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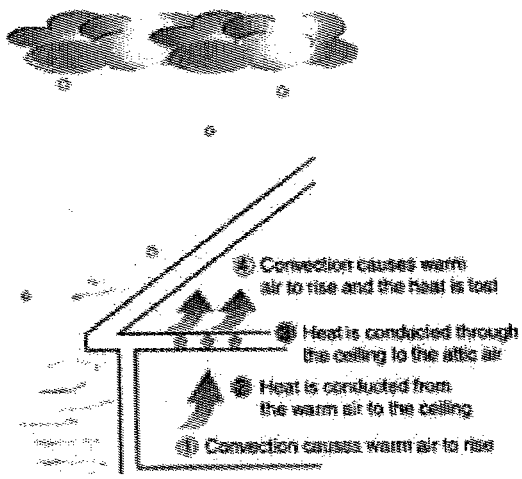
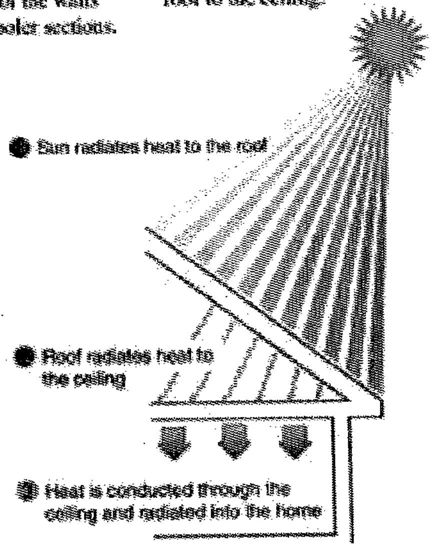
UNIT = 5

Your Home Loses and Gains Heat in 3 Ways

	Convection	Conduction	Radiation
Definition:	The transfer of heat by moving air.	The transfer of heat through a solid material.	The transfer of heat in the form of electromagnetic waves.
Example:	Warm air rises and transfers heat to the ceiling	Heat is transferred from warmer sections of the walls and ceilings to cooler sections.	Heat is transferred from the roof to the ceiling.





CONDUCTIVITY

- Heat flow in conduction takes place through bodies in direct contact, the molecular movement constituting the flow of heat.
- The rate at which such molecular movements spreads varies with different materials and is described as a property of materials called **thermal conductivity (k-value)**
- **Thermal conductivity** (or **'k-value'**) is defined as the rate of heat flow through unit area of unit thickness of the material, when there is a unit temperature difference between the two sides.

CONDUCTIVITY & RESISTIVITY

- The unit of measurement is **W/m degC.**
- Its value varies between 0·03 W/m degC for insulating materials and up to 400 W/m degC for metals.
- The lower the conductivity, the better insulator a material is.
- **Resistivity** is the reciprocal of this quantity (1 /k) measured in units of: **m degC/W.**
- Better insulators will have higher resistivity values.

CONDUCTANCE & RESISTANCE

Whilst conductivity and resistivity are properties of a material, the corresponding properties of a body of a given thickness are described as conductance (C), or its reciprocal resistance (R).

C = 1/R

Conductance is the heat flow rate through a unit area of the body when the temperature difference between the two surfaces is 1 degC. The unit of measurement is **W/m² degC.**

Resistance of a body is the product of its thickness (b) and the resistivity of its material:

R = b x 1/ k = b/k

It is measured in **m² degC/W.**

SURFACE CONDUCTANCE

- Along with the body, the surface of a material offers a resistance as well, where a thin film of air separates the body from the surrounding air: **Surface or thin film resistance.**
- Surface conductance is taken to be 'f', so surface resistance will be taken as 1/f.
- It includes convective and radiant components of the heat exchange at surfaces.

CONVECTION

In convection, heat is transferred by the bodily movement of a carrying medium, usually a gas or a liquid.

The rate of heat transfer in convection depends on three factors:

- temperature difference (difference in temperature of the medium at the warmer and cooler points)
- the rate of movement of the carrying medium in terms of kg/s or m^3/s
- the specific heat of the carrying medium in J/kg degC or J/m^3 degC

These quantities will be used in ventilation heat loss or cooling calculations.

RADIATION

In radiation heat transfer, the rate of heat flow depends on the temperatures of the emitting and receiving surfaces and on certain qualities of these surfaces: the **emittance** and **absorbance**.

Radiation received by a surface can be partly absorbed and partly reflected: the proportion of these two components is expressed by the coefficients **absorbance (a)** and **reflectance (r)**.

The sum of these two coefficients is always one: $\mathbf{a + r = 1}$

Light coloured, smooth and shiny surfaces tend to have a higher reflectance.

For the perfect reflective theoretical white surface: $r = 1$, $a = 0$.

The perfect absorber, the theoretical 'black body', would have the coefficients: $r = 0$, $a = 1$.

U- VALUE

- A U value is a measure of heat loss in a building element such as a wall, floor or roof.
- It can also be referred to as an 'overall heat transfer co-efficient' and **measures how well parts of a building transfer heat**.
- This means that the **higher the U value the worse the thermal performance** of the building envelope. (Less insulation)

U- VALUE

- **A low U value usually indicates high levels of insulation.**
- They are useful as it is a way of predicting the composite behaviour of an entire building element rather than relying on the properties of individual materials.
- U values are important because they form the **basis of any energy or carbon reduction standard.**

U- VALUE

- The U value is defined as being reciprocal of all the resistances of the materials found in the building element.
- The resistance of a building material is derived by the following formula:

  R = (1/k) x d

  where **k** is the conductivity of the building material and d is the material thickness.

- The formula for the calculation of a U value is

  U(element) = 1 / (Rso + Rsi + R1 + R2 ...)

  where **Rso** is the fixed external resistance
  where **Rsi** is the fixed internal resistance
  and **R1**... is the sum of all the resistances of the building materials in the constructional element.

- Thermal resistance (R) and thermal conductance (C) of the materials are reciprocals of one another and can be derived from thermal conductivity (k) and the thickness of the materials.
- **Thermal conductance**
  A measure of the ability of a material to transf er heat per unit time, givenone unit area of th e material and a temperature gradient throug h thethickness of the material.

k-value – Thermal Conductivity

Thermal conductivity is the time rate of steady state heat flow through a unit area of a homogeneous material induced by a unit temperature gradient in a direction perpendicular to that unit area, W/m-K.

(1)

$$k = q\frac{L}{\Delta T}$$

Where,

L – Thickness of the specimen (m)

T – Temperature (K)

q – Heat flow rate (W/m2)

R-value – Thermal Resistance

Thermal resistance is the temperature difference, at steady state, between two defined surfaces of a material or construction that induces a unit heat flow rate through a unit area, K m2/W. According to this definition and Equation 1, Equation 2, therefore, can be obtained.

As indicated in Equation 2, the value of the thermal resistance can be determined by dividing the thickness with thermal conductivity of the specimen.

(2)

$$R = \frac{\Delta T}{q} = \frac{L}{k}$$

C-value – Thermal Conductance

Thermal conductance is the time rate of steady state heat flow through a unit area of a material or construction induced by a unit temperature difference between the body surfaces, in W/m2-K. C-value, hence, is the reciprocal of the R-value and can be expressed as Equation (3).

(3)

$$C = \frac{q}{\Delta T} = \frac{1}{R} = \frac{k}{L}$$

Consequently, the value of the thermal conductance can be calculated by dividing the thermal conductivity with the thickness of the specimen.

Climate Design

Design for climate:

Design for climate requires that homes be designed or modified to ensure that the occupants remain thermally comfortable with minimal auxiliary heating or cooling in the climate where they are built. Passive design — working with the climate, not against it — is an important component, as are energy efficient heating and cooling systems, and smart behaviour by the occupants.

Approximately 40% of household energy is used for heating and cooling to achieve thermal comfort. This rate could be cut to almost zero in new housing through sound climate responsive design and, indeed, should be our aspirational goal. Taking into account current consumer preferences and industry practices, halving the rate to 20% is a highly achievable in the short term.

The 40% of household energy used for heating and cooling to achieve thermal comfort could be cut to almost zero in new housing through sound climate responsive design.

Reducing or eliminating heating and cooling needs in existing homes is a significant challenge, particularly those designed and built before building energy efficiency standards were introduced, when appliances were effective but inefficient. Based on 1.5% annual renewal rates, at least 50% of our current housing stock will still be in service in 30 years' time.

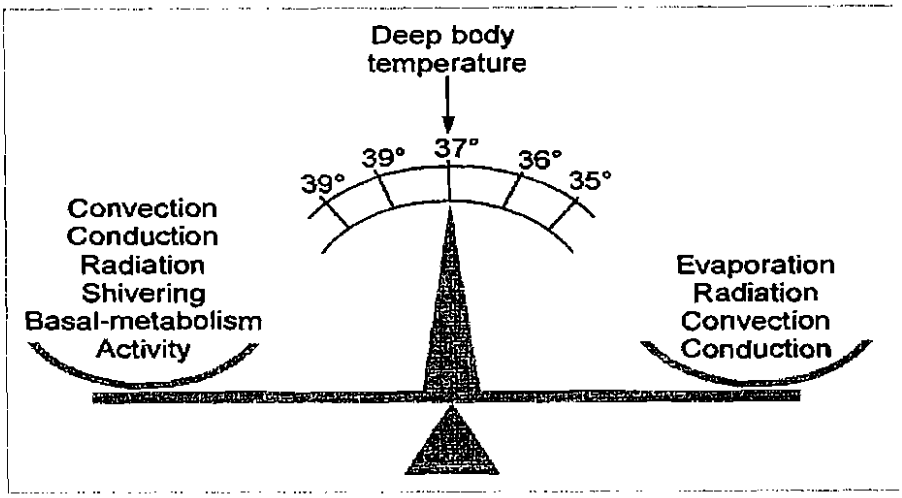
New homes built now will be in service in future times when we expect to see significant changes in the climate. Designing for today's climate is important; ensuring that those designs can be just as efficient after 30 years of climate change would certainly be desirable.

Affordability is often cited as the main barrier to greater efficiency but increasing energy costs are rapidly shifting the affordability focus from initial or upfront cost to ongoing or operational cost. With this shift, high levels of thermal performance are becoming increasingly valuable and the payback or amortisation period for thermal performance upgrades is diminishing rapidly.

This introductory overview of key design objectives and responses to creating thermally comfortable homes in each main climate zone in Australia needs to be further refined and customised to your individual site, locality and design brief. Use this overview, and the references to other articles, to access more detailed information as you proceed through the various stages of designing, purchasing or altering your home.

Human thermal comfort

Humans are comfortable only within a very narrow range of conditions. Our body temperature is about 37°C, despite the fact that the body generates heat even while at rest: we must lose heat at the same rate it is produced and gain heat at the same rate it is lost. The diagram below shows the various ways by which our bodies achieve this.



Source: Steve Szokolay

Human thermal comfort has two components: psychological and physiological. Both are governed by the processes in the diagram but reach the brain and trigger responses by very different pathways. Both needs must be met before we feel truly comfortable.

The main factors influencing both physical and psychological human comfort are:

- temperature
- humidity
- air movement (breeze or draught)
- exposure to radiant heat sources
- exposure to cool surfaces to radiate, or conduct to, for cooling.

Thermal simulation software can model with great accuracy the amount of heating or cooling energy required to achieve physiological comfort; it is unable to model highly variable human perceptions of comfort.Sound building envelope design based on modelling delivers an environment that addresses all the physical factors necessary for comfort (except humidity) but can't always meet our psychological comfort needs.

Important triggers for psychological discomfort are radiation, air movement and conduction. Although they are less effective physiologically, they trigger innate self-preservation responses that override our ability to perceive physical comfort. Until they are met, we don't feel thermally comfortable and our behaviour can render the best of design solutions ineffective. Acclimatisation is a critical component of psychological comfort.

Psychological thermal discomfort can make us set the thermostat on heating or cooling systems well beyond levels required for comfort. For every 1°C change in thermostat setting, it is estimated that our heating or cooling bill rises by around 10%. In other words, failure to address psychological comfort can increase heating and cooling energy use by up to 50% (Australian Greenhouse Office 2005).

Losing body heat

We lose heat in three ways: through evaporation, radiation and conduction.

Our most effective cooling method is the evaporation of perspiration. High humidity levels reduce evaporation rates. When relative humidity exceeds 60%, our ability to cool is greatly reduced.

Evaporation rates are influenced by air movement. Generally, a breeze of 0.5 m per second provides a one-off comfort benefit equivalent to a 3°C temperature reduction.

We also lose heat by radiating to surfaces cooler than our body temperature, such as tiled concrete floors cooled by night breezes or earth coupling. The greater the temperature difference, the more we radiate. While not our main means of losing heat, radiation rates are very important to our psychological perception of comfort.

A third way to lose heat is conduction, i.e. through body contact with cooler surfaces such as when going for a swim or sleeping on an unheated waterbed. Conduction is most effective when we are inactive (e.g. sleeping) and is a particularly important component of psychological comfort.

Gaining body heat

When the heat produced by our bodies is insufficient to maintain body temperature, we shiver. This generates body heat and has a short-term physiological effect but also triggers our deepest psychological discomfort warning mechanisms. Our first response is generally to insulate ourselves by putting on more clothes and sheltering from wind and draughts. These actions are effective because we generate most of the heat we require from within, and reducing heat loss makes body heat more effective. Our minds quickly decide whether the adjustment is adequate for thermal comfort.

A secondary source of heat gain is radiation. As with cooling, radiation is very important to our perception of comfort. For example, we can feel cold in a room that is a comfortable 22°C if there is a cold window nearby; conversely, we can feel warm at 0°C if we are well insulated with warm clothing and standing in the sun.

The final source of heat gain is conduction. Simply holding someone's hand can create psychological thermal comfort though a small amount of conduction. We conduct to cool floors and from heated floors. Heated floors also provide radiant heat and raise air temperatures through conduction and convection.

Building thermal comfort

The Nationwide House Energy Rating Scheme (NatHERS) uses computer simulations to assess the potential thermal comfort of Australian homes on a scale of zero to 10 stars. The more stars, the less heating or cooling energy is likely to be required to keep the occupants comfortable. The computer simulations take into account standard occupancy patterns, climate, season and envelope design but not psychological comfort.

A thermal comfort rating reveals only the energy performance of a building's design and fabric: it does not measure other areas of energy consumption (e.g. appliance efficiency, transport costs, embodied energy). In warmer climates, these variables can account for more energy consumption during the life span of a home than the performance of the envelope. The rating is also based on the combined heating and cooling energy required over a year, but the proportions of heating and cooling required varies across climate zones. For that reason, both heating and cooling options are addressed in the overviews of climate responsive design strategies below.

Zone	Description
1	Hot humid summer, warm winter
2	Warm humid summer, mild winter
3	Hot dry summer, warm winter
4	Hot dry summer, cool winter
5	Warm temperate
6	Mild temperate
7	Cool temperate
8	Alpine

Zone 1: Hot humid summer, warm winter

Main characteristics

High humidity with a degree of 'dry season'

Moderate to high temperatures year round

Low to moderate seasonal temperature variation

Minimal diurnal (day–night) temperature range

Key design objectives

Homes in these climates use substantially more energy to achieve thermal comfort than homes with the same NatHERS star rating in more benign climates. It is therefore imperative to use design strategies that reduce cooling energy use to achieve similar carbon reductions. For example, a 6 star house in Darwin uses more than double the energy of a 1 star house in Brisbane, and a 9 star house in Wyndham (WA Kimberley region) uses about the same as the Brisbane 1 star house.

One of three distinctly different design approaches should be chosen at the outset of the design process. Each produces a very different solution that is often difficult to change in the future.

- **Free running**: These buildings should not be conditioned (mechanically heated or cooled). Abundant air movement from fans, whirlybird ventilators, stack ventilation and cross-ventilation is essential.
- **Conditioned**: These buildings must be well insulated and able to be made airtight while conditioning is running. Both inward and outward condensation issues should be addressed.

- **Hybrid design**: These buildings include air conditioned, insulated core rooms in the centre of the house (e.g. a TV room) for peak discomfort periods, surrounded by free running spaces.

Unconditioned sleeping comfort is a critical design consideration in both conditioned and hybrid design approaches.

Key responses

Design considerations

- Orientate the building to take full advantage of cooling breezes, and position landscaping and outbuildings to funnel breezes over, under and through the building (see Orientation and Passive cooling).
- Prioritise design for night-time sleeping comfort. Consider sleep-out spaces.
- Provide shaded outdoor living areas.
- Locate pools and spas on the northern side of the building where they are shaded in the hot humid season and warmed during the dry season.
- Install ceiling fans in all rooms.

Windows and shading

- Shade all windows and walls, including south facing, with extended eaves where possible or vertical shading where not.
- Use low solar heat gain coefficient (SHGC) glazing (see Glazing).
- Use multiple layers of reflective roof and ceiling insulation to create a one-way valve effect.
- Insulate internal wall surfaces well from any external thermal mass (e.g. brick veneer).
- Exclude solar radiation from roof, windows and walls (see Shading).
- Consider shading the whole building with a fly roof (see Passive cooling).

Insulation

- Refer to Insulation for appropriate insulation levels in each climate zone.
- Avoid bulk insulation to ceilings and walls except in conditioned spaces.
- Ventilate roof spaces well with fans or whirlybirds and design for condensation removal (see Passive cooling).
- Insulate elevated floors with reflective, closed-cell bulk insulation to resist upward heat flow and condensation.
- Line open ventilated spaces with reflective foil insulation.

In conditioned buildings

- Avoid overuse of glazing.
- Use the highest energy rated conditioning appliances and install smart control systems and a variable output speed compressor to maximise efficiency (see Heating and cooling).
- Condition only critical rooms in preference to the entire house.
- Design air conditioned spaces to be sealed off, preventing loss of cooling when running.
- Design to accommodate both inward and outward condensation (wherever humid warm air first meets a cooler surface).
- Use low U-value glazing to avoid ambient or conducted heat gain or cooling loss (see Glazing).
- Provide ceiling fans in conditioned spaces — they provide effective cooling when conditioning lowers humidity.
- Use internal thermal mass walls surrounding conditioned central cores for radiant cooling of adjoining unconditioned sleeping spaces.

In free running buildings

- Encourage natural air flow with large, high level openings.
- Use only 100% openable windows such as louvre or casement.
- Locate sleeping spaces in lower levels.
- Use low or no thermal mass finishes in sleeping spaces to prevent radiant heat at bed-time.
- Maximise external wall areas (plans with one room depth are ideal) to encourage cross-ventilation.
- Elevate building to permit air flow beneath floors.

Construction systems

- Use lightweight (low mass) construction (see Thermal mass).
- Use light coloured reflective materials externally.
- Design and build for cyclonic conditions.

Zone 2: Warm humid summer, mild winter

Main characteristics

High humidity with a definite 'dry season'

Hot to very hot summers with mild winters

Distinct summer/winter seasons

Moderate to low diurnal (day–night) temperature range, which can vary significantly between regions (e.g. inland to coastal)

Key design objectives

Eliminate auxiliary heating and substantially reduce cooling with appropriate passive design.

Key responses

Design considerations

- Always site for exposure to cooling breezes and design for cross-ventilation.
- Use thinner plans and design openings to encourage movement of breezes through and within the building (see Passive cooling).
- Always design for night-time sleeping comfort.
- Provide screened and shaded outdoor living areas.

Windows and shading

- Avoid overuse of glazing.
- Use low SHGC glazing in all cases and low U-value glazing in regions with cooler winters or hotter summers (see Glazing).
- Shade all east and west-facing walls and glass year round (see Shading).
- Shade south-facing walls north of the tropic of Capricorn.
- Use appropriate levels of passive shaded north-facing glass as heating requirements increase in more southerly and inland regions.
- Use 100% openable windows area such as louvre or casement.

Insulation

- In areas where no winter heating is required, use multiple layers of reflective foil in ceiling/roof to create a one-way valve effect.
- Insulate internal wall surfaces from any external thermal mass (e.g. brick veneer).
- Refer to Insulation for recommended minimum insulation levels.
- Use highly breathable reflective vapour barriers in walls and add bulk insulation to rooms that are air conditioned.
- Use roof spaces to provide heat loss/gain buffer zones by ventilating them in summer and sealing them in winter with fans or 'smart' ventilators (see Passive cooling).
- Line open ventilated spaces with reflective foil insulation and design to remove condensation.
- Avoid installing bulk insulation in ceilings and walls unless winter heating is used.

- Choose light coloured roof materials.
- Calculate thermal lag in high thermal mass walls such as rammed earth or mud brick to determine appropriate insulation levels.

Zone 7: Cool temperate

Main characteristics

Low humidity, high diurnal (day–night) temperature range

Four distinct seasons: summer and winter exceed human comfort range; highly variable spring and autumn conditions (range increasing with climate change)

Cold to very cold winters with majority of rainfall (decreasing with climate change)

Hot dry summers (increasing with climate change)

Key design objectives

Homes in these climates use substantially more energy to achieve thermal comfort than homes with the same NatHERS star rating in more benign climates. An 8 star or better level of thermal performance is required to achieve life cycle carbon reductions equivalent to other zones.

Designers often include large north-facing windows to maximise solar gains in these climates, which can make double glazing very expensive. However, double glazing is recommended in this climate because on each winter's day there are 19–20 hours of heat loss through glass with a maximum of 4–5 hours of heat gain. The glass to mass ratios in Thermal mass indicate appropriate glazing levels in relation to exposed thermal mass. Exceeding these ratios can lower thermal performance and increase initial and operational costs.

Key responses

Design considerations

- Apply best practice passive solar design principles where access to sunlight permits. Use high glass to mass ratios.
- Consider climate change when choosing type, location and quantity of thermal mass.
- Maximise the use of north-facing walls and passively shaded glazing.
- Locate living areas on the north, bedrooms and service areas on the south.
- Minimise external wall areas, especially east and west.
- Use cross-ventilation and night-time cooling in summer.
- Avoid high ceilings and provide airlocks between lower and upper floors.

- Design for controllable (zoned) convective air movement throughout the house to distribute heat while minimising draughts and temperature stratification.
- Site new homes for solar access, exposure to cooling breezes and protection from cold winds.
- Where passive solar access is unavailable, minimise all glass areas and limit thermal mass except where exposed to heating sources.
- Design furniture layouts to minimise exposure to convection draughts.
- Ventilate roof spaces in summer and seal them in winter (use automated fans or closable roof ventilators).
- Install carbon efficient auxiliary heating.
- Use renewable energy sources.

(see also Passive solar heating; Passive cooling; Thermal mass; Orientation; Renewable energy)

Windows and shading

- Avoid overuse of glazing.
- Careful sizing and orientation of windows is essential.
- Use high SHGC, low U-value double glazing.
- Specify insulating or thermally improved frames.
- Design and detail for preventing window condensation.
- Passive solar shading to northerly windows is essential.
- Minimise and shade all east and west-facing glass in summer (see Shading).
- Consider using adjustable shading to some west-facing glass areas to boost afternoon solar heat gains in winter and allow variable solar access in spring and autumn.

Insulation

- Use bulk insulation in walls, ceilings and exposed floors.
- Use heavy drapes with sealed pelmets to insulate glass in winter.
- For walls use bulk insulation with highly breathable sarking or multiple layers of reflective foil insulation, with detailed design to ensure condensation discharge.
- Insulate all thermal mass externally (including rammed earth and mud brick).
- Use high levels of bulk insulation in ceilings and line underside of roofing material with down-facing reflective foil.
- Use closed cell reflective insulation in preference to compressed bulk insulation where supplier recommends an anti-condensation layer under roof material.
- Insulate all elevated floors (concrete and lightweight).
- Insulate slab edges.
- Insulate under concrete slabs if using in-slab heating.
- Provide airlocks to entries.

- Effectively air seal all spaces (see Sealing your home).
- Refer to Insulation for recommended optimal insulation levels.

Heating and cooling

- Even 10 star homes in the more extreme regions of these climates might require some auxiliary heating for psychological comfort.
- Lower rated homes will require heating.
- High level passive or active solar heating is highly desirable where available.
- Well-designed active solar energy systems with substantial heat storage capacity or an efficient heat pump (ground, water or air source) are the most carbon efficient (see Heating and cooling).
- Wood heating, although it is carbon neutral, has negative health and biodiversity impacts and should be avoided in built-up areas.
- Well-positioned, adequately heated thermal mass will provide sufficient thermal comfort in bedrooms (sleeping comfort is less of an issue in cool or cold climates).
- Cooling is unnecessary with good cross or closable ventilation and ceiling fans in living and sleeping spaces.

Construction systems

- Earth coupled slabs are beneficial except where 3m earth temperatures are below 16°C in winter (e.g. Tasmania). Insulate under the slab or use insulated, lightweight floors in these regions.
- Use low thermal mass walls on sites with no solar access.
- Use lightweight wall construction where diurnal temperature ranges are low (e.g. Hobart) and increase thermal mass and solar exposed glass as they increase above 6°C.
- Choose light coloured roof materials.

Zone 8: Alpine

Main characteristics

Low humidity, high diurnal temperature range

Four distinct seasons: winter exceeds human comfort range and will likely continue to do so under climate change

Cold to very cold winters providing majority of rainfall; some snow

Warm to hot, dry summers; highly variable spring and autumn conditions

Key design objectives

Homes in these climates have the highest thermal comfort energy use of any climate zone. For example, a 6 star house in Cabramurra uses more than double the energy of a 1 star house in Sydney's eastern suburbs and around the same energy as a 3 star house in Canberra.

Therefore, an 8 star or better thermal performance is imperative to match the life cycle carbon reductions of other zones. Because the need for cooling is low, design strategies can focus on heating energy use.

Key responses

Design considerations

- Apply best practice passive solar design principles where solar access is available.
- Use highest glass to mass ratios.
- Consider not building on sites without good access to sunlight.
- Maximise north-facing walls and passively shaded double glazing.
- Locate living areas on north; bedrooms and service areas on south.
- Consider multi-level designs that allow sunlight into all rooms while maintaining a compact form.
- Minimise external wall areas, especially east and west.
- Ensure the interior is airtight and consider a heat-recovery ventilation system.
- Opening windows usually provides adequate ventilation and night-time cooling in summer.
- Avoid high ceilings and provide airlocks between lower and upper floors.
- Design for controllable (zoned) convective air movement throughout the house to distribute heat while minimising draughts and temperature stratification.
- Site new homes for optimum access to sunlight and protection from cold winds.
- Design furniture layouts to minimise exposure to convection draughts and maximise exposure to radiant heat.
- Seal roof spaces.
- Install carbon efficient auxiliary heating.
- Use off-site renewable energy sources like GreenPower to compensate for snow related inefficiencies and maintenance.

(see also Passive solar heating; Thermal mass; Orientation; Heating and cooling; Renewable energy)

Windows and shading

- Use high SHGC, lowest U-value double glazing.
- Avoid overuse of glazing.
- Careful sizing and orientation of windows is essential.
- Specify thermally improved or insulated frames (timber or PVC).

- Design and detail for high levels of window condensation
- Minimise and shade all east and west-facing glass in summer (see Shading).
- Consider using adjustable shading on west-facing glass areas to boost afternoon solar heat gains and allow variable solar access in spring and autumn.
- Avoid east-facing glazing where fog limits winter solar gains but long periods of heat loss prevail.

Insulation

- Refer to Insulation for recommended optimal insulation levels.
- Bulk insulate all walls, ceilings and exposed floors.
- Consider using 150mm or 200mm deep studs to achieve higher rating wall insulation.
- Use additional layers of insulation fixed to frames to reduce thermal bridging.
- Detail and specify insulation provisions carefully and supervise installation.
- Use heavy drapes with sealed pelmets to insulate glass in winter.
- Consider double drapes or tight fitting airtight blinds behind drapes.
- Externally insulate all thermal mass to high levels, especially rammed earth and mud brick.
- Use highest levels of bulk insulation in ceilings.
- Line underside of roofing material with downward-facing, closed cell, foil-coated bulk insulation to avoid loss of R-value through compression.
- Insulate all elevated floors (concrete and lightweight) to highest level.
- Insulate slab edges and under concrete slabs.
- Provide airlocks to entries.
- Ensure all spaces are effectively air sealed (see Sealing your home).

Heating and cooling

- All homes in this zone require auxiliary heating for both physiological and psychological comfort.
- As heating is a major cost in these climates, the additional cost of 10 star design is quickly recouped.
- High level passive or active solar heating is essential for reducing auxiliary heating and creating psychological comfort.
- Well-designed active solar energy systems with substantial heat storage capacity or an efficient heat pump (ground or water source) are the most carbon efficient (see Heating and cooling).
- Wood heating, although it is carbon neutral, has negative health and biodiversity impacts and should be avoided in built-up areas.

- Consider highly insulated first floor bedrooms that are heated by convection and conduction from ground floor heating.

Construction systems

- Insulate under slabs or use highly insulated, lightweight floors in these regions.
- Use highly insulated, low thermal mass walls in rooms with no exposure to direct sunlight.
- Choose dark coloured roof and wall materials.

Definition of IAQ:

Indoor air quality (IAQ) is a term which refers to the **air quality** within and around buildings and structures, especially as it relates to the health and comfort of building occupants.

Definition of IEQ:

Indoor environmental quality (IEQ) refers to the **quality** of a building's **environment** in relation to the health and wellbeing of those who occupy space within it. ... Understanding the sources of **indoor environmental** contaminants and controlling them can often help prevent or resolve building-related worker symptoms.

Why IEQ is important for buildings:

Since the personnel costs of salaries and benefits typically surpass operating costs of an office building, strategies that improve employees' health and productivity over the long run can have a large return on investment. IEQ goals often focus on providing stimulating and comfortable environments for occupants and minimizing the risk of building-related health problems.

To make their buildings places where people feel good and perform well, project teams must balance selection of strategies that promote efficiency and conservation with those that address the needs of the occupants and promote well-being. Ideally, the chosen strategies do both: the solutions that conserve energy, water and materials also contribute to a great indoor experience.

Common Sources of IAQ and IEQ:

- Carbon monoxide (CO) Carbon monoxide is an odorless, invisible gas. ...
- Radon. ...
- Nitrogen dioxide (NO_2)...
- Secondhand smoke. ...
- Lead particles. ...
- Asbestos. ...
- Mold
- People smoking tobacco inside the building or near building entrances or air uptakes
- Building materials such as paints, coatings, adhesives, sealants, and furniture that may emit volatile organic compounds (VOCs), substances that vaporize at room temperature and can cause health problems.
- Combustion processes in HVAC equipment, fireplaces and stoves, and vehicles in garages or near entrances.
- Mold resulting from moisture in building materials.
- Cleaning materials
- Radon or methane off-gassing from the soil underneath the building
- Pollutants from specific processes used in laboratories, hospitals, and factories
- Pollutants tracked in on occupants' shoes
- Occupants' respiration, which increases carbon dioxide levels and may introduce germs

Effective strategies improving occupants' comfort and control (IAQ&IEQ):

- Use day lighting.
- Install operable windows.
- Give occupants temperature and ventilation control.
- Give occupants lighting control.
- Conduct occupant surveys.
- Provide ergonomic furniture.
- Include appropriate acoustic design.

Difference Between IAQ and IEQ:

Indoor Environmental Quality (IEQ) is most simply described as the conditions inside a building. It does not refer to the air quality alone, but the entire environmental quality of a space, which includes air quality, access to daylight and views, pleasant acoustic conditions, and occupant control over lighting and thermal comfort. Americans spend a majority of their time indoors; not surprisingly, studies have shown an increase in worker productivity when improvements are made to a space's IEQ. Building managers and operators can increase the satisfaction of building occupants by including thoughtful IEQ details in the design and operation of a space.

IAQ is a subset of IEQ. Indoor Air Quality focuses on, not surprisingly, air. IAQ is a measure of the building's interior air in terms of the occupant's potential health and comfort. Chemical, physical, and biological (mold & bacteria) contaminants can cause symptoms ranging from discomfort to serious illness. Potential contaminants can include dust, cigarette smoke, carbon dioxide, carbon monoxide, ozone, radon, VOCs (volatile organic compounds), and various other chemical compounds from off gassing of building materials and cleaning supplies. Careful selection of building materials and cleaning agents, as well as having air filters and sufficient ventilation increases air quality.

In short, IAQ is about what we breathe. IEQ, more comprehensively, is about what we breathe, see, hear, and feel inside a building.

Heating, Ventilation, and Air Conditioning (HVAC):

Heating, ventilation, and air conditioning (HVAC) is the technology of indoor and vehicular environmental comfort. Its goal is to provide thermal comfort and acceptable indoor air quality. HVAC system design is a sub discipline of mechanical engineering, based on the principles of thermodynamics, fluid mechanics, and heat transfer. "Refrigeration" is sometimes added to the field's abbreviation, as HVAC&R or HVACR, or "ventilation" is dropped, as in HACR (as in the designation of HACR-rated circuit breakers).

HVAC is an important part of residential structures such as single family homes, apartment buildings, hotels and senior living facilities, medium to large industrial and office buildings such as skyscrapers and hospitals, on ships and submarines, and in marine environments, where safe and healthy building conditions are regulated with respect to temperature and humidity, using fresh air from outdoors.

Ventilating or ventilation (the V in HVAC) is the process of exchanging or replacing air in any space to provide high indoor air quality which involves temperature control, oxygen replenishment, and removal of moisture, odors, smoke, heat, dust, airborne bacteria, carbon dioxide, and other gases. Ventilation removes unpleasant smells and excessive moisture, introduces outside air, keeps interior building air circulating, and prevents stagnation of the interior air.

Ventilation includes both the exchange of air to the outside as well as circulation of air within the building. It is one of the most important factors for maintaining acceptable indoor air quality in buildings. Methods for ventilating a building may be divided into mechanical/forced and natural types.

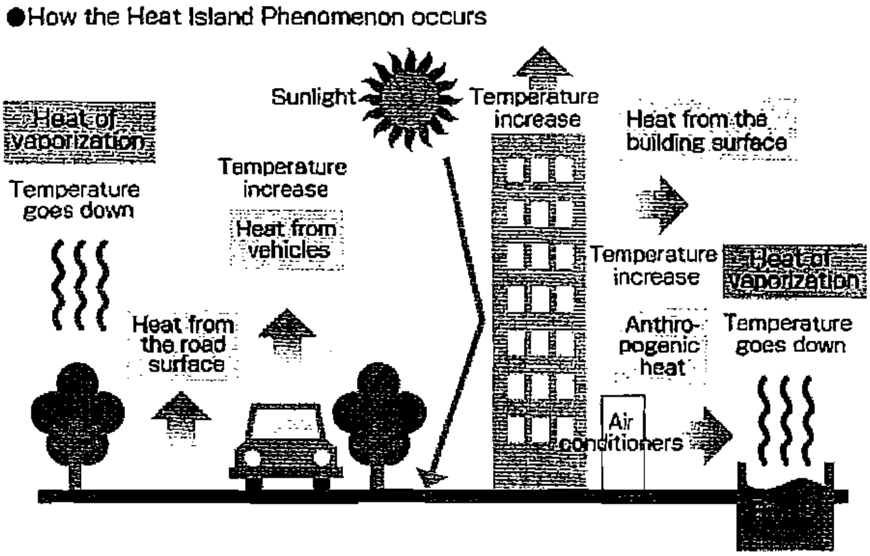
What is the Heat Island Effect:

The elevated temperature in urban areas as compared to rural, less developed areas is referred to as the urban heat island effect. As cities grow and develop, more buildings and people are added. The process of urban development leads to this phenomenon.

Temperatures are often a few degrees higher in cities than they are in their surrounding rural areas. This temperature discrepancy is the result of a bizarre phenomenon known as the urban **heat island effect.**

Although we tend to think of heat islands as a modern ecological problem, scientists first noted this issue as early as the 1800s. Any area (rural, urban, or otherwise) can experience the heat island effect, but urban areas are typically of more concern since they represent a more serious threat to local climate warming.

For smaller cities, heat islands are less noticeable. For a large city of one million people, the average temperature can be anywhere from around 1°C to 12°C warmer than the surrounding area. Cities such as Toronto experience a cumulative heat island effect. Since the late 1800s, Toronto has experienced an average temperature increase of 2.7°C This may not seem significant at first, but over time, these increases can cause major problems.



What Causes the Heat Island Effect:

When urban and suburban areas lose land surface and naturally occurring vegetation, heat can no longer easily escape. Tall buildings, concrete, and asphalt trap heat and contribute to the warming effect. Waste heat from energy use is another source of additional heat. Other contributing factors include local weather, seasonal changes, time of day, and geographic location.

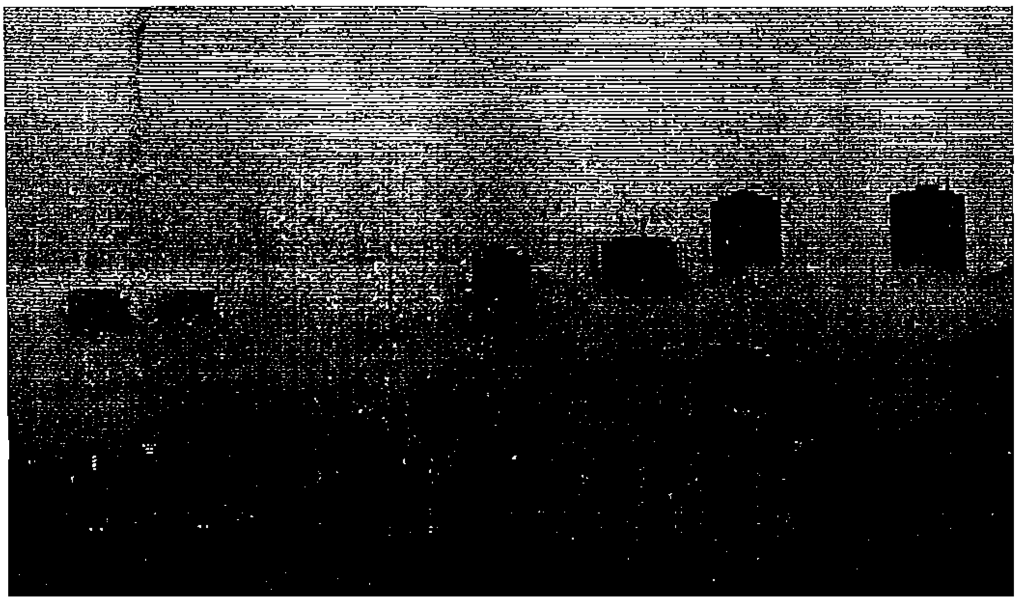
There are three basic types of heat islands: canopy layer, boundary layer, and surface. Both canopy layer and boundary layer heat islands refer to atmospheric heating (warmer air temperatures). Surface heat islands refer to the actual temperature of surfaces in a specific heat island. Although the timing and intensity of these types may vary, they can all be harmful to urban and suburban environments.

What are the Implications of Heat Island:

Heat islands are considered a form of local climate change as opposed to global climate change. The effects of heat islands are confined to specific areas, and do not have a larger impact on climate change. Despite being confined to a certain locality, heat islands can still make a significant impact.

Of course, one of the most noticeable impacts on urban dwellers is an increase in hot, summer weather. On particularly clear and hot days, when the heat island effect is at its worst, inhabitants of larger cities will notice hotter and more uncomfortable temperatures. New York City is a great example of just how hot and unpleasant this effect can be. New York City has been called a "floating oven" due to the sweltering summer heat caused by the urban heat island effect.

When people are hot, they often crank up their air conditioners. Increases in air conditioning use not only results in more heat being released into the air, this also contributes to air pollution, as more greenhouse gas emissions are discharged. This negatively impacts air quality and can also lead to a surge in urban smog.



Some urban areas have even seen the effects of heat islands negatively impact health. The increase in temperature and air pollution can lead to problems such as asthma, increased spread of vector-born disease, heat stroke, and childhood obesity. The city of Toronto averages about 120 deaths per year which are attributed in some way to spikes in heat. Other large cities experience similar heat-related deaths due to the heat island effect.

How Can we Reduce the Heat Island:

Since the impact of heat islands is mostly negative, scientists and researchers are searching for ways to reduce and reverse the effects. Dark roof surfaces are one of the major culprits of temperature increases. One popular technique for combating the heat island effect is installing green roofs on urban buildings. Green roofs, which are lined with soil and certain types of vegetation, can actually help cities regain some of the cooling and evaporative effects that the natural landscape once provided. As this idea becomes more popular, there is more and more scientific evidence that green roofs can reduce heat in urban areas.
Dark building surfaces that absorb more heat account for some of the rising temperatures in urban areas. One simple method for reducing this effect is to paint buildings with light or white colors that do not absorb nearly as much heat. Some cities are also using paint treatments that reflect light to combat the heat island effect. Another rooftop technique that can help to ameliorate the heat island effect is roof sprinkling. As moisture from the sprinklers evaporates, this helps to cools the surrounding air.

Many cities have urban forestry initiatives that have been in place for years for a variety of purposes. Even though many of these programs started as purely aesthetic ventures, we now know that focused urban forestry programs can have a tremendous positive impact on urban heat islands.

There are many different methods for reducing and even reversing the urban heat effect, but one basic idea lies at the heart of all of these efforts: intentional building and urban planning. When building and expanding cities, we must acknowledge the impact we have on the climate and the environment.

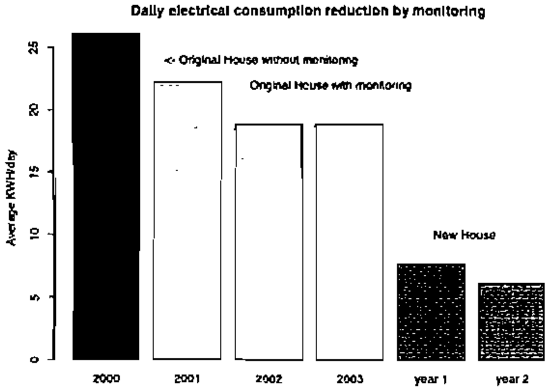
Difference between Active and Passive cooling:

Active cooling = a power fan blowing over the heat sink on top of a cpu; and
Passive cooling being provided by the heat sink itself
The source defines it as:
•Passive cooling — does not use a fan or other means of forced-air cooling. Relies on natural convection cooling.
•Pseudo-passive cooling — does not use a fan mounted directly onto the heat sink but does use forced air cooling from a nearby fan. May incorporate a fan duct or shroud.
•Active cooling — uses a fan directly mounted onto the heat sink for forced-air cooling.

STEPS REDUCING ENERGY DEMAND:-

There are a number of things that all homeowners can do to make significant reductions in their energy consumption, whether or not they are embarking on a major home construction or remodeling project. These include the following steps that the owners of this house have taken to reduce their energy consumption and that in turn contribute to the overall energy efficiency of the house.

1. Monitor Energy Consumption.



Just as keeping a record of the foods eaten each day can help people eat less and lose weight, so can keeping track of the amount of energy used help homeowners reduce their energy consumption and their energy bills.

The owners of this house had always considered themselves to be pretty savvy about using energy efficiently but discovered that they could do a lot better when they began monitoring their actual energy consumption in their former home. They experimented with compact fluorescent lights (CFLs) in a few fixtures and saw the impact immediately in lower electric bills. They gradually replaced most of the incandescent bulbs in the house with CFLs, ultimately reducing their electrical consumption by 30 percent.

Electrical consumption in the new house is roughly 70 percent lower than it was in the former home. Big contributors to this high performance include wide use of CFLs, of course, as well as the selection of a super-efficient clothes washer and a super-efficient dish washer, and reliance on ceiling fans in the main living areas rather than air conditioning on all but the hottest days.

Daily monitoring of energy usage continues and has led to further adjustments. Consumption is lower in year two, for example, because the owners turned off the small basement refrigerator during the winter months and discontinued the use of the air handling system.

2. Replace incandescent bulbs with compact fluorescent lights.

Most of the energy consumed by a standard incandescent bulb is wasted; 90 percent is given off as heat while only 10 percent is converted into light. A compact fluorescent light (CFL) is much more efficient, using roughly one-fourth of the electricity an incandescent bulb consumes to give off the same amount of light. CFLs cost more initially, but they last ten times longer and easily pay back their higher purchase price through lower utility bills. Simply replacing the incandescent bulbs in the five most heavily used fixtures in a home, as recommended by ENERGY STAR, will result in at least $60 in energy savings every year.

Halogen lights use slightly less energy than standard incandescent bulbs, but they put out a great deal of heat. This can be dangerous (especially in the case of halogen torchieres) and can also add to the cooling load of a home during hot weather. By comparison, CFLs are nearly three times as efficient and produce far less heat.

CFLs are now available in hundreds of different styles and a range of colors, including "warm" colors comparable to incandescent lamps. The color that a light bulb will emit is indicated by its Correlated Color Temperature (CCT), which is measured in degrees Kelvin. Incandescent lamps have a CCT of 2700 as do the residential CFL models typically found in retail stores. CFLs with higher numbers (and correspondingly "cooler" colors) are also available, from a warm white (3000 degrees K) to a cool white (4100 degrees K), and even higher. Lamps in a shared space will look best if they are all of the same color temperature.

While still living in their former home, the owners replaced most of their incandescent bulbs with CFLs and found that they reduced their electrical consumption by 30 percent. CFLs are used almost exclusively in the new house. Exterior landscape lighting is solar-powered.

3. Choose ENERGY STAR appliances

ENERGY STAR-labeled appliances meet strict guidelines for energy efficiency set by the U.S. Environmental Protection Agency and the U.S. Department of Energy. The label helps consumers easily identify products that use less energy, reduce home utility bills, and help protect the environment. The savings can be significant: a home that is fully equipped with ENERGY STAR-qualified products will operate on about 30 percent less energy than a house with standard products and will save the homeowner about $450 per year.

A companion program--the Super-Efficient Home Appliances Initiative of the Consortium for Energy Efficiency (CEE)--promotes a subset of "super-efficient" ENERGY STAR appliances. As part of this initiative, CEE has developed performance specifications for super-efficient clothes washers, dishwashers, refrigerators and room air conditioners and endorses appliances that are generally in the top 25 percent of efficiency.

A third resource for consumers is the yellow-and-black EnergyGuide label that manufacturers of most major home appliances are required to attach to their products. Appliances covered by the Federal Trade Commission's Appliance Labeling Rule include refrigerators, freezers, dishwashers, clothes washers, room air conditioners, water heaters, furnaces, boilers, central air conditioners, heat pumps and pool heaters. The label provides an estimate of that appliance's annual energy use, together with estimates for similar models, as well as an estimate of the annual operating cost for the appliance.

- **Clothes washers** are among the most energy-intensive appliances in the home and offer the greatest potential for energy savings. An ENERGY STAR publication estimates annual savings of $41 (in 2000 dollars) in home electrical bills with an ENERGY STAR-qualified clothes washer compared to a standard new machine. (Savings of $8 per year are estimated for an ENERGY STAR dishwasher and savings of $4 per year for an ENERGY STAR refrigerator.)

Even among ENERGY STAR-qualified clothes washers there is a wide range of efficiency, with some models as much as two to four times more efficient than others.

- The more efficient the machine, the higher its **Modified Energy Factor (MEF)**, which takes into account the capacity of the tub, the energy used for a load of laundry, and the dryer energy required to remove the remaining moisture in the wash load.
- Since heating water accounts for 80 to 85 percent of the energy used in washing clothes, selecting a machine that uses less water is also important. The lower a machine's **Water Factor (WF)**--the number of gallons of water needed for each cubic foot of laundry--the more efficient its use of water. Using cooler water for washing and rinsing can also make a big difference; switching temperature settings from hot to warm water can cut energy use in half.

According to the American Council for an Energy-Efficient Economy, front-loading washing machines continue to earn the highest energy-efficiency ratings. These horizontal-axis machines tumble the clothes in a partially-filled tub of water; by contrast, vertical-axis top-loading machines fill up completely with water and agitate the clothes to clean them. Newer top-loading models that spray rinse water on the clothes (rather than soaking them in a full tub) are more efficient than traditional models, but they don't rank among the ACEEE's 20 top-rated machines.

Front-loading washers use 50 to 70 percent less energy than traditional top-loading washers and 30 to 60 percent less water. They generally are more expensive than vertical-axis washing machines, but their substantial energy and water savings will more than offset their higher purchase price.

- Although **clothes dryers** are typically the second or third largest energy-consuming appliances used in the home, they are not rated by ENERGY STAR because the different models don't vary much in the amount of energy they use. Nor are clothes dryers required to display an EnergyGuide label. The more energy-efficient dryers are those with a control that shuts off the machine when the clothes are dry. These controls range from simple timers, which rely on the user to guess how long the load will take to dry, to temperature sensors, which indirectly estimate dryness by sensing the temperature of the exhaust air, to moisture sensors--the most effective--which directly measure dryness.

  In most parts of the country, gas dryers will cost less to run than electric dryers. The cost of drying a typical load of laundry in an electric dryer is 30 to 40 cents compared to 15 to 25 cents in a gas dryer.

- For **dishwashers** as for clothes washers, most of the energy used is the energy required to heat the water consumed. An efficient dishwasher, therefore, is one that uses less water to do the job. The most water-efficient dishwashers on the market today use about five gallons of hot water per load in light or energy-saving cycles, compared to eleven gallons or more for conventional dishwashers in the same mode.

In addition, virtually all dishwashers available today have a built-in booster heater, which further heats the water to the higher temperature required for dishwashing, so the homeowner can reduce the setting for the home's hot water heater to 120°, the highest temperature needed for other household uses. Another energy-saving option is a switch that allows the user to choose between heated- and unheated-air drying.

- Of all appliances, **refrigerators** are the single biggest consumer of electrical power in most households, accounting for about 15 percent of all residential electrical usage. Advances in technology, however, have improved refrigerator efficiency substantially over the last 20 years, making it cost-effective in many cases to replace a still-working refrigerator with a current model. ENERGY STAR-qualified refrigerators use at least 15% less energy than required by current federal standards and 40% less energy than conventional models sold as recently as 2001.

4. Use less water

Fresh, clean water is scarce and getting more so. Moreover, conserving water is an important means of saving energy. Reducing the demand for water can help to save rivers and wetlands, maintain aquatic habitats, and protect groundwater from depletion and contamination. Using water more efficiently also helps reduce the amount of energy needed to pump, treat and heat water and to treat wastewater.

In addition to making water efficiency a criterion when selecting appliances (as described above), installing water-efficient plumbing fixtures can go a long way towards protecting this valuable natural resource.

- **Toilets** are the greatest water user in the house, accounting for over one-quarter of the total daily indoor water use in a typical single-family home. Installing high-efficiency toilets, however, can result in dramatic water savings. "Low flush" residential toilets--toilets using 1.6 gallons of water per flush (compared to the 3.2-gpf standard of older models)--have been shown to save an average of 10.5 gallons of water per person daily.

  The Caroma dual flush toilets used in this house reduce water use still further. The key feature of these toilets is Caroma's 0.8/1.6 gallon two-button technology--one button for liquid waste and the other for solid waste.

- **Water-efficient showerheads and faucets** are also important water-saving devices. Low-flow showerheads cut the water flow through the showerhead to levels below the federal minimum standards for showerhead flow rate. By replacing standard 4.5-gallon-per-minute showerheads with 2.5-gallon-per-minute heads, a family of four can save approximately 20,000 gallons of water per year.

  Flow reducers, which fit into the aerator at the tip of the faucet, can be installed easily in most conventional faucets. Newer, more efficient kitchen and bathroom faucets are also available. These use only 2 gallons of water per minute compared to standard faucets, which use 3 to 5 gallons per minute.

5. Use window treatments to control heat loss and heat gain.

The owners have installed Hunter Douglas duette shades on all the windows of this house and use them conscientiously--at night in the winter months to retain heat and on sunny days in the summer to block unwanted heat gain.