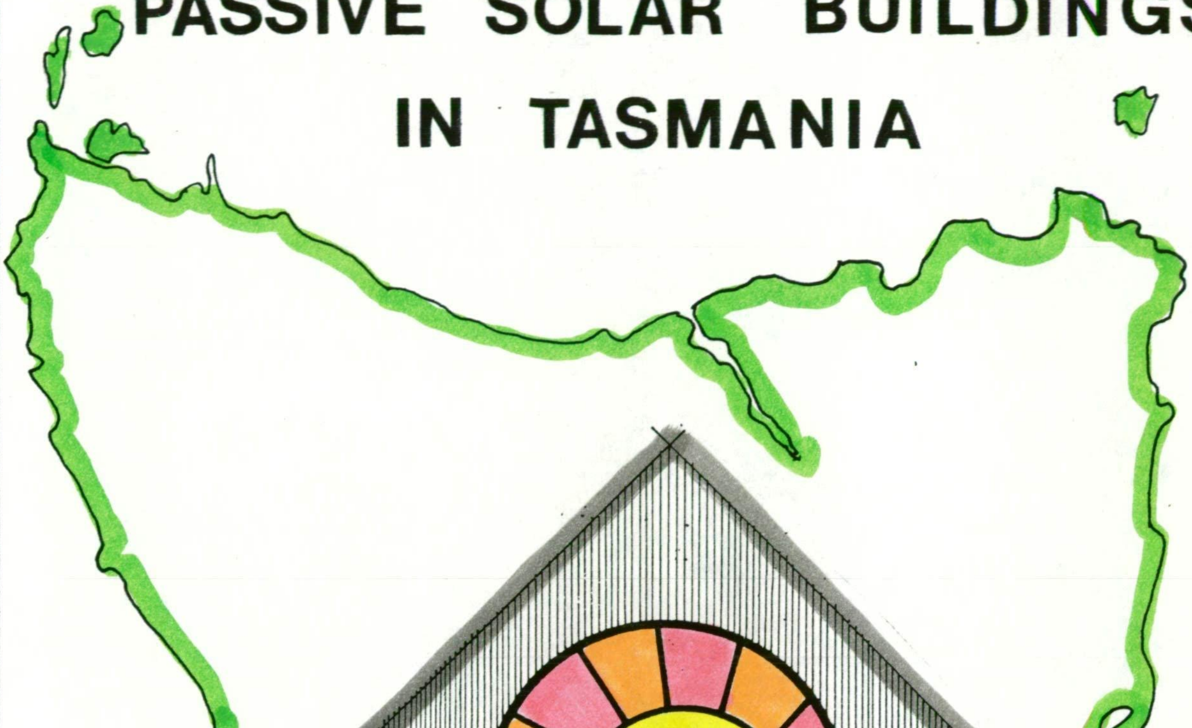
THE ASSESSMENT OF TEN PASSIVE SOLAR BUILDINGS IN TASMANIA



graduating
1985

DETLEV GNAUCK

THE ASSESSMENT OF TEN PASSIVE SOLAR BUILDINGS IN TASMANIA

Detlev Gnauck **Grad.Dip.Arch.**

Being a thesis submitted in part fulfilment of
the requirement for the Degree of Master of
Environmental Studies.

Centre for Environmental Studies
University of Tasmania
April, 1985

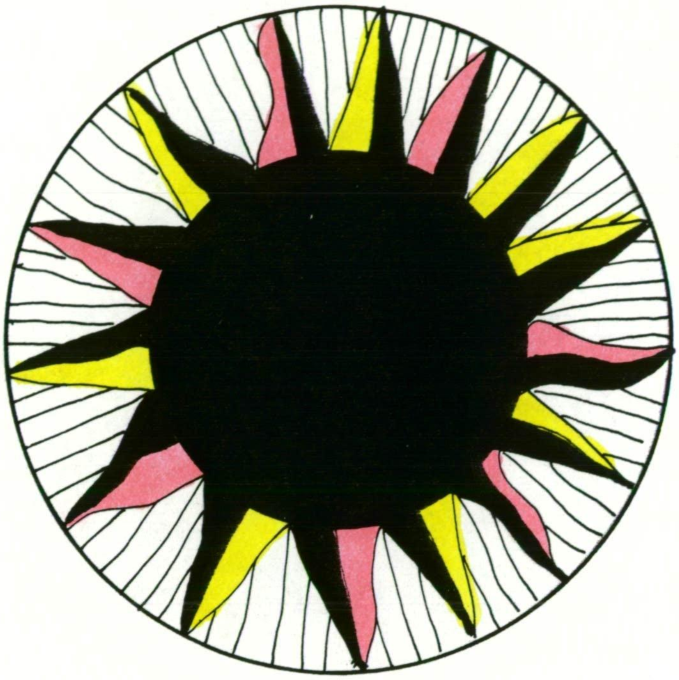
CONTENTS

Appendices:

ACKNOWLEDGEMENT

This thesis has been produced as a result of contributions of people too numerous to mention. Special thanks are due to my supervisors, Dr. Richard Jones and Robert Sutton, for providing information, inspiration and advice; to the owners of the solar buildings, who kindly for many hours answered all my questions; and to Jill Roberts for a monumental and meticulous typing effort.

CHAPTER 1



INTRODUCTION

1.1 INTRODUCTION

THE NEED FOR SOLAR BUILDINGS IN TASMANIA

Tasmania's space heating requirement is among the highest in Australia, amounting to a yearly average consumption of 10 000 kWh of electricity per dwelling.[1] This electricity is needed to heat a domestic dwelling to a comfortable level during a heating season and only represents an average heating consumption. Insulated houses with restricted heating periods would use considerably less electricity for space heating, while uninsulated dwellings with long daily heating periods and central heating systems could use even more electricity than 10 000 kWh.

With a cost between 2.75 (off peak rate) and 6.08 (residential tariff) cents per kWh (January 1985), the average annual cost of providing such an amount of heat by electric space heating can range between $275 and $608 per dwelling.

As the cost of electricity at the present time is rising at a significantly faster rate than inflation, a great section of the community, especially those on low incomes and social benefits, will find it more and more difficult to buy electric heating. This closes another fuel option to many people since the significant price increase of heating oil in 1975 had caused a switch away from oil heating.

A large section of the community now uses wood heaters and open fireplaces, and, as a result, there has been a greater demand for firewood, especially in winter 1983, and the price of this fuel increased up to 20% from winter 1983 to winter 1984.

Many people, especially the older section of the community, are not prepared to handle the physical constraints of catering and preparing the firewood for heating purposes. There still exists the problem of quality and quantity control on the delivery of firewood, since often the quantity of delivered firewood is significantly less than specified, and frequently it is wet and not suitable to be used for heating purposes, especially if the firewood is delivered during the winter months.

Despite these significant price increases in heating fuels, most buildings are still being built with too little insulation and without solar heating systems. The price of future heating costs over a life span of the building is seldom considered by the designer or building owner. This is surprising because one of the major aims of a solar building is to significantly reduce the traditional heating requirements which can save the owners substantial heating costs over the life time of the building.

There are already a number of solar buildings in Tasmania, (although the exact number is not known), but the vast majority of buildings are still being built without regard to energy conservation, due to the following reasons:

(a) building costs are high, especially the interest cost of loans. In addition, many people are under the impression, that the use of solar heating in buildings means only expensive solar panels, pumps and complicated control systems, and are not aware of the less expensive passive solar heating systems;

(b) many building owners disregard the cost of space heating over future years, the rate at which heating costs are increasing, the future availability of certain forms of energy, and future environmental problems resulting from the construction of power plants;

(c) to many people, the principles of passive solar energy systems are still relatively little known. Although there seems to be sufficient general information on the topic, most of it is not detailed or clear enough for practical design purposes. Due to many other design constraints, the building designer often does not take the time to consider, research, and apply solar principles into the design of buildings;

(d) to many building designers and owners, the effectiveness of the passive solar energy methods are not known, and hence the actual cost effectiveness of the passive systems is uncertain. The use of a life cycle analysis regarding energy consumption and cost of energy is seldom undertaken. These analyses should include considerations of inflation, cost of interest and the rate of fuel cost increase;

(e) many designers and building owners have a misconception of the aesthetic appearance of passive solar buildings. To them, the use of solar energy in buildings means large, unattractive-looking solar panels located on the roof. Only few are aware that many passive solar energy features can be part of the actual building fabric and not a dominant or ugly-looking supplement.

There is now an urgent need to show the wider section of the community the appearance and effectiveness of existing solar buildings, and to highlight experienced design and building problems, so that future designers and owners can learn and benefit from the experiences of these existing passive solar buildings.

1.2 DEFINITIONS OF PASSIVE AND ACTIVE SOLAR BUILDINGS

There are two basic approaches to the utilisation of solar energy in buildings. Active systems are generally those that the public sees as solar energy systems: collectors on roofs, pumps, plumbing, control systems, and storage tanks. Passive systems, on the other hand, are defined as those where the heat moves by natural means; that is, by conduction, convection, and radiation.

Another definition used by the United States Department of Housing and Urban Development is: "A Passive Solar Energy

System is one which uses the building structure as a collector, storage and transfer mechanism with a minimum of mechanical equipment."[2]

This definition suits most of the simple systems where thermal storage forms a part of the basic structure of walls, ceiling, and floor. There are also systems that provide thermal storage as a permanent but additional element within the building structure, such as rock-beds and water-filled drums.

A building, if designed correctly, can be a solar energy collector and storage system in one. In this way, a comfortable shelter can be provided for the occupants. To achieve this aim, a great number of conditions must be satisfied, which this project will demonstrate in the following chapters.

1.3 THE HISTORY OF SOLAR BUILDINGS

Passive Solar Design of buildings is an attempt to combine the utilisation of the sun's energy with the characteristics of a local climate to directly maintain thermally comfortable conditions within them. The concepts used are certainly not new. There are now a number of buildings in Australia that optimise the pleasant aspects of the local climate and minimise the unpleasant aspects. Some were designed that way intentionally, while others achieved the same result accidentally. The majority of modern designers and builders, however, has lost touch with the local environment with the consequence that most buildings are constructed without much consideration of the local climate and, least of all, with a view to using the sun in building design.

The history of passive solar design can be traced back to Socrates (469-399 BC)[3] who conceived the idea of a solar house when he developed a functional house which made maximum use of the winter sun, and completely shut out the direct radiation on the south side in summer.

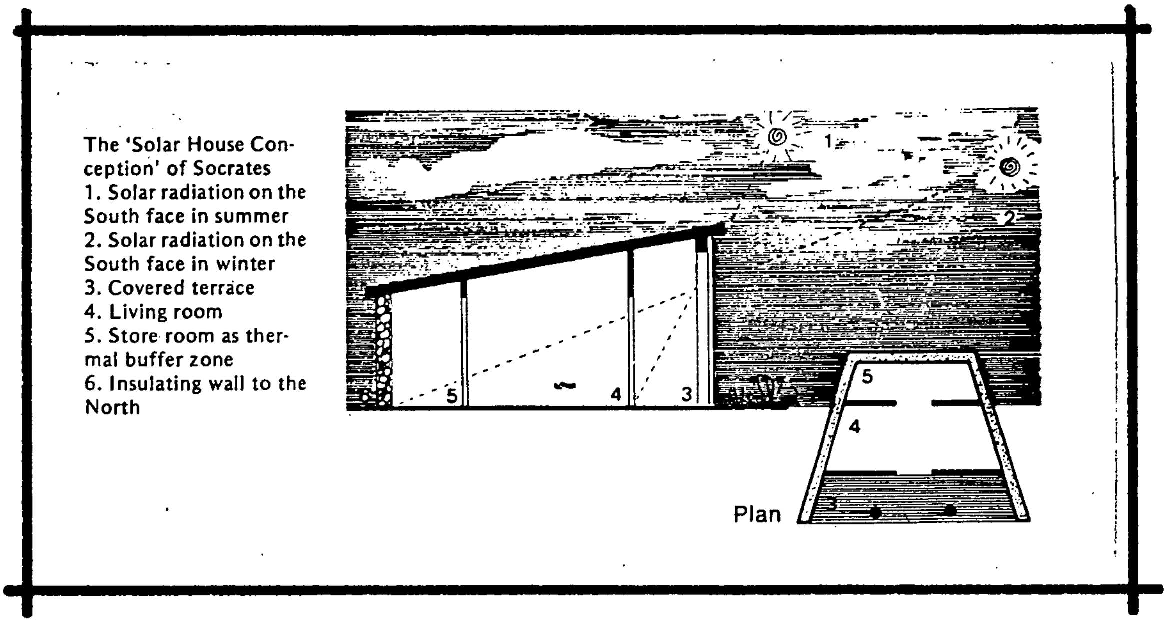


Figure 1.1 The Solar House Conception of Socrates
Source: Sabady, P.R., 1978;
<u>The Solar House</u>; Newnese Butterworths, London, Boston.

Early buildings of some American Indians applied basic passive heating principles with great sophistication. Pueblo Bonito in Chaco Canyon, New Mexico, USA, is one of several extraordinary examples of early Southwest Indian settlement.[4] The pueblo once housed 1200 inhabitants within its semicircular structure.

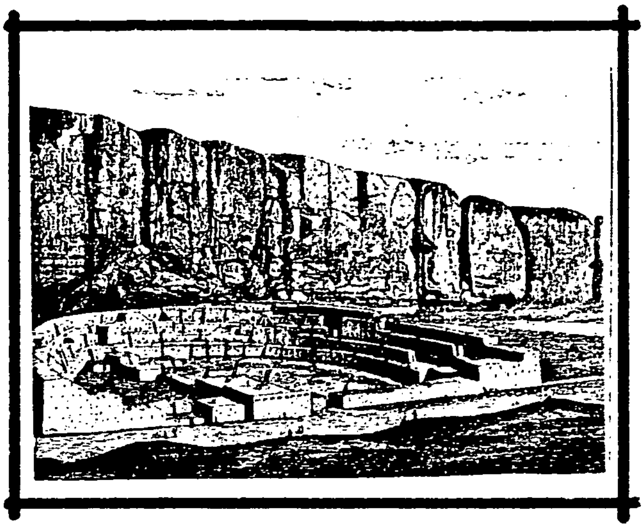


Figure 1.2 Early Buildings of American Indians. Source: Watson, D., 1977; Designing and Building a Solar House; Garden Way Publishing, Charlotte, Vermont, USA.

The determining points of the plan's geometry were based on the position of the sun at the summer and winter solstices. The effect was that the temperatures maintained within the interior of the building remained as evenly balanced as possible, despite the outside seasonal and daily temperature variation. Wall and roof construction were varied in thickness and composition to store the sun's heat and to permit the proper time lag of the day's heating effect into the interior at night. In the winter, when the sun's heat was welcomed, it reached into the interior through door and window openings dimensioned to shade the higher summer sun. The outside public spaces enjoyed a higher daytime temperature because they were protected from the winter winds by the structure's arcing plan.

The Acoma Pueblo near Albuquerque, New Mexico, provides a similar illustration of design in response to the daily and annual movement of the sun.[5] Positioned high on a protected mesa, the settlement has continued in use for 400 years. The horizontal terraces outside each dwelling, used throughout the year for food preparation and drying, are never in shadow. Even in December, when the sun is lowest on the horizon and its daily warmth is needed, no part of the south-facing wall of the houses is shaded by adjacent buildings, hence providing an early example of how 'sun rights' can in fact be respected within a dense urban settlement.

An unique example of these principles of solar design can be found in the cliff dwellings of the Siraqua and Anasazi Indians in Arizona, USA.[6] The cliff dwellings, called Montezuma's Castle, built in 1100 AD, made use of the heat capacity of mud, rock and other indigenous materials to absorb direct solar radiation on the south facing vertical walls.

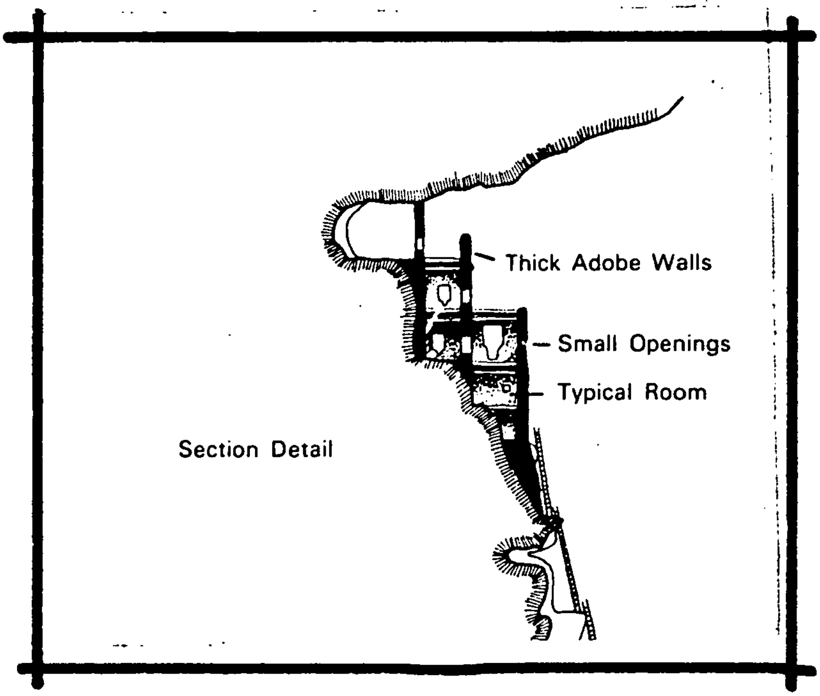


Figure 1.3 Montezuma's Castle (Cliff dwelling). Source: Cotton, N., 1978; Solar Heated Houses; Tutur Press, Toronto, Canada.

The heat was then re-radiated to the interior spaces during the evening. The compactly grouped dwellings were light in colour and had small wall openings to reduce direct and reflected radiation heat gain. The cliff dwelling also had one interesting feature which distinguished it from the Pueblo structures of the surrounding area. Because the dwellings were built under an extended portion of the mountain, the overhang blocked the high summer sun, hence providing natural cooling for the dwellings.

The term "solar house" was first used in Chicago newspaper articles to describe houses with large south-facing windows designed to obtain heat directly from the sun's rays.[7] Pioneered by architects George and William Keck, the houses began when the architects observed the sun's direct heating effect in the 1932 House of Tomorrow exhibit and the 1933 Crystal House at the Chicago World Fair, which they had designed with walls of glass. The architects Keck designed many dwellings with extensive glass areas to the south expressly to take advantage of direct solar heat in winter.

From 1938 to 1961, four solar houses were built and documented by the Massachusetts Institute of Technology. In 1949, a house was built in Dover, Massachusetts with a solar system designed to supply all of its heating requirements. Architect Eleanor Raymond and Solar Engineer Maria Telkes designed this house as one of the first to use air-type solar collectors, air being used to remove heat from the collectors and transfering

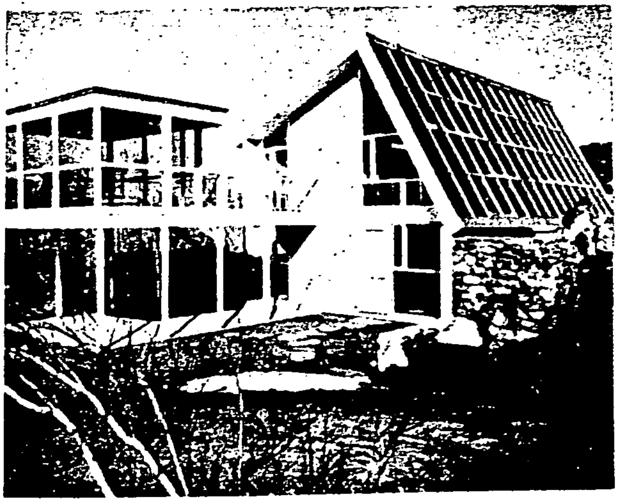


Figure 1.4 MIT Solar House IV, Lexington, Massachusetts, USA; (The last of four experimental solar houses undertaken by the MIT Cabot Foundation Research Program (1939-1961).
Source: Watson, D., 1978; Designing and Building A Solar House. Garden Way Publishing, Charlotte, Vermont, USA.

it to the house. In the 1950s, George Löf of Denver and Harry Thomason in Washington D.C. designed pioneering solar installations for solar space heating.

A French team, (Engineer Dr. Felix Trombe and Architect Jacques Michel) popularized a passive solar heating system, referred to as the Trombe-Michel wall.[8] In 1956, they built the first house using that system at Odeillo, France. It consists of a dark-coloured massive wall with outside glazing. In addition, dampers through the top and bottom of the wall enable a natural convection air circulation to be created upwards through the cavity during the day time for winter heating to supplement the wall's radiant heating capacity.

One of the first known houses using the Trombe-Michel wall system is the Kelbaugh house in Princeton, New Jersey USA.[9] This house, built in 1975, uses a 56 m^2 storage wall and is about 80% solar heated.

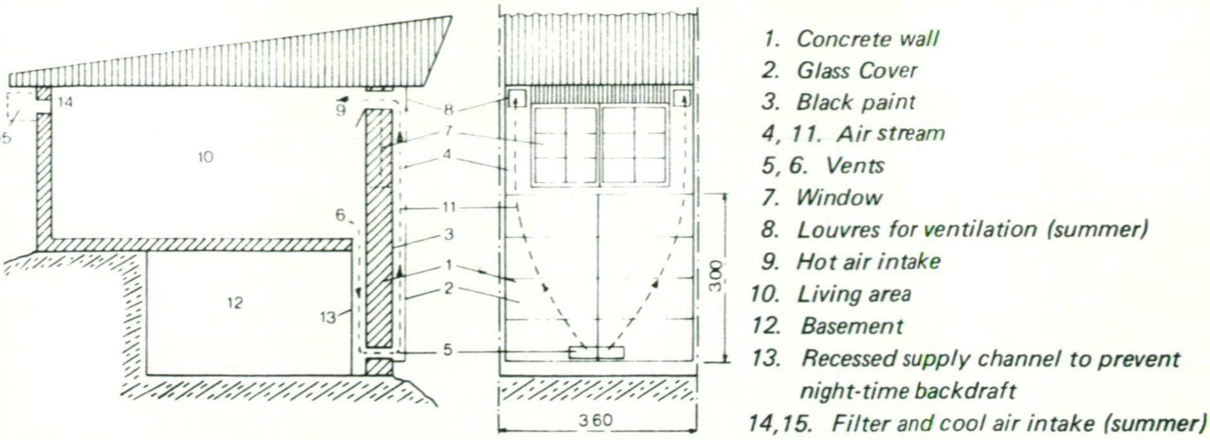


Figure 1.5 Trombe-Michel Solar Wall.
Source: Trombe, F., 1974; Maisons Solaires, <u>Techniques de Ingenieur 3</u>, 27-36.

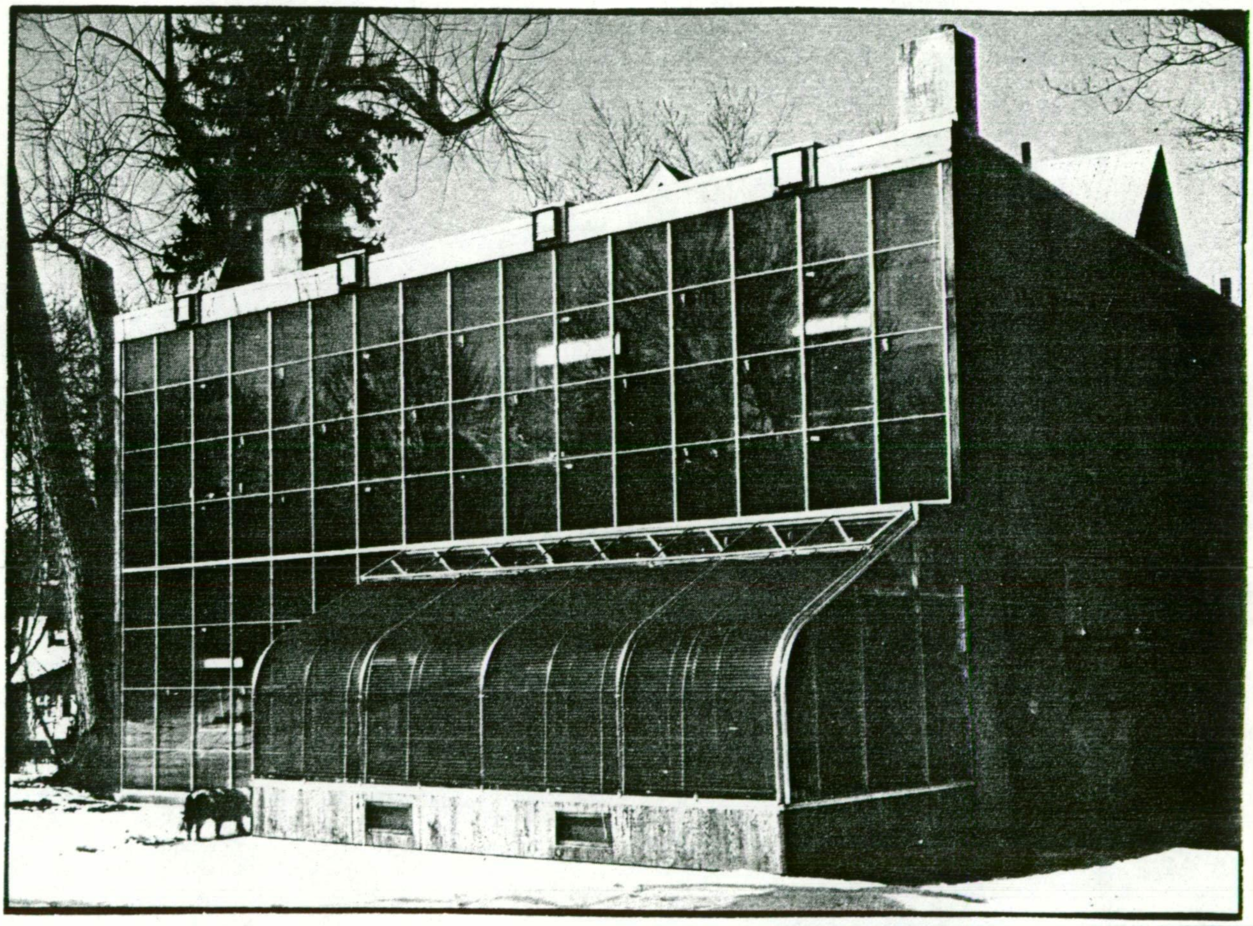


Figure 1.6 The Kelbaugh passive solar house uses a Trombe-Michel wall for the solar heating system.
Source: Mazria, E., 1979; <u>The Passive Solar Energy Book;</u> Rodale Press, Emmaus.

It was an Australian architect, Walter Butler[10], who, in 1903, showed how to exploit the difference in the sun's altitude in summer and winter, and advocated a northern exposure for all rooms and an eave of calculated width which would shade the glass only in the summer. In 1930, another architect, Walter Bunning,[11] produced sun oriented designs which would be still accepted today since they are both modern and thermally effective.

In the years immediately following the Second World War, the Federal Government established the Experimental Building Station in Sydney and researchers such as T.W. Drysdale[12] and R.O. Phillips[13] produced a series of publications on climate and building design. At the University of New South Wales Faculty of Architecture, the Solarch Group was formed in 1975 with aims for promoting the application of solar architecture throughout Australia. Also, other groups and individuals are working on these aspects of building, such as the Commonwealth Scientific and Industrial Research Organization (CSIRO) and the Schools of Architecture at Colleges and Universities around Australia.

In 1978, the CSIRO Division of Building Research at Highett, Melbourne constructed a low energy consumption house.[14] The research phase commenced in 1976 and the design uses passive and active solar heating methods. The building is used for research and demonstration purposes only. Detailed test results show, that the CSIRO low energy house achieves a 70%

energy reduction for space and water heating compared with a standard house in Melbourne.[15]

In 1977, the Victorian Gas and Fuel Corporation chose the Low Energy House 1, designed by Terry Williamson and Willys Span, as the winner of a low energy house design competition, resulting in 180 entries.[16] The aims of the competition were to produce a marketable low energy house suitable for a family of four and to demonstrate low energy principles to the general public.

In 1978, the South Australian Housing Trust financed the construction of two houses, a standard house with no solar features and a passive solar house immediately adjacent to the standard house.[17] The solar house incorporated a number of energy saving measures, including a modified version of the Trombe-Michel Solar Wall. The houses were occupied by tenants with families of a similar age and number and the thermal performance of the dwellings was compared from October 1980. The standard house used 4139 kWh and the solar house only 1450 kWh for space heating, showing a 65% energy saving for the solar house.

In 1980, the Tasmanian Department of Housing, in conjunction with the Tasmanian College of Advanced Education, designed and constructed two passive solar houses with identical floor plans at Rokeby, near Hobart.[18] They were built to demonstrate the technical suitability of a north storage wall for passive solar heating. One storage wall was built of 300 mm thick concrete whilst the other was built of water-filled steel tubes. Both used solar selective surfaces and single glass cover. The houses were occupied by Housing Department tenants in September 1980. Measurements taken over two years indicate a substantial improvement in thermal comfort and a halving of the space heating requirements as compared with that of an average Tasmanian house.[19]

Often, the promotion of solar housing has concentrated on complex active or semi-active systems, with high initial costs for the solar systems. However, Max Granger, an architect with the Cement and Concrete Association of Australia, stated in his paper "A Poor Man's Guide to Solid Solar Housing", that passive solar houses can even be built cheaper than traditional brick veneer standard houses.

There exist already a number of solar buildings in Tasmania, but only a very few have been documented to the general public.[21, 22, 23]

The public interest, however, in solar heating in Tasmania is fast increasing. When, in June 1980, the Department of Housing opened the two solar wall project houses for public inspection, more than 2000 people visited these houses over a period of two weekends. In July 1984, Sunspaces Pty Ltd.

in Ulverstone, Tasmania opened a passive display house to be inspected over a 5 week period. This project created an enormous public interest and over 2000 people visited that display house.

In 1981, the Adult Education Centre at Hobart conducted a few tours to solar houses in the greater area of Hobart. These tours were extremely well received and many people participated. However, after a few tours, the owners of these solar houses saw their privacy diminished and the solar house tours ceased. The Adult Education Centre is presently conducting courses on the theoretical aspects of solar building design, and the major request from the participants is to obtain significant information on existing solar buildings.

1.4 THE AIM OF THE THESIS

As many future home owners and professionals in the building industry are looking for existing solar buildings to find out information on features such as their appearance, price ranges, and the effectiveness of solar heating design, this thesis intends to provide that information and will assess a variety of passive solar buildings in Tasmania.

This thesis will catalogue ten Tasmanian passive solar buildings and particularly highlight the following factors:

a) the theoretical concepts of using passive solar designs;

b) the appearance and architectural layout of the passive solar buildings;

c) how, and how effectively, the passive solar system works;

d) the problems (if any) related to the actual construction and maintenance of the solar systems; and

e) the owner's own personal experience living and using such a solar building.

The thesis is presented in two major parts. The first part, consisting of Chapter Two and Three, introduces some theoretical aspects of passive solar design and briefly reviews several other surveys of solar buildings.

Chapter Two looks at aspects of thermal comfort and shows why space heating is such an important factor in Tasmania. This is then related to the various key components of passive solar design as they apply in the State. Chapter Three demonstrates that the technique of cataloguing existing solar buildings is a valid and useful means of advancing the state of the art in solar design, but that regional differences in climate, building practice, and lifestyle mean that these catalogues should be prepared for a particular region to be most effective.

The second part of this thesis catalogues and evaluates ten passive solar buildings, all situated in Tasmania. Documenttation of each of these buildings is presented in two parts, first, the technical aspects of the building are explained and, secondly, an owner analysis of the building's performance is given.

The technical aspects of this documentation describe factors such as construction techniques, solar heating systems, methods of insulation, and thermal performance data. The owner analysis indicates important aspects such as the building experience, experienced thermal comfort in the building, problems related with the solar systems, and future design and building changes the owner would choose to make should the chance to build again occur.

The thesis has a practical purpose in showing that solar buildings are viable now in Tasmania. By showing solar buildings over a wide range of costs, the analysis should interest a wide variety of prospective home owners from most socio-economic levels. By highlighting practical experiences and problems regarding the solar heating systems, the thesis will indicate which are the lessons to be learned in passive solar buildings under Tasmania's conditions. The information necessary to design a passive solar building to suit particular climatic and economic circumstances in Tasmania will be the eventual outcome.

References, Chapter 1

1. DEPARTMENT OF TRANSPORT AND CONSTRUCTION, 1983; Energy Efficient Australian Housing; Australian Government Publishing Service, Canberra.

2. UNITED STATES OF AMERICA HOUSING AND URBAN DESIGN, 1978; Residential Use of Solar Energy; U.S. Government Printing Office, Division of Public Documents, Washington D.C.

3. KNOWLES, R., 1972; The Early Indian Settlements; University of Southern California, San Francisco.

4. SOLERI, M., 1979; The City in the Image of Man; MIT Press, Cambridge.

5. NEUTRA, R., 1971; Building with Nature; Universe Books, New York.

6. ARONIN, T.E., 1953; Climate and Architecture; Reinhold Publishing Cooperation, New York.

7. WATSON, D., 1978; Designing and Building A Solar House; Garden Way Publishing, Charlotte, Vermont.

8. TROMBE, F., 1974; Maisons Solaires, Techniques de Ingenieur 3, 27-36.

9. KELBAUGH, D., 1976; Solar Home in New Jersey, Architectural Design 46, 57-68.

10. BUTLER, W., 1903; Healthy Buildings; a paper presented to the Australian Health Society, Melbourne.

11. BUNNING, W., 1930; Sunny Spaces, Royal Australian Planning Institute Journal 17, 72-91.

12. DRYSDALE, T.W., 1952; Designing Houses for Australian Climates; Experimental Building Station, Bulletin No.6; Australian Government Publishing Service, Canberra.

13. PHILLIPS, R.O., 1975; Sunshine and Shade in Australia; Experimental Building Station, Bulletin No.8; Australian Government Publishing Service, Canberra.

14. PARNELL, M. and COLE, G., 1983; Australian Solar Houses; Second Back Row Press, Solar Scope, Sydney.

15. COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION, 1981; Solar Energy in Your Home, film on the principles of low energy consumption,12 minutes, Melbourne.

16. PARNELL, M. and COLE, G., 1983; See note 14.

17. SOUTH AUSTRALIAN HOUSING TRUST, 1981; *The Seaton Experimental Low Energy House*; Department of Urban and Regional Affairs, Adelaide, South Australia.

18. SUTTON, R.G. and McGREGOR, R.J., 1983; *Solar Wall, Two Demonstration Houses with passive solar heating in Tasmania;* A report to the National Energy Research Development and Demonstration Council, Department of Resources and Energy, Canberra; Tasmanian College of Advanced Education, Launceston, Tasmania.

19. As above.

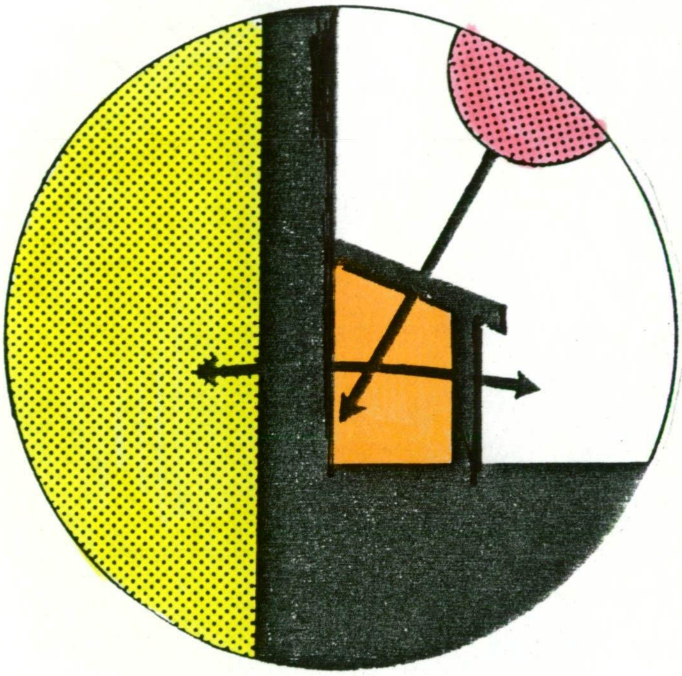
20. GRANGER, M., 1981; *The Exploitation of the Masses or A Poor Man's Guide to Solid Solar Housing;* Promotion of low cost Solar Housing in temperate Australia; University of N.S.W., Duntroon.

21. SUTTON, R.G. and McGREGOR, R.J., 1983; see note 18.

22. PARNELL, M. and COLE, G, 1983; see note 14.

23. AUSTRALIAN AND NEW ZEALAND SECTION OF THE INTERNATIONAL SOLAR ENERGY SOCIETY, 1978; *Solar Progress 5*, Solar Energy Developments Pty. Ltd., Brisbane.

CHAPTER 2



THERMAL COMFORT AND PASSIVE SOLAR HEATING SYSTEMS

2.1 INTRODUCTION

Buildings are constructed mainly for the purpose of providing shelter from the climatic environment and security for the occupants, they modify the natural environment to approach optimum conditions of livability. Buildings should filter, absorb, or repel environmental elements according to their beneficial or adverse contribution to human comfort.

The first section of this chapter briefly discusses thermal comfort including human comfort zones and looks at the major elements of the climatic environment, especially regarding Tasmania's condition.

One of the first steps designing a successful solar building is to adopt energy conservation principles including factors such as insulation of the building shelf, controlled ventilation and low infiltration rates. Energy conservation measures can be carried out on existing buildings, if solar heated or not, and as there is sufficient literature available on the topic[1], it is not included in this thesis.

The second section then discusses some theoretical aspects of passive solar heating by describing the four most commonly applied passive solar heating systems used in the surveyed buildings, and highlights some of the advantages and disadvantages of each solar system.

2.2 THERMAL COMFORT

Thermal comfort can be defined as "that condition of mind which expresses satisfaction with the thermal environment".[2] A person experiences thermal comfort when he or she is affected by a suitable combination of thermal influences. The main environmental influences affecting thermal comfort are depicted in figure 2.1.

The human body constantly produces heat. To be in thermal comfort, it must lose just the right amount of heat to its environment; to much, and the body becomes too cold, too little and it becomes hot. The body can maintain thermal equilibrium over a wide range of conditions by shivering (cold)

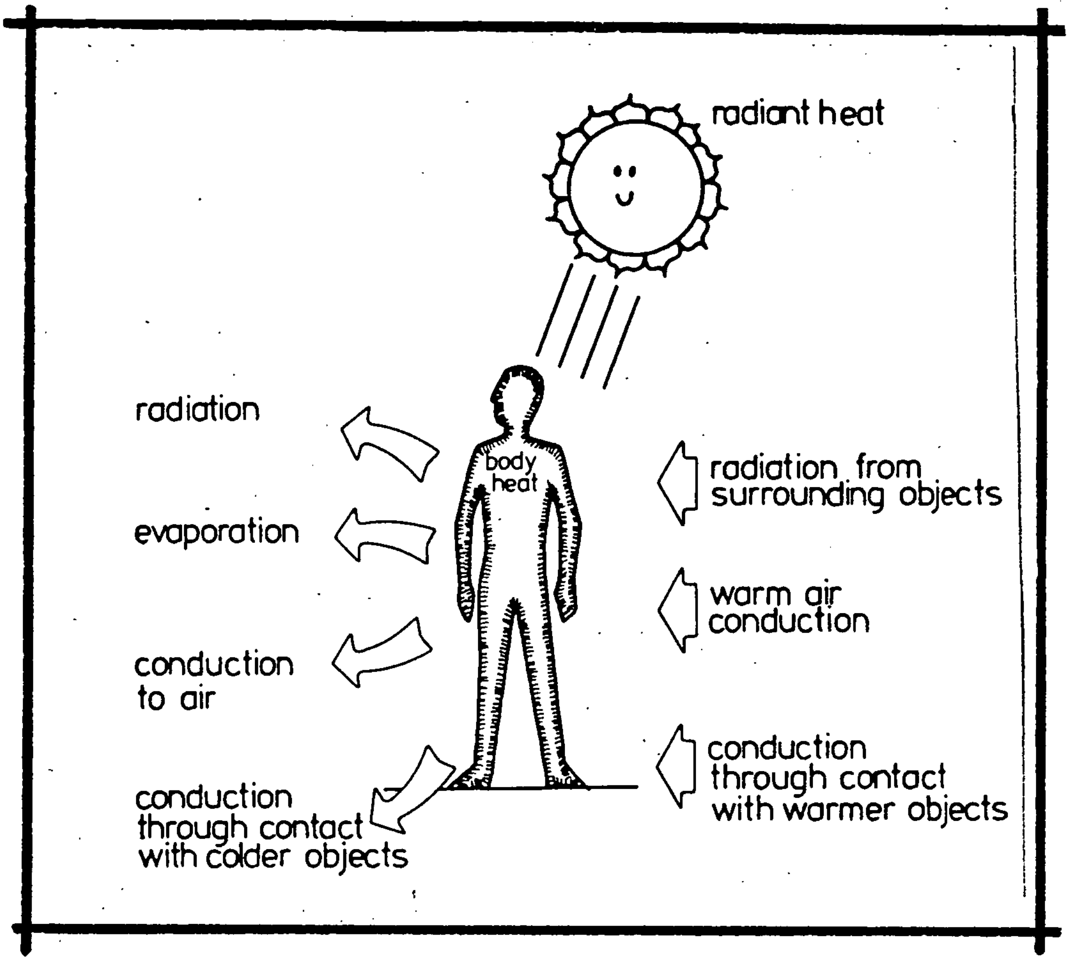


Figure 2.1 Body Heat Balance.
Source: Parnel, M., and Cole, G., 1983; Australian Solar Houses; Second Back Row Press, Solar Scope, Sydney.

or sweating (hot). The range of conditions for thermal comfort (as opposed to equilibrium) is much narrower.

Under normal conditions in a comfortable environment, a person gains or loses heat in four ways[3] in approximately the following proportions:

Evaporation	25%
Convection	30%
Radiation	44.5%
Conduction	0.5%

A thermal comfort range should be determined by the occupants of a building. As a general rule, the air temperature should be between 18°C and 24°C in winter and 20°C and 28°C in summer, and the relative humidity should be 40-50%.[4] The mean radiant temperature, being one of the major factors in thermal comfort, should, in winter, be at least 3°C higher than the air temperature.

Victor Olgyay, in his book Design with Climate, devised a bioclimatic chart, showing the comfort zones and also the conditions outside these comfort zones.[5] Above 30°C, cooling is necessary, indicated on the chart by air movement. Below 21°C, heating is necessary, indicated in the chart by radiant heating. For example, at 11°C, 800 W/m^2 radiant heat are needed to stay within the comfort range.

There are six main variables that influence thermal comfort[6] and they are as follows:

(a) activity level;
(b) air temperature;
(c) thermal resistance of clothing;
(d) mean radiant temperature;
(e) relative air velocity;
(f) and humidity.

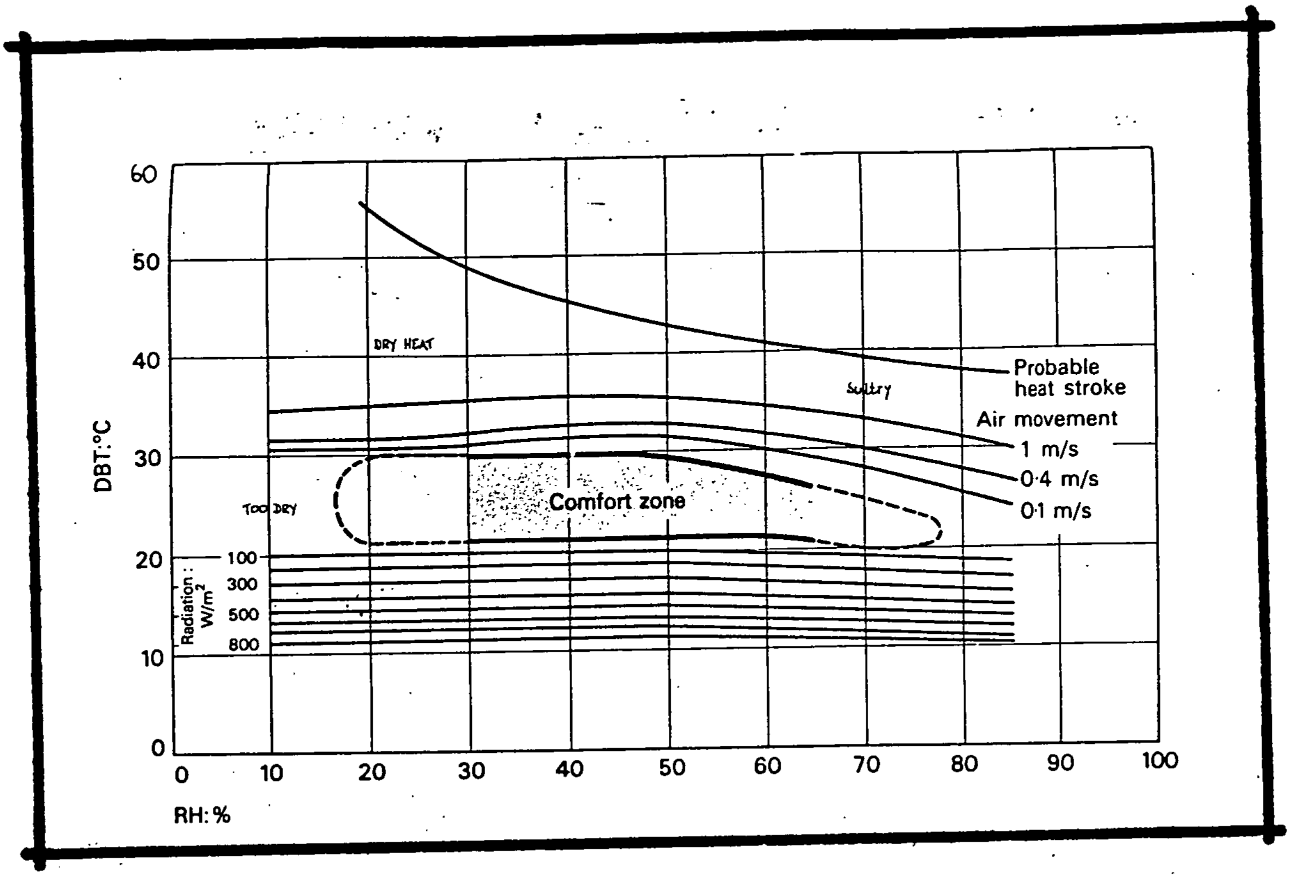


Figure 2.2 The Bioclimatic Chart
Source: Olgyay, V., 1957; <u>Design with Climate</u>; Princeton University Press, Princeton, New Jersey.

The effect of radiation and re-radiation from surrounding surfaces greatly affects thermal comfort and is included in the environmental temperature; it is the combination of both air-temperature and mean radiant temperature in the following proportion:[7]

$$te = \frac{2}{3} tr + \frac{1}{3} ta$$

where te = environmental temperature
tr = mean radiant temperature of surroundings
ta = air temperature

The effects of humidity and temperature can be combined on a complex graph, known as the psychrometic chart. The comfort zone is defined by any combination of humidity and environmental temperature which gives thermal comfort. Using information on environmental variables establishes comfort zones for various activities, with a fairly large degree of tolerance, particularly if there is freedom to

(a) move about,
(b) change activity, and
(c) change clothing.

Zones also vary according to physical adaptation to certain conditions; for instance, the acceptable comfort zone for winter will probably be cooler and less humid than for summer. Much cooler and less humid conditions can be tolerated for sleeping than those for day time living, since the body is usually well protected by the bedding when sleeping.

The areas of the body most sensitive to thermal change are the head, feet and hands in that order. This fact can be used to measure thermal comfort by a simple rule of thumb. For example, if the head and feet are comfortable, then the desirable thermal conditions are probably present.

The level of thermal comfort in passive solar buildings is of a very high quality. The most important factor is the effect of the thermal radiant environment on comfort. In a passive solar building, the enclosing surfaces of a room are usually warmer than in a conventional building which leads to an increase in the radiant temperature. This increase in surface temperature results from two effects: well insulated walls and storage of solar heat. The individual in a passive solar building can experience the same comfort sensation, when the air temperature is only around 18°C, as in a conventional house with an air temperature of around 22°C.

A second effect which underlines overall comfort is the great thermal stability of a well insulated building with solar collecting areas and large thermal mass. Temperatures change slowly, resulting in less physical stress than in a building with the same average temperatures, but with abrupt temperature fluctuations. For example, the occupants of many of the buildings discussed in Chapter 4 have indicated that their health has improved considerably since moving into their solar buildings.

2.3 CLIMATIC FACTORS

2.3.1. Introduction

The climate (from Greek: klima) is defined by the Oxford dictionary as "region with certain conditions of temperature, dryness, wind, light, etc." A somewhat more scientific definition[8] is: "an integration in time of the physical states of the atmospheric environment, characteristic of a certain geographical location."

The earth receives all its energy from the sun in the form of radiation and it is the dominating influence on climates.

Generally, climate can be classified into macro-climate and micro-climate. The macro-climate of an area is the sum of the general climatic conditions that affect the region, and, as a result of its location and particular seasonal characteristics, produces a recognisable physical environment. Micro-climate is the specific detailed climatic conditions affecting a local area and is influenced by the macro-climate and other factors such as local topography, buildings,and vegetation.

Australia may be divided into six major climatic zones (Figure 2.3) as follows:[9]

(a) hot humid;
(b) sub tropical;
(c) hot arid;
(d) dry warm temperate;
(e) temperate;
(f) and cool temperate.

2.3.2. Tasmania's Climate (a short summary of climatic data)

A. Introduction

Tasmania is classified as having a temperate to cool temperate climate. Summer day temperatures are as high as 30°C, while night temperatures are moderate, between 12 and 18°C. Winter day temperatures can be as high as 12°C, while nights are cold, usually between 2-5°C. Rainfall occurs throughout the year, but predominantly in winter.

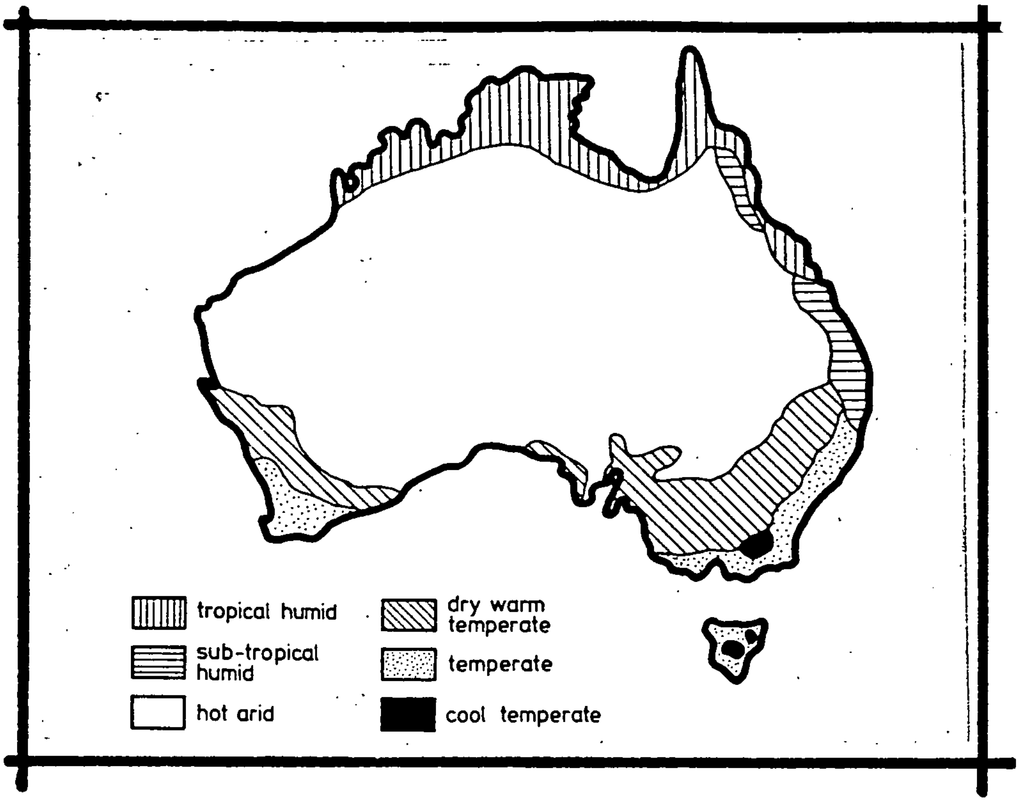


Figure 2.3 Climatic Zones of Australia;
Source: Drysdale, J.W., 1975;
<u>Designing Houses for Australian Climates;
Experimental Building Station, Sydney.</u>

Humidity is moderate, averaging 30-40%. Dividing Tasmania into two climatic zones is only a broad generalisation; major differences in climate can occur over comparatively short distances. For example, a building constructed for the Hobart city area might not be appropriate for the Hobart-Ferntree area, where only a 5km distance from the city results in a difference of up to 360 metres in elevation, and hence, different micro-climates within this distance.

The climatic elements, which strongly affect human comfort and building techniques, such as air temperature, solar radiation and wind effects are discussed in the following section. The concept of heating degree days is also included, showing the severity of the winter climate for a variety of locations in Tasmania.

B. Air Temperature Data for Hobart and the Concept of Heating Degree Days

(1) Air Temperatures

Figure 2.4 shows three different daily air temperatures between January and December for Hobart, the average maximum, the average minimum and the average mean temperature.

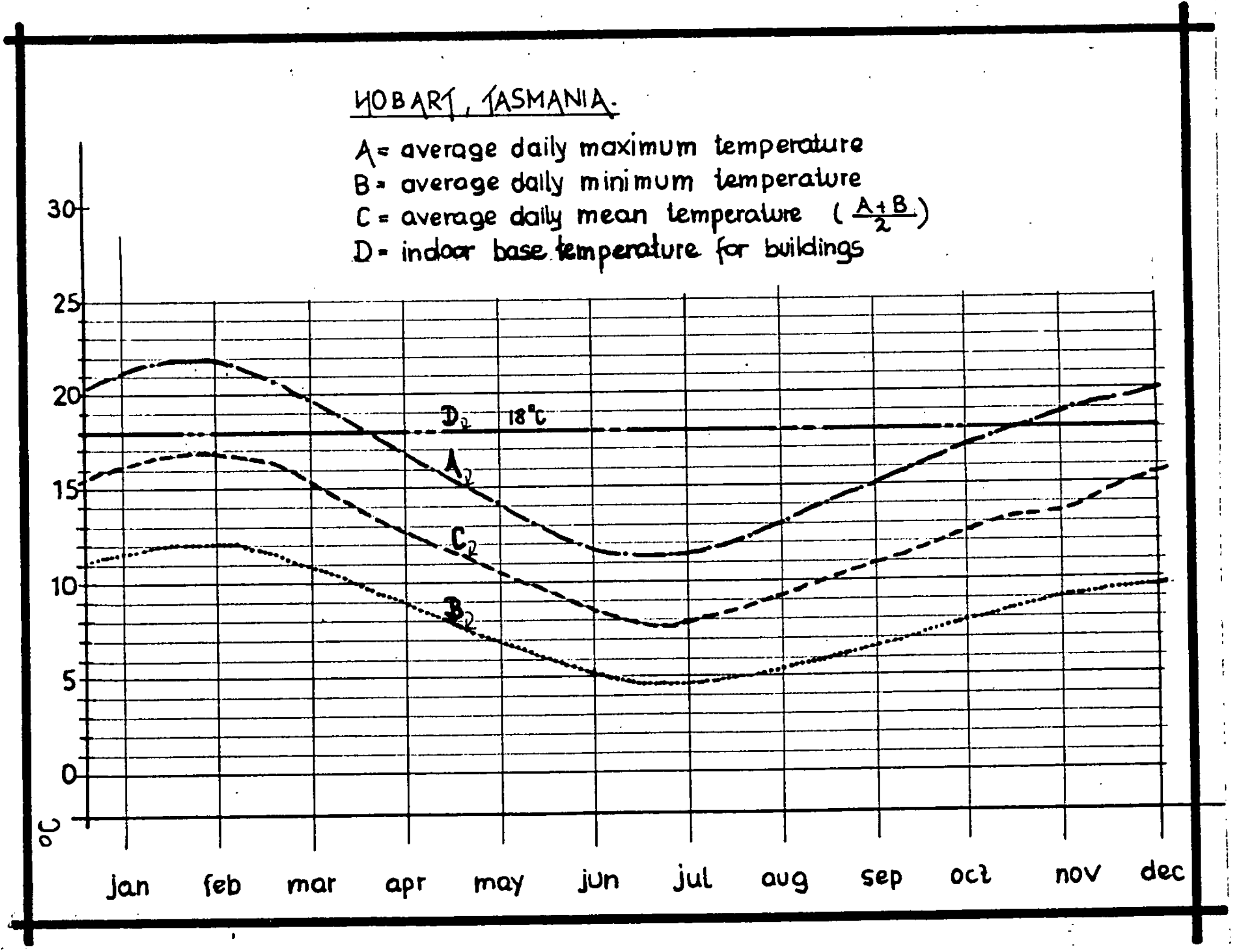


Figure 2.4 Average Air Temperatures for Hobart; Source: Bureau of Meteorology, Department of Science, Hobart.

Figure 2.4 also indicates the relationship between a preselected internal temperature of 18°C (usually applied for the selection of Heating Degree Days) and the various average external temperatures over a period of 12 months. It can be seen that space heating in the Hobart area is required for most of the year, or at least between the middle of March and the middle of October. Additional information on air temperatures recorded in Hobart is presented in Appendix A.

(2) The Concept of Heating Degree Days

The Heating Degree Day concept represents an expression of a climatic heating requirement expressed by the difference in degrees Celsius between the average outdoor temperature for each day and an established indoor temperature base of usually 18°C. The Heating Degree Days figure is calculated according to the following equation:[10]

$$\text{Heating Degree Days} = \sum \Delta t \quad 365 \text{ days}$$

$$\Delta t = t_b - \tfrac{1}{2}\,(tmax + tmin);\ \text{if}\ \tfrac{1}{2}(tmax + tmin) < t_b$$

$$\Delta t = \quad 0 \quad ;\ \text{if}\ \tfrac{1}{2}(tmax + tmin) > t_b$$

where: t_{max} and t_{min} are the daily maximum and minimum temperatures.

$\frac{1}{2}(tmax + tmin)$ is the mean daily temperature.

t_b is the selected indoor base temperature.

Δt is the selected indoor base temp. - the mean daily temp.

For the calculation of heating requirements, the choice of an indoor base temperature is important. The base temperature is an established indoor temperature, initially 18.3°C (65°F). Now Heating Degree Day figures are based on different base temperatures and are available in Appendix B for various locations in Tasmania.

Figure 2.5 shows the yearly Heating Degree Days, based on various locations in Tasmania.

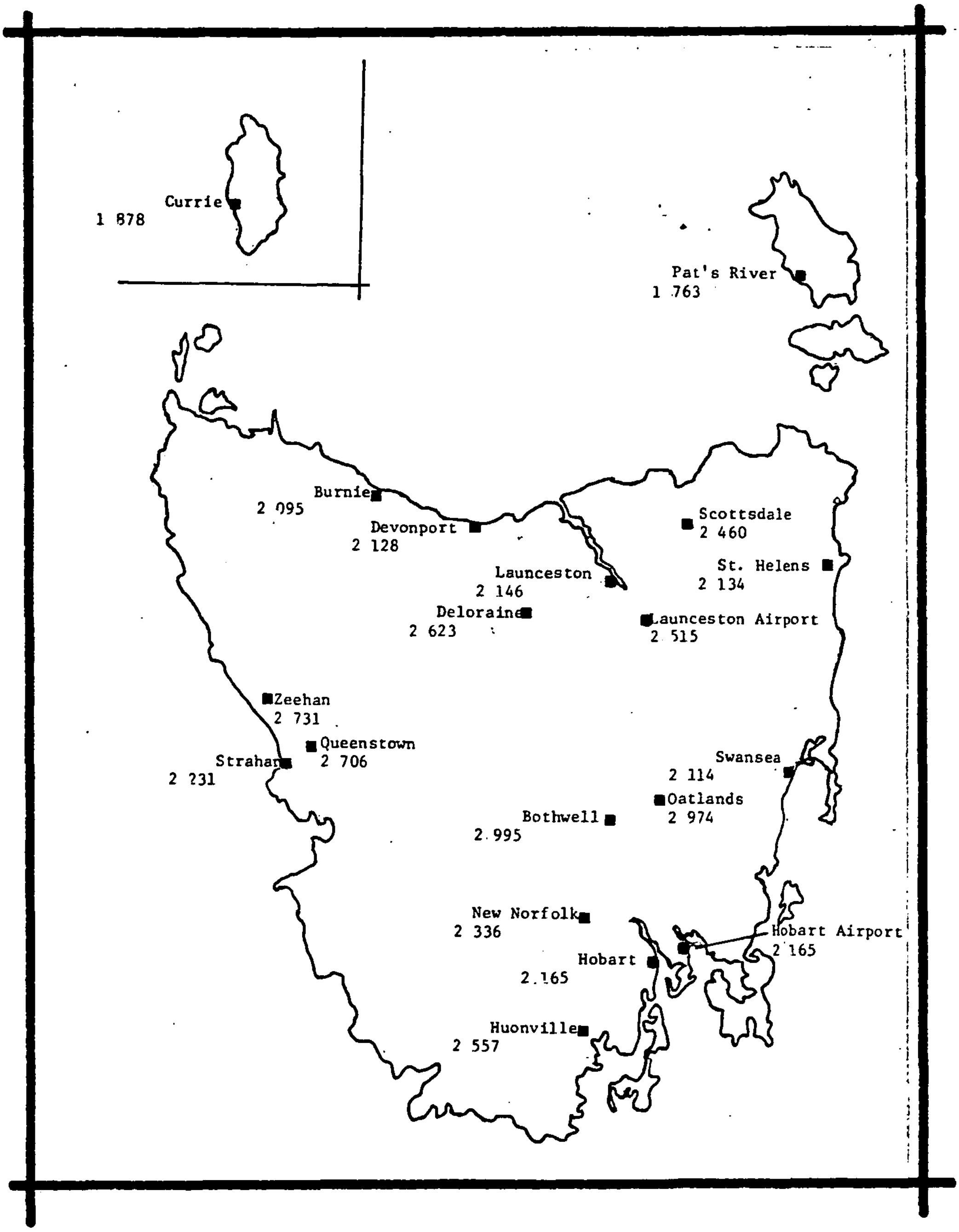


Figure 2.5 Heating Degree Days, base temperature 18.3°C.
Source: Arundell, L.F., 1979; <u>The Feasibility of heat pumps for domestic heating in Tasmania</u>; Thesis presented for the Master of Environmental Studies, University of Tasmania.

The annual heat requirement to maintain a building at a comfort level can be calculated from the Heating Degree Day figure as follows:[11]

$$\text{Annual heating requirement (kWh)} = \text{Heating Degree Days} \times \frac{24}{1000} \times U_{total}$$

where: U_{total} is the total rate of heat loss (conduction and convection) from the building, per Watt/degree Celsius.

Using Heating Degree Day figures for establishing annual or monthly heat requirement is a simple and fast method and often used by the public and architects for estimation purposes. However, as this method is based on steady state conditions and continuous space heating over 24 hours, this method cannot be used if heat load calculations are to be carried out for only part of the day, and it is then preferable to use a calculation method based on hourly temperatures.

C. Solar Radiation

(1) Background to the Reception of Solar Radiation

The energy received from the sun by earth is known as insolation (incoming solar radiation). At the outer limits of the earth's atmosphere, insolation is received at the rate of 1353 W/m^2 and is referred to as the solar constant.[12]

Approximately 30% of this solar radiation is reflected back into outer space, another 2% (mainly in the ultra-violet portion of the spectrum) is absorbed by oxygen and ozone molecules high in the atmosphere. Water vapour, dust particles and atmospheric pollution absorb and scatter a further 18% so that a global average of about 50% of the incoming radiation finally reaches the surface of the earth.[13] Local cloud cover further reduces the amount of solar radiation available at the earth's surface. As a result of these phenomena, the 1353 W/m^2 of solar radiation falling on the outer atmosphere are significantly reduced so that, by the time it reaches the surface of the earth, between zero and 1050 W/m^2 are recorded.[14] Depending on local atmospheric conditions, a large proportion of radiation may be diffuse, but even when the sun is unobstructed by clouds, as much as 10% may arrive as scattered radiation.[15]

The availability of solar radiation is the most important factor in solar buildings and will be now discussed, especially in relation to Tasmania.

(2) Data on the Reception of Solar Energy in Tasmania

The reception of solar radiation in Tasmania compares well with various European countries, as it can be seen in Table 2.1. Figure 2.6 shows the annual mean insolation (incoming solar radiation) for Tasmania, indicating a higher solar potential for the eastern parts of Tasmania as compared to the west coast.

Region	Solar Radiation (GJ/m^2 year)
Sweden	3.2
Norway	3.2
Finnland	3.2
United Kingdom	3.2
Federal Republic of Germany	3.6
Netherlands	3.6
France	4.3
Italy	5.0
Tasmania	5.0

Table 2.1 Regional difference in solar energy potential on horizontal surface; Source: Lyttkens, J., and Johansson, T., 1980; The European Transition away from Oil; Paper prepared for the Nobel Symposium, Stockholm. Tasmanian figure taken from: Hydro-Electric Commission of Tasmania, 1979; Report on the Gordon River Power Development Stage Two; The Hydro Electric Commission, Hobart.

Measurements of solar energy taken on a horizontal surface do not give a true indication of the amount of useful solar energy available for solar buildings, as solar collection areas are either constructed vertically, such as solar walls or solar windows, or inclined to the horizontal, such as sunspaces or solar water heaters.

Figure 2.7 presents the wide variation in insolation for different oriented surfaces, such as horizontal, vertical and inclined north facing surface (43° from horizontal) under clear sky conditions.

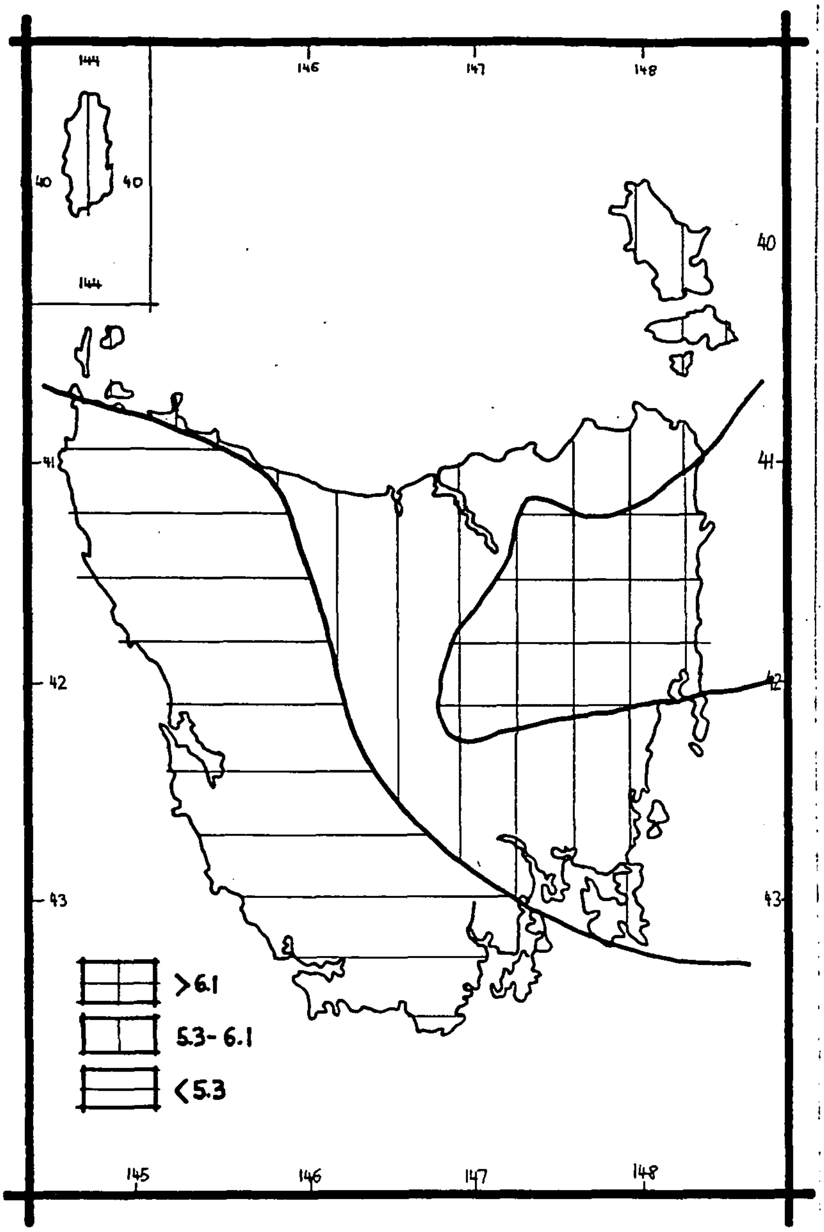


Figure 2.6 Annual mean insolation for Tasmania. (GJ/m^2 year) on horizontal surface. Source: Hydro-Electric Commission of Tasmania. 1979; Report on the Gordon River Power Development Stage Two; Hydro-Electric Commission of Tasmania, Hobart.

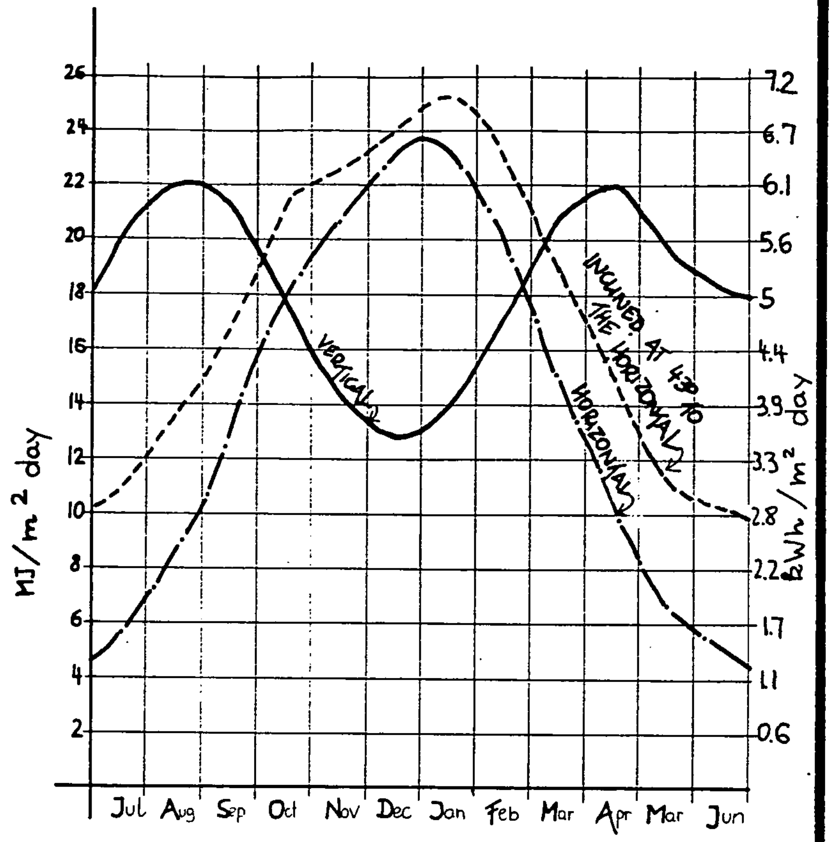


Figure 2.7 Comparison between total insolation on a vertical surface facing north, a horizontal surface, and a surface inclined at 43° to the horizontal, facing north under clear sky conditions, for Hobart; Source: Sutton, R., 1977; <u>Paper on Domestic Heating Usage in Tasmania</u>; College of Advanced Education, Hobart.

From figure 2.7 it can be seen that, between April and September, a vertical surface, facing north, will receive more solar radiation than the horizontal and inclined surfaces. This phenomenon will greatly benefit the passive solar energy systems, as most of the collectors, such as glazing areas and thermal storage walls, are constructed vertically.

For thermal building calculation purposes, measured radiation values on vertical north facing surfaces, actually taking the effect of cloud cover into consideration, have been produced by Robert Sutton, Tasmanian College of Advanced Education, and are listed in Table 2.2.

Month	Insolation on vertical, north facing surface per day (mean values). Values for Hobart only.	
	$MJ/m^2/day$	$kWh/m^2/day$
January	12.2	3.38
February	11.8	3.27
March	11.7	3.25
April	10.5	2.91
May	9.2	2.55
June	9.2	2.55
July	9.6	2.66
August	11.6	3.22
September	12.2	3.39
October	12.1	3.36
November	11.4	3.17
December	11.3	3.14

Table 2.2 Measured insolation on north facing surfaces, values for Hobart only.
Source: Sutton, R., 1981;
<u>Private Communication on global radiation data on vertical surfaces facing north</u>;
Tasmanian College of Advanced Education, Hobart.

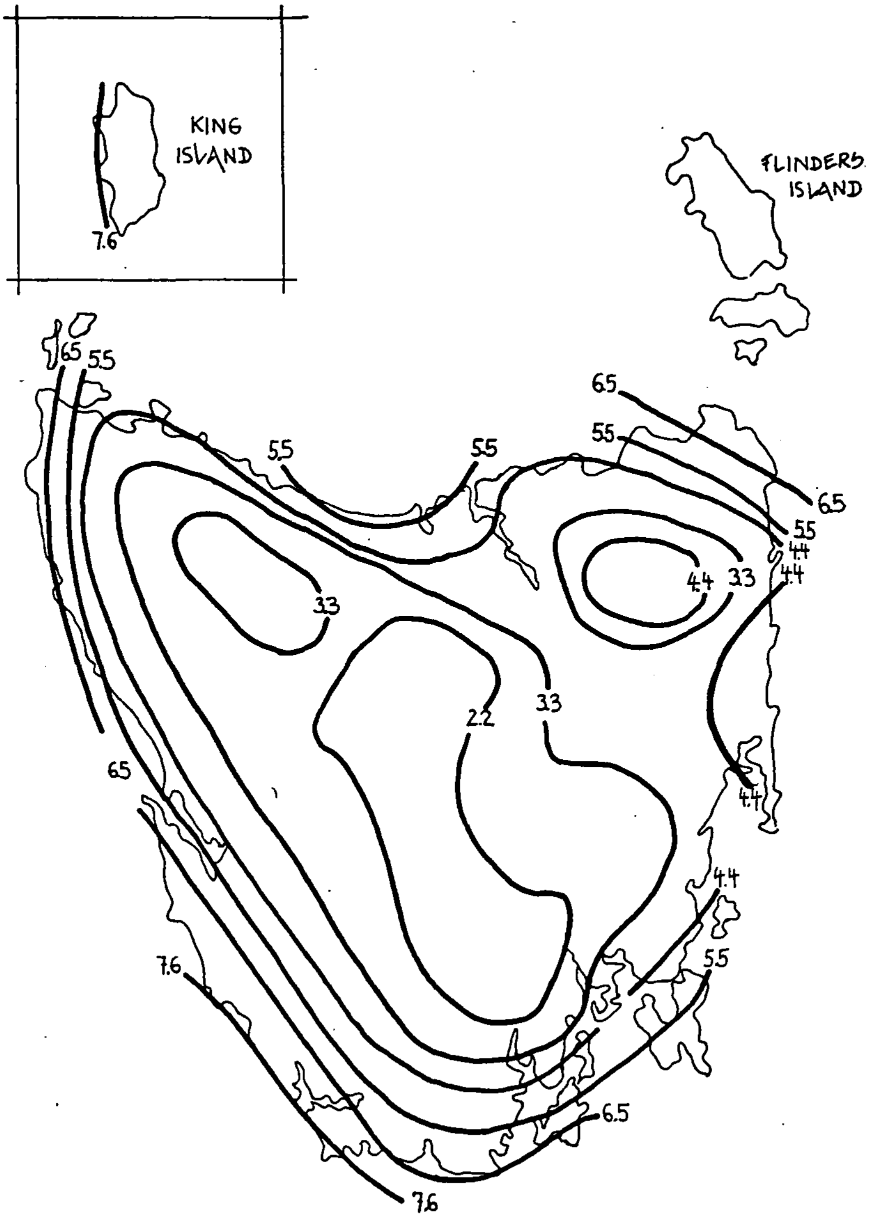
Additional data on measured daily global radiation on horizontal surfaces for Hobart, can be found in Appendix C.

D. Wind effect and Data for Tasmania

For solar buildings, the effect of winds, especially in winter, have a major influence on their thermal performance, and care must be taken when siting these buildings. The designer must determine the prevailing directions of cold winds, whether predictable daily or seasonal shifts occur and whether there is a recognisable pattern of daily or seasonal velocities.

Figure 2.8 represents the mean annual wind speed for Tasmania and shows that higher winds occur on the coastal areas of Tasmania, as compared to the central area. It must be pointed out that Figure 2.8 is based on rather limited meteorological data; exposed and elevated sites are likely to experience higher average wind speeds than indicated by the Figure.

More wind data, presented in Appendix D, shows the average windspeed for each month and the average wind direction for the area of Hobart, Tasmania.



ISOVENTS OF ANNUAL MEAN SPEED FOR TASMANIA

NOTES:

1. ANNUAL MEAN WINDS ARE IN m/s
2. ISOVENTS ARE INDICATIVE ONLY AND DO NOT COVER ELEVATED AREAS.

Figure 2.8 Isovents of annual mean wind speed for Tasmania.
Source: Hydro Electric Commission, 1979; Report on the Gordon River Power Development, Stage Two, Alternatives to Hydro Electric Energy; Appendix 111; Hobart.

2.4 PASSIVE SOLAR HEATING SYSTEMS

2.4.1 Introduction

The fundamental principles of passive solar design, such as orientation, building shape, glazing, thermal mass, thermal zoning, insulation and ventilation are well known and there exists sufficient general information on the topic, clear and detailed enough, to be used for building purposes.[16] There also exists an Australian Insulation Standard on the Thermal Performance and Insulation of Dwellings[17], which gives guidance in improving the thermal performance of buildings to achieve higher thermal comfort while still being cost effective.

Passive solar space heating systems use large areas of north-facing glass in conjunction with a large volume of thermal mass. Solar radiation enters the building, is converted into heat, and then used to heat the buildings. Four general types of passive space heating are commonly used and will be described in this section.

The most common systems are the Direct Gain System and the Thermal Storage Wall System. The Attached Sunspace System is becoming more and more popular and finally, the Convection System is discussed.

A short summary of advantages and disadvantages has been included after the description of each solar heating system. Some rule of thumb guidelines are also included in this section to compare their relevance in connection with the surveyed passive solar buildings in Chapter 4. Rule of thumb guidelines are formed over many years of theoretical and practical experiences and are a quick method for architects, designers, and builders to determine the size of a solar system.

2.4.2. Direct Gain System

The Direct Gain System is the simplest, most cost-effective approach to solar space heating. In winter, the sunlight is allowed to enter the house through the large area of glass facing north. This solar radiation is then either absorbed by the surface on which it falls, or is reflected until it is eventually absorbed.

In order to reduce the possibility of overheating of surfaces, objects with low mass (such as light furniture and plaster walls) are painted a light colour so that a large fraction of the light falling on them is reflected. The surfaces of the more massive objects, such as concrete floors or solid walls, should be given a dark colour so that they absorb most of the radiation falling on them. In practice, solid walls can be painted a dark colour, or

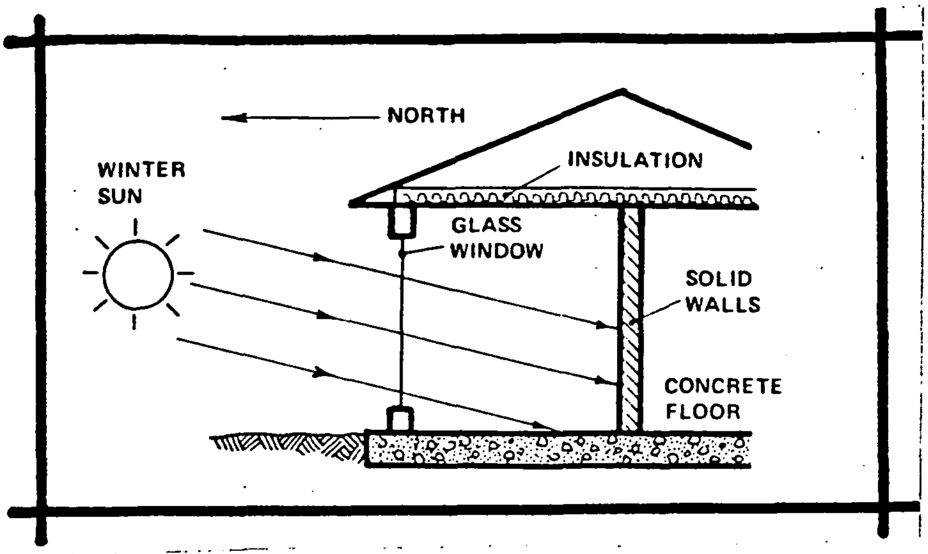


Figure 2.9. Principles of Operation of a Direct Gain System.
Source: Charters, W., 1981; Introduction to the Installation of Solar Energy Systems; Victorian Solar Energy Council, Melbourne.

made from dark bricks, and concrete floors covered with dark-coloured tiles or slates to achieve the above effect. It is most important, apart from correct orientation and insulation, to place a large amount of solid materials inside the building, usually referred to as the thermal mass. Apart from preventing overheating, the solid material acts as a heat storage.

As the temperature of the living space drops, heat that has been absorbed during the day is transferred from the warm surfaces to the room. In this way, the massive surfaces can provide heating for the living spaces for periods well after sunset, (e,g, electric storage heaters use the same principles; hot air is blown through the heat storage bricks at day time, and, during the night, the bricks again release the heat.)

Heat losses through glass windows can be one of the main causes of heat loss from a building. Therefore, most windows in a Direct Gain System should face north so that, during sunny days, they can act as solar collectors. At night, and on cold cloudy days, heavy curtains, blinds, and shutters have to be used to reduce heat loss from the house through the windows.

An important factor is to obtain a correct area of north glazing, which, in turn, relates closely with the floor area to be solar heated and the internal thermal mass. For a temperate climate, such as in Tasmania, the north-facing glazing should total 25-30% of the floor area.[18]

Table 2.3 shows a quick rule of thumb method to determine the size of northern glazing.[19] The area of northern glazing is closely connected with the characteristics of the local climate and hence the number of Heating Degree Days per year are given in that Table.

Regarding the volume of thermal mass inside the building, the most accepted rule is to use as much as possible.[20] The N.S.W. Institute of Technology Solar System Design Course[21] recommends that, in areas exposed to direct sunlight, at least 700 kg of masonry material, or at least 150 kg of water, should be allowed for each square metre of north facing window area.

Heading Degree Days re 18.0°C		Area of glass (m^2) for every m^2 of floor area to be solar heated.
3500		0.40
3000		0.35
2500)	Typical Heating Degree Days in Tasmania	0.30
2000)		0.25
1500		0.17
1000		0.12
500		0.06

Table 2.3 Heating Degree Days and Area of North Glazing.
Source: Department of Transport and Construction, 1983; Energy Efficient Australian Housing; Australian Government Publishing Service, Canberra.

Advantages and Disadvantages of the Direct Gain System

A) Advantages:

- Glazing is a relatively inexpensive form of solar collector, is readily available and thoroughly tested.
- The overall system can be one of the least expensive means of solar heating.
- Direct gain is the simplest solar energy system to conceptualize and can be the easiest to build.
- The glazing serves multiple functions, allowing solar radiation to enter the building while also admitting natural daylight and providing visual access to the outside.

- To provide only a small fraction of the heating needs of the building (especially daytime heating) direct gain systems do not necessarily need thermal storage.

B) Disadvantages:

- Large areas of glass can result in too much glare during the day and loss of privacy.
- Ultraviolet radiation in the sunlight will degrade fabrics (carpets, furniture) and photographs.
- If the design is to achieve large energy savings, then relatively large glazing areas and large amounts of thermal mass are required to decrease temperature swings.
- Thermal mass is expensive, particularly if it serves no structural purpose.
- Interior diurnal temperature swings of 12 °C are common.
- Providing for reduced heat loss at night through double glazing and/or additional shutters can be expensive and awkward.

2.4.3. Thermal Storage Wall System

A thermal storage wall is a passive solar heating system which combines north-facing glazing with a wall of thermal-mass material. The thermal mass is usually in the form of brickwork, concrete-filled concrete blockwork and cast-in-situ concrete, although mud brick, water walls and precast concrete are sometimes used. The mass wall is commonly 200 mm to 300 mm thick and is situated just behind the north-facing glazing. This creates an air space of 50-100 mm between the wall and the glazing.

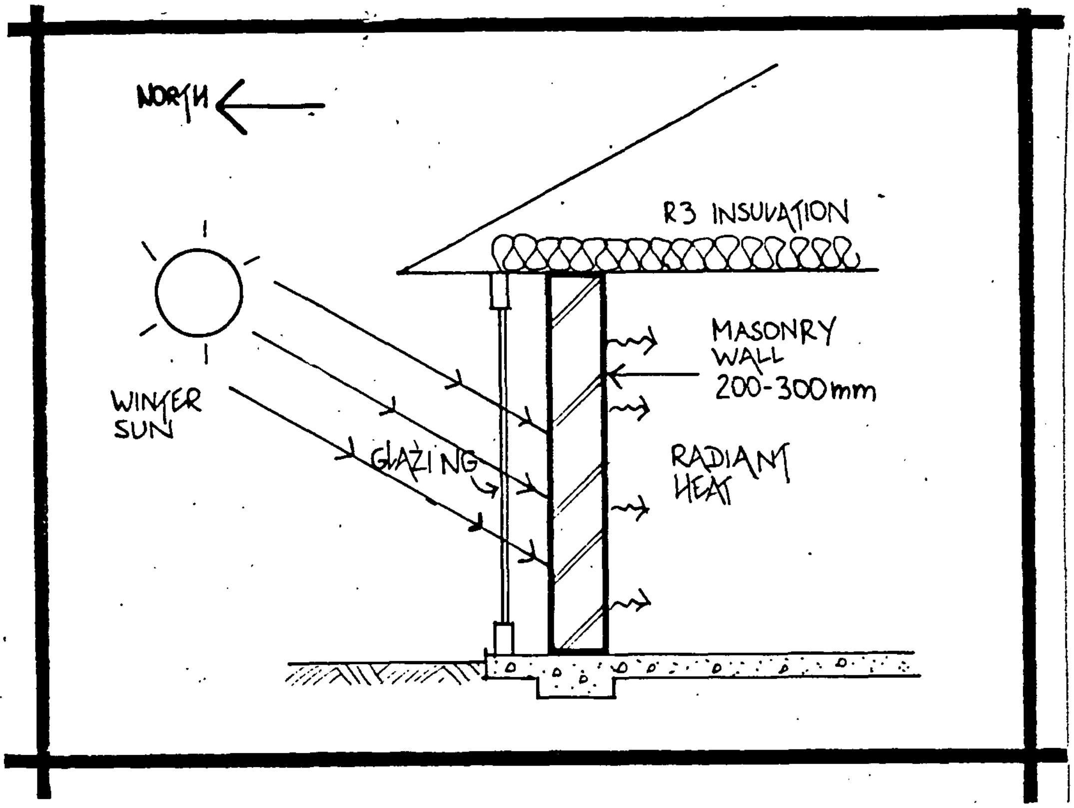


Figure 2.10 Principles of Operation of a Thermal Storage Wall System.
Source: Gnauck, D., 1981; Solar Architecture, A Design Handbook for Using Passive Solar Energy Systems In Buildings; T.C.A.E., Hobart.

Operation of the thermal storage wall is quite simple. The low-angled winter solar radiation shines through the glazing to be absorbed by the thermal mass, which sould be of a dark non-reflective colour, preferably black. The glazing creates a greenhouse effect between the wall and the glass, with a subsequent heat build up. Gradually, during the day, the heat conducts through the wall and radiates to the interior, as depicted in Figure 2.10.

The time lag can be described as the period of time taken for the heat to pass through a building element. Due to the time lag of the thermal storage wall, this radiation occurs usually in the late afternoon and into the evening. For a 300 mm thick brick storage wall, the time lag of heat conduction is about 8 hours.[22]

Thermal storage walls have almost always been combined with a Direct Gain System. A building with an entire northern side of thermal storage wall will have little light. In addition to extra light, the Direct Gain System provides heat immediately, whereas the thermal storage wall provides heat later in the day and into the night. Combining the two systemes takes advantage of both these thermal characteristics. The presence of a thermal storage wall provides heat without direct sunlight and hence protects valuable furnishings and carpets which could be sensitive to direct sunlight.

Advantages and Disadvantages of the Thermal Storage Wall System

A) Advantages:

- Glare and ultraviolet degradation of fabrics inside the building are not problems.
- Temperature swings in the living space (behind the Thermal Storage Wall) are lower than with direct gain.
- The time delay between the absorption of radiant energy by the surface and the delivery of the resulting heat to the interior spaces provides warmth in the evening when most residences need it.
- The development and analysing of thermal storage walls is well-advanced.
- Thermal storage walls require little maintenance.

B) Disadvantages:

- Considerable heat is lost to the outside from the warm wall through the glazing, unless the glazing is insulated at night; movable insulation tends to be expensive.
- The thermal storage wall occupies valuable space and blocks views and the penetration of sunlight.
- Solar glazing tends to be costly.
- The appearance of glazed, dark painted solar walls has not been accepted by many building owners.
- Large glazed areas can be subject to breakage.
- Builders are often not familiar with solid solar walls.

2.4.4. Convection Systems

Convection systems are passive solar heating systems which distribute collected solar heat by air-convection. Many possibilities exist, including Trombe-Michel walls, Lawrence walls, thermosiphon walls, convective air loop systems, window box collectors, thermic diode panels, thermosiphon roofs, etc. This section describes the most commonly used convection systems such as the Trombe-Michel wall, the thermosiphon wall, and the convective loop system.

A) Trombe-Michel Thermal Wall

This passive solar heating system is named after its French inventors and is a further development of the thermal storage wall. Again, solar radiation entering the glazed area is absorbed by a dark-coloured wall. Along the top and bottom of the wall there are a series of slots called vents. These allow air from the room to enter the air gap and air from the gap to re-enter the room.

On a sunny winter's day, solar radiation passes through the glass cover and is absorbed by the wall surface. As the temperature of the wall rises, heat is transferred away from the wall surface by a number of processes. Some heat is transferred slowly through the wall by conduction. Some heat is used to heat the air close to the wall surface. As the air in the air gap is heated, it expands and becomes less dense than the air in the room. The less dense air rises and enters the room through the top vents while colder air from the room enters the air gap through the bottom vents. An air flow, called the "thermocirculation loop" is then developed. Cold air from the room enters the air gap through the bottom vents, is heated, rises and flows back to the room through the top vents. Therefore, the glazed wall system acts as a simple passive vertical air heater.

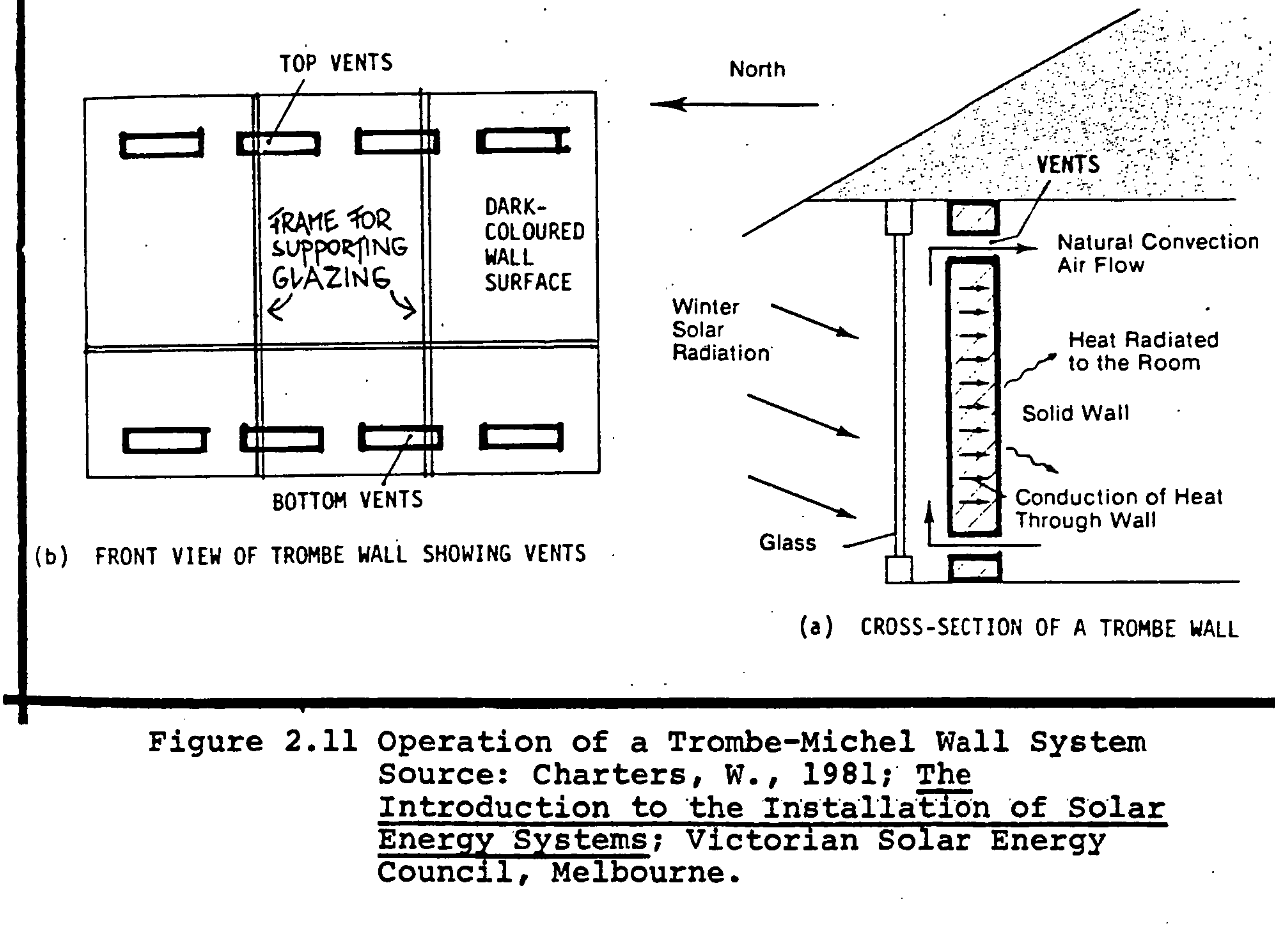


Figure 2.11 Operation of a Trombe-Michel Wall System
Source: Charters, W., 1981; The Introduction to the Installation of Solar Energy Systems; Victorian Solar Energy Council, Melbourne.

When the air in the air gap is colder than the room air (for example, at night), the reverse process will occur. Air in the air gap will be more dense than the room air and will tend to sink. A reverse air flow will be set up where air from the room enters the air gap through the top vents and, as it cools, becoming more dense, sinks and re-enters the room via the bottom vents. To prevent this process, which actually removes heat from the room, covers (usually called dampers) are placed over the vents to stop the air flow.

At night, when the air in the air gap is generally colder than the room air, the vents are closed. However, the heat that was conducted into the wall will eventually reach the inside wall surface. This warm inside wall surface will then deliver heat to the room by radiation and by warming the air close to the wall.

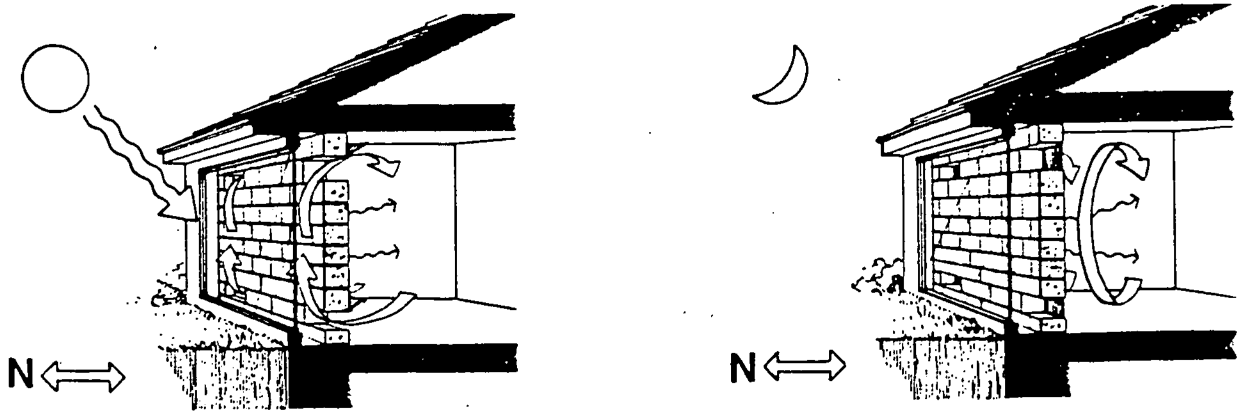


Figure 2.12 Trombe-Michel wall day and night time operation; at night, the dampers are closed. Source: Sweetland, H., 1982; Solar Remodelling; Sunset Books, Lane Publishing Co., Menlo Park.

The Trombe-Michel wall passive heating system has two methods of providing heat to the house: the thermocirculation loop during the day, and the delayed action of the wall late into the afternoon and into the night.

Advantages and Disadvantages of the Trombe-Michel Thermal Wall System

A) Advantages

- Provides both day time and night time heating.
- Temperature swings in the living spaces are lower than with direct gain or thermosiphon wall system.
- Glare and ultraviolet degradation of fabrics inside the building are not problems.
- The development and anaylising of Trombe-Michel walls is well advanced and documented.

B) Disadvantages

- Operating of the thermosiphon ducts needs manual input.
- The inclusion of thermosiphon ducts increases the construction costs.
- The Trombe-Michel wall occupies valuable space and blocks views and the penetration of sunlight.
- Large sections of Trombe-Michel walls in a building might be aesthetically unpleasing.
- Considerable heat is lost to the outside from the warm wall through the glazing, unless the glazing is insulated at night; movable insulation tends to be expensive.

B) Thermosiphon Wall

This passive solar heating system is a wall-mounted collector, using solar energy to create a convection current within the collector to distribute the heat in a manner identical to that of the Trombe-Michel wall. In this system, heat is

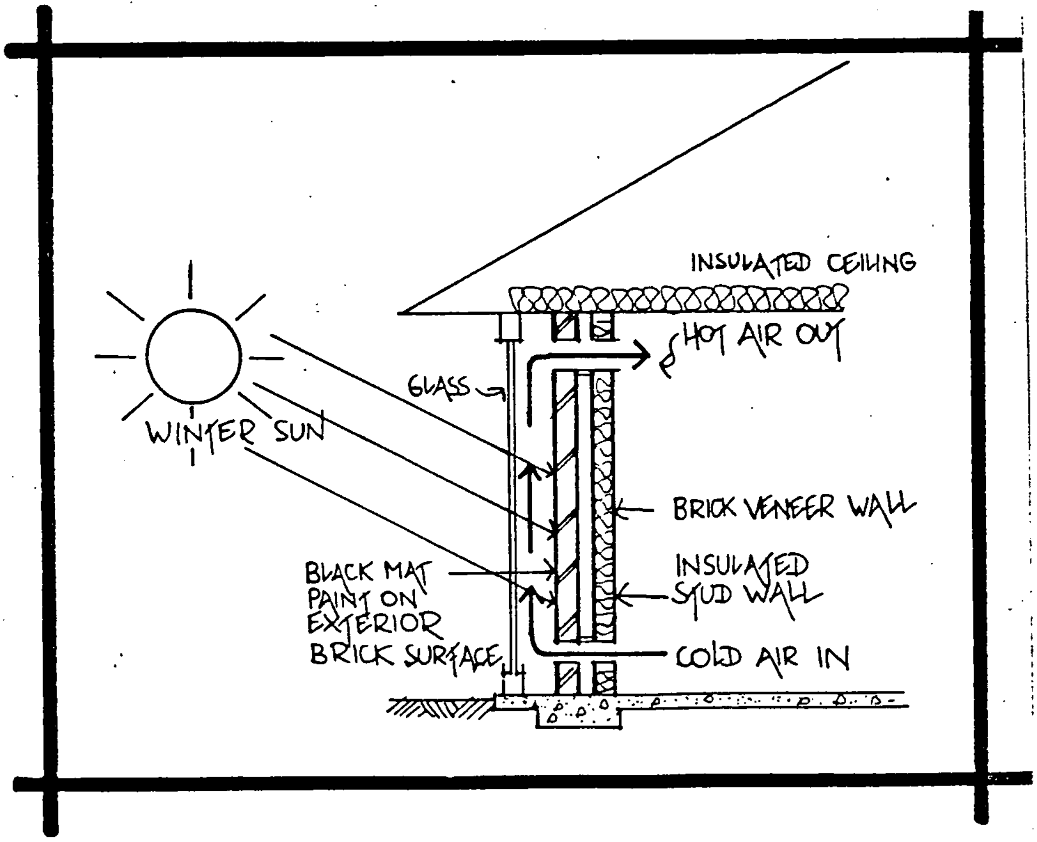


Figure 2.13 Operation of a Thermosiphon Brick Veneer Wall.
Source: Gnauck, D., 1981; Solar Architecture, A Design Handbook For Using Passive Solar Energy Systems in Building, T.C.A.E., Hobart.

not distributed by radiation by only by convection. It has no useful thermal mass and usually consists of a well-insulated black-painted timber or brick veneer wall behind glazing materials.

Figure 2.14 shows how a convective loop system can be added onto an existing timber framed structure.

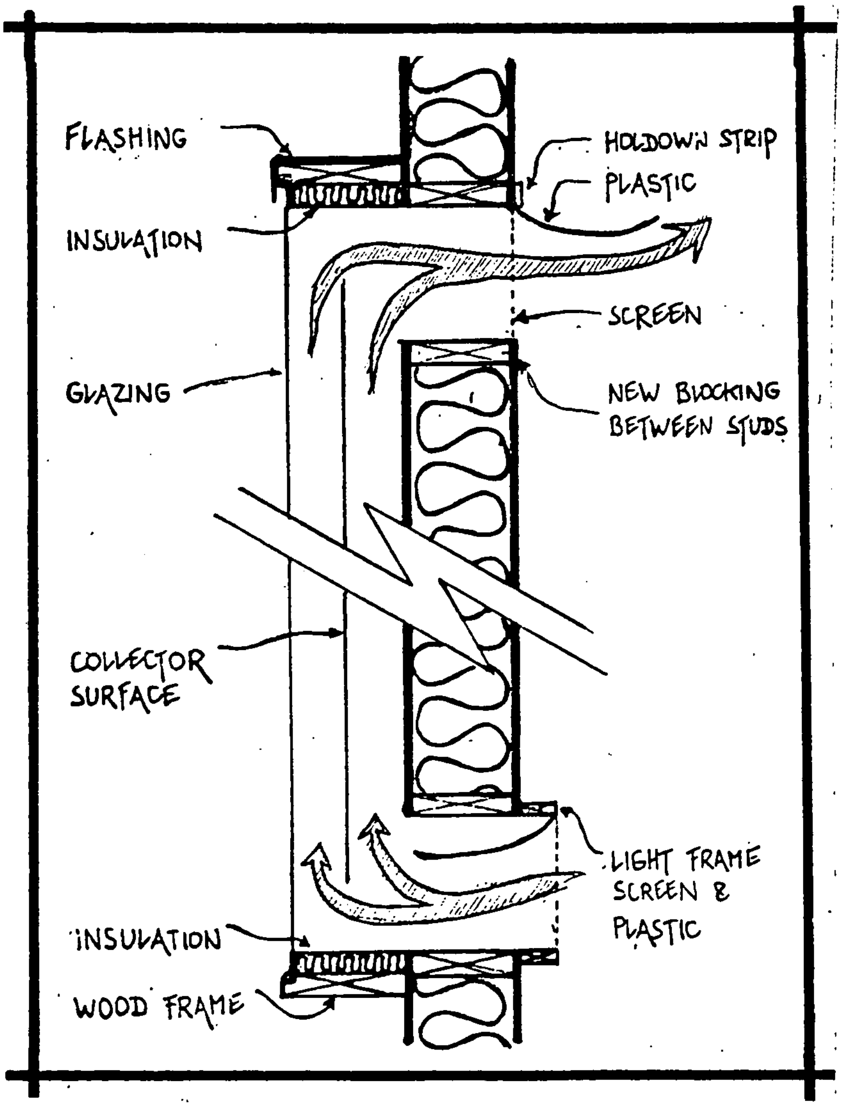


Figure 2.14 Simplified construction detail of a convective loop collector to an existing timber wall.
Source: Gnauck, D., 1981; Solar Architecture, A Design Handbook for Using Passive Solar Energy Systems in Buildings, T.C.A.E.Hobart.

Advantages and Disadvantages of the Thermosiphon Wall System

A) Advantages

- Glare and ultraviolet degradation of fabrics inside the building are not problems.
- Thermosiphon walls provide one of the least expensive ways to solar heat.
- To provide only a small fraction of the heating needs of a building, thermal storage is not necessarily needed.
- A thermosiphon is easily incorporated into north facades.
- A thermosiphon is readily adaptable to existing buildings.
- Because the collector can be thermally isolated from the building interior, night heat losses can be lower than for any other passive design system.

B) Disadvantages

- The collector is an "add-on device" to the building and might be aesthetically not pleasing.
- Both, careful engineering and construction are required to ensure proper airflows and adequate thermal isolation at night.
- The thermal energy is delivered as warmed air; it is difficult to then store this heat for later retrieval because air has poor heat transfer characteristics to thermal mass as compared if thermal to mass is directly irradiated by the sun.
- When thermal storage is used, this system works best when the collector is located below the building and the storage; such a configuration is difficult to achieve with conventional construction.

C) Convection Loop System

This system features collection and storage systems which are separate from a building's interior space. The collectors and the heat store are located facing north, below floor level, to enable efficient natural air convection. The collectors are similar to those used in active air heating systems. They consist of a timber or metal tray or casing containing black-painted metal sheeting. Collecting ducts and plena connect to the rock store, which usually consists of blue-metal or river gravel.

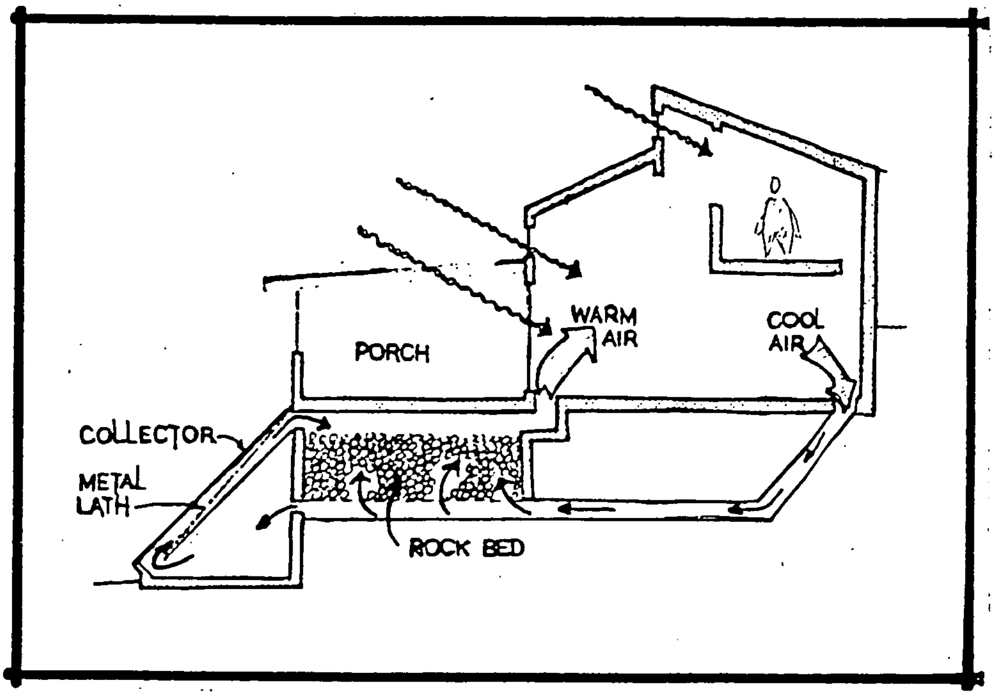


Figure 2.15 Operation of a Convective Loop System.
Source: Total Environment Action, Inc., 1980; Passive Solar Design Handbook; US Department of Energy, Washington, D.C.

Ducts then run in between the heat store and the floor registers. A return air duct takes cool air from the house back to the solar collectors. This completes the circuit and allows for a convective loop to operate by thermosiphon action. At night, heat either radiates through the floor or rises from the heat store as hot air. Often, the night-time operation of the system is facilitated by an electric fan which blows room air through the heat store and back.

These systems are only appropriate on north-sloping sites which are essential in maintaining acceptable air convection through the ducts and heat store. The cost is greater than most passive systems, being comparable to that of an active air-based system.

Advantages and Disadvantages of Convective Loop Systems

A) Advantages

- Because the collector is thermally isolated from the building interior, night heat losses can be lower than for other passive design.
- Heat flow into the building can be controlled.
- There is potential for adequate heat storage below the building.
- Heat storage can be insulated to ensure a high system efficiency.

B) Disadvantages

- This system needs a north facing building site to ensure the lower placement of the collector in regard to the building.

- This system is more expensive than other systems.
- Careful engineering and construction are required to ensure proper air flows and adequate thermal isolation at night.

2.4.5. Sunspace System

The term "sunspace" defines a series of solar heating systems known as attached solar greenhouses, glasshouses, conservatories, or sunrooms. A sunspace represents a separate area within a house which is almost completely glazed, including the roof as well as the walls. The sunspaces are designed in a way to collect low-angled winter solar radiation and are built using a wide range of techniques. There are two main approaches to sunspace design, the attached sunspace and the integral sunspace.

In the Attached Sunspace System, a glasshouse is built on the north face of the building. The dividing wall between the sunspace and the main interior of the building is usually a solid masonry wall or window wall. The masonry wall is usually of a dark material, or even painted black where it faces the sun. It often contains a system of vents identical to those used in Trombe-Michel walls and operates in a similar way.

Sometimes, heat distribution is assisted by electric fans instead of vents. A dividing window-wall allows sunlight to penetrate through the sunspace and into the main interior of the building in much the same way as the Direct Gain System. Some systems have no division between the sunspace and the main part of the building.

Figure 2.16 shows the building possibilities and heating methods using an Attached Sunspace System for solar heating.

The integral sunspace is constructed with the main part of a building being essentially a room with a glazed northern wall and roof. Construction of a sunspace with glazed walls and roof does not work alone. The efficient solar heat collection should preferably be combined with the thermal mass for heat storage, insulation to minimise winter heat loss, shading systems for keeping out the summer sun, and venting systems to prevent overheating. Shading and venting are most important, being vital for the prevention of summer overheating. Thermal mass and night insulation may be dispensed with if the sunspace is thermally isolated from the inside of the building at night. This can make the sunspace useless on winter nights as a living space and will probably make it inappropriate for plant propagation.

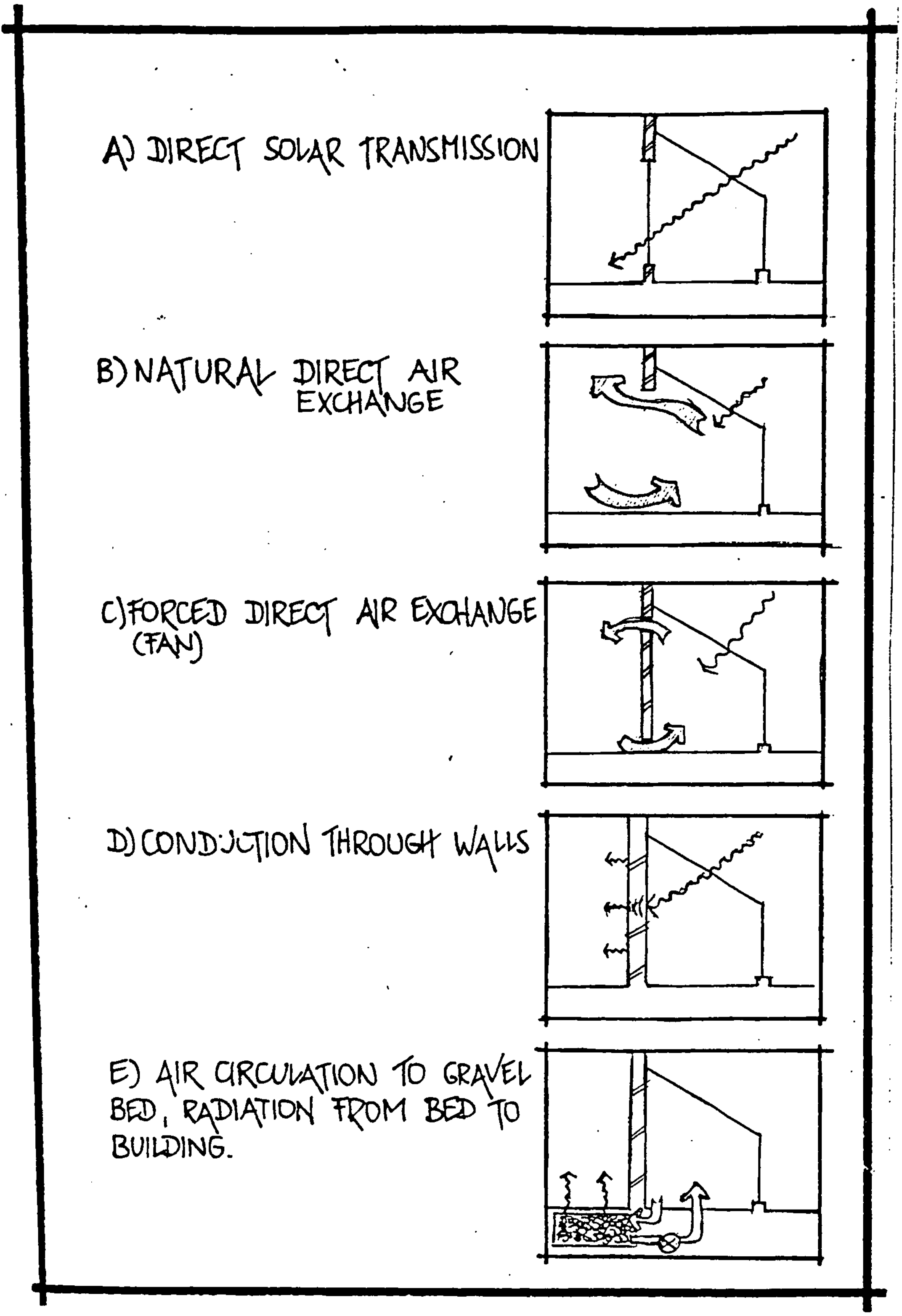


Figure 2.16 Heat Transfer Methods between an Attached Sunspace and Building; Source: Total Environment Action, Inc., 1980; *Passive Solar Design Handbook*; US Department of Energy, Washington D.C.

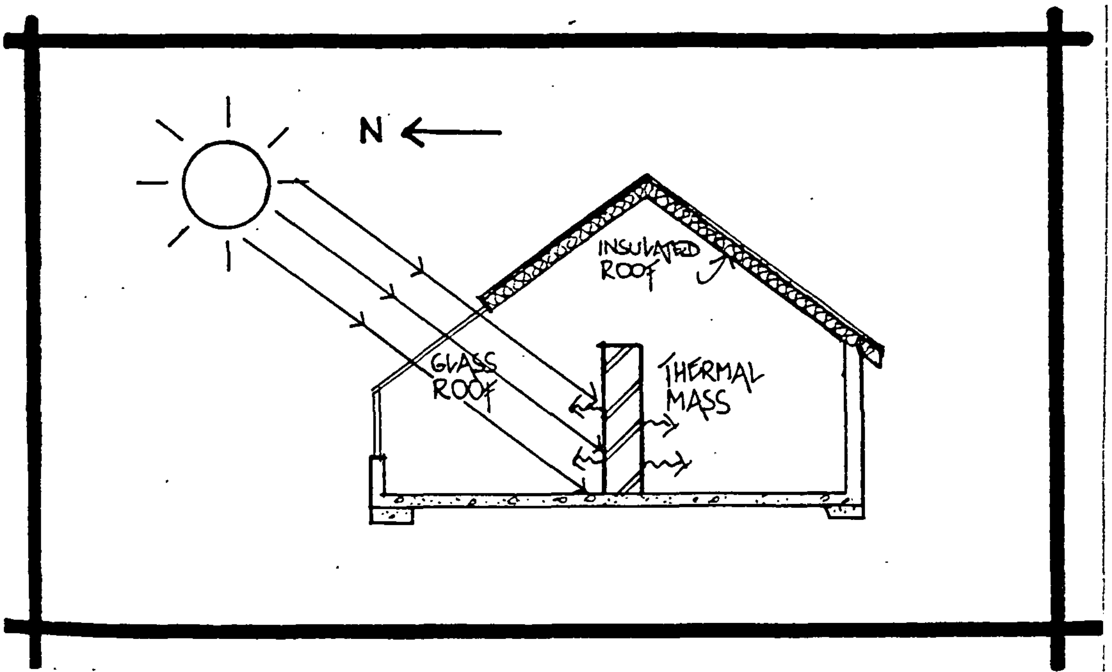


Figure 2.17 Operation of an Integral Sunspace

Advantages and Disadvantages of the Sunspace System

A) Advantages

- Temperature swings in adjacent living spaces are small.
- Sunspaces provide space for growing food, other plants and provide additional living spaces.
- Sunspaces reduce heat loss from buildings by acting as buffer zones.

B) Disadvantages

- Thermal performance varies greatly from one design to another, making the performance difficult to predict.
- Although construction cost can be kept low, commercial quality construction is expensive.

References, Chapter 2

1. AUSTRALIAN DEPARTMENT OF TRANSPORT AND CONSTRUCTION, Energy Efficient Australian Housing, Australian Government Publishing Service, Canberra.

2. SHAW, R.A. and STEPHENSON, J., 1977; The Feasibility of Heat Pumps for Residential Space Heating in New Zealand, New Zealand Energy Research and Development Committee Report No.18; University of Auckland, Auckland, New Zealand.

3. KOENIGSBURGER, O.H., INGERSOLL, T.G., MAYHEW, A., and SZOKOLAY, S.V., 1974; Manual of Tropical Housing and Building, Part 1, Climatic Design; Longman Group Limited,

4. TOTAL ENVIRONMENT ACTION, 1980; Passive Solar Design Handbook, Volume 2, US Department of Energy, Washington, D.C.

5. OLGYAY, V., 1957; Design with Climate; Princeton University Press, Princeton, New Jersey.

6. BALLINGER, J.A., 1980; Thermal Design of Buildings, Handbook 1980; School of Architecture, University of New South Wales, Sydney.

7. as above.

8. KOENIGSBURGER, O.H., INGERSOLL, T.G., MAYHEW, A., and SZOKOLAY, S.V., 1974; see note 2.

9. SZOKOLAY, S.V., and SALE R.W., 1979; The Australian and New Zealand Solar Home Book; Australia and New Zealand Book Company, Sydney.

10. ARUNDELL, L.F., 1979; The Feasibility of Heat Pumps for Domestic Heating in Tasmania; Thesis presented for the Master of Environmental Studies, University of Tasmania.

11. SZOKOLAY, S.V., 1983; Solar Energy and Buildings; Architectural Press, London.

12. DUFFIE, J.A., and BECKMANN, W.A., 1974; Solar Energy Thermal Processes, John Wiley & Sons, New York.

13. as above.

14. FARRINGTON, D., 1971; Direct Use of the Sun's Energy; New Haven University Press, New York.

15. as above.

16. GNAUCK, D., 1981; Solar Architecture, A Handbook for Using Passive Solar Energy Systems in Buildings, Architectural Thesis, Tasmanian College of Advanced Education, Hobart.

17. STANDARDS ASSOCIATION OF AUSTRALIA, 1983; Thermal Insulation of Dwellings, Design Guide, Part 1, Thermal Insulation of Roof/Ceiling in Dwellings which require Heating.

18. AUSTRALIAN DEPARTMENT OF TRANSPORT AND CONSTRUCTION, 1983; see note 7.

19. as above.

20. COLE, G., and PARNELL, M., 1983; Australian Solar Houses; Second Back Row Press, Solar Scope, Sydney.

21. NEW SOUTH WALES INSTITUTE OF TECHNOLOGY, 1981; Solar System Design Course, Appropriate Construction and Insulation; New South Wales Institute of Technology, Sydney.

22. HASSAL, D., 1978; Insulation and Thermal Mass, Thermal Comfort in Small Buildings by Natural Means, University of New South Wales, Sydney.

CHAPTER 3

SOLAR BUILDING REVIEW

3.1 INTRODUCTION

Despite the growing publicity given to passive solar design, the design concepts are not being widely adopted yet in Tasmania. It is argued below that one important reason why there are not more solar buildings in Tasmania is the lack of information available on existing solar buildings. Although passive solar design principles "in theory" are well understood and documented, the quantitative analysis of thermal performance is not yet within the grasp of many building designers. Predicting the cost effectiveness of the passive design systems is seldom undertaken, and, until such predictions are available, these solar systems will not be accepted within the hard core of the architectural profession and the construction industry.

The aim of the solar building survey, presented later in this thesis, is to remedy this situation by providing information on a number of existing passive solar buildings by underlining and emphasising their thermal performance, and by providing some economic analyses and information on the user's personal experience of these solar buildings.

Section 3.2 looks at the different approaches of some American and Australian solar building reviews presently available and identifies their usefulness to further solar design purpose.

Section 3.3 outlines the importance of a solar building survey for Tasmania's conditions, taking factors such as climate, building materials and practice and people's life-styles into consideration.

3.2 A HISTORY OF SOLAR BUILDING REVIEWS

The specialised literature on the application of passive solar energy systems in buildings is fast increasing, and many general text books also include some data on existing solar buildings. Bruce Anderson, in 1973, produced a brief solar house survey in his thesis "Solar Energy and Shelter Design"[1], and described ten American solar buildings built between 1938 and 1972.

Donald Watson (1977), in his book "Designing and Building a Solar House"[2], also provides a short section on existing solar houses in the USA, showing photographs, sketches and addresses of 129 solar buildings. This survey can be used only for reference purpose as the description of the building is far too short to be of any practical use.

"The Solar Age"[3], the official magazine of the American Solar Energy Society, frequently features solar buildings, and has done so since the beginning of its publication in 1977. These reviews are generally well documented, including colour photographs, precise technical descriptions of the solar systems, and an analysis of thermal performance if the building had been monitored.

A further publication on solar houses features 48 energy-saving house designs in the book "Solar Houses" (1978)[4], which includes plenty of photographs, floor plans and a short description of each house, outlining the solar system and the building costs.

"At Home in the Sun" (1979)[5], written by Norah Deakin Davis and Linda Lindsey provides a comprehensive survey of 30 American solar houses. This review of houses shows floor-plans, section diagrams, photographs and describes each solar system in great detail. This collection of solar houses provides the prospective solar building designer with a great variety of design possibilities, including an interview with solar home owners, assessing their own solar building in reference to building experience and thermal comfort levels throughout the year.

In 1981, Ralph M. Lebens published the results of the First European Passive Solar Competition[6], (1980) showing a variety of passive solar buildings from many European countries. This book called "Passive Solar Architecture in Europe", includes the review of the first passive solar buildings, such as the St. George's School in Wallasay, England, (1962), the Prototypes Trombe Wall houses in Odeillo, (1967) and the Scuola Materna di Crosara, at Vicenza, Italy, (1975). As most of the content of this book concentrates on the design-competition's presentation drawing, the actual solar building survey only features 8 buildings. The descriptions have been kept too short to be used for any design purpose.

One of the first publications of Australian solar buildings can be found in Steve Szokolay's book, "Solar Energy and Building" (1975)[7] where the author, in part 5, presents 38 solar buildings in Europe, USA, Japan, and Australia. This solar building review provides a detailed description of the various solar heating systems, providing data of collector sizing and tilting, collector construction techniques, glazing systems, storage volume and heat capacity of the different storage materials and flow rates in active solar heating systems. While this survey presents an excellent technical description of all the different solar heating systems, it fails to assess the effectiveness of these solar heating systems, and does not provide the reader with any photographs which would provide a better understanding of the appearance of the buildings.

In his following publication, "The Australia and New Zealand Solar Home Book"[8] (1979), Steve Szokolay and R.W. Sale present 21 solar houses in Australia and New Zealand. While the descriptions of these houses are only brief, they represent one of the first collected reviews aimed at reaching a wide section of the community. The description includes factors such as design aims, building techniques, and solar heating system details, and is accompanied by photographs and floor plan and section drawings of the houses. At the stage of publishing the book in 1979, most of the buildings had just been constructed, and there exists very little information on the thermal performance of the houses. Two Tasmanian solar houses, the Button house and Fergusson house, are included in this survey.

Since January 1980, "Solar Progress"[9], the official journal of the Australian and New Zealand Section of the International Solar Energy Society, has published a detailed description and illustration of solar buildings built in Australia and New Zealand. Over the last five years "Solar Progress" has assimilated data on over 60 solar buildings, presenting details on local climate, location of the building, description of the solar heating system and, occasionally, the thermal performances. While the building survey has been presented with significant detail between 1980 and 1984, the quality and quantity of this building survey has substantially diminished during 1985. "Solar Progress", in general, is only available to members of the Australian and New Zealand Section of the International Solar Energy Society, unless specially ordered.

The South Australian Housing Trust[10] (1981) published a detailed report on the "Seaton Experimental Low Energy House", situated at the western suburb of Adelaide, South Australia.

The intention for the Housing Trust was to finance the construction of two dwellings, a standard house and a passive solar house, and to compare the thermal performances of the dwellings under different modes of operation. This report represents one of the most comprehensive thermal and cost analyses of Australian solar buildings.

Detlev Gnauck included a solar building review in his architectural thesis, "Passive Solar Architecture, A Design Handbook for using Passive Solar Energy Systems in Buildings" (1981)[11]. Eighteen different solar buildings presented in the thesis show a wide variety of design possibilities and include four Tasmanian solar houses, built between 1978 and 1980. The Tasmanian solar houses included are the Fergusson, Button, Moon, and Solar Wall Project Houses, and, while there exists substantial detail on the thermal performance of the Solar Wall Project houses and the Moon house, there is little information given for the Fergusson and Button residences.

In October, 1983, a detailed report to National Energy Research Development and Demonstration Council was compiled by Robert Sutton and Robert McGregor on the thermal performance and cost effectiveness of the two Solar Wall Project houses in Rokeby, near Hobart.[12] Both demonstration houses with passive solar heating features were monitored over two years and the report presents a substantial thermal analysis, including factors such as free running temperatures inside the buildings, solar wall temperature swings, summer shading, and supplementary heating. The section on cost analysis firstly describes the cost comparison method used in the report, establishes an average energy use for the average Tasmanian dwelling, shows the additional capital construction costs for the passive solar heating systems and, finally, justifies the extra costs on grounds of the yearly energy savings by the solar heating systems. While the thermal analysis is very substantial in this report, important factors such as the human response living in, and using the passive solar buildings have been ignored.

The most comprehensive Australian solar building survey was compiled in 1983 by Matthew Parnell and Gareth Cole[13], and their book, "Australian Solar Houses" features 68 different solar buildings. This book catalogued a large number of Australian solar buildings, with emphasis placed on quantitative and qualitative performance information to highlight the effectiveness of the solar heating systems. The book is divided into three sections:

a) theoretical information;
b) the survey of 68 solar houses;
c) the appendices.

This survey includes important information such as basic background details on the location of the buildings, latitude, people involved in the design and construction stages, climatic data and proceeds with a discussion of the basic design approach of each particular house. This is followed by a description of the particular site conditions, construction methods, solar heating systems, thermal performance and finally the construction costs involved.

The most detailed information is presented in the description of the solar systems and their thermal performance, giving account of various materials used for the construction of the buildings, sizes of all the solar heating systems, as well as performance calculation techniques, ranging from computor simulation to subjective impressions of the occupants living in these solar buildings. The review of each building includes high quality photographs and diagrams of floor plan and section drawings. Preceding the housing survey is a summary table revealing the basic details of each building in an easily comparable fashion. This survey concludes with a brief discussion of the major trends of solar buildings in Australia.

Six Tasmanian solar houses have been included in the survey with two houses using an active solar heating system. The passive Tasmanian solar houses, the Button, Fergusson and Solar Wall Project houses represent the buildings, where substantial information has been available in earlier publication. The survey included only little information on the thermal performance of the Button and Fergusson houses and there also exists some description errors of the solar heating systems; therefore, these two houses have been reviewed again in this thesis.

3.3 THE NEED FOR A SOLAR BUILDING SURVEY FOR TASMANIA

Before designing a solar building, the designer needs to familiarize him or herself with existing solar buildings, taking into consideration their appearance, aesthetic appeal and thermal performance as well as investigating the different problems owners can experience living in and using these buildings.

While the reviewing of solar buildings is not new, it has not been carried out in detail for Tasmania. The importance of assessing solar buildings in Tasmania can be related to a number of factors elaborated below.

a) Solar design is strongly affected by local meteorological conditions, both macro and micro, taking into account that solar buildings in other regions might not be suitable for Tasmania's conditions. The designer in Tasmania cannot rely entirely on literature and examples from other regions, or precisely copy solar design features, as they might not be optimum for Tasmania's conditions. The general principles of passive solar buildings will apply in most climatic regions, but the detailed design must be modified to suit local conditions. Some design features which will be different in Tasmania from other Australian states include the optimum size of north-facing windows and storage walls, overhangs, economic insulation thickness, vapour barriers, orientation, and draught proofing.

b) Conventional building practice and availability of building materials varies from one country to another, even from one region to another, affecting costs and performance of solar buildings.
This especially relates to American and overseas products, where solar hardware is much more common and easily available in shops.
However, costs and availability of certain building materials even vary within Australia. Building products produced on the mainland of Australia are often more expensive in Tasmania due to additional transport costs, and the building designer in Tasmania might concentrate on the use of local building products, or even, in some cases, alter construction techniques and design features to reduce excessive costs.

c) Solar design and its performance depends closely on user habits and lifestyles, which, of course, vary from person to person and family to family, but this is also influenced by the local culture and society. It is therefore useful to have information relating to the users' impressions of how successful or otherwise solar buildings have been in any particular region.
Initial theoretical thermal performance calculations have very little input based on users' lifestyles and so are not an entirely reliable method of analysing a

solar building's performance. Only if the building is used (lived in) can a total thermal performance analysis of the building be carried out. In addition, the users' personal impression of comfort in a solar building is the closest, most reliable assessment of thermal comfort.

While most building surveys give some indication of the building's thermal comfort, only a few actually investigate the people's opinions and impressions of living in solar buildings. A major part of the following chapter looks at a most important aspect of buildings, how the people actually feel living in these buildings.

d) The future designer can assess the performance of a building in a particular area, and adopt changes and recommendations for specific design purposes.

The designer of a solar building must research well before proceeding into design solutions, with the main interest being to study existing solar buildings to see how well they work, and to obtain an appreciation of their appearance. However, many solar home owners do not wish to have their privacy diminished by many inquisitive visitors and do not, or only occasionally, welcome people to inspect their homes. This survey intends to provide an alternative to solar house tours by presenting a detailed analysis of ten passive solar buildings in Tasmania. Only by underlining experienced problems in both the construction of these buildings and the functioning of the solar heating system, can the future building designer benefit from the lessons learned and design appropriate solar buildings.

References, Chapter 3

1. ANDERSON, B., 1973; Solar Energy and Shelter Design, Architectural Thesis, University of California, Berkeley, U.S.A.

2. WATSON, D., 1977; Designing and Building a Solar House, Garden Way Publishing, Charlotte, Vermont.

3. SOLAR AGE, 1977-1985; American Solar Energy Society Inc., United States Section of the International Solar Energy Society, Harrisville, N.H.

4. GROPP, L., 1978; Solar Houses, 48 Energy Saving Designs, Pantheon Books, New York.

5. DAVIS, N.D. and LINDSEY, L., 1979; At Home in the Sun, An Open-House Tour of Solar Homes in the United States, Garden Way Publishing, Charlotte, Vermont.

6. LEBENS, R.M., 1981; Passive Solar Architecture in Europe, The Result of the First European Passive Solar Competition - 1980; The Architectural Press Ltd., London.

7. SZOKOLAY, S.V., 1975; Solar Energy and Building, The Architectural Press, London.

8. SZOKOLAY, S.V. and SALE, R.W., 1979; The Australia and New Zealand Solar Home Book, A Practical Guide, Australia and New Zealand Book Company, Sydney, Melbourne and Auckland.

9. AUSTRALIAN AND NEW ZEALAND SECTION OF THE INTERNATIONAL SOLAR ENERGY SOCIETY, 1980-1985; Solar Progress, Solar Energy Developments Pty, Ltd., Brisbane.

10. SOUTH AUSTRALIAN HOUSING TRUST, 1981; The Seaton Experimental Low Energy House, Department of Urban and Regional Affairs, Adelaide.

11. GNAUCK, D., 1981; Solar Architecture, A Handbook for Using Passive Solar Energy Systems in Buildings, Architectural Thesis, Tasmanian College of Advanced Education, Launceston.

12. SUTTON, R.G. and McGREGOR, R.J., 1983; Solar Wall, Two Demonstration Houses with Passive Solar Heating in Tasmania, A report to the National Energy Research Development and Demonstration Council, Department of Resources and Energy, Canberra, Tasmanian College of Advanced Education, Launceston, Tasmania.

13. PARNELL, M. and COLE, G., 1983; Australian Solar Houses, Second Back Row Press, Solar Scope, Sydney.

CHAPTER 4

THE ASSESSMENT OF TEN PASSIVE SOLAR BUILDINGS IN TASMANIA

4.1 INTRODUCTION

There are many solar buildings in Tasmania, although the exact number is not known.

At the beginning stage of the thesis, all known building designers with an interest in solar energy were contacted to obtain the location and names of the owners of solar buildings. Subsequently, owners were contacted with the request to inspect their buildings and also to respond to a survey.

Most of the owners responded to the request, but some of them declined to be included in this survey for private reasons. Twenty two buildings were inspected, but some of these buildings did not meet the definition of a passive solar building which, as explained at the beginning of this project, required that the building collect, store and distribute solar heat with a minimum of mechanical equipment.

Many inspected buildings incorporated the principle of solar collection without including thermal storage, while only about 15 buildings met all the pre-requisites.

Finally, ten buildings were selected for analysis. All have been primarily designed as passive solar buildings to collect, store, and distribute solar energy.

Two passive Tasmanian solar houses, the Solar Wall Project houses, built by the Department of Housing in 1980, were not included in this survey, as a detailed report on the thermal performance and the cost effectiveness of these houses was published in October 1983.[1]

Due to time restrictions and financial constraints of the thesis, not all of the known solar buildings have been studied. However, the ten selected solar buildings show a wide variety of prices, present interesting solar energy systems, highlight many design possibilities, and are all located in different locations in Tasmania.

Detailed information on these buildings has been collected from face to face interviews with the owners, builders, and architects. The owners kindly provided the data collection.

The buildings are presented, firstly by a technical description and, secondly, by the owner's experience of their operation.

4.1.1 Technical Data Content

The technical description of each building includes a table of basic background information: location, latitude, date completed, people involved, building costs, and some climatic data. The costs given are approximate only and must be viewed in terms of the date of completion. Climatic data has been included as a basis for comparison of the design and performance of the buildings. The parameters of heating degree days and temperature ranges show the particular condition for which the building has been designed. The heating degree days expressed to base 18^{o}C and the air temperatures were obtained from the Bureau of Meteorology, Hobart, Tasmania.

The main text of each case commences with a brief discussion of the design objective and is followed by an account of the particular site conditions. The nature of any obstruction to solar radiation and the direction of the prevailing winds in winter are the major factors discussed.

The construction methods are reviewed next, the usual sequence being: wall, floor, roof, window and door frames and, where appropriate, thermal zoning. This is followed by the description of the solar heating system, which covers heat collection systems, heat storage, auxiliary heating, provision for summer cooling and domestic hot solar water. The north facing collecting area is expressed as a percentage of the total floor area of the building, which gives an indication of the emphasis of the solar application.

Insulation techniques are then summarized, including those for walls, ceilings, roofs, floors and windows.

One of the most important aspects of the basic information is included under "Thermal Performance". Emphasis is placed on pre-design calculation techniques, measured data on internal and external temperature ranges and subjective impressions of the occupants, where no monitoring has been done. Five buildings have been monitored for some time and the ranges for indoor and outdoor temperature are given in these cases.

The final item in this first part of the survey looks at the cost of the solar systems. This information is only included where the owners knew the additional cost of the solar system. The review of the technical description includes photographs and diagrams. Where possible, the diagrams include a floor plan and a section drawing of the building.

4.1.2. The Owner Experience

The second part of the survey concentrates on the owner's experience with the building after construction; this gives a practical assessment by the owners, of the building design through living in and operating the structure.

The first objective was to determine the primary reasons for including passive solar heating features as presented by the owners. The following item looks at the Council's view to the approval of these solar buildings. Often, the solar systems require special or new building construction techniques which, in some cases, may contravene the existing building regulations.

The owner's building experience is reviewed next, a factor which is important, as it is often associated with the cost of the building. Frequently, because of the different building techniques, builders can encounter difficulties, which can lead to delay, cost increases and frustration.

The experienced thermal comfort is then discussed by the owners, giving an indication of how well these solar buildings actually perform.

This is followed by the owner's account of the problems related to the passive solar heating systems. Only by highlighting problems and difficulties can the future prospective solar building owner learn and benefit from these given experiences.

Finally, the owners reveal future changes they would like to make if they were to build again.

The survey of each building concludes with a summary, looking at successful solar design, highlighting progressive design details, or where necessary, pointing at possible design changes or improvements to the solar buildings, especially directed to the heating system.

Many owners have expressed apprehension at the thought of their building's being included in this thesis. As the privacy of the owners must be respected, the exact location of these buildings has not been included.

4.2 FERGUSSON HOUSE

4.2.1 Technical Description

Location: Cambridge Road, near Hobart
Latitude: $42^{o}50'$ S
Date completed: August 1978
Architects: Mike Leach & Greg Strickland
Solar Design: Bob Sutton
Owner: Ailsa Fergusson
Size: 160 m^2
Cost: \$38 720 (\$242/m^2)
Climate: Temperate
Heating Degree Days (base $18^{o}C$): 2230
January average temperature: $16.9^{o}C$
July average temperature: $8.2^{o}C$

Photograph 4.2.1 Fergusson Solar House
Mt. Rumney, Tasmania

(A) Objective

The main objective of this house was to provide a low cost solar house for a single person. The owner specified the use of natural materials where possible.

(B) Site

The site consists of 3.4 ha of north sloping rural grassland, with the house overlooking a valley. A hill to the north of the house provides some obstruction to the afternoon sun. The western side is protected by natural bushland. Prevailing winter winds occur from the north-west.

(C) Construction

The single storey, split level three-bedroom house has 270 mm brick cavity external walls. Internal walls are timber framed and lined with white painted plasterboard and Tasmanian oak boarding. The floor is timber framed. The roof is timber framed and covered with brown colourbond zincalume steel deck sheeting. The ceilings, featuring exposed timber beams, are Western red cedar. The house is oriented to the north and divided into three zones: the living zone on the east, the sleeping zone on the west, and the glasshouse.

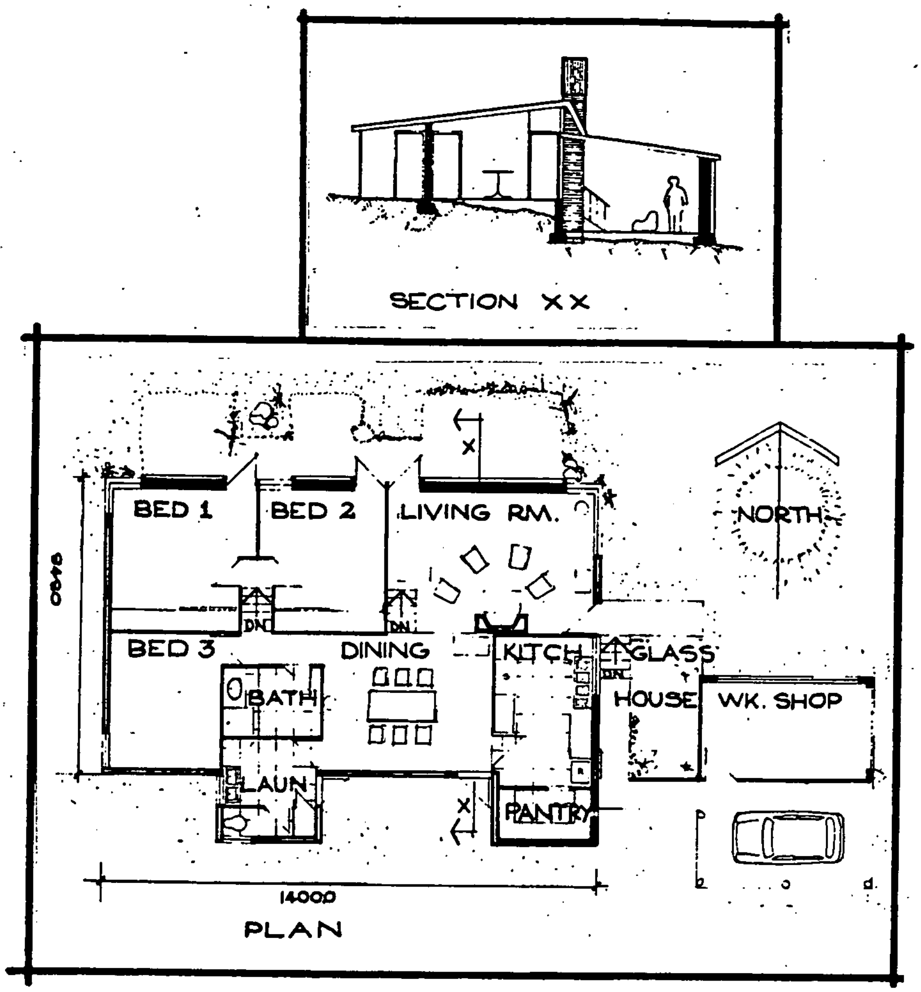


Figure 4.2.1 Floor plan and section drawing.
Fergusson house.

(D) Solar Heating Systems

Three passive solar heat collection methods are used. The major component of the system is a Trombe-Michel wall with a collection area of 18 m^2, which is 11% of the floor area.

The direct gain component incorporates approximately 12 m^2 of north-facing windows and 12 m^2 of north-facing clerestory, amounting to 15% of the floor area.

The sunspace has an area of 15 m^2 and a total glazing area of 13 m^2, which is 8% of the floor area of the house.

The Trombe-Michel wall consists of a 300 mm thick concrete-filled concrete block wall painted matt black. The glazing is supported by a steel frame, 77 mm away from the wall. The wall is divided into three separate sections by the areas of north-facing windows. One section of the Trombe-Michel wall has a selective surface glued onto the solar wall.

Day time heating is distributed via seven sets of top and bottom vents, controlled by sliding timber grates at the internal surface on the Trombe wall.

Heat storage is provided by the Trombe-Michel wall (5 m^3) and by the internal skin of the brickwork and the bricks in the fireplace.

The sunspace, which acts as an airlock, is framed with a combination of timber and galvanised steel. Heat is stored in brick floor paving and a shallow rock bed.

Auxiliary heating is provided by a heat recirculating fireplace in the living room and a slow combustion wood stove in the kitchen. Approximately 7 tonnes of firewood accounts for cooking, auxiliary space heating and water heating. About 3 tonnes of firewood has been used for the fireplace in the living room, amounting to a cost of \$96 (\$0.60/m^2).

Summer cooling is rarely needed, because the Trombe-Michel wall is equipped with 450 mm eaves for shading and is designed to draw air currents through the house by means of operable external vents in the solar wall glazing.

Hot water is supplied by a gravity-feed thermosiphon solar system incorporating four 1.5 m^2 Beasly flat plate collectors located on the roof above the sunspace, tilted at 43°. The 180 litre storage tank is located on a boxed-in platform within the chimney structure. This system is boosted by a coil in the wood stove.

(E) Insulation and Sealing

The external walls are not insulated. There is a double-sided reflective foil laid under the floor joists, 50 mm fibre-glass batts and double-sided reflective foil to the roof, double glazing to the clerestory windows, curtains with reflective linings plus pelmets to the other windows, and mastic sealant around window and door frames at their junction with the external walls.

(F) Thermal Performance

The house was designed to meet basic year-round comfort re-requirements. The owner is very satisfied with the thermal performance of the house, which has attained desirable levels of thermal comfort, especially in the winter months.

The house has been monitored by a minimum/maximum thermometer for two years. In the winter months, the house is basically 8-10°C warmer than the external temperature without any back-up heating. On cold winter nights, when the external temperatures dropped as low as 2°C, the internal temperatures never fell below 11°C.

The timelag of the Trombe-Michel wall is approximately 8.5 hours, reaching its highest internal surface temperature at 8.30pm with a surface temperature up to 29°C on sunny winter days.

The difference of the internal solar wall temperature from the external selective surface to the matt black painted areas is about 1°C.

The following temperature graphs show the minimum temperatures in winter (July 1980) (Figure 4.2.2) and the maximum temperatures in summer (Figure 4.2.3).

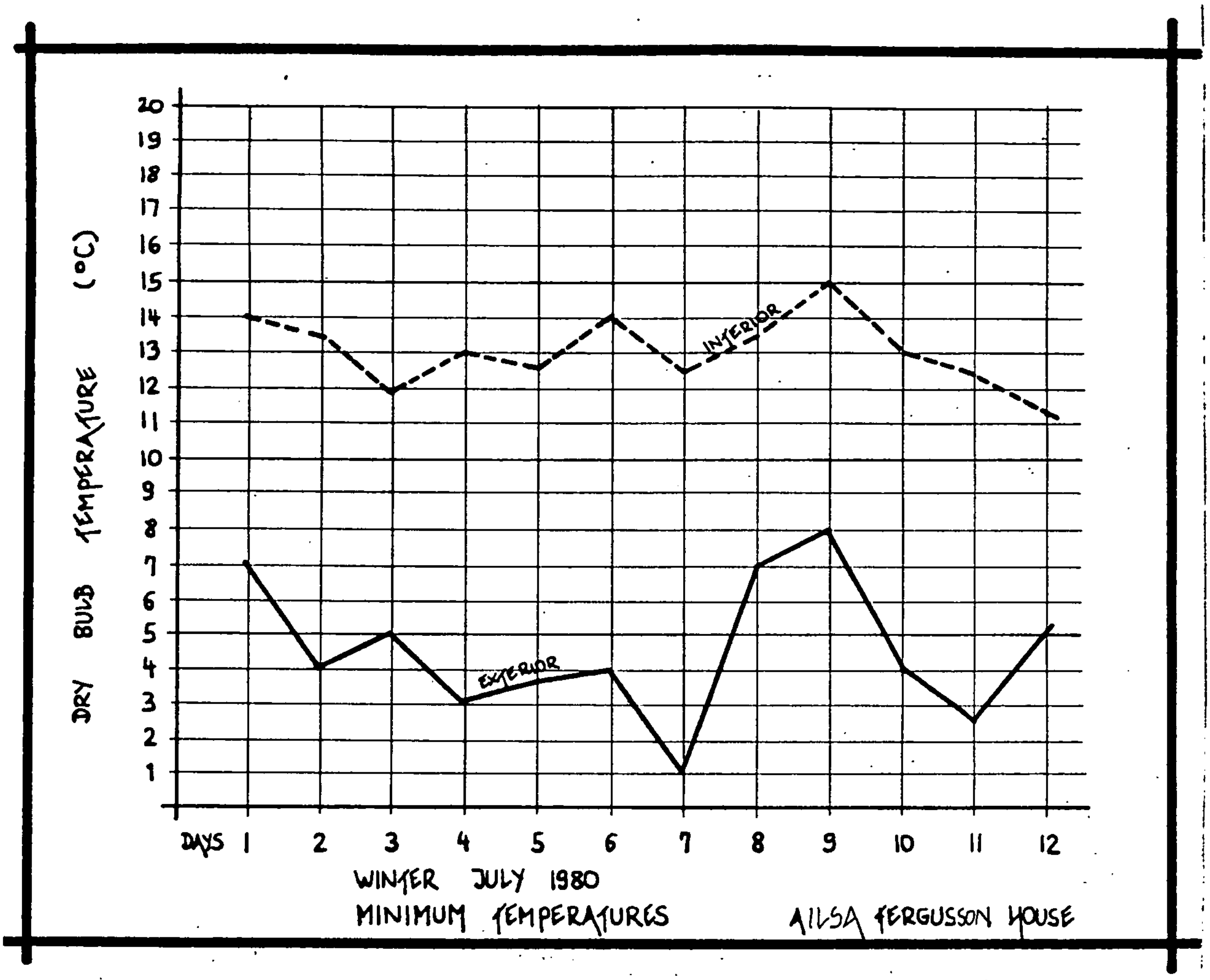


Figure 4.2.2 Minimum temperature experienced in the Fergusson house, winter, July 1980.
Source: Ailsa Fergusson.

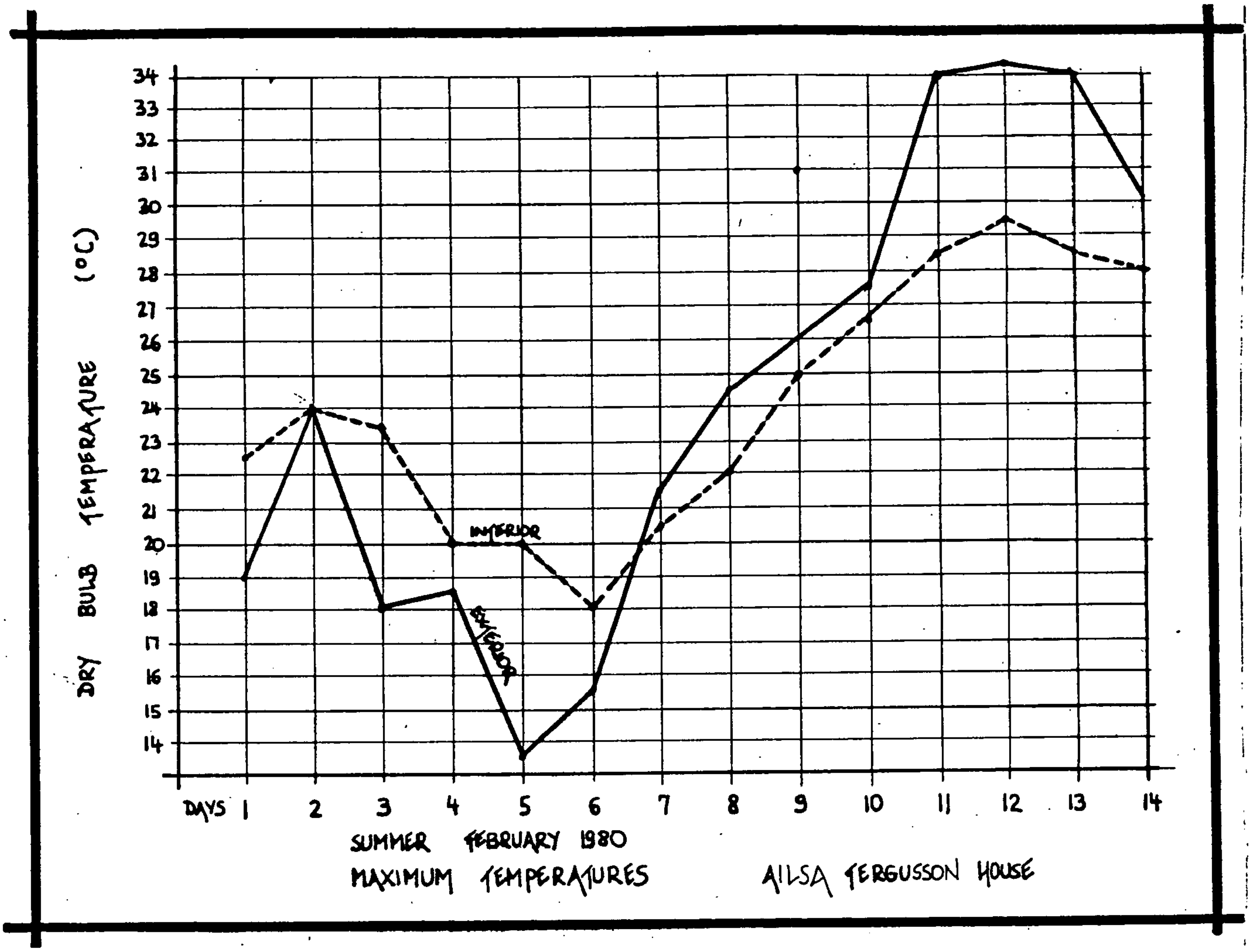


Figure 4.2.3 Maximum measured temperatures in the Fergusson house, summer, February 1980.
Source: Ailsa Fergusson.

(G) Cost of the Solar System

The extra cost of the Trombe-Michel wall over the cost of a brick cavity wall was $1285, amounting to $71.30 per square metre.

4.2.2. Owner Experience

(A) Primary reasons for including passive solar heating features

For the owner, a high degree of thermal comfort is very important; consequently, a warm and sunny house were the primary design objectives. Also, the owner wanted to demonstrate that all these solar principles actually work. The owner's house was one of the first buildings in Australia to include a Trombe-Michel wall for space heating.

(B) Council approval

There were no problems.

(C) Building experience

The building did not follow the architects' plans to a great detail. For example, the dimensions of the overhang were altered from 300 mm to 450 mm by the builder's own decision. While building the solar storage wall, the builder did initially not fill the concrete blocks with mortar,as it was specified on the plans. There were also problems in sealing the clerestory windows, as the flashing was penetrated by nails.

(D) Experienced thermal comfort in the building

The owner is very satisfied and comfortable with the thermal comfort experienced in the house. Only on occasional days, especially in autumn, the house overheats near the clerestory window area. The owner has to check outdoor temperatures in order to choose the appropriate clothing for outdoor activities.

(E) Problems related to the solar heating systems

A few minor problems were reported by the owner, as follows:

1. too much glare in the winter months through the clerestory windows;
2. continuing leakage at the clerestory windows;
3. condensation at the clerestory windows (as they are double glazed, condensation occurs between the glazing sheets);
4. split level difference of one metre is too high and the kitchen area accumulates too much warm air.

(F) Future changes to design and building techniques should the owner build again

The owner highlights the following changes which would be made:

1. lower split level difference;
2. re-location of the kitchen at the lower level of the house;

as a significant amount of heat is generated in this area, the heated air would then automatically rise to the elevated living areas;

3. the thermal ducts in the solar wall are not necessary, as sufficient heat is collected through the glazed areas.

(G) Summary

There are significant amounts of light and heat entering through the clerestory windows, although they represent some problem due to excessive glare, overheating at times, and water penetration. The addition of insulation in the wall cavities would further improve the thermal performance and is strongly recommended for any house.

The northern elevation of the house demonstrates a skilful integration of the Trombe-Michel wall with the Western red cedar windows and doors.

The attached sunroom at the eastern side of the house does not greatly contribute to the solar heat gains in the house, but represents an attractive area to be viewed from the kitchen. The sunroom also contributes to indoor food growing.

As one of the first passive solar houses in Australia, it shows clearly, that the solar systems work well in Tasmania and that the initial cost of the solar space heating system represents only about 3% of the total cost of the house.

Photograph 4.2.2 Fergusson Solar house
North elevation viewing Trombe-Michel wall and sunroom.

4.3 COLLINS HOUSE

4.3.1 Technical Description

Location: Abbotsham, 8km South West from Ulverstone, Tasmania.

Latitude: 41° 06' S

Date completed: July 1982

Designer, Owner Builder: Nick Collins

Size: 122 m^2

Cost: \$26 000 (\$213/m^2)

Climate: Temperate

Heating Degree Days (base 18°C): 2070

January average temperature: 17°C

July average temperature: 8.3°C

Photograph 4.3.1 Collins House at Abbotsham, near Ulverstone

(A) Objective

The initial design objective was to create a low energy, environmentally responsive, warm and comfortable house.

(B) Site

The 15 acres site slopes towards the north. It is heavily treed on the northern section of the site. The trees protect the house from the winter winds, however they obstruct it from the reception of solar radiation in the winter months after 3 pm.

(C) Construction

This single storey, three bedroom house uses timber framed external walls, except at the north side, which represents the solar wall, constructed of concrete blocks.

There is a 120 mm concrete floor in the living area, while the remaining floor is timber framed.

The timber-framed roof features exposed oregon pine rafters; the ceiling is lined with white painted plasterboards. The roof is cladded with orange colorbond zincalume material.

Door and window frames are made from Western red cedar.

The house is zoned with the living area and the kitchen to the north and the sleeping and study area to the south. The house is oriented to due north. (See floor plan, Figure 4.3.1)

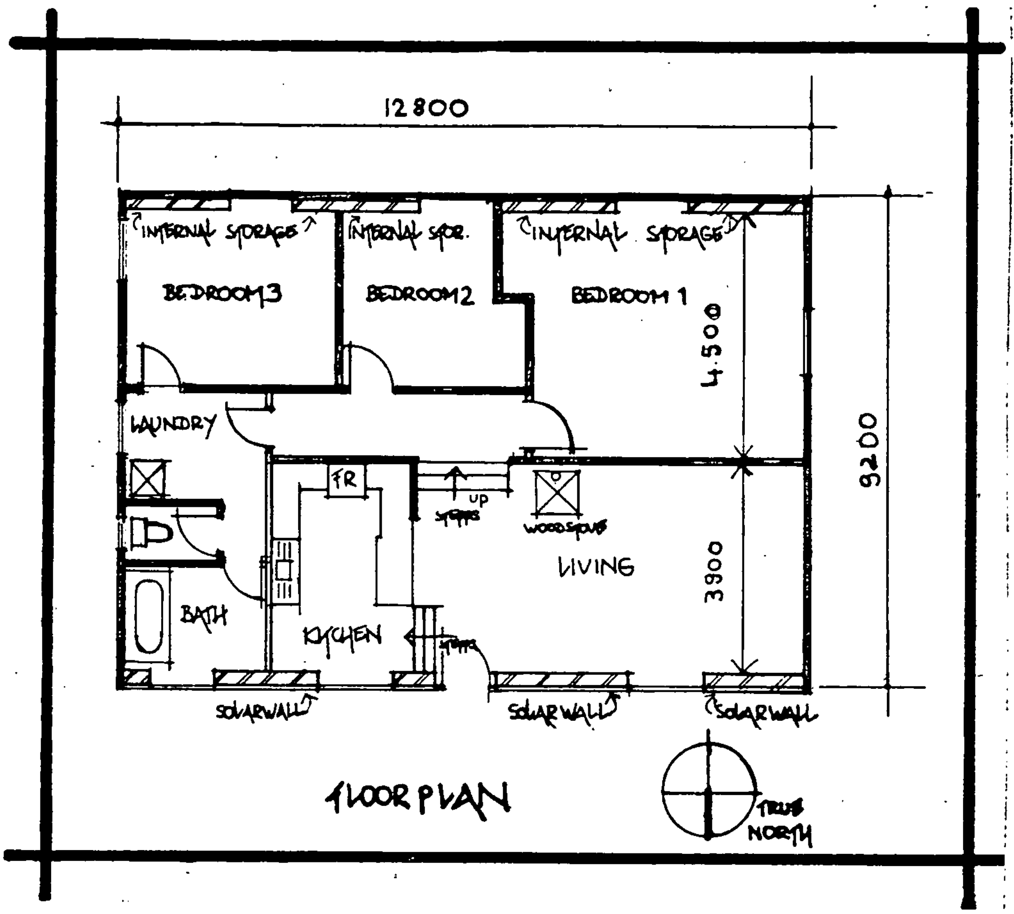


Figure 4.3.1 Floorplan of the Collins House
Abbotsham, Ulverstone.
Source: Nick Collins

(D) Solar Heating Systems

The major component of the passive solar system consists of a thermal storage wall with an area of 12 m^2, being 9.8%

of the total floor area of the house. The thermal storage wall, consisting of a 190 mm thick concrete block wall, is painted black on the exterior surface. The solar wall glazing is supported by Western red cedar window frames, installed 75 mm apart from the solar wall.

The Direct Gain System incorporates 9.2 m^2 of north facing windows and 3 m^2 of north facing clerestory windows, amounting to 10% of the total floor area.

The clerestory windows directly admit solar radiation to an internal concrete block wall in the southern bedrooms, acting as a storage wall with an area of 16 m^2. The cavities of the concrete blocks are filled with concrete for increased heat storage capacity.

Heat storage is provided by the thermal storage wall (2.28 m^3), the internal concrete floor in the living area (3.4 m^3), and the internal concrete block wall in the bedroom (3 m^3).

Auxiliary heating is provided by a slow combustion wood heater in the living area using approximately 3 tonnes of firewood per heating season with an estimated cost of $96 ($0.78/m^2).

Summer cooling. The thermal storage wall is shaded in the summer months by a 600 mm overhang. The clerestory windows can be opened for ventilation purposes in summer.

Hot water is provided by 4 m^2 of "Rheem" solar water flat plate collectors and a 260 litre storage tank located in the roof area.

(E) Insulation and Sealing

The external walls are insulated with 50 mm fibreglass batts and double sided reflective foil, and the ceiling with 75 mm rockwool batts and double sided reflective foil to the underside of the metal roof.

The perimeter of the concrete floor is insulated with 50 mm polystyrene foam.

The clerestory windows are double glazed, while the remaining single glazed windows are covered with heavy curtains.

(F) Thermal Performance

The house was designed by rule of thumb methods, and some basic thermal calculations were carried out at the beginning of the design. The owner has monitored the thermal performance to some extent by the use of several thermometers.

Figure 4.3.2. shows an especially cold period in winter, July 1984. With the coldest recorded outdoor temperature of 1°C, the minimum indoor temperature was 11°C. On sunny

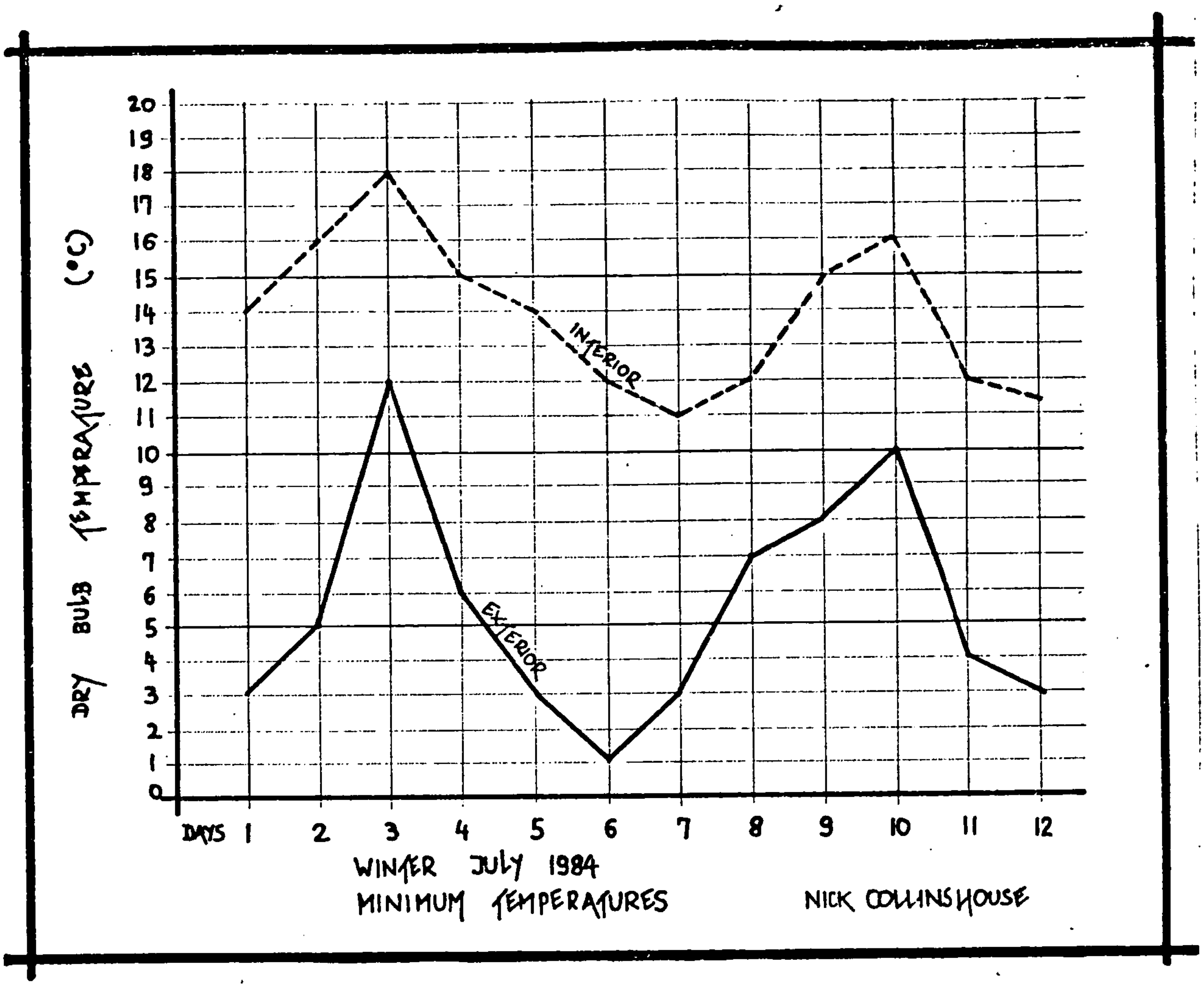


Figure 4.3.2 Minimum temperatures measured in the Collins house, July 1984. These temperatures are free running values; no auxiliary heating was used in that period.
Source: Nick Collins

winter days, the house reached a temperature of 15°C with an average outdoor temperature of 5°C.

The warmest room temperature was obtained in the living area at about 5 pm, when the interior surface of the solar wall reached its highest temperature, rising to 35°C on sunny winter days.

(G) Cost of the Solar System

The cost of the solar glazing and framing was approximately $800.

4.3.2. The Owner Experience

(A) Primary reasons for including passive solar heating features

The owner, having lived in an uninsulated weatherboard house before, wanted to create a warm and comfortable house. Another reason for including passive solar heating features is the environmental concern of the owners who want to save on traditional energy resources.

(B) Council approval

As this was the first passive solar house in that area, the council was not acquainted with passive solar heating features, questioned the necessity for the solar wall and initially rejected the plans. However, after some research information was presented, the council approved the plans.

(C) Building experience

While building the thermal solar wall using concrete blocks, the owner did not fill the cavities with concrete. After the full height of the solar wall was reached (2.2 metres) the owner had the difficult task of filling the cavities of the concrete blocks.

(D) Experienced thermal comfort in the house

The owner is very satisfied with the experienced temperature in the house, especially in winter. Only occasionally the owner uses the wood heater on cold winter nights, after some days without sunshine.

(E) Problems related to the solar heating systems

A few problems were reported as follows:

1. the timelag of the 190 mm thick solar wall is about 5½ hours, which is too short in the owner's opinion;
2. there is no vapour barrier installed on the interior side of the ceiling; consequently there is a considerable amount of condensation within the insulation of the ceiling;
3. the owner stated that, because of the significant area of the thermal storage wall, the living area is too dark.

(F) Future changes to design and building techniques should the owner build again

The owner wants to make the following changes in the next building:

1. to enlarge the window area at the northern side, to increase the direct gains and the light penetration to the living area;
2. to increase the thickness of the thermal storage wall to obtain a time lag of about 9 hours;
3. to include a vapour barrier to the internal skin of the ceiling and walls.

(G) Summary

This house represents the only owner built structure in this survey, and is also one of the less expensive buildings. The dominating feature, the thermal storage wall, is covered by Western red cedar window frames and blends in well with the house. This house employs a building technique, seldom used in Australia, referred to as "reverse brick veneer". The masonry in this case is situated at the interior of the house, and is insulated on the outside by the insulation in the studwall and external timber cladding. This is one of the prefered building techniques for solar houses. It does not, however, have wide community acceptance, owing to the external timber cladding, which requires regular maintenance and hence, lowers the re-sale value.

Photograph 4.3.2 Collins House at Abbotsham, near Ulverstone, showing the Thermal Storage Wall and Solar Glazing.

4.4 BUTTON HOUSE

4.4.1 Technical Description

Location: Mt. Nelson, Hobart

Latitude: $42^{\circ}56'$ S

Date completed: February 1979

Architect & Owner: David Button

Builder: Laver Construction Pty Ltd.

Size: 140 m^2

Cost: \$ 34 000 (\$243/m^2)

Climate: Cool temperate

Heating Degree Days (base $18^{\circ}C$): 2340

January average temperature: $16.8^{\circ}C$

July average temperature: $7.3^{\circ}C$

Photograph 4.4.1 Button House, Mt. Nelson Hobart.

(A) Objective

The owner required an economic solar house which would cater for the needs of two people. They desired a house which would complement the bushland surrounding, so it was built with minimal disturbance of the site.

(B) Site

The site, a sloping block of average size on the suburban fringe of Hobart, has an unobstructed northern aspect, with the exception of a group of eucalyptus trees at the north-east corner of the house. It is sheltered from the prevailing north-west winter winds.

(C) Construction

This two-storey, two bedroom house has 270 mm double brick cavity external walls to the ground floor living area, timber stud frame external walls to the downstairs services area, and brick veneer external walls to the first floor. Internal walls are 110 mm bagged and white-painted brickwork downstairs, and timber stud frame upstairs. External brick wall is of brown/red face bricks, while internal brickwork is bagged and painted white. Timber stud walls are lined internally with white-painted plasterboard.

The ground floor is a 113 mm concrete slab covered with black slate tiles. All other flooring is timber framed, including the section of the ground floor over the heat storage. The timber framed roof is clad with galvanised steel deck sheeting. The ceiling is lined with whitewashed pine boarding or white-painted plasterboard. Window frames are aluminium, with the exception of several recycled timber framed windows.

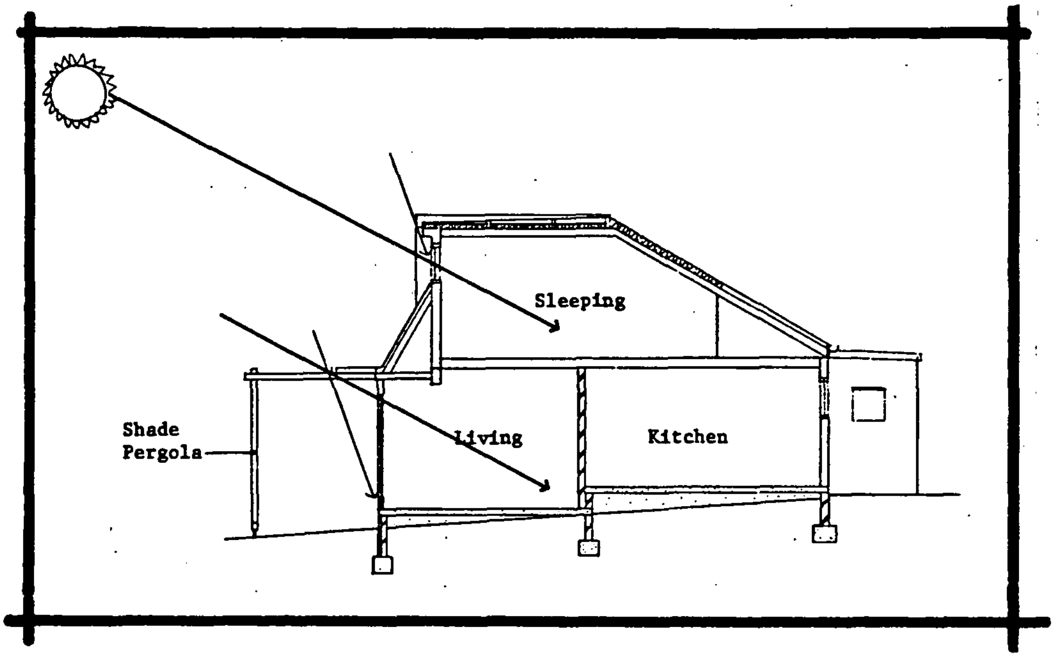


Figure 4.4.1 Section drawing, Button House, Mt. Nelson, Hobart, showing the method of passive heat collection.
Source: Gnauck, D., 1981; Passive Solar Architecture, Architectural Thesis Report; Tasmanian College of Advanced Education, Hobart.

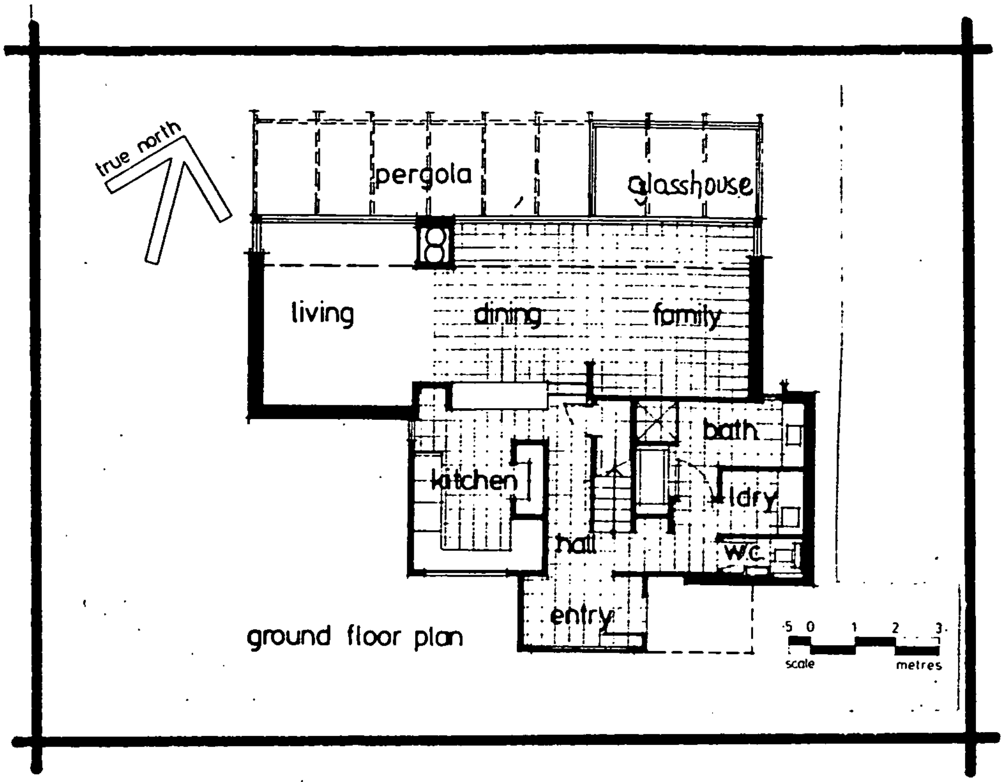


Figure 4.4.2 Ground floor plan, Button House,
Mt. Nelson, Hobart.
Source: David Button

(D) Solar Heating Systems

The house is presently heated by Direct Gain through north-facing windows, although provision has been made for the future addition of an active air-based solar system.

The Direct Gain component has a collection area of 26 m^2, which is 18.6% of the floor area. Heat is directly stored in the floor and downstairs internal walls. A small commercial greenhouse has been fitted to the east end of the north elevation of the house, but this is essentially intended to act as a buffer zone rather than as a heat collector.

The active system, planned for installation some time in the future, will have a single 16.5 m^2 solar collector mounted on the north roof with a 60° tilt. This collector area is 12% of the floor area. The rock bed, located in a concrete and masonry pit under the living room floor, contains 8 m^3 of 12 mm gravel supported on a wire mesh base, allowing 0.5 m^3 of gravel per m^2 of collector.

Auxiliary heating is provided by an electric floor heating system under the kitchen, bathroom and passageway areas and a slow combustion wood heater in the living area. The annual space heating cost in 1983 has been estimated at \$180 (\$1.28/m^2).

Summer Cooling. The downstairs north facing windows are shaded by a 2200 mm wide pergola with a 800 mm wide overhang, while the clerestory windows are shaded by a 300 mm wide overhang. The greenhouse acts as a humidifier in summer. Any excessively heated air is vented through its roof. Any hot air trapped within the house is vented via the clerestory windows.

(E) Insulation and Sealing

The following insulation has been installed:
50 mm urea formaldehyde foam in the external brick cavity walls; double-sided reflective foil in the timber framed walls; double sided reflective foil to brick veneer walls; 75 mm thick fibreglass blankets with double-sided reflective

foil in the roof; lined curtains with pelmets to most glazed areas; blinds to the clerestory windows; standard hair seals to aluminium windows; and a sealed threshold to the entrance door.

(F) Thermal Performance

The house has been designed to maintain an average temperature of 18°C over a two day period without solar imput. The minimum indoor temperature initially was expected to be 13°C. The owner carried out some simple thermal calculations, using the steady-state technique.

The house has been monitored over a period of two years, using a series of thermometers. Figure 4.4.3 shows the temperature variation between the exterior and the interior of the house over a cold period in July 1980. It should be noted that no additional auxiliary heating was used during that period(referred to as free running temperature).

The minimum exterior temperature in that period was 1°C, while the minimum internal temperature was 10°C. Over a 3 year period, the lowest internal temperature was 10°C, while the lowest recorded external temperature was 0°C. The average difference between internal and external temperatures in winter is about 9°C (assuming no auxiliary heating).

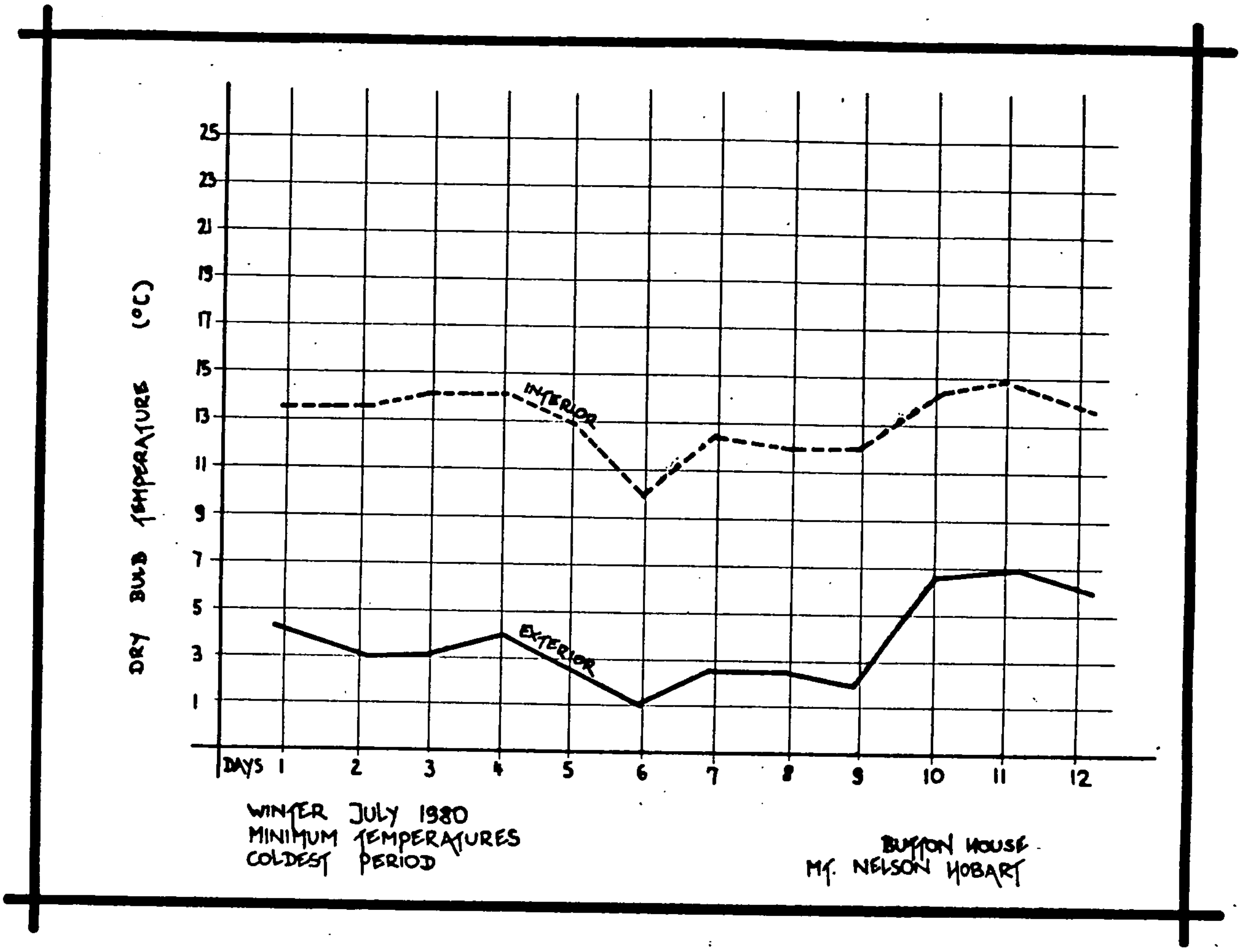


Figure 4.4.3 Temperature swings in the Button House, Mt. Nelson, Hobart.
Source: David Button

Figure 4.4.4 reveals the temperature fluctuation over an especially hot period in February 1983. The maximum internal temperature reached 29°C, when the exterior recorded temperature was 32°C.

The thermal performance of the house is expected to improve with the installation of the air collectors; however, this is not planned for quite some time.

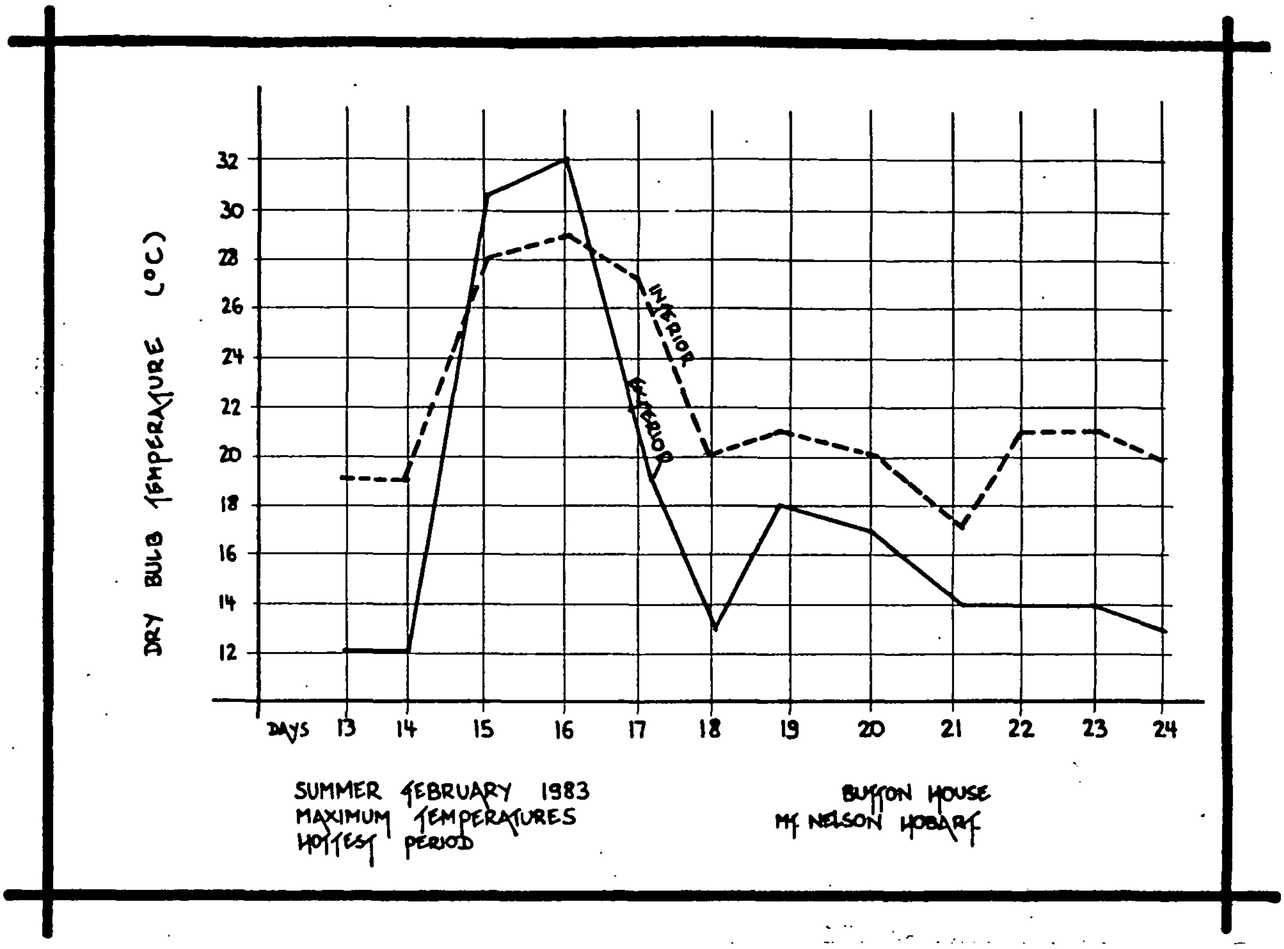


Figure 4.4.4 Temperature swings in the Button House, Mt. Nelson, Hobart.
Source: David Button

(G) Cost of the Solar System

Cost figures of the basic passive heating features were not available. The cost of the additional thermal heat storage underneath the house and the ducting system was $1200.

4.4.2 The Owner Experience

(A) Primary reasons for including passive solar heating features

The owner designed the house for experimental reasons, to demonstrate that the use of solar energy is feasible in Tasmania.

(B) Council approval

There were no problems.

(C) Building experience

There were no recorded problems.

(D) Experienced thermal comfort in the house

The owner reported that the house needs additional heating on cold winter nights, while during the winter days, it usually stays warm and requires no additional heat.

(E) Problems related to the solar heating features

According to the owner's report, there is too much thermal mass placed inside the house, which does not correlate with the size of the north facing windows.

The 800 mm wide overhang at the northern side blocks out too much solar radiation in the winter months and the width should be reduced.

The berber carpet in the living area is exposed to a great amount of solar radiation and exhibits some bleaching.

The curtains, when opened, take up about one third of the window area and hence reduce the amount of direct gains.

(F) Future changes to design and building techniques should the owner build again.

The owner would design a new house with smaller rooms which could be opened to form larger spaces, for the more efficient use of heat.

The owner pointed out that a pergola for summer shading is not necessary in Tasmania and he would not include it in a new design. Also, in his opinion, 1.5 - 2 metres width of the floor along the northern windows should be left clear of carpets and furniture, so that the floor can be used as heat storage. The remaining floor area can then be covered with carpets or furniture.

(G) Summary

This house represented one of the first solar houses in Hobart and has created significant interest over the last few years.

Due to the poor quality of the attached glasshouse, it will not contribute much solar gains and can only be seen as a buffer zone.

The double storey open planned house contains a significant amount of air to be heated in winter, an arrangement not suited for effective passive solar heating. In this case, the northern windows, acting as solar collectors, are not large enough to effectively heat the entire house.

Photograph 4.4.2 Button House, Mt. Nelson, Hobart. View to the attached glasshouse.

4.5 CHRISTIAN SCHOOL

4.5.1 Technical Description

Location: Riverside, Launceston, Tasmania

Latitude: 41°30' S

Date Completed: March 1981

Designer: Johannes Harder and Grade 10 Students from the Christian School

Owner: Christian School, Launceston

Size: 70 m^{2}

Cost: \$19 000 (\$271/m^{2})
For building materials and some labour only

Climate: Cool temperate with an average of one day per week over June to August dropping to 0°C and rising to 10°C during the day.

Heating Degree Days (base 18°C: 2200

January average temperature: 18°C

July average temperature: 6.8°C

Photograph 4.5.1. Christian School Launceston, View to the Trombe-Michel Wall and Attached Greenhouse.

(A) Objective

The objective was to provide an "actual life" learning situation for grade 10 students to research, design and construct, with community help, a building using natural resources which will become part of the learning facilities.

(B) Site

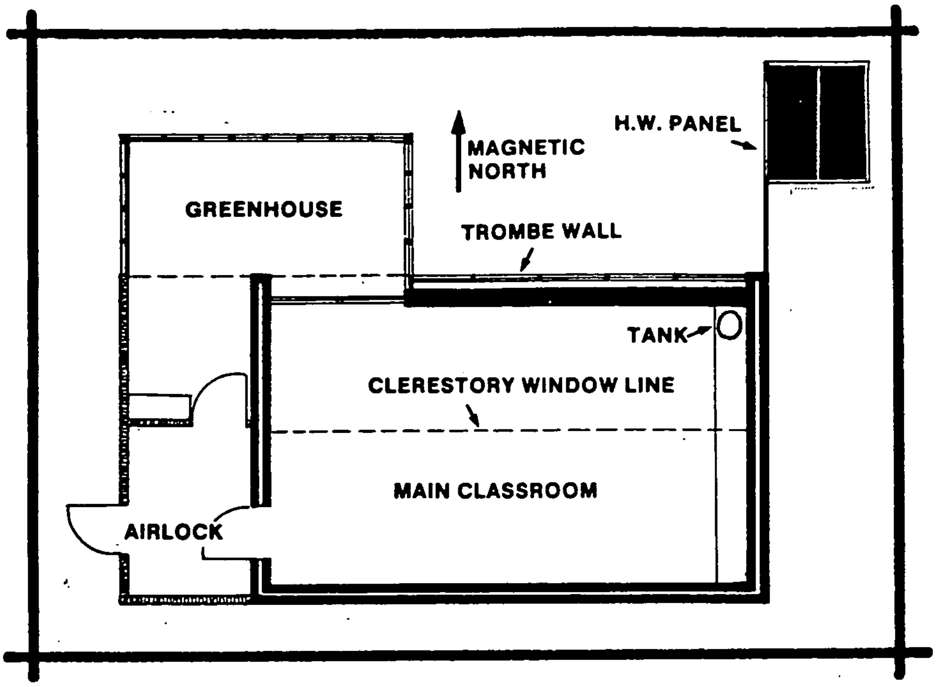
The site has an unobstructed northern aspect; however, it is occasionally affected by river fog in winter.

(C) Construction

The single storey school is constructed on a 150 mm concrete slab with 50 mm polystyrene slab edge insulation. The east, south and west classroom walls are 300 mm brick cavity walls. The roof is covered by Spandek zincalume steel. A moveable single glazed window separates the classroom from the single glazed greenhouse, which is attached on the northern side of the building. The remaining area of the northern elevation is occupied by a Trombe-Michel solar wall. The building is oriented to magnetic north.

(D) Solar Heating Systems

This school building combines three passive solar heat collection methods, the major component being a Trombe-Michel



Floor plan

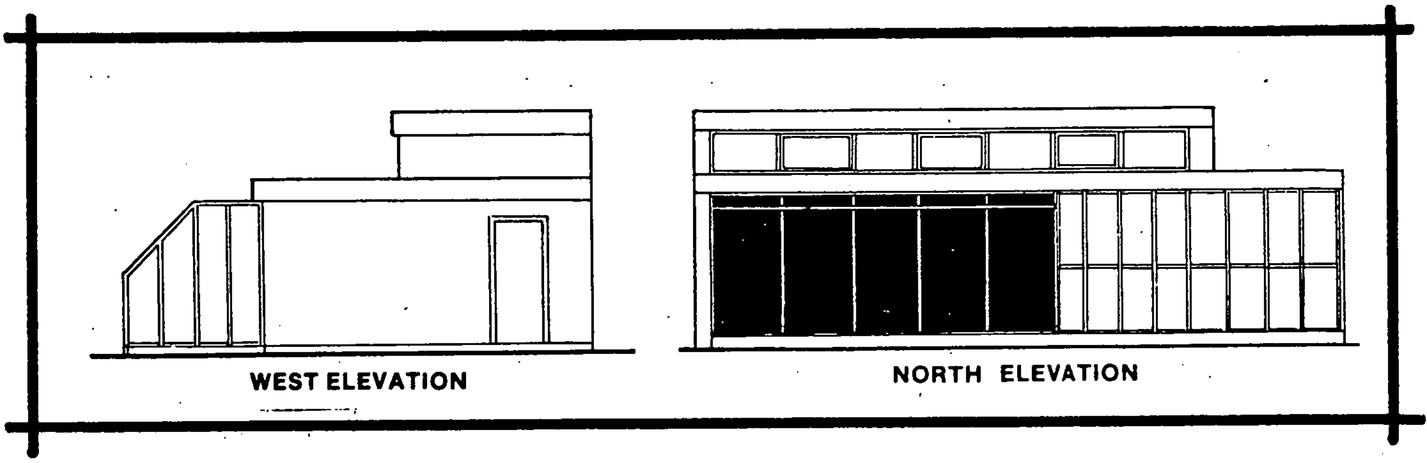


Figure 4.5.1 Floor plan and Elevation drawing, Christian School, Launceston. Source: Johannes Harder

wall with a collection area of 14.4 m^2 (21% of the floor Area). The Trombe-Michel wall, constructed of 300 mm thick concrete, is double glazed and has three thermocirculation vents on the top and bottom. For summer cooling purposes, three shutters on the top of the solar glazing can be opened to direct the hot air outside. The air gap between the solar wall and the first layer of glazing is 100 mm; the double glazing is 50 mm apart.

The Direct Gain System comprises a northern window area of 7.5 m^2, including the clerestory window area of 4 m^2 (11% of the classroom's floor area). The attached greenhouse uses steel-glazing frames, is single glazed and the heated greenhouse air can enter the classroom through the window, if it is in open position.

Heat storage is provided by the Trombe-Michel solar wall, (4.32 m^3), the internal brick walls and the concrete floor. There are eight black painted water-filled 200 litre drums in the greenhouse for thermal storage; in addition the concrete floor in this area is 200 mm thick.

Hot water is provided by two flat plate collector panels, with the storage tank located in the classroom.

Auxiliary heating has not been needed up to date.

Summer Cooling. The Trombe-Michel wall is equipped with three operable vents in the solar glazing to draw cool air currents through the house in summer. The greenhouse is vented by two louvre windows. The Trombe-Michel wall is almost shaded by the 450 mm wide overhang. No overheating problem has been reported in the classroom.

(E) Insulation and Sealing

The external walls are insulated with 50 mm polystyrene sheets. The ceiling comprises 50 mm Stramit boards and 100 mm loose fill cellulose insulation. Night heat losses through the single glazed clerestory windows are reduced by hinged insulating panels, made from 25 mm polystyrene faced hardboard sheets. The timber air-lock wall is insulated with urea formaldehyde foam and the slab edges insulated with 50 mm polystyrene sheets.

(F) Thermal Performance

Table 4.5.1 summarises the results for one month temperature collection, starting on the 28th of July 1983. Over this period no auxiliary heating was used, although the external temperatures dropped to -3°C on two occasions. Daily routine included dropping the clerestory window shutters and covering the Trombe-Michel wall vents at 4 pm.

	Min	Max	Mean
Room temperature swing (°C)	1.0	8.0	4.0
Room temperature rise above ambient (Δt, °C)	4.5	12.5	6.5
Daily irradiation (MJ/m^2)	1.0	20.0	13.0
Room temperature (°C)	15.0	27.0	19.0

Table 4.5.1 Thermal Performance, Christian School, Launceston; August 1983.
Source: Sutton, R., 1983; Private Communication, Tasmanian College of Advanced Education, Launceston.

(G) Cost of the Solar System

The cost of the solar wall glazing was $750. The cost of the attached greenhouse has been estimated as $1200. The total cost of the solar system of $1950 aomounts to 10% of the capital building cost.

4.5.2. The User Experience

(A) Primary reasons for including passive solar heating features.

The teachers initiated the project to provide a learning experience for Grade 10 students, to present a demonstration passive solar building project, and eventually save energy for space and water heating.

(B) Council approval

There were no problems.

(C) Building experience

There were no problems with the construction of the solar heating features.

(D) Experienced thermal comfort in the building

Teachers and students are very satisfied with the internal temperatures of this building, especially in winter. There is no auxiliary heating necessary. The internal temperature in the classroom never dropped below 15°C in winter, the temperature in the glasshouse never below 10°C. Often the students show surprise at how comfortable the classroom is on winter mornings.

(E) Problems related to the solar heating features

The greenhouse overheats in the summer months due to insufficient ventilation. No other problems have been reported.

(F) Future changes to design and building techniques should the owner build again.

The following changes would be necessary:

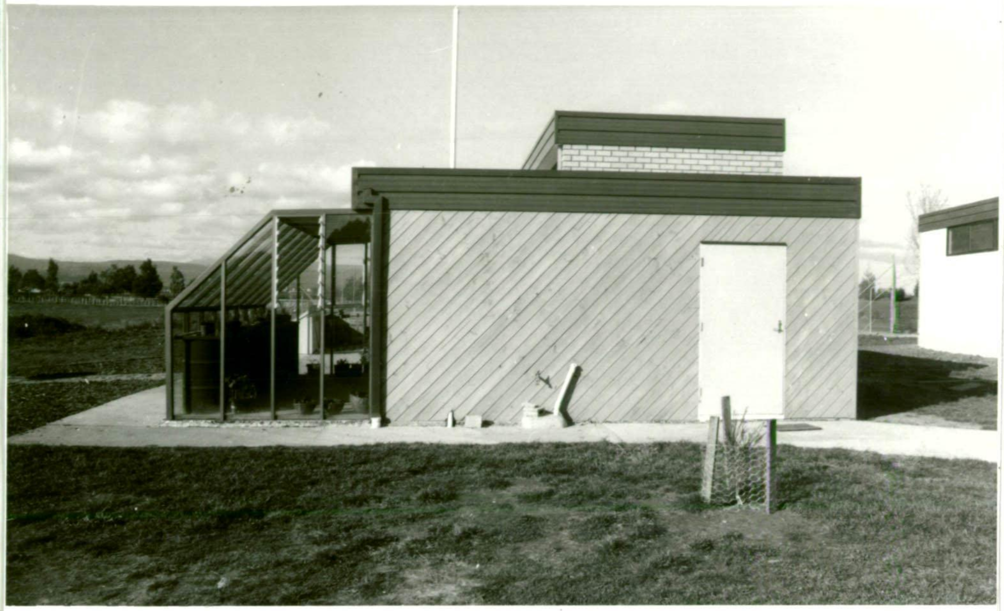
(1) to increase the ventilation in the greenhouse;

(2) to place a shading-cloth on the greenhouse during the summer months

(G) Summary

This school building presents the only known 100% solar heated building in Tasmania and shows the great potential for passive solar heating features. With substantial heat collection and storage areas in combination with adequate insulation, this classroom has not needed any auxiliary heating and will save significant heating costs over its lifetime.

This building should give every prospective solar building owner great confidence to apply passive solar heating features to their buildings.



Photograph 4.5.2. Christian School, Launceston
The greenhouse is used for food growing purposes, throughout the year.

4.6 SUNSPACES PROJECT HOUSE

4.6.1 Technical Description

Location: Ulverstone, Tasmania

Latitude: 41°18' S

Date completed: June 1984

Architect: James Buttenshaw

Owner: Sunspaces, Ulverstone

Size: 124 m^2 (without carport)

Cost: $65 000 ($406/m^2)

Climate: Temperate

Heating Degree Days (base 18°C): 2070

January average temperature: 17°C

July average temperature: 8.3°C

Photograph 4.6.1. Sunspaces, Passive Solar Project House, Ulverstone.

(A) Objective

The designer's objective was to design, build and market a high quality project house, with particular emphasis on energy conservation through passive solar energy systems. This house was designed and built for demonstration purposes to encourage and promote the use of solar energy systems for space heating.

(B) Site

The 729 m^2 flat site has an unobstructed northern aspect.

(C) Construction

The single storey, three bedroom house is constructed with 250 mm brick veneer external walls. Internal walls are timber framed and lined with radiata pine boards in the living areas, and white painted plasterboards in the bedrooms and laundry. The ceiling, featuring exposed oregon pine beams, is lined with radiata pine boards.

The windows and doors are made from Western red cedar, and all windows and doors are single glazed.

The house is oriented 15° west of magnetic north and divided in two major zones: the family, lounge and master bedroom area to the north-west and the remaining bedrooms to the east side of the house.

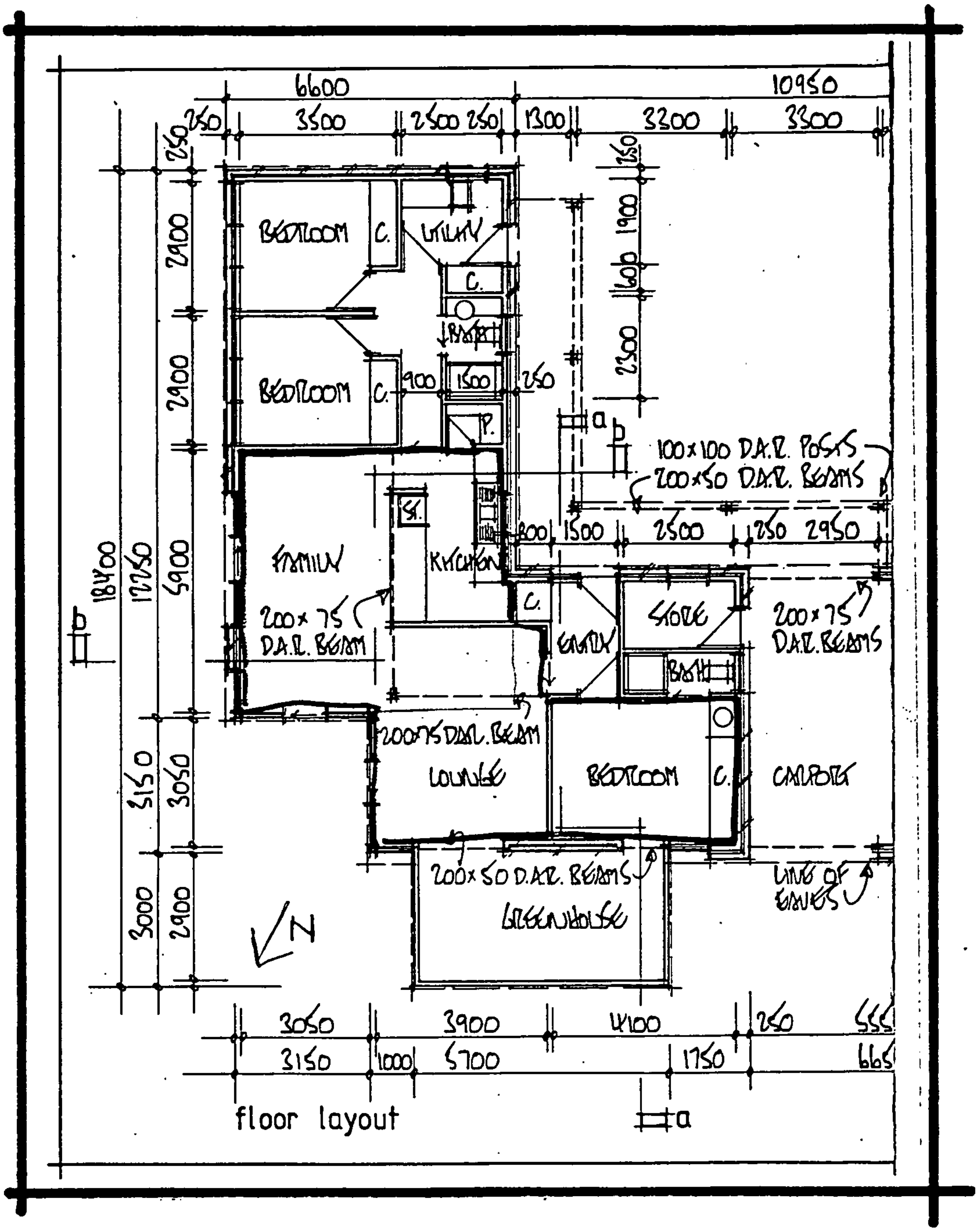


Figure 4.6.1 Floor plan details, Sunspaces Project House, Ulverstone.
Source: James Buttenshaw

(D) Solar Heating Systems

This house uses two passive solar heat collection methods: the attached greenhouse, which is the major heating system, and the north facing windows.

The 14.3 m^2 greenhouse exposes 14.85 m^2 of twin-walled polycarbonate for solar energy collection. The Direct Gain System consists of 6.50 m^2 north facing windows, which amounts to about 10% of the floor area to be solar heated.

Heat storage is provided by a concrete floor, covered with brown tiles in the area to be solar heated. In addition,the brick storage wall, separating the greenhouse from the lounge and master bedroom, has an area of 6.48 m^2 and a volume of 1.60 m^3.

Auxiliary heating is provided by a slow combustion wood heater in the family room. Annual heating costs are estimated not to exceed $100 ($0.81/m^2).

Summer Cooling Four windows in the greenhouse can be opened for ventilation purposes.

(E) Insulation and Sealing

The ceiling and external walls are insulated with R1.5 fibreglass insulation batts and double sided sisalation. The concrete slab edges are insulated with 50 mm polystyrene. The windows are covered with heavy woollen curtains. The entry is air locked.

(F) Thermal Performance

The thermal performance of this house has not been fully evaluated yet. After a very cold night in July 1984, (-2°C) the measured interior temperature in the lounge room without any auxiliary heating, was 12°C.

(G) Cost of the Solar System

The cost of the attached greenhouse has been estimated as \$3500, the heat storage wall as \$550 (6% of the capital cost).

4.6.2 The Owner Experience

(A) Primary reasons for including passive solar heating features

The owners wanted a high degree of thermal comfort and to save energy and costs for space heating purposes.

(B) Council approval

In the planning process, the council rejected the lowest ceiling height of the attached greenhouse (1.4 metres) as being too low for a domestic building. However, after the architect pointed out that the greenhouse is mainly used as a solar energy system, the council finally approved the structure.

(C) Building experience

There were no problems.

(D) Experienced thermal comfort in the house

The owners had lived in the house for only a few weeks when interviewed. They pointed out, that during the coldest three weeks in July 1984, they did not use any additional heating during the day time. They also reported how warm and comfortable they feel, especially in the lounge area and master bedroom. They never anticipated such high thermal comfort and are extremely satisfied with their new solar house.

(E) Problems related to the solar heating features

The attached greenhouse experienced some leaks. The problem has been rectified by applying silicon onto a polycarbonate seam. No other problems have been reported.

(F) Future changes to design and building techniques should the owner build again

The owners would like to build part of the south side of the house underground to ensure lower heat losses in winter.

(G) Summary

The attached greenhouse is well integrated with the remaining floor plan and contributes significantly towards the space heating requirement. The solid thermal brick storage wall, separating the greenhouse from the internal areas, is necessary and will store a substantial amount of heat during sunny winter days to release it during later hours.

During summer months, the greenhouse has to be covered by a shading cloth to prevent overheating of the house.

Photograph 6.4.2. Sunspaces Project House, Ulverstone. View to the attached greenhouse and the heat storage wall.

Photograph 4.6.3 Sunspaces Project House, Ulverstone. The heat storage wall, separating the greenhouse from the living areas.

4.7 MITCHELL HOUSE

4.7.1 Technical Description

Location: Lindisfarne, Hobart

Latitude: $42^{\circ}54'$ S

Date completed: September 1982

Architect: David Button

Owner: Dr. Derek & Mary Mitchell

Size: 260 m^{2}

Cost: \$120 000(\$462/m^{2})

Climate: Temperate

Heating Degree Days (base 18°C): 2300

January average temperature: 16.9°C

July average temperature: 8.2°C

Photograph 4.7.1. Mitchell House, Hobart.
Northern Elevation.

(A) Objective

The objective of the design was to provide a solar house for a family. The design had to be suitable for a steep, south facing slope and the magnificent view to the south.

(B) Site

The 1100 m^2 double block slopes steeply to the south. Winter winds experienced are from west and south-west. In the winter months, a hill to the north of the house creates some obstruction to the morning sun.

(C) Construction

The two storey, four bedroom house has 300 mm double brick cavity external walls to the ground floor living areas and timber stud frame external walls to the upstairs area. The timber stud frame walls are lined externally with Western red cedar and internally with white painted plaster boards.

The basement floor is of slab-on-ground construction, while for the ground and first floors a suspended, 125 mm reinforced concrete slab has been used.

The timber framed roof is covered by a zincalume colorbond roof sheeting. Window and door frames are of aluminium, being double glazed at the south side.

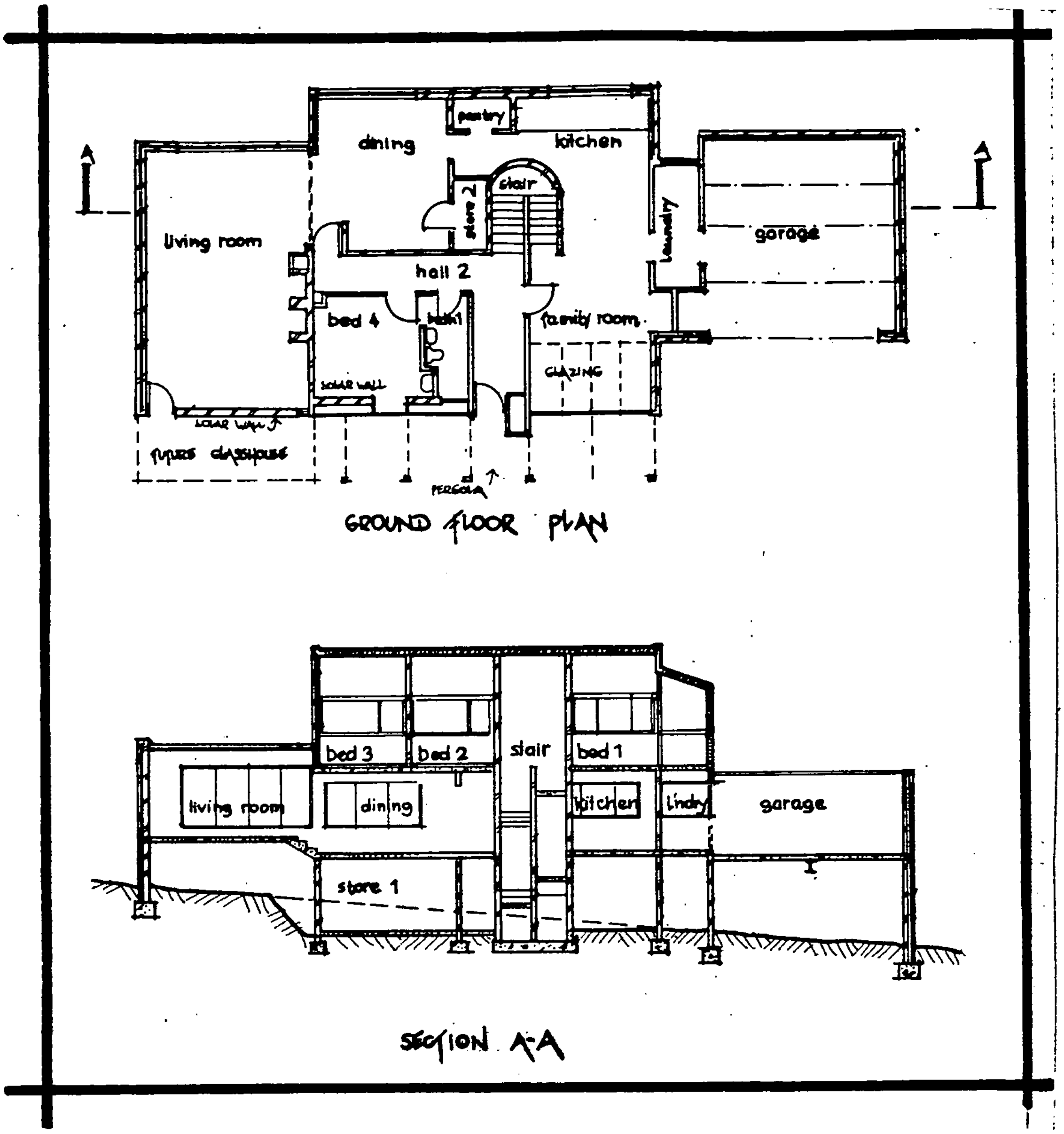


Figure 4.7.1 Floor plan and section drawing
Mitchell House, Hobart
Source: David Button

(D) Solar Heating Systems

The house is presently heated by two passive solar heating systems. The Direct Gain System is the major heating feature, consisting of 18.65 m^2 of vertical north facing glazing and 8.64 m^2 of 20° north tilted glazing over the family room. The area of glazing represents a total of 27.29 m^2, which is approximately 10% of the floor area.

The second heating system is a Trombe-Michel wall with a collection area of 7.56 m^2, which is 53% of the bedroom and bathroom area, intended to be heated by this solar wall. The Trombe-Michel wall consists of a 230 mm solid brick wall, painted black on the exterior surface. The aluminium framed 6 mm solar glazing is spaced 360 mm apart from the solar wall. Air is thermosiphoned via 2 sets of top and bottom vents, each 480 x 172 mm in size.

An attached glasshouse is planned for the near future and will assist the solar heating in the living room. The 230 mm heat storage wall, separating the future glasshouse and living room, is 7.77 m^2, which is 21% of the living room's area.

Heat storage is provided by the internal brickwork, the Trombe-Michel wall, the heat storage wall between the living room and the future glasshouse, and the concrete floor.

Auxiliary heating is provided by an open fireplace and four electric panel heaters. Provision has been made for a water under-floor heating system. Polythene tubes are installed under the living room, kitchen and family room areas to be later connected to a wood furnace. The annual auxiliary heating cost for 1983 has been estimated at $250 ($1.12/m^2).

Hot water is provided by 3 panels of flat plate collectors with a total area of 6 m^2. The heated water thermosiphons in a 300 litre storage tank, mounted above the collectors in the roof space.

Summer Cooling The Trombe-Michel wall is shaded in summer by a 400 mm wide overhang. The glazed roof area in the family room is protected by a shading cloth in summer.

(E) Insulation and Sealing

The house is insulated as follows: 50 mm urea formaldehyde foam to the external brick cavity walls, 75 mm (R1.5) thick mineral wool and reflective foil to interior and exterior sides in the upstairs timber framed walls, and 100 mm (R2.0) mineral wool on top of the double sided reflective foil insulation in the roof.

Heavy curtains are installed to most of the glazed areas with the exception of the glazed roof in the family room.

(F) Thermal Performance

The house was designed by rule of thumb methods. It has been monitored by a temperature recorder during a cold period and figure 4.7.2 shows the temperature fluctuation during that period, September 23 to October 7, 1984.

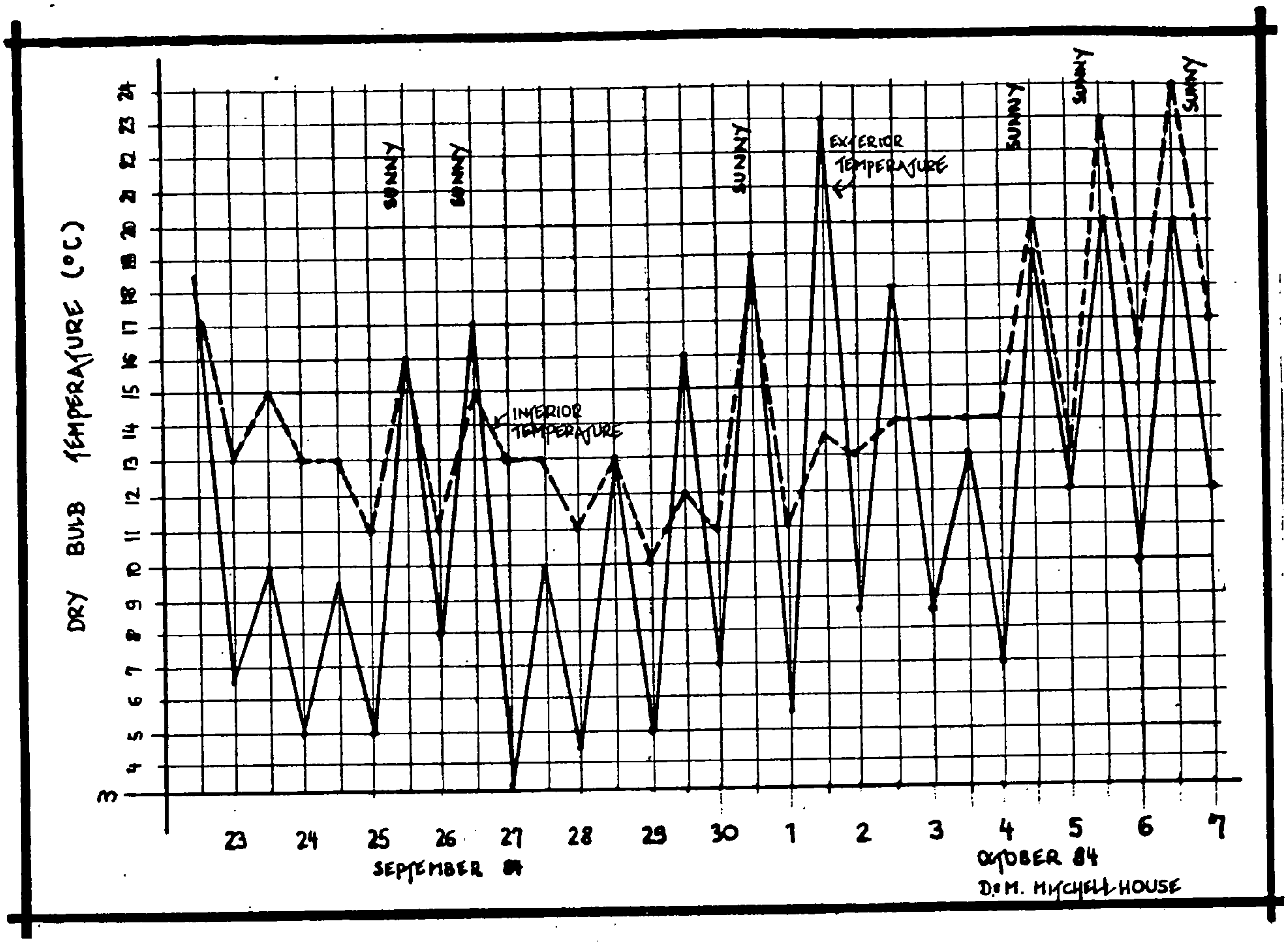


Figure 4.7.2 Thermal Performance of the Mitchell House. Minimum temperatures experienced during a cold period, September 23-October 7, 1984
Source: Dr Derek Mitchell

Figure 4.7.2 shows the coldest external temperature recorded in that period of 3°C, while the coolest internal temperature in the living room was 10°C, recorded 2 days later. In that period, no auxiliary heating was used. At the average, the house is approximately 8°C warmer than recorded external temperatures.

The warmest recorded internal temperature in that period was 24°C (external 20°C) after three consecutive sunny days. The internal temperatures were recorded in the family room, 1.5 metres above the floor level.

(G) Cost of the Solar System

The glazing system for the Trombe-Michel wall has been estimated as $750; the glazed roofing above the family room as $1600.

The future cost for the attached glass house has been calculated to be $2500.

The total cost of $4850 for the solar heating features amounts to 4% of the capital cost of the building.

4.7.2 Owner Experience

(A) Primary reasons for including solar heating features

The owners have special interest in the solar technology and wanted to experiment with the heating features. Also, the primary objective was that these passive heating features should be installed at a reasonable cost.

(B) Council approval

There were no problems regarding the solar heating system.

(C) Building experience

The bricklayer did not follow the architect's instruction to fill the solar wall cavities with concrete. The cavities had to be filled with concrete when the solar wall was already built up to 2.2 metres, which was a very difficult task.

(D) Experienced thermal comfort in the building

The owners are very satisfied with the internal temperatures, even without the future under-floor heating. They experience the most comfortable temperatures in winter in the fourth bedroom, which is used as a sitting-reading area on cold winter nights. The family room also keeps warm during sunny winter days, however becomes rather cool at nights.

(E) Problems related with the solar heating systems

There is some water penetration through the glazing bars above the family room.

The shading cloth, used during summer over the glazed area in the family room, is difficult to instal and the owners would prefer a fixed, but adjustable shading device.

(F) Future changes to design and building techniques should the owner build again

The owners would recommend the following changes:

1. to use concrete blocks filled with liquid concrete for the solar wall, rather than bricks;
2. to use an internal shutter-shading device for the glazed area above the family room;
3. to increase the area of solar wall and north windows;
4. to build the southern part of the building underground.

(G) Summary

The addition of the glasshouse would greatly increase the thermal performance of the living room. The glasshouse should be constructed as soon as possible as the solid thermal storage wall between the living room and the future glasshouse will lose a significant amount of heat, as it is not insulated.

With the building's floor area of 260 m^2, the size of the passive solar systems (Direct Gain 27.29 m^2, Trombe-Michel wall 7.56 m^2) appears to be too small to have a significant overall heating effect, and will only affect the areas close to the solar systems.

The extensive glazing area above the family room needs to be covered by effective insulation to reduce night heat loss.

Photograph 4.7.2 Mitchell House, Lindisfarne, Hobart

4.8 PICKUP HOUSE

4.8.1 Technical Description

Location: Riverside, Launceston

Latitude: $41^{\circ}28'$ S

Date completed: August 1982

Architect: A.G. Walsh

Builder: Allan King, Launceston

Owner: Cormiston Pty Ltd (J.M. Pickup)

Size: 450 m^2

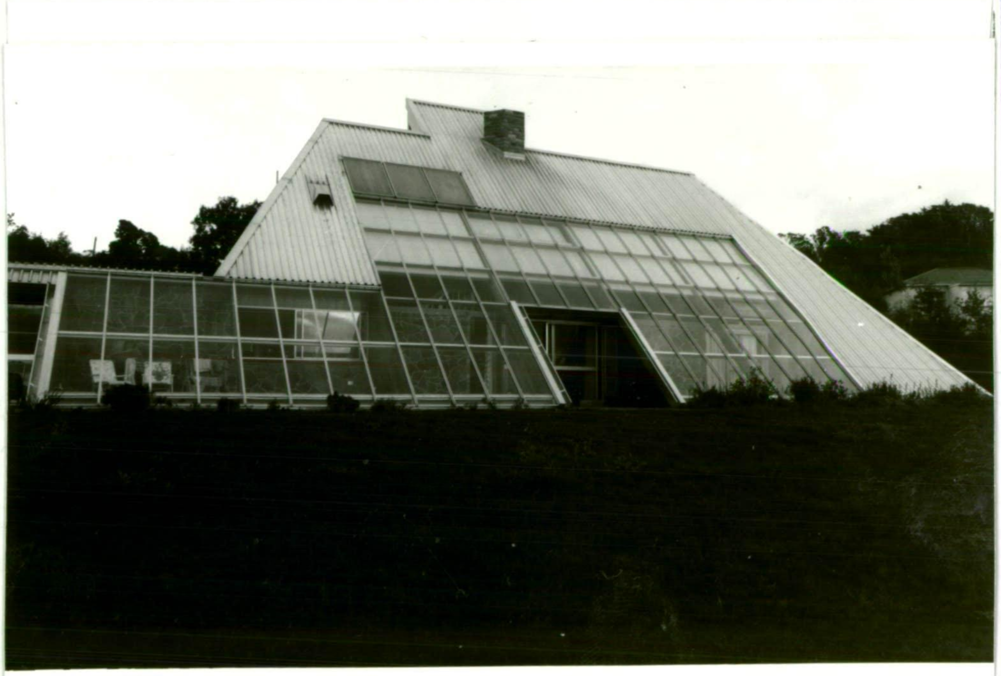
Cost: approximately $200 000 ($444/m^2)

Climate: Cool temperate

Heating Degree Days (base $18^{\circ}C$): 2280

January average temperature: $17^{\circ}C$

July average temperature: $6.8^{\circ}C$



Photograph 4.8.1 Pickup House, Launceston
View to the north elevation, showing the glazed areas and solar wall.

(A) Objective

The objective was to create a home for a large family, suitable also for entertaining visitors; and to reduce energy requirements to a minimum by using passive solar technology.

(B) Site

The 6000 m^2 gently sloping site has an unobstructed northern exposure. The prevailing winter winds are experienced from the south-west.

(C) Construction

The two storey, five bedroom house is based on an A-frame system, with the main frames of 300 x 100 mm oregon beams spaced at 3 metres centres. The ground floor is a 125 mm concrete slab; the first floor is timber framed.

Wood and stone are the main interior materials for structure, heat storage and finishing. The external roof is cladded with profiled aluminium sheets. The southern side of the house is partly buried; a retaining wall of about 1.6 metres forms the base of the A-frames on this side. Along the northern side of the house a 3 metre wide space of a triangular cross-section is a greenhouse, interrupted by two recessed entrances.

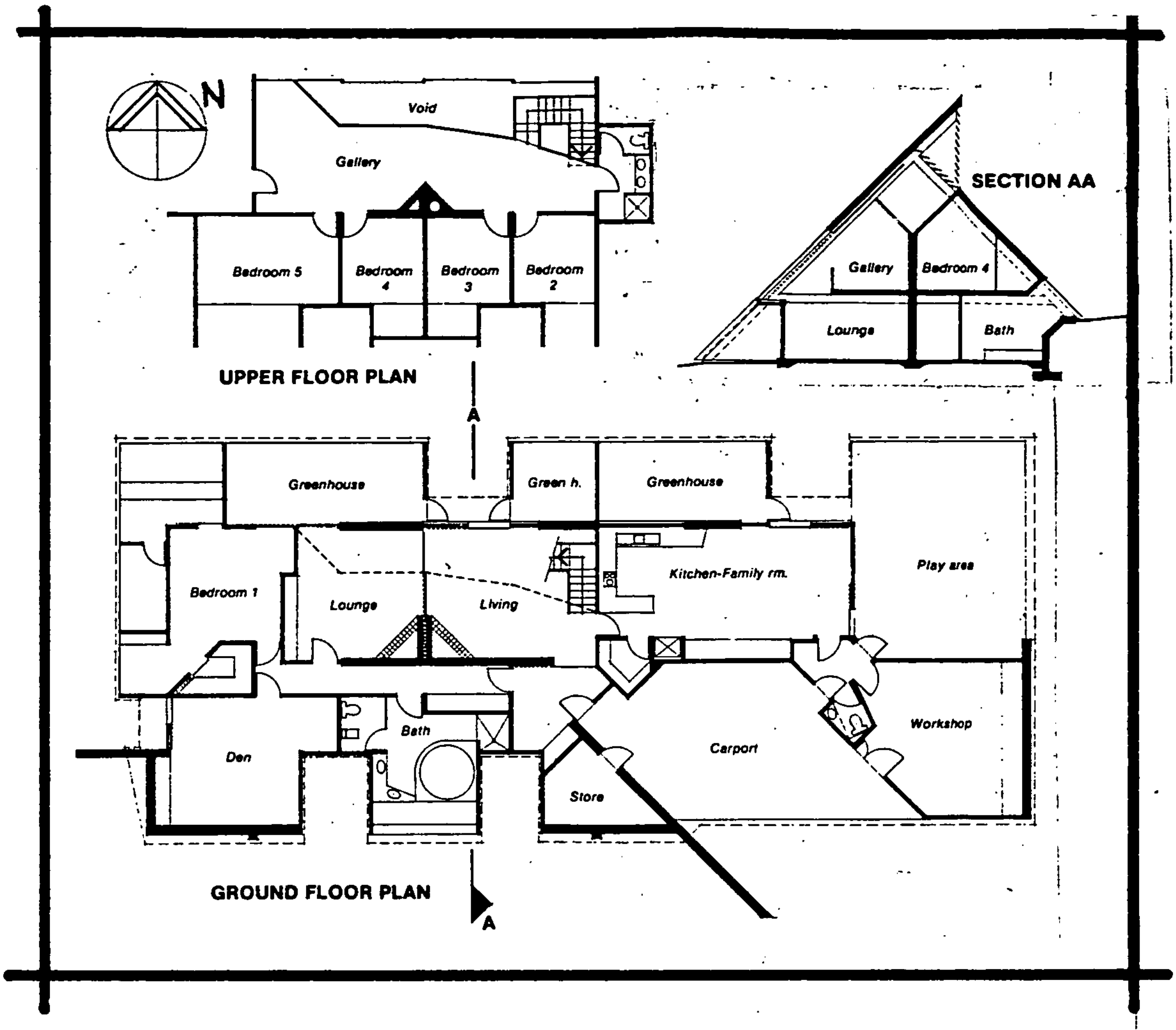


Figure 4.8.1 Floorplan and section drawing of the Pickup House, Launceston. Source: A.G. Walsh

(D) Solar Heating Systems

Direct Gain is provided through 50 m^2 of north glazing (11% of the floor area) which is situated over the lounge, living room and the upstairs gallery. Large insulated sandwich panels slide on rails between the A-frame members on the inside of the glass and can completely cover the entire glazing surface, or can be 'parked' under the higher part of the roof. Their movement is motorised and controlled by a photo-sensor (with manual override).

The massive centre stone wall incorporates a de-stratification duct. The hot air collecting under the ridge can be brought down through this duct by a fan and distributed to the ground floor rooms along the south side.

Heat storage is provided by two interior massive stone walls and the concrete floor. The stone wall separating the greenhouses from the lounge, living area and kitchen-family room has a volume of 4.29 m^3, and the massive stone spine wall, incorporating also 2 fireplaces, has a volume of 14.03 m^3.

Auxiliary heating is provided by two open fireplaces in the lounge and living room and by various electric panel heaters. The annual heating cost in 1983 has been estimated as $320, amounting to $0.71/$m^2$.

Summer cooling is achieved by a dormer like roof window. On summer days the warm air can be discharged through this window to the south side of the ridge.

Hot water is provided by three flat plate collector panels pumped into a 360 litre tank located near the upstairs bedroom.

(E) Insulation and Sealing

The roof is insulated with 75 mm polystyrene and lined internally with 15 mm plywood. The glazed areas over the lounge, living room and upstairs gallery can be automatically covered by insulated panels which slide on rails between the A-frame 300 x 100 mm oregon beams on the inside of the glazing.

The slab edges are insulated with 50 mm polystyrene sheets.

(F) Thermal Performance

The house was designed to provide about 80% of the annual heating requirement, Thermal calculations have been undertaken by the engineer at the design stage, using an interior design temperature of 18-25°C.

While winter outdoor temperature can fall to minus 2°C, the interior temperature never drops below 11°C. Only on a few occasions the open fireplace is used, mainly after two to three continuous days of rain and cold weather. The upstairs temperature is usually 3-5°C higher than downstairs.

(G) Cost of the Solar Systems

The cost of the glazing amounted to about $12 000. The mechanical equipment, including the motor to operate the insulating screens, has been estimated as $3500, and the cost of the insulating screens as $10 000.

Considering the capital cost of about $200 000 for the house, the cost of the solar heating system amounts to about 13%.

4.8.2. Owner Experience

(A) Primary reasons for including passive solar heating features

The owner wanted to experience the potential of solar heating in Tasmania. High thermal comfort and light sunny areas were important initial design considerations.

(B) Council approval

There was no problem regarding the council approval. However, four neighbours lodged an objection to the appearance and the high market value of the house. They felt that the high value of the solar house would result in devaluation of their properties. The shiny roof produced some glare to the complaining neighbours, which resulted in painting of some sections of the roof with a matt, non reflective green colour by the owner.

(C) Building experience

There were some smaller problems related to the engineering aspect of the insulating shutters and its mechanical construction. Initially the insulating panels were sliding on plastic rollers, which proved to be unsatisfactory. The insulating shutters now are fixed to steel bearing rollers, which slide along a steel track.

(D) Experienced thermal comfort in the building

The house performs to the full satisfaction of the owners After three days without any winter sun, May to August, the house needs auxiliary heating. The house stays very cool in summer, as the shutters are mainly closed during hot days and opened for cooling purposes at nights.

(E) Problems related to the solar heating system

The initial public acceptance of this house by four neighbours was a major problem to the owners, which has been solved after a lengthy legal argument and great financial constraints to the owners.

There is some leakage occurring in the glasshouse.

The mechanical device driving the shutters into position has been subject to breakdowns.

(F) Future changes to design and building techniques should the owner build again.

The owners registered the following future changes:

1. to build one level only, as the upstairs area gets much warmer and the heatflow cannot be controlled;
2. to locate the greenhouse below the living areas to obtain a natural thermosiphon heating effect into the house;

3. to eliminate all mechanical equipment, as the costs are too high to make it an economical proposition;
4. to install the shutters on horizontal sliding rails, rather than in a vertical position.

(G) Summary

This house represents a lived-in sunspace system. It is an ideal concept of exposing a significant amount of glazing to the sun and at the same time control heat losses and gains by operating the shutters into the necessary position. The concept of heat storage works well in this example, as the house in winter stays comfortable for about 3 days without sunshine.

As the thermal performance of the house depends on the proper functioning of the moveable shutters, special maintenance care must be taken to counteract mechanical breakdowns.

The capital cost for the shutters and mechanical equipment is significant in this house and makes the solar heating features hardly an economic proposition at the present time. This house represents an innovative solar heating concept and is most pleasant to be in, as most of the living areas can be exposed to the sun.

Photograph 4.8.2 Pickup House, Launceston

Photograph 4.8.3. Pickup House, Launceston
View to the greenhouse and internal
heat storage stone wall.

4.9 FIELD HOUSE

4.9.1 Technical Description

Location: Merseylea, near Railton, Tasmania
Latitude: 41° 15' S
Date completed: May 1983
Architect: A.G. Walsh
Builder: Des Saunders, Devonport
Owners: Ted and Mary Field
Size: 195 m^2
Cost: \$90 000 (\$461/m^2)
Climate: Cool temperate
Heating Degree Days (base 18°C): 2464
January average temperatur: 17.5°C
July average temperature: 6.3°C

Photograph 4.9.1 Field House, Merseylea.
View to the northern elevation.

(A) Objective

As the owners lived in a cold, uninsulated weatherboard house, they wanted a warm, sunny, comfortable house which would use as little auxiliary heating as possible. Also, the use of low maintenance materials was one of the original objectives.

(B) Site

The site consists of approximately 9 ha of gentle north-east sloping pasture land. Prevailing winds are from the north-east to the north-west.

(C) Construction

This single storey, four-bedroom house uses three different construction techniques for the exterior walls.

The south and east walls consist of 250 mm concrete, the north wall of brick cavity and the west wall of timber stud frame construction. The internal walls are timber framed with the exception of the heat storage brick wall, which separates the service/bedroom area from the living/kitchen area. The timber framed roof is clad with beige colorbond Spandek Zincalume sheeting. The ceilings are lined with Tasmanian oak. Windows and door frames are made of aluminium.

The southern and eastern walls will be earth bermed in future years to reduce heatloss in winter and to integrate the house more within the landscape.

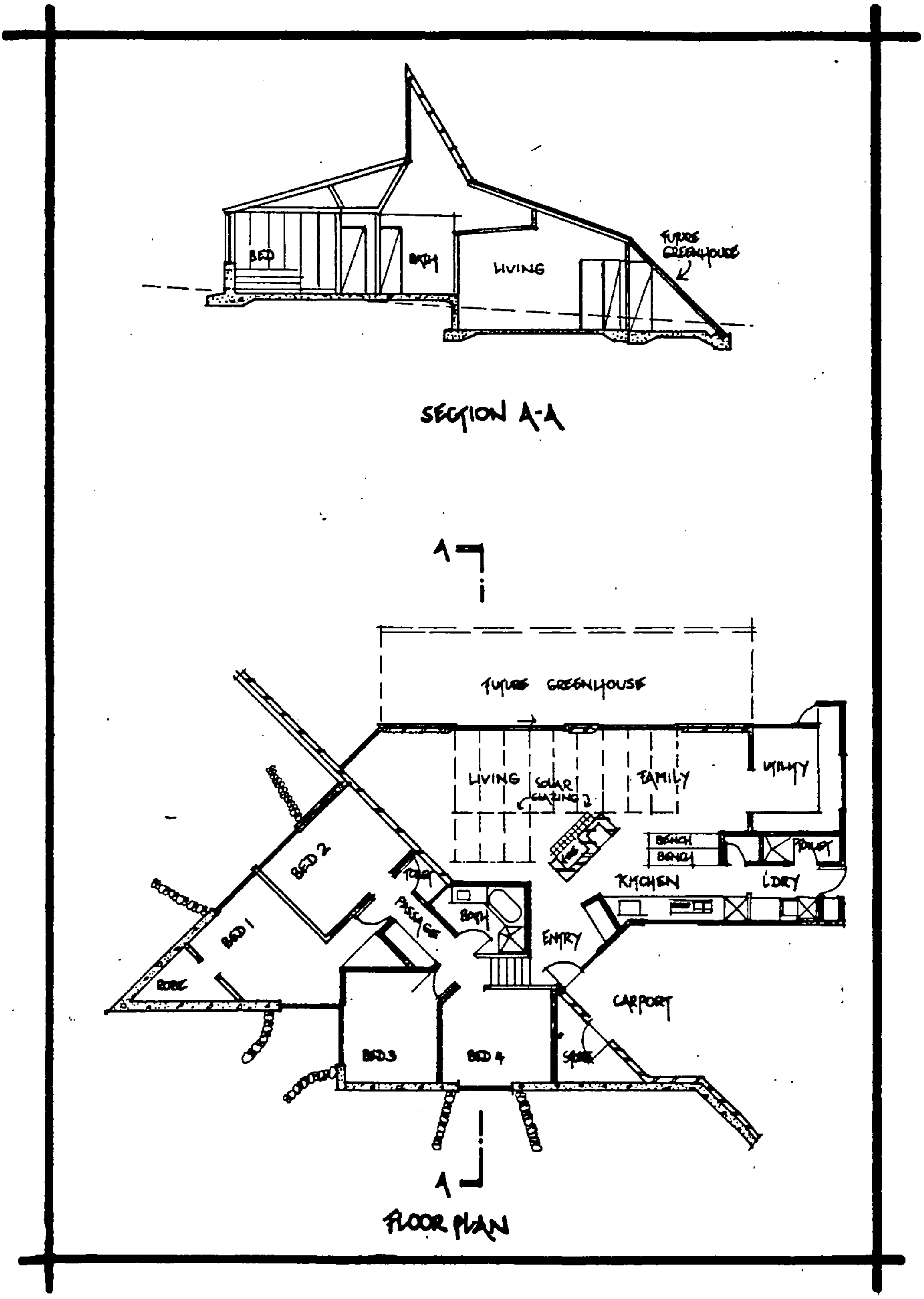


Figure: 4.9.1 Field House, Merseylea. Floor plan and section drawing. Source: A.G.Walsh

(D) Solar Heating Systems

Passive solar heating is provided by the Direct Gain System. Heating is provided through 18 m^2 of vertical north-facing windows and 21 m^2 of north facing skylights, totalling a Direct Gain collection area of 39 m^2 which represents 20% of the floor area. The dominating feature of the solar heating system is two horizontal sliding insulating screens to reduce the heatloss in winter and heat gains in summer.

The 80 mm thick insulation screens consist of a core of polystyrene with colorbond steel surfaces and aluminium channel edges and wheels.

Heat storage is provided by the internal dark brown coloured brick wall, and the concrete floor in areas where it is not covered by carpets.

Auxiliary heating is provided by an open fireplace and a small pot belly wood stove. In 1983, 5 tonnes of firewood have been used, which cost \$140 (\$0.72/m^2).

Summer cooling is achieved by a 750 mm wide overhang at the northern side and by a south facing dormer like roof window. On hot summer days the warm air in the living areas can be discharged through this window to the south side of the ridge. The insulating screens, covering the north facing skylights, are closed during hot days and opened at night for cooling effect.

Hot water is supplied by 6 m^2 Rheem Solar Collectors. The 240 litre storage tank is located below the collectors and a small water pump is required for the circulation of water through the collectors.

(E) Insulation and Sealing

The house is insulated as follows: double sided reflective foil and 75 mm polystyrene insulation to the external timber stud walls and roof; and 50 mm polystyrene slab-edge insulation. All windows and glass doors are provided with cotton curtains and pelmets. The skylights in the living and family rooms are insulated by two horizontal sliding screens. The 80 mm panels consist of polystyrene with colorbond steel surfaces and are manually operated.

(F) Thermal Performance

The house was designed by rule-of-thumb methods to maintain year round comfort levels. It has not been monitored, although manual readings from several thermometers have been taken from time to time. The minimum recorded internal temperature was 11°C, when the minimum external temperature was -2°C. On sunny winter days, the air temperature in the house generally remains considerably higher than the external air temperature. A spot check by the author on a reasonably sunny winter day (July 1984) revealed that, with an external air temperature of 7°C, the internal air temperature was a comfortable 19°C.

(G) Cost of the Solar Systems

The 6 mm skylight glazing and framing cost $2654, the insulating screens, made to special order, cost $2865, totalling $5519, which is 6% of the building cost.

4.9.2. Owner Experience

(A) Primary reasons for including passive solar heating features

The owners are planning to become, as far as possible, independent of commercial power supplies, to counter future energy crises, and aim to establish a self-sufficient life-style with regard to both food production and power generation.

(C) Building experience

No problems were experienced regarding the passive solar features.

(D) Experienced thermal comfort in the building

As the house has still not been sealed well, it is not performing to the full potential. With the addition of the greenhouse at the northern side of the house, the owners expect that the building's thermal performance will significantly improve.

Already, in the present stage, the owners are very satisfied with the thermal comfort in their house and also feel that their health has greatly improved since living in this house.

(E) Problems related to the solar heating system

The southern dormer window uses a louvre window system and does not seal well, and also rattles in windy conditions.

There has been some leakage at the skylights, which has been rectified by re-sealing a horizontal glass seam with silicone.

(F) Future changes to design and building techniques should the owner build again

The owner would request the following two changes:

(1) to construct the south side of the house underground, however leaving the north side open for the reception of light, solar energy and the view;

(2) to locate at least one bedroom at the northern side of the house for solar heating purposes.

(G) Summary

The skylight area of 21 m^2 above the living and family rooms allows for light, sunny areas and for a significant collection of solar energy. The insulating screens, which can be manually operated, effectively control the heat flow out of and into the building, depending on the season of the year.

The cost of the insulating screens, however, could be reduced by using a different cladding material.

The addition of the greenhouse would increase the thermal performance of the house and should be added as soon as possible. At the present stage, the northern brick cavity wall is uninsulated and imposes a great source of heat loss in winter.

This house, when finally completed, will demonstrate that passive solar heating in Tasmania can reduce auxiliary heating to a minimum and at the same time, significantly improve the thermal comfort in the home.

Photograph 4.9.2. Field House, showing the living area. The skylights are in open position.

Photograph 4.9.3. Field House, showing the southern concrete wall, which will be earth bermed in future years.

4.10 COTTON HOUSE

4.10.1 Technical Description

Location: Kingston, near Hobart

Latitude: 42°56' S

Date completed: November 1983

Architect: David Button

Owner: Geoff and Jane Cotton

Size: 145 m^2

Cost: \$54 000 (\$372/m^2)

Climate: Temperate

Heating Degree Days (base 18°C): 2300

January average temperature: 16.9°C

July average temperature: 8.2°C

Photograph 4.10.1 Cotton House, Kingston
View to the northern elevation

(A) Objective

The house was designed to create a light, warm comfortable and sunny environment and at the same time, use low maintenance building materials.

(B) Site

The site consists of 1 acre of unobstructed north facing hill in an outer suburban area, with the dominant winter winds experienced from north-west.

(C) Construction

The single storey, three bedroom house uses brick-veneer external walls, with the exception of the western wall, which consists of a 270 mm brick cavity wall. The internal walls are timber framed and lined with plaster board with the exception of a single concrete block wall in the family room. The floor is a 100 mm concrete slab, finished with light grey tiles in the living and family rooms and in the kitchen.

Door and window frames are made from Western red cedar and are single glazed. The roof is timber framed and clad with klip-lock zincalume sheeting. The house is divided into two zones, the living, family and kitchen area to the north and the service and sleeping areas to the east and south side of the house.

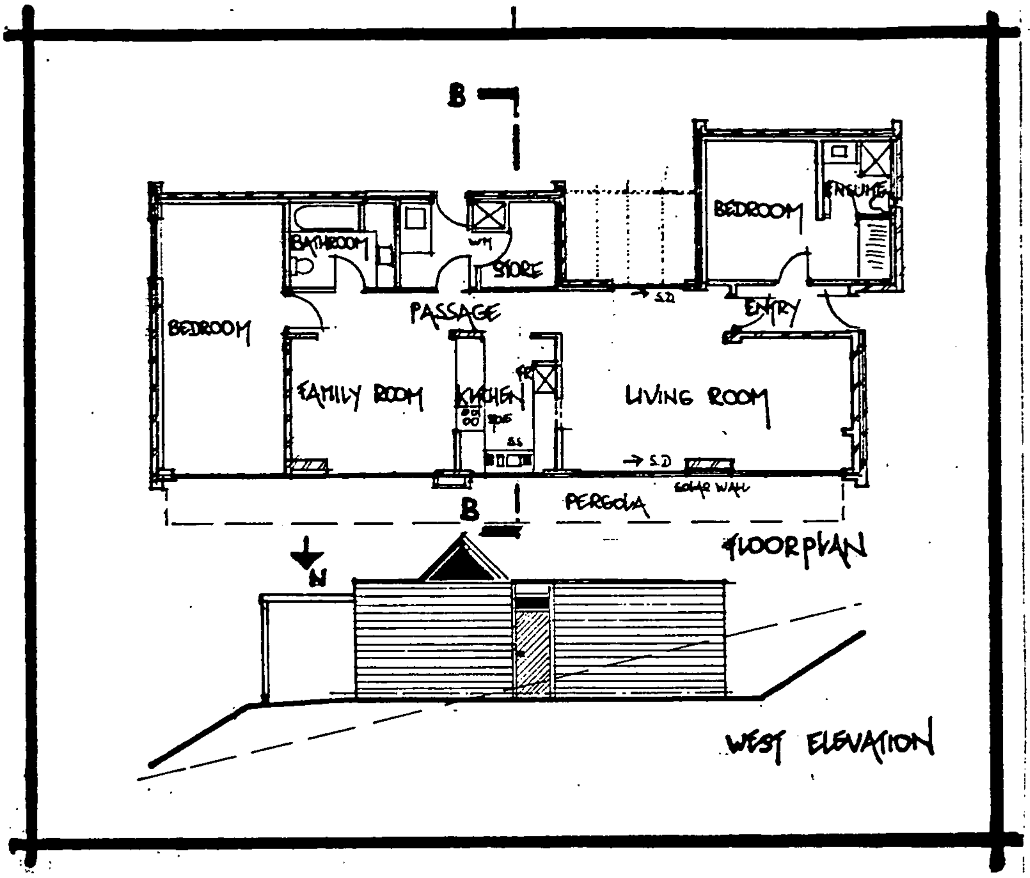


Figure 4.10.1 Floor plan and western elevation Cotton House, Kingston. Source: David Button

(D) Solar Heating Systems

The house is heated predominantly by the Direct Gain System and to a smaller extent by two Trombe-Michel walls.

The Direct Gain System includes 16.4 m^2 of north facing windows, representing 11% of the floor area of the house. The Trombe-Michel walls with a collection area of 4 m^2 represent about 2% of the floor area of the house. Each consists of a 230 mm thick brick wall painted black on the exterior surface. The solar wall glazing is supported by Western red cedar windows, 200 mm from the solar wall. The upper section of the windows can be opened to maintain the solar wall surface and for summer ventilation. Day time heating of the Trombe-Michel wall is distributed via four sets of top and bottom vents, with an individual size of 230 x 86 mm.

Heat storage is provided by the Trombe Michel walls (1.08 m^3), the internal brick walls and the tiled concrete floor.

Auxiliary heating is provided by an electric off-peak underfloor heating system in the living and family rooms and by a slow combustion wood heater in the living room. The cost for the underfloor heating between May and October 1984 was $100. The wood heater used 2 tonnes of firewood in 1984, costing $64. The total auxiliary cost in 1984 was $164 amounting to $1.13/$m^2$.

Summer cooling is provided by a pergola system at the north side of the house, which includes the shading battens over the kitchen.

(E) Insulation and Sealing

The roof and walls are insulated with double sided reflective foil and R2 fibreglass batts. The concrete slab is provided with 50 mm polystyrene edge insulation. Windows and glass doors will be lined with curtains of closely woven material with pelmets to all windows. The entry uses an air lock system with sealed thresholds to the entrance doors.

(F) Thermal Performance

In the winter months, after a reasonably sunny day, the house does not need any auxiliary heating until about 9pm. The back up under floor heating is set on 17°C, and in the winter quarter 1984 used 3900 kWh, costing about $100 (off peak tariff 61). The house is not monitored.

(G) Cost of the Solar System

The cost of the additional materials for the passive solar heating features is not known to the owners, as the main objective to achieve a warm, comfortable house eliminated the need for financial justification for the solar features.

4.10.2 Owner Experience

(A) Primary reasons for including passive solar heating features

The owners used to live in an old uninsulated brick house which consumed a considerable amount of energy for space heating. For their new home, one of the objectives was to use as little electricity for space heating as possible, and at the same time, stay comfortable.

(B) Council approval

The plans were approved within 2 weeks by the local council.

(C) Building experience

The builders had no problems at any building stage.

(D) Experienced thermal comfort in the building

The owners have experienced only one winter in their new home, and are extremely satisfied with the thermal comfort of the house. Often visitors remark how warm the house is, and are surprised when they find out that the house is mainly solar heated. The underfloor heating is used only in winter after about two days of successive cloud cover and external temperatures below 8°C.

The house did not overheat in summer 83/84.

(E) Problems related to the solar heating systems

The owners reported no problems.

(F) Future changes to design and building techniques should the owner build again

The owners are very satisfied with the house and indicate no future changes.

(G) Summary

This house demonstrates a very suitable internal layout for a passive solar house, with the living and dining areas to the north, and the service and bedroom areas to the south. With the installation of a slow combustion wood heater in the living room, the electric floor heating is now only used occasionally during cold winter nights, when the interior air temperature drops below 13°C. The capital cost of this solar house of \$54 000 (\$372/m^2) is similar to the price range of conventional brick veneer houses and demonstrates that passive solar houses can be financially viable propositions.

Photograph 4.10.2 Cotton House, Kingston. This Trombe-Michel wall uses an ordinary timber window system for the solar glazing.

Photograph 4.10.3. Cotton House, Kingston.
View to the living room with the internal solar wall and the wood heater on the left side.

Photograph 4.10.4. Cotton House, Kingston

4.11 BAYLEY- STARK HOUSE

4.11.1 Technical Description

Location:	Blackmans Bay, near Hobart
Latitude:	42°56' S
Date completed:	November 1981
Architect:	David Button
Builder:	Bill Cooper
Owner:	Jamie and Sue Bayley-Stark
Size:	155 m^2
Cost:	\$59 000 (\$381/m^2)
Climate:	Temperate
Heating Degree Days (base 18°C):	2280
January average temperature:	17.2°C
July average temperature:	7.5°C

Photograph 4.11.1 Bayley-Stark House, Blackmans Bay, view to the northern elevation

(A) Objective

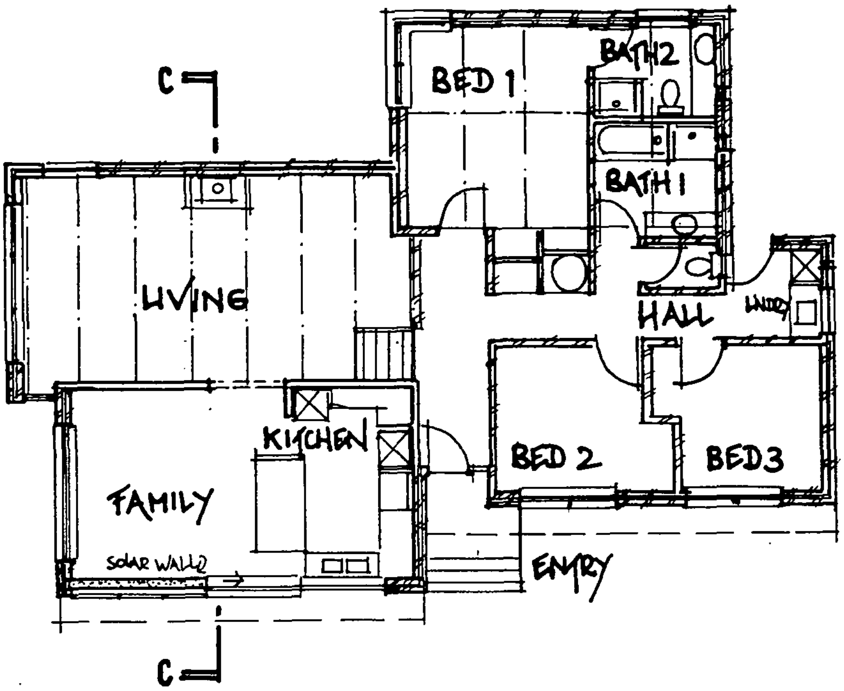
The owner's initial aim was to create a warm, comfortable, light house with big open living areas at the same time using the magnificent river views to the best advantage.

(B) Site

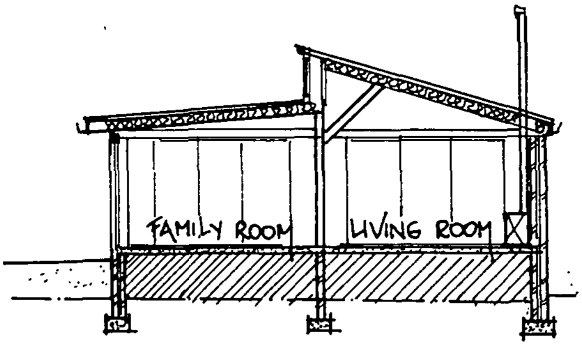
The site consists of 6 acres with the view to the river Derwent. The land slopes to the east and north and is very exposed to the north-western winter winds. There are no obstructions to the northern reception of solar radiation.

(C) Construction

The single storey, split level three bedroom house uses 280 mm wide external cavity brick walls. Internally there are single brick walls in the bathroom and bedrooms, and timber framed walls in the living room and kitchen. The floor is a 125 mm suspended concrete slab. The roof is timber framed and covered with klip-lock zincalume sheeting. The ceiling in the living room features exposed timber rafters. Windows and door frames are made of anodized aluminium and are single glazed. The house is oriented to the north and divided into two major zones. The family, living and kitchen areas are situated on the lower eastern section and the bedrooms and bathrooms on the upper level on the western side of the house.



FLOORPLAN



SECTION C-C

Figure 4.11.1 Bayley-Stark House
Floor plan and section drawing
Source: David Button

(D) Solar Heating Systems

This house uses the Direct Gain System and the Trombe-Michel wall for heating purposes. The Direct Gain System represents 13.26 m^2 of north facing windows and 8.22 m^2 of clerestory windows, amounting to a total area of 16.98 m^2, which is 11% of the floor area of the house. All the windows, including the clerestory windows, are single glazed. The Trombe-Michel wall, with a collection area of 5.5 m^2 (3.5% of the floor area) consists of a 300 mm thick concrete-filled concrete block wall, painted dark brown on the exterior surface. The solar glazing is housed by an aluminium framing system, 100 mm away from the concrete block wall. Air is distributed via two 400 x 200 mm bottom vents and a continuous fixed-top vent above the Trombe-Michel wall. In summer, heated air in the cavity of the glass and the storage wall surface can be vented to the exterior by a 15 mm horizontal vent, situated on top of the glazing.

Heat storage is provided by the Trombe-Michel wall in the family area, the concrete floor and by the interior brick walls.

Auxiliary heating: A slow combustion wood heater is located in the living room. During 1983, four tonnes of firewood were used, costing the owners \$128 (\$0.82/m^2).

Summer cooling is achieved by the 500 mm wide overhang at the north side of the house and the summer vent in the Trombe-Michel wall's solar glazing.

(E) Insulation and Sealing

The external walls are insulated with urea-formaldehyde foam, the ceiling with double sided reflective foil and with R.2 fibreglass batts. All the windows are covered with heavy curtains and pelmets.

(F) Thermal Performance

The house was designed to meet basic year-round comfort requirements. The owner reported that, after a sunny winter day, there is usually no auxiliary heating required for the following two days. The house occasionally overheats on sunny days in February and March, due to the clerestory windows. The house is not monitored.

(G) Cost of the Solar System

The additional cost of the Trombe-Michel wall over a conventional brick veneer wall was approximately $750. The owners pointed out that they selected a concrete floor for the heat storage feature. As this floor construction consists of a suspended concrete slab, the cost was significantly higher than if they had selected a timber floor construction.

4.11.2 Owner Experience

(A) Primary reasons for including passive solar heating features

As the owners wanted to improve their health, they included the passive solar heating system to achieve a light, warm and especially dry environment inside their structure. The owners are also concerned with environmental issues and they feel that by harnessing solar energy, natural resources can be conserved.

(B) Council approval

The council initially rejected the use of urea-formaldehyde foam insulation in the brick cavities. However, after some discussion with the building inspectors, the council approved the building.

(C) Building experience

The builders constructed a fixed summer vent for the Trombe-Michel solar glazing, although the architectural plans showed an adjustable vent, which could be opened in summer and closed in winter. The owners now close the vent in winter with the help of a mastic tape.

(D) Experienced thermal comfort in the house

The owners are very satisfied with the thermal comfort and indicate that the house is always warm in winter. As the house stays very dry in winter, the health of all the family members has markedly improved, since they moved into the solar house.

(E) Problems related to the solar heating systems

There was some water penetration through the southern brick cavity wall, due to gaps within the urea-formaldehyde foam insulation. This problem has been alleviated by painting the exterior south wall with silicon paint.

Also the owners feel that the house overheats occasionally in late summer, due to the clerestory windows. This problem will be countered by installing internal shutters to the clerestory windows in the near future.

(F) Future changes to design and building techniques should the owner build again

The following changes were indicated by the owners:

1. not to use urea formaldehyde foam in brick wall cavities;
2. to increase the width of the northern overhang (from 500 mm to about 650 mm);
3. to design and install double glazed clerestory windows with an overhang.

(G) Summary

This house is a good example of a well designed and good working passive solar house. A few factors should however be pointed out.

The clerestory windows provide some overheating problems in late summer, and some shutter device is needed to rectify this problem.

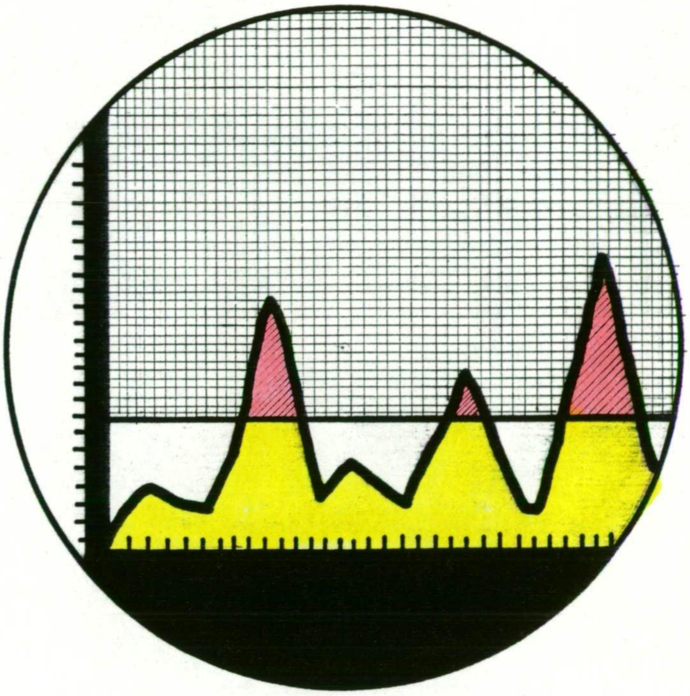
The single glazed clerestory windows are a source of high heat loss and should have been double glazed or provided with night insulation.

The owners regret having used urea formaldehyde foam for the brick cavity insulation which caused some water penetration through the southern wall. Instead of using urea formaldehyde, the owners should have used polystyrene panels fixed to the inside surface of the cavity, while still leaving an air gap to the external surface of the brick wall.

In this case, the owners selected the passive solar heating features partly for health reasons, a factor which also has been recognized by other solar house owners. Since living in the solar house, the health of the occupants has markedly improved, especially in the winter months.

Photograph 4.11.2 Bayley-Stark House, Blackmans Bay. View to the Trombe-Michel Wall.

CHAPTER 5



THE FEASIBILITY OF PASSIVE SOLAR BUILDINGS IN TASMANIA

5.1 INTRODUCTION

This chapter provides an evaluation of the ten solar buildings, highlighting the use of different solar systems, their thermal performance and the various problems encountered by building and living in passive solar buildings.

While chapter 4 provided the basic data for these buildings, this chapter aims to assess the effectiveness of the buildings by analysing their heating systems, comparing collector sizes and costs, emphasizing building experiences and outlining various suggestions to improve their thermal performance.

In providing this evaluation, the same use was made of the headings as applied in the solar building survey, in chapter 4.

Finally this chapter concludes by providing a short summary of the effectiveness of the solar buildings and looking at various aspects of financing the Passive Solar Heating Systems.

5.2 EVALUATION OF THE SOLAR BUILDINGS

(A) Objective

Most of the owners specified a warm, sunny and comfortable building as one of their main objectives. On two occasions increased standard of health was given as one of the objectives. Other specified requirements were energy conservation (and, hence, economic savings), demonstration of the effectiveness of various solar systems, and the desire to live by environmental principles.

As the majority of Tasmania's buildings are not insulated[1], it is not surprising that most of the owners featured in this survey wanted first to increase the standard of thermal comfort before actually concentrating on lowering heating costs.

One of the objectives of the Button and Fergusson houses was to demonstrate the feasibility of passive solar buildings in Tasmania and, since completion, these houses have been featured in many magazines and newspaper reports, and they have been visited by many prospective solar home owners.

At the Christian School, the main objective to provide an actual-life learning opportunity has been achieved, with the students using and experiencing passive solar buildings in their daily school environment.

Two owners specified improved health as one of their objectives, a factor most important to human living conditions, but initially realized by only two owners. Givoni, in his book Man, Climate and Architecture[2], points out that, due to internal thermal storage and higher mean radiant temperatures of surroundings, the temperature fluctuation in solar buildings is significantly lower, resulting in healthier living conditions.

(B) Site

Most building sites take advantage of an unobstructed exposure to the sun, with the exception of the Mitchell, Fergusson and Collins houses. These building sites experience some obstruction during the winter months, mainly by nearby hills or trees. The owners of these houses, initially were fully aware of the diminished sun-reception, which amounts to approximately one hour per day during the winter months, May to August. This loss of solar radiation in the winter months will, to some degree, diminish the efficiency of these solar systems, but, in all cases, the buildings were exposed to direct solar radiation between 10am and 3 pm. Many owners reported that finding the suitable building site for the purpose of constructing a solar building was the most difficult task, especially in the area of Hobart. Here, many building sites are south-facing and face obstruction to the northern side by nearby houses, fences, or trees. In many cases, the conflict of a superb southern view and the northern reception of solar radiation made design decisions for many owners difficult, often resulting in larger southern glazing areas than recommended for solar buildings.

As there still exists no legal guarantee for solar access in Tasmania, and new subdivision of land is still undertaken without any recognition for solar orientation and shading effects of buildings and trees, the selection of suitable building sites for future solar buildings will remain difficult.

The householder wishing to use solar energy systems in Tasmania can take little comfort from the existing building regulations or various planning schemes under the Town and Country Planning Act. The building regulations restrict the height of buildings and make requirements regarding the light and ventilation of rooms, but take no account of whether one building shades another. Planning Schemes establish zones for various purposes such as housing and business, they regulate the proportion of open space, the distance buildings must be set back from boundaries, and even the maximum height of fences, but are not concerned whether sunlight actually reaches individual buildings.

One solution to this problem presented by Reitze[3] is that an appropriate government agency guarantees, on application by the individual, that current and foreseeable town planning schemes will not cause the owner of solar systems to suffer financial loss by shading the collector areas. The holder of a guarantee-certificate would be entitled to at least seven hours of solar access per day, three and a half hours either side of solar noon. If a neighbour interferes with this access, the interference must be removed, or the interfering neighbour must pay a reasonable amount of compensation.

Since 1978, New Mexico (U.S.A.) has possessed a law providing that appropriation of sunlight for the use of a solar energy system entitles the user to continue to receive the same amount of sunlight.

Different micro-climates can have a significant influence on the thermal comfort range in buildings. For example, buildings located at higher altitudes are subject to excessive winds and lower average air temperatures. The Button house, situated at Mt. Nelson (260 m above sea-level) near Hobart, experiences, on the average, a 2°C lower temperature than the remaining surveyed solar buildings and often is exposed to high winds resulting in a higher auxiliary heating cost than the average surveyed solar buildings.

The Christian School is subject to fog in the winter months, a factor which can severely affect the thermal performance of a solar building. However, as fog occurs only occasionally at the Christian School, the thermal performance of the school building is only slightly affected.

A detailed site assessment is necessary before commencing the design of a solar building, to ensure that the property is suited for this purpose to take the best advantage of the local climate.

At the present time, some building designers[4] in Tasmania, specializing in the aspect of solar buildings, will provide clients with a full assessment of their properties to ensure a successful thermal performance of their future solar building.

(C) Construction

Traditional building materials and building techniques are commonly used throughout the solar buildings with the exception of the Collins house and the Pickup house. At the Collins house, the south side is constructed of an insulated reverse concrete block veneer wall, placing the concrete blocks to the inside of the house. The concrete blocks, acting as thermal mass, are heated by the sunlight through the clerestory windows.

The Pickup house uses an A-frame construction technique with a significant glazed area oriented to the north. The motorized shutters can be automatically closed and opened depending on the selected heating system.

Night shutters will increase the thermal efficiency of buildings and should be more commonly used to insulate large glazed areas.

Floor Structure

All buildings, with the exception of the Fergusson house, use a concrete slab for the floor structure. An insulated concrete slab on ground is essential for optimal thermal performance in buildings.[5] The slab on ground is in contact with the earth temperature which will remain around 17°C ± 2°C at a depth of 2.5 metres in any climate in Tasmania[6]. The ground underneath the concrete slab will act as additional thermal storage, providing the concrete slab is insulated at the edges.

The second consideration to optimize the heat storage capacity of a concrete slab is to increase its thickness from 100 to 200 mm in the areas receiving direct sunlight.[7] This method has not been used in any of the surveyed solar buildings. In an average family house of approximately 140 m^2, this would require an extra 3 to 4 cubic metres of concrete in the slab.

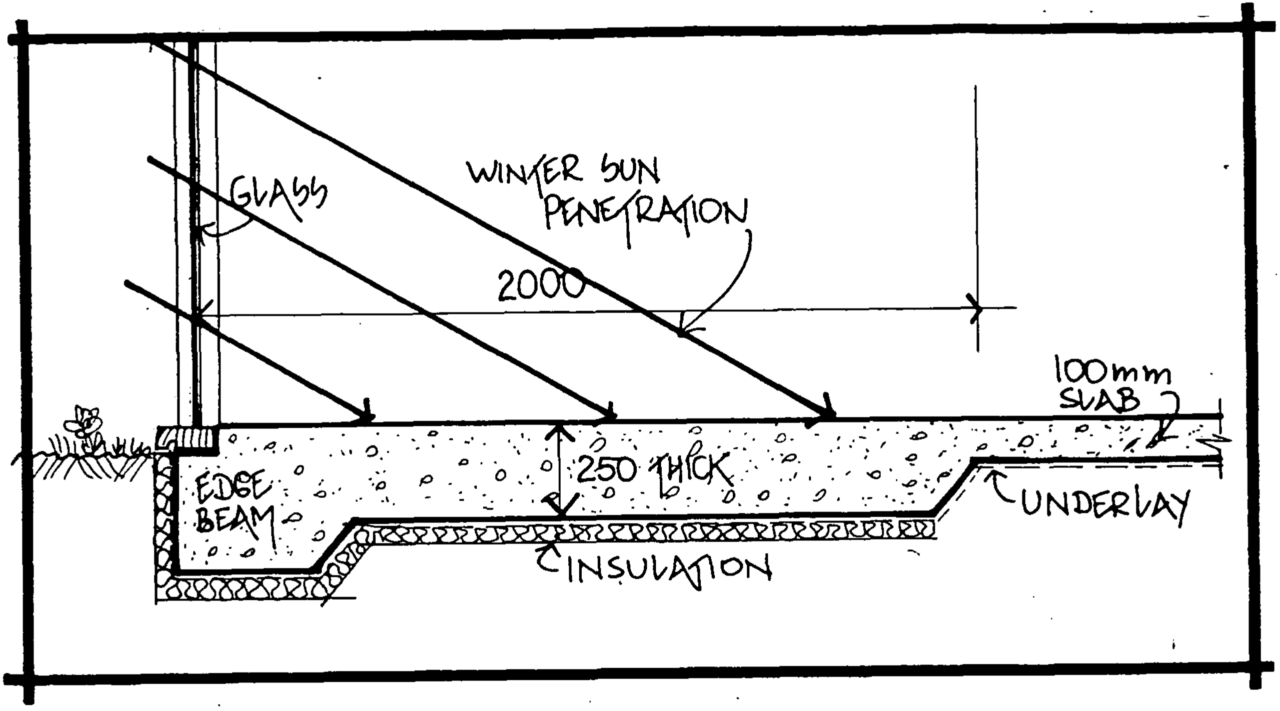


Figure 5.1 Slab edge thickening recommended at the northern side of the building, in areas receiving direct sunlight. Source: Granger, M., 1981. The Exploitation of the Masses, or the Poor Man's Guide to Solid Solar Housing; Promotion of low cost solar housing in temperate climates, 3rd Seminar, University of New South Wales, Duntroon.

The addition of cost for the concrete thickening along the north side of the building, including the insulation, would amount to approximately $400 to $450 over the cost of a normal 100 mm thick concrete slab. However, on flat building sites, a concrete slab on ground is about $800 to $1000 less than a conventional timber framed floor, making even the thickened concrete slab an economical choice.

Wall Structure

All of the Trombe-Michel Walls, with the exception of the Trombe Michel Wall at the Christian School, are constructed of hollow concrete blocks, filled with liquid mortar. At the present time, this is the most economical method of building solid thermal storage walls in both 200 mm and 300 mm thickness. It is interesting to note that none of the surveyed solar buildings uses water for heat storage purposes, except the Christian School, where eight 200 litre drums are stored in the greenhouse. The lack of water storage walls in the solar buildings is due to the difficult task of manufacturing long-lasting, non-corrosible and well-sealed water containers. In addition, using water containers for the purpose of heat storage walls still requires additional structural components, whereas, for masonry thermal storage walls, the heat storage capacity and structural requirements are covered in one process, making it the more economical construction method.

Glazing

At the Christian School, the Trombe-Michel wall employs a double glazed aluminium framing system and represents the only double glazed Trombe-Michel Wall in this survey. Selecting double glazing for a Trombe-Michel Wall, significantly increases the efficiency of the solar wall. However, due to the cost increase for double glazing, none of the remaining buildings used double glazing for the Trombe-Michel Wall.

At the Collins and Cotton houses, Western red cedar single glazed windows are used for the purpose of solar glazing, achieving a balanced appearance of the northern glazing system, and, at the same time, improving the appearance of the Trombe-Michel Wall. Also, using normal Western red cedar windows for the purpose of solar glazing ensures they easily can be opened for summer ventilation and maintenance to the solar wall.

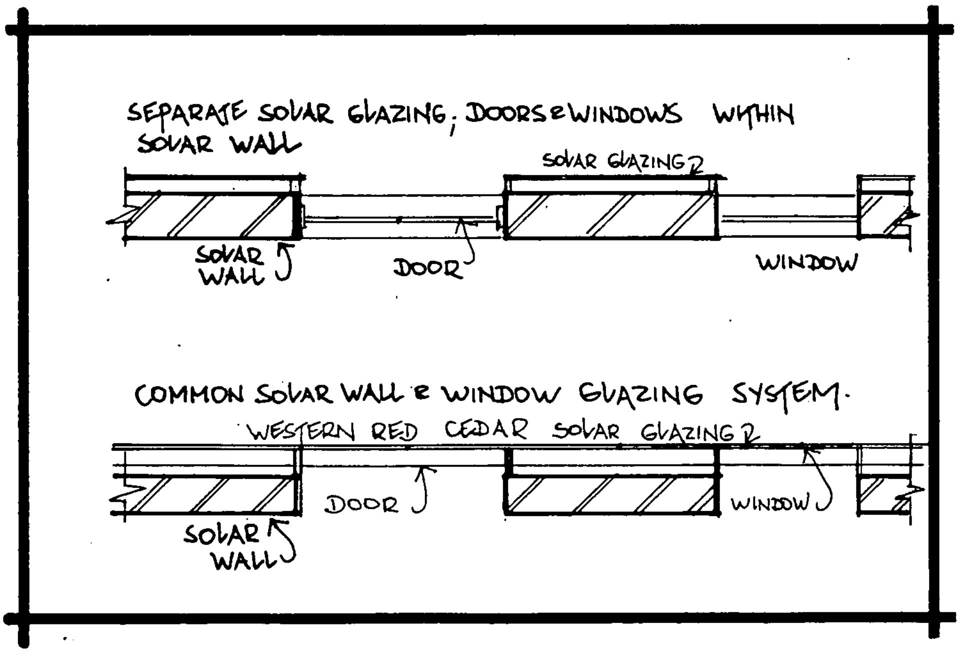


Figure 5.2. Two different solar wall glazing systems used by the surveyed solar buildings.

(D) Solar Heating Systems

The most common and popular solar heating system, the Direct Gain System, is used to some extent by all surveyed buildings. At the present, only the Field house uses the Direct Gain System as the sole heating system, while the remaining buildings use more than one system for their space heating.

Figure 5.3 shows the combinations of the different passive solar systems used by the ten solar buildings, which are identified by the names of their owners.

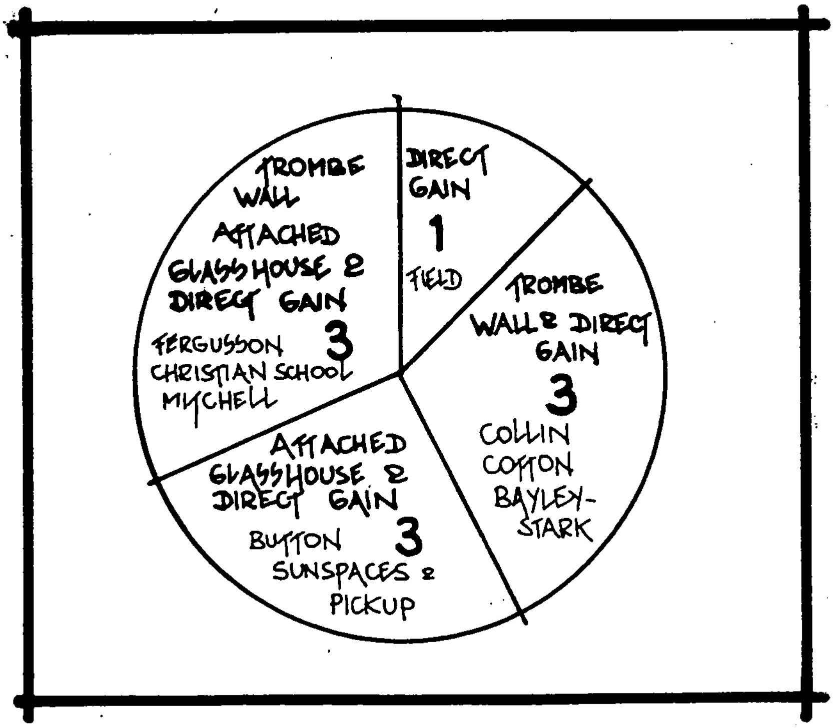


Figure 5.3. Passive Solar Systems used in the ten surveyed solar buildings in Tasmania.

Three buildings use the combination of Trombe Wall and Direct Gain, three buildings use the combination of Attached Glasshouse and Direct Gain and the remaining three buildings use the combination of Trombe Wall, Attached Glasshouse and Direct Gain.

The collector to floor area ratio indicates the size of the solar heating system in relation to the size of the building, and, in this survey, ranges between 0.13 and 0.32 as can be seen in Table 5.1.

The Christian School uses the greatest collector to floor area ratio of 0.32 and does not rely on any heating system other than solar. The Cotton house, with the smallest collector to floor area ratio of 0.13, uses both an electric underfloor heating system and a slow combustion wood heater for back up heating.

In general, it can be argued that many of the solar buildings (with the exception of the Christian School, Fergusson and Collins houses) incorporated the solar heating system according to the most convenient architectural layout; and it appears, looking at the collector to floor area ratio, that in these buildings, the solar heating systems are somewhat undersized.

Building & Floor Area in m^2	Passive Solar Systems & Size in m^2	Collector to Floor Area Ratio	
Fergusson 160	Direct 24	0.15)	0.26
	Trombe 18	0.11)	
Collins 122	Direct 12	0.10)	0.20
	Trombe 12	0.10)	
Christian School 70	Direct 7.5	0.11)	0.32
	Trombe 14.5	0.21)	
Sunspace Project 124	Direct 6.5	0.05)	0.17
	Greenhouse 14.8	0.12)	
Mitchell 260	Direct 27.3	0.10)	0.13
	Trombe 7.56	0.03)	
Pickup 450	Direct 50	0.11)	0.14
	Storage Wall 14.3	0.03)	
Field 195	Direct 39	0.20	
Cottom 145	Direct 16.4	0.11)	0.13
	Trombe 4	0.02)	
Button 140	Direct 26	0.19	
Bayley Stark 155	Direct 16.98	0.11)	0.145
	Trombe 5.5	0.035)	

Table 5.1 Size of solar heating systems and collector to floor area ratio for 10 passive solar buildings in Tasmania.

However, up to the present time, it is usually the general trend not to design self-sufficient solar buildings, but to incorporate the solar heating systems where they conveniently integrate with the architectural layout, and use them in conjunction with the conventional heating system.

This trend may change in future years as the public will become more and more familiar with these buildings and observe how well they actually work.

At the Christian School, the Fergusson house, and the Collins house, the passive solar systems were actually calculated in respect to the floorspace and volume of air, resulting in a satisfactory thermal performance.

In most cases, the external appearance of the passive solar heating systems is not distinguishable from an average building, and generally, the public is not aware of these passive solar features. Only the owners of the Pickup house experienced some major problems with the public acceptance of their home. This was due to the somewhat unusual appearance of the house and mostly to the extremely high market value, rather than to the nature of their solar heating system.

In most cases, the solar heating systems are constructed of quality materials, the solar system's glazing components are well sealed, and the houses require little maintenance.

However, the Trombe-Michel Wall glazing and the attached glasshouse at the Fergusson house use a galvanised steel framing system which only possesses poor sealing properties, and is not suitable for solar glazing, where a well-sealed glazing unit is necessary for an efficient functioning of the heating system.

At the Button house, an attached glasshouse employs a similar galvanised glazing system. Due to the inadequate sealing properties of these glazing bars, this glasshouse only to a small degree contributes to the solar heat gain in the house, and is only seen by the owner as a buffer zone to the outside. By using a well-sealed glazing system this glasshouse could significantly contribute towards the heat requirements of this house.

In some cases, the contribution of the solar systems has not been completed, a factor which strongly affects the thermal performance of the Button, Field, and Mitchell houses. At the Field and Mitchell houses, constructing an attached glasshouse to an existing brick storage-wall will significantly increase the solar heat gain in these houses and should be completed in the near future. At the Button house the angle of the roof was constructed to incorporate 12 m^2 of solar air collectors, however, the owners intend not to install these collectors within the near future due to financial constraints, leaving the passive solar system in that house undersized.

Auxiliary heating

The most popular form of auxiliary heating system is the slow combustion wood heater, which has been installed in five of the buildings surveyed, while the remaining buildings use open fire places, electric floor heating or small-sized electric radiator panel heaters as the additional heating source. Only the Christian School building does not use any form of additional heating. The annual heating cost in 1983 ranged from zero dollars at the Christian School to about $320 at the Pickup house.

Table 5.2 represents the correlation of the auxiliary heating cost with the collector to floor area ratio for each building, collected during 1983.

The average heating cost of the assessed buildings in 1983 was $147.70. As the average space heating consumption of a Tasmanian dwelling is estimated at 10 000 kWh[8] and hence, the annual electric heating cost in 1983 would have ranged between $225 and $500, depending on the tariff, the average heating cost of the solar buildings is considerably less than might be expected for the average Tasmanian dwelling.

The heating requirement will vary considerably, depending on the severity of the weather and the variety of psychological and physiological factors of particular owners. Some passive home owners have adapted their lifestyles slightly,

Building	Size m^2	Heating Cost \$ (1983)	Heating cost per m^2	Collector to floor area ratio
Christian School	70	0	0	0.32
Fergusson	160	96	0.60	0.26
Pickup	450	320	0.71	0.14
Field	195	140	0.72	0.20
Collins	122	96	0.78	0.20
Sunspace Project	124	100	0.81	0.17
Bayley Stark	155	128	0.82	0.145
Mitchell	260	250	1.12	0.13
Cotton	145	164	1.13	0.13
Button	140	180	1.28	0.19
Average	182	147	0.797	0.188

Table 5.2 Relation between annual heating cost and collector to floor area ratio for 10 passive solar buildings in Tasmania

preferring a jumper to an increased heating bill. However, this is an exception rather than a rule, with the majority of the owners emphasizing an increased thermal comfort rather than significant cost savings.

If the price of the annual auxiliary heating is correlated to the size of the floor area, the Fergusson house with \$0.60/m^2 and the Pickup house with \$0.71/m^2 represent the buildings with the lowest heating costs (except only the Christian School which used no auxiliary heating). The Cotton house with \$1.13/m^2 and the Button house with \$1.28/m^2 are the houses with the highest heating costs.

However, the internal temperature range at the Button and Cotton houses has been reported as relatively high, with an internal temperature in winter up to 24°C, while the range of temperature in the Pickup house is only between 17-19°C. The different internal temperature ranges make a cost comparison somewhat difficult. The remaining owners of the solar buildings are content with an internal temperature range of 18-20°C.

As can be seen from Table 5.2, there exists a general trend that the heating cost per square metre correlates with the collector to floor area ratio of the solar buildings. The buildings with a higher collector to floor area ratio show a lower heating cost per square metre than the buildings which employ a lower collector to floor area ratio. The only exception is the Pickup house which employs a relatively low collector to floor area ratio of 0.14. However, this house uses 50 m^2 of glazing oriented to most of the living areas, internal shutters and a significant volume of thermal mass resulting in a higher system efficiency than the remaining buildings. It also must be pointed out that the temperature range in this house is somewhat lower than in the remaining buildings.

Summer Cooling

The buildings are all equipped with a northern fixed overhang with a width between 450 and 800 mm. The overhang width of 800 mm has been reported as producing too much shading during the winter months at the Button house, while the overhang of 450 mm created some slight overheating problems at the Bayley-Stark house. Depending on the personal preference for sunlight penetration, an overhang width of 450 to 600 mm would be the most effective width for the northern side of a solar building with a height of 2.4 metres.

All the Trombe-Michel walls employ a summer vent to release the warm air from the cavity between the glass and the solar wall surface. It should be noted that, in most cases, these summer vents are not sufficiently sealed, and, in most cases, not even operated as the fixed overhang creates sufficient shading onto the Trombe-Michel wall in the summer months.

In Tasmania, with its temperate climate with average summer air temperature of 17°C, the problem of overheating solar buildings in that period is not a significant concern to the building designer. Fixed overhangs, shading cloths onto attached glasshouses, fresh air cross-ventilation and internal curtains can successfully be used to keep the building comfortable on the rare occasion of hot, long-lasting summer days in Tasmania.

(E) Insulation and Sealing

Insulation in ceiling spaces, roof, and walls is a standard item in all the solar buildings with the exception of the Fergusson house, where the brick cavity walls are not insulated. The insulation value varies between R1.5 (about 75 mm bulk insulation) and R2 (about 110 mm bulk insulation) in the walls and R2 and R2.5 (about 125 mm bulk insulation) in the ceilings. The Button and Bayley-Stark houses employ urea formaldehyde foam in their brick cavity, resulting in water penetration through the south wall at the Bayley-Stark house. This material is non-porous, but there are potential problems, particularly from poor quality control. When urea formaldehyde foam dries, it shrinks and can develop cracks, particularly around obstructions in the cavity such as pipes or electrical conduits. These cracks, or other gaps, can cause the cavity to be bridged, with consequent water penetration.

The Australian Uniform Building Regulations Co-ordinating Council maintains that, where a cavity is included to prevent the penetration of moisture, the cavity should remain, and should not be breached by a filling of any kind unless there is conclusive evidence that the purpose of the cavity will not be defeated. Corrosion of wall ties and fumes from the formaldehyde have also been observed where urea formaldehyde foam has been used overseas.

An alternative to urea formaldehyde foam is to install 25 mm polystyrene sheets to the cavity side of the internal brickwork while still maintaining the cavity. However, this can be a laborious task that requires the close co-operation of the bricklayer, and is only applicable to new construction.

The need for proper weather sealing has been neglected in some solar buildings (Field, Cotton, and Mitchell houses) and, in these houses, the heat loss rate is significantly higher than in the remaining solar buildings. In some cases, the effectiveness of the solar heating systems, is somewhat defeated by the building's large gaps under door frames and half-finished wall structures at the Mitchell and Field houses. However, the owners indicated that all these gaps and unfinished structures will be sealed in the near future.

The method of super insulating the buildings as applied to many buildings in the U.S.A. and Europe has not been adopted by any of the surveyed solar buildings. This is probably due to the relatively mild Tasmanian climate as compared to the climate conditions in the U.S.A. and Europe, where the super insulated buildings are most popular.

However, adding more than the recommended insulation value into the building shell of Tasmania's solar buildings, could provide the potential to virtually eliminate any supplementary heating and should be seriously considered by any prospective solar building owner.

(F) Thermal Performance

Five buildings have been monitored by a series of thermometers, while, in the remaining buildings, the assessment of thermal performance relies only on subjective impressions by the owners.

Of the five monitored buildings, the Fergusson and the Button houses have been monitored by the owners for a period of several years, while the remaining three buildings were only monitored by the owners for a period of several weeks, at the request of the author.

The Christian School in Launceston is the only building which is totally solar heated, as no auxiliary heating has been used since the completion of the school building in 1981. However, it can be argued that the internal heat generation, created by some 15 students and the teacher, is significantly higher than in a domestic situation and assisting the heating requirements in that school building. Even with the added internal generation of heat by the occupants, it is a great achievement to design a building in Tasmania, which requires no heating systems other than solar.

The remaining owners of the buildings are all satisfied with their buildings' thermal performance. At the Fergusson house, the internal winter temperature averages to be 8-10°C above the external temperature, with an average daily temperature of 11 to 15°C, provided there is no additional heating. The maximum measured temperature in summer showed an internal temperature range of 18-29°C, while exterior temperature fluctuated between 14-35°C in the same period.

The coldest interior temperature at the Button house has been recorded as 10°C during a cold winter period, while the external temperature dropped as low as 1°C. The maximum internal temperature reached 29°C, when the exterior recorded temperature was 32°C.

At the Christian School, the coldest interior temperature was recorded as 15°C when the minimum external temperature showed -3°C. The temperature in winter ranges between 15°C and 27°C, with a mean temperature of 19°C. The minimum temperature in the attached glasshouse was 10°C.

At the Collins house, the coldest recorded internal temperature was 11°C when the external temperature was 1°C. On sunny winter days, the house reaches an internal temperature of about 15°C, with an average external temperature of only 5°C.

The Mitchell house has only been monitored over a period of two weeks during a cold spell in September 1984. During that period the internal temperature range was 10 to 24°C while the external temperature ranged from 3 to 20°C.

There exists some difficulty in the exact technical thermal assessment of these solar buildings, and further research is needed to achieve this aim. The solar buildings have all been monitored by different equipment, at different times, at different room locations and heights, by different owners and hence, a great variation of test results can be expected. However, sophisticated temperature monitoring equipment is expensive and unless a government body undertakes co-ordinated research, and is also responsible for the financial requirements, most of the owners will continue to rely more or less on their own judgement, to assess the thermal characteristics of their solar buildings.

Different life-styles of the different owners, especially those with children, will make a sophisticated thermal analysis by temperature recorders somewhat complicated. In many cases, children, especially when playing, leave doors open which can create a significant source of heat loss in the winter months.

However, most of the owners are aware of the various means to successfully control the heat flow in their buildings, and it only relies on continuing educational explanation to children to ensure a proper thermal functioning of these solar buildings.

(G) Cost of the Solar Systems

The exact cost of the solar systems was in many cases difficult to determine as the passive solar systems are often part of the actual building fabric. Where possible, the cost of the solar systems has been isolated from the rest of the building, but can be seen only as an estimation, rather than an exact cost.

Table 5.3 presents the capital cost of each building, the cost of the solar system and the latter as a percentage of the total building cost.

The cost of the solar systems ranged from $25 000 at the Pickup house to only $750 at the Bayley-Stark house. The cost for the passive heating systems amounts to an average of 5.5% of the building's capital cost. The most expensive solar systems, at the Pickup house, amounted to 13% of the building's capital cost, and the two least expensive solar systems, at the Collins and the Bayley-Stark houses, amounted to 3% and 1% respectively.

Only the owners at the Cotton house could not estimate the cost of their solar system, as a financial justification to them was not necessary.

In most cases, the capital cost of the solar system initially did not reflect its real value to the owners, as they were

Building and year of Completion	Capital cost & cost per m^2	Cost of Solar System $	% of Capital Cost
Fergusson 1978	$38 000 $242	$1285	3.3%
Collins 1982 owner built	$26 000 $213	$ 800	3%
Christian School March 1981	$19 000 $271	$1950	10%
Sunspace Project June 1984	$65 000 $406	$4050	6%
Mitchell Sept 1982	$120 000 $462	$4850	4%
Pickup Aug 1982	$200 000 $444	$25 000	13%
Field May 1983	$90 000 $461	$5519	6%
Cotton Nov 1983	$54 000 $461	NOT AVAILABLE	NOT AVAILABLE
Button Feb 1979	$34 000 $243	$1200	4%
Bayley-Stark Nov 1981	$59 000 $381	$750	1%

Table 5.3 Cost Comparison of the Capital Cost and Cost of the Solar Systems for 10 Passive Solar Buildings in Tasmania.

uncertain of the potential of their solar heating systems, their collection of solar heat, and hence, the cost savings of future heating costs.

Detailed thermal calculation and estimation of future heating cost savings would clarify the owner's perception of the effectiveness of the solar systems, and professional assessment of the thermal performance and future cost savings should give the owners a clear understanding of the value of their solar heating systems.

Solar buildings will provide large savings in energy requirement and fuel bills over their life-time, and in most cases these can be reduced to about half to two thirds as compared to uninsulated buildings.

The extra capital cost for Passive Solar Systems are small, especially in Direct Gain Systems. Insulation costs for a building of 160 m^2 total about $800, and this extra cost will be offset partially, or even entirely, by the use of a smaller, cheaper auxiliary heating plaint. Other costs, such as for Trombe-Michel walls, attached glasshouses or additional interior thermal mass will involve extra costs; however these costs should be only a small part of the building's capital costs.

For a relatively small cost outlay for the passive solar systems, great savings in life-time running costs can be expected in solar buildings, in addition to the much improved thermal comfort.

If the potential for energy savings as a result of thermal improvement is actually realised, and furthermore, encouraged by special grants or low interest loans for the cost outlay for the improvements by the Tasmanian Government, the long term requirement of energy can be substantially reduced in Tasmania.

(H) Council approval

Most of the solar buildings were promptly approved by the local Councils. However, a few minor problems at the Sunspaces Project house concerned the lowest point of ceiling height at the attached greenhouse of only 1.4 metres. The Council approved the drawings only after the architect pointed out that the attached greenhouse's function is to act as a heating system only and not as a habitable room. The Tasmanian Building Regulation[9] refers to "habitable room" as a room designed for use as a living room, an office, a work-room, or for the purpose of sleeping, or of eating or cooking food, and the purpose of an attached greenhouse has to be initially classified by the owner to determine its relation to the building regulation. When greenhouse glazing is installed as a flat or low-slope roofing, it is particularly susceptible to damage. This could result from people walking on it or from falling objects. Therefore the Building Regulation will demand special safety glass to be used if the attached greenhouse is classified as a habitable area.

The Collins house, near Ulverstone, was the first house in that area which used a Trombe-Michel Wall, and the Council initially asked the owner for more information regarding the purpose of the solar wall. After sufficient research information was presented to it by the owner, the Council finally approved the house plans.

The remaining owners reported that the Councils showed great interest towards the passive solar heating features and provided full co-operation and advice to the owners.

(I) Building experience

Only minor problems were experienced with the construction of the passive solar systems. At the Mitchell, Fergusson, and Collins houses, the Trombe-Michel Wall was not built according to the specification, as the solar wall cavities initially were not filled with concrete. As the walls were already built up to a height of 2.2 metres, the additional filling of the cavities with liquid concrete proved to be a difficult task.

Any different construction technique, which only slightly differs from the conventional "day to day" building practice, has to be clearly documented on the drawings, included in the specification, explained to the builder prior to the construction, and closely supervised by the owner or building designer to achieve satisfactory results.

(K) Problems related to the solar heating systems

The owners specified only small problems related to the heating systems. Frequently, the clerestory windows created some overheating problems during late summer, and the owners of the Fergusson and Bayley-Stark houses intend to solve this problem by installing internal shutter devices over these window areas.

Many owners complained about water penetration through skylights, glasshouses, and clerestory windows, a problem often due to poor workmanship or damaged materials. Special care should be taken to seal all glazing areas and only approved flashing material is recommended for successful sealing purposes.

The owner of the Collins house reported that the area of the Trombe Michel Wall restricts the light and sun penetration into the northern living areas, a factor which the owner did not realize before constructing the house. This problem can be solved by future owners by constructing a scale model. This model should include all windows, other glazed areas and the Trombe-Michel Wall and can then be tested under a solar scope to study the light penetration into the rooms and shading effects created by the fixed overhang.

(L) Future changes to design and building techniques should the owners build again.

Many individual changes have been reported by the owners, the most common being the intention to build part of the building underground.

The next common change is to alter the width of northern fixed overhangs. At the Button house, the width of the overhang is 800 mm which, in the opinion of the owner, is much too wide and should be changed to 450 mm. At the Bayley-Stark house, the owners would like to change the overhang width from 500 mm to about 650 mm.

The width of the overhang has to be clearly specified by the owners and depends on the individual preference for sun penetration into the building. In general, an overhang width of 450-600 mm should be satisfactory for summer shading for a common wall height of 2.4 metres.

The Button house employs a double storey open plan layout and the owner would, in his future design, separate the downstairs and upstairs area to prevent the warm air escaping to the upstairs areas, where it is usually 3-5°C warmer.

It is a general rule in passive solar housing, to keep living areas reasonably sized (up to 30 m^2) so that they can be easily heated, and to separate the upstairs areas in order to keep the volume of air to be heated as small as possible.

5.3 GENERAL CONCLUSION

Solar heating systems are mostly needed in temperate and cool climates where space heating plays a major role in the consumption of energy. In Tasmania, with its cool, but frequently sunny, winter days, solar buildings, if designed correctly, will provide the occupants with high thermal comfort and will only need minor auxiliary heating resulting in small heating expenses.

All the surveyed solar buildings perform to the full satisfaction of the owners and occupants with the major emphasis placed on increased thermal comfort before actually achieving heating cost savings.

The Christian School is the only building which is heated only by the sun and this building clearly demonstrates the great potential of the passive solar heating systems in

Tasmania. All the remaining surveyed solar buildings show a significantly smaller heating bill with an increased thermal comfort to that of an average Tasmanian dwelling.

All passive solar buildings require to some degree more occupant awareness of the environment and their passive solar systems. All the owners are fully aware of their building's heating function and enjoy its operation. To some people, this could be an imposition, but all the owners in this survey find it not only tolerable, but actually a pleasant way of growing closer to their environment.

Radiant heating from large surfaces, characteristic of passive solar buildings, produces a comfortable and healthy environment. According to some owners, their health standard has significantly improved, especially in the winter months.

There still exists the problem of finding suitable building sites for the purpose of constructing solar buildings, especially in medium and high density areas. Planning codes will be urgently required to protect individual occupant's right to sun access on their northern walls and roofs.

The important factor in the acceptance of new solar buildings will be that of costs. With the high interest on building loans, any additional cost for the passive heating systems imposes a heavy burdon to the owner. However, if the future energy and cost savings can be clearly realized by the owner (for example, using thermal computer analysis and establishing a life cycle cost benefit figure), the initial cost outlay for these passive solar systems may appear relatively insignificant and fully warranted.

Any responsible government, concerned with the aspect of energy conservation, will emphasise the application of thermal improvements, such as the installation of insulation and passive solar systems, by providing financial assistance to the public. This can be achieved by providing low interest loans, tax exemptions, or special energy grants to the prospective solar building owner.

However, at the present time, the potential of energy conservation in buildings is still ignored by the Tasmanian Government and there exists no financial assistance for thermal improvement in buildings. Tasmania's Building Regulation still fails to recognise the need for any insulation, and needless to say, the great importance of solar orientation, correct sizing of glazed areas, and the inclusion of thermal storage.

From time to time, it has been fashionable among architects and technologists of this century to consider the building forms of early human civilization as primitive. In contrast, modern architecture, based on high technology and ever increasing rates of energy consumption, has symbolised the human defiance of nature and natural processes. A rational future architecture must recognise climate once again as a substantial determinant of form. Early pueblos of the Acoma tribe in New Mexico exhibited a sophisticated understanding of the principles of building orientation, colour, mass, and thermal insulation. They used heavy dark vertical walls to collect and store winter solar energy, but thin light coloured horizontal slabs to reject the summer sun. This so-called "primitive" group has shown a willingness to co-operate with nature and natural processes. They offer us the lesson that if we adopt their approach augmented by our improved understanding of the mechanics of nature, then we may be able to achieve the goal which should be the hallmark of the new generation, - a sustainable economy using as its base energy obtained primarily from the sun.

References, Chapter 5

1. COLDICUTT, A.B., 1978; *Thermal Performance & Life-Time Costs of Public Housing Units in Victoria and Tasmania*; Department of Architecture and Building, University of Melbourne.

2. GIVONI, B., 1976; *Man, Climate and Architecture*; Building Research Station, Israel Institute of Technology, Applied Science Publishers Ltd., London.

3. REITZE, L., 1976; A Solar Rights Guarantee: Seeking New Law in Old Concepts, *47 University of Colorado Law Review*, 421.

4. A list of some Tasmanian Solar Building Designers can be found at Appendix E.

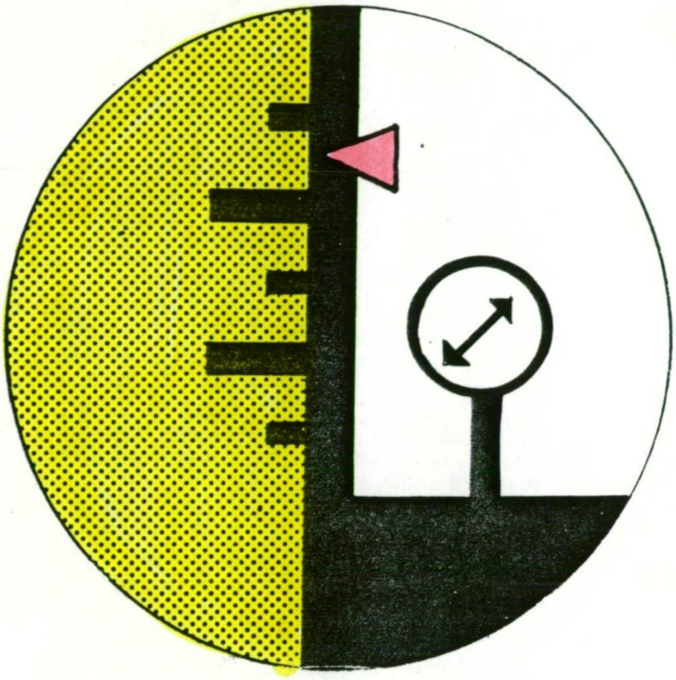
5. GRANGER, M., 1981; *The Exploitation of the Masses or a Poor Man's Guide to Solid Solar Housing*. Promotion of low cost solar housing in temperate Australia, 3rd Seminar, University of New South Wales, Duntroon.

6. As above.

7. GRANGER, M., 1981; see note 5.

8. DEPARTMENT OF TRANSPORT AND CONSTRUCTION, 1983; *Energy Efficient Australian Housing*, Australian Government Publishing Service, Canberra.

9. TASMANIAN BUILDING REGULATION, 1978; Statutory Rules 1978, No.135, Tasmanian Government Printer, Hobart.



APPENDICES

APPENDIX A

Average Dry Bulb Temperatures for Hobart, Tasmania

Average dry bulb temperatures are used to determine the number of Heating Degree Days, as explained in Chapter 2.

Average dry bulb temperatures are the product of $\frac{A + B}{2}$

where A = average daily maximum temperature

B = average daily minimum temperature

Table A1 shows the average dry bulb temperature for Hobart.

TABLE A 1

Hobart - Average dry bulb temperature (Degrees Celsius)

Time/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
0.00	14.4	15.2	14.0	12.3	9.5	7.5	7.1	7.5	8.6	9.8	11.1	13.0
1.00	14.2	14.9	13.8	12.0	9.4	7.3	6.9	7.3	8.3	9.5	10.9	12.8
2.00	13.9	14.7	13.5	11.8	9.2	7.1	6.8	7.1	8.1	9.2	10.7	12.6
3.00	13.7	14.5	13.2	11.6	9.0	7.0	6.6	6.8	7.9	9.0	10.6	12.4
4.00	13.6	14.3	13.0	11.4	8.8	6.8	6.5	6.6	7.7	8.8	10.5	12.3
5.00	13.5	14.2	12.8	11.1	8.7	6.6	6.3	6.4	7.5	8.6	10.3	12.3
6.00	13.8	14.3	12.6	10.9	8.5	6.5	6.2	6.1	7.3	8.5	10.7	12.6
7.00	14.9	15.3	13.5	11.6	8.8	6.7	6.4	6.7	8.2	9.8	11.7	13.6
8.00	15.9	16.2	14.5	12.3	9.2	6.8	6.7	7.2	9.2	11.1	12.7	14.5
9.00	17.1	17.4	15.5	13.0	9.5	7.0	6.9	7.7	10.1	12.3	13.7	15.5
10.00	18.0	18.4	16.4	14.0	10.5	8.0	7.9	8.8	11.0	13.2	14.4	16.3
11.00	18.9	19.3	17.4	15.1	11.6	9.0	8.9	9.9	11.8	14.1	15.1	17.0
12.00	19.4	20.0	18.3	16.1	12.6	10.0	9.9	10.9	12.7	15.0	15.5	17.5
13.00	19.6	20.2	18.5	16.3	12.8	10.3	10.2	11.2	12.9	15.1	15.6	17.7
14.00	19.7	20.3	18.7	16.6	13.0	10.6	10.5	11.5	13.0	15.2	15.6	17.8
15.00	19.6	20.2	18.8	16.8	13.3	10.9	10.9	11.7	13.2	15.3	15.4	17.6
16.00	19.0	19.6	18.1	16.1	12.6	10.2	10.2	11.0	12.4	14.4	14.8	17.1
17.00	18.5	19.0	17.4	15.3	11.8	9.6	9.5	10.3	11.6	13.5	14.3	16.5
18.00	17.8	18.2	16.7	14.6	11.1	8.9	8.8	9.5	10.8	12.7	13.6	15.8
19.00	17.0	17.5	16.0	14.1	10.8	8.6	8.5	9.1	10.3	12.0	13.0	15.1
20.00	16.2	16.7	15.4	13.6	10.4	8.3	8.1	8.7	9.8	11.4	12.4	14.4
21.00	15.6	16.1	14.8	13.1	10.1	8.0	7.8	8.2	9.3	10.8	12.0	13.8
22.00	15.2	15.8	14.5	12.8	9.9	7.8	7.6	8.0	9.1	10.5	11.7	13.5
23.00	14.8	15.4	14.2	12.5	9.7	7.6	7.4	7.8	8.8	10.2	11.4	13.2
Daily Average	16.4	17.0	15.5	13.5	10.4	8.2	8.0	8.6	10.0	11.7	12.8	14.8
Sunup Average	17.7	18.4	16.9	15.1	11.7	9.5	9.4	10.0	11.4	13.0	13.9	15.9

Source: ROY, G. and MILLER, S., 1980: *Data Handbook for Australian Solar Energy Designers;* School of Architecture, University of Western Australia, Perth.

APPENDIX B

Annual Heating Degree Days for various locations in Tasmania

The heating degree days give an indication of the amount of heating required in a particular location during the year. Heating degree days are calculated from an indoor base temperature, usually 18°C. For each month, the average monthly temperature is subtracted from the base temperature (18°C). If the average monthly temperature is greater than the base temperature, the figure is not included in the calculation. The difference between the average monthly temperature and the base temperature is multiplied by the number of days in that month. This is then repeated for each month of the year to produce the monthly heating degree days.

The annual Heating Degree Days for various locations in Tasmania to base 18°C is given in Table B.1.

TABLE B.1.

HEATING NUMBERS (BASE TEMPERATURE 18°C) - TASMANIA

BICHENO	1641
BOTHWELL	2898
BRIDPORT P.O.	1798
BRONTE PARK	3458
BURNIE A.P.P.M.	1998
BUSHY PARK (HOPS RESEARCH)	2397
BUTLERS GORGE	3693
CAMPBELL TOWN (RESERVE)	2313
CAPE BRUNY (LIGHTHOUSE)	2279
CAPE SORELL LIGHTHOUSE	2098
CLAREMONT H.S.	2105
CRADLE VALLEY	4145
CRESSY RESEARCH	2481
CURRIE P.O.	1692
DELORAINE	2696
DELORAINE EAST	2464
DEVONPORT EAST	2070
EDDYSTONE POINT (LIGHTHOUSE)	1698
ELLIOT RESEARCH	2349
ERRIBA P.O.	3462
FORTHSIDE (AGRIC RES STN)	2343
GEEVESTON	2498
GEEVESTON (FOURFOOT)	2373
GEORGE TOWN	1990
GROVE RESEARCH	2470
HASTINGS CHALET	2622
HOBART AIRPORT M.O.	2066
HOBART REGIONAL OFFICE	2000
KINGSTON	2383
LAKE LEAKE CHALET	3276
LAKE ST.CLAIR	3674
LAUNCESTON (ELPHIN)	1992
LAUNCESTON (MT.PLEASANT)	2210
LAUNCESTON AIRPORT M.O.	2364
LAUNCESTON 7 E X	2109
LOW HEAD (LIGHTHOUSE)	1833
MAATSUYKER IS. (LIGHTHOUSE)	2479
MARRAWAH (GREENE)	2224
MARRAWAH (MARSHALL)	1978
MAYDENA (NEWSPRINT MILLS)	2890
MT.BARROW	4914
MT.WELLINGTON	5039
NEW NORFOLK	2257
OATLANDS	2863
ORFORD P.O.	2024
PALMERSTON (POATINA)	2583
PATS RIVER (FLINDERS IS.)	1681
PORT DAVEY	2444
PREOLENNA P.O.	2486
QUEENSTOWN SOUTH (70T)	2649
QUOIBA	2285
REDPA	2221
RISDON	1944
ROSS	2566
ROSSARDEN (ABERFOYLE)	3119
SAVAGE RIVER	2874
SCOTTSDALE (KRAFT FOODS)	2282
SCOTTSDALE NO.2	2310
SHANNON (H.E.C.)	4061
SHEFFIELD	2707
SMITHTON P.O.	2021
ST.HELENS P.O.	1962
STANLEY P.O.	1867
STRAHAN (VIVIAN ST)	2087
STRATHGORDON (CHALET)	2924
SWANSEA MARIA ST.	2018
TASMAN ISLAND LIGHTHOUSE	2661
TEWKESBURY RESEARCH	2999
THE KNOB (GORDON RIVER)	3263
THE SPRINGS	3795
WARATAH	3532
WHITEMARK P.O.	1681
WYNYARD AIRPORT	2373
WYNYARD WEST (JACKSON ST.)	2110
ZEEHAN (STATE SCHOOL)	2552
ZEEHAN P.O.	2684

Source: BUREAU OF METEOROLOGY, Melbourne. Available on microfiche at local offices of the Bureau of Meteorology.

APPENDIX C

Mean Daily Global Radiation Values for horizontal and vertical north-facing surfaces in Hobart, Tas. 42°54'S

Table C.1 shows the mean daily global radiation totals on horizontal and vertical north facing surfaces.

It should be noted, while the yearly total radiation values on vertical north-facing surfaces are less than for the horizontal values, in the winter months from April to August, the vertical north-facing surfaces receive more solar radiation.

TABLE C.1.

Mean Daily Radiation Totals on Horizontal and Vertical Surfaces
(megajoules per square metre)
Station: Hobart, City 42°54'S; 147°18'E, 57.0 metres above sea level

Mean Value 1967-1981	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR 1967-1981
Horizontal MJ/m^2 day	22.62	19.3	14.25	9.95	6.26	5.03	5.96	8.51	12.56	17.38	19.80	21.79	13.62
Correlation factor, horizontal to vertical	0.53	0.64	0.82	1.02	1.45	1.77	1.67	1.36	0.96	0.71	0.57	0.54	
North facing vertical surface MJ/m^2 day	11.98	12.35	11.68	10.15	9.08	8.90	9.95	11.57	12.06	12.34	11.28	11.77	11.09

Source: Radiation Value on Horizontal Surfaces, Department of Science and the Environment, 1981. Bureau of Meteorology, Hobart. Radiation Value on Vertical Surfaces, using the Correlation Method for Transformation from Horizontal to Vertical Solar Radiation Intensity BOES, E.C., 1976; <u>Distribution of Direct and Total Solar Radiation Availabilities</u>; ISES Annual Meeting, Winnipeg, Canada.

APPENDIX D

Average wind speed and direction for Hobart

Table D.1. presents the average wind speed for Hobart, measured in metres per second.

Figure D.1. shows a graphical presentation of the average wind direction, from January to December.

The main wind direction is experienced from the north-west, with the second major wind direction from the south east.

TABLE D.1.

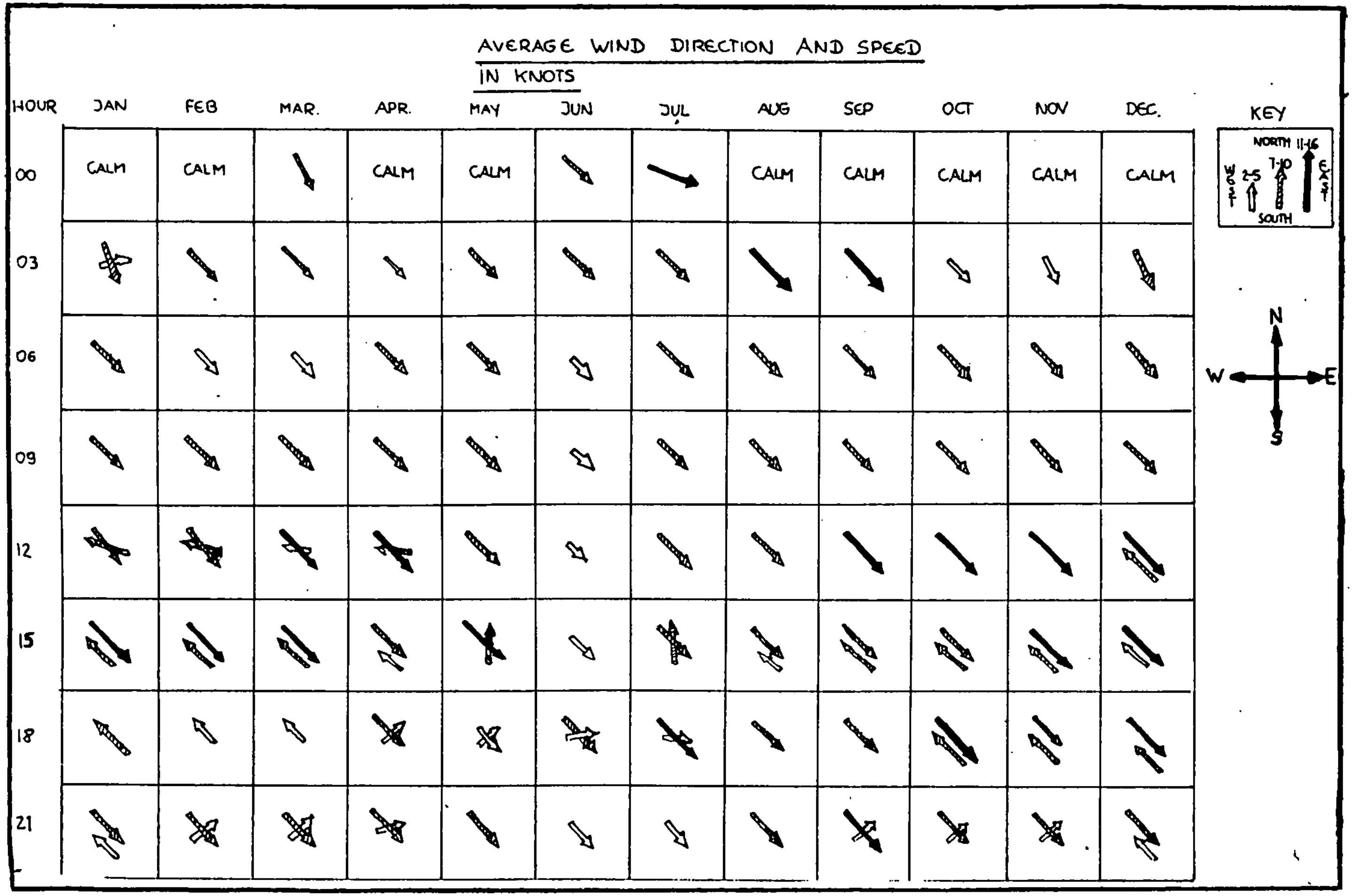
```
*******************************************************************
*                                                                 *
*               HOBART ___ AVERAGE WIND SPEED [M/S]               *
*                                                                 *
*******************************************************************
```

TIME\MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0.00	2.3	2.1	1.8	2.4	2.5	2.6	3.1	2.7	3.3	2.7	2.5	2.9
1.00	2.3	2.1	1.8	2.5	2.6	2.6	3.1	2.8	3.3	2.7	2.5	2.9
2.00	2.3	2.1	1.8	2.6	2.7	2.7	3.1	2.7	3.3	2.8	2.6	2.9
3.00	2.2	2.1	1.9	2.7	2.7	2.7	3.2	2.8	3.3	2.9	2.6	2.9
4.00	2.2	2.1	1.9	2.6	2.8	2.7	3.2	2.7	3.3	2.8	2.7	2.9
5.00	2.2	2.1	1.8	2.6	2.8	2.6	3.1	2.7	3.2	2.9	2.7	2.9
6.00	2.4	2.2	1.8	2.5	2.8	2.6	3.1	2.6	3.1	2.9	2.9	3.1
7.00	2.7	2.6	2.3	2.8	2.9	2.7	3.3	2.9	3.5	3.4	3.3	3.5
8.00	3.1	2.9	2.8	3.0	3.0	2.8	3.5	3.2	3.9	3.9	3.6	3.9
9.00	3.5	3.3	3.3	3.3	3.1	2.9	3.7	3.5	4.4	4.4	3.9	4.3
10.00	3.8	3.5	3.4	3.5	3.3	3.1	3.9	3.7	4.7	4.5	4.2	4.5
11.00	4.2	3.7	3.5	3.7	3.6	3.4	4.1	3.9	5.0	4.6	4.4	4.7
12.00	4.5	3.9	3.6	3.9	3.8	3.7	4.3	4.0	5.4	4.7	4.6	4.9
13.00	4.7	4.3	3.8	3.8	3.6	3.6	4.2	3.9	5.3	4.7	4.9	5.1
14.00	5.0	4.7	3.9	3.8	3.4	3.4	4.0	3.9	5.2	4.7	5.3	5.2
15.00	5.1	4.9	4.1	3.8	3.2	3.2	3.9	3.8	5.1	4.8	5.4	5.2
16.00	4.9	4.6	3.8	3.5	3.0	2.9	3.6	3.4	4.6	4.5	5.1	5.0
17.00	4.7	4.4	3.6	3.2	2.8	2.6	3.2	3.1	4.2	4.2	4.7	4.8
18.00	4.3	3.9	3.3	2.9	2.5	2.3	2.9	2.7	3.7	3.9	4.2	4.5
19.00	3.7	3.3	2.9	2.7	2.5	2.4	2.9	2.7	3.6	3.5	3.6	3.9
20.00	3.2	2.7	2.4	2.6	2.5	2.4	3.0	2.8	3.5	3.1	2.9	3.4
21.00	2.7	2.3	1.9	2.4	2.5	2.5	3.0	2.8	3.3	2.7	2.5	3.1
22.00	2.6	2.1	1.9	2.4	2.5	2.5	3.0	2.8	3.3	2.7	2.4	3.0
23.00	2.4	2.1	1.8	2.4	2.5	2.6	3.0	2.7	3.3	2.7	2.4	3.0
AVERAGE	3.4	3.1	2.7	3.0	2.9	2.8	3.4	3.1	3.9	3.6	3.6	3.8

Source: ROY, G., and MILLER, S., 1980; Data Handbook for Australian Solar Energy Designers; School of Architecture, University of Western Australia, Perth.

Figure D.1. Average Yearly Wind Direction for Hobart

Source: GNAUCK, D., 1978; Solar Energy Utilization in Dwellings, Department of Environmental Design, Tasmanian College of Advanced Education, Hobart.



APPENDIX E

Some Tasmanian Solar Building Designers

Button, David,	263 Nelson Rd., Mt. Nelson, Hobart.
Gnauck, Detlev,	213 Bathurst St., West Hobart, Tas. 7000.
Legge, Nigel,	82 Goulburn St, Hobart, Tas., 7000.
McGregor, Robert,	134 Waterworks Rd., Dynnyrne, Tas. 7005.
Palmer, Brian,	c/- National Parks and Wildlife Service, Magnet Court, Sandy Bay, Tas., 7005.
Sutton, Robert,	c/- Customer Advisory Section, Hydro Electric Commission, Hobart, Tas., 7000.
Walsh, Tony,	45 Cormiston Rd., Riverside, Tas., 7250.