Recommended for use in schools by the Education Department of Victoria

PRŌLOGIC.

Designing an Energy-efficient House

A Printer is recommended for use with this product

Apple //e / //c Version requires 64k Memory and 1 Disk Drive

Designing an Energy-efficient House

This program allows students to design and construct a theoretical house. Students draw up their design on the computer and make decisions about the location, orientation, building materials, roofing, flooring, insulation and window shading. Extensive use of graphics is made in this course.

The program introduces students to the features of design and construction of houses which influence energy requirements.

The students' design and construction decisions are assessed by the computer and a breakdown of the house energy balance is given.

The accompanying guide includes worksheets, which provide a framework for the program.

Useful in Science, Social Studies or General Studies classes.

This program is available for Apple II+, IIc and IIe computers.

Age 13—17

Published in association with Longman Cheshire Pty Limited and Control Data Australia Pty Limited.

Produced in cooperation with
The Department of Minerals and Energy,
State Electricity Commission of Victoria,
Gas and Fuel Corporation of Victoria,
Victorian Solar Energy Council.

Energy Victoria.

PRŌLOGIC.
Incorporated in Victoria

Unit 6, 663 Victoria Street,
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Telephone (03) 429 3188

ISBN 0 949159 40 9


837 pic
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DESIGNING AN ENERGY EFFICIENT HOUSE
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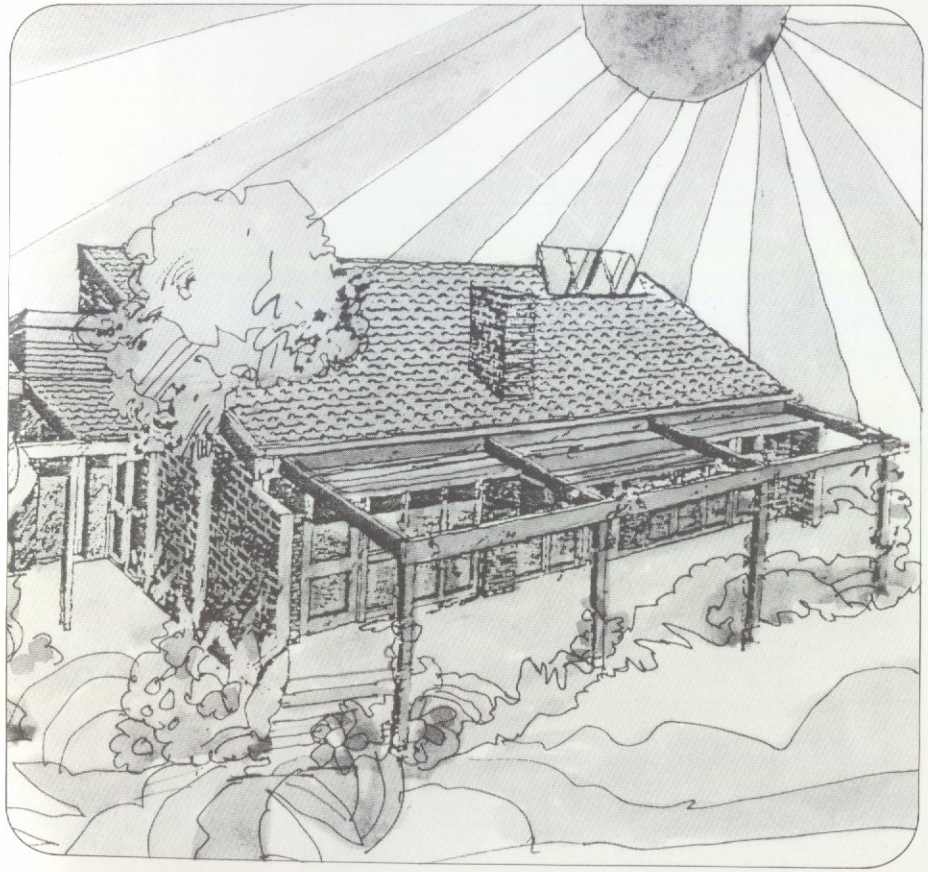

Designing an Energy-efficient House

An interactive program by
Brian Sharpley

Assisted by
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St Annes Gippsland Grammar School
Sale

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For Apple][, //e and //c computers

PRŌLOGIC.

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Contents

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Teacher's guide

Introduction

Description

This is an interactive program which allows students to design and construct a theoretical house.

Students draw up a house design on the computer screen and are able to decide on its location, orientation, construction materials, type of home heating, ventilation rates, heated/unheated zones and planting of trees.

The design and construction decisions made by students are assessed by the program and a breakdown of the house energy balance for the colder months is given.

Summer conditions are not directly considered by the assessment model although important aspects are highlighted throughout the program and the documentation.

The major purpose of the program is to introduce students to the features of housing design and construction that influence energy requirements.

Suggested worksheets covering a tutorial, experiments into design and construction, and a project are included in the student's section of this document. Teachers may duplicate these worksheets.

Level

This program was written for students in the middle and senior levels of secondary school.

Objectives

This computer program will encourage students to:

- analyse a house as a system with inputs and outputs of energy;
- investigate and utilise design features which lead to low-energy housing;
- investigate the construction of houses and the properties which lead to low-energy housing.

Hardware requirements

Apple computer with a minimum 64K RAM, DOS 3.3, disk drive and a monitor.

A printer is optional.

1 About the program

The program consists of four major parts.

1 The introduction is a reading exercise and gives some background to the program.

2 A floor-plan sketch pad and a side-elevation sketch pad to enable students to draw up their house designs on the screen.

3 An assessment model which enables students to determine construction, location and orientation details.

4 The program has been designed to give maximum flexibility to the user. Three menus enable students to control the flow of the program.

There are three entry points into the program. Students may read the introduction, go straight to the floor-plan sketch pad or move into the assessment model.

The program stores design data on disk so that students are able to turn off the computers and resume experimentation on their house later without re-entering the design and construction details.

The computer calculates the volume, floor, wall and window areas of the house from the designs sketched on the screen. The algorithms used to do these calculations are complex and although all efforts have been made to minimise odd designs, it is possible for a skilled operator to create unrealistic floor plans and, under certain conditions, to overlap windows. Under normal use, however, these anomalies do not occur.

The program is self-contained and the user can work through it without referring to the documentation. Each of the sketch pads has an associated help file which can be called up by pressing the ? key.

2 Teaching ideas

Classroom strategies

To obtain the most out of this program it is suggested that the students' work is organised in three stages.

1 Introduction to the program

Students need to know how to use the program. They can explore the program on their own, following the built-in guidelines, or use the tutorial on page 12.

At least one lesson is required for familiarisation with the program.

2 Experiments into the construction and design of houses

Students can alter a wide range of variables and investigate the changes that occur to the energy balance of houses.

Worksheets are supplied, concentrating on the following:

orientation;
location;
building materials;
ventilation;
heated/unheated zoning.

3 Designing an energy-efficient home project

After completion of the experiments students should have a sufficient grasp of the important factors which lead to low-energy housing.

The final stage is for students to design and construct their own energy-efficient house. An assignment to guide the project is included.

Classroom management

This depends on the number of computers available. If only one or a few computers are available, it would be best to use the program as part of a wider range of activities for students. Those lucky enough to have a computer centre can permit a more open-ended approach.

It is suggested that students design their houses and decide upon their construction criteria using the design sheet provided.

This has a number of advantages. First, it allows students to consider the design and construction questions before moving on to the computer. Second, student groups will be working at different rates and will require the computer at staggered times, and the time spent on the computer is minimised.

Other resources

The program is self-contained and could be used by students without any assistance or support documentation. However, to gain maximum educational value from this program, it is advised that it be used in the context of a wider curriculum plan.

It is important for teachers to emphasise the differences between designing an energy-efficient house for winter and summer. Although there are major similarities, the size and shading of east and west windows and the use of heavy construction materials are two important factors in summer design which are not emphasised in the winter model.

To understand this program fully, students need to have a working knowledge of energy, energy efficiency and heat flows. The Australian Science Education Project (ASEP) units *Heat and Temperature* and *Solar Energy* offer many experiments and activities.

The inputs and outputs of energy for the house are measured in gigajoules. Students should have a general concept of the size of this unit.

A general introduction to building materials and their insulation and thermal storage properties would be useful. Simple activities with materials and heat can be found in the ASEP unit *Places for People,* the Curriculum Branch unit *Low Energy Living,* and the Royal Australian Institute of Architects publication *Undesign your House* (see references).

The difference between passive and active solar-heating systems should be discussed.

Excursions to low-energy homes could be carried out either before or after the program is used in the classroom.

Arrange a visit to a building site in your area and discuss the design and construction with the builder or architect.

Guest speakers from the local council can explain local building regulations.

A visit to the Energy Information Centre (139 Flinders Street, Melbourne. Telephone [03] 63 1986) will allow students to see many displays demonstrating low-energy-housing principles. Lectures on low-energy housing can also be presented by energy information staff.

3 The assessment model

How does the assessment model work?

The model used to assess the students' houses has been designed with the help of staff from the Department of Minerals and Energy.

The energy flow via each path in the building for the heating season is considered. The aim is to calculate the heating energy demand (EH).

$$EH = EE + EV + EZ - ES - EI$$

Where:

EH = heating energy demand;

EE = nett energy loss from the house system via walls, windows, floor and roof;

EV = nett energy loss via infiltration/ventilation;

EZ = nett energy loss via internal walls to unheated zones;

ES = nett solar input through glazing;

EI = nett energy input due to internal gains.

A wide range of variables is considered in the model. After the completion of the house design, the computer defaults the variables as follows:

location – Melbourne;
home heating – gas;
walls – weatherboard/plasterboard;
roof – tiles;
floor – timber floorboards;
window coverings – none;
trees – none;
ventilation – average;
zoning – 75 per cent of house area heated. Unheated areas are spread evenly throughout the house.

These variables may then be altered by the students.

The model assesses winter conditions using heating numbers for the various locations. The heating number is based on climatic conditions. Design and construction features which would be useful in summer are not always considered.

It is assumed that the house has central heating, to simplify the decisions made by the students. Students may, however, alter the area of the heated zone in extension exercises.

What are the model's limitations?

A house is a dynamic system with many uncontrollable variables influencing the energy demands. For example, climatic and weather conditions can vary greatly from day to day, people can use their houses in vastly different ways, the condition of the house can deteriorate over time, and solar input can be influenced by a variety of conditions.

The model makes a number of assumptions.

1 The assessment model is steady state and assumes constant external and internal environmental conditions.
2 Average conditions prevail for the heating season. This is the basis of the heating number concept.
3 The house is occupied by a family of four for an average of fourteen hours per day. They heat the home for six hours per day at a temperature of 21°C. The internal gains due to the occupants and their activities are kept at a constant figure under all conditions.
4 The zoning of the house into heated and unheated areas is an approximation. For rectangular houses, the calculations are accurate. The more irregular the house design, the less accurate are the solar input and the internal loss measurements.
5 The loss through internal partitions is assumed to be constant under all conditions.
6 The heating number of wall elements is kept constant in all directions.
7 The house is single storey.

The model has not been designed to measure the home heating requirements of actual houses accurately. The major aim is to allow students to develop an understanding of the factors which affect energy demand and to carry out experiments on these factors.

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D. Theodore, *Natural Energy in your Home,* Paul Hamlyn, Sydney, 1977.

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Student's activities

1 Tutorial

This program allows you to investigate the design and construction of houses.

You are able to draw up the house design on the screen and make decisions about location, orientation, building materials, insulation and many other factors.

The flow of the program is controlled by three menus. Each menu gives you several options, and you select the one you want by keying in the number of your choice. This gives you a great deal of control over the use of the program.

The floor plan and the side elevations are drawn on sketch pads.

This tutorial will take you step by step through the program and will show you how to use the menus and the sketch pads.

You will need an Apple computer to work through this tutorial. The boxed instructions tell you what to do.

1	PLACE THE DISK INTO THE DRIVE AND TURN ON THE COMPUTER.

The program will start automatically.

After the introduction frames, Menu 1 appears as follows:


```
DO YOU WANT TO
    1 – READ THE INTRODUCTION
    2 – DESIGN A HOUSE
    3 – USE PREVIOUS HOUSE DATA

    USE THE SPACE BAR OR TYPE THE NUMBER OF
    YOUR CHOICE, THEN PRESS <RETURN>.
```

Selecting from Menu 1

2	PRESS THE KEYS [1], [2], [3] AND THE [SPACE BAR]

This moves the selector through the menu and allows you to highlight your choice. The choice is registered by pressing the [RETURN] key.

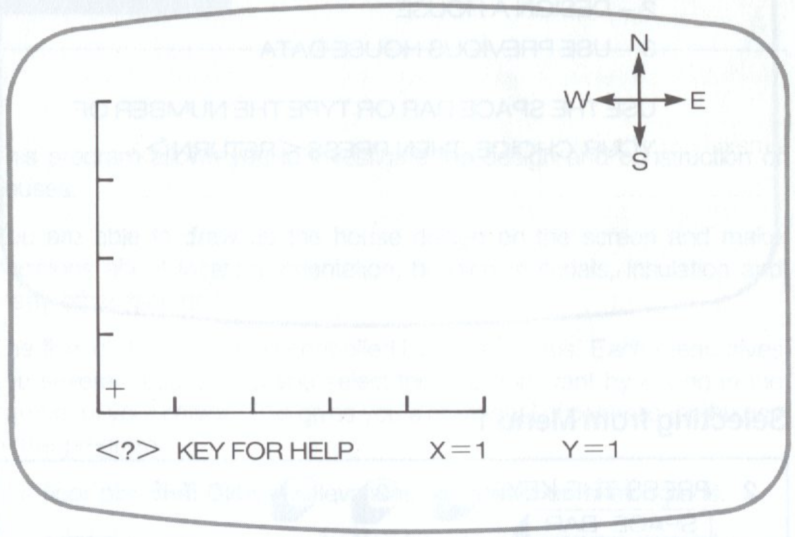
3	TYPE IN [1] AND PRESS THE [RETURN] KEY. READ THE INTRODUCTION. USE THE [RETURN] KEY TO MOVE TO THE NEXT FRAME.

(Options 2 and 3 skip the introduction text. Option 2 allows you to design a new house. If you have previously designed a house, option 3 allows you to move straight into the construction experiments.)

The floor-plan sketch pad

The sketch pad for drawing the house plan is automatically loaded after the introduction is completed.

The screen appears as follows:



The + (called the cursor) on the screen can be moved about by using the arrow keys or [I], [J], [K] and [M] keys.

4	PRESS THESE KEYS AND MOVE THE CURSOR AROUND THE SCREEN.

Notice that the X and Y co-ordinates are given on the screen.

Useful keys:

[?] the help file is displayed on the screen;

[P] turns the plotter on and off;

[D] deletes a line;

[S] saves the plan.

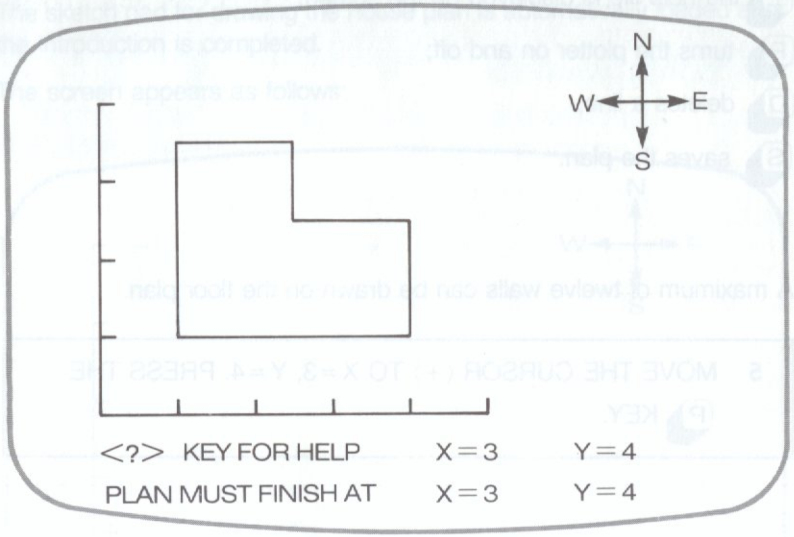
A maximum of twelve walls can be drawn on the floor plan.

5	MOVE THE CURSOR ⟨+⟩ TO X=3, Y=4. PRESS THE [P] KEY.

A message appears on the screen.

6	MOVE THE CURSOR ⟨+⟩ TO THE FOLLOWING POINTS X=17, Y=4 X=17, Y=10 X=10, Y=10 X=10, Y=15 X=3, Y=15 X=3, Y=4

The screen should appear as follows:



7 PRESS S TO SAVE THE PLAN.

You are then asked to select the height of your ceilings.

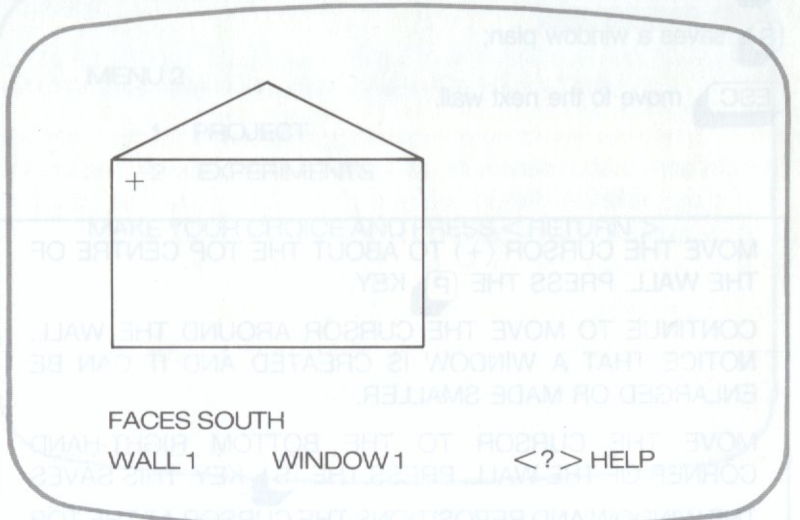
8 TYPE IN 2.4 THEN PRESS THE RETURN KEY.

The program will then display details of the volume, floor area and wall area.

The window sketch pad

The window sketch pad is automatically loaded after the completion of the floor plan program.

The screen appears as follows:



Each wall on your house will be shown in the order that you drew them on the house plan.

The drawing of windows is done in a different way to the floor plan. The windows are 'grown' from a starting point until the window is the correct size.

It is possible to draw up to eight windows on any one wall.

Useful keys:

[?] the help file is displayed on the screen;

[P] turns the plotter on and off;

[D] deletes the last window;

[S] saves a window plan;

[ESC] move to the next wall.

> MOVE THE CURSOR ⟨+⟩ TO ABOUT THE TOP CENTRE OF THE WALL. PRESS THE [P] KEY.
>
> CONTINUE TO MOVE THE CURSOR AROUND THE WALL. NOTICE THAT A WINDOW IS CREATED AND IT CAN BE ENLARGED OR MADE SMALLER.
>
> MOVE THE CURSOR TO THE BOTTOM RIGHT-HAND CORNER OF THE WALL. PRESS THE [S] KEY. THIS SAVES THE WINDOW AND REPOSITIONS THE CURSOR AT THE TOP LEFT-HAND CORNER OF THE WALL.
>
> PRACTISE DRAWING IN ANOTHER WINDOW AND SAVING IT. PRESS THE [ESC] KEY AND MOVE TO THE NEXT WALL.
>
> CONTINUE DRAWING WINDOWS ON ALL THE WALLS. IF AT ANY TIME YOU WANT TO DELETE THE LAST WINDOW PRESS THE [D] KEY.

Menu 2

Menu 2 is loaded automatically from the window sketch pad and looks as follows:

MENU 2

1 PROJECT

2 EXPERIMENTS

MAKE YOUR CHOICE AND PRESS <RETURN>.

The Project option moves you through the remainder of the program without any choice. The Experiments option allows you to choose options.

> **10** PRESS [2] KEY AND [RETURN]

You are now into the main menu and at the end of the tutorial.

2 Experiments

In this series of experiments you will use the computer program to investigate how orientation, location and building materials affect the energy balance of a house.

1 Orientation

Draw up a house plan of any floor area with four sides. One wall should have a large window area, the opposite wall no windows and the two remaining a small but similar window area (see Fig. 2.1).

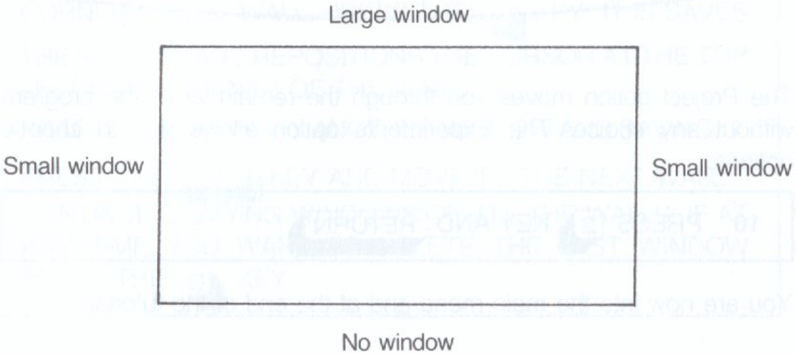


Fig. 2.1

Ignore the construction details. For this experiment the program will use the following default values:
location – Melbourne;
weatherboard/plasterboard construction;
tile roof;
floorboards;
no curtains.

By moving through the menus, alter the orientation of the house and check the assessment for each change. Complete Table 2.1.

Table 2.1

Direction	*Total energy loss*	*Energy gains*	
		Solar	*Internal*
1 N			
2 NW			
3 W			
4 SW			
5 S			
6 SE			
7 E			
8 NE			

All units in gigajoules.

1 Which of the factors has changed?

2 Can you explain the pattern that has occurred?

3 When designing a low-energy home outline:
  a how you would orientate the house.
  b where you would place the windows.

4 The assessment model in this program is winter orientated. To see how the situation might change in summer consider Fig. 2.2, which shows the amount of solar radiation received by various wall surfaces throughout the year.

Complete Table 2.2 showing the amount of solar radiation on walls for summer and winter.

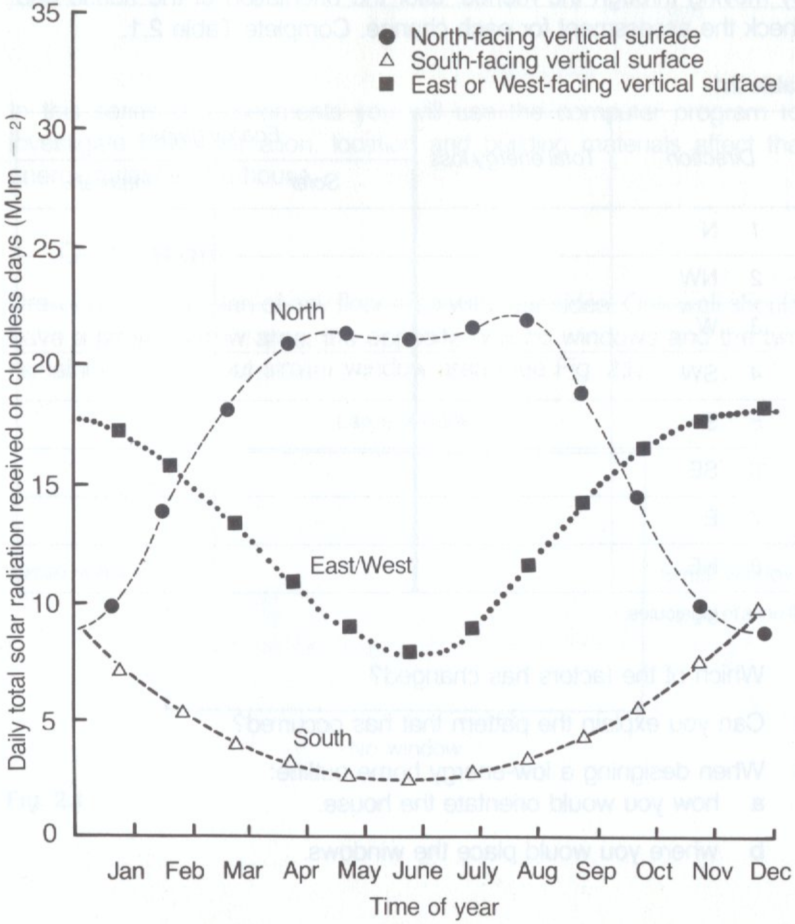


Fig. 2.2 Solar radiation received at 34°S

Table 2.2

Walls	*Summer (January)*	*Winter (July)*
North		
East		
South		
West		

Which wall(s) receive the most solar radiation during winter?

Which wall(s) receive the most solar radiation during summer?

If, in summer, the aim is to prevent solar radiation entering your house how would you adjust your plan?

2 Location

Victoria has been divided into seven regions for this exercise. The actual figures, however, relate to the towns listed in Table 2.3.

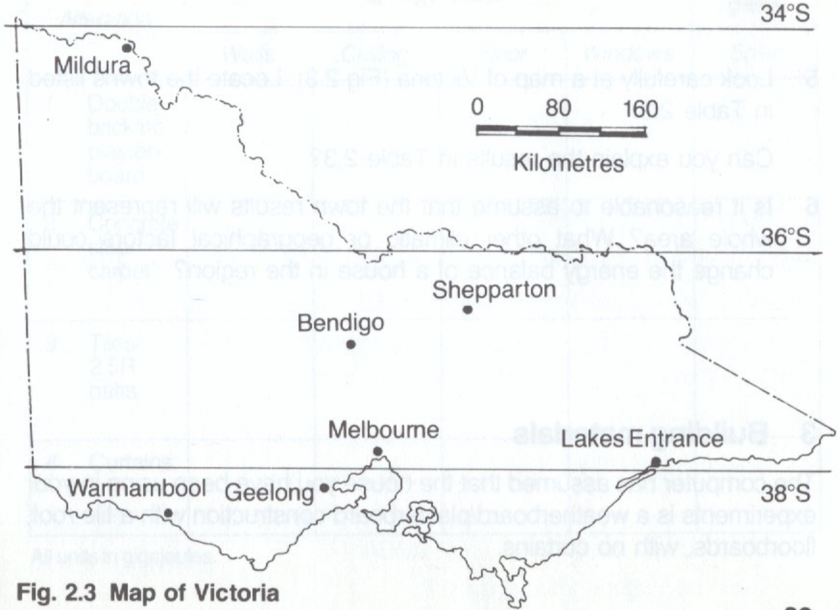


Fig. 2.3 Map of Victoria

Alter the location of your house site and obtain an energy assessment.

Complete Table 2.3.

Table 2.3

Location	Total energy loss	Energy gains	
		Solar	*Internal*
1 Melbourne			
2 Geelong			
3 Mildura			
4 Warrnambool			
5 Shepparton			
6 Bendigo			
7 Lakes Entrance			

All units in gigajoules.

5 Look carefully at a map of Victoria (Fig 2.3). Locate the towns listed in Table 2.3.

Can you explain the results in Table 2.3?

6 Is it reasonable to assume that the town results will represent the whole area? What other climatic or geographical factors could change the energy balance of a house in the region?

3 Building materials

The computer has assumed that the house you have been using in your experiments is a weatherboard/plasterboard construction with a tile roof, floorboards, with no curtains.

Obtain an assessment of your house and complete Table 2.4.

Table 2.4

Energy losses				Energy gains
Walls	*Ceiling*	*Floor*	*Windows*	*Solar*

All units in gigajoules.

Now change the construction of your house. Make one alteration at a time and obtain an assessment of the new house. Complete Table 2.5.

Table 2.5

Alteration	Energy losses				Energy gains
	Walls	*Ceiling*	*Floor*	*Windows*	*Solar*
1 Double brick/no plaster-board					
2 Concrete slab/ carpet					
3 Tiles/ 2.5R batts					
4 Curtains					

All units in gigajoules.

7 Briefly outline the changes that have occurred with each alteration.

8 **a** Can you explain these changes?

b In summer, heavy materials such as concrete and masonry help to moderate extremes in temperature. This is not clearly shown by the winter assessment model.

In designing a house for summer conditions, outline the materials you would use in constructing the walls, floor and ceiling.

4 Ventilation

Houses lose heat through poor sealing of doors and windows, cracks, and windows and doors left open.

The program has assumed average ventilation figures. You can investigate the importance of ventilation by changing the conditions as shown in Table 2.6.

The ventilation conditions assume average use of external doors and an airchange rate of 3m/sec.

9 Can the ventilation conditions have a large effect on the total heating bill?

10 Briefly outline how the heat loss from ventilation can be kept to a minimum.

5 Heated/unheated zones

The program has assumed that your house has been 75 per cent centrally heated. In many houses, however, only a few rooms are heated.

In this experiment you can see how heating different zones changes the energy demand.

Complete Table 2.7.

11 Which heating situation is the most expensive?

12 Compare the figures for heating zones 1 and 2 with heating 3 and 4. Which situation is the most efficient?

Can you explain your answer?

Table 2.6

Ventilation condition	*Ventilation loss*	*Total energy loss*	*Home heating required*
1 Unsealed chimney			
2 Poor sealing of doors/ windows			
3 Very good sealing of doors/ windows			
4 Average sealing of doors/ windows			
5 Leave windows open			

All units in gigajoules.

Table 2.7

Heated zones	*Total energy loss*	*Total energy gain*	*Home heating requirements*
Centrally heated			
1			
4			
1 and 2			
3 and 4			

All units in gigajoules.

3 Project

In this activity you are able to design and construct a house within a budget of $60 000.

The aim of this project is to design a low-energy house.

Before starting this project you should have carried out experiments into the design and construction of houses.

Draw up plans for your house on the design sheet supplied and select your building materials before you turn on the computer.

A building cost sheet is supplied. Use it to estimate your overall construction cost.

The cost of your house is estimated at $.........

Turn on the computer and work through the program.

Design your house and then choose the project option at Menu 2. The program will then automatically direct you through the construction options and will continually assess the cost of construction.

Work through the program and enter your construction details on the computer. Remember, the assessment model is for winter conditions only. Some of the factors which are useful for summer comfort may not be fully shown by the model.

Complete Table 3.1.

Obtain a print-out of the assessment summary.

1 Write a full report on the design and construction of your house. *Carefully explain your decisions.*

Table 3.1

	Your choice
Region	
External wall construction	
Internal wall construction	
Floor	
Roof/ceiling	
Window coverings	
Fuel type	
Heating zone size	
Ventilation condition	

2 In this program you have the ability to plant trees around the house. How do trees influence the energy flow into a house? Suggest the best planting scheme around your house to cater for both winter and summer conditions.

3 What aspects of your design and construction are specifically for summer conditions?

4 Your house was assessed assuming a family of four as occupants. Briefly outline how the energy assessment would alter if a larger family was assumed.

5 Submit your final plan and summary sheet.

Extension exercise

Using the ideas gained in this project, assess the design and construction of your family house or flat.

Complete the low-energy living checklist on page 30.

What improvements could be made to lower the energy demands of your house?

What changes in family lifestyle could lead to lower energy consumption?

Low-energy living checklist

		YES	NO
1	Is your dwelling free from draughts?		
2	Are all windows and frames in good condition?		
3	Are doors properly weather stripped?		
4	Are exterior doors closed quickly after use?		
5	Are all drapes, blinds, etc., closed at night during winter?		
6	Do the drapes fully cover the windows?		
7	Are the drapes made of a close weave material?		
8	Are plants, trees and shrubs located around the house to provide shade against unwanted sunlight?		
9	Is natural ventilation used as much as possible?		
10	Is there insulation in the roof?		
11	Do you know how much insulation there is in the roof?		
12	Are the walls insulated?		
13	Is the floor insulated?		
14	Are air ducts insulated in unheated and uncooled spaces?		
15	Is furniture located so there is no obstruction to heating or air conditioning appliances?		
16	Are the heating/cooling appliances serviced each year?		
17	If you have a fireplace, does it have a damper?		
18	Is the fireplace fully covered to stop draughts when not in use?		
19	Is the air conditioning unit located on the shaded side of the house?		
20	Is the hot water unit insulated?		
21	Do family members take short showers? (5 minutes or less)		
22	Are clothes usually washed in cold water?		

		YES	NO
23	Is the dishwasher only used when there is a full load?		
24	Is the frost inside the freezer of the refrigerator less than 6mm?		
25	Is the oven used to cook or bake more than one meal at a time?		
26	Do family members dress more warmly indoors during cold weather?		
27	Is less cooking done in the home during summer?		
28	Has the home's potential for using 'passive solar energy' been used?		
29	Does the 'living area' of the dwelling face north?		
30	Is part of the dwelling exposed to the sun all day?		
31	Are lights always turned off in rooms that are not being used?		
32	Are leaking taps (hot and cold) fixed as soon as possible?		
	TOTAL		

Yes answers to 28 or more questions show that your household is conserving energy at all times.

24-27 Shows energy consciousness.

20-23 Shows some awareness.

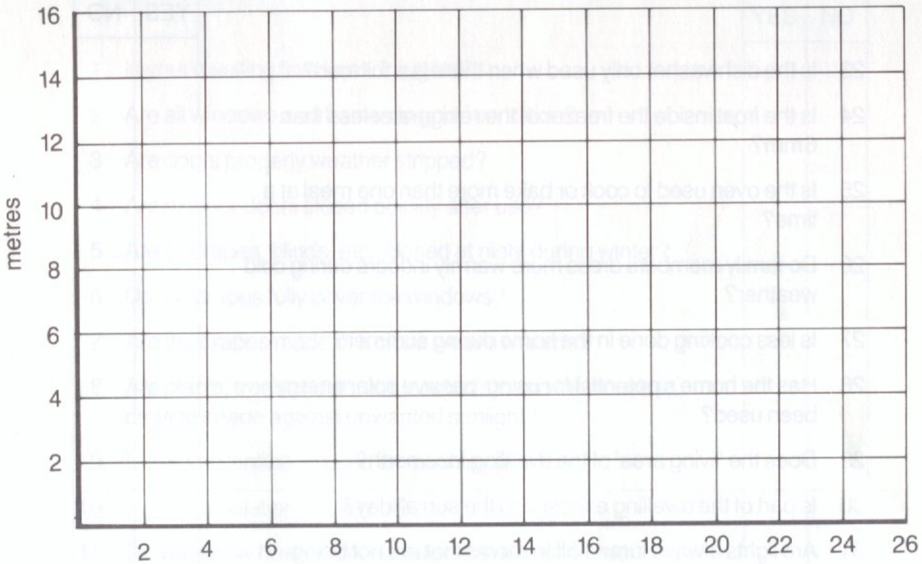
16-19 Shows that you are wasting energy and need to make an effort to improve.

15 or less, shows that your household is making an effort to waste energy.

Reproduced from P. Hicks *Low Energy Living* (Technology), Curriculum Branch, Education Department of Victoria, 1984.

House Plan

Floor Plan



Average size house: 100-140 m^2

Construction details

Building materials

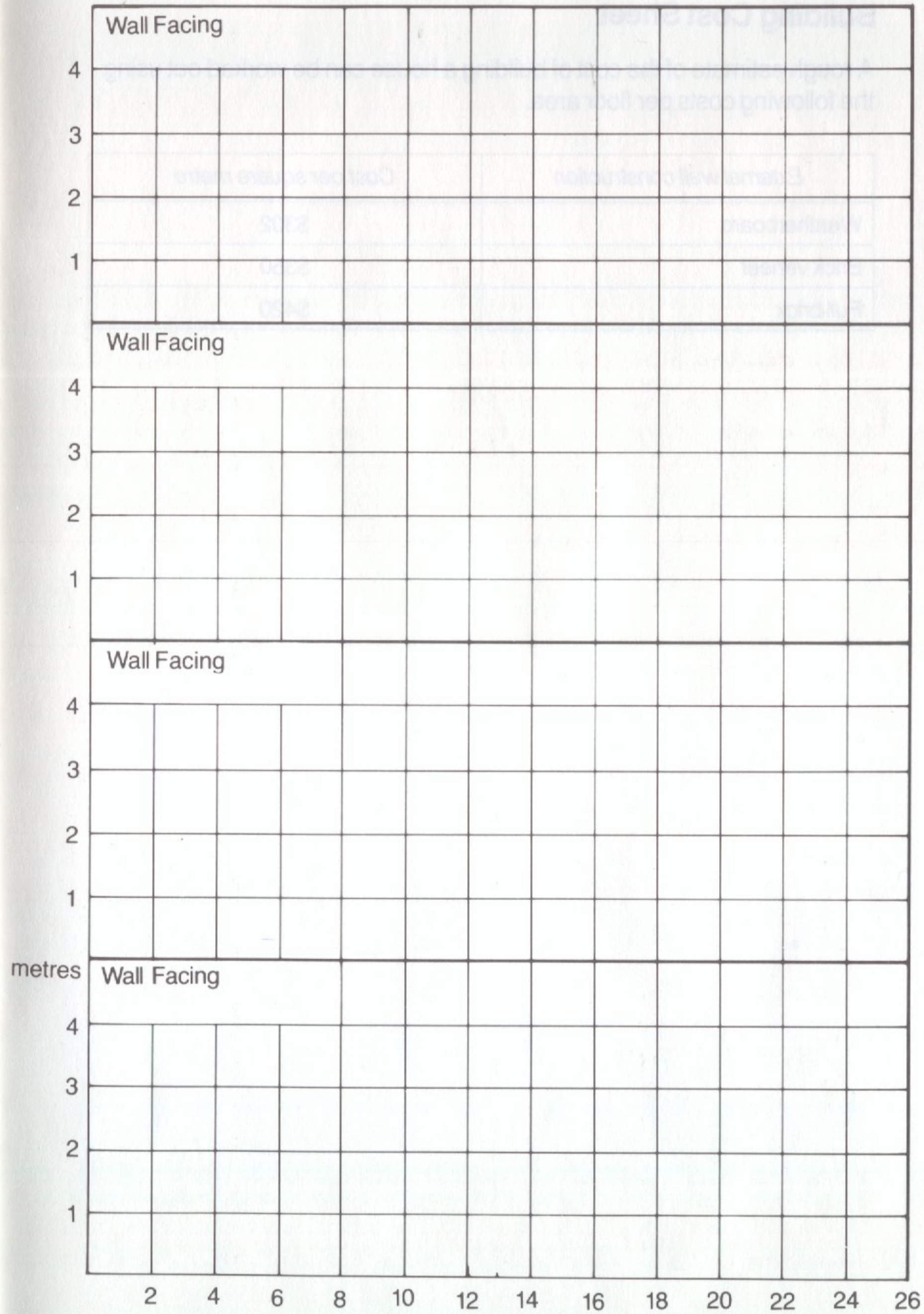
1 Walls ______________________

2 Roof ______________________

3 Floors ______________________

Region chosen for building ______________________

Student Name(s) ______________________



Building Cost Sheet

A rough estimate of the cost of building a house can be worked out using the following costs per floor area.

External wall construction	*Cost per square metre*
Weatherboard	$302
Brick veneer	$350
Full brick	$420