) as shown in figure 18. The maximum outdoor was 18.0 °C at 4:00 pm on 20th September.

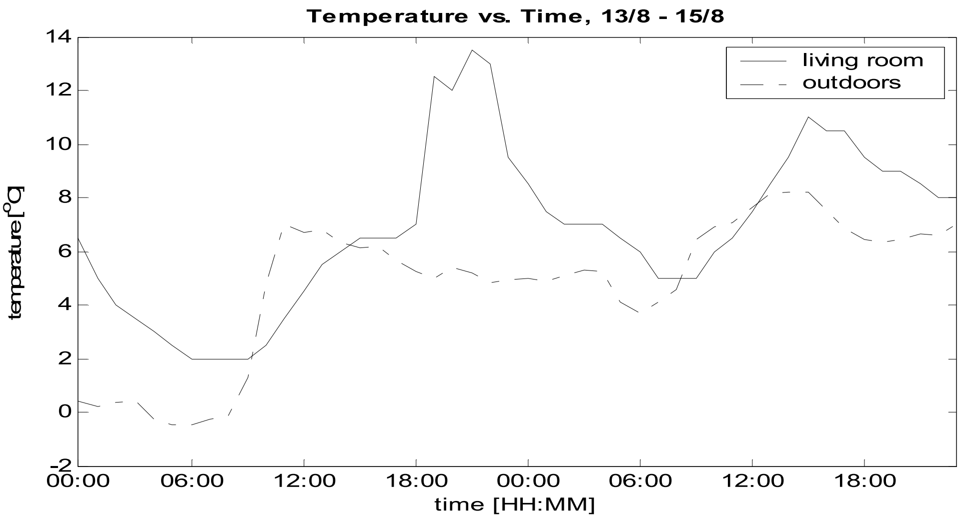

Figure 18 – Example: living room temperature versus time. Note the time lag between changes in outdoor temperature and indoor temperature, and the peak in the centre of the graph, indicating evening heating.

During the period when fifty or more flats had monitoring equipment installed (from 22nd August to 5th October) the average outdoor temperature was 8.5 °C, while the average indoor temperature was a mere 13.0 °C in the living rooms and 12.5 °C in the bedrooms. Figure 19 shows the vast majority of flats had an average indoor temperature below the 16 °C minimum recommended by the WHO.

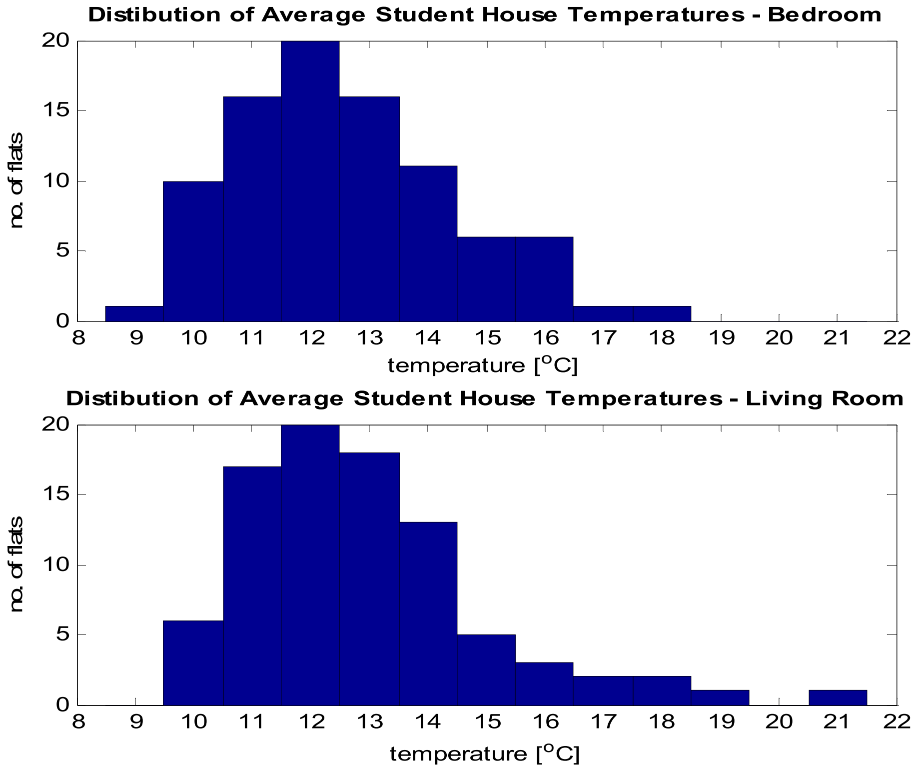

Figure 19 - The distribution of average indoor temperatures among the surveyed houses

The average daily indoor and outdoor temperatures over the same period are shown in figure 20. It can be observed from this figure that the living room was always slightly warmer on average than the bedroom, indicating that it is heated more often.

As might be expected with low indoor heating levels, both indoor temperatures were strongly correlated with the outdoor temperatures. A plot of the average daily temperature difference between the living room and outdoors versus the outdoor temperature (figure 21) shows clearly that the student houses are heated more on cold days than on warmer days. The students did not appear to be heating their houses warmer than an average temperature of about 16°C even when it would be possible for higher temperatures to be achieved. This data indicated that a level of acceptance of the thermal environment was reached around the temperature of 16 °C.

Since many students indicated on their questionnaires that they heated only occupied parts of their house, usually the living room in the evenings when people were home, the average evening temperature was investigated in more detail. The distribution of average living room temperatures among the surveyed houses for the daily period of 6:00 pm – 10:00 pm is shown in figure 22. It can be seen that the distribution is not as “smooth” as in figure 19, most likely due to the fact that a 6:00 pm – 10:00 pm heating schedule was not employed at all of the surveyed houses. However, the data indicated that the majority of flats were still below the recommended minimum temperature even when occupied.

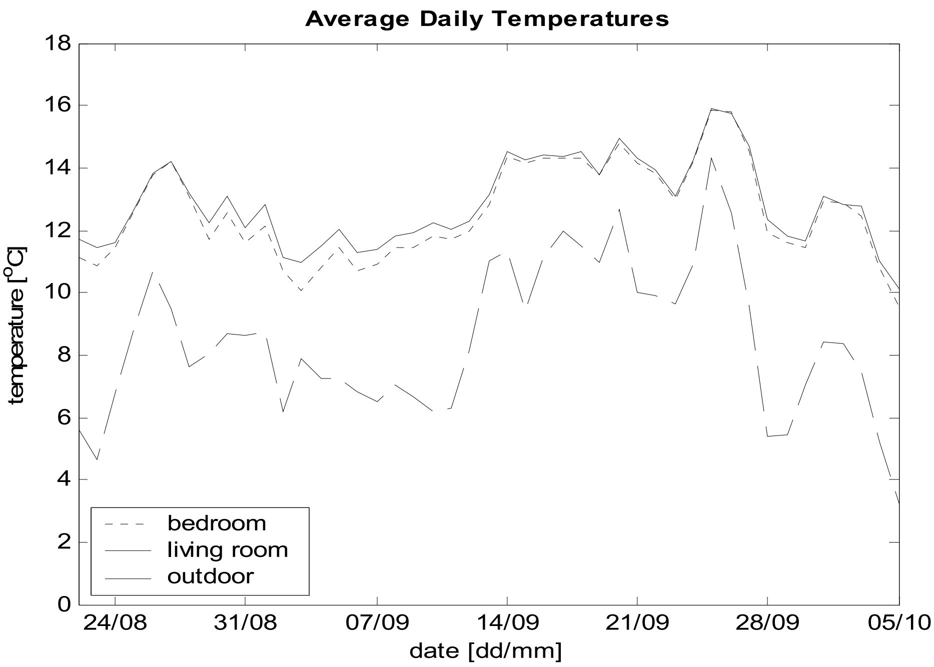

Figure 20 – Average daily temperature across all installed flats as a function of date.

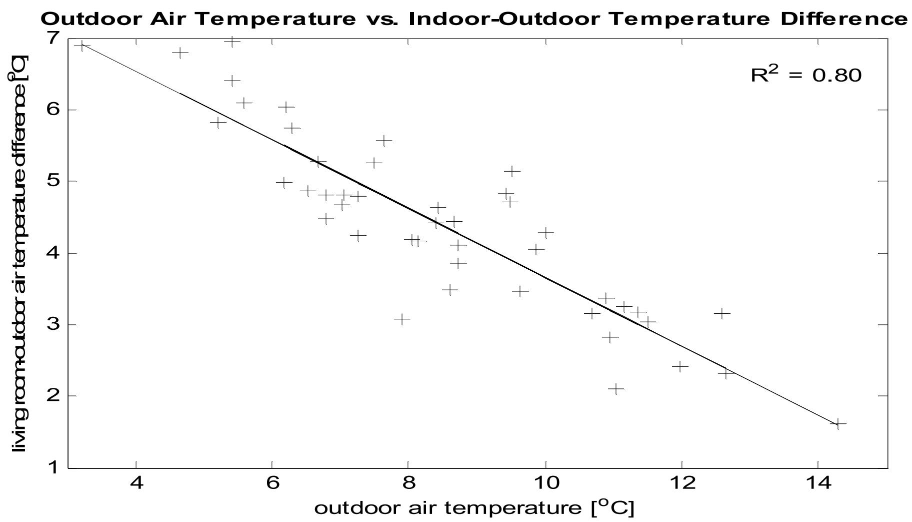

Figure 21 – Correlation between indoor/outdoor temperature difference (amount of heating/thermal performance of building) and outdoor temperature.

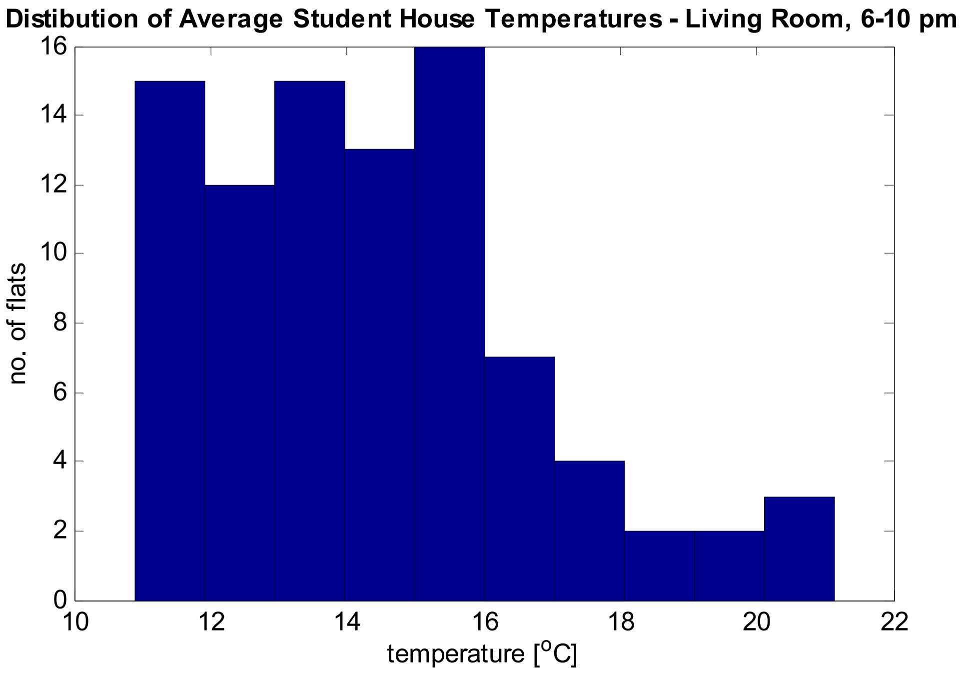

Figure 22 – Distribution among surveyed houses of average living room temperature during a commonly occupied period.

5.4. Student Perceptions and Behavior

At the time of the survey, the survey participants were asked a number of subjective questions regarding their perceived thermal comfort and whether they experience mould or draughts. Their responses are summarized in figure 23. More than 70 % of tenants claimed to experience mould, damp and draughts in their house. This information tallied well with what would be expected given the type of housing stock the students occupy.

61 % of students did not think their house was comfortable in winter, and even in summer 13 % did not think their house was comfortable. While these percentage values are high, they do not correspond with accepted comfort standards and the average temperatures found. In fact, over 90 % of the houses experienced temperatures that were below the commonly accepted comfort range of 18 – 21°C during the survey period, either over a full 24 hours or in the evening.

A second round of questionnaires was carried out in order to obtain more detailed information on student attitudes to thermal comfort. Forty Dunedin-based students were specifically interviewed. When asked what they expected the temperature of their house to be on a cold winter day, 100 % of the respondents said they expected it to be below 15 °C. On the other hand, 50 % of respondents claimed their heating equipment was sufficient for their needs, indicating a level of acceptance of thermal conditions below 15 °C. For comparison, 100 % of students who had lived in rented accommodation overseas (predominantly in Europe and North America) expected their overseas accommodation to be warmer than 15 °C, and 90 % expected it to be warmer than 20 °C.

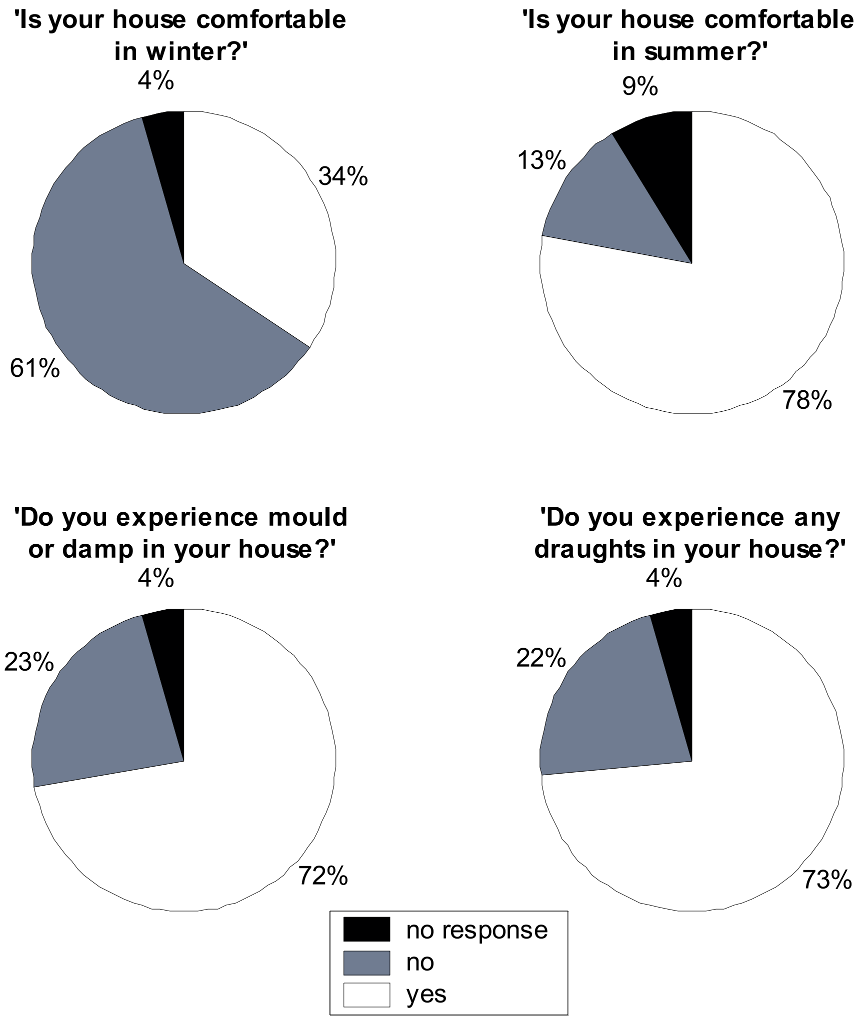

Figure 23 – Tenant responses to questions on comfort conditions within their house.

Some of the possible behavioral actions to reduce discomfort in low temperatures were altering clothing, altering heating or activity levels or leaving the space. On a cold winter day, nearly 60 % of the interviewed students said they would leave their house, even if they did not have lectures. Of those that would leave their house, 70 % said they would go to the library to study, and 39 % said they would go to the local hotel. Of those students that would stay at home, only 60 % they would use their heating equipment and 45 % said they would put on more clothing insulation, such as a sleeping bag and hat.

More than 75 % of the interviewed students stated they would like to live in a better insulated flat and more than 50 % indicated they thought this would improve their quality of life. However, only 5 % of those interviewed would spend more than NZ$10 extra per week on a house that would be more thermally comfortable. It was interesting to note that students rated the importance of location and price significantly higher than the importance of thermal comfort. Even if living in a better insulated flat, more than 25 % students said they would prefer to maintain their current conditions and save money on heating instead.

5.5. Summary of Student Housing Survey Findings

The survey conducted confirmed anecdotal archetypes that many students live in old, un-insulated accommodation. Although student houses are on average lower than the WHO recommended minimum temperature, there appears to be a certain level of acceptance of these conditions by the students who live in them.

Insulating flats would have the benefit of either improving internal comfort conditions, which may improve student health, or improving energy efficiency and saving students money. However, since students are more concerned with location and price, and in general, landlords do not pay for the heating energy used in the houses they rent out and therefore do not benefit from installing insulation, there seems to be an impasse. To obtain the societal benefits of better insulation in student housing in Dunedin, there needs to either be a shift in student attitudes and priorities, or some form of incentive or legal compulsion for landlords to modernize and insulate the pre-1977 student housing. As these options are unlikely to be pursued at this stage, progress will only proceed as fast and as far as the turnover of building stock and minimum requirements of the building code allow.

5.6. Public Housing

The monitoring of an energy efficiency retrofit program of state houses in southern New Zealand regions has being undertaken since December 2002 (Lloyd and Shen 2003). Monitoring equipment consisting of temperature, energy dataloggers and hot water run-of time counters were deployed among the three groups of the 111 monitored houses during a three stage installation. Historical and sociological information concerning the occupants and the household energy use was obtained by the initial formal site survey. From the collected data in the first year the preliminary findings suggest low internal temperatures occur during the winter months. The minimum internal living room temperature recorded during a period in which a household room was occupied was just over 3.0 ^{o}C.

The monitored data for public housing with regards to indoor temperatures in fact showed a striking similarity to the student survey data and we may surmise that the indoor temperature situation characterized by the two surveys is fairly representative of the housing constituting the lower end of the socio economic groups in Dunedin.

6. Seasonal Variation of Mortality in Dunedin and NZ

Seasonality of mortality is a clear indicator that ambient temperatures are affecting the health of the sample selected. A low level of seasonality of mortality and a high seasonal temperature variation would indicate that the population was being shielded from exposure to ambient extremes by a healthy living environment. And conversely, high seasonality of mortality and a high seasonal temperature variation indicates significant exposure to ambient conditions.

Data was obtained from New Zealand Health Information Service (Ministry of Health) for the monthly mortality for both NZ as a whole and Dunedin City for the years 1992 to 2000. The NZ data is shown below in figure 24 and shows a clear seasonal component.

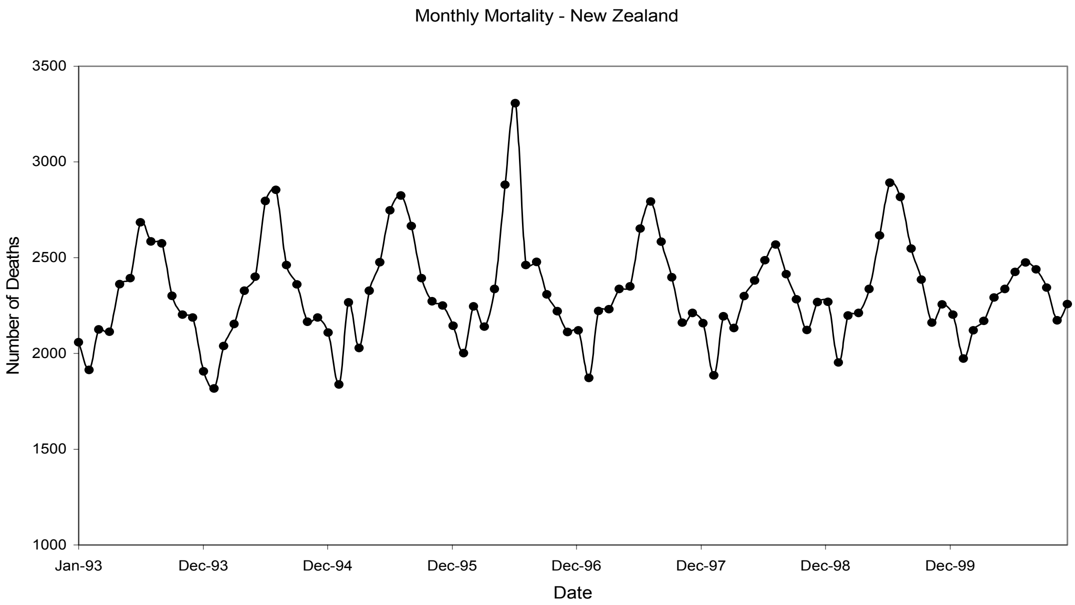

Figure 24 – Seasonal variation in mortality – New Zealand

The NZ data when analyzed as a function of age showed that the main seasonality in monthly deaths occurred in the 65 and over age group. Figures 25 to 27 show the aggregated seasonal variation (i.e. all the deaths during months of January averaged over the 8 years etc). The national data for total mortality showed a peak (July) to trough (February) difference of 44% and a peak (July) to average mortality difference of 18.5%. When monthly mortality (averaged over the 8 years) was plotted against average monthly temperature a good fit was obtained with an R^2 value of 0.83 and a temperature coefficient of 2.8% increase in mortality per degree decrease in temperature. Here the average temperature used was the average of all NZ main centre temperatures as provided by NIWA (Note: a more appropriate temperature would be a population weighted average temperature). The same UK study quoted earlier by Wilkinson et al (2001) found that in the

UK the mortality was found to rise by 2% per degree Celsius fall in ambient temperature below 19 °C. Thus NZ has stronger temperature related mortality than the UK. As the average ambient temperatures in the UK are comparable with or below those in NZ it might be surmised that the pertinent temperatures for health, the indoor household temperatures (or living room temperatures) must be lower in general in NZ than in the UK. That this is likely to be true is borne out by the Student Survey and by the concurrent Public Housing Survey carried out in the south of the South Island.

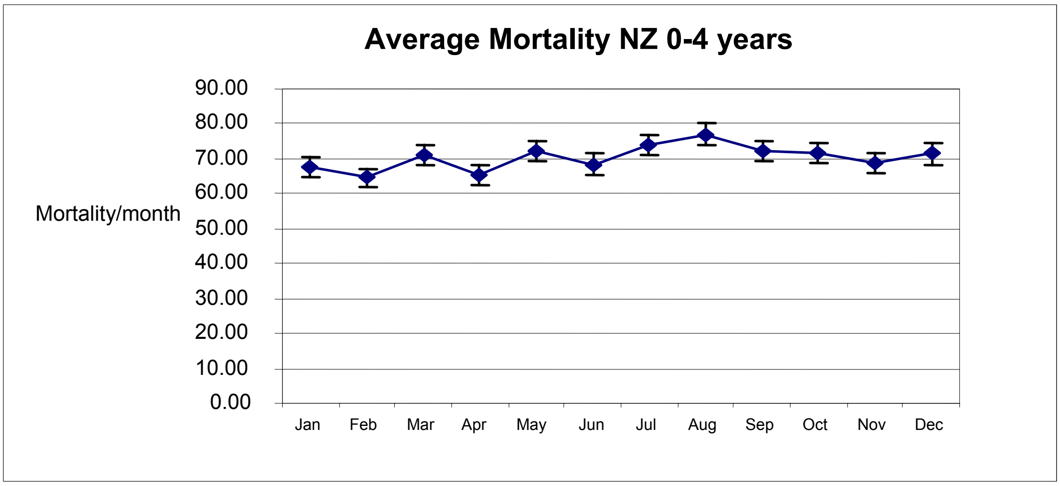

Figure 25

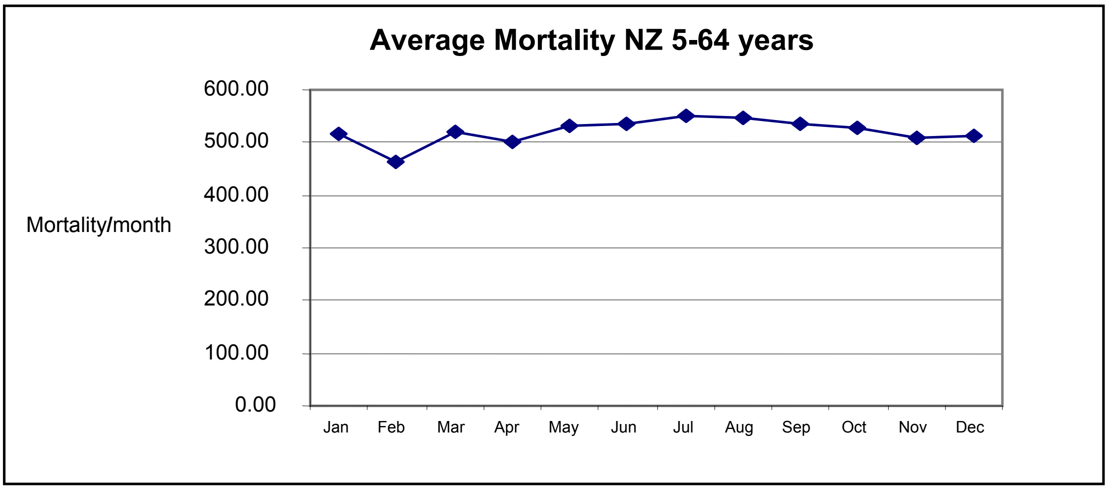

Figure 26

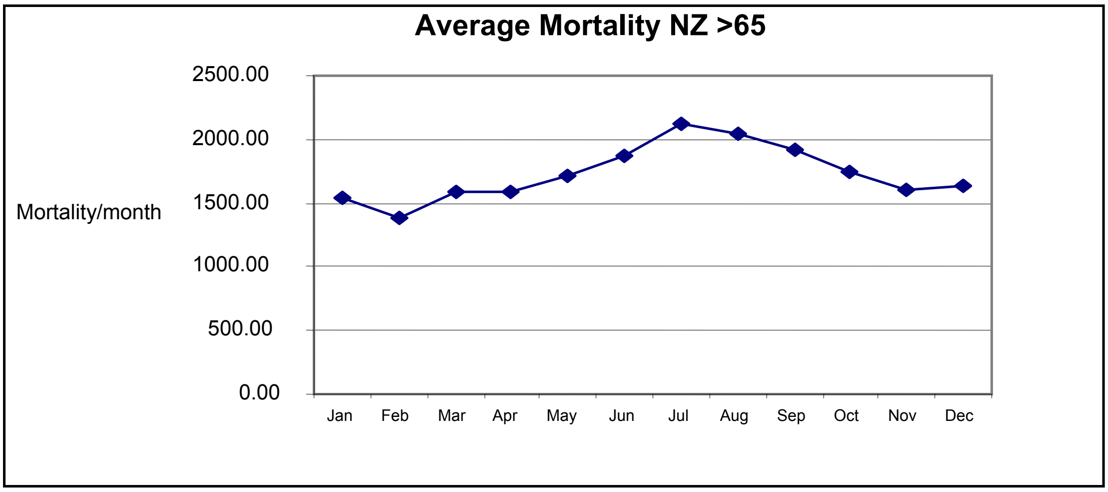

Figure 27

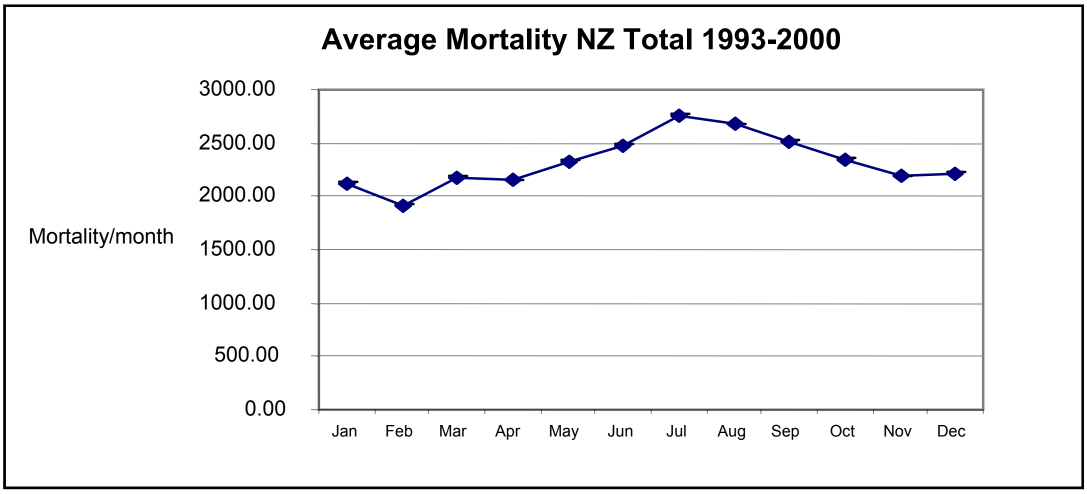

Figure 158

The same analysis of Dunedin mortality for the years 1992 to 2000 showed considerably more random variation due to the smaller data set but nonetheless a significant seasonal variation is seen, again particularly for the 65 and over age group (see figure 33). The regression of mortality versus temperature again showed a similar trend as that of the national data but with a reduced R^2 value of 0.63, due to lower absolute mortalities, and a similar temperature coefficient of 2.8% increase in mortality per °C fall in temperature. Again the at risk population are the residents over the age of 65 years.

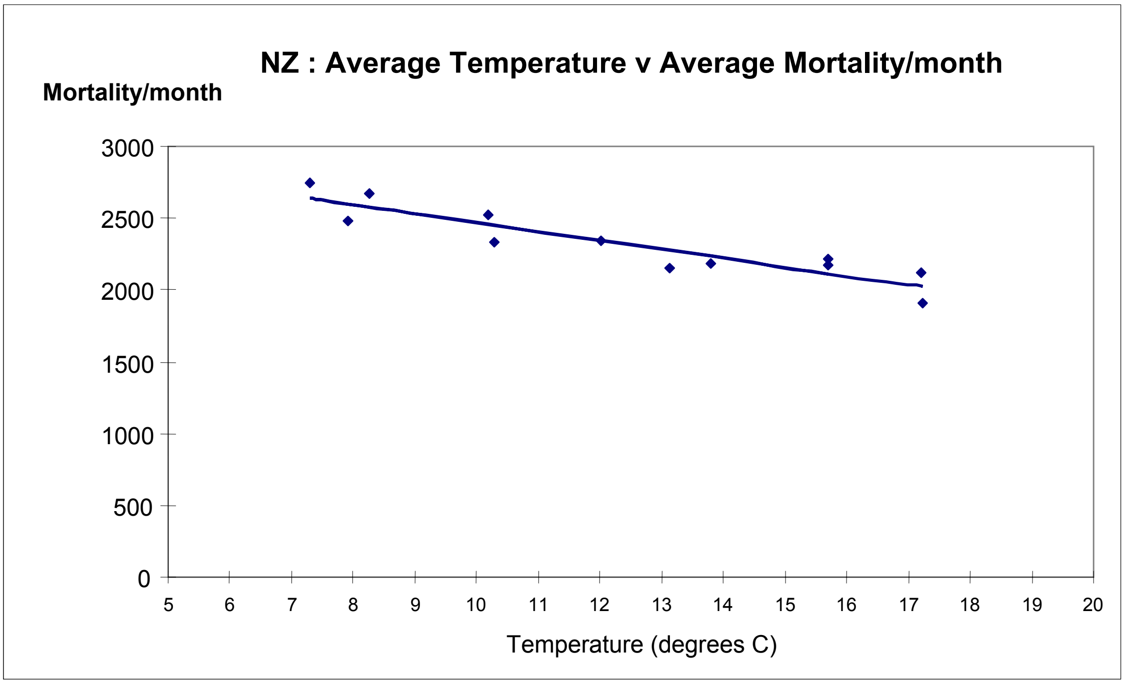

Figure 29

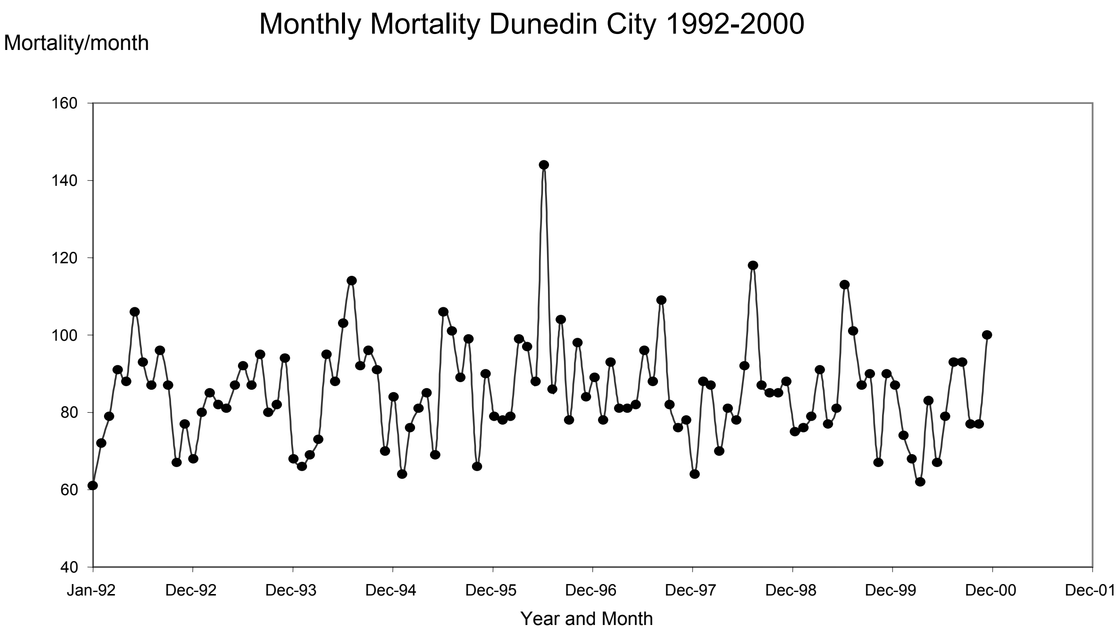

Figure 30

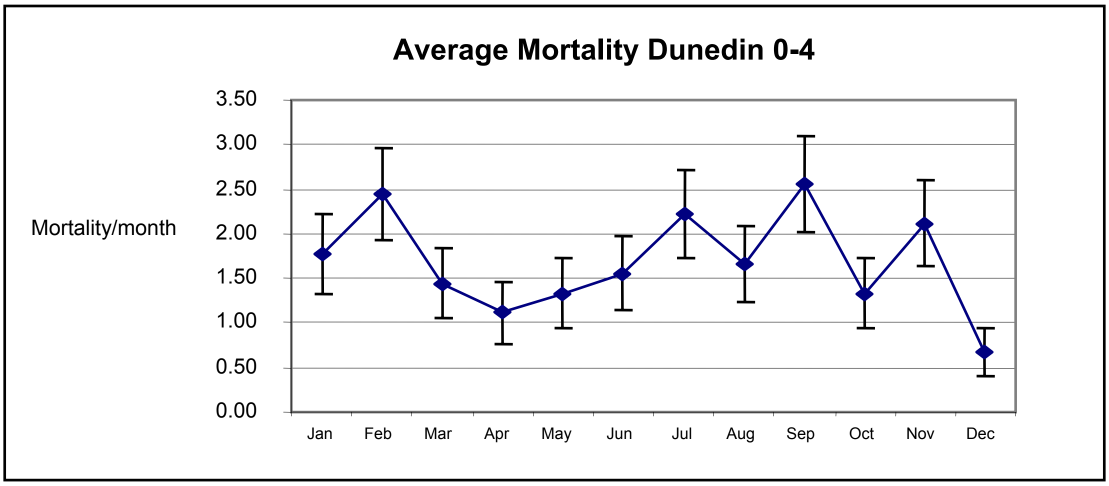

Figure 31

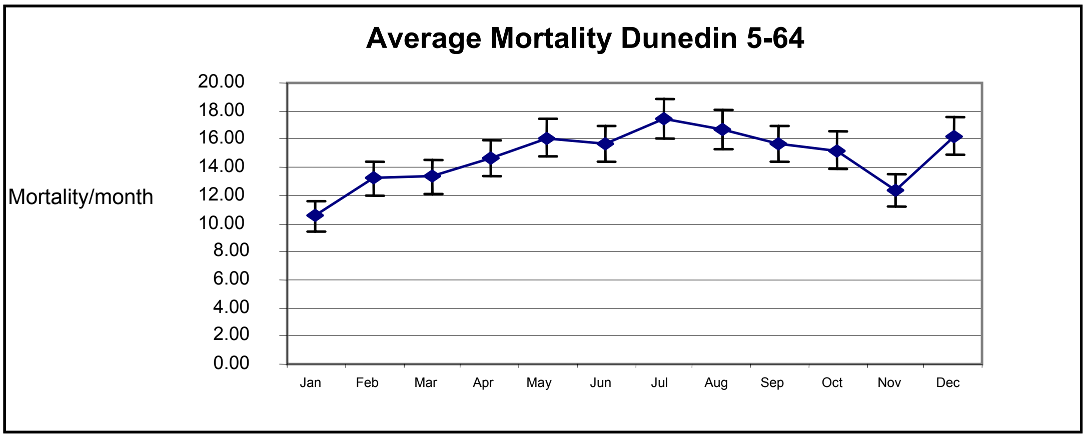

Figure 32

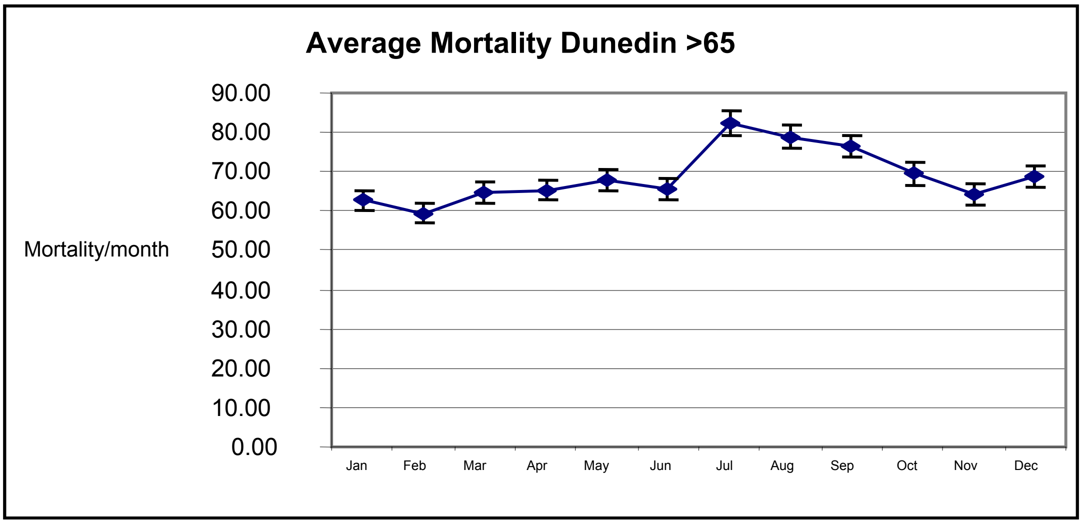

Figure 33

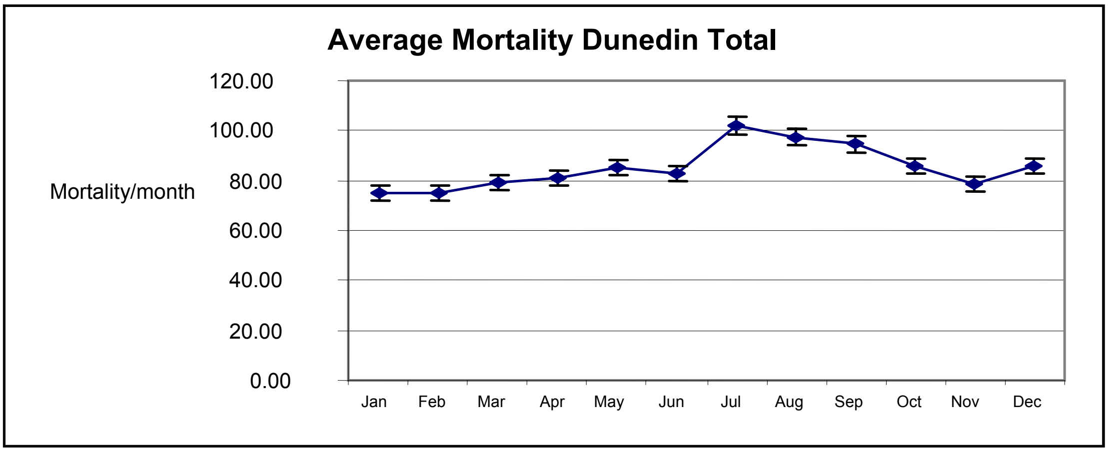

Figure 34

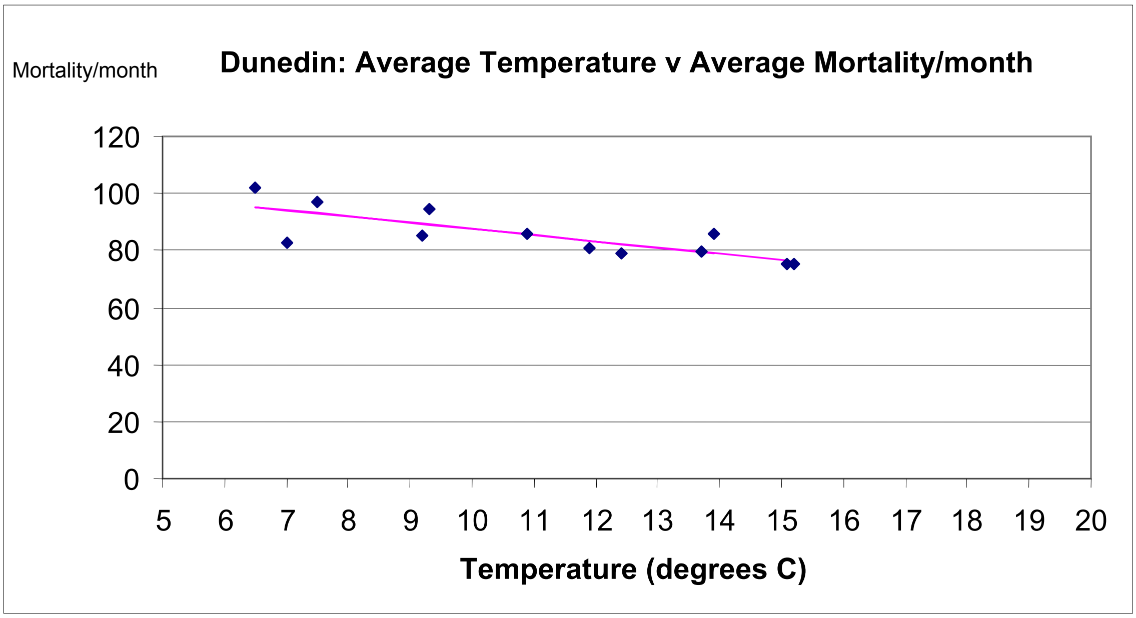

Figure 35

7. Summary and Conclusions

Dunedin is a coastal city of approximately 120,000 people living in around 40,000 residential dwellings in the lower South Island of New Zealand. The housing stock is old, even by New Zealand standards with the vast majority or 86% of homes being constructed before the national insulation standards were introduced in 1977. Furthermore some 60% were constructed before 1960 and 20% before 1910. The population growth of the city has been low over the past few decades which has contributed to the low housing construction rate. Dunedin is a "University Town" with a high number of students (20%) and also of elderly people (15,000 or 13.3% over the age of 65). The residential sector has been traditionally built using timber frame houses with either wood (as weatherboard) or brick veneer construction. Roofing material is mostly a combination of steel (as corrugated Iron) and masonry tiles.

Dunedin has a cooler climate than the majority of New Zealand with an annual average temperature of some 11 °C and some 2800 heating degree days to a base temperature of 18 °C. Dunedin is a very hilly city with the possible dubious distinction of having the steepest street in the world (Baldwin Street). Certain areas of the city are considerably disadvantaged in the amount of solar radiation they receive because of the surrounding topography. In addition orientation of houses has not tended to be in favor of solar access, rather being oriented according to the street layout. From a GIS survey as many as one third of the population of Dunedin is estimated to be affected by poor solar aspect due to the prevailing topography. In addition the inner city areas with a high proportion of narrow terrace housing would tend to acerbate the solar access problem in the more densely populated areas.

The income of people in Dunedin is considerably lower than the national average; that is an average income of $14,500 compared to $18,500 nationally. (Otago $15,700: 2001 data, source Statistics NZ). Lower incomes are ameliorated somewhat by low housing costs. The median price of residential housing in Dunedin (2003) is $97,000 which is significantly lower than other cities in New Zealand. In contrast the median price of residential dwellings in Auckland is $298,000. Electricity and other heating fuel costs, however, are close the national average meaning that the cost of home heating would be less affordable than elsewhere in the country. Nearly 90% of homes in Dunedin use electricity as the preferred heating fuel followed by wood stoves.

Evidence is emerging from a survey of student housing and from a concurrent survey of public housing in Dunedin indicates in fact that home heating is not taken as a priority and that some homes are seriously under heated. Data indicates that in mid-winter, indoor temperatures are often below 12 °C with a few samples showing living area and bedroom temperatures of as low as 3 °C *while the rooms were occupied*.

Thus with a cool climate, poor solar access, relatively poor population (by NZ standards) and an old mostly un-insulated housing stock, Dunedin could be surmised to be a health risk in terms of having indoor house temperatures below normally acceptable levels. Here it may be mentioned that the WHO considers indoor temperatures of below 16 °C a health risk. In fact the seasonality of mortality in Dunedin was found to be not too different from the national average where one degree decrease in outdoor ambient temperature gives rise to around 2.7% increase in mortality (Dunedin - 2.8%). This seasonality, however, is very high by international standards with NZ having a higher degree of seasonal mortality than most of the developed world. The health risk due to low ambient temperatures is mostly confined to the elderly age group, that is those 65 years and above, where the seasonality of mortality is most pronounced.

In summary, the city needs to develop a strategy aimed in the short term at its aged population in terms of housing quality and thermal comfort; and in the longer term at the housing stock in general, as today's younger population will be tomorrows elderly.

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