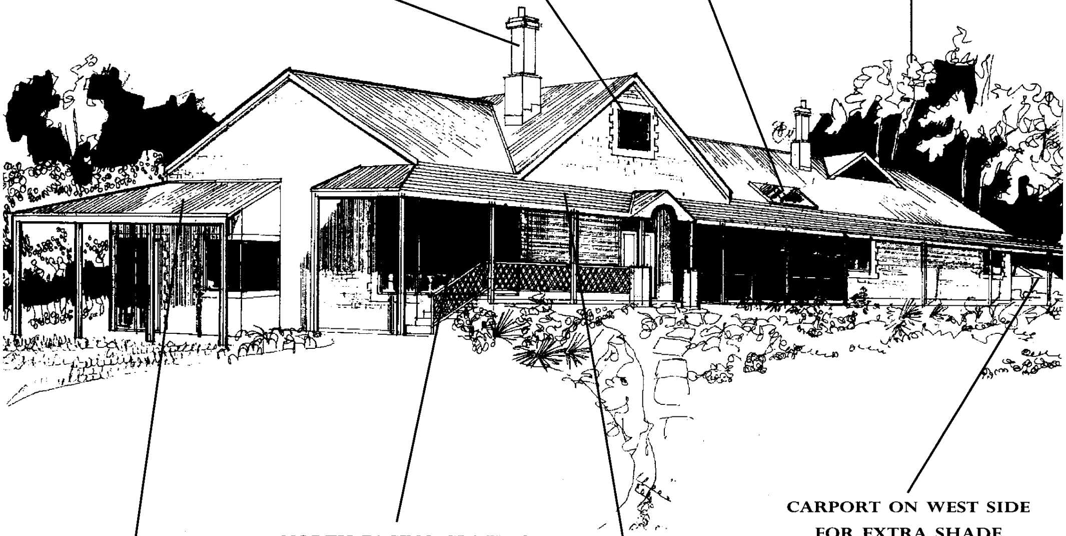
Energy Efficient Buildings



An Introduction to Solar Design

ACRE
Australian CRC for Renewable Energy Ltd

Australian Cooperative Research Centre for Renewable Energy

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CRC

Welcome to Energy Efficient Buildings: An Introduction To Solar Design.

This resource covers a number of different areas which are involved in the design of buildings which use solar energy to provide a naturally comfortable building and the concept of an energy efficient building.

The resource and activities were developed for lower secondary high school aged students, but may be suitable for use with upper primary or upper secondary students as part of Senior Science.

The activities and materials contained in this resource aim to promote the following objectives:

• To provide teachers with an introduction to the important elements which effect the energy efficiency of buildings

• To provide teachers with up-to-date activities and resources for teaching about Energy Efficient Housing and Solar Design in West Australian Schools

This resource includes activities from a number of different sources, which have been modified by staff within the Schools Education Program of the Australian Cooperative Research Centre for Renewable Energy (ACRE).

These sources include:

Energy Savings Kits for Schools (Renewable Energy Authority Victoria)
Energy Technology and Society (Victorian Solar Energy Council)
Energy Efficient Housing for Perth (Office of Energy)
Energy Matters Magazine (Office of Energy)
Energy Efficient Australian Housing (Ballinger, Prasad and Rudder)
Low Energy Buildings in Australia (Baverstock and Paolino)
Warm House, Cool House (Nick Hollo, Choice Books)
Green by Design Video (Institute of Architects)

Further Information or suggestions on resources for schools on renewable energy, energy efficiency and the Climate Change can be obtained by contacting:

Schools and Community Education Officer
ACRE
C/- Murdoch University
Murdoch WA 6150
Ph 08 9360 2865
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Email komara@acre.murdoch.edu.au

Alternatively, you may like to visit our website:
http://www.acre.murdoch.edu.au/school

The Jargon!

Like any field of interest there is a certain set of jargon which is used. Here is a brief description of each of the terms. When teaching, it may be a valuable exercise to encourage the students to investigate the differences themselves, time permitting of course!

Passive Solar Design

Buildings which use a number of principles (usually 5) to ensure a naturally comfortable building using energy from the sun. The five principles are; orientation of building, windows and shading, building materials, insulation and landscaping. Climate is also important, but unfortunately there is not much that designers can do to influence that! Passive designs are usually ones which utilise the building design as a combined solar collector and thermal storage facility. Heat is transferred through the building by natural means without the use of mechanical devices.

Active Solar Design

Buildings which involves Active Solar Design usually incorporate the elements of passive design as well as the inclusion of roof mounted solar collectors, below ground storage tanks and mechanical devices to ensure that heat is circulated throughout out the house after being collected on the roof.

Energy Efficient Designs

These buildings usually include the elements of passive or active solar design to provide a naturally comfortable home all year round, but also ensure that appliances and fixtures throughout the house are also energy efficient, through the use of five star energy rated appliances and compact fluorescent lights.

Solar Collectors

The common name of the panel attached solar hot water systems and other solar thermal devices (those which use the solar energy as a heating source). The panels consist of a glass top which allows the sunlight to penetrate into the collector which is then absorbed by the dark colours on the bottom of the panels. In the case of water heating, water is pumped through tubes which run through the panel. When the panels are used as a heating source in the building, air may be pumped through the tubes.

Solar Electric Panels/ PV Panels

Solar panels which use photovoltaic (PV) cells (either crystalline, polycrystalline or amorphous) to generate electricity from sunlight.

Cover Image

View of the North Facade of an Energy Efficient House designed by Baverstock and Associates and winner of the HIA Design for Climate 1987. (Courtesy of Western Power Coporation: A Naturally Comfortable Home)

Energy Efficient House?

In Australia, staying cool in summer and warm in winter can be a real problem, particularly for your house. Little things like where you plant your trees and whether you have insulation in your roof can make a big difference to how comfortable your house is to live in. You can use this simple checklist to help you determine the energy efficiency of buildings. Buildings which score less than 60 are not Energy Efficient Buildings!

	Feature	Design Points	Your Score
1	Insulation in the Roof	13	
1	Insulation in the Walls	7	
1	Living rooms on the North side of the House	10	
3	Kitchen, Bathroom and Laundry on South or West Side of House	1 point each	
1	Windows to living rooms shaded during summer	8	
2	Compact fluoroscent lights or Fluoro's used instead of tungsten filament globes	5	
1	Gas or wood heaters for winter	5	
	Electric heaters for winter	-5	
1	Solar hot water system	8	
2	Gas or wood hot water system	4	
1	Draftshields fitted to doors and windows	2 for doors 2 for windows	
2	Heated rooms can be closed off from rest of house	4	
2	Curtins or blinds have a pelmet or top cover	4	
2	Windows on East, West and North sides shaded during summer	1 point for each side of house	
	Windows on East, West and North sides shaded during winter	-2 for each side of house	
	East or West windows unshaded during summer	-5 for each side of house	
	Large windows facing East or West	-3 for each side of house	
	Windows always left open	-1 for each window	
	Lights left on when no one is home	-1	
	Airconditioner or heater left on when no one is home	-5	

Some of the features are marked with a little symbol which tells you how important that feature is in the design:

1 Features are Extremely important
2 Features are Very Important
3 Features are Important

Unfortunately, its not always practical or possible to use the sun when doing experiments, especially if its during the middle of winter. However, it is possible to construct a simple solar simulator that will do the same job.

Materials

Meter rule
Retort stand
100 - 150W light globe (spotlights work well!)

Method

1 To construct simulators that model the suns position in the sky at noon in the middle of summer, place the stand 18cm from the centre of the model, with the lamp at a height of 1m. This creates an 80° angle, which is approximately the altitude of the sun during this time.
2 To construct simulators that model the suns position in the sky at noon in the middle of spring/autumn, place the stand 38cm from the centre of the model, with the lamp at a height of 0.65m. This creates a 60° angle, which is approximately the altitude of the sun during this time.
3 To construct simulators that model the suns position in the sky at noon in the middle of winter, place the stand 87cm from the centre of the model, with the lamp at a height of 0.5m. This creates a 30° angle, which is approximately the altitude of the sun during this time.

Hints

- Don't forget to turn down any other lights in the room so that you don't get any unexpected shadows!

- If you don't have access to this equipment, try using an overhead project as your solar simulator

Better Than a Door?

Windows can be great to look out of and can provide wonderful natural sunlight into rooms during sunny days but on cold cloudy days they can let heat escape from a room up to 9 times faster than brick.

Things to Get

Clear plastic sheeting (from hardware stores)
Ruler
Scissors
Adhesive tape
Two cardboard boxes (corrugated cardboard works best)
Four thermometers

Things to Do

1. Cut a window in each of the boxes which is about 5 x 5 cm.
2. Cover one of the windows with the plastic sheeting on the outside and the window in the other box with plastic on both the inside and outside.
3. Make a small hole in the top of both of the boxes and carefully insert a thermometer into each box.
4. Tape a second thermometer to the outside of each box.
5. Turn the boxes upside down and place them with the windows facing the sun, or a solar simulator.
6. Record the temperatures inside the boxes two minutes for ten minutes.

Results

Box with one layer of plastic

Time
Inside Temp
Outside Temp

Box with two layers of plastic

Time						
Inside Temp						
Outside Temp						

The box with the hottest temperature inside was: . . . .

Would you expect that windows that are double glazed would be as effective in winter as they are in summer? Why?

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Extension Activities

Using the boxes that you used in the Better than a Door? activity, try testing the influence of curtains by covering the windows with material. You can test both light and dark coloured material on both of the windows to see the effect that good curtains has on the transfer of heat through windows.

Single Glazing, Dark Material

Time						
Inside Temp						
Outside Temp						

Single Glazing, Light Material

Time						
Inside Temp						
Outside Temp						

Double Glazing, Dark Material

Time						
Inside Temp						
Outside Temp						

Double Glazing, Light Material

Time						
Inside Temp						
Outside Temp						

The box with the hottest temperature inside was:

The box with the coolest temperature inside was:

If you were building a new house in Western Australia, what type of windows and curtains would you use? Why?

Just Scratching the Surface

Homes come in different shapes and sizes, some of them big, some of them small but does size really matter when you are trying to keep you house warm in winter or cool in summer?

1. Calculate the floor area, volume, surface area and volume to surface area ratio of the common house shapes on the just scratching the surface activity sheet
2. Answer the questions on the back of the activity sheet and determine which house design is the best at slowing the transfer of heat.

Shape	Dimensions	Floor Area (m^2)	Volume (m^3)	Surface Area (m^2)	Vol to Surf Area ratio
Square	h = 3m l=5m w=5m				
Ranch	h = 3m l=10m w=5m				
L Shaped	Same as ranch less a 3m x 2m chunk				
A Frame	h = 10m l=5m vh=5m				
Pyramid	h = 3m l=5m vh=5m				
Igloo	d = 10m vh=5m				
5 Storey Apartment	h = 15m l=5m w=5m				
2 Storey Townhouse	h = 8m l=5m w=5m				

How practical are each of the shapes as houses? Why?

What is the average floor area for the difference shapes?

Which of the floor plans has the greatest potential for reducing heat losses? Hint: Look at the Volume to Surface Area ratios!

Investigating Insulating

When you fill a container full of hot water in the morning to make a hot drink for lunch, you want to make sure that it stays warm, which is why you put it in a thermos or dewar flask. Alternatively, in the middle of summer you put your drinks in an esky to keep them cool.

Well, your house is just like a thermos or an esky, in winter you want to keep the insides warm and in summer you want the heat to stay out. What both the esky and the thermos have in the walls of the container is insulation material.

Things to Get

Beaker of boiling water
Two Cardboard boxes (one 2.5cm x 2.5cm smaller than the other one) with a small hole in the middle of each box for the thermometer to go through
Two thermometers
Foam, Shredded newspaper, Wool or other materials to test
Clock or stopwatch

Things to Do

1. Place the small box inside the larger box, making sure that the box is in the middle.
2. Stuff the gap between the two boxes with the first type of insulation material.
3. Turn the boxes upside down and carefully insert the thermometer through the holes in centre of the two boxes.
4. Tape the second thermometer to the outside of the larger box.
5. Fill a beaker with boiling, or very hot water.
6. Place the boxes over the beaker, making sure that the thermometer is not touching the beaker of water.
7. Record the temperature differences between the outside and inside of the box every two minutes for ten minutes.
8. From your results and those from the groups who used different materials, which of the materials would make the best insulator?

Results

Our groups insulation material was: . . . .
Table of Results:

Time						
Inside Temp						
Outside Temp						

The best insulation material from our class was: . . . .

Can you think of any materials which would not be good insulators? Why?

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Draught Detective

One of the biggest sources of heat loss in winter and cooling loss in summer is due to infiltration. Infiltration is what happens when the air from outside your house is coming in through gaps around windows and doors as well as unsealed parts of the house such as dog or cat doors, fireplaces and exhaust fans.

If your house is draughty, you can feel a lot colder than it actually is due to the wind chill factor. In a very draughty house, the air from the entire house can be replaced as often as once every fifteen minutes!

Things to Get

Plastic Food Wrap
Sticky Tape
Pencils

Things to Do

1. Construct a draft meter by cutting a 12x25cm strip of plastic wrap and tape one of the 12cm sides to a pencil.
2. Gently blow the plastic wrap to test how freely the plastic moves when air is blowing on it.
3. Hold or pin the draft meter near the edge of the window or door and watch to see if the plastic wrap moves.
4. Test all of the windows and doors around the room and draw up a floor plan, showing where all of the draughty areas are in the room with a cross (X).

Results

Draw your floor plan on the back of this page.

Things to Talk About

Why did we only test around the doors and windows for drafts?

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Is there anywhere that we should have tested?

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What can done to stop the drafts around the doors and windows?

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Does More Really Mean Less?

Almost every building is passively heated to some extent, just not always when you need or even want a hot house. Heat from the sun penetrates the roof and the walls of the buildings and is stored in the materials that make up the roof or wall.

Buildings which are made out of heat absorbing materials such as bricks and concrete are able to store lots of warmth in winter and yet remain relatively cool in summer because they have a high thermal mass. During winter, you can heat a house by allowing direct sunlight to shine onto the bricks and concrete where the heat can be stored. At night time, the heat is re-radiated from the bricks and the concrete providing warmth for the building. During Summer, it is important to shade the walls from direct sunlight so that the heat is not absorbed into the materials, thus allowing the house to remain cool.

Things to Get

Two Polystyrene foam or corrugated cardboard boxes lined with foam
Six dark coloured house bricks
Six blocks of wood (about the same size a house brick)
Six limestone or similar rocks (about the same size a house brick)
Twenty four, 2x2cm cubes of wood or similar material
Clear plastic sheeting
Adhesive tape
Thermometers
Sunlight or solar simulator
Graph paper

Things to Do

1. Place six bricks (or six pieces of the material your group has to test) into one of the boxes so that the sunlight will shine onto all of the objects.
2. Carefully tape a thermometer to the inside of the box, so that it is not in the direct sunlight, but so you can read it without disturbing your experiment too much.
3. Cover the front of the box with plastic sheeting so that you can trap the heat inside the box. This is the test box.
4. Cover the front of the second box with plastic sheeting, just as you did with the first box. This is your control box.
5. Place the test box out in the sun or under the solar simulator so that all of the bricks are exposed to the sunlight. Place the control box next to the test box, so that about the same amount of sunlight is entering the box.
6. Record the temperature of each of the boxes every two minutes for twenty minutes.
7. Graph your results on a piece of graph paper.

Results

The building material that we tested was: . . . .

Table of Results:

Time						
Control Box Temperature						
Test Box Temperature						

How can you explain the differences between the temperature of your control box and your test box?

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Compare your results to the results of groups with different building materials and complete the following table.

	Temperature		
Test Material	Start	End	Difference
Control			

Which of the materials that your group tested are the best absorbers of heat? (Hint: which material has the greatest difference between the inital and final temperatures)

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After you have graphed your results, look at the shape of the graph. What does the shape tell you about what is happening to the temperature inside the box?

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The Air Through There

Ventilation, or air movement is an important aspect of building design. If fresh air and breezes cannot travel through buildings regularly, they begin to heat up and smell! This activity looks at how quickly rooms can heat up if they are not properly ventilated.

Things to Get

Two polystyrene foam or corrugated cardboard boxes lined with foam
Clear plastic sheeting
Adhesive tape
Thermometers
Sunlight or solar simulator
Graph Paper

Things to Do

1. Carefully tape a thermometer to the inside of both of the boxes, so that they are not in the direct sunlight, but so you can read it without disturbing your experiment too much.
2. In one of the boxes, cut a 5cm x 15cm vent on the bottom of the box about 3cm away from one of the side walls.
3. Cover the front of this box and cut another 5 x 15cm vent in the plastic about 3cm from the wall directly opposite to the vent. This is the test box.
4. Cover the front of the second box with plastic sheeting without cutting a vent hole . This is your control box.
5. Place the test box out in the sun or under the solar simulator so that the sunlight is entering the box and the vent in the plastic is at the bottom. Place the control box next to the test box, so that about the same amount of sun light is entering the box.
6. Record the temperature of each of the boxes every two minutes for twenty minutes.
7. Graph your results on a piece of graph paper.

Results

Table of Results:

Time	
Control Box Temperature	
Test Box Temperature	

How can you explain the differences between the temperature of your control box and your test box?

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Which Colour is the Hottest?

Different colours are better at absorbing the heat from the sun than others, so the colour of the roof and walls of a building can significantly effect how easy it is to keep your house naturally comfortable.

Things to Get

5 clear plastic drink bottles
Aluminium foil
White paper
Black material
Red material
5 Thermometers
Plasticine

Things to Do

1. Cover one of the clear plastic bottles with aluminium foil so that only the neck of the bottle is exposed.
2. Cover three of the remaining four bottles with the white paper, black material and the red material in the same way that you covered the first bottle.
3. Cover the tops of all of the bottles with plasticine so that the air inside the bottle cannot escape.
4. Carefully, insert a thermometer through the plasticine in each of the bottles so that the bottom of the bulb of the thermometer is about half way in the bottle.
5. Place the bottles out in the sun.
6. Record the temperatures inside each of the bottles every two minutes for about fifteen minutes.

Results

Record your temperatures in the following table:

	Temperature							
Colour	Start	2	4	6	8	10	12	End

Which of the colours do you think is the best at absorbing the light from the sun? Why?

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Perth has a temperate climate with warm to hot summers and mild winters. Given the results from your table, what colour roof would be most suitable for a house in Perth? Why?

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You decide to build a holiday home in Antarctica. What colour bricks and roof would be most suitable to the cold, snowy climate of the Mawson base? Why?

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Compact Fluoroscents

One of the easiest ways to increase the energy efficiency of a building is to install Compact Fluorescent Lamps (CFLs) instead of the traditional incandescent, or tungsten filament globes.

CFLs are mini versions of the fluorescent lights that are used in shops and classrooms, which have screw or pin fittings so that they can fit inside your regular light fittings. But how do they compare in cost to traditional light globes?

Incandescent globes last on average 1000 hours and cheaper versions cost about 70c. However, CFLs have a lifetime of around 8000 hours but they cost around $20 per light but only use a small proportion of electricity to give the same brightness as an incandescent globe (a 75W incandescent globe can be replaced by a 15W CFL for the same brightness!) .

Things to Get

Compact Fluorescents activity sheet
Calculator

Things to Do

1. Using the information contained on this sheet, calculate the cost of running a CFL for 8000 hours, including the purchase price and electricity usage and record in the table.
2. Now calculate the cost of running enough incandescent globes to last the same length of time, including the purchase price of each globe and the cost of the electricity. Record these results in the table.
3. Graph your results on one graph, starting off each line at the purchase price of the globe. For the incandescent globes graph, place a step equal to the cost of a globe each time you needed to replace the globe.

Hints

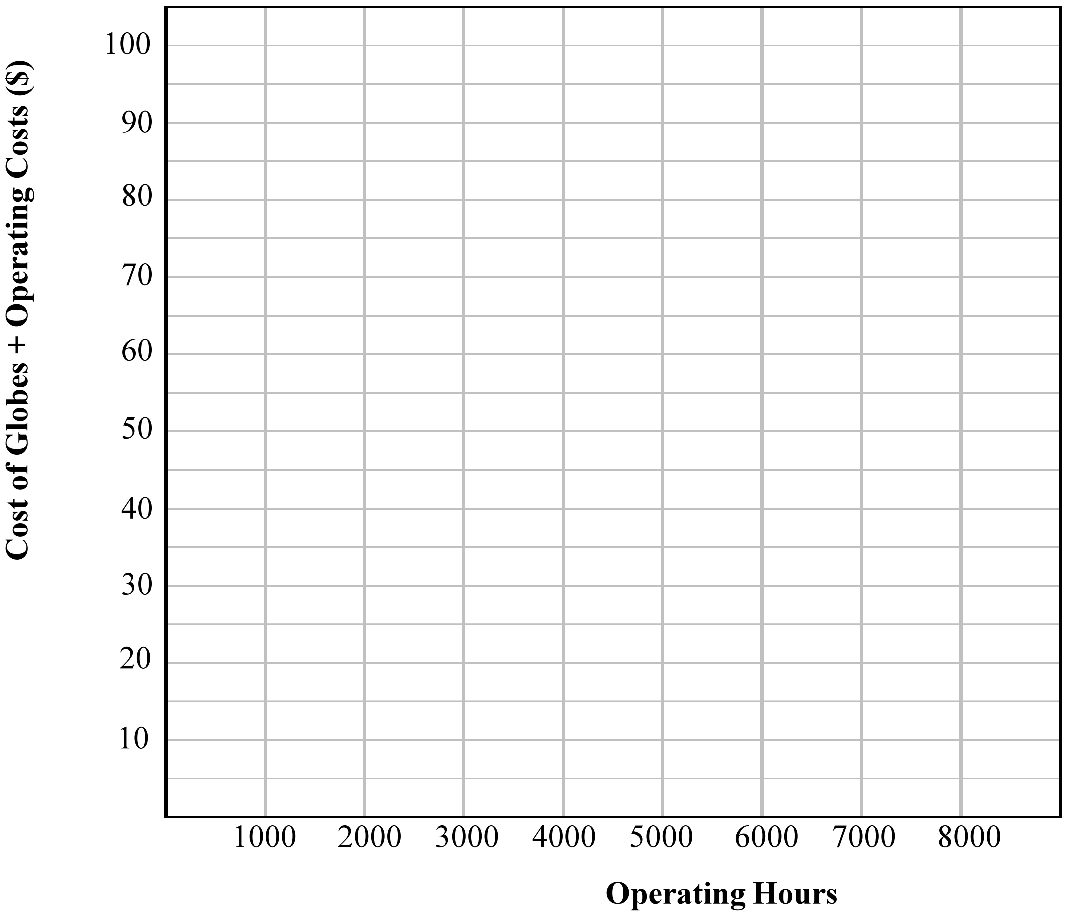
- Electricity in WA costs 12.75c/kW, so total cost over life time of globe is:

$$\text{cost (\$)} = \left[\frac{\text{(number or hours x wattage of the globe)}}{1000} \times \frac{12.75}{100} \right]$$

Results

Operating costs table:

	Purchase Cost	Number of Globes	Electricity Cost	Total Cost
CFL				
Incandescent				



Over 8000 hours, the lifetime of the CFL, which globe was the most economical?
What is the cost saving? (The difference between the two globes))

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If the operating time of the globes was 5 hours per day, how long would the globes last (in years)?

Incandescent: . . . . CFL: . . . .

What is the payback time of a Compact Fluorescent Lamp? (a payback time is the time when the total cost of the CFL is equal to the total cost of the incandescent globe)

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Can you think of any places around the house where it might be cheaper to use incandescent globes?

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Green Architects

Architects are the people who are responsible for designing buildings and today, many of them are beginning to realise that passive solar design and energy efficiency can save their clients thousands of dollars in electricity usage as well as contributing to the abatement of greenhouse gases.

Using the principles of energy efficient housing and the **Energy Efficient House** Design Checklist, design and build your very own model of an energy efficient home based on the following specifications:

- 4 bedrooms
- two bathroom
- games room
- lounge room
- dining room
- Windows in each room with external wall
- three external doors (one main, one laundry, one sliding glass)
- Verandah and pergola
- Fireplace or slow combustion wood stove
- brick and tile house

1. Write a project description, outlining the areas suggested in the Hints section and any others that may be important. (250 words)
2. Draw a floor plan for your house and include the dimensions of the rooms.
3. Construct your home using materials which you have available, carefully labelling what each of the materials will be if you were to build that house.

Hints

Don't forget to include type of building materials, climate, lighting, windows and shading, insulation, landscaping, hot water system and a double carport!

More Green Architects

Unfortunately, there aren't too many homes built by major home builders who take energy efficiency into account when they are designing homes. However, little things can make all the difference between a naturally comfortable home and an uncomfortable one.

Things to Get

Floor Plan from a project home advertised in the paper
Energy Efficient House? Design Checklist

Things to Do

Using the principles of energy efficient housing, modify the design of a project home so that it would be an Energy Efficient House on the Design Checklist and be considered as an Energy Efficient home.

Hints

Don't forget to include building materials, orientation, insulation, landscaping, hot water system and the double carport in your modifications!

Things to Talk About

What kinds of things did you need to do to the house plan to make it an energy efficient house?

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If this house was built on the block that your house is currently built on, with the same orientation, would it be energy efficient?

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Compare your plan to others in the class. What can you say about the energy efficiency of project homes being advertised?

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Energy Sleuth

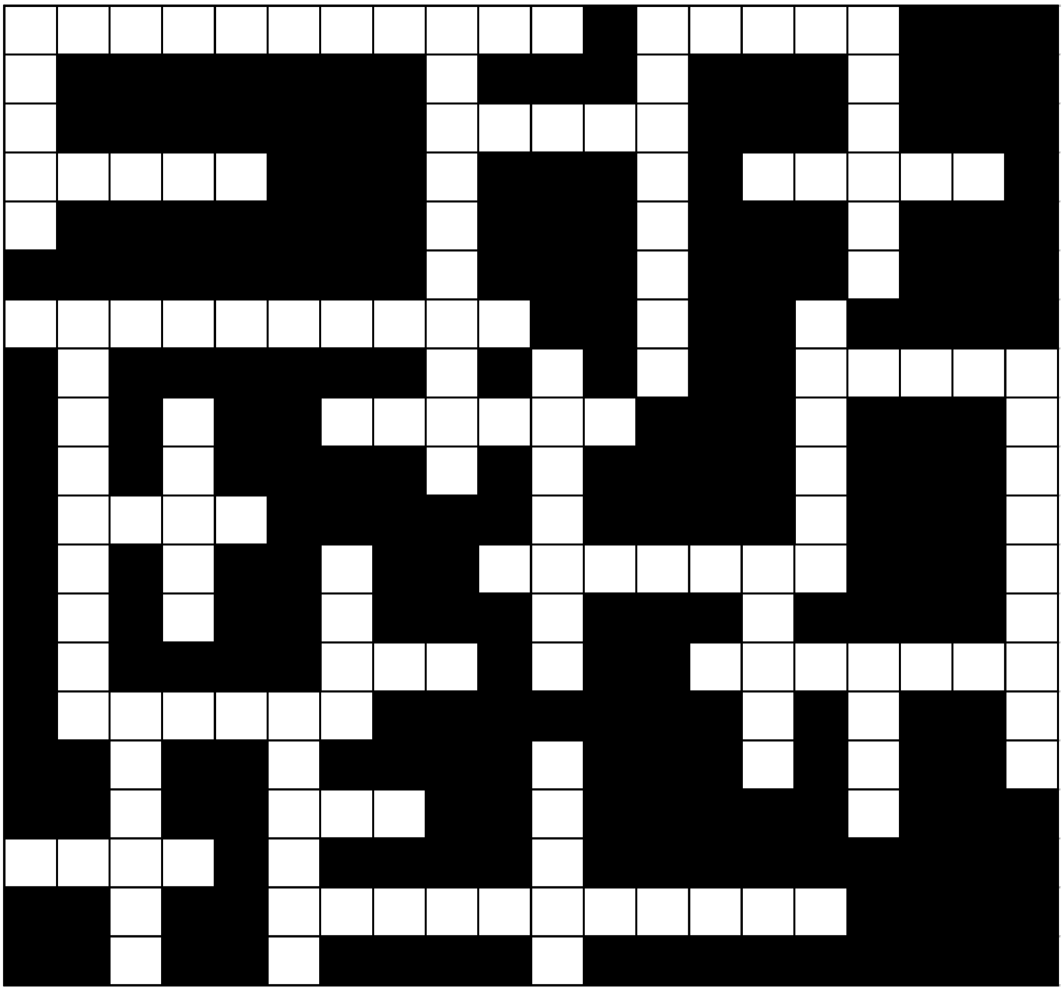
Now that you know all about designing houses which are energy efficient and use the passive solar design, lets see how you go at solving the puzzle!

Across

1 This factor in energy efficient design involves how you plant your trees and shrubs
3 These Arctic bears are very efficient solar collectors!
5 The type of energy that comes from the sun
6 What you live in
7 About this much energy is used in heating water
8 These people design houses and buildings
12 There is a 'hole' in this gas over the south pole, where it is very thin
15 and 11 Down This is also known as the Greenhouse Effect
16 A type of renewable energy and what causes drafts
18 see 24 Down
20 We get solar energy from this
21 _____________ Solar Design
26 The Greenhouse _____________
27 This place in South America was the host for the 1992 Earth Summit
28 The sun sets in this direction
29 This factor in energy efficient design involves how you place your house on the block

Down

1 These coloured materials are best at reflecting the summer sun
2 This factor in energy efficient design involves what you put in the roof to keep the house warm in winter and cool in summer
3 These Egyptian buildings use large thermal mass to keep them naturally cool all year round
4 The House Energy __________ Scheme
9 Solar, Wind, Biomass and Geothermal are all examples of ____________ Energy
10 This type of glazing on windows will make your house more efficient
11 See 15 Across
13 Houses that use the least amount of energy are known as Energy __________
14 This planet has a runaway greenhouse effect and is known as the evening star
17 The sun rises in this direction
19 This type of breeze sneaks in through cracks around doors and windows
22 You can __________ lots of money by building an energy efficient home
24 Coal, Gas and Petrol are all forms of _______ fuels
25 This gas is the major greenhouse gas
26 This type of insulation comes in pink or yellow flat rectangles of cellulose



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