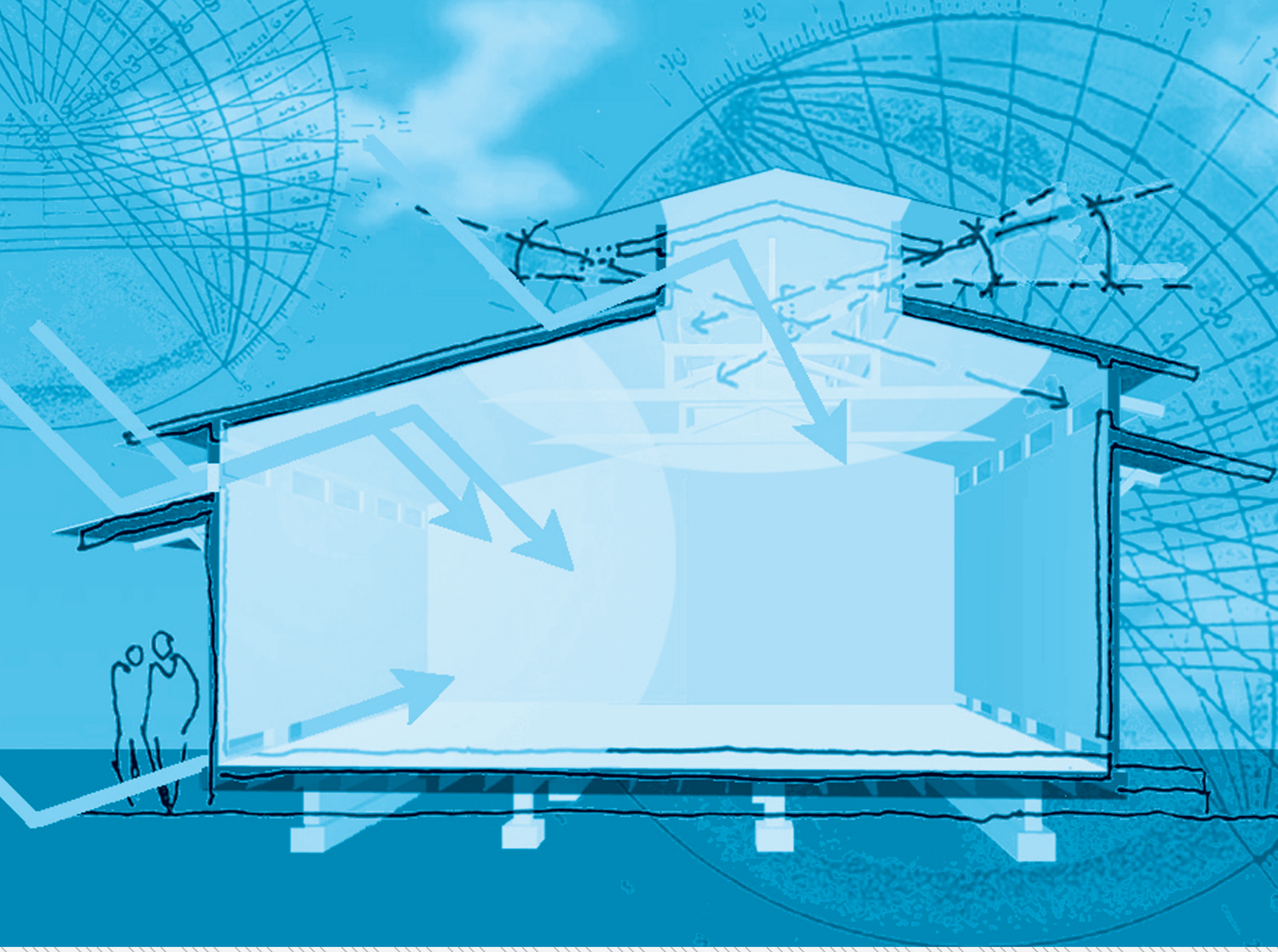
Field Guide

for Energy Performance, Comfort, and Value in Hawaii Homes



DBEDT
THE DEPARTMENT OF BUSINESS, ECONOMIC DEVELOPMENT & TOURISM
STATE OF HAWAII

AIA
Honolulu

Field Guide for Energy Performance, Comfort, and Value in Hawaii Homes

State of Hawaii
Department of Business, Economic Development & Tourism
Energy, Resources & Technology Division

The Honolulu Chapter
American Institute of Architects

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Table of Contents

About the Field Guide.. 1

Energy Efficiency Guidelines... 3

Section I: Introduction.. 6

Chapter 1: Building for Energy Performance, Comfort, and Value in Hawaii..... 9

Chapter 2: Climate and Comfort.. 11

Chapter 3: Hawaii's Climate.. 13

Chapter 4: Special Site Conditions... 15

Section II: Design for Comfort and Value... 17

Chapter 5: Heat Basics... 19

Chapter 6: Landscape and Site Design.. 23

Chapter 7: Insulation and Radiant Barriers.. 27

Chapter 8: Heat Mitigation in Roofs.. 31

Chapter 9: Heat Mitigation in Walls... 39

Chapter 10: Controlling Heat Gain for Windows and Other Openings............... 41

Chapter 11: Natural Ventilation: Air Flow Around Buildings............................. 47

Chapter 12: Natural Ventilation: Air Flow in Buildings...................................... 51

Section III: Reduce Energy Use.. 59

Chapter 13: Water Heating.. 61

Chapter 14: Daylighting... 63

Chapter 15: Electric Lighting.. 69

Chapter 16: Appliances.. 77

Chapter 17: Air Conditioning.. 81

Section IV: The Big Picture: How You Build Your Home Matters............................... 89

Chapter 18: The Cost of Energy.. 91

Chapter 19: Energy Efficient Features Pay Off in Savings and Comfort............ 93

Chapter 20: Incentive Programs and Other Resources.. 97

Chapter 21: Going the Extra Mile to Build "Green"... 101

Appendices:

A: Recommended Techniques.. A-1

B: Resources.. B-1

C: Bibliography.. C-1

D: Shading Formulas.. D-1

E: Operation and Maintenance... E-1

F: Equivalencies for Energy Star® Homes in Hawaii.. F-1

G: Utility Co-Payments.. G-1

H: Certification Programs and Other Resources.. H-1

I: Case Study: Model Demonstration Home.. I-1

List of Figures

Fig. 1-1: A Comparison of Daily Temperature and Humidity Variations for an Air Conditioned Home, an Energy-Inefficient Home, and an Energy-Efficient Home 9
Fig. 1-2: A Well-Designed, Energy-Efficient Home 10
Fig. 2-1: Climate Conditions and the Human Comfort Zone 11
Fig. 2-2: Keeping Cool 12
Fig. 3-1: Hawaii's Climate and the Human Comfort Zone 13
Fig. 3-2: Average Monthly Temperature and Relative Humidity in Honolulu 13
Fig. 3-3: Average Monthly Temperature and Relative Humidity in Hilo 13
Fig. 3-4: Typical Trade Wind Patterns on Oahu 14
Fig. 4-1: Air Temperature Variation with Altitude 15
Fig. 4-2: Rainfall Patterns 15
Fig. 4-3: Wind Patterns 16
Fig. 5-1: Heat Sources for a Home 19
Fig. 5-2: Modes of Heat Transfer 20
Fig. 5-3: Heat Transfer by Conduction 20
Fig. 5-4: Heat Transfer by Convection 20
Fig. 5-5: Electromagnetic Spectrum 21
Fig. 5-6: Heat Transfer by Radiation 21
Fig. 6-1: Building Orientation and Solar Heat Gain 23
Fig. 6-2: Building Shape and Solar Heat Gain 23
Fig. 6-3: Shading the Home with Landscaping 24
Fig. 6-4: Shading Hardscapes with Landscaping 24
Fig. 6-5: Hardscapes and Solar Gain 24
Fig. 6-6: Porous Paving 25
Fig. 7-1: Insulation is an Effective Barrier to Heat Transfer 27
Fig. 8-1: Preventing Heat Gain by Shading the Roof 31
Fig. 8-2: Using Roof Materials to Reflect the Sun's Heat 32
Fig. 8-3: Insulate Ceilings to Reduce Heat Gain 33
Fig. 8-4: Use Radiant Barriers in Ceilings to Reduce Heat Gain 34
Fig. 8-5: Roof Ventilation: Continuous Ridge and Soffit 36
Fig. 8-6: Roof Ventilation: Gable End Vents 36
Fig. 8-7: Integrating the Roof Design 37

Fig. 9-1: Light Colored Surfaces Reflect Heat and Stay Cooler.. 39
Fig. 9-2: Wall Construction with Insulation.. 40
Fig. 9-3: Wall Construction with Radiant Barrier.. 40
Fig. 10-1: Sunlight and Window Glazing.. 41
Fig. 10-2: Sunlight and Heat Production Inside the Home.. 41
Fig. 10-3: Window Shading: Horizontal Shading Devices.. 42
Fig. 10-4: Window Shading: Vertical Shading Devices.. 42
Fig. 10-5: Interior Shading.. 43
Fig. 10-6: Sunlight and Low-e Glazing (Temperate Climates).. 43
Fig. 10-7: Sunlight and Low-e Glazing (Tropical Climates)... 43
Fig. 10-8: Sunlight and Tinted Window Glazing.. 44
Fig. 11-1: Building Orientation for Cooling.. 47
Fig. 11-2: Spacing of Multiple Buildings for Cooling... 47
Fig. 11-3: Arranging Multiple Buildings for Good Air Flow... 48
Fig. 11-4: Using Landscaping to Improve Air Flow Around Structures... 49
Fig. 11-5: Using Landscaping for Cooling.. 49
Fig. 12-1: Basic Natural Ventilation Strategies.. 51
Fig. 12-2: Designing for Good Cross Ventilation.. 52
Fig. 12-3: A Poor Design for Cross Ventilation... 53
Fig. 12-4: Room Orientation for Improved Air Flow... 53
Fig. 12-5: Window Sizing for Air Flow... 54
Fig. 12-6: Effective Open Areas for Various Window Types... 54
Fig. 12-7: Sizing Inlet and Outlet Openings... 55
Fig. 12-8: Window Arrangement for Cross Ventilation (Adjacent Walls).. 55
Fig. 12-9: Window Arrangement for Cross Ventilation (Same Wall).. 55
Fig. 12-10: Window Heights and Cross Ventilation (Good Design).. 56
Fig. 12-11: Window Heights and Cross Ventilation (Poor Design)... 56
Fig. 12-12: Using Window Overhangs to Assist Ventilation.. 56
Fig. 14-1: Daylighting Methods... 64
Fig. 14-2: Distribution of Daylight... 64
Fig. 14-3: Daylight Penetration.. 65
Fig. 14-4: Room Proportions and Daylight Penetration.. 65

Fig. 14-5: Use Light Shelves when Sidelighting.......... 66
Fig. 14-6: Use Clerestories or Roof Monitors for Toplighting.......... 66
Fig. 14-7: Use Vented Skylights to Offset Heat Gain.......... 67
Fig. 14-8: Light Baffles Reduce Glare by Diffusing and Directing Incoming Sunlight.......... 67
Fig. 14-9: Toplighting Distribution.......... 68
Fig. 15-1: Indirect, Ambient Lighting.......... 71
Fig. 15-2: Diffuse, Ambient Lighting.......... 71
Fig. 15-3: Direct-Indirect Lighting.......... 71
Fig. 15-4: Direct Lighting.......... 71
Fig. 16-1: Average Monthly Energy Costs for Common Household Appliances.......... 77
Fig. 16-2: Energy Guide Label.......... 77
Fig. 17-1: Window AC Systems.......... 81
Fig. 17-2: Split AC Systems.......... 82
Fig. 17-3: Central AC Systems.......... 82
Fig. 17-4: Passive Cooling Strategies.......... 82
Fig. 17-5: Estimating Fresh Air Requirements for Air Conditioned Homes.......... 85
Fig. 17-6: Ensuring Balanced Air Flow.......... 86
Fig. 17-7: Air Sealing of Ductwork.......... 86
Fig. 18-1: Energy Production, US and Hawaii.......... 91
Fig. 18-2: Sources of Greenhouse Gases.......... 91
Fig. 18-3: Solar Hot Water Heaters Reduce Greenhouse Gas Emissions.......... 92
Fig. 19-1: Energy-Efficiency in the Home Means $$ Savings!.......... 93
Fig. 19-2: Solar Water Heating Payback.......... 94
Fig. 19-3: Benefits of Radiant Barriers.......... 94
Fig. 19-4: Design for Natural Ventilation.......... 95

List of Tables

Table 6-A: Comparing the Benefits of Site Elements for Air Conditioned Homes.............................. 25

Table 7-A: Comparison of Typical Home Insulation Products.. 28

Table 7-B: Comparison of Radiant Barriers.. 29

Table 8-A: Comparison of Different Roofing Materials, Showing White (Cooler Options)................. 32

Table 8-B: Recommended Insulation R-values With and Without Radiant Barrier............................. 35

Table 9-A: Overhang size for walls.. 39

Table 10-A: Comparing Improved Window Options to Conventional Glazing...................................... 42

Table 10-B: Comparison of Glazing Type, Heat Gain, and Light Transmittance.................................. 44

Table 13-A: Comparison of Energy Use for Water Heaters... 61

Table 15-A: Lighting Styles... 70

Table 15-B: General Comparison Incandescent vs. Fluorescent.. 73

Table 15-C: Comparison of Various Incandescent and Fluorescent Bulbs.. 74

Table 15-D: Cost Effective Residential Light Scenarios... 75

Table 15-E: Lighting Control Types... 76

Table 17-A: Matching Square Footage to AC Capacity... 84

Table 19-A: Comparison of the Operating Savings from Incorporating Energy Efficient Features........ 96

Table 20-A: Lower Minimum Income Requirement for Financing Due to Solar Water Heating Savings (HECO, 2000).. 99

Table 20-B: Increased Buying Power Due to Solar Water Heating Savings (MECO, 2000)................. 99

About this Field Guide

The Energy Efficiency Guidelines

In early 2000 the State of Hawaii Department of Business, Economic Development & Tourism developed voluntary guidelines for energy-efficient design and construction of single family homes. Entitled *Guidelines for Energy Performance, Comfort, and Value in Hawaii Homes,* the *Guidelines* are a resource for architects, builders, developers, and owner-builders. The *Guidelines* identify significant opportunities to reduce energy use, improve comfort, lower utility bills, provide value, and improve the quality of life for Hawaii's home owners. (A copy of the *Energy Efficiency Guidelines* follows on page 3.) The overall approach in developing and implementing the *Energy Efficiency Guidelines* is to:

1. Reduce heat build-up and energy use in the home through passive cooling strategies that minimize or eliminate the need for air conditioning.

2. Reduce the need for electric lighting through the controlled use of daylight.

3. Reduce energy requirements even further by installing energy-efficient systems and equipment for water heating, lighting, household tasks, and air conditioning, when it is required.

The Field Guide

This *Field Guide* provides detailed illustrations and other information that show how to design and build an energy-efficient, comfortable, and economical home in Hawaii using the strategies recommended in the *Energy Efficiency Guidelines*.

Section I of the Field Guide provides basic information about climate, topography, and human comfort that lays the foundation for understanding the special opportunities and challenges when designing energy-efficient homes in Hawaii.

Sections II and III of the Field Guide present recommended techniques based on the *Energy Efficiency Guidelines*, along with illustrations and details that will help you implement the techniques for your home. Recommended techniques are identified as in the following example:

Recommended Technique: Use design elements to shade walls.

Section IV of the Field Guide discusses the cost of energy and the identifies several opportunities for significant cost savings, such as solar water heating, natural ventilation, and radiant barriers. *Section IV* also describes additional financial incentives and other resources available in Hawaii for building energy-efficient homes.

At the end of the *Field Guide* you will find these appendices:

Appendix A: Recommended Techniques—A summary listing of recommended techniques for (1) energy-efficient equipment and appliances, and (2) design.

Appendix B: Resources—Where to go for more information.

Appendix C: Bibliography—A list of the major sources for the information in this *Field Guide*.

Appendix D: Shading Formulas—Additional information related to developing a window shading design (discussed in *Section II*, Chapter 10).

Appendix E: Operation and Maintenance—A summary of operational "Do's and Don'ts" and maintenance tasks for common household appliances, which will help home owners *keep* their home operating in an energy-efficient manner.

Appendix F: Equivalencies for ENERGY STAR® Homes in Hawaii— ENERGY STAR® Homes developed these to aid implementation of ENERGY STAR® for homes participating in the HECO, MECO, and HELCO solar domestic water heating programs.

Appendix G: Utility Co-Payments—A summary of co-payments available through utility programs that encourage the use of solar hot water heating systems and other energy-efficient measures.

Appendix H: Certification Programs and Other Resources—Information about certification programs that help identify environmentally preferable products.

Appendix I: Case Study—Model Demonstration Home—Description of the Model Demonstration Home (dedicated May 15, 2001, as the First Hawaii BuiltGreen™ Home), which incorporates affordable techniques to provide energy efficiency and comfort without air conditioning.

Note: This *Field Guide* is intended as a resource for builders and owner-builders wishing to improve the energy performance of homes in Hawaii. However, this document is not a substitute for nor does it eliminate professional design and engineering judgment or accepted engineering and construction practices. Each home and site may have characteristics that could render any one or more of the practices suggested in this *Field Guide* inappropriate or inapplicable. It is the responsibility of the home builder or owner-builder to select measures that are appropriate in each case. It is highly recommended that owner-builders consult with professionals when planning their home.

Guidelines for Energy Performance, Comfort, and Value in Hawaii Homes

I. Introduction. The *Energy Efficiency Guidelines* were prepared as a guide for home builders and owners to use in creating homes that are energy-efficient and comfortable with little or no air conditioning. The guidelines include suggestions for reducing the use of electric power in homes with a strong focus on how homes can be built for comfort without air conditioning. In this way, home owners can enjoy the indoor/outdoor life style and close contact with the natural environment that are so much a part of life in these Islands.

II. Design for Comfort and Value

A. Control Heat Gain: Use strategies to reduce solar heat gain through roofs, walls and windows.

1. Orient and arrange building to control heat gain.
2. Landscape and design outdoor surfaces to reduce air temperatures and glare; minimize paving area and use grassed and planted areas to provide lowered site temperatures, shade and evaporative cooling.
3. Shade roofs, walls and windows with:
    a. Architectural elements such as eaves, awnings and carports, and
    b. Window treatments such as blinds and shutters.
4. Use insulation and/or radiant heat barriers in roofs and walls exposed to the sun.
5. Use high performance windows (Low-e, spectrally selective, or tinted glazing) to keep solar heat out of interior spaces while admitting daylight.
6. Use light colored roofing and wall finishes.
7. Shade or insulate materials with high thermal mass, such as concrete floors, to avoid heat build up and uncomfortably hot surface temperatures.

B. Use Natural Ventilation: Provide ample fresh air ventilation for living spaces and areas where hot air and humidity accumulate, such as attics, high ceiling spaces, kitchens, bathrooms, and laundry areas.

1. Orient buildings to maximize the cooling potential of prevailing winds and minimize morning and afternoon heat gain.
2. Design floor plans and opening placement and type to provide effective cross ventilation with good air circulation throughout room areas and at body level.
3. Provide generous screened openings well protected from the rain.
4. Use architectural design elements such as vents and casement windows to improve interior air circulation.
5. Enhance natural ventilation with fans as needed:
    a. Use ceiling and whole house fans to provide comfort on warm, humid or still days.
    b. Use solar powered attic vent fans when appropriate and economically feasible.

III. Reduce Energy Bills.

A. Water Heating: Minimize the energy required for water heating.

1. Use solar water heating systems.
2. When solar water heating is not an option, use energy efficient alternatives such as heat pumps, high efficiency electric or gas water heaters.
3. Use high efficiency water tanks, insulate older tanks.
4. Insulate hot water supply lines.
5. Provide water heater thermostats adjustable to as low as 120˚ F.

B. Lighting: Minimize electric lighting energy demand and heat gain.

1. Use controlled, filtered and indirect daylighting to light interior spaces and reduce electric lighting loads. Increase the effectiveness of daylighting with generous wall openings, open floor plans and light colored interior finishes.
2. Use energy efficient electric lighting to reduce heat gain and energy demand.
3. Don't over light interior and exterior spaces. Use focused or task lighting in preference to whole room or large area lighting.
4. Provide controls such as timers, dimmers, sensors and separate fan/light controls to limit power use to the times and levels needed.
5. Use solar powered landscape lighting when economically feasible.

C. Appliances: Use energy efficient appliances.

1. Use energy efficient refrigerator, range, clothes and dish washers and dryers. Look for energy ratings and Energy Star® compliance labels.
2. Use microwave ovens to reduce reliance on less efficient cooking appliances.
3. Use laundry lines for clothes drying.

D. Air Conditioning: Use air conditioning only when it is required by special circumstances such as environmental noise, dust and pollution, very warm micro-climates, home offices where heat or humidity control is needed or to provide appropriate comfort levels for occupants with special needs.

1. If air conditioning is used, meet or exceed code recommendations for air conditioned buildings, including insulation requirements, shading of walls and windows and limits on glazing area.
   a. Seal the building envelope to prevent air leaks and loss of cooled air to the exterior and to control interior humidity levels.
   b. Shade windows or use high performance glazing.
2. Select and design energy efficient air conditioning system:
   a. Select minimum unit size and energy efficient system type to reduce operating and maintenance costs and facilitate repair.
   b. Design in zoning and controls to turn systems off when not needed; cool only spaces that need air conditioning, not the whole house.

c. Provide operable windows, screened doors and ceiling fans so that natural ventilation and fans can be used instead of the air conditioning system whenever possible.

3. Insulate and ventilate attic spaces housing air conditioning equipment and ducts.

4. Seal and insulate chilled water lines and cold air ducts in unconditioned spaces.

IV. Reduce environmental impact and life cycle energy costs of construction.

A. Refer to the guidelines in DBEDT's HABiT Guide to Resource Efficient Building in Hawaii and the DBEDT Clean Hawaii Center's "Construction & Demolition Waste Management Guide."

V. Take advantage of State income tax credits (See DBEDT's "Hawaii Energy Tax Credits" brochure) and utility program rebates (HECO [Oahu]: 947-6937; HELCO [Big Island]: 969-0127; Kauai Electric: 246-8280; MECO [Maui, toll-free]: 1-888-632-6786).

VI. Receive reduced mortgage costs through HECO's partnership with the U.S. Environmental Protection Agency's "Energy Star® Homes" mortgage program. Call the HECO, HELCO, and MECO numbers above.

VII. Honsador Lumber Corporation (682-2011) offers a predesigned home incorporating the three "Big Bang" techniques of these *Guidelines*: HECO-approved solar water heater, radiant barrier, and natural ventilation.

Development of these *Guidelines* was funded by U.S. Department of Energy Grant #DE-FG51-97R020881, administered by the Hawaii State Department of Business, Economic Development & Tourism, and the Honolulu Chapter, American Institute of Architects. Any opinions or recommendations expressed herein are those of the authors and do not necessarily reflect the views of, nor constitute an endorsement by, the USDOE, State of Hawaii, AIA, or any of their agents.

Section I: Introduction

The first step in implementing the *Energy Efficiency Guidelines* approach is to reduce heat build-up through passive cooling strategies. It is therefore important to understand Hawaii's climate conditions and how to work with them in designing a home for improved comfort and quality of life. *Section I, Introduction*, focuses on this area and presents:

- Climactic opportunities and challenges when using an energy-efficient approach for the design of homes in Hawaii (Chapter 1)
- Human comfort and climatic conditions that affect design (Chapter 2)
- General climatic conditions in Hawaii that relate to human comfort (Chapter 3)
- Special site conditions that affect human comfort (Chapter 4)

Chapter 1: Building for Energy Performance, Comfort and Value in Hawaii

Typical climate conditions in Hawaii provide significant opportunities to build comfortable energy efficient homes without air conditioning. Mild temperatures and gentle trade winds make natural cooling viable while steady sunlight offers the ability to heat water with the sun.

Hawaii's climate does present challenges, however. Intense sunlight, occasional high humidity, and variable winds must be addressed to achieve optimum comfort levels. Specific locations may present conditions requiring additional thought.

Homes can be protected from the sun's heat through the use of passive cooling strategies that reduce heat gain and incorporate natural ventilation. Variable trade winds can be supplemented with ceiling fans and openings that admit air to circulate freely through the home.

Human beings are highly adaptable. If we live in close contact with our natural environment we develop greater tolerance for the brief periods in Hawaii when the weather may be too warm or too humid for comfort. A home designed to soften the impact of variations in temperature, humidity, and available breezes can provide comfort without air conditioning. This allows its occupants to enjoy Hawaii's mild climate and the indoor/outdoor life style that is so natural to the islands.

The advantages of a naturally cooled home compared to an inefficiently designed home with or without air conditioning is illustrated below. As outside temperatures climb throughout the morning and afternoon, an inefficient home without air conditioning heats up to temperatures that can be even hotter than outside. The home retains the heat and keeps interior temperatures high even while the outside air cools into the evening.

Air conditioned homes strive to create uniform temperature and humidity conditions. Occupants of such homes are isolated from the natural environment and suffer greater stress from temperature and humidity when they venture out of their homes.

In contrast, an efficiently designed home more closely parallels the outside temperatures and improves comfort conditions with fans during hot days when the air is still. An air conditioned home uses energy to maintain the home at uniform temperatures throughout the day. The difference between indoor and outdoor temperatures and the stress that home owners experience when they go from indoors to natural outdoor environment increases as the day warms.

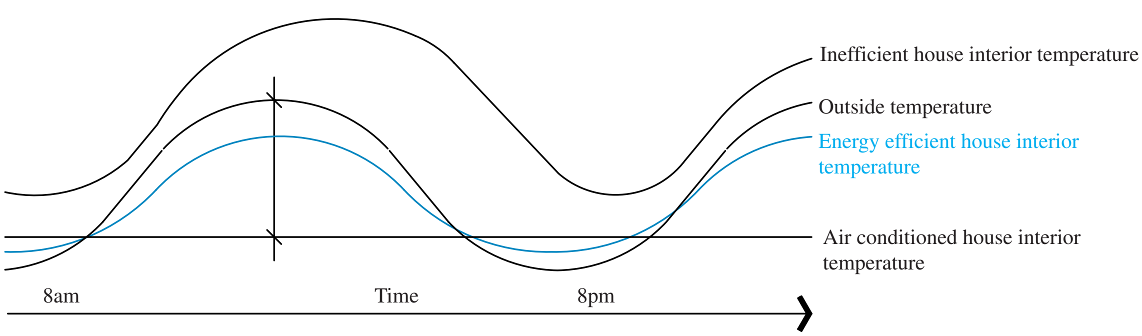


Fig. 1-1: A Comparison of Daily Temperature and Humidity Variations for an Air Conditioned Home, an Energy-Inefficient Home, and an Energy-Efficient Home.

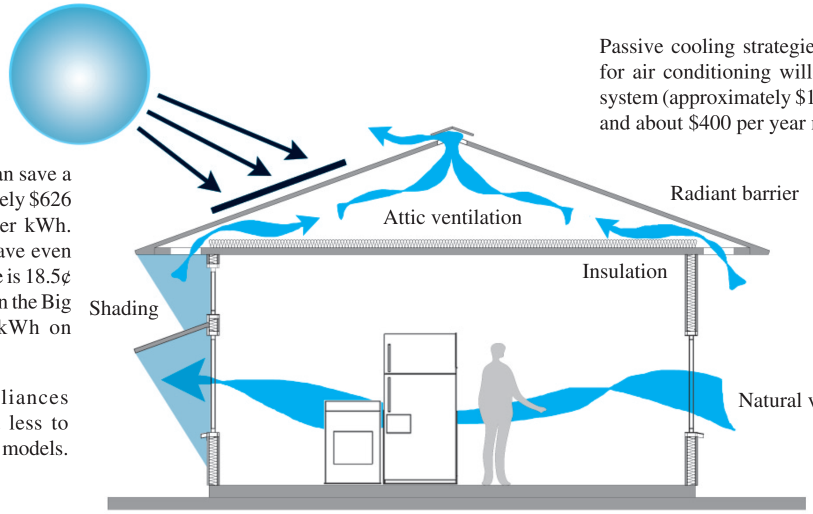


Fig. 1-2: A Well-Designed, Energy-Efficient Home.

In a well-designed energy efficient home without air conditioning, you can stay comfortably connected to the natural environment. You can also save money. Just eliminating air conditioning equipment can save about $400 a year in lower energy bills and, of course, the cost of the equipment and yearly maintenance. Incorporating the Guidelines comprehensively can provide substantial additional savings.

Special conditions can make air conditioning necessary. Examples include home offices where heat or humidity control is needed, occupants who have special needs, and neighborhoods where environmental noise, dust, pollution or very warm micro-climates are a problem. When air conditioning is used, the recommended approach is to employ passive cooling strategies first, then use only the amount of air conditioning actually required by limiting the areas and times of use.

Chapter 2: Climate and Comfort

Human comfort is affected by air temperature, humidity, air movement, solar and heat radiation, and temperature differences within a space and in building materials. Other factors, such as clothing, physical activity, physical condition, and non-climatic sources of heat and humidity (for example cooking, showers, and clothes washing) further affect comfort in the home.

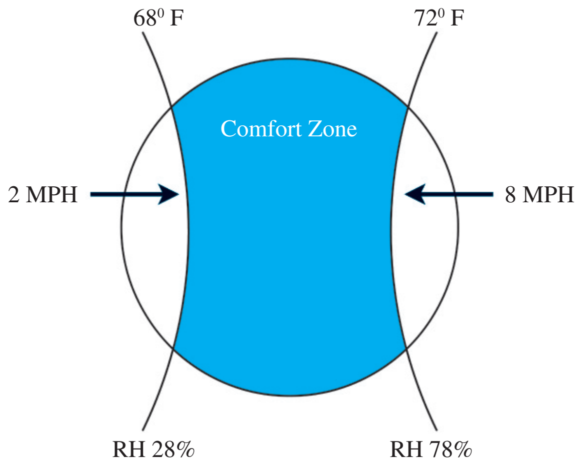


Fig. 2-1: Climate Conditions and the Human Comfort Zone.

Based on conventional research used to design air conditioning systems, most people are comfortable when the temperature is between the low 70s and low 80s degrees F and at relative humidity levels of 30% to 70%. These ranges apply when people are dressed in light clothing, are in the shade, and are relatively inactive.

Our perceptions of comfort and tolerance for changes in environmental conditions are affected by whether we have enjoyed the benefits of a naturally cooled environment or become dependent upon air conditioned spaces.

Recent research sponsored by the American Society of Heating, Refrigeration and Air Conditioning Engineers indicates that people in naturally ventilated buildings are comfortable over a wider range of temperature and humidity conditions than people accustomed to air conditioning. Perceived comfort in naturally ventilated buildings is affected by local climatic expectations and higher levels of personal control (occupants can choose appropriate clothing, open windows, or turn on fans).

Keeping Cool

Excess heat, whether from the environment or our own metabolism, must be removed to maintain a constant body temperature and thermal comfort. Mild air movement (less than 100 feet per minute) improves comfort levels when temperatures and humidity are high, aiding convective cooling and increasing the evaporation of perspiration. Air movement above 100 feet per minute can begin to be less effective and may be experienced as draft, and above 200 feet per minute (2 to 3 mph) can be annoying.

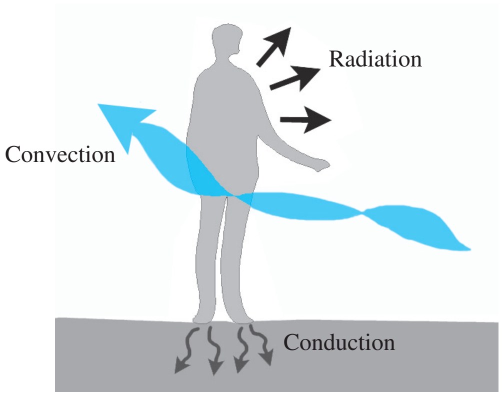


Fig. 2-2: Keeping Cool.

Our bodies eliminate excess heat through convection, radiation, and evaporation. *Convective cooling* occurs when air that is cooler than the body moves across the skin. *Radiant cooling* occurs when heat is radiated to the air from the skin. *Evaporation* of perspiration from the skin and in the respiratory tract also helps cool the body.

Chapter 3: Hawaii's Climate

Seasonal swings in temperature, precipitation, and wind conditions are moderate in Hawaii. Temperatures and humidity levels in Hawaii generally fall within or are only slightly outside of the ideal range for human comfort all year long. Fairly steady gentle trade winds help to offset these variations.

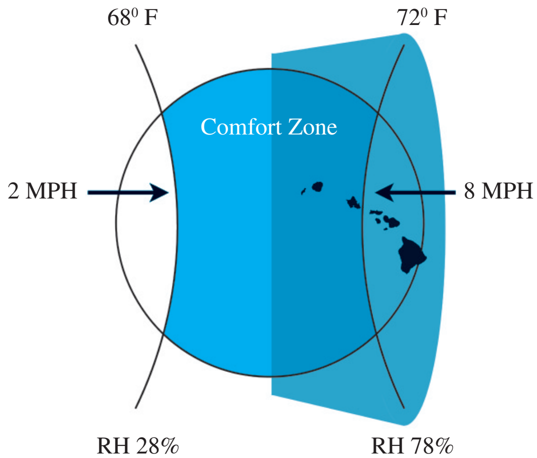
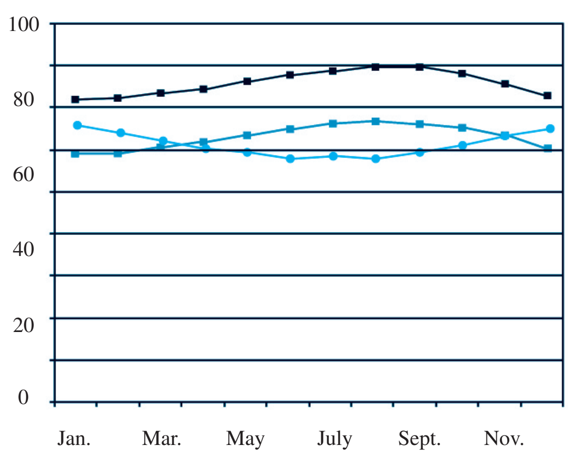


Fig. 3-1: Hawaii's Climate and the Human Comfort Zone.

Hawaii's climate provides near ideal temperature and humidity conditions throughout the year.

Sunlight and Temperature

The inhabited islands of the Hawaiian Island chain lie just within the tropics. Because of their low latitude, the islands experience relatively little annual variation in the length of the day, in sun angle and in solar insolation levels. (*Solar insolation* is energy received at ground level.) The surrounding ocean waters moderate temperatures and supply moisture to the air. In the course of the year, ocean temperatures range between 73^0 F and 80^0 F, with only a couple of degrees separating day and night time surface temperatures. Air temperatures closely parallel sea temperatures, with the yearly variation in average air temperature of 9^0 F or less.



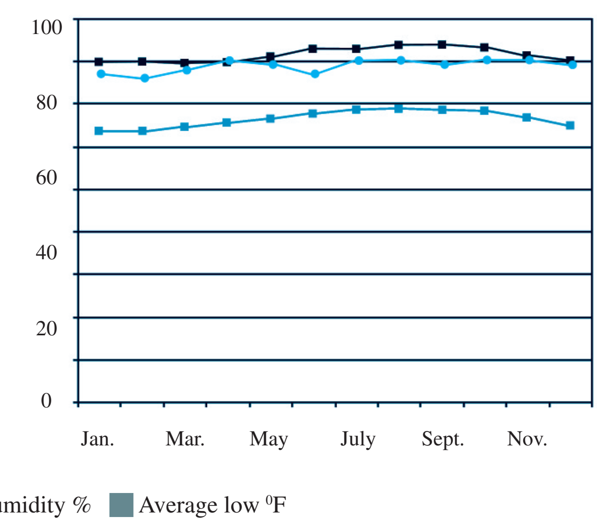


Fig. 3-2: Average Monthly Temperature and Relative Humidity in Honolulu. January and February are the coolest months with average air temperatures of around 70^0 F in most locations. August and September are the warmest months with average air temperatures of around mid to high 80s.

Fig. 3-3: Average Monthly Temperature and Relative Humidity in Hilo.

The daily range in temperature in the islands (day to night) can easily exceed annual temperature variations. Lower lying areas, such as Honolulu, can experience daily temperature changes of 10˚ to 12˚ F. High mountain areas such as the upper slopes of Haleakala (Maui) and Mauna Loa (Big Island) can experience daily temperature changes of 20˚ or more.

The islands' typically cool evenings help make homes more comfortable during their primary hours of occupancy.

Rainfall and Humidity

Relative humidity is an important comfort factor closely related to rainfall. Hawaii has a general pattern of wet winters and drier summers, with winter storms providing Hawaii's heaviest rains during the October to April storm season.

Relative humidity ranges between average lows of 60% and average highs of 80% with typical yearly averages of 70%. The highest humidity levels occur during the rainier winter months, but the effect of humidity is felt the most in August, September, and October when temperatures are still high and winds are less dependable. Refer back to Figure 3-2.

Winds

Hawaii benefits from steady gentle trade winds typically moving at 15 to 20 mph from the northeast to the southwest. Trade winds are quite steady through much of the year, blowing approximately 50% of the time in winter and 90% of the time in summer. They tend to be stronger in the afternoon than at night.

Reading a wind chart
- Location of shaded area within circle represents wind direction.
- Concentric lines indicate amount of time during year wind comes from a particular direction.
- Shaded areas represent various wind velocities.

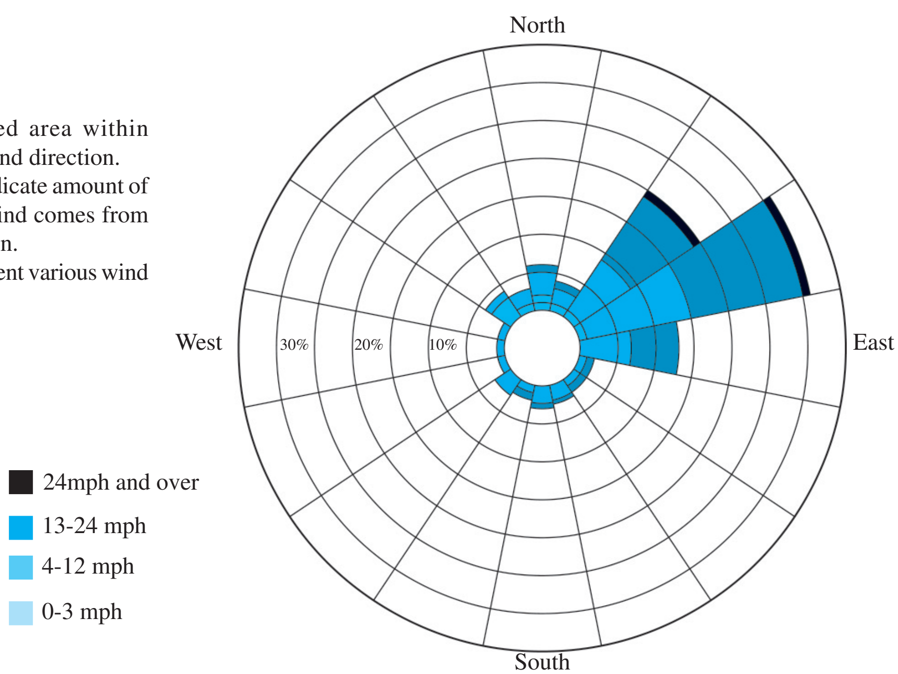


Fig. 3-4: Typical Trade Wind Patterns on Oahu (wind speed and direction).

Southerly or Kona winds occur with some regularity between October and April, and passing storms and cold fronts can bring southwest and north winds. Winter storms occurring between October and April can bring heavy rains and risk of damage from infrequent but potentially serious hurricanes.

Chapter 4: Special Site Conditions

Local site conditions play an important role in home design. To achieve optimum interior comfort at a given site, local variations or "micro-climate" conditions should be considered when identifying specific strategies for building and site design. These variations are largely the result of differences in elevation above sea level, topography, and orientation to the prevailing trade winds. See Figure 4-1, below. Additional data and references listed in the Appendices provide more information.

Talk to people who are familiar with the area where you plan to build. In addition, observe the type and patterns of natural vegetation in the area. They can tell you a great deal about climate conditions.

Sunlight and Temperature

Solar radiation levels, average air temperature, and daily temperature range vary with elevation, exposure to the trades and cloud cover. Cloud cover is substantially more common on windward coasts and over lower mountain areas. Leeward coasts and high mountain areas receive the most sunlight.

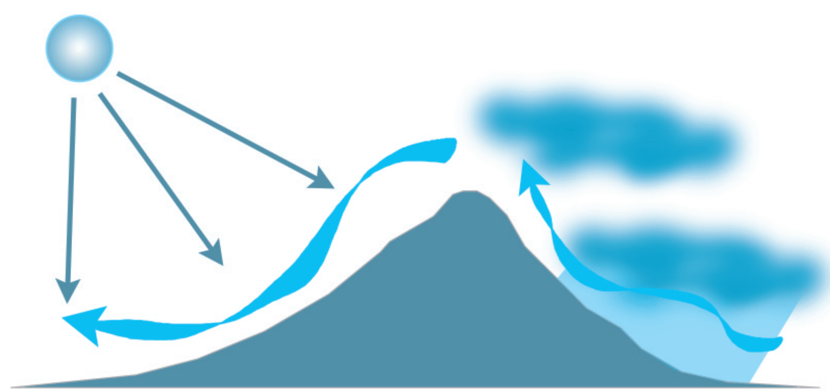
Fig. 4-1: Air Temperature Variation with Altitude.
Air temperatures decrease about 3^0 F per thousand feet of rise above sea level.

Rainfall and Humidity

Variations in rainfall are primarily due to differences in elevation, topography, and exposure to prevailing and seasonal winds. The open sea near Hawaii averages 25 to 30 inches of rain annually. Rainfall over the islands ranges from less than a third to fifteen times that amount. Humidity levels closely parallel rainfall patterns in the islands.

Fig. 4-2: Rainfall Patterns.

Mountains deflect the prevailing trade winds upward, cooling the air and trapping rain. Windward areas get substantially more clouds and rainfall than the nearby open sea and leeward areas. Leeward regions, where air that has lost its moisture over windward slopes descends, tend to be sunny and dry.



Adiabatic cooling (cooling as air rises and expands) combs rain from the moist ocean breezes that pass over the land. As a result, rainfall varies with altitude on windward slopes and closely parallels elevation on the lower islands.

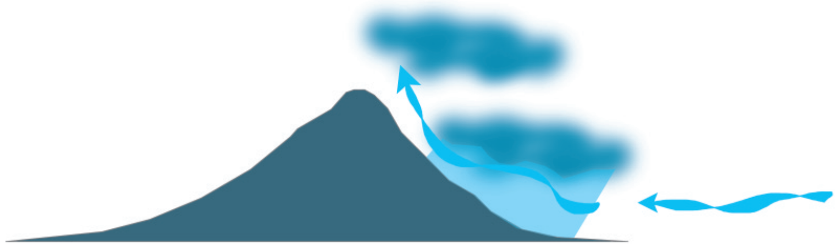
Windward areas such as Hilo on the Big Island receive much of their rain during the cooler evening and early morning hours. Leeward areas such as the south and west shores of the island of Hawaii may get most of their rain in the afternoon and early evening hours when onshore breezes created by heating of the land pull moist sea air over the land and up mountain slopes.

Wind

Mountains and valleys affect airflow. Winds that normally rise on encountering mountain slopes may deflect around larger mountain masses. Wind flowing over ridges, around headlands, and through valleys often accelerates and becomes turbulent. High mountains on Maui and the Big Island significantly disrupt the smooth flow of the trade winds experienced on islands with lower mountain masses.

Protected leeward areas may be more affected by local and daily shifts in wind than by the trades. The Big Island with its high mountains and substantial land mass, sees a daily pattern on leeward coasts of air moving landward during the day and seaward at night as the land heats and cools relative to steady sea temperatures.

Fig. 4-3: Wind Patterns.



Warm onshore breezes during the afternoon and early evening hours can bring rain.

Offshore breezes at night and in the early morning hours can bring cooler temperatures.

Section II: Introduction

Designing a home for optimum comfort and value requires an understanding of:

1. The basics of heat gain in the home (Chapter 5).

2. Strategies you can use to control heat build up:

   - Landscape and site design (Chapter 6);
   - Insulation and radiant barriers (Chapter 7);
   - Reducing heat transfer through roofs (Chapter 8);
   - Reducing heat transfer through walls (Chapter 9);
   - Reducing heat transfer through windows and other openings (Chapter 10).

3. How you can use natural ventilation to reduce heat build up in interior spaces:

   - Airflow around buildings (Chapter 11);
   - Airflow in buildings (Chapter 12).

A summary of key strategies and recommended techniques from Chapters 5 through 12 is provided at the end of this section on page 57.

Chapter 5: Heat Basics

The primary goal in an energy-efficient home in Hawaii is to provide adequate temperature control and comfort while eliminating or reducing the use of air conditioning. This translates to two key design objectives:

1. Control heat build up using orientation, landscape, and design strategies that keep heat away from and out of buildings.

You can prevent heat build up through the careful placement of buildings on the site, through the use of shading strategies and devices, and by taking advantage of a site's natural features. Using materials which, because of their physical qualities, color, or texture are "cool," can help to prevent heat build up, as will limiting the use of materials that are inherently "warm." Insulation and radiant barriers are also powerful tools for reducing heat build up in interior spaces.

2. Use natural ventilation to remove heat and naturally cool interiors.

Natural ventilation can be used to remove heat and humidity from interiors and increase occupant comfort.

There are a variety of methods that can help to accomplish the objectives described in Chapters 6 through 12. But first, let's do a quick review of the basics. Where does heat in a home come from? How does it travel? And how is heat transfer measured?

Sources of Heat

Heat in a home comes from internal sources such as appliances, equipment, electric lighting, and people, as well as external sources such as the sun (Figure 5-1).

Fig. 5-1: Heat Sources for a Home

- Sunlight
- Hardscape surfaces
- Electric lights
- Appliances
- Equipment
- People

Heat Transfer

Heat travels into and through the home in a variety of ways, but it always travels from warmer locations to cooler locations. The greater the temperature difference, the faster the heat transfers. Air conditioned homes in Hawaii create significant differences between indoor and outdoor temperatures. In such conditions, blocking the transfer becomes critically important for comfort and energy savings. For this reason it is important to understand how heat transfers through, into, and out of the home. There are three types of heat transfer: conduction, convection, and radiation. (Figures 5-2 though 5-8).

Measuring Heat Transfer

When talking about how readily heat will transfer in a home, we usually speak in terms of a material's ability to transfer heat or its resistance to heat transfer.

The ability of a material to transfer heat is quantified in terms of its *U-value*, measured in Btus per square foot of area per hour (Btu/ft^2/hr). (A *Btu* [British thermal unit] is the amount of heat needed to increase the temperature of one pound of water by 1° F.) The higher the U-value, the more readily (faster) the heat will transfer through the material.

The *R-value* is a measure of a material's *resistance* to transferring heat. U and R are related by: R=1/U. The higher the R-value, the greater the resistance to heat transfer.

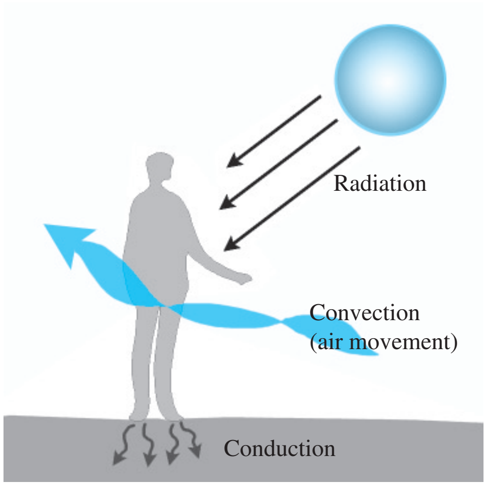


Fig. 5-2: Modes of Heat Transfer.

Heat is transferred to and through your home in the same way it is transferred to and through your body: conduction, convection, and radiation.

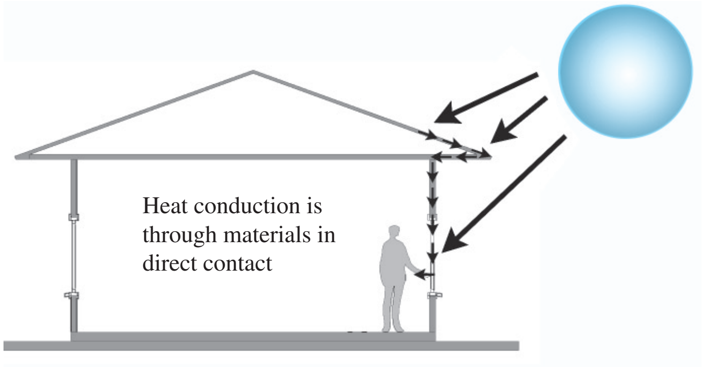


Fig. 5-3: Heat Transfer by Conduction.

In *conduction,* heat is transferred when warm and hot surfaces are in contact.

Insulation works by acting as a buffer between materials with significant temperature differences, such as hot exterior siding, and cool(er) interior wall surfaces. (Insulation may also reduce heat transfer through walls by radiation and convection).

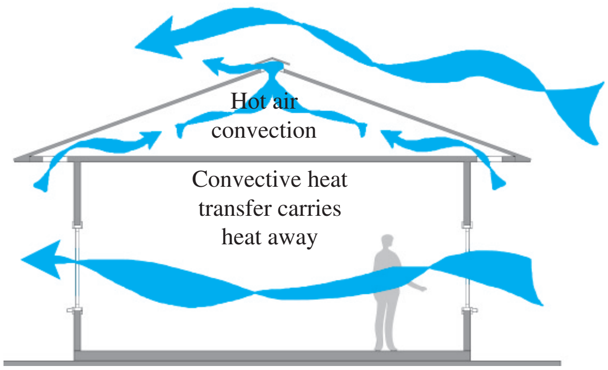


Fig. 5-4: Heat Transfer by Convection.

In *convection,* heat is transferred through a fluid (air or water). Warm fluids rise, cooler fluids sink.

Venting hot air can prevent heat build up in attics and occupied spaces. Natural ventilation uses convective heat transfer to carry heat away.

Heat from the sun radiates through space as electromagnetic energy in the near infrared range (near IR). Heat re-radiated from hot surfaces is in the form of electromagnetic energy in the far infrared range (far IR).

Understanding the difference between near infrared solar heat and far infrared heat radiated by materials that have been warmed by the sun is critical for selecting glazing that can prevent the buildup of heat in building interiors (see Chapter 10).

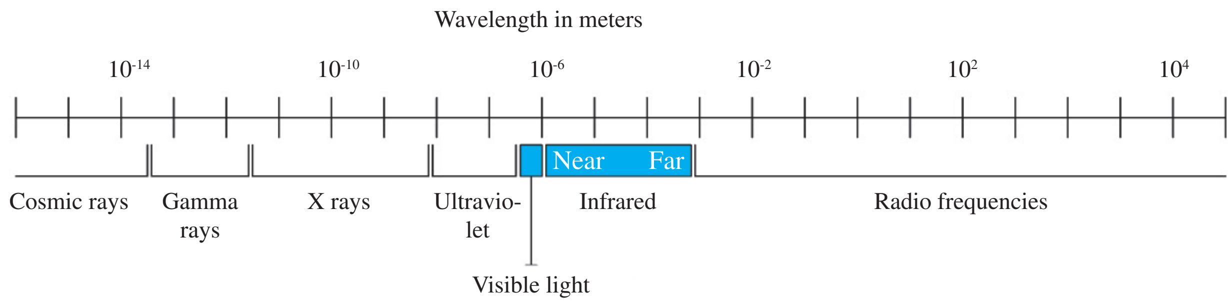
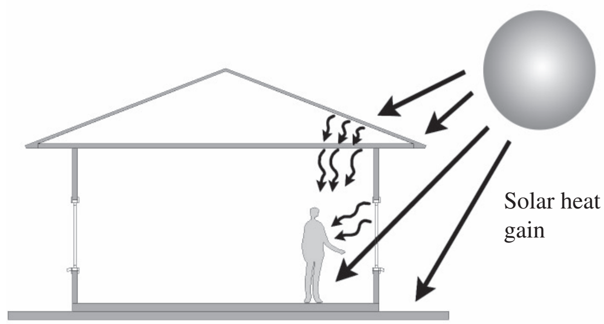


Fig. 5-5: Electromagnetic Spectrum.

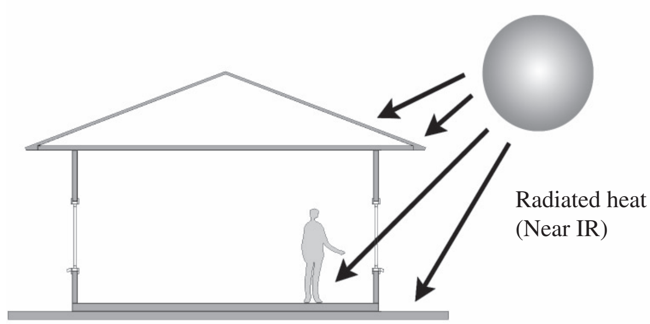
Fig. 5-6: Heat Transfer by Radiation.

In *radiation,* heat is transferred in the form of invisible electromagnetic waves. When the energy of radiation strikes an absorbing material, it is converted to heat. People absorb radiant heat from sunlight, hot walls, and ceilings.



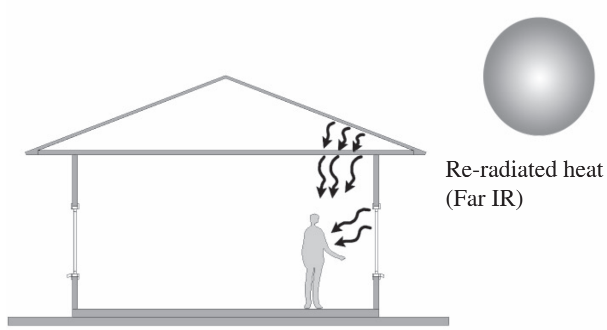
Radiated heat (near IR radiation): Sunlight (solar radiation) heats up surfaces exposed to the sun, such as roofs, walls, and pavement.

Radiant barriers reflect the sun's radiant heat protecting homes from solar radiation.



Re-radiated heat (far IR radiation): Objects heated by the sun re-radiate heat at a different wavelength.

Careful selection of low thermal mass materials can help avoid storage, build-up, and re-radiation of heat from building materials.



Chapter 6: Landscape and Site Design

Heat gain can be reduced with thoughtful building placement and site layout, through landscaping design, and through careful selection of materials for paving outdoor surfaces. See Table 6-A for a comparison of cooling elements.

Building Orientation and Shape

Recommended Technique: Limit heat build-up by orienting longer sides of the home north and south.

Solar Insolation* Btu/Sq. Ft. per day
21° Latitude

	East	South	West	North	Horizontal
Winter	780	1381	780	197	1374
Summer	950	309	950	591	2051

**Insolation* is the amount of solar radiation striking a surface.

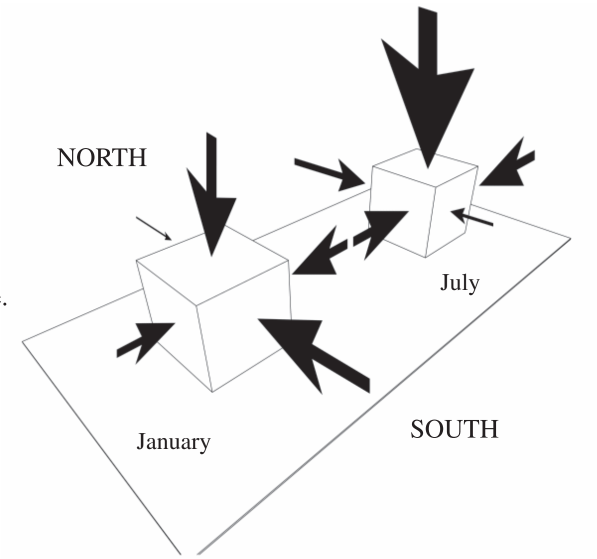
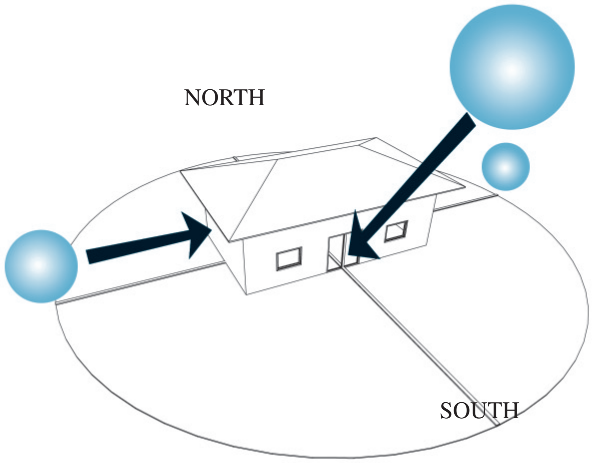


Fig. 6-1: Building Orientation and Solar Heat Gain.

Solar heat gain has the largest impact on surfaces perpendicular to the sun's rays. In Hawaii these are the roof, the east and west walls, and the south wall (especially during winter months).

Fig. 6-2: Building Shape and Solar Heat Gain.

Homes oriented with the narrow sides facing East-West will reduce low sun angle exposure and provide the best shading opportunities.



Elongated floor plans with the narrow sides facing within 15 degrees of East-West will minimize heat gain from the low angle morning and afternoon sun.

Although the south facade receives high solar insolation in the winter, this value can be reduced with roof overhangs. For more information on shading see Chapters 9 and 10.

Landscape Elements

Recommended Technique: Use existing or new landscape elements (trees) to shade the building.

Shaded areas stay cooler

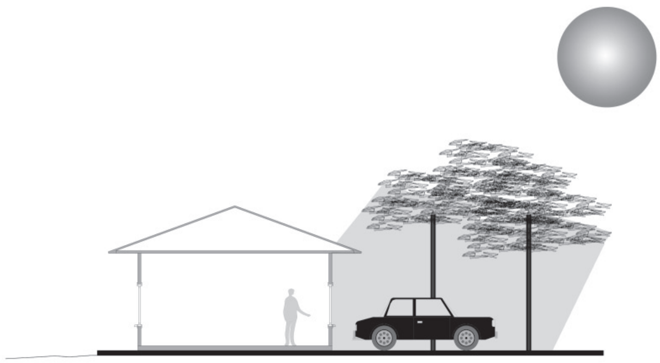
Fig. 6-3: Shading the Home with Landscaping.

Shading walls and roofs with plantings, such as shrubs, shade trees, and trellises supporting plants such as bougainvillea, can reduce solar heat gain.

Recommended Technique: Shade hardscapes, such as walls and paved areas.

Fig. 6-4: Shading Hardscapes with Landscaping.

Plantings, such as trees and shrubs, absorb solar radiation and shade the ground, lowering surface temperatures. Plants also cool the air around them through transpiration of water vapor.

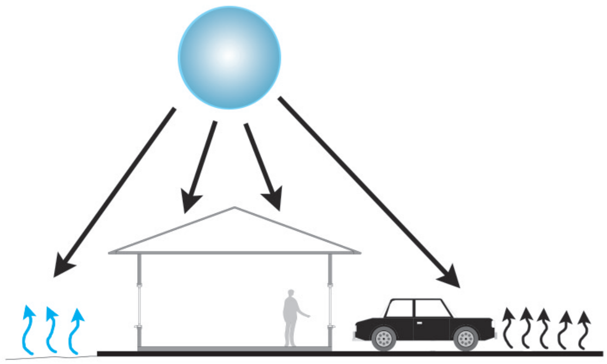


Shaded areas stay cooler

A single mature tree can provide nearly $300 annually in energy and resource values in terms of cooling, erosion and pollution control, and wildlife shelter. (Source: U.S. EPA, 1992)

Note: Prune lower branches to avoid blocking natural breezes.

Recommended Technique: Limit the area of unplanted and paved exterior surfaces. Provide generous areas of planting and ground cover to help reduce temperatures on the site.



The air temperature around unshaded landscaped areas are up to 10˚ cooler than unshaded hardscape areas.

Fig. 6-5: Hardscapes and Solar Gain.

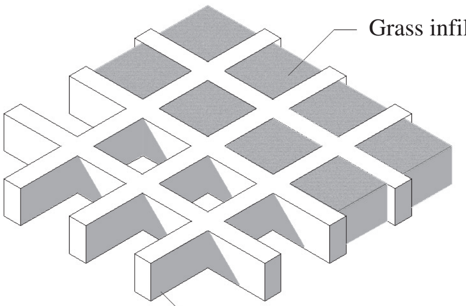
Air temperatures above unshaded hardscape surfaces are up to 10˚ hotter than air temperatures above unshaded landscape areas, and up to 26˚ hotter than shaded landscaped areas.

Non-planted surfaces affect temperature and visual comfort. Dark materials, such as asphalt, absorb, conduct, and re-radiate heat. But they are easier on the eye. Light materials, such as concrete, absorb, conduct, and re-radiate significantly less heat but can cause glare.

Recommended Technique: Use porous paving materials to reduce thermal mass, heat gain, and glare.

Fig. 6-6: Porous Paving.

Usually made of plastic or concrete, porous pavers have a grid-like pattern that allow vegetation to grow in the "pores" of the product. They are appropriate for areas of light traffic such as parking lots and driveways.



Porous paving is a good substitute for standard concrete or asphalt paving. Porous pavers reduce hardscape surfaces without sacrificing "drivable" areas.

Table 6-A: Comparing the Benefits of Site Elements for Air Conditioned Homes

Site Element	Potential Cooling Benefit
Trees and plantings	Carefully placed trees that provide both shading and evaporative cooling can reduce cooling energy requirements between 10% and 50%.
Light hardscapes	Computer simulations show light colored outdoor surfaces can reduce cooling energy use between 30% and 50% when compared to the same amount of dark colored surfaces. EPA, 1992
Porous Pavers	Porous pavers suitable for light traffic areas increase landscaping and provide added reductions in cooling energy use.

Chapter 7: Insulation and Radiant Barriers

Insulation and radiant barriers can significantly reduce heat buildup in the home. Many of the recommended practices in Chapters 8 and 9 incorporate these materials. To use insulation and radiant barriers effectively, it is important to understand these materials and how they work.

Insulation

Insulation works by resisting the transfer of heat through building walls, roofs, and ceilings. As discussed in Chapter 5, this "resistance" is stated in R-values. The higher the R-value, the greater the ability of the material to insulate. Insulating products have relatively high R-values compared to other building materials, such as concrete and steel. There are pros and cons to specific insulation types. For example, different insulation materials with the same thickness will have different R-values. A comparison of insulation types is summarized in Table 7-A. For construction details, see Chapters 8 and 9.

Insulation products come in a variety of forms**,** typically, rolls or batts, loose-fill, and rigid boards, providing ease of installation in a variety of applications. For example, loose-fill, which can be blown into the walls or attic of an existing structure, is a good option for renovation projects. Rigid foam, which provides more insulation per inch of thickness and may have structural properties, is easy to apply over framing members during the construction of a new home.

Insulation in air conditioned homes creates significant temperature differences between the interior and exterior of a home (see Figure 7-1). The dew point — the point at which water vapor in the air condenses to form liquid water — can be a concern in insulated air conditioned homes. When air is cooled below the dew point, water vapor in the wall cavity can wet the insulation. Wet insulation loses its insulating characteristics. Also, accumulation of water within the wall can produce mold or mildew and damage the wall assembly. *Vapor retarders* are sheets of plastic or felt that are highly resistant to water vapor. If installed on the exterior (more humid) side of the insulation, they can prevent moisture from condensing within the wall assembly.

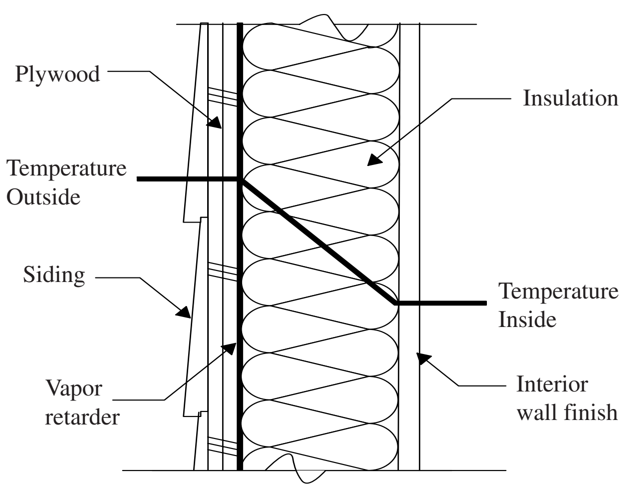
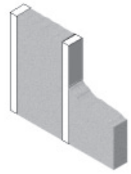
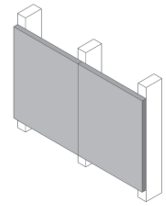


Fig. 7-1: Insulation is an Effective Barrier to Heat Transfer.

Insulation acts as a thermal buffer by reducing the amount of heat passing through walls and ceilings to the interior. Insulation is an effective barrier to conduction, convection, and radiant heat transfer.

For air-conditioned homes, a vapor retarder should be installed on the humid side of the insulation to prevent moisture condensation problems.

Table 7-A: Comparison of Typical Home Insulation Products

Type	Batts 	Loose-Fill 	Rigid Board 
Made from	Fiberglass, mineral wool	Fiberglass, mineral wool, or cellulose	Expanded polystyrene (EPS or beadboard), extruded polystyrene, polyisocyanurate, fiberglass
Description	Produced in widths and thickness to fit standard wood stud wall cavities (16" or 24" wide; 4" or 6" thick); kraft paper or foil backing helps in fastening to studs	Bulk	Lightweight, produced in large sheets
R-Value (per inch of thickness)	3.2	2.2 to 3.6	4 to 6.5
Energy Issues	Must be installed correctly to eliminate voids and hot spots	Unless installed with a binder, the material can be blown around or settle causing voids and hot spots	When installed as sheathing, provides continuous barrier, reducing thermal conduction; material's R-value can degrade over time. Polystyrene is better in moist conditions, and polyisocyanurate has a higher R-value.
Health and Environmental Issues	Several batt products include recycled content, a plus. However, with fiberglass, safety measures should be taken during installation and disposal to avoid undue exposure to fibers (and formaldehyde, found in the binders used in most fiberglass products). Fiberglass should not be used inside air ducts where it can break down and enter the airstream. Significant environmental concerns exist related to disposal of fiberglass insulation.	Several loose-fill products include recycled content, a plus. However, with fiberglass, safety measures should be taken during installation, demolition, and disposal to avoid undue exposure to fibers (and formaldehyde, found in the binders used in most fiberglass products). Fiberglass should not be used inside air ducts where it can break down and enter the airstream. Significant environmental concerns exist related to disposal of fiberglass insulation.	Many produced with CFCs (chlorofluorocarbons) and HCFCs (hydrochloro-fluorocarbons), generally believed to cause ozone depletion in the Earth's atmosphere. Rigid fiberglass and expanded polystyrene (EPS or beadboard) are produced without CFCs and HCFCs, and other rigid board manufacturers are working to eliminate this problem. Often contain urea formaldehyde in the foaming agent and may release toxic fumes when burned.
Application	New and remodels	New and remodels	New and remodels
Installation Information (See Chapters 8 and 9 for construction details.)	Fiberglass batts with paper or foil backing can be stapled to wood studs and joists when walls or ceilings are open.	Can be blown into walls and attics of existing structure and other difficult areas.	Nailed to framing or sheathing. Laid between ceiling joists.
Installed Cost	\$0.80 to \$1.00 per sq. ft.	\$0.80 to \$1.00 per sq. ft.	\$1.00 to \$2.00 per sq. ft.

Radiant Barriers

Radiant barriers are thin sheets of highly reflective material that prevent heat from building up in the home by "reflecting" rather than absorbing and then re-emitting heat. The lower the "emissivity" rating, the more effective the radiant barrier. Radiant barriers without insulating properties should be considered a supplement to, not a replacement for, insulation.

For ease of installation, the reflective material is normally adhered to a substrate, such as paper, plastic film, insulation, fabric, cardboard, or plywood. Radiant barriers can be installed in walls, but are more commonly used in attics. For construction details, see Chapters 8 and 9.

Table 7-B: Comparison of Radiant Barriers

Type	Roll/Reflective Insulation	Single-Sided Foil, Double-Sided Foil, & Multi-Layered Foil
Made from	Polyethylene air bubble pockets sandwiched between thin layers of reflective aluminum foil.	Foil with another material backing, such as kraft paper or polypropylene.
Physical description	4 and 6 ft. widths, 125 and 250 ft. lengths. Thin, lightweight, has little or no effect on building design loads. Impervious to insects, birds, and nesting rodents. Can be pressure washed.	Make sure material is listed as a radiant barrier.
Energy Issues	In addition to reflectivity, has an R-value of up to 15. Can act as a vapor and/or air barrier.	Not all foil barriers are alike; in general the shinier the material, the better the reflectivity. Look for emissivity below .10.
Health and Environmental Issues	Requires no special safety measures during installation.	Requires no special safety measures during installation.
Application	New construction and remodels.	New construction and remodels.
Installation Information (See Chapters 8 and 9 for construction details.)	Drape over rafters before the roof is installed, or stapled to the underside of rafters. Shiny side should face down. Useful in thin furred spaces above open beam ceilings. Must have soffit and ridge or gable vents and allow an airspace next to the foil side of material.	Drape over rafters before the roof is installed or stapled to the underside of rafters. Shiny side should face down. Must have soffit and ridge or gable vents and allow an airspace next to the foil side of material.
Installed Cost	$0.60 to $1.20	$0.60 to $1.00 per sq. ft.

Chapter 8: Heat Mitigation in Roofs

The roof is the greatest source of heat gain for homes in Hawaii, receiving about 1,700 Btu per sq.ft. per day. Solar radiation coming through the roof can account for a third of the heat build-up in a house. A roof can reach temperatures of 150^0 F, even when the ambient outdoor temperature is only 80^0 F. By paying special attention to the roof, you can make significant strides in preventing uncomfortable heat build-up in your home.

Several strategies address heat transfer through the roof. These include:

- Shading from existing trees, nearby structures, and topography
- Light colored roof surfaces
- Insulation
- Radiant barriers
- Roof vents

Using a combination (or all) of these strategies is the most effective way to achieve a comfortable, cool home, significantly reducing or even eliminating the need for air conditioning.

Shading

Recommended Technique: Shade roof to prevent heat build-up.

Fig. 8-1: Preventing Heat Gain by Shading the Roof.

One of the easiest ways to prevent the transfer of heat through a roof is to not let the roof get hot in the first place. Shading a roof will reduce its surface temperature.

Roof Assembly

Recommended Technique: Use roofing materials that will reflect the sun's heat rather than absorb and transfer it to the home's interior.

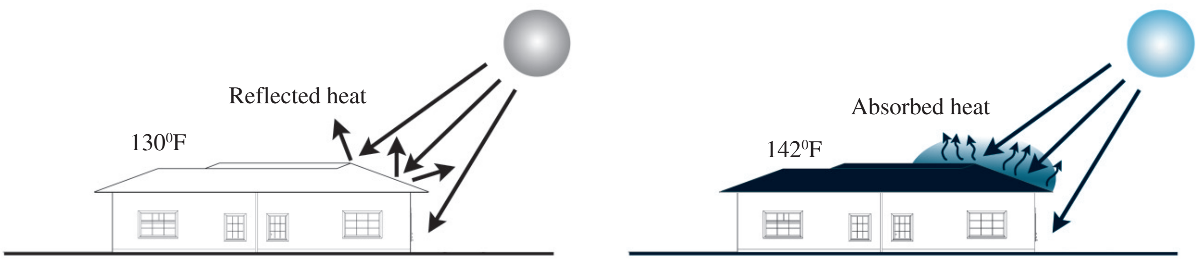


Fig. 8-2: Using Roof Materials to Reflect the Sun's Heat.

A light colored roof can reflect 25-30% of the sun's radiant heat and can be as much as 12° cooler than a dark colored roof. (*Source: Department of Education, State of Hawaii, 1979.*)

Both the color and the type of material affect amount of radiant heat reflected (measured in "reflectance"). Table 8-A compares the reflectance value of a number of roofing materials.

Table 8-A: Comparison of Different Roofing Materials, Showing White (Cooler Options).

Roofing material	Reflectance Value	Reflectance for White (Cooler) Option	Cost Increase for White (Cooler Option)
Asphalt Shingle	5-15%	31-35%	<1%
Clay tile	25-35%	70-80%	~35%
Concrete tile	10-30%	70-80%	~20%
Cementitious shingle	10-30%	60-80%	None
Metal sheet or shingle	70%	70-80%	None

Source: Green Seal, Energy Star® Homes Project

Recommended Technique: Insulate ceilings and attic spaces.

Insulation slows the transfer of heat from warm to cooler areas. When used in a roof assembly insulation can substantially reduce heat gain through a roof. Insulation can be effective when installed in either the roof (at the rafters) or in the ceiling. To keep a home cool, an R-value of 19 is recommended in roof construction.

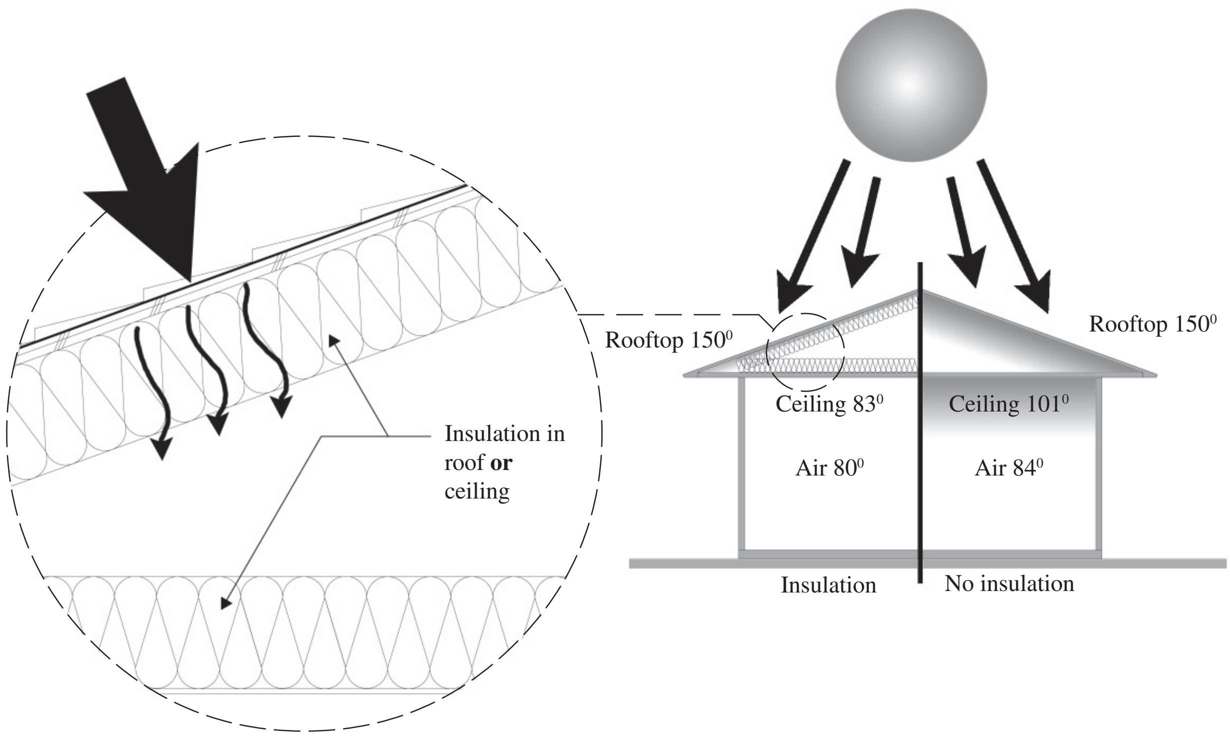


Fig. 8-3: Insulate Ceilings to Reduce Heat Gain.

Heat conducted through the roof heats the ceiling, which in turn radiates to the interior surfaces and occupants. R-19 insulation can reduce ceiling temperatures by more than 15˚ F (not including the impact of radiant barriers).

People are particularly sensitive to heat from overhead sources, and this reduction in real surface temperatures can make a room feel 9˚ F cooler.

Recommended Technique: Install radiant barriers in ceilings or attic spaces.

While insulation slows the rate of heat transfer, radiant barriers reflect the sun's radiant heat away from the home. *Proper installation is extremely important if a radiant barrier is to work effectively*. Installation details will depend upon the type of radiant barrier used (see Chapter 7, Table 7-B for a comparison of radiant barriers). However, two guidelines always apply:

1. Radiant barriers must be installed next to a minimum 3/4-inch air space. The air space can be located on either side of the radiant barrier, but best performance is achieved when the air space is on the exterior side of the radiant barrier.
2. Radiant barriers should be installed with the shiny foil side down to avoid dust build-up on the reflective surface, which reduces the barrier's effectiveness.

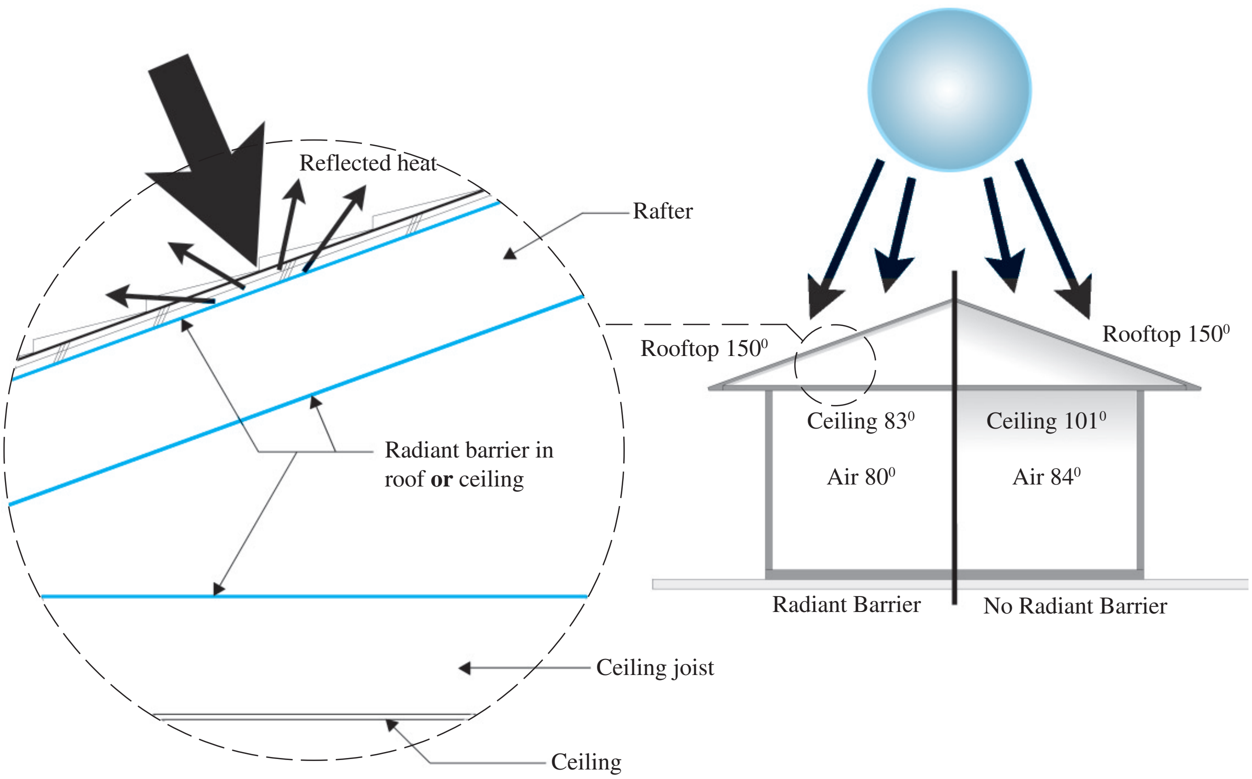


Fig. 8-4: Use Radiant Barriers in Ceilings to Reduce Heat Gain.

The reflective side of the radiant barrier must face an airspace to prevent the transfer of heat. In attics, this can be done by laying the material on top of the joists or by attaching it to the rafters as shown. Avoid damaging the radiant barrier during installation.

Properly installed radiant barriers can reflect up to 95% of the sun's radiant heat and reduce indoor air temperature by 4˚ F. A 4˚ reduction will make occupants will feel 9˚ cooler.

Because radiant barriers can reflect up to 95% of the sun's radiant heat, they reduce the amount of insulation needed to keep a home cool. Table 8-B shows the R-value of insulation recommended with and without a radiant barrier.

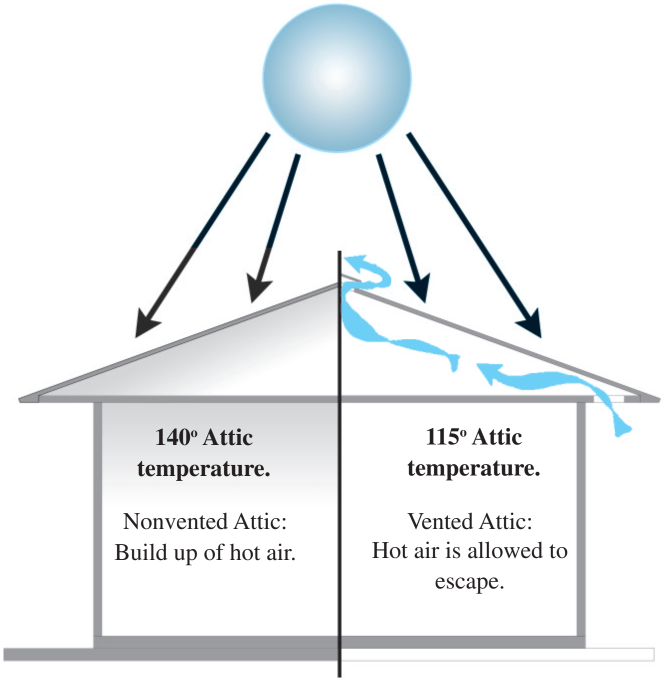
Table 8-B: Recommended Insulation R-values With and Without Radiant Barrier.

Roof Surface Color	Absorptivity*	Minimum R-Value of Roof Insulation	
		With Radiant Barrier	Without Radiant Barrier
Black or Dark Gray	0.90	R-3	R-19
Medium Red, Green, Brown, Gray	0.75	R-2	R-15
Yellow, Buff	0.60	R-1	R-11
Light Gray	0.55	R-1	R-8
White (built-up roof)	0.50	R-0	R-7
White (tile, paint, plaster)	0.40	R-0	R-5
White (glazed brick, tile or metal)	0.30	R-0	R-3

* *Absorptivity* is the amount of radiation absorbed by an object relative to the amount radiation striking its surface. The range for absorptivity is 0.0 to 1.0.

Recommended Technique: Ventilate roof properly.

There are several ways to ventilate roof and attic spaces. All techniques admit cool air and allow hot air to escape. A properly ventilated attic will keep the attic cooler and reduce moisture build-up.



Source: Air Vent Inc., 1997

Fig. 8-5: Roof Ventilation: Continuous Ridge and Soffit.

With a continuous ridge-and-soffit vent system, vents draw in cool air from the eaves and exhaust hot air through the roof's ridge. Air moves through the attic either through wind movement or through convection.

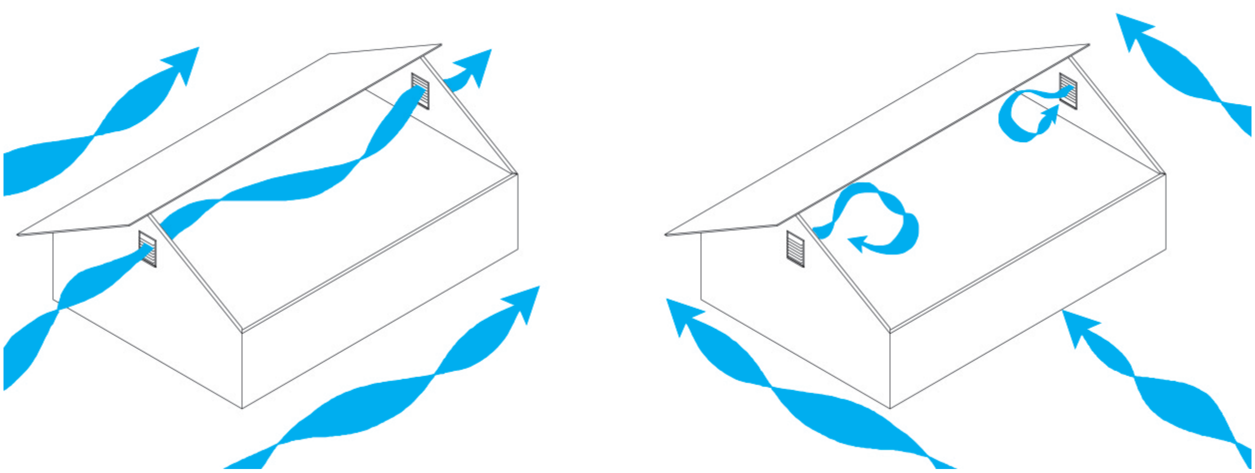


Fig. 8-6: Roof Ventilation: Gable End Vents.

Generous gable end vents can provide openings to vent hot air and admit a free flow of cooling outdoor air through attic spaces. However, when the wind direction is parallel to the roof gable, attic ventilation is limited.

Tips for installing ridge vents:

- Exterior baffles (Figure 8-7) deflect wind and rain, substantially increasing the effectiveness of ridge vents.
- Intake (soffit) and exhaust (ridge) vent areas should be equal. These areas should be calculated using the net unobstructed area and not the area of the vent itself. Vents often contain screens or grills that decrease their effective open areas.
- Ridge vents need baffles to stop water infiltration from wind-driven rain.
- If foam blocks are used to seal vent ends, make sure blocks are covered with a UV-resistant coating.
- Leave a 3/4-inch gap on each side of the roof peak.
- Alignment tabs help to maintain a uniform distance between vent panels, and allow for faster installation. If the vent does not have alignment tabs, leave a 1/8-inch gap between the panels to allow for expansion.

Recommended Technique: Integrate roof strategies.

Using a combination (or all) of the measures listed above is the best, most complete way to ensure a cool home. Using these materials and techniques will reduce heat gain and can reduce or eliminate the need for air conditioning.

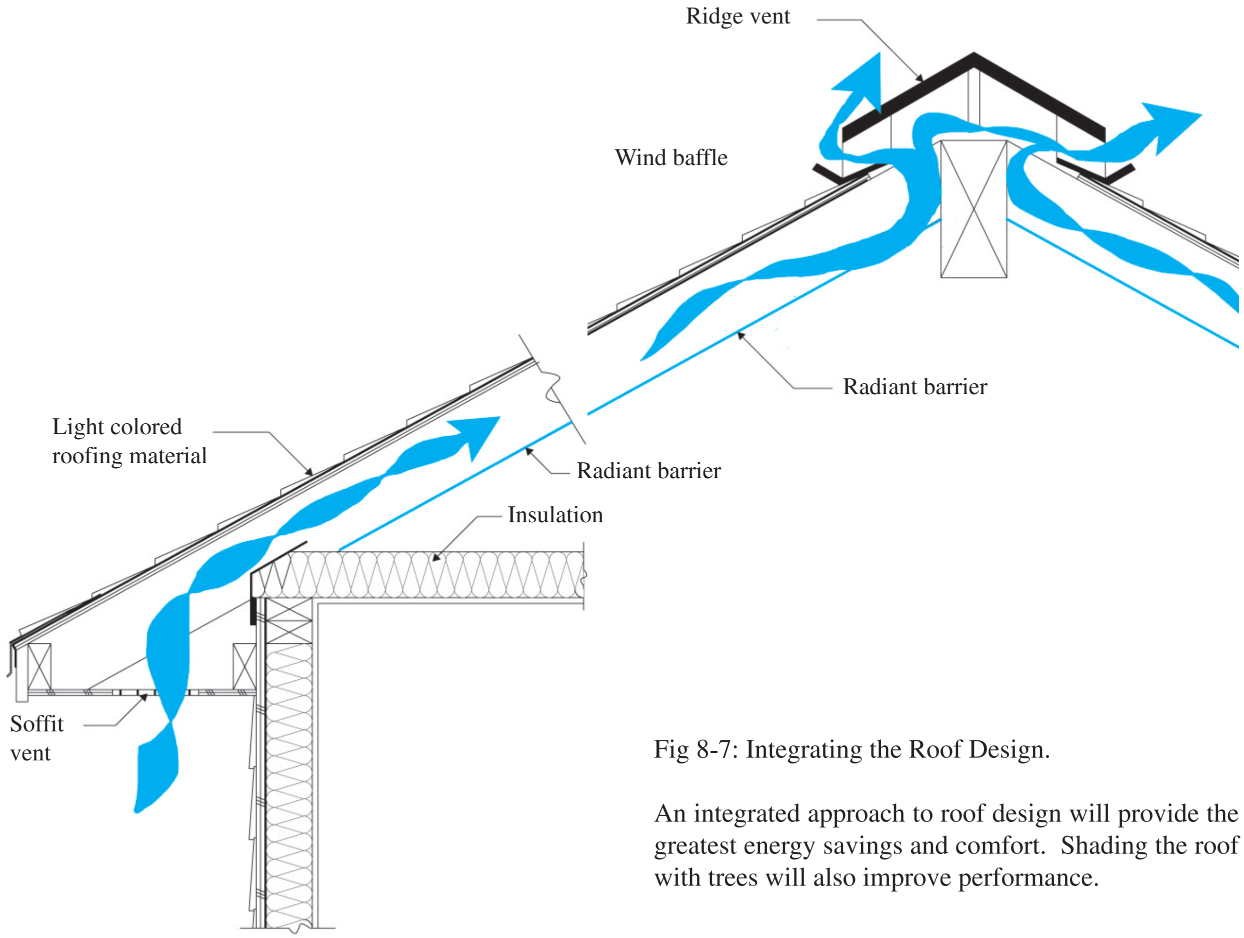


Fig 8-7: Integrating the Roof Design.

An integrated approach to roof design will provide the greatest energy savings and comfort. Shading the roof with trees will also improve performance.

Chapter 9: Heat Mitigation in Walls

In Hawaii, unshaded walls are exposed to high levels of solar radiation. During the winter months, south facing walls can receive over 1,300 Btu/sq.ft./day. During the summer, east and west walls receive nearly 1,000 Btu/sq.ft./day. If this heat is allowed to re-radiate into interior spaces, it can create discomfort in the home. The same techniques and materials used to keep roofs cool apply to walls. Keep walls cool with:

- Shading from architectural (see below) and landscape elements (see Chapter 6)
- Light colored wall surfaces
- Insulation
- Radiant barriers

Recommended Technique: Use design elements to shade walls.

Trellises, covered lanais, carports, and roof eave overhangs make effective shading devices for walls (Table 9-A shows the recommended overhang size for walls). See Chapter 10 for more information on shading devices.

Table 9-A Overhang Size for Walls.

Wall Height (feet)	Minimum Overhang Size (inches)	
	North	East, South, West
7	17	26
8	20	29
9	22	33
10	24	36
11	27	40
12	29	44
13	32	47
14	34	51
15	36	54

Recommended Technique: Use light colored wall finishes.

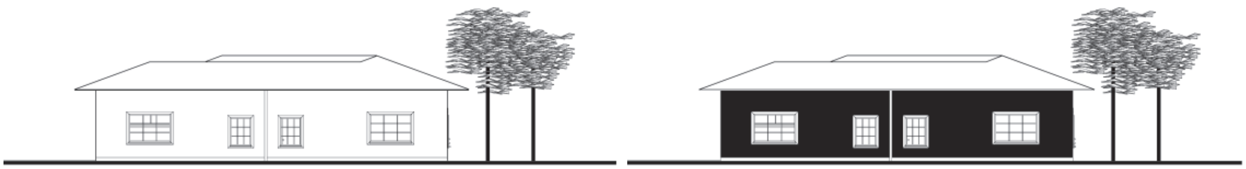


Fig. 9-1: Light Colored Surfaces Reflect Heat and Stay Cooler.

Recommended Technique: Insulate walls exposed to the sun.

By insulating walls exposed to the sun, you can lower the indoor temperature of the home significantly. For walls, insulating to R-11 is recommended. For more information on insulation, see Chapter 7.

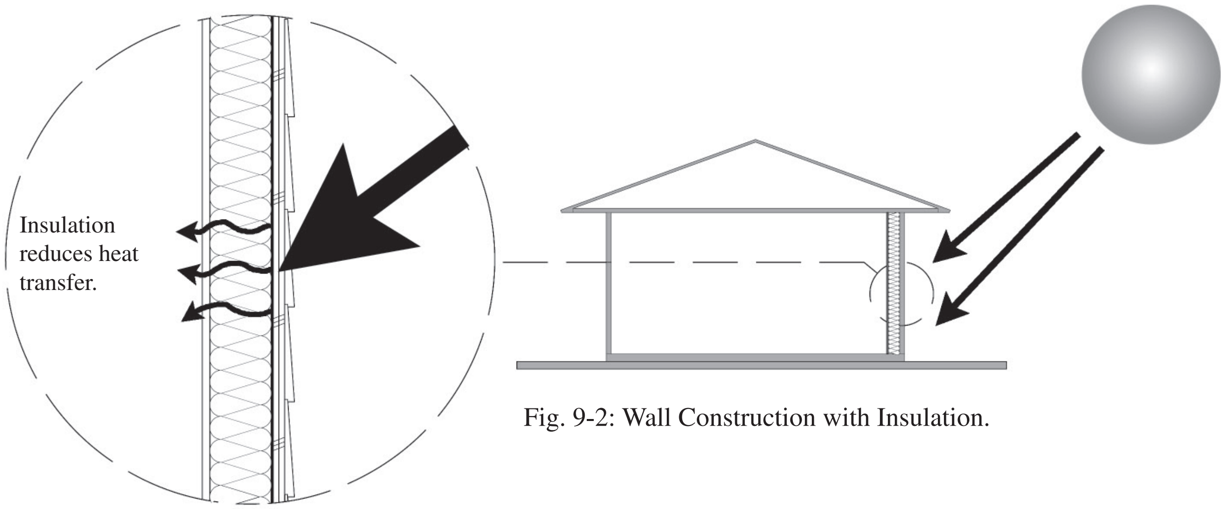


Fig. 9-2: Wall Construction with Insulation.

Recommended Technique: Install radiant barriers in walls exposed to the sun.

Just as with roofs, radiant barriers in walls can greatly reduce the heat transferred to the interior of a home. For more information on radiant barriers, see Chapter 7.

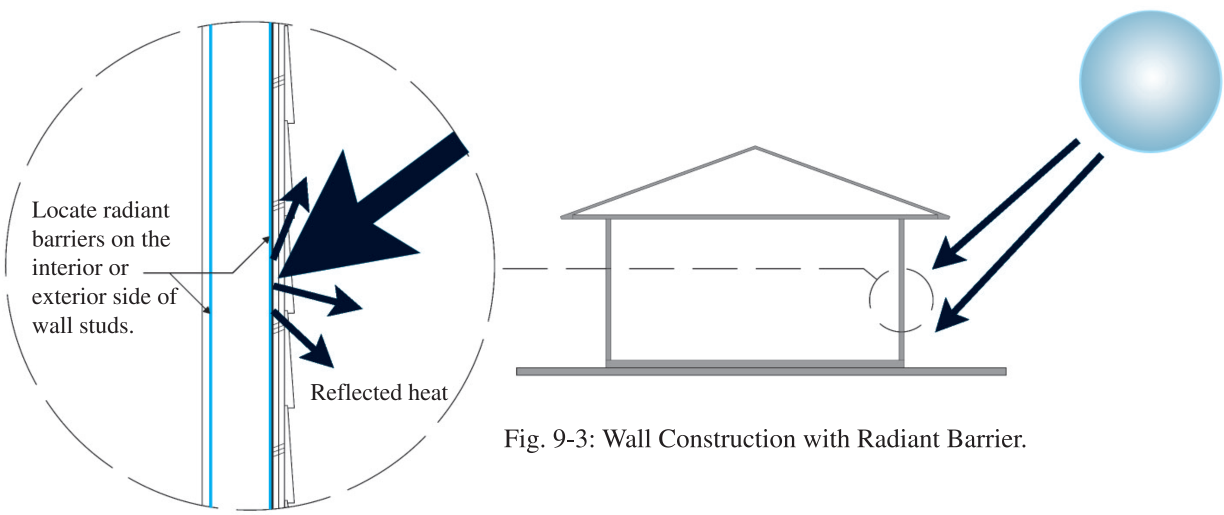


Fig. 9-3: Wall Construction with Radiant Barrier.

Chapter 10: Controlling Heat Gain for Windows and Other Openings

Windows provide access to views, natural light, and natural breezes. However, direct sunlight from windows can account for over half of the summer cooling energy load in an air conditioned home. This chapter discusses strategies to prevent heat build-up while still maintaining a connection to the outdoors and access to natural light. (Chapter 12 will discuss optimizing window placement and configuration as part of a natural ventilation plan.)

The strategies for preventing heat build-up through windows, skylights, and other openings (such as glazing in doors) include:

- Shading
- High performance glazing
- Limiting the size of openings

Fig. 10-1: Sunlight and Window Glazing.

The energy in sunlight (solar radiation) hitting a window is reflected, transmitted, or absorbed and re-radiated.

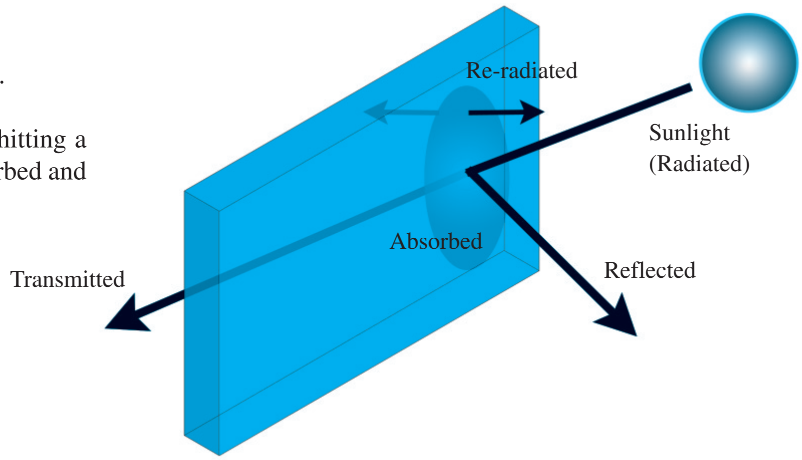


Fig. 10-2: Sunlight and Heat Production Inside the Home.

The solar radiation passing through a window is near infrared radiation (near IR). This heat is absorbed and then re-radiated from warmed interior surfaces as far infrared radiation (far IR). Near IR heat passes very easily through the glass into the home. Far IR heat does not pass easily through glass and gets trapped in the home. This is the same process that heats your car up when it is left out in the sun all day.

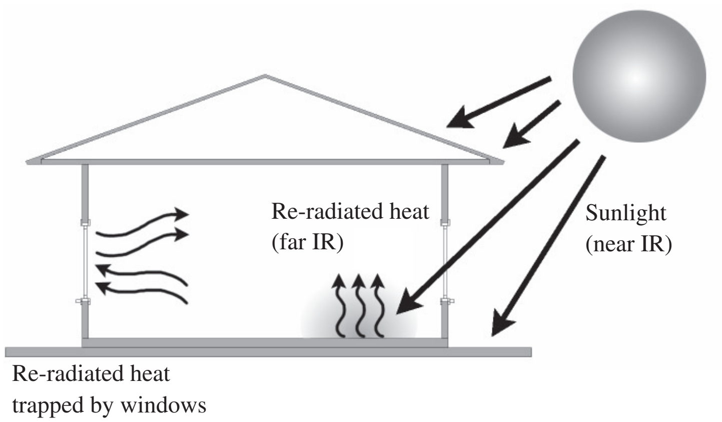


Table 10-A compares the percent reduction in solar heat gain using improved window options verses 1/4-inch single-pane glazing. Exterior shading provides the biggest reduction in heat gain. When exterior shading is not possible, combining strategies, such as partial exterior shading and/or interior shading and high performance glazing, can be effective.

Table 10-A: Comparing Improved Window Options to Conventional Glazing

System	Reduction in solar heat gain vs. 1/4-inch single-pane clear glazing
Exterior shading	80%
Reflective glazing/films	37-68%
Spectrally selective glazing	37-58%
Tinted glazing	26-37%
Interior light colored blinds, lowered but open	30%
Interior medium colored blinds, lowered but open	22%
Interior translucent shade	54%
Interior opaque shade, white	59%
Interior opaque shade, dark	15%

Source: ASHRAE Handbook of Fundamentals, 1989

Recommended Technique: Shade windows and other openings.

Exterior Shading

Exterior shading is the most effective method for reducing heat gain in a home through windows. To work, however, shading devices must be adapted to the sun's path and angle as it hits the surfaces of the home.

North- and south-facing windows are best shaded by horizontal devices, such as overhangs and trellises. East- and west-facing windows, which are subject to lower sun angles, are better protected by vertical shading devices, such as walls and fins (see Figures 10-3 and 10-4). For more information on sizing shading devices, see Appendix D.

Fig. 10-3: Window Shading: Horizontal Shading Devices.

Horizontal shading devices, such as overhangs, are good for blocking high angle sunlight. They work best on the north and south facades of the home.

To calculate the eave width needed to shade south-facing openings use a 45° angle.

To calculate the eave width needed to shade south-facing openings use a 70° angle.

Fig. 10-4: Window Shading: Vertical Shading Devices.

Vertical shading devices such as walls and fins are good for blocking low angle sun on the east and west facades.

Vertical shading devices can also aid in natural ventilation (see Chapter 12).

Plan (top) view of vertical shading wall.

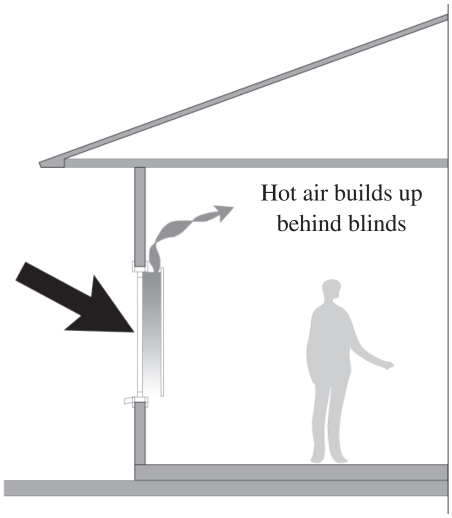
Isometric view of vertical shading wall.

Interior Shading

Fig. 10-5: Interior Shading.

Interior window treatments, such as shades, blinds and shutters, reduce heat build-up in the home by reducing the amount of direct sunlight entering interior spaces. However, they don't work as well as exterior shading devices because the air behind the shading device warms up. Eventually, this warm air circulates into the room.

Interior shades still can reduce interior temperatures somewhat by keeping the sun's rays away from high thermal mass materials, such as concrete floors.



Recommended Technique: Use high performance glazing on windows exposed to the sun.

Sunlight allowed to pass through a window brings both visible light and heat. The *Visible Light Transmission Coefficient (VLTC)* measures the amount of visible light admitted through a window. The higher the VLTC, the greater the light transmission. The amount of solar radiation admitted through a window is measured by the *Solar Heat Gain Coefficient (SHGC)*. The lower the SHGC, the less heat transmitted. High performance or *spectrally selective glazing* reduces the heat transmitted through the window while permitting high levels of visible light to pass through. As a result, high performance glazing can reduce cooling energy needs while reducing electrical lighting needs. Such glazing also reduces the fading of interior furnishings due to ultraviolet radiation.

You will not enjoy the benefits, however, unless you choose glazing that is designed for Hawaii's tropical climate. Many *low emissivity (Low-e)* glazing systems are designed for temperate (mainland) climates and aim to keep a home cool in the summer and warm in the winter. Windows designed for temperate climates can actually make homes in Hawaii hotter.

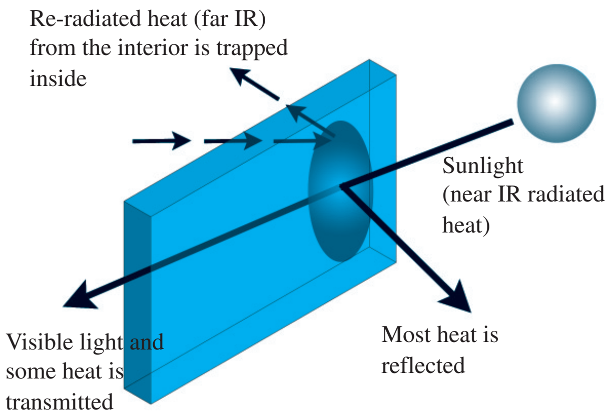


Fig. 10-6: Sunlight and Low-e Glazing (Temperate Climates).

Low-e glazing designed for temperate climates reflect far IR heat back into the house to keep the home warm in winter. The coating reflects both near and far IR radiation.

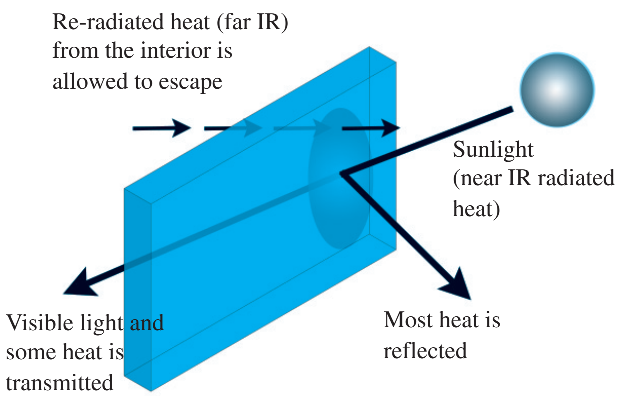


Fig. 10-7: Sunlight and Low-e Glazing (Tropical Climates).

Low-e glazing suitable for Hawaii allows interior heat to escape as well as reflects exterior heat. The coatings reflect near IR and transmit far IR radiation.

Unfortunately, Low-e glazing designed for Hawaii is still expensive and does not perform as well when compared to a well-shaded window.

It is important not to confuse Low-e and spectrally selective coatings with tinting. Tints do not reflect near infrared radiation. They absorb it. As the tint absorbs radiation it will get warmer and eventually re-radiate the energy as heat. In effect, the tint becomes a heat source. Some dark tints actually admit more heat than visible light. For example, a dark gray tint can have a high SHGC of 0.58 and a low VLTC of 0.30. In addition, tinted glass can make a room feel gloomy, and result in higher lighting bills. Conversely, low-e and high performance glazing such as green and blue tints transmit more visible light than heat. Table 10-B shows the heat gain (SHGC) and light transmittance (VLTC) for various glazing types.

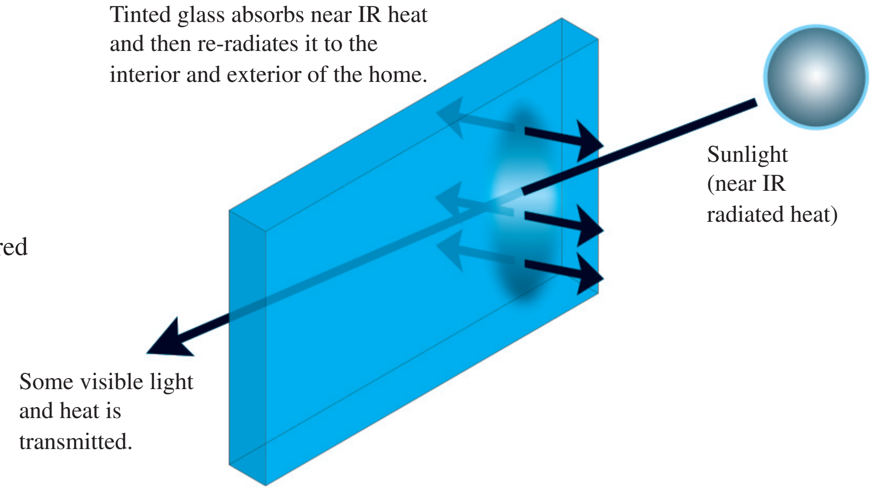


Fig. 10-8: Sunlight and Tinted Window Glazing.

Tinted windows absorb near infrared radiation, becoming a heat source.

Table 10-B Comparison of Glazing Type, Heat Gain, and Light Transmittance.

Glass type	Solar Heat Gain Coefficient (SHGC)	Visible Light Transmittance (VLTC)
Single Pane Glazing– Standard Glass		
Clear	0.85	0.90
Bronze	0.72	0.67
Gray	0.68	0.60
Dark Gray	0.58	0.30
Single Pane Glazing– Spectrally Selective Glass		
Standard Green Tint	0.70	0.83
High Performance Green Tint	0.61	0.76
High Performance Blue Tint	0.57	0.77
Double Pane Glazing		
Clear	0.76	0.81
Standard Low-e Coating	0.65	0.76
Spectrally Selective Low-e Coating	0.38	0.71

Here are some tips for selecting high performance windows:

- Seek a Solar Heat Gain Co-efficient (SHGC) of .65 or *less*.
- Seek a Visible Light Transmission Co-efficient (VLTC) of .7 or *more*.
- Look for a U-value *equal to or less* than 0.45, which corresponds to an R-value *equal to or greater* than 2.22.
- For air conditioned homes, make sure the Air Leakage Rate (ALR) is 0.2 *or less.* (*ALR* measures the air leakage for windows subjected to a wind of 25 mph. The lower the ALR the better the window seal. ALRs are reported per area for fixed windows, and per opening length for operable windows.)
- If you want to go the extra mile, look for frame and sash materials that contain non-toxic, recycled, or recyclable materials. New eco-labels (such as Green Seal) certify windows that are extra energy-efficient and are produced or shipped in an environmentally responsible manner.
- Windows with Low-e and spectrally selective coatings can be obtained from a large number of manufacturers. Use the standards listed above to ensure that windows are designed for a tropical (Hawaiian) climate.

Recommended Technique: Limit area of openings.

The total area of glazed openings will greatly affect the amount of light and solar heat gain transmitted into a home. Large windows can provide beautiful views and create dramatic spaces, but they can also result in significant heat gain. Larger windows require more shading or better performing glazing. The size of a window should be balanced against how much solar heat gain it will admit.

Recommended Technique: Use skylights with great care.

Skylights are an attractive way to bring natural daylight into a home. However, unless they are designed properly, skylights can cause glare and result in heat gain. For more information on skylights and their design, see Chapter 14.

Chapter 11: Airflow Around Buildings

Natural ventilation refers to the process of exchanging warm building air for cooler outside air without the use of energy-consuming mechanical devices, such as fans and air conditioners. Used in conjunction with insulation and/or radiant barriers, natural ventilation can reduce or eliminate the need for air conditioning in residential construction. To maximize opportunities for natural ventilation *inside* the home, you must make sure your building has unrestricted access to the breezes *outside*. (See Chapter 12 for more information about designing the interior of your home for natural ventilation.)

Recommended Technique: Orient buildings to maximize the cooling potential of prevailing winds.

Use open, elongated, or segmented plans, which are set at a slight angle to prevailing winds with the narrow building ends facing east and west. This approach will reduce solar heat gain on east and west facades and will provide maximum opportunities for cross ventilation.

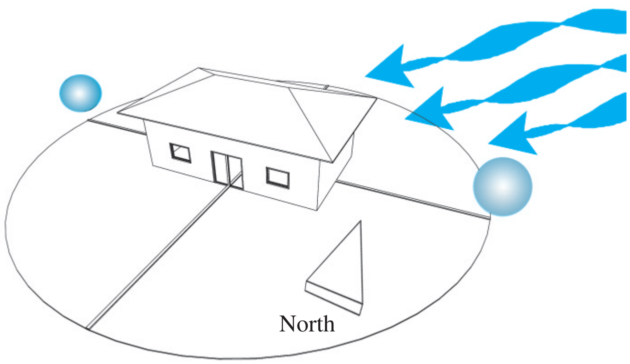
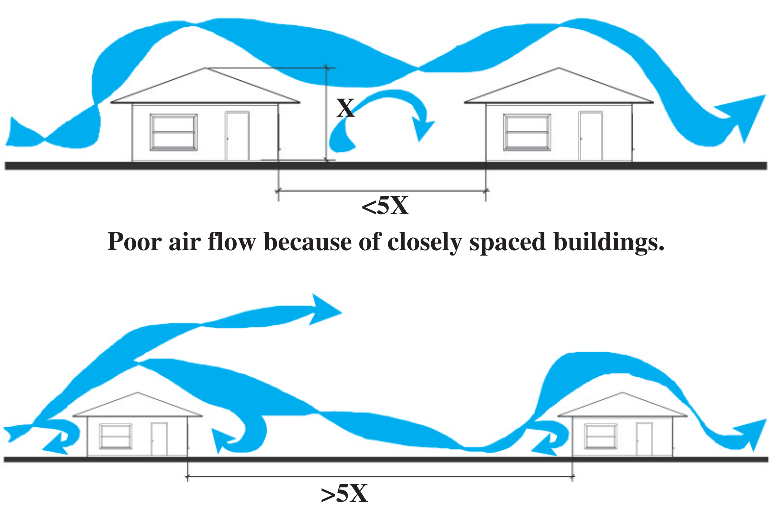


Fig. 11-1: Building Orientation for Cooling.

Proper building orientation will improve cross ventilation and solar control.

Recommended Technique: Provide ample spacing between buildings in the direction of wind flow.

Spacing buildings by a distance of at least five times the height of the upwind building provides greater natural ventilation opportunities for the down wind building.



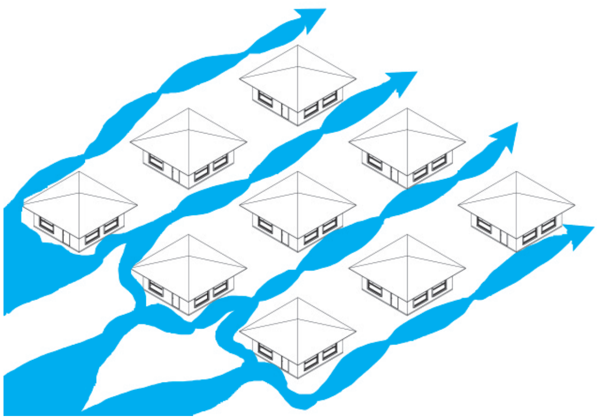
Poor air flow because of closely spaced buildings.

Good air flow because of adequately spaced buildings.

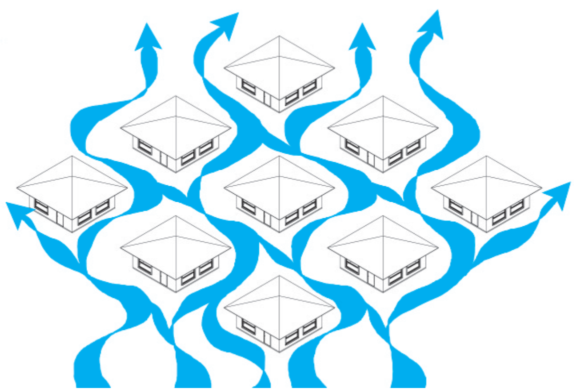
Fig. 11-2: Spacing of Multiple Buildings for Cooling.

Recommended Technique: Arrange buildings to provide for good air flow around all structures.

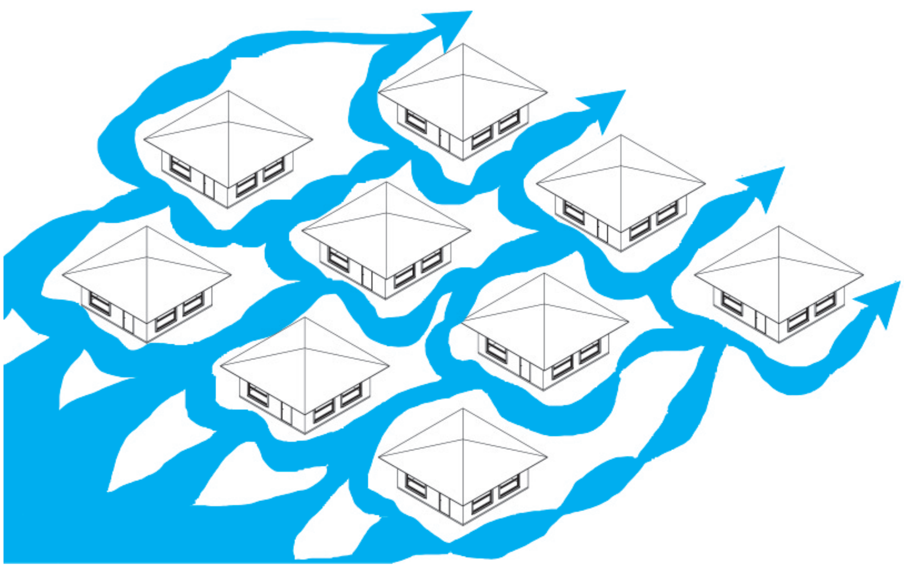
Air flow around a building creates a high-pressure zone on the windward face and low-pressure zones on the leeward face and on sides that are parallel to the wind direction. Buildings aligned with the wind direction create "wind shadows" and poor ventilation conditions. Ventilation around buildings can be improved by orienting the buildings at an angle to the predominant wind direction. This can also increase the effective distance between the buildings.



A linear arrangement of homes lined up parallel to the wind direction creates poor airflow.



A linear arrangement of homes lined up at an angle to the wind direction provides good airflow.

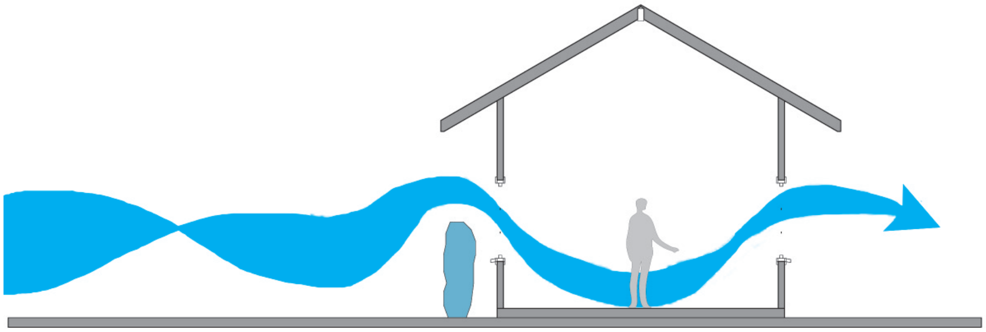


A staggered arrangement of homes creates good airflow regardless of wind direction.

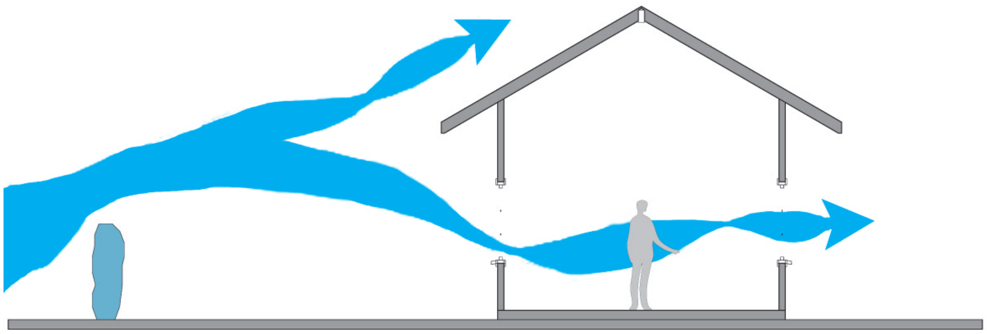
Fig. 11-3: Arranging Multiple Buildings for Good Air Flow.

Recommended Technique: Use landscaping elements to improve air flow around structures.

Plantings or bermed and built elements, such as trees, hedges, fences, and garden walls, can direct breezes to improve natural ventilation.



Hedges or planting close to a house can restrict airflow and deflect breezes downward.



Better airflow is achieved with hedges farther from the home.

Fig. 11-4: Using Landscaping to Improve Air Flow Around Structures.

Select and prune trees to allow air to flow freely at window levels. Monkeypod trees are wonderful models for energy efficient building design. The tree's sheltering canopy shades surrounding surfaces, reduces radiant heat, provides adequate views, and allows for cooling breezes to penetrate from the sides.

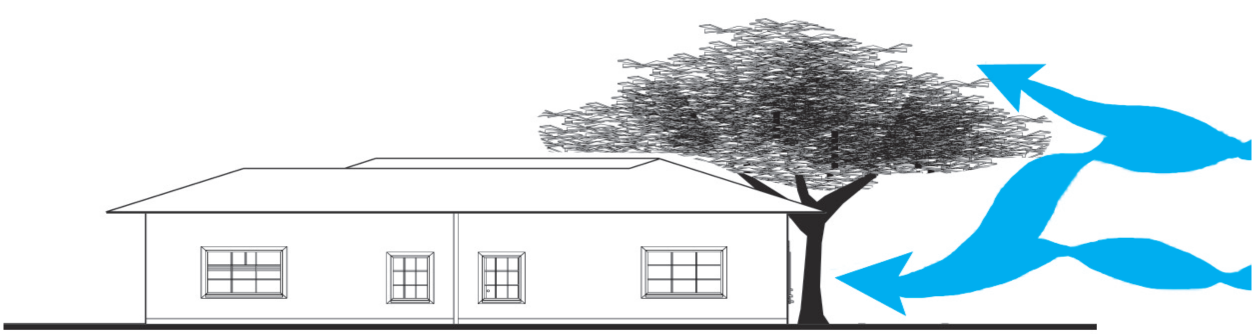


Fig. 11-5: Using Landscaping for Cooling.
Landscaping can keep homes cool by shading and directing airflow.

Chapter 12: Airflow in Buildings

As we mentioned in Chapter 11, *natural ventilation* refers to the process of exchanging warm building air for cooler outside air without the use of energy-consuming mechanical devices, such as fans and air conditioners. To maximize opportunities for natural ventilation in the home, you must orient the building for maximum access to outside breezes as discussed in Chapter 11, and your design must provide openings that will encourage cross-ventilation inside the home. The primary strategies for creating effective cross ventilation inside the home are:

- Provide an adequate number of windows
- Design for optimum window type, size, and placement
- Use ceiling fans where required to improve airflow.

Floor Plan Design and Orientation

> **Recommended Technique: Design floor plans that provide effective natural ventilation and good air circulation at body level.**

For adequate ventilation, there should be at least two operable openings to the outside in each space. Operable openings include operable windows and entries (doors). Entries should have screen doors. Solid doors should be provided with a door catch to hold them open. Two common window configurations are: openings on adjacent walls (A), and openings on opposite walls (B) (see Figure 12-1). Spaces with only one exterior wall are difficult to ventilate effectively. In this situation casement windows or a wing wall may be used to improve ventilation (C).

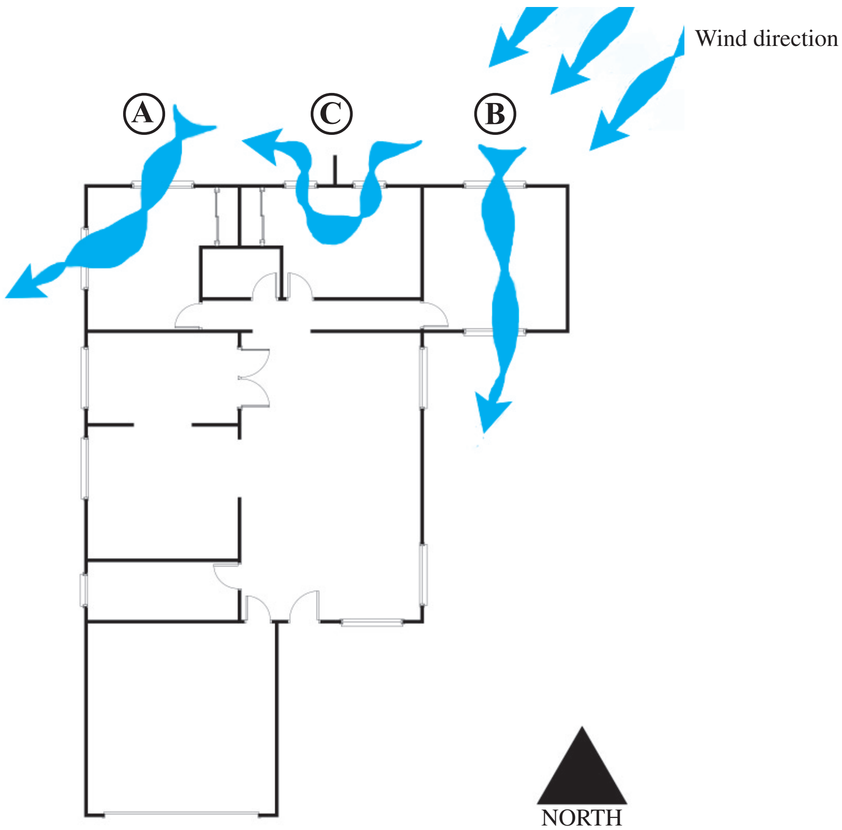


Fig. 12-1: Basic Natural Ventilation Strategies.

Open floor plans enhance air flow and daylighting of interior spaces. Narrow cross sections also improve air flow and daylight penetration. Staggered configurations or building wings can be used to improve air circulation throughout the home (see Figure 12-2).

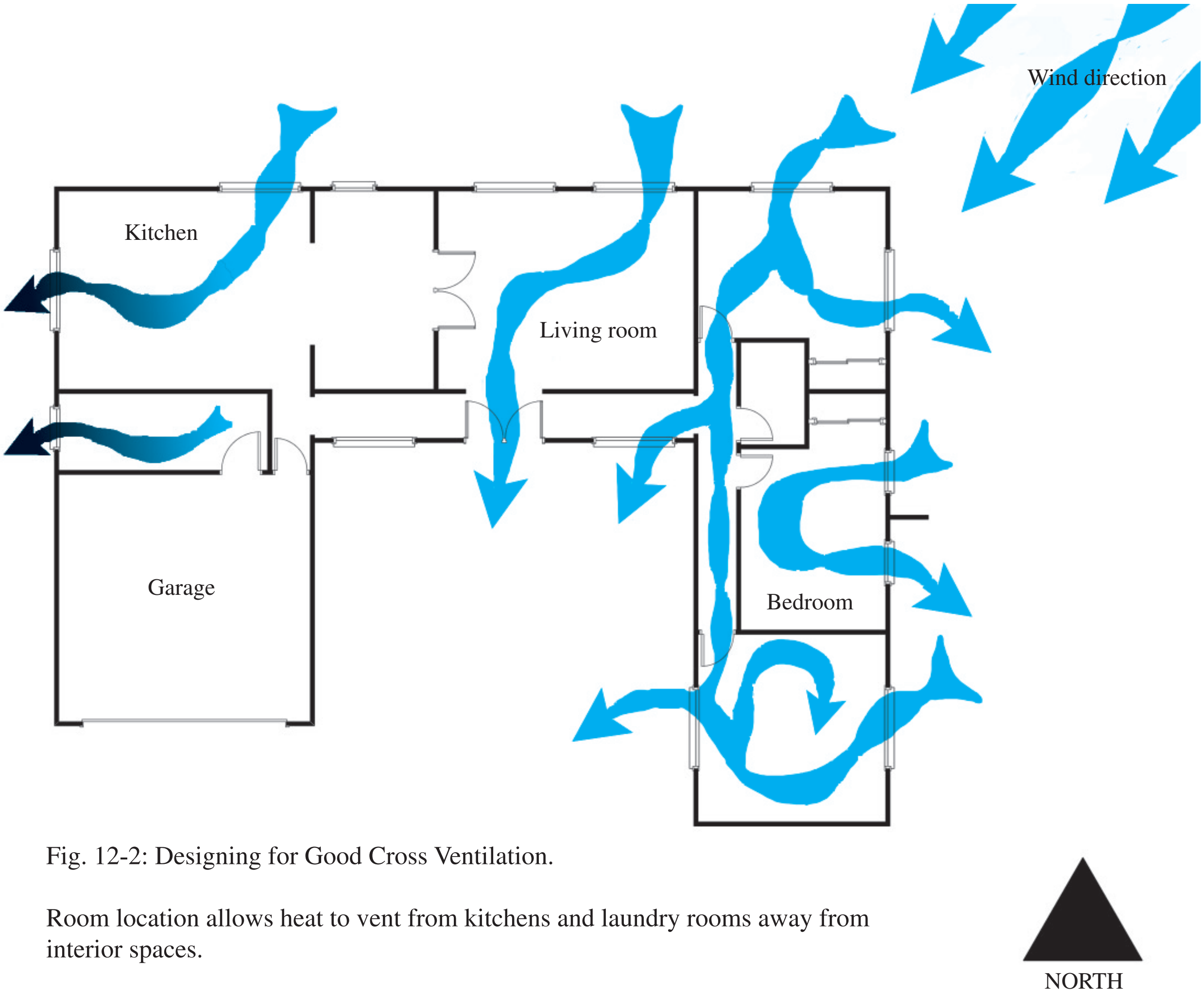


Fig. 12-2: Designing for Good Cross Ventilation.

Room location allows heat to vent from kitchens and laundry rooms away from interior spaces.

Here are some tips for designing for effective natural ventilation:

- Use open floor plans with a minimum of interior partitions to improve air circulation throughout the home.
- Use louvered doors and shutters to allow air to circulate freely through spaces while maintaining visual privacy.
- Rooms that produce heat and humidity such as kitchens, laundry rooms, and bathrooms require special planning. They should be well ventilated and placed on the leeward side of the house to prevent hot humid air from spreading into other living spaces.
- Protect exterior doors from rain with generous eaves and screens if they are to be used for natural ventilation. Hinged doors should have stops and hold-open devices.
- Use louvers or catches on interior doors.
- Install a ceiling fan for every 400 square feet of floor space to improve comfort levels when breezes are light.
- Separate garages or place them on the leeward side of the home so they do not block needed airflow.

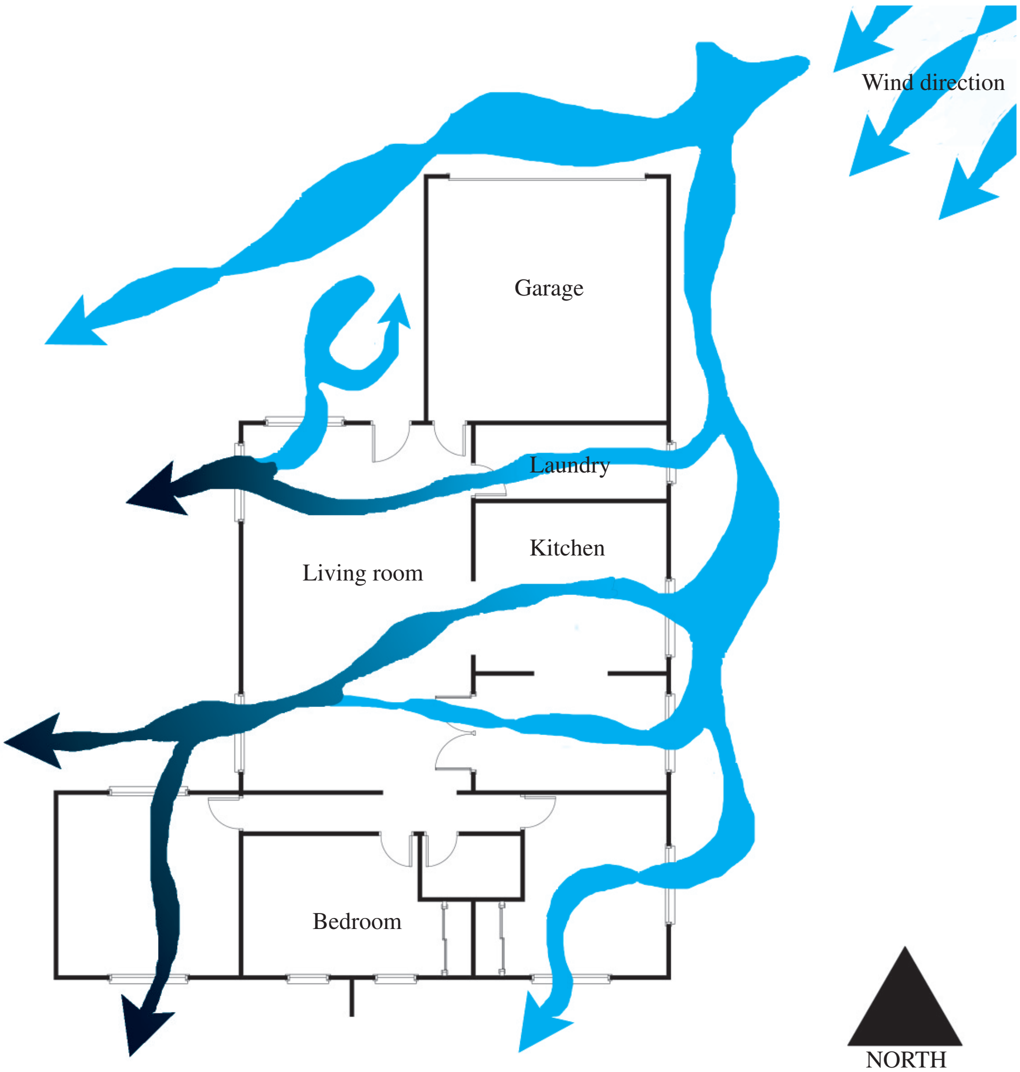


Fig. 12-3: Poor Design for Cross Ventilation.

The garage blocks airflow, and location of kitchen and laundry directs heat from these areas to other occupied spaces.

Recommended Technique: For spaces with openings on opposite walls, orient the room 45^0 from the wind direction.

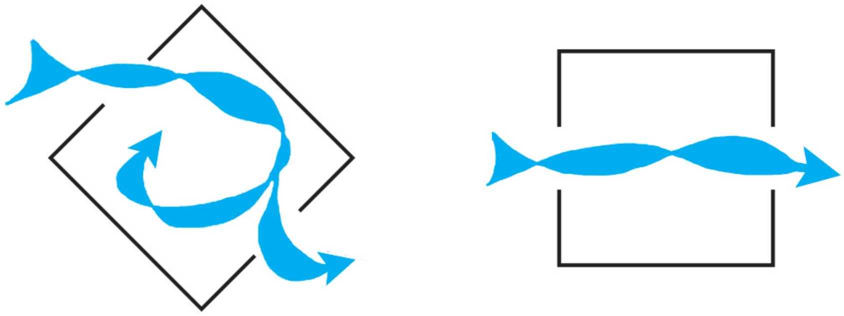


Fig. 12-4: Room Orientation for Improved Air Flow.
Rooms oriented 45^0 relative to the prevailing wind direction will see 20% improved air flow.

Window Type and Size

Windows types vary substantially in their net opening size, the degree of protection they offer from rain, and their ability to direct airflow. All window types should be provided with screens and protected from direct sunlight. To admit sufficient outside air, windows and other operable openings should have a net opening area equal to at least 12% of the room's floor area. Only the area of the window that can be opened is considered towards the 12% (see Figure 12-5). For a list of window types and their net open areas see Figure 12-6. No more than 70% of the opening area should be placed on one wall or to one side of a wing wall.

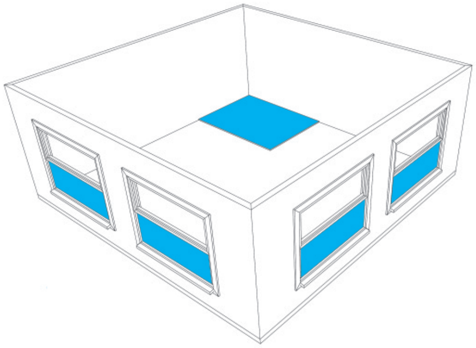


Fig. 12-5: Window Sizing for Air Flow.

Operable openings should be at least 12% of the floor area.

Single and double hung windows are the least effective window for controlling rain and air flow due to their small open area and vertical orientation. Single hung windows especially are a poor choice since the upper sash, although usually protected by eave overhangs, is not operable and does not allow for ventilation. Sliding windows are also vulnerable to rain. Casement windows have the largest open area but they do not provide as much protection against rain. Awning windows have relatively large open areas and provide good rain protection when open. Awning and jalousie windows have approximately the same open area. Both provide reasonable rain protection, but jalousie windows offer better airflow control.

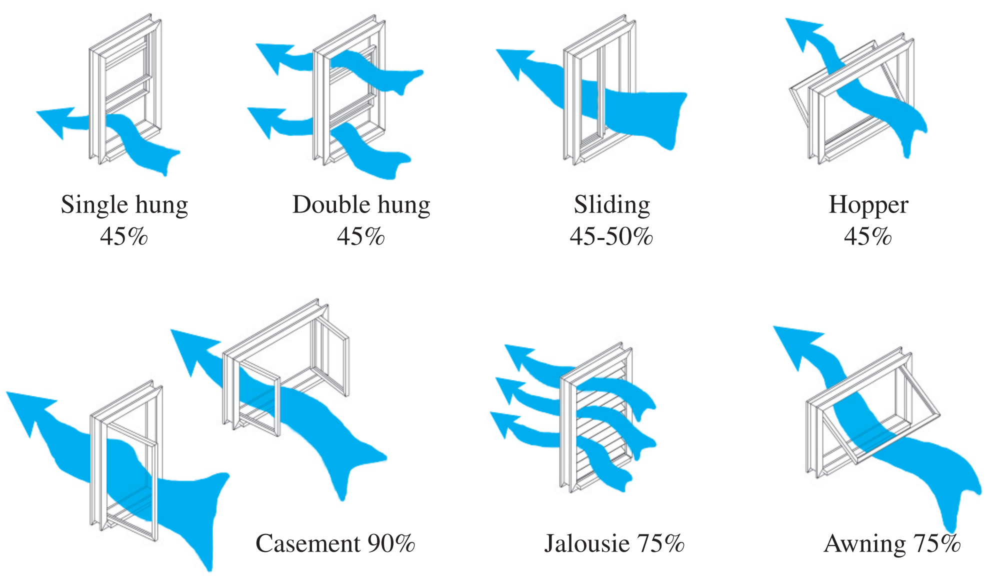


Fig. 12-6: Effective Open Areas for Various Window Types.

Recommended Technique: Keep inlet openings slightly smaller than outlet openings.

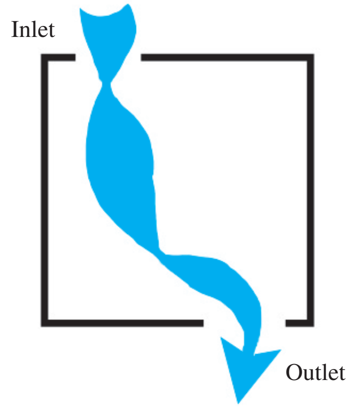


Fig. 12-7: Sizing Inlet and Outlet Openings.

Cross ventilation is optimum well when inlet openings are slightly smaller in total area than outlet openings (1:1.25 is a good ratio).

Recommended Technique: For spaces with openings on adjacent walls, place windows far apart and at a diagonal.

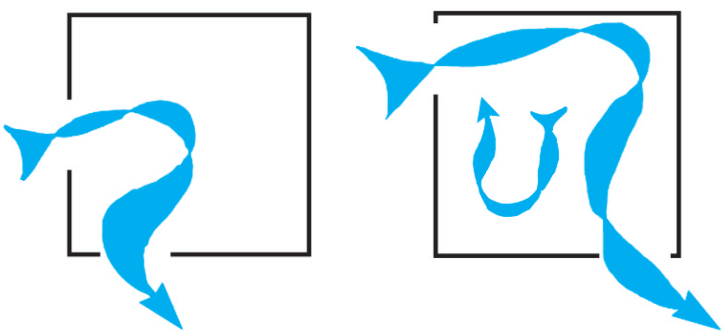


Fig. 12-8: Window Arrangement for Cross Ventilation (Adjacent Walls).

Air flow is limited when windows are placed close together. Improved airflow is achieved when windows are spaced further apart. Casement windows are a better choice in this situation because the window's glazing acts as a small wing wall and maximizes airflow.

Recommended Technique: For spaces with openings on the same wall, use casement windows or wing walls spaced as far apart as possible.

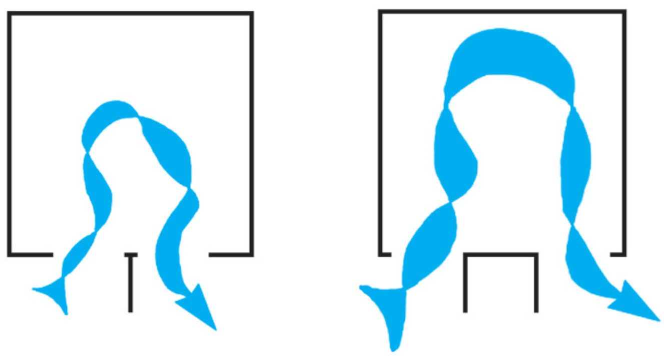


Fig. 12-9: Window Arrangement for Cross Ventilation (Same Wall).

Two wing walls spaced apart perform better than a single wing wall. Casement windows are a good choice in this situation because the window's glazing acts as a wing wall to maximize airflow.

Recommended Technique: Locate windows at body level.

Inlet windows at body level ensures the occupants will enjoy cooling air movement. However, outlet window location does not significantly effect airflow.

Body levels change depending on the activities within the room. For example, lower level vents work best in bedrooms.

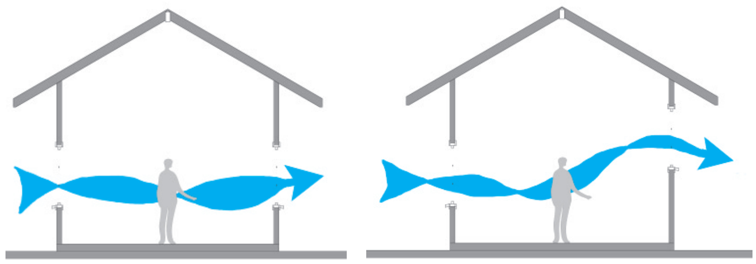


Fig. 12-10: Window Heights and Cross Ventilation (Good Design).

High windows produce poor air movement at body level. A low outlet window does not correct bad airflow in this situation.

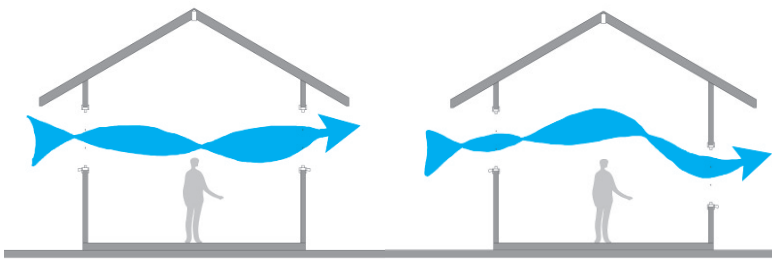


Fig. 12-11: Window Heights and Cross Ventilation (Poor Design).

Window overhangs with a space at the wall produce the best air movement at body level. The gap helps to push air downward increasing airflow at body level.

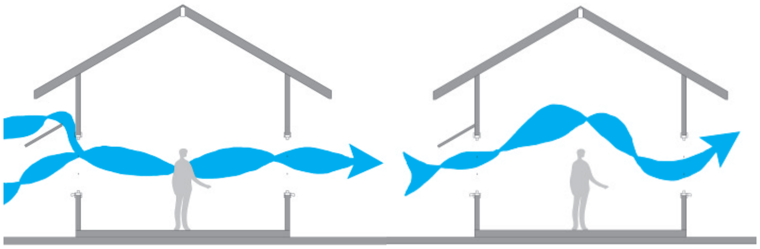


Fig. 12-12: Using Window Overhangs to Assist Ventilation.

Summary of Key Strategies and Recommended Techniques for Section II.

Reduce heat buildup:

- Limit exposure to heat build-up by orienting longer sides of the home north and south.
- Use existing or new landscape elements to shade the site and the roof, walls, and openings.
- Limit the area of unplanted and paved exterior surfaces.
- Use porous paving materials to reduce thermal mass, heat gain, and glare.
- Use light colored materials that will reflect sun's heat rather than absorb and transfer it to the home's interior.
- Insulate the building shell (roof, ceilings, walls).
- Install radiant barriers in the roof and walls.
- Ventilate the roof or attic properly.
- Use high performance glazing on windows exposed to the sun.
- Limit the area of openings (windows, skylights, glass doors) to prevent solar heat gain.

Provide natural ventilation to remove heat and humidity from building interiors:

- Orient buildings to maximize the cooling potential of prevailing winds.
- Provide ample spacing between buildings in the direction of wind flow so that all structures have good airflow.
- Arrange buildings to provide for good airflow around all structures.
- Use landscaping elements such as trees, fences and hedges to improve airflow around structures.
- Design floor plans that provide effective cross ventilation and good air circulation at body level.
- For spaces with openings on opposite walls, orient the room 45^0 from the wind direction.
- Keep inlet openings slightly smaller than outlet openings.
- For spaces with openings on adjacent walls, place windows far apart and at a diagonal.
- For spaces with openings on the same wall, use casement windows or wing walls spaced as far apart as possible.
- Locate windows at body level.

Section III: Introduction

This Section of the *Field Guide* focuses on further reducing the home's energy demand by optimizing the systems and equipment typically used to operate the household. The goal is to select energy efficient equipment and to utilize natural sources of energy (sunlight) as much as possible. To do this successfully, it is important to:

1. Implement the design techniques described in Section II as appropriate.
2. Use the information in this section to integrate system and appliance choices into the design process for:

   - Water Heating (Chapter 13)
   - Lighting (Chapters 14 and 15)
   - Appliances (Chapter 16)
   - Air Conditioning (Chapter 17)

A summary of key strategies and recommended techniques from Chapters 13 through 17 is provided at the end of this section, on page 88.

Chapter 13: Water Heating

Water heating typically accounts for up to 40% of utility bills in non-air conditioned homes. Strategies to reduce energy used for water heating include:

- Solar water heating
- Water-conserving fixtures and appliances
- Properly sized, high performance equipment
- Proper maintenance and operation.

Recommended Technique: Install solar water heating.

Choosing a solar water heater over a conventional water heater can reduce water heating costs by 80% to 90%. Table 13-A compares energy use among water heating types.

Table 13-A: Comparison of Energy Use for Water Heaters

Type of Water Heater	How it Operates	Recommended Energy Efficiency Standard	Savings Compared to Conventional Electric Resistance Water Heater
Solar Water Heater	Uses the warmth of sunlight to heat water.	Highly efficient so no rating is necessary.	80-90%
Heat Pump	Removes heat from surrounding air and transfers it to a water tank.	COP* of 2.7 or higher.	65%
Gas	Uses a flame powered by natural gas to heat the water.	EF** of 0.60 or higher.	Typically some savings, but dependent on the variable cost of natural gas and electricity.
Electric Resistance	Uses an electric element to heat the water.	EF** of 0.88 or higher (value depends on tank size).	Typically the most expensive type of water heater to operate.

* COP (*Coefficient of Performance*) is the rate of heat delivered divided by the energy needed to run the heat pump.

** The EF (*Energy Factor*) measures how well the heater retains heat. The higher the EF, the more efficient it is.

With current state income tax credits and utility rebate programs, the cost of a new solar water heating system is paid back through utility bill savings in less than four years. For more details on the benefits of solar water heating, see Chapter 19.

Since solar water heating is the most energy efficient choice, anything a builder does to facilitate its installation now or later in the home is encouraged. If installing a solar water heating system is not possible initially, there are ways you can make a future installation more cost effective, such as providing water line stub outs to the roof and providing hot water tanks suitable for a solar hot water system. Builders can also offer a "pre-solar" package by providing the stub out and no tank, allowing the home owners to hire a contractor themselves to install the solar hot water system later. Check with your local electric utility company for rebates and contractor recommendations.

Recommended Technique: Install water-conserving fixtures and appliances.

When you decrease the amount of hot water used in the home, you reduce the amount of energy used to heat the water. Aerators in faucets and low-flow showerheads can cut hot water requirements by 50%. Install bathroom faucets that use no more than 2 gallons per minute (gpm). Other sink faucets and showerheads should use no more than 2.5 gpm.

Running full loads and using water conserving dishwashers and clothes washers provide more opportunities for savings. See Chapter 16, for more details.

Recommended Technique: Select high efficiency equipment.

For heat pump, gas, or electric water heaters, select high efficiency equipment. See Table 13-A for recommended efficiency levels and Appendix G for the utility rebate plans.

Recommended Technique: Properly size water heating equipment.

To properly size the equipment, first estimate the household's hot water requirements. Generally, a four-person household in Hawaii uses about 80 gallons of hot water per day. Energy performance is best when the system is sized to meet 110% of the household's projected demand. (Source: DBEDT "A Home Owner's Guide to Solar Water Heating," March 2000)

Recommended Technique: Provide for efficient operation and maintenance.

Techniques for achieving additional efficiencies include:

- Control heat loss through pipes delivering hot water by wrapping pipes with a diameter up to 2 inches with insulation of R-4 or greater. Pipes with a diameter of more than 2 inches should be covered with insulation of R-6 or greater.
- Adjust the water heater's thermostat to 120ºF.
- Install a heat trap in the water heater lines. A heat trap is a piping arrangement that prevents hot water from rising up in the pipes, thereby reducing heat losses.
- For electric water heaters, install a timer that can automatically turn the water heater off at night and on in the morning. A simple timer can pay for itself in less than a year. OR, enroll in a demand control program through the local electric utility. The program will require larger storage capacity tanks and timers to limit heating hours to night time.
- Provide owners with information about proper maintenance procedures. Proper maintenance can prevent tank sediments from building up, which reduces efficiency. For details, see Appendix E.
- If installing a solar water heating system, refer to "Solar Standards and Specifications, April 1, 2000, List" for pre-approved equipment from Hawaiian Electric Company, Hawaii Electric Light Company, or Maui Electric Company.

Chapter 14: Daylighting

People prefer natural light to artificial light because it connects us to the outdoors and natural rhythms. In addition, daylight can provide ambient illumination reducing electrical lighting needs. Thus, “daylighting” makes a home more livable and pleasant and can save on utility bills.

Natural light, however, can be difficult to control. Misapplied, it can produce excessive heat gain, uncomfortable glare, and degradation of furniture and finishes. If building orientation is ignored and window and door openings are designed without regard to the distribution of daylight, the result can be a home with blinds drawn to block excessive daylight, with electric lights on during the day.

This chapter covers strategies that prevent direct light from entering the home while optimizing distribution of daylight. Techniques include:

- Minimizing difficult-to-shade east- and west-facing windows
- Interior layouts that match lighting needs to daylight availability
- Improved interior distribution through light-colored finishes
- Floor plans that allow deep daylight penetration
- Light shelves for sidelighting
- Clerestories or roof monitors for toplighting
- Minimizing heat gain and glare when using skylights

Combining daylighting strategies effectively with strategies covered in Chapter 15 will provide maximum energy savings and visual comfort. Coordinate your choice of daylighting techniques with other passive design strategies such as natural ventilation and shading. See Chapter 10.

Daylighting Methods

Two effective methods for allowing daylight into the home are sidelighting and toplighting. *Sidelighting*, as the name implies, is achieved through openings in the side of a building. *Toplighting* is accomplished through openings in the roof. See Figure 14-1.

Clerestories, roof monitors, and skylights are examples of toplighting. *Clerestories* are vertical openings located high in the wall. *Roof monitors* are vertical glazed openings located in the roof or in the roof plane. Because they are vertical, they are easier to shade and much less likely than skylights to produce excessive heat gain. Typically, clerestories have fixed glazing, and roof monitors have operable glazing. Thus, roof monitors can assist natural ventilation while providing daylighting.

Skylights in Hawaii should be used sparingly and designed to minimize heat gain and glare. Even when heat gain through skylights may be beneficial, such as in homes located at cooler elevations above 2,500 ft., glare can still be a problem.

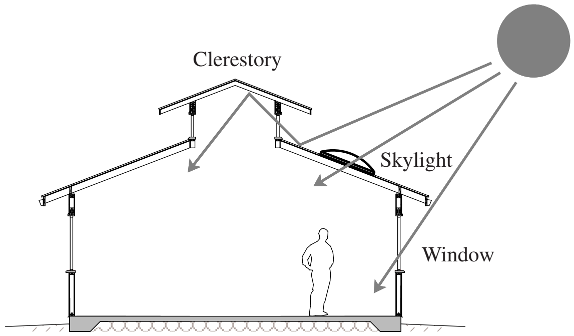


Fig. 14-1: Daylighting Methods.

Windows provide sidelighting. Clerestories, roof monitors, and skylights provide toplighting.

Daylight Distribution

The secret to designing with natural light is distribution. The goal is to bring light in where it is desired while avoiding excessive contrasts, glare, unwanted heat gain, and high light levels. To use the sun's light comfortably, sunlight should be reflected and diffused deep into interior spaces.

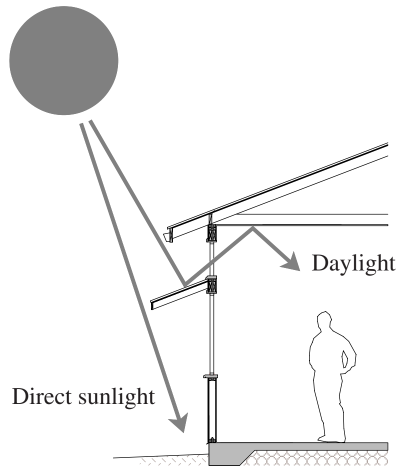


Fig 14-2: Distribution of Daylight.

Daylight is indirect light (ambient or reflected). Direct sunlight should not be allowed to enter the home's interior.

Recommended Technique: Minimize difficult-to-shade east- and west- facing windows.

The exterior building envelope should be designed to admit indirect light through the windows or the roof. Be careful to minimize east- and west-facing windows, which are difficult to shade and may admit unwanted heat and glare. See Chapter 10 for additional details on window placement and shading techniques.

Recommended Technique: Design interior layouts to match lighting needs to daylight availability.

The building's interior design should provide daylight where it is most needed. Activities with higher illumination needs should be placed along the home's perimeter where access to natural light will be greatest. Activities with lower lighting demands can be located deeper inside.

Although light coming from the north or south generally provides a more even level of lighting, client preference may require a customized approach. For example, "morning people" may prefer to have the bedroom, bathroom, and kitchen facing east so they can enjoy the morning sun. Others may prefer a darker bedroom in the morning and brighter living spaces in the afternoon/evening for late-day activities.

Recommended Technique: Use light-colored interior finishes.

The color of interior finishes can greatly affect light distribution. Light-colored, glossy surfaces reflect more light than dark or matte surfaces and improve overall light distribution in a space. Typically the color of the ceiling and walls has the greatest impact on light distribution. Floor color can affect light quality, but not as significantly.

Although light-colored glossy surfaces reflect more light, they must be used judiciously in order to avoid glare. Light-colored matte surfaces reflect and diffuse light, creating a more controlled and evenly lit environment.

Recommended Technique: Design floor plans to allow deep daylight penetration.

Daylight penetration depends on the proportions of the interior space and the size, number, and location of openings that bring light into the space. For example, the back of a large, deep room with one small window will not receive much light. Interior penetration of daylight is most effectively achieved with high ceilings and a narrow building plan with openings on several sides. Open floor plans with few interior partitions also allow deeper light penetration. Single-story buildings are generally easier to daylight than multi-story structures because roof openings can be used to bring light into deep spaces. The proportions of a room also have a significant impact on the distribution of the light. Higher ceilings allow deeper light penetration.

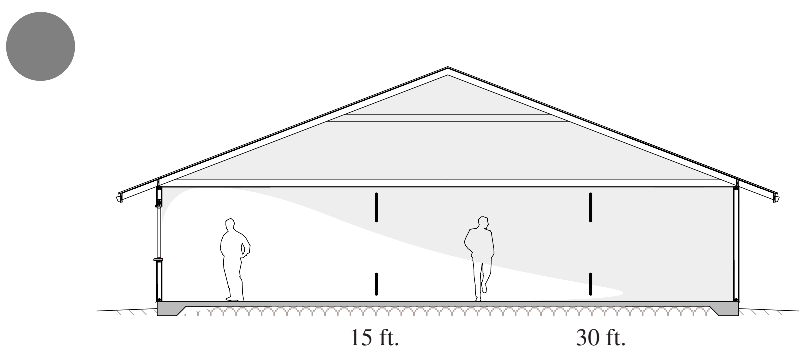


Fig. 14-3: Daylight Penetration.

With an 8 ft. ceiling, daylight is typically sufficient for normal activities 15 ft. into the space. Between 15 ft. and 30 ft. from the window, some electrical light will be needed to augment the daylight. More than 30 ft. from the window, electrical light will supply most of the illumination.

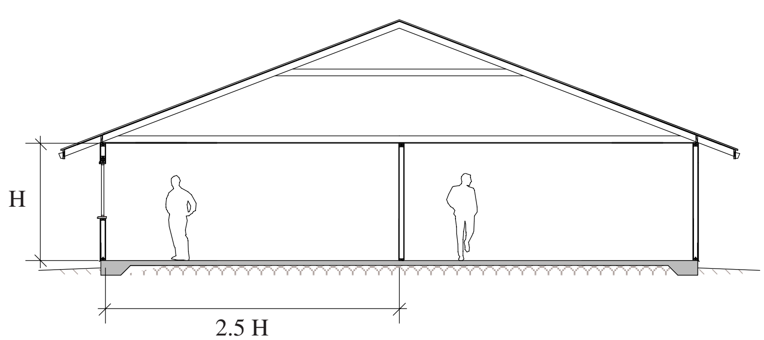


Fig. 14-4: Room Proportions and Daylight Penetration.

For a single sidelit room, the depth of the room should be no greater than 2.5 times the height of the wall with the opening(s).

Recommended Technique: Use light shelves when sidelighting.

A light shelf is a horizontal reflector used to direct light into the interior of a building.

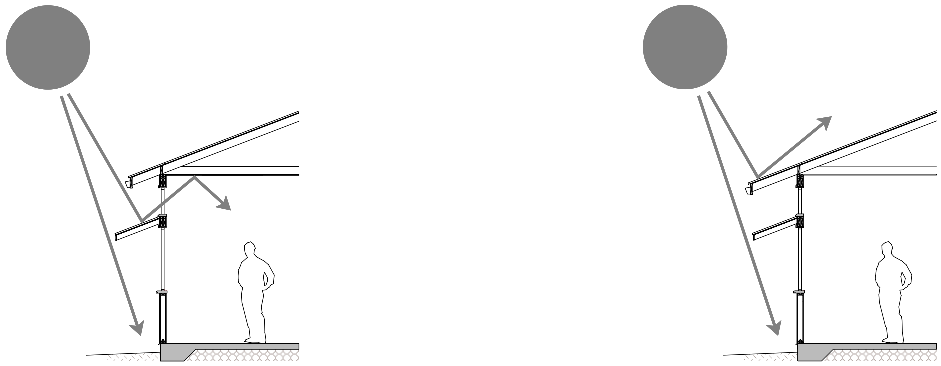


Fig. 14-5: Use Light Shelves when Sidelighting.

A light shelf can provide shading and indirect light when sidelighting. When placed between windows, it prevents heat gain through the lower window and reflects light through the upper one.

Locations and placement of light shelves must be carefully dimensioned with roof overhangs. Poorly coordinated light shelf and overhang relationships can reduce the benefits of the light shelf.

Recommended Technique: Use clerestories or roof monitors for toplighting.

Clerestories and monitors can be located independently of walls, so they can be placed where daylight is needed. They can be very small while delivering effective illumination. Shading design for clerestories and monitors is the same as for standard windows. For more information on proper shading design see Chapter 10.

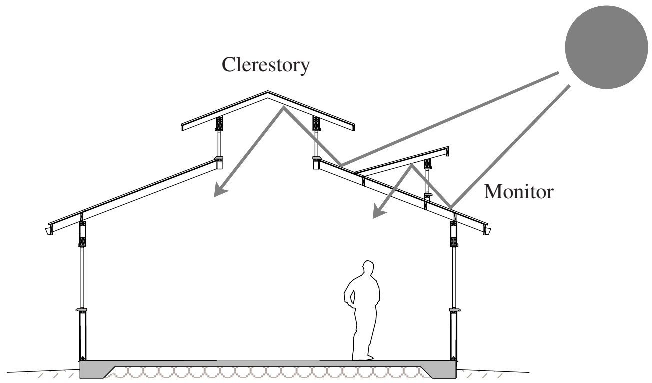


Fig. 14-6: Use Clerestories or Roof Monitors for Toplighting.

Clerestories and monitors are easier to shade and admit less heat than skylights.

Recommended Technique: Minimize heat gain and glare when installing skylights.

Hawaii's tropical latitude of 19° to 22° north exposes roofs to intense sunlight. As a result, skylights can cause excessive heat gain and glare. Avoid overheating by selecting the appropriate glazing and by limiting the size of unshaded skylights.

When selecting skylight glazing, look for a solar heat gain co-efficient (SHGC) of 0.5 or less. The SHGC measures the amount of solar radiation admitted through the window. For more information on glazing attributes, see Chapter 10.

Operable and vented skylights help offset heat gain by venting hot air. Venting skylights should be placed on the leeward side of the house to facilitate venting. If the openings are placed on the windward side, the incoming air can trap hot air in the building. If the vents are fixed open, they must be shielded from rain infiltration. If vents are operable and exposed, they must be closed like any window to prevent water penetration.

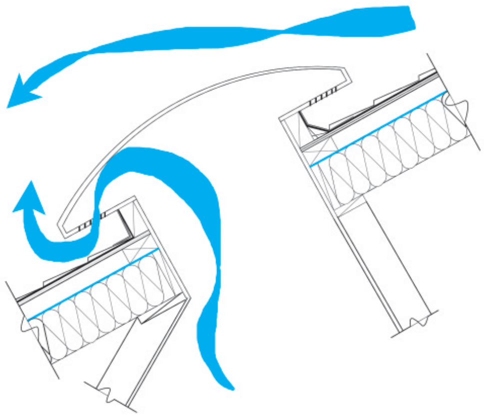
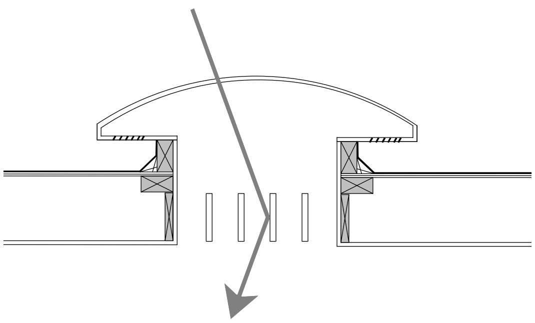


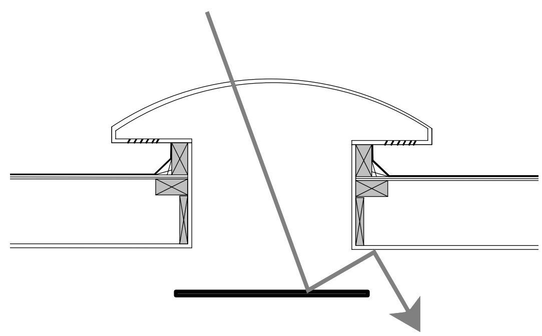
Fig. 14-7: Use Vented Skylights to Offset Heat Gain.

A built-in vent can help offset heat gain caused by skylights. The venting skylight should be installed on the leeward side of the house so breezes can help draw hot air out of the home.

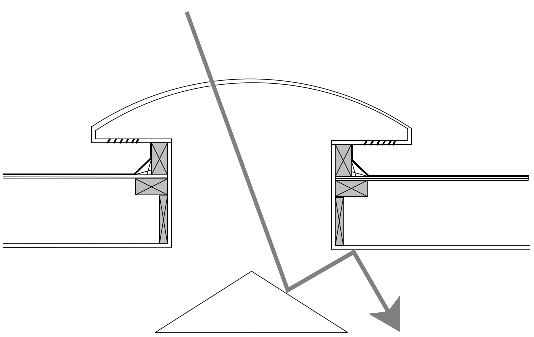
Unshaded skylights admit direct sunlight into a home. Skylights that incorporate translucent materials, such as white plastic, diffuse the incoming light and help reduce glare. Another way to reduce glare is to diffuse or reflect the light with a baffle that is placed below the ceiling plane (see Figure 14-8 below).



Vertical baffle.



Horizontal baffle.



Angled baffle.

Fig. 14-8: Light Baffles Reduce Glare by Diffusing and Directing Incoming Sunlight.

Brightness contrasts can be reduced by locating the skylight next to a wall, which will receive and distribute the light, or by sloping the ceiling up to the skylight ("splaying," see Figure 14-9).

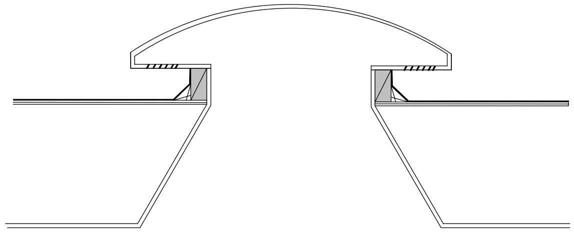


Fig. 14-9: Toplight Distribution.

Splaying is another way to distribute toplight. Brightness contrasts can be reduced by sloping the ceiling up to the skylight.

High ceilings will also improve light distribution. These specific recommendations address light quality, not heat gain.

Chapter 15: Electric Lighting

In Hawaii, 8% of the average household electric bill is for electric lighting. Unfortunately, most of this energy goes into powering inefficient incandescent bulbs. Only 10% of the energy used by incandescent bulbs produces light; the other 90% is wasted as heat. Switching from incandescent to fluorescent bulbs in key locations can save energy and money while reducing an interior source of heat build-up.

A well-considered lighting design can significantly reduce the energy used for lighting. Efficient lighting design ensures that the right amount and the right type of light gets to where it is needed. Efficient lighting avoids overlighting and incorporates daylighting. (For daylighting strategies, see Chapter 14).

Lighting design can be highly complex. This *Field Guide* provides only an overview of key concepts needed to understand the rationale for the strategies presented. It is not intended to be a comprehensive lighting design guide. Please refer to the resources listed in Appendix B for in-depth coverage of lighting design principles.

Strategies presented in this Chapter include:

- Effective electric light delivery
- Fluorescent bulbs

The following is a brief glossary of useful terms to assist you as you read this chapter:

- *Lamp:* A generic term used for a manufactured item that produces light (light bulb). In this chapter, the more common term *"bulb"* will be used, rather than the term "lamp."
- *Incandescent lamp:* A lamp that produces light by heating a wire with electricity.
- *Fluorescent lamp:* A lamp that contains an inert gas and produces light by exposing its internal coating to UV radiation.
- *Ballast:* A device used with fluorescent lamps to establish the circuit conditions necessary to start and operate the lamp.
- *Fixture* or *luminaire:* A lighting fixture. In this chapter, "fixture" will be used when referring to the bulb and the housing that holds it.
- *Lumen:* A measure of the amount of light given off by a light source.
- *Efficacy:* A bulb's efficiency expressed in lumens per watt (lum/W). In this chapter, the more commonly understood term "efficiency" will be used.
- *Footcandle (fc):* A measure of the amount of light that actually reaches a surface.
- *Watt:* A measure of energy. The wattage on bulbs shows how much power is being drawn to create the light—*not* how much light is produced.
- *Color Rendering Index (CRI):* The CRI measures how "natural" colored objects appear when illuminated by a bulb. The higher the CRI, the truer the color of the objects being lighted. The CRI ranges from 0 to 100.
- *Correlated Color Temperature (CCT):* The CCT measures the appearance of the light itself. Light with a low CCT (below 3100K) looks warm while light with a high CCT (above 4000K) looks cool; those in between appear neutral, neither warm nor cool. A soft white incandescent bulb has a CCT of 2800.

Recommended Technique: Design for effective electric light delivery.

Efficient lighting design delivers the right quantity and quality of light where it is needed. The first step then is to determine how much electric light is needed to augment daylighting and what quality of light is needed. This will depend on what kinds of activities will be happening in a given location. Generally speaking, the more complex a task, the more light is needed to perform it. In addition, the more detailed the task, the more focused the light should be that illuminates it.

Distribution

You may recall from the discussion of daylighting in Chapter 14 that the key to good lighting design is getting the right distribution. There are three lighting styles: ambient or general, task, and accent. These styles offer specific distribution types: direct, indirect, direct-indirect, and diffuse (spread out), which are achieved through a variety of fixture designs. Table 15A matches lighting style to distribution type and purpose. Figures 15-1 through 15-4 provide examples of lighting methods.

Fixtures (Luminaires)

As seen in Table 15-A, ambient light can be provided by more than one distribution type. Different distributions are achieved by varying the type, size, and location of fixtures. For example, suspended, architectural, wall, and some portable fixtures, such as table, desk, or floor lamps, can provide soft, indirect light that eliminates shadows or dark gloomy ceilings. Globe fixtures, chandeliers, and some portable lamps can provide diffused light, or light that is spread out equally in all directions. To achieve these effects without uncomfortable glare, fixtures will include design features that shield, redirect, or diffuse the light. (Glare can also be avoided by adequate illumination of surrounding surfaces.)

Table 15-A: Lighting Styles

Lighting Style	Distribution Types	Appropriate for:
Ambient (general) provides uniform illumination for a whole room. Amount of light will depend on the reflectance of surfaces in the room. See Figures 15-1 and 15-2.	• Indirect • Direct-Indirect • Diffuse • Direct	Simple activities, such as watching TV, dining, or casual reading.
Task directs light to a specific area. See Figure 15-3.	• Direct • Direct-Indirect	Detailed tasks, such as reading or working in the kitchen. Using focused, task lighting rather than ambient lighting can save energy.
Accent is focused, similar to task lighting, but highlights features rather illuminates an activity. See Figure 15-4.	• Direct	Highlighting art or architectural features.

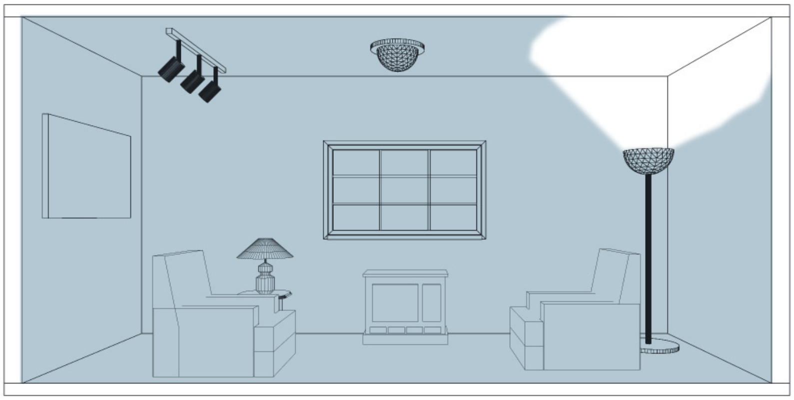


Fig. 15-1: Indirect, Ambient Lighting.

Light reflects off a surface (typically the ceiling) to illuminate the room.

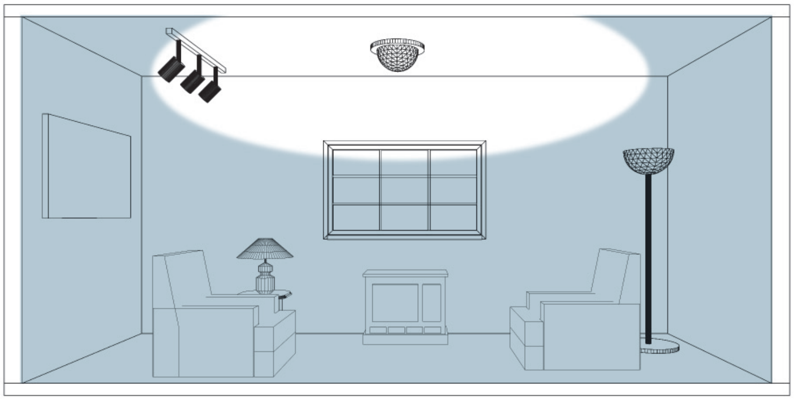


Fig. 15-2: Diffuse, Ambient Lighting.

Light is distributed uniformly in all directions through a diffusing globe (usually a white glass) that encases the bulb. For minimal glare, the globe should be large and the bulb wattage should be low.

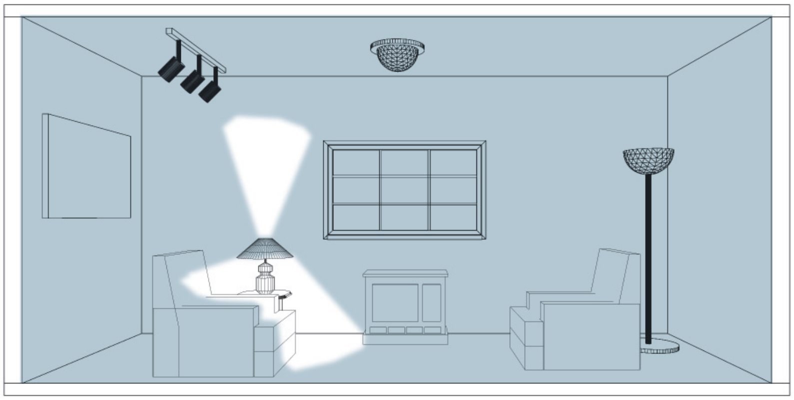


Fig. 15-3: Direct-Indirect Lighting.

The light source directs light upward and downward. Some fixtures provide some light to the side. This type of lighting provides a good compromise between the efficiency of direct lighting and the comfort of indirect lighting.

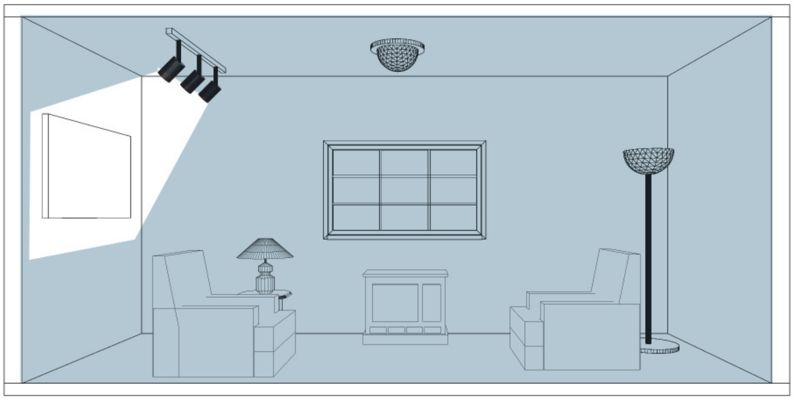


Fig. 15-4: Direct Lighting.

The fixture aims the light directly at a surface. In the example, the purpose is for accent lighting, but can also be used for task lighting.

Bulbs (Lamps)

In choosing a bulb type for a particular lighting application, evaluate its efficiency expressed in lumens per watt, color rendering ability (CRI), and color appearance (CCT).

Efficiency (Efficacy)

Efficiency (expressed in lumens per watts) is a more important characteristic than wattage to use in selecting bulbs. It is similar to comparing fuel efficiency for cars. Cars that can travel more miles per gallon use less fuel to operate. In the same way, bulbs that use fewer watts to produce the same amount of light are more efficient. For example, an 18-watt compact fluorescent bulb produces approximately the same amount of light as a 60-watt incandescent bulb. Thus it is several times more efficient and has a higher lumen/watt ratio.

Color Rendering

The importance of color rendering will vary from room to room. Remember, the higher the CRI, the more natural objects will appear. A CRI of 80 or higher will be satisfactory for most applications. Modern fluorescent bulbs are available with CRIs of 80 and above. Lighting in a bathroom may require bulbs with CRIs of 90, since color rendering may be more critical in these areas.

Color Appearance

Largely a matter of personal preference, the color appearance of bulbs is measured by their CCTs. Home owners with a preference for a warm look will prefer bulbs with CCTs of 3000K or less. There are now fluorescent bulbs that meet this criteria. Neutral color appearance can be obtained with bulbs that have CCTs of 3500-4000K, and for a truly cool appearance, use CCTs above 4000K. See table 15-C for CCT values by bulb type.

Bulbs are labeled with a code that identifies bulb type, CRI, and CCT. For example a fluorescent bulb labeled RE730 means that the bulb is a rare-earth-phosphor bulb (the high-quality phosphors achieve higher efficiency and excellent color rendering) with a CRI in the 70s and a CCT of 3000K.

Ballasts

Fluorescent bulbs require ballasts to operate. *Ballasts* are devices that control the voltage needed to start the bulb and the current required during bulb operation. A ballast may operate one or more bulbs. There are two types of ballasts, magnetic and electronic. *Electronic ballasts* are preferred because they operate at much higher frequencies (20,000 Hz) than *magnetic ballasts* (60 Hz). This higher frequency results in a 10% to 12% increase in bulb efficiency and eliminates the perceptible flicker and hum that many people associate with fluorescent bulbs. Note: Ballasts manufactured before 1978 may contain toxic polychlorinated biphenyls (PCBs). All ballasts manufactured after 1978 should have a "No PCBs" label.

Recommended Technique: Use fixtures that accept fluorescent bulbs.

The improved color performance and energy efficiencies of modern fluorescent bulbs make them an excellent choice for an energy efficient home. Table 15-B summarizes the general attributes of incandescent and fluorescent bulbs. See Table 15-C for a technical comparison of several types of incandescent and fluorescent bulbs. As previously discussed, those fluorescents that have a CCT of 3000 and a CRI of above 80 satisfy the criteria for color performance for most applications while providing excellent efficiency.

Table 15-B: General Comparison Incandescent vs. Fluorescent

Incandescent Bulbs	Fluorescent Bulbs
Short life of 2,000 hours maximum.	Long life of up to 20,000 hours.
Inefficient at about 10 to 15 lumens per watt.	Efficient at up to 90 lumens per watt, depending on size. Uses 75% less energy than a standard incandescent bulb.
Produce large amounts of heat.	Produce minimal amounts of heat because more watts are converted to light, less to heat (higher efficiency).
Good color quality.	Good color quality.
Expensive to operate.	Inexpensive to operate.
Low price per bulb.	High price per bulb; offset by operational savings. See Table 15-D. They are especially cost-effective in high use locations where lights will be on for long periods of time.
Available as screw-in units for standard fixtures.	Compact fluorescent bulbs (CFL) are available as standard screw-in units for fixtures. Beware of height and girth for table bulb applications; bulbshade harp may not fit over CFL; harp extenders are available.
Can be disposed, but not recycled.	Because most contain mercury, should not be disposed with regular garbage. Recycling options are increasing.

Table 15-C: Comparison of Various Incandescent and Fluorescent Bulbs.

Bulb Type	Watts	Lumens	Efficiency (Lum/W)	Average Bulb Life (hours)	Initial Cost	CRI	CCT (°Kelvin)
Incandescent Soft White	100	1710	17.1	750	$0.30	95+	2800
Incandescent Double Life	90	1510	16.8	1500	$0.60	95+	2800
Incandescent Energy Saver	90	1510	16.8	750	$0.50	95+	2800
Incandescent Halogen A-Bulb	75	1040	13.9	2500	$5.94	95+	3050
Incandescent Halogen Flood, 50 Beam Spread	75	1100	14.7	2500	$6.24	95+	3050
Fluorescent, 48" Tube T12 Cool White	34	3050	89.7	20,000	$2.00	60+	4200
Fluorescent, 48" Tube T8 RE730	32	2850	89.1	20,000	$2.80	70+	3000
Fluorescent, 48" Tube T8 RE830	32	3050	89.7	20,000	$5.75	80+	3000
Compact Fluorescent, Lower Power	13	710	54.6	10,000	$15	80+	3000
Compact Fluorescent, Higher Power	27	1620	60	12,000	$21	80+	3000

Source: Build Green & Profit. Advanced Concepts Participant Guide. University of Florida Extension Service, 1999. p13.

Note: Wattages for fluorescent tubes need to add a few watts for the ballast. Integrated screwbase CFLs will have the ballast watts already incorporated. Modular screwbase CFLs and other CFLs will also need ballast watts added.

Table 15-D (next page) provides a summary of several typical and energy-efficient lighting scenarios, and illustrates potential savings. Yearly costs were calculated using a $0.15 per kilowatt hour cost. Current utility rates on Oahu are $0.145 per kilowatt hour. Utility rates for the neighbor islands run as high as $0.22 per kilowatt hour, making for even more dramatic savings when applying the efficient scenarios.

Table 15-D: Typical and Efficient Residential Light Scenarios

Living Room Lighting Design	**Kilowatt Hours (per year)**	**Yearly Cost at $0.15 per kWh**
Typical: One ceiling fixture using two 60W incandescent bulbs for three hours a day. Two portable bulbs using one 75W incandescent bulb each for two hours per day.	241	$36.14
Efficient: Replace the 60W incandescent bulbs with 18W compact fluorescent bulbs. Replace the 75W incandescent bulb with a 24W compact fluorescent bulb.	74	$11.17
Kitchen Lighting Design		
Typical: One ceiling fixture in the center of the room using four T12 40W fluorescent bulbs for four hours a day. One ceiling fixture over the sink using one 60W incandescent bulb for two hours per day.	277	$41.61
Efficient: Replace the T12 bulbs with T8 bulbs. Replace the 60W incandescent bulb with an 18W compact fluorescent bulb.	200	$30.00
Bedroom Lighting Design		
Typical: One ceiling fixture in the center of the room using two 60W incandescent bulbs for three hours a day. Two table bulbs using one 60W incandescent bulb each for three hours a day. One portable bulb using one 75W incandescent bulb for three hours per day.	131	$19.71
Efficient: Replace the 60W incandescent bulbs with 18W compact fluorescent bulbs. Replace the 75W incandescent bulb with a 24W compact fluorescent bulb.	66	$9.86
Bathroom Lighting Design		
Typical: One ceiling fixture using one 60W incandescent bulb for two hours a day. One wall-mounted vanity fixture using three 60W incandescent bulb for two hours per day.	175	$26.28
Efficient: Replace all 60W incandescent bulbs with 18W compact fluorescent bulbs.	53	$7.88

Tips for selecting fluorescent bulbs and fixtures:

- For good color quality, choose fluorescent bulbs with a CRI above 80 and a CCT of 3000K.
- Use T8 or T5 fluorescent tubes, which are more efficient than the larger T12s.
- Look for the Energy Star® label on compact fluorescent bulbs and fixtures. Energy Star® is a USDOE/EPA Efficiency Rating Program. For more information about the program, see Appendix H.
- Choose low-mercury fluorescent tubes, such as Philips Alto, GE, or OSRAM-Sylvania bulbs, which are not classified as hazardous waste for disposal.
- Use electronic ballasts. They provide a higher efficiency and better quality of light.
- Use reflectors to direct light and increase the efficiency of bulbs.
- Use a single, higher-wattage bulb instead of several low-wattage bulbs. One high-wattage bulb will produce more light and use less energy than two small-wattage bulbs.

Recommended Technique: Conserve energy use for lighting with appropriate controls.

Controls such as switches, dimmers, timers, occupancy sensors, and photo sensors allow home owners to regulate lighting levels and use. Controls can be used to save energy and money and to change the "mood" of a room. They can also extend bulb life. When installing lighting controls, it is important to separate fan controls (such as bathroom and ceiling fans) from the lighting controls. This will ensure that lights are not activated when only the fan is desired.

As with fixtures, the best way to select the controls for a lighting system is to match them with the room's activities. Table 15-E presents a list of control types, their benefits, and appropriate uses.

Table 15-E: Lighting Control Types

Control Type	Benefits/Disadvantages	Application
Dimmers allow occupants to reduce lighting levels.	Saves energy, extends lamp life. Inexpensive method of creating intimate settings. Increases functionality.	Dining rooms, sitting areas, other rooms where low-level levels are sometimes desired.
Timers automatically turn lights on and off based on a programmed schedule.	Saves energy. Once set, doesn't depend on occupants remembering to turn lights off; however, because it is time-based, it may activate lights when not needed.	Living rooms, dining rooms, kitchen, bedrooms, or other rooms with regulated daily routines.
Motion sensors turn lights on when someone enters a room. After a period of inactivity, turns lights off.	Saves energy, because once set, doesn't depend on occupants remembering to turn lights off. Unfortunately because they're motion based, pets may activate lights when not needed.	Infrequently used areas, such as basement or storage areas.
Photo or light sensors turn lamps off when sufficient daylight is available and on when it is not. Daylight thresholds are preset.	Saves energy; usually more efficient than motion sensors because photo/light sensors are activated by light level.	Generally, photo sensors are used in large commercial applications such as office buildings. Most homes will benefit just by turning lights off when they are not needed.

Chapter 16: Appliances

Over the life of most household appliances, home owners will pay more money for the electricity to operate the appliances than it cost to purchase them. Energy-efficient appliances may cost more than standard appliances to purchase, but cost less to operate. Initial cost differences are made up in savings on monthly utility bills.

Computer: $0.92
Printer: $0.58

Refrigerator: $34.62
Range: $5.77
Microwave: $3.46
Toaster: $1.50
Exhaust hood: $0.69
Coffeemaker: $0.58

Television: $6.92
Stereo: $1.15
Answering machine: $0.58

Fig. 16-1: Average Monthly Energy Costs for Common Household Appliances.
Note: Costs are based on a utility rate of 15 cents per kilowatt hour of electricity.

This Chapter focuses on one strategy: installing energy efficient household appliances. It provides tips for selecting energy efficient:

- Refrigerators
- Cooking appliances
- Laundry equipment
- Dishwashers

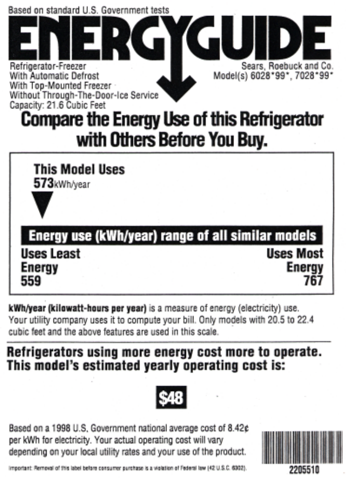


Fig. 16-2: Energy Guide Label.

To identify appliances with good energy performance, look for energy efficiency ratings (Energy Guide Labels) and Energy Star® and Green Seal compliance labels. Energy efficiency ratings can be found on the familiar yellow Energy Guide labels and show how the model compares to average energy use.

The ratings are not required for kitchen ranges, microwave ovens, or clothes dryers.

Appliances that carry Energy Star® or Green Seal labels exceed minimum energy use standards. These appliances are extremely efficient and will provide excellent payback in energy savings. For more information about the Energy Star® or Green Seal Label certifications, see Appendix H.

Recommended Technique: Select energy-efficient refrigerators.

In Hawaii, electrical demand for kitchen activities approaches 40% of the total energy consumed in the home. Refrigerators are the second biggest power consumer in most households and account for about 20% of electric bills of non-air conditioned homes. Home owners can achieve significant energy savings by purchasing an energy-efficient refrigerator.

Tips for selecting and installing energy-efficient refrigerators:

- Buy the right size model. Oversized units cost more to run. Undersized units will become overcrowded and use energy inefficiently. A unit of 14 to 17 cu. ft. is appropriate for three or four people. For each additional person in the household, add 2 cu. ft. The recommended sizes refer to the combined capacity of the refrigerator and freezer.
- Position the refrigerator away from heat sources such as stoves, ranges, and dishwashers.
- Models with overhead freezers are 10% to 25% more efficient than side-by-side models.
- Avoid models with ice makers and through-door water dispensers.
- Select models with separate temperature controls for the freezer and refrigerator compartments. This will reduce food spoilage and save energy.
- Provide ample air space (at least 3 inches) around refrigerator coils so they can operate efficiently.
- Select a unit with wheels to make it easier for home owners to move the refrigerator when it is time to vacuum the coils (twice a year).
- Set temperatures only as low as necessary (between 36° F and 38° F in the refrigerator, and between 0° F and 5° F in the freezer). A 10° decrease in temperature below these levels will increase energy use by 25%.

Recommended Technique: Select energy-efficient cooking appliances.

Cooking with electrical appliances accounts for about 10% of the home's overall energy demand. Ranges and ovens do not have Energy Guide labels, so it is important to look for the features listed below.

Tips for selecting and installing ranges and ovens:

- Install gas cook tops. Replacing an old electric range with a gas one can reduce cooking costs by 50% because cooking with gas is more efficient.
- Induction or halogen cook tops use less energy than conventional electric burners.
- Install hoods to vent heat and humidity from cooking.
- Use microwave and toaster ovens for reduced energy use.
- Install self-cleaning ovens. They have upgraded insulation and are more energy-efficient.
- Convection ovens perform better than conventional ovens. They cook more evenly and rapidly than non-convection types.
- Select an oven with a window. The cook can check on progress without opening the unit. Every time the oven is opened, as much as 20% of the heat escapes.

Recommended Technique: Select energy-efficient laundry equipment.

Modern energy-efficient clothes washers use about half the water of traditional machines and can reduce energy use by up to 65%.

An ideal combination is a front-loading horizontal axis clothes washer and a clothes line. A report done for the city of Portland, Oregon, estimates that a typical family can save about $120 each year using a horizontal axis clotheswasher and electric dryer. An H-axis washer saves energy because it uses one-third less water. This reduces the amount of energy required to heat the wash water (two-thirds less). In addition, an H-axis washer spins the clothes faster (and drier), reducing the amount of energy used by the clothes dryer.

H-axis washers offer other advantages over conventional, toploading machines, as well. They get clothes cleaner with less wear and tear on fabrics. They can also handle bulky items like comforters and rugs that top-loaders can't.

Laundry equipment produces heat and humidity and should be located in isolated non-air conditioned spaces. This will avoid increasing the home's cooling load.

Tips for selecting and installing laundry equipment:

- Choose an H-axis front loading clothes washer.
- Select a dryer with moisture sensors and cool down cycles.
- Vent clothes dryers directly to the outside of the building.
- Install a clothes line to cut heat and humidity generated by electric clothes dryers and save energy. Landscaping and fences can be used to screen clothes lines from view. If not permitted outdoors, install in a garage and provide ventilation.

Recommended Technique: Select energy-efficient dishwashers.

Like clothes washers, most of the energy used by dishwashers goes towards heating wash water. Look for dishwashers that require less water to do the job.

Tips for selecting and installing dishwashers:

- Install a washer with a built-in booster heater. The heater allows the homeowner to lower the temperature setting of the home's water heater while still having water hot enough to properly clean the dishes; every 10^0 F reduction in water heater temperature setting lowers energy consumption by 3% to 5%.
- Select a dishwasher that provides a "light wash" or "energy-saving" wash cycle.
- Look for a dishwasher that allows both heat-drying and air-drying. Air-drying uses less electricity.
- Select a dishwasher that is set up for easy cleaning of the filter at the bottom of the dishwasher. Regular cleaning will keep the machine running efficiently.
- Select a dishwasher equipped with a "Delay Search Start" feature. Home owners can use it to run the dishwasher during off-peak energy hours.
- Size the machine properly. Compact models use less energy, but hold fewer dishes. For larger households, a compact machine may end up using more energy because it may have to be run more often.

Chapter 17: Air Conditioning

Air conditioning a home can easily increase electricity costs by about $400 per year. In addition, air conditioning can produce an uncomfortable transition for those leaving or entering the air conditioned space due to significant differences in temperature and humidity. Thus, substantial energy savings over the life of the home and comfort are two excellent reasons to reduce or eliminate one's reliance on air conditioning. Perhaps an even more compelling reason is that there are few circumstances in Hawaii that warrant air conditioning. Hawaii's relatively stable and moderate weather provides a comfortable climate most of the year. (For more information on human comfort and Hawaii's climate, review Section I.)

The *Energy Efficiency Guidelines* strongly encourages well-designed, naturally ventilated energy-efficient homes (see Chapters 11 and 12). The *Guidelines* do, however, recognize special circumstances where air conditioning may be warranted, such as areas where microclimates require greater heat or humidity control, when occupants have special needs, or where existing conditions include environmental noise, dust, and pollution.

A note about codes: The *Guidelines* are voluntary and are not intended to substitute or replace existing jurisdictional construction requirements. Each county has its own code requirements for air conditioned homes. Refer to the code in your county before purchasing or installing an air conditioning system. Your home designer and building officials can help you identify energy-efficient strategies that are code compliant.

This Chapter introduces strategies for optimizing the energy use and comfort of air conditioned homes. Strategies include:

- Passive cooling strategies
- Sealing against energy "leaks"
- Energy-efficient air conditioning equipment
- Properly sized and designed air conditioning system

Three general types of air conditioning systems can be used for residential construction: window, split, and central. The system most appropriate for a particular home will depend upon the size, number, and type of spaces you wish to cool. Window units are ideal when you only need to cool a home office, for example. Central AC might be appropriate when the home is located near noisy air traffic or on a dusty highway.

Once an air conditioning system is installed, maintaining it properly is vital to ensure that the system performs efficiently. Maintenance tips for AC and other energy-using equipment are included in Appendix E.

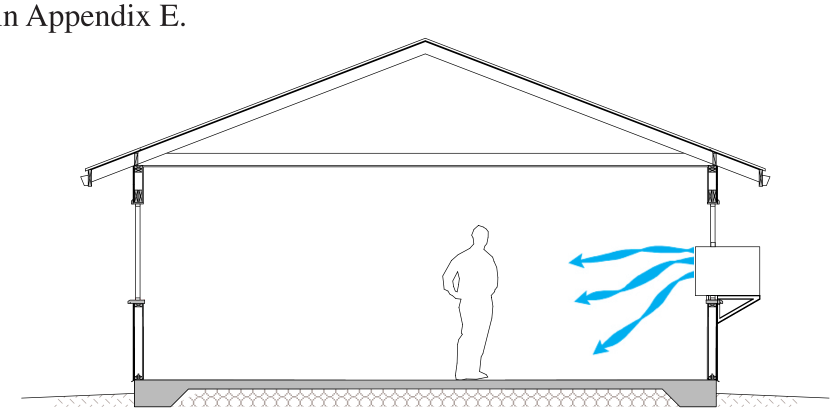


Fig. 17-1: Window AC Systems.

Window AC systems are factory assembled and encased in a single package. They are designed to cool one or two rooms without the use of ducts and are usually installed in a window or wall.

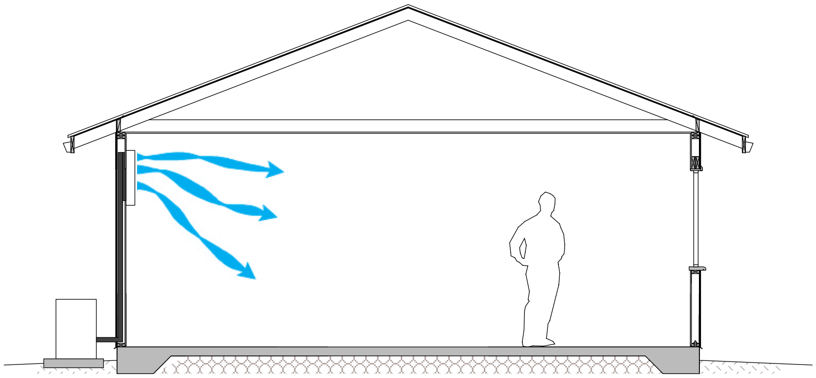


Fig. 17-2: Split AC Systems.

In *split AC systems,* the condenser and compressor are in one package outdoors, and the fan and cooling coils are located in wall or ceiling mounted units indoors. Chilled water lines run from the compressor unit outside to the fan unit inside. They can cool several rooms, are more efficient than window units, and are less noisy because the compressor is outside.

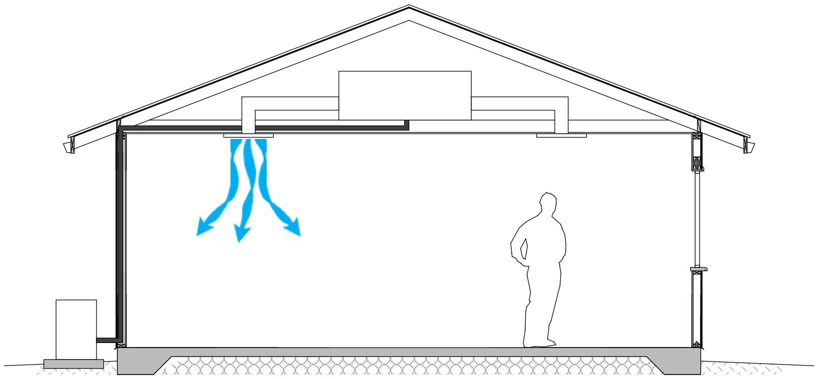


Fig. 17-3: Central AC Systems.

Central AC systems use factory-made components that are assembled by a contractor. They are designed to cool an entire house. A central unit delivers cool air to each room through ducts. Return vents circulate air in the house back to the unit where it is mixed with fresh air and recooled. Like split systems, they frequently have outdoor compressor/condenser packages linked to centrally located indoor air handlers by chilled water circulation lines.

Recommended Technique: Employ passive cooling strategies to reduce cooling load.

Even when a home is air conditioned, use passive cooling strategies that reduce heat build up such as insulation, radiant barriers, shading, ceiling fans, and operable windows. By keeping the home cooler, insulation, radiant barriers, and shading reduce the amount of air conditioning needed. Operable windows permit the use of natural ventilation on cool days. Ceiling fans can improve airflow with natural ventilation or allow for comfort with higher AC thermostat settings. Together, these strategies can reduce the amount of energy required to run an AC system by 20% to 50%.

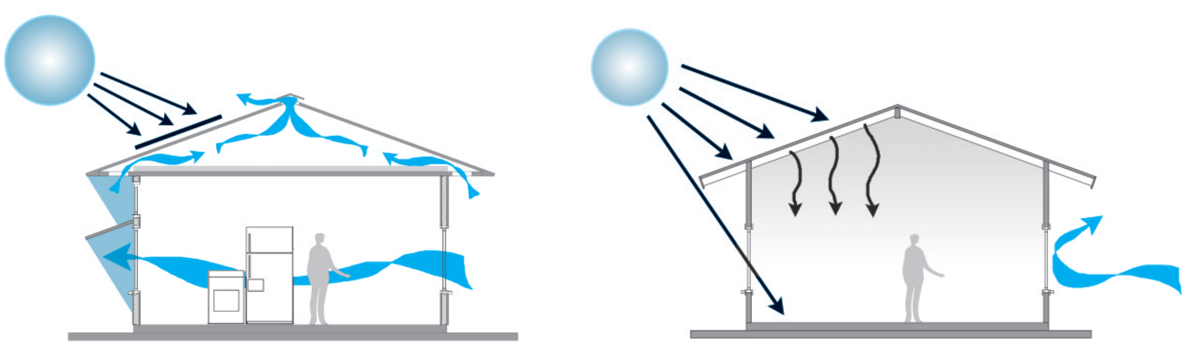


Fig. 17-4: Passive Cooling Strategies.
A house with proper insulation, operable windows, and radiant barriers will require a much smaller air conditioning system compared to a “conventional” home. An AC system in the same house without these passive cooling strategies will cost more to operate, especially during the hot summer months.

Recommended Technique: Seal the building envelope against energy leaks.

Once you have incorporated insulation, radiant barriers, and shading in your design, the next step is to prevent cooled air from leaving and warm air and humidity from entering the home. Such energy "leaks" are inexpensive to prevent but very expensive to ignore. Air leaks waste energy and reduce comfort levels in the home by letting cold air out, and allowing warm humid air in.

Use high-quality caulking products and plug all potential leaks at door and window openings, joints, cracks, and holes in and between walls, ceilings, and floors. Although higher-quality products such as acrylic latex, polyurethane, or silicone-based sealants cost more than PVC or oil-based materials, they last five times longer. Plus, the upgrade cost is minimal relative to the overall cost of construction.

Look for caulking products that have the Green Seal label. Green Seal rates caulking products based on durability, ease of clean up, VOC level, and hazardous materials. Check their recommended product list online at www.greenseal.org. See Appendix H for more information about the Green Seal program.

Important Note: Indoor Air Quality in Tightly Sealed Air-Conditioned Homes

In energy-efficient air conditioned homes, windows, doors, and other openings are sealed to prevent the loss of cool air. This also prevents fresh air from entering the house. Without an alternative source of fresh air, high levels of contaminants including mold, fungi, carbon monoxide, and *volatile organic compounds* (VOCs) can build up. (VOCs are responsible for the troublesome odors associated with the installation of new carpet, paint, and other building products.)

It is important to ensure the AC system brings in a generous supply of fresh air. In addition, AC systems must be properly maintained to avoid introduction of contaminants. Installation allowing for easy maintenance is therefore key. These issues are discussed later in this chapter.

For further discussion of Indoor Air Quality issues within the home see resources listed in Appendix B.

Recommended Technique: Design windows for use in air conditioned spaces.

Use double-pane insulating windows that are designed for use in air conditioned spaces to maintain comfort while saving energy and money. For more information on windows and glazing see Chapter 10. Windows that cannot be tightly sealed, such as jalousies, should not be used in conditioned spaces. If they are necessary, limit them to 2% of floor area, or choose cam-locking types that can be tightly closed.

Recommended Technique: Select systems with a Seasonal Energy Efficiency Ratio (SEER) of 12 or higher.

Air conditioners are rated by their *Seasonal Energy Efficiency Ratio (SEER)*. The SEER indicates an air conditioner's efficiency by measuring cooling output divided by electrical energy input. It is expressed in British thermal units per watt-hours (Btu/Wh). The higher the SEER, the more efficient the unit. High SEER models generally cost more than lower-efficiency models, but this initial cost is offset by lower utility bills. Some units have SEER ratings as high as 17.

Recommended Technique: Properly size AC unit(s).

Proper sizing is critical for air conditioner efficiency. Many people buy large air conditioners, thinking they will do a better job. This is not the case. An oversized air conditioner will actually be less effective at cooling a home than one that is the correct size. An oversized system will cost more to install, waste energy, increase your electric bill, and potentially create moisture and indoor air quality problems.

Air conditioners work by removing heat and humidity from the air. Humidity is removed when air passes over the cooling coils of an air conditioner. If the unit is too large it will cool the air quickly and then shut off. Unfortunately, short-run cycles like this keep the air conditioner from effectively removing humidity. In effect, an oversized unit will cool a room quickly, but only remove a portion of the humidity. This will leave the room with a damp, clammy feeling and can also lead to mold and mildew problems. A properly sized unit will remove humidity effectively as it cools. Use Table 18-A to estimate the appropriate size air conditioner for your application.

Table 18-A: Matching Area to AC Capacity

Area to be Cooled (sq. ft.)	Capacity (Btu/hr)
100 to 150	5,000
150 to 250	6,000
250 to 300	7,000
300 to 350	8,000
350 to 400	9,000
400 to 450	10,000
450 to 550	12,000
550 to 700	14,000
700 to 1000	18,000

Adjust the estimated size if any of the following apply:

- If the room is heavily shaded, reduce capacity by 10%.
- If the room is very sunny, increase capacity by 10%.
- If more than two people regularly occupy the room, add 600 Btu/Hr for each additional person.
- If the unit is for a kitchen, increase the capacity by 4,000 Btu/Hr.

Source: www.energystar.gov

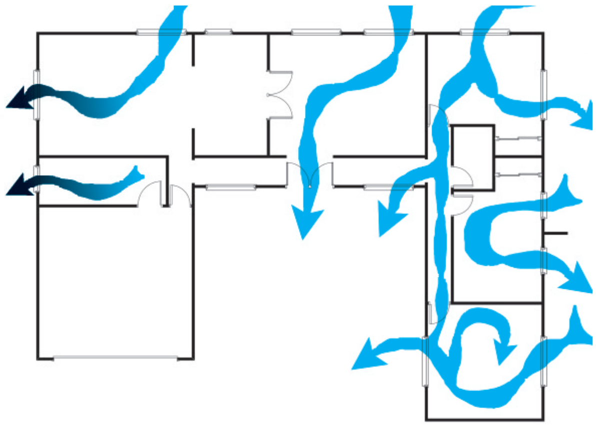
17 Air Conditioning

Recommended Technique: Zone and control the AC system.

Various areas, or zones, within the home have different cooling needs due to differing activities and thermal exposures. For example, the cooling requirements for a bedroom on the north side of a house would be very different from those of a busy kitchen with a wide western exposure. Separate controls for each zone increase the efficiency of the overall system, which increases comfort and decreases operating costs.

Recommended Technique: Ensure AC system provides a generous supply of fresh air.

When air conditioning is used, it is important that the system provide adequate fresh air. The American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) has set a guideline for home ventilation of 0.35 air changes per hour (ACH). One air change is the volume of fresh outside air needed to replace all of the air inside a house. An ACH of 0.35 means that about one-third of the air in a house is replaced with fresh air every hour. Ventilation for air handling systems can also be measured in cubic feet per minute (CFM). A rule of thumb often used for ventilation in a home is 15 CFM of fresh air per person. To estimate the amount of fresh air needed to provide adequate ventilation, calculate using both methods and use the larger result. See example below.



- Method 1 (Rule of Thumb): Number of persons: 4 x 15 CFM = 60 CFM.
- Method 2 (ASHRAE ACH): 1,800 sq.ft. x 8' ceiling = 14,400 cubic feet. 14,400/60 x 0.35 = 84 CFM

Fig. 17-5: Estimating Fresh Air Requirements for Air Conditioned Homes.

In this three-bedroom 1,800 square foot house with 8-foot ceilings and four occupants, the ASHRAE method gives the higher result and recommends 84 CFM of fresh air.

Recommended Technique: In central air conditioned homes, ensure balanced airflow.

A centrally air conditioned home usually has supply vents in every room and often only one return air vent. If the doors to one or more rooms are shut, the air being supplied to those rooms will not be recirculated by the AC system. The return vent will be "starved" for air, which will cause the room with the return vent to become under pressurized. The closed rooms will become over-pressurized, forcing air out through any leaks in the building envelope. In this way, an air conditioning system can become unbalanced and allow air infiltration, which will result in wasted energy and money.

Door cuts (increasing the gap at the bottom of the door) are often used as a method to balance pressure between rooms. This is not a reliable practice. Instead, install return vents in every room with an air supply or install transfer registers in uninsulated interior walls to allow the pressure between rooms to equalize. Figure 17-6 illustrates a transfer grille.

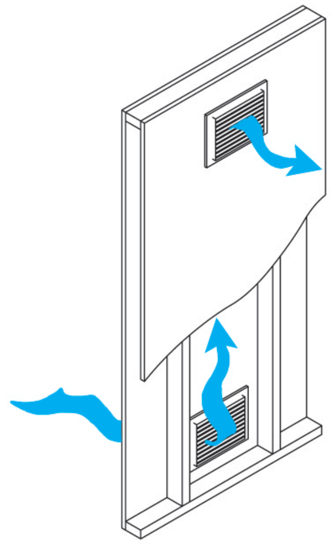


Fig. 17-6: Ensuring Balanced Air Flow.

Transfer grilles can prevent rooms with supply vents from being over-pressurized.

Recommended Technique: When installing a central air conditioner, seal ducts to avoid leaks.

A survey by the Florida Solar Energy Center found that the average home in Florida lost 11% of its cooling energy because of poorly sealed ductwork. After the duct systems of those homes were repaired, their annual heating and cooling bills were reduced by an average of $110.

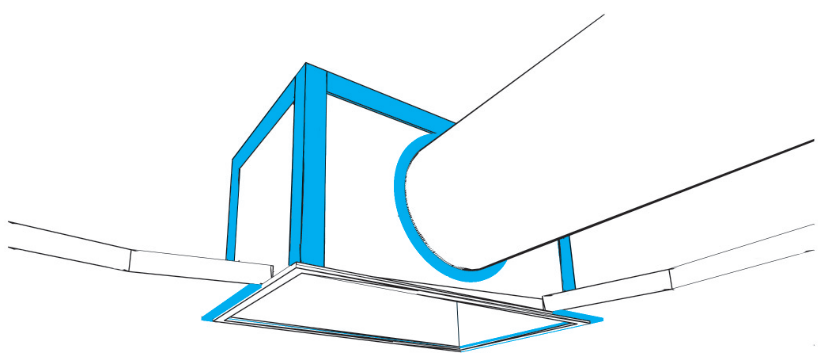


Fig. 17-7: Air Sealing of Ductwork.

Leaky ductwork can contribute up to 60% of the air leakage in a home. If ducts are insulated with fiberglass, sealing will also prevent these fibers from entering the air stream, which creates a health hazard. Sealing will also protect moisture buildup, which fosters the growth of mold and mildew, another health hazard.

Tips for optimizing ductwork performance:

- Properly seal ducts using a "mastic" (adhesive paste). Duct tape can deteriorate quickly and should not be used to seal ducts. If a gap is larger than .25 inch, reinforce the mastic with a fiberglass mesh tape. Note: Lawrence Berkeley National Laboratories is developing a new sealing technology using an aerosol spray.
- Install galvanized ducts. The zinc coating will deter mold growth.
- Insulate the ducts to R-11 or above. Or install them in conditioned spaces to keep them in the same temperature range as the spaces to which they are supplying conditioned air. An un-insulated duct in a hot attic will lose energy across the duct wall through conduction. Ducts can lose about the same amount of energy through conduction as they can through leaks.
- Avoid flexible ducts whenever possible. Their corrugated surface resists airflow and forces the AC system to work harder.

Recommended Technique: When installing window units, optimize performance.

Here are some guidelines to follow when installing window units:

- Install window air conditioners on a level surface so that the drainage system and other mechanisms operate efficiently.
- If possible, install the unit in a shaded spot on the home's north side. Direct sunlight on the unit's heat exchanger decreases efficiency.
- Use plantings or shading devices to shade the air conditioner, but do not block the airflow. A unit operating in the shade uses as much as 10% less electricity than the same one operating in direct sunlight.

Recommended Technique: Install the AC system so it can be easily maintained.

A poorly maintained AC system will waste energy, have higher repair costs, and could lead to mold and mildew problems. With regular maintenance, an air conditioner can retain up to 95% of its efficiency. If not properly maintained, an air conditioner can lose 5% of its operating efficiency every year. This means that without regular maintenance an AC unit with a SEER of 12 could actually be operating with a SEER of 9 after just a few years. Builders should refer owners to the AC maintenance tips in Appendix E.

Summary of Key Strategies and Recommended Techniques for Section III

Water heating:
- Install solar water heating.
- Install water-conserving fixtures and appliances.
- Properly size water heating equipment.
- Select high performance hot water heating equipment.
- Practice efficient operation and maintenance.

Daylighting:
- Minimize difficult-to-shade east- and west-facing windows.
- Design interior layouts to match lighting needs to daylight availability.
- Use light-colored interior finishes effectively.
- Design floor plans to allow deep daylight penetration.
- Use light shelves when sidelighting.
- Rely on clerestories or roof monitors for toplighting.
- Prevent heat gain and glare when installing skylights.

Electric lighting:
- Design for effective electric light delivery.
- Use fixtures that accept fluorescent bulbs.
- Conserve energy use for lighting with appropriate controls.

Appliances:
- Select energy-efficient refrigerators.
- Select energy-efficient cooking appliances.
- Select energy-efficient laundry equipment.
- Select energy-efficient dishwashers.
- Select systems with a seasonal energy efficiency ratio (SEER) of 12 or higher.

Air conditioning:
- Use air conditioning only when absolutely necessary.
- Employ passive cooling strategies to reduce cooling load.
- Seal the building envelope against energy leaks.
- Select AC systems with a Seasonal Energy Efficiency Ratio (SEER) of 12 or higher.
- Properly size the AC system.
- Zone and control the AC system.
- Ensure AC system provides a generous supply of fresh air.
- In central AC homes, ensure balanced airflow.
- When installing central AC, seal ducts to avoid leaks.
- When installing window units, optimize performance.
- Install the AC system so it can easily be maintained.

Section IV: Introduction

This *Field Guide* presents over 50 recommended techniques to use when building energy-efficient homes. These techniques are based on DBEDT's *Energy Efficiency Guidelines* (see page 3) that are intended to save energy, add value, and improve the comfort and quality of life of Hawaii's home owners.

As an architect, contractor or owner-builder, you may wonder how one energy efficient home can make such a difference. Why should you care? This section addresses these legitimate concerns and:

- Presents information about the true cost of energy to you and our natural environment. (Chapter 18)
- Highlights the three "big bang" techniques that will provide the greatest improvements in terms of comfort, energy savings, and reduced impact on the environment. (Chapter 19)
- Provides information about incentives and other resources that will help you make these improvements. (Chapter 20)
- Provides information about enhancing your efforts to protect the environment by using additional "green" building methods beyond energy efficiency. (Chapter 21)

Chapter 18: The Cost of Energy

The energy used to operate your home brings with it great convenience and comfort. Unfortunately, energy use has significant economic and environmental costs as well.

The most obvious cost is reflected in your utility bill. Electricity rates are high in Hawaii, from one and one-half to nearly three times the national average. This is primarily because most of the electricity purchased in Hawaii is produced from burning fossil fuels, fuels that must be imported from the mainland USA and foreign countries.

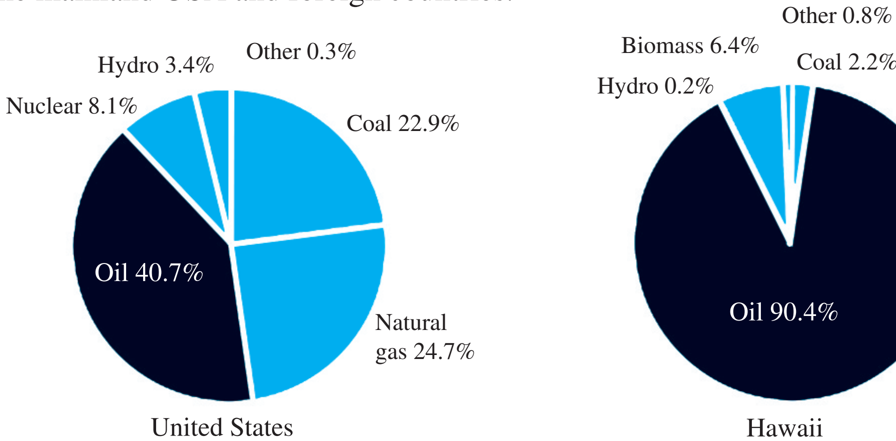


Fig. 18-1: Energy Production, USA and Hawaii.

Nearly 90% of Hawaii's energy is produced by burning fossil fuel (oil and coal). All this fuel is imported to the islands at an annual cost of about \$2.5 billion, 7% of our Gross State Product. (Source: DBEDT Energy Resources Coordinator's Annual Report 2000)

Besides affecting your pocketbook, this reliance on petroleum-based energy has other significant disadvantages, including:

- It diverts money from more constructive purposes.
- It makes Hawaii residents highly vulnerable when there are disruptions in fuel supply and price fluctuations.
- Oil-to-energy conversion pollutes the environment.

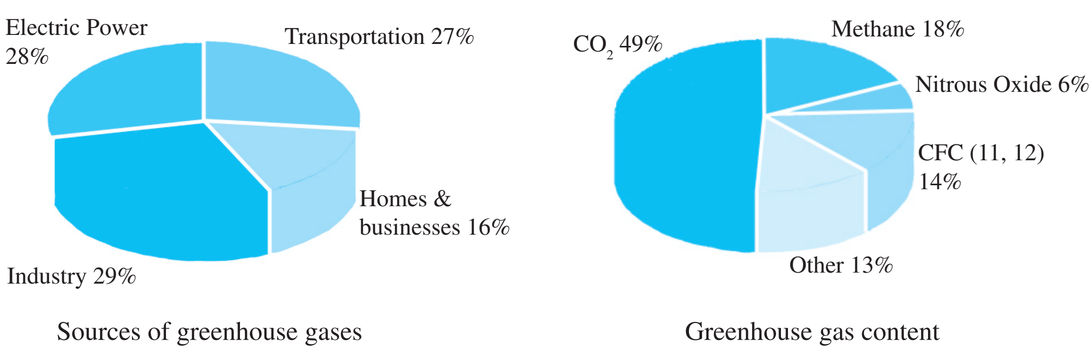


Fig. 18-2: Sources of Greenhouse Gases.

Oil-to-energy conversion (burning oil to generate electricity) produces large amounts of carbon dioxide (CO_2), methane, nitrous oxide (NO_x) and other products of combustion. These "greenhouse gases" contribute significantly to global warming and environmental pollution. (Source: DBEDT)

Reducing the use of petroleum in Hawaii through energy efficiency and the use of solar water heating can reduce this trend and have a significantly positive effect. So each house you build using the State's *Energy Efficiency Guidelines* can make a difference!

Fig. 18-3: Solar Hot Water Heaters Reduce Greenhouse Gas Emissions.

As of July 1998, roughly 70,000 Hawaii households in owner-occupied dwellings (about 36%) were using solar water heating systems, helping to significantly reduce greenhouse gas emissions. (Source: DBEDT)

47,518 barrels of oil not burned

24,800 tons of CO_2 not emitted

69 tons/kWh of NO_x not emitted

Conservation is Common $ense in Hawaii

Given climatic conditions so favorable to conservation in Hawaii, it is hard to justify building anything but energy-efficient homes. By using solar water heaters, the home owners referred to in Figure 18-3 have saved 735 gigawatt hours (the equivalent of a 10.2 megawatt power plant) since HECO's solar water heating program was initiated in 1996.

This is only a small measure of the vast energy savings possible if all homes in Hawaii were built using the comprehensive *Energy Efficiency Guidelines* presented in this *Field Guide*. These energy savings translate to a cleaner environment and a stronger, vital economy.

Chapter 19: Energy-Efficient Features Pay Off in Savings and Comfort

Three "Big Bang" Techniques for Hawaii

This chapter reviews and expands on three energy-efficient features previously discussed, which offer "big bang" results in comfort, energy savings, and increased livability. These "big bang" strategies are:

- Utility-approved Solar Water Heater
- Radiant Barrier
- Natural Ventilation

A 1999 survey of home shoppers conducted by the National Association of Home Builders (NAHB) and Fulton Research, Inc. lists energy efficiency as one of the top ten items home buyers want. (NAHB)

These three are an excellent place to start because in combination they provide significant reductions in energy use and operating costs for home owners.

For builders, the added comfort and energy savings, as well as financial incentives currently available (see Chapter 20), will make your homes more appealing to cost and value-conscious home buyers. In addition, home buyers will appreciate efforts to protect and connect with the beauty of Hawaii's natural environment.

Naturally, you will get the best "bang for your buck" by combining and integrating several energy-efficient features. After the three highlighted examples in this chapter, you should consider other features that do not add significant cost and are easy to implement, such as shading and using light-colored finishes for the buildings roof and walls. Next, consider additional features that may add cost but significantly improve on the overall efficiency or cost-effectiveness of the features you have already decided to incorporate. For example, by combining energy- and water-efficient appliances with solar water heating you can reduce the size requirements of the solar water heating system.

Considering the cost of living in Hawaii, combining solar water heating with energy- and water-saving appliances and equipment, natural ventilation, and insulation/radiant barrier will save about $8,000 to more than $20,000 over 20 years for a typical Oahu family of four. (Source: DBEDT)

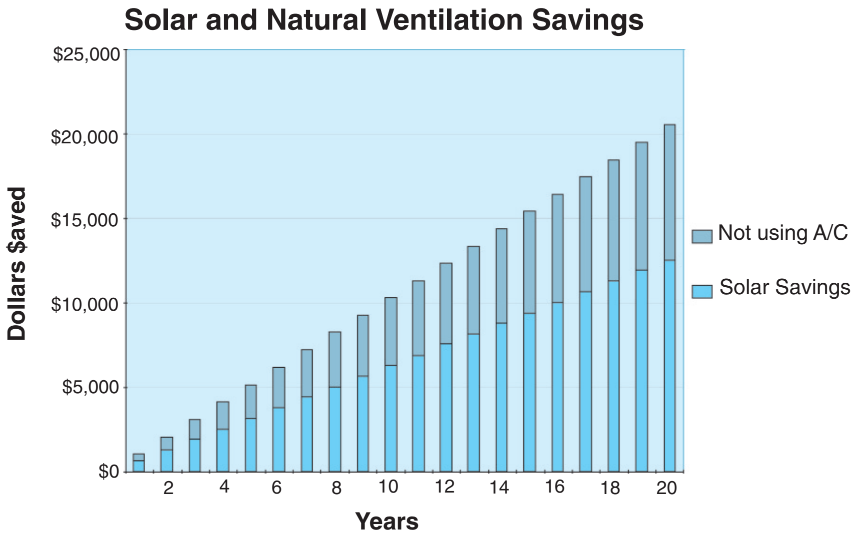


Fig. 19-1: Energy-Efficiency in the Home Means $$ Savings!

DBEDT identified $8,000 to $20,520 savings (not including energy income tax credit or utility rebates) resulting from selected energy efficient features. This chart illustrates the cumulative "cash flow," or funds available for uses other than utility bills, resulting from incorporating solar water heating and not using air conditioning over a 20-year period for a typical Oahu family of four (solar savings calculated at 14.5¢ per kWh). (Source: DBEDT)

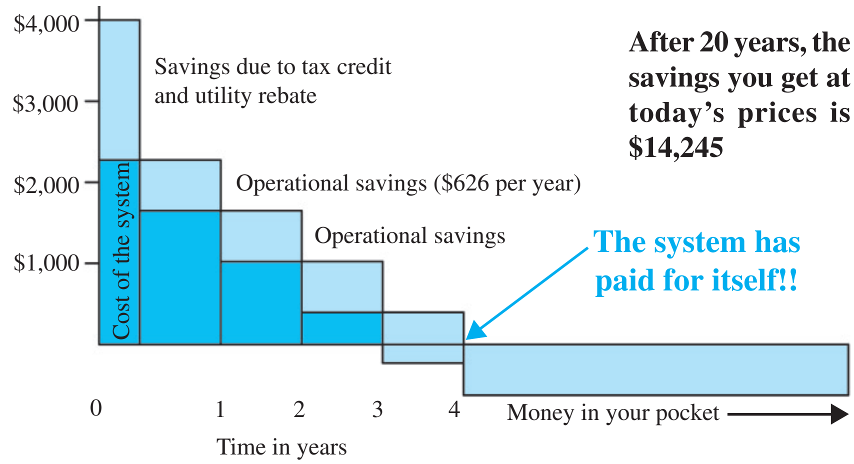
Solar Water Heating: When Getting in Hot Water is a Good Thing!

The “Number One” method to conserve energy in Hawaii’s homes is through the installation of a utility approved solar water heating system (see Chapter 13). With a properly sized solar water system, a family of four can save nearly 40% on their monthly electricity bill — about $626 per year for a family of four at 14.5 cents per kilowatt hour. The initial cost for installation is about $4,000, but current state income tax credits and utility rebates reduce this cost by about $1,725 (Oahu). Annual savings provide an effective payback period of about 3.6 years. Households using solar water heating have been surveyed to determine level of satisfaction and repair requirements. HECO reports that 90% of those surveyed were satisfied with their system’s performance, and 85% said their system had required no major repairs.

Fig. 19-2: Solar Water Heating Payback.

The chart shows how the payback from a solar water heating system works, showing system cost, operational savings, and incentives. This chart is based on estimated hot water usage by an average Oahu family of four calculated at 14.5 cents per kWh. Neighbor Island residents would realize an even faster payback and greater lifetime savings because their electricity rates are higher.

See page G-3, Appendix G, for the savings calculation.



Radiant Barriers: No Sweat

A radiant barrier properly installed in the roof (see Chapters 7 and 8) will typically:

- Reduce ceiling temperature by 18˚ F.
- Reduce indoor temperature by 4˚ F
- Make people feel 9˚ cooler
- Can eliminate the need for air conditioning, which will save the cost of the air conditioner plus the $200 to $400 per year needed to run it.
- Make you eligible for possible utility incentive programs.

A radiant barrier installed in the walls (see Chapter 9) provides measurable benefits by reducing heat gain on the east and west walls during early morning and late afternoon hours. Cooler indoor temperatures naturally reduces the need for artificial cooling.

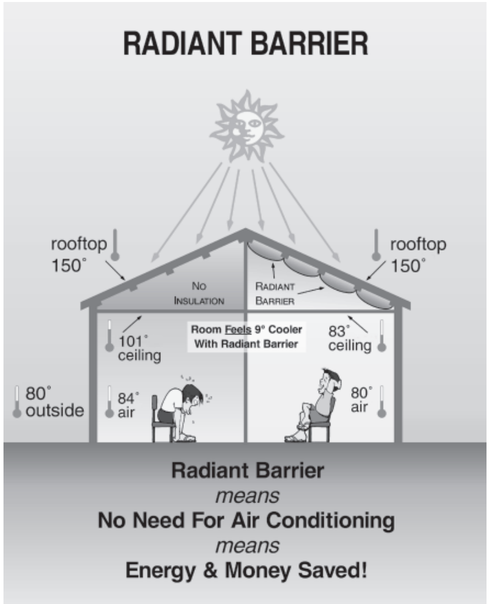


Fig. 19-3: Benefits of Radiant Barriers.

Natural Ventilation: Stay Connected

The most obvious benefit of a high quality natural ventilation design is the ability to eliminate air conditioning (see Chapter 12). It saves you the cost of the air conditioning system, plus the $200 to $400 per year needed to run it.

As noted in Chapter 17, there are occasions when air conditioning may be necessary. In general, however, effectively designed natural ventilation provides comfort along with the health and quality of life benefits of staying connected to Hawaii's beautiful outdoor environment.

Our climate allows us to have our windows open during most of the year. This helps flush out pollutants that would otherwise accumulate in our homes, such as volatile organic compounds (VOCs), pollen, mold spores, and dust mites – all health hazards to those suffering from allergies or asthmatic conditions.

In addition, staying connected means you will benefit from a greater tolerance to temperature and humidity variations indoors and you will not experience extreme differences in temperature and humidity when you move from indoors to outdoors. In addition to causing discomfort, environmental health professionals believe that moving between artificially cooled indoors to warmer outdoor environments on a regular basis can make you more vulnerable to a variety of health complaints.

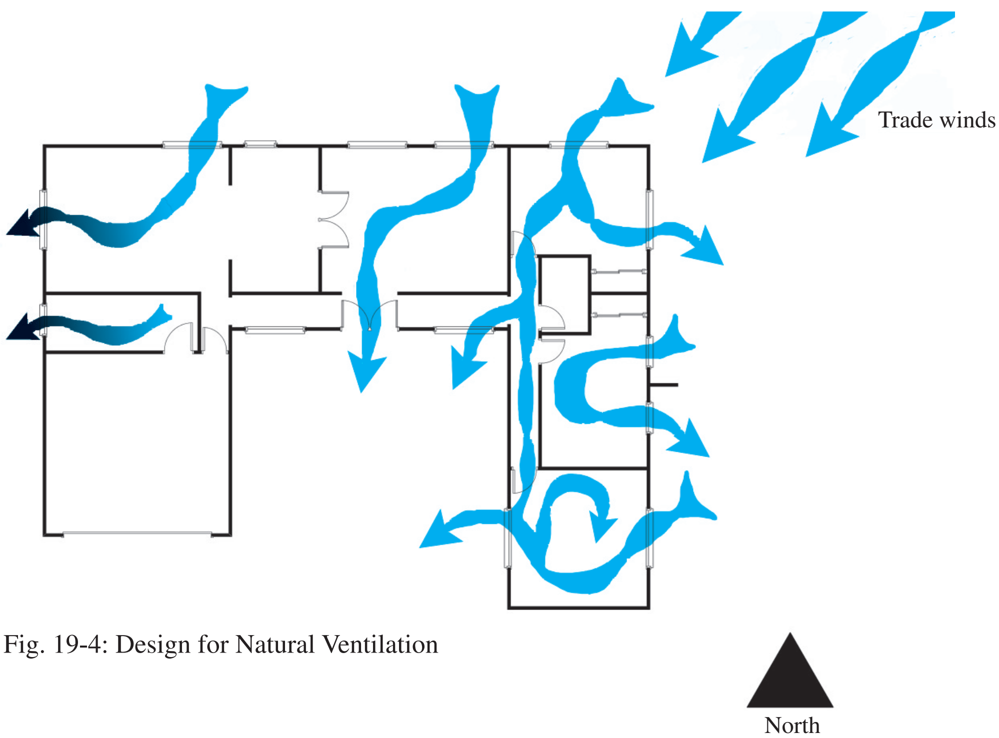
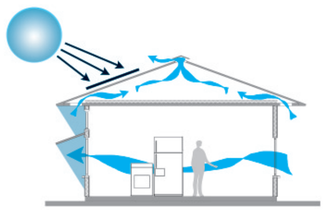
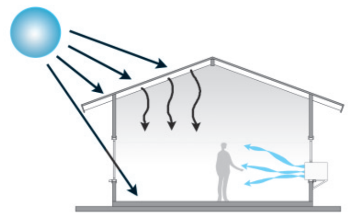


Fig. 19-4: Design for Natural Ventilation

Putting It All Together

Table 19-A (on the next page) compares the operating savings that result from incorporating several of these recommended energy-efficient features. (These estimates are based on average residential conditions on Oahu.)

Table 19-A: Comparison of an energy-efficient home and an inefficient air conditioned home.

Energy Efficient House		**Inefficient Air-conditioned House**	
			
Energy Efficient item	*Operating cost per year*	*Item*	*Operating cost per year*
Solar water heater	$0	Electric water heater	$400
Keeping your house cool with radiant barrier, insulation, and natural ventilation	$0	Window AC unit	$200-400
		Central AC unit	$400-500
Energy efficient clothes washer	$45	Standard clothes washer	$140
Energy Star refrigerator	$80	Standard refrigerator	$116
Energy efficient lighting	$90	Standard lighting	$190
Total	**$215**	**Total**	**$1,046-1,346**
Saving due to energy efficiency	**$831-1,131 per year!**		

Note: Family energy uses are rapidly changing here and throughout the USA. Spas, large entertainment systems, computer equipment, and other amenities are creating higher demand for the residential energy sector. The figures of Table 19-A above reflect a traditional, lower residential energy demand. The costs for electricity are calculated at 14.5 cents per kWh.

The Model Demonstration Home, dedicated on May 15, 2001, as the First Hawaii BuiltGreen™ Home, was built using several of these energy-efficiency features, as well as many other environmentally responsible construction materials and practices. It provides an excellent "real" example of an economical, energy and resource efficient home that is comfortable without air conditioning. See Appendix I for more information.

"Big Picture" Benefits

Besides these benefits to homeowners, the features highlighted in this chapter provide benefits to *everyone* in Hawaii. For example:

- The Hawaii solar industry estimates that there are about 700 people employed in the solar industry and its ancillary businesses.
- The labor income effect is $6.6 million per year for an annual installation of 2,477 solar systems. (Source: DBEDT)
- Using solar energy and energy-efficient technologies instead of imported energy keeps money in Hawaii. Assuming all of the single family households in Hawaii (191,894 owner-occupied units) incorporated the features included in Table 19-A and incurred the operating savings estimated, between $159,463,914 and $217,032,114 would be available for constructive purposes in Hawaii, rather than for buying energy produced from imported oil. (Source: DBEDT)
- Avoiding petroleum-based energy reduces pollution (see Chapter 18).

Chapter 20: Incentive Programs and Other Resources

Solar Energy Incentives

The State of Hawaii provides Energy Income Tax Credits through Chapter 235-12 of the Hawaii Revised Statutes. For example, solar systems installed and placed in service between January 1, 1990, and July 1, 2003, earn a tax credit of 35% or $1,750 (whichever is less) for single family homes, and a tax credit of 35% or $350 (whichever is less) for units in a multi-family structure. The tax credit applies to solar water heaters and photovoltaic systems, as well as to other devices that convert solar radiation to electricity or thermal energy. The State also provides tax credits for heat pumps, wind systems, and ice storage. For more information on the State tax credit, contact the Taxpayers Services Branch, State Department of Taxation, 587-4242. Neighbor Island residents call toll free, 1-800-222-3229.

In addition, savings in utility costs generated from a U.S. Department of Housing and Urban Development (HUD) accepted solar energy system may be considered when qualifying borrowers for HUD-insured mortgages. Some restrictions apply. Contact HUD at 522-8190 for more information.

Local utilities offer incentive programs as well, summarized below. See Appendix G for more information.

Hawaiian Electric Company (HECO)

Through its "Energy $olutions for the Home" program, HECO offers the following benefits to those installing solar water heating systems:

- Standards and specifications for system installation.
- A $500 discount on installation costs.
- Inspection by HECO to ensure proper installation.

HECO provides a list of participating solar contractors. For more information on HECO's Utility Rebate Program, including a copy of the booklet "Energy $olutions Power Book," call 947-6937.

Hawaii Electric Light Company (HELCO)

Through its "Residential Efficient Water Heating Program," HELCO offers the following benefits to those installing solar water heating systems:

- HELCO's standards and specifications for installation.
- A $1,000 co-payment for new construction and remodels to reduce installation cost.
- Inspection by HELCO to ensure proper installation.

HELCO provides a list of participating solar contractors. For more information on HELCO's Residential Efficient Water Heating Program, call 969-0127.

Maui Electric Light Company (MECO)

MECO's "SolarWise" program encourages builders to include solar water heating as a standard feature on all new residential construction. MECO works with several builder partners who offer this feature as part of their homes. These SolarWise homes qualify for the EPA's Energy Star® Program as well, making them eligible for discounts on closing costs or other favorable financing (see "Energy Efficient Mortgages," below).

MECO provides a list of participating SolarWise builders. For more information on MECO's SolarWise Program, call 888-632-6786 (tollfree).

Kauai Electric Division, Citizens Utilities

Kauai Electric's "Energy Wise Residential Program" is different from the other utility programs in that it is primarily geared towards providing incentives for retrofitting existing housing, in particular homes that have a conventional electric heater or a solar water heating system with electric backup. The utility offers free home audits, as well as upgrades including energy-saving showerheads, faucet aerators, and tank wraps, and compact fluorescent lamps to replace heavily used incandescent lamps. In addition, the utility may provide recommendations regarding heater temperature settings. As part of the analysis, the utility evaluates the feasibility of either installing a heat pump or solar water heating system. If the utility's recommendation is to install such a system, the utility provides an incentive rebate and information on participating installers.

Kauai Electric offers incentive rebates only when the maximum allowable cost is greater than a threshold determined by the utility. For example, as of this writing, incentives are paid when the maximum allowable cost for a solar water heating system is greater than $3,268 or when the maximum allowable cost for a heat pump is greater than $2,400. The amount of rebate can vary depending on the owner's income and other circumstances. For example, an owner occupant can receive a 45% rebate. An owner occupant qualifying under federal income guidelines (or an apartment tenant with a willing landlord) can receive a 70% rebate on installation costs. For current information call Kauai Electric at 808-246-8232.

For new construction that is being built for an owner occupant and where the owner intends to install conventional electric water heating, the utility can perform a cost-benefit analysis to determine if a solar water heating system is cost effective. If so, an incentive rebate is available, (80% of the maximum allowable cost) less $500, the amount the owner would have paid for the electric heater.

Energy Efficient Mortgages

Lenders around the country, including some in Hawaii, recognize the value of energy efficient homes. Homes built in Hawaii that qualify for the USDOE/EPA-sponsored Energy Star® Program are eligible for new mortgage products being offered by Fannie Mae and other lending institutions.

Energy efficient mortgages (EEMS) allow home owners to borrow more money or pay less money down because of projected lower monthly costs for operating a high performing energy-efficient home. In the first case, the owner gets more home for their money. In the second case, the owner enjoys a positive monthly cash flow when compared to a conventional home.

Solar water heating savings can be reflected in a lower minimum income requirement for financing as in the example using HECO data in Table 20-A. In this example, a home with a solar water heater *decreases* your utility bill by *$29 a month*, offsetting the $19 per month mortgage increase.

Table 20-A: Lower Minimum Income Requirement for Financing Due to Solar Water Heating Savings (HECO, 2000)

Monthly Savings	Without Solar	With Solar
Mortgage amount	$200,000	$202,650
Monthly mortgage payment	$1,398	$1,417
Monthly electric bill	$103	$74
Monthly mortgage and electric bill combined	$1,501	$1,491
Monthly savings	$0	$10

Lower Income Requirement	Without Solar	With Solar
Debt-to-income ratio	28%	30%
Annual income requirement	$60,000	$56,000

Or in increased buying power, as in the example using MECO data in Table 20-B.

Table 20-B: Increased Buying Power Due to Solar Water Heating Savings (MECO, 2000)

Monthly Savings	Without Solar	With Solar
Monthly mortgage payment	$160,000	$162,480
Monthly electric bill	$1,119	$1,136
Monthly mortgage and electric bill combined	$126	$1,232
Monthly savings[1]	$0	$13
Increased Buying Power	**Without Solar**	**With Solar**
Buyer's total monthy income	$5,000	$5,000
Qualifying ratio	28%	30%
Maximum monthly payment	$1,400	$1,500
Maximum loan amount	$178,850	$191,600
Added borrowing power with Energy Star mortgage	$0	$12,750

1 Note: based on 7.5%, 30-yr. Fixed, 35% State Tax credit of $1,085, MECO rebate of $1,000.

For ease of implementation in Hawaii, Energy Star® Homes Program has developed equivalencies for homes participating in the HECO, MECO, and HELCO solar domestic water heating programs. Non-air conditioned homes participating in the programs comply with Energy Star® requirements if they have a solar water heater. Air conditioned homes must be built to the "Hawaii Model Energy Code – Residential Requirements for Air Conditioned Homes," and perform additional measures from three options described in a memo dated April 11, 2000 (see Appendix F). For more information about Energy Star®, check out: www.epa.gov/docs/GCDOAR/energystar.html. See Appendix B for additional resources.

Chapter 21: Going the Extra Mile to Build "Green"

By building an energy efficient home you do a great deal to protect the quality of life in Hawaii. If you wish to do even more, consider building a "green" home.

What is a green home? It is a resource-efficient home that incorporates environmentally sensitive concepts and products in its design, construction, and operation. In addition to energy efficiency, a green home provides improved air quality; uses environmentally preferable building materials, including recycled-content products; conserves and protects water supplies; reduces construction waste; and preserves valuable natural site features.

Green homes are healthier, perform better, last longer, and are easier to maintain. In the long run, owners of green homes in Hawaii save energy, save money, preserve the environment, and help improve the state's economy, all at the same time.

By building green you add value and reduce the life-cycle cost of a home.

On May 15, 2001, a model demonstration home built to the State's *Energy Efficiency Guidelines* (see page 3) was dedicated as the First Hawaii BuiltGreen™ Home in the state (see Appendix I for Case Study). That means it not only met the intent of the *Guidelines*, but it met a set of "green" criteria developed by the Building Industry Association of Hawaii (BIA) in partnership with government and utility representatives. These criteria were reviewed and approved by developer members of the BIA.

The Hawaii BuiltGreen™ program is a voluntary program where home projects are certified by the builder to include energy efficient, materials efficient, improved air quality, and site protection features. For more information about the program, please call the BIA-Hawaii at 847-4666.

For information about resource-efficient building in Hawaii, see:

"HABiT Guide to Resource-Efficient Building in Hawaii," a 1999 publication of DBEDT and the Hawaii Advanced Building Technologies Training (HABiT) Program. The HABiT program seeks to improve the quality of Hawaii's buildings by promoting structures that are climatically adapted, energy and resource efficient, durable, comfortable, and healthy for Hawaii's people. The Guide focuses on residential, primarily new, construction.

Also see additional resources in Appendix B.

APPENDIX

Recommended Techniques A
Resources B
Bibliography C
Shading Formulas D
Operation and Maintenance E
Energy Star Homes in Hawaii F
Utility Co-Payment Levels G
Certification Programs H
Organizations I
Model Demonstration Home J

Appendix A: Recommended Techniques

Recommended Techniques - Design

Landscape & Site Design

- Limit heat build-up by orienting longer sides of the home north and south.
- Use existing or new landscape elements (trees) to shade the building.
- Shade hardscapes, such as walls and paved areas.
- Limit area of unplanted and paved exterior surfaces. Provide generous areas of planting and ground cover to help reduce site temperatures.
- Use porous paving materials to reduce thermal mass, heat gain, and glare.

Roofs

- Shade roof to prevent heat build-up.
- Use roofing materials that reflect the sun's heat rather than absorb and transfer it to the home's interior.
- Insulate ceilings and attic spaces.
- Install radiant barriers in ceilings and attic spaces.
- Ventilate roof properly.
- Integrate roof strategies.

Walls

- Use design elements to shade walls.
- Use light-colored wall finishes.
- Insulate walls exposed to the sun.
- Install radiant barriers in walls exposed to the sun.

Windows and Other Openings

- Shade windows and other openings.
- Use high performance glazing on windows exposed to the sun.
- Limit area of openings.
- Use skylights with great care.

Airflow Around Buildings

- Orient buildings to maximize the cooling potential of prevailing winds.
- Provide ample spacing between buildings in the direction of wind flow so that all structures have good air flow.
- Arrange buildings to provide for good air flow around all structures.
- Use landscaping elements such as trees, fences, and hedges to improve air flow around structures.

Airflow in Buildings

- Design floor plans that provide effective cross ventilation and good circulation at body level.
- For spaces with openings on opposite walls orient the room 45 degrees from the wind direction.
- Keep inlet openings slightly smaller than outlet openings.
- For spaces with openings on adjacent walls place windows far apart and at a diagonal.

- For spaces with openings on the same wall use casement windows or wing walls spaced as far apart as possible.
- Locate windows at body level.

Recommended Techniques – Energy Efficient Equipment & Appliances

Water Heating
- Install solar water heating.
- Install water-conserving fixtures and appliances.
- Properly size water heating equipment.
- Select high performance water heating equipment.
- Provide for efficient operation and maintenance.

Daylighting
- Minimize difficult-to-shade east- and west-facing windows.
- Design interior layouts to match lighting needs to daylight availability.
- Use light-colored interior finishes effectively.
- Design floor plans to allow deep daylight penetration.
- Uses light shelves when sidelighting.
- Rely on clerestories for toplighting.
- Prevent heat gain and glare when installing skylights.

Electric Lighting
- Design for effective electric light delivery.
- Use fixtures that accept fluorescent bulbs.

Appliances
- Select energy efficient refrigerators.
- Select energy-efficient cooking appliances.
- Select energy-efficient laundry equipment.
- Select energy-efficient dishwashers.

Air Conditioning
- Use air conditioning only when absolutely necessary.
- Employ passive cooling strategies to reduce cooling load.
- Seal the building envelope against energy leaks.
- Select AC systems with a seasonal energy efficiency ratio (SEER) of 12 or higher.
- Properly size the AC system.
- Zone and control the AC system.
- Ensure AC system provides a generous supply of fresh air.
- In central AC homes, ensure balanced airflow.
- When installing central AC, seal ducts to avoid leaks.
- When installing window units, optimize performance.
- Install the AC system so it can easily be maintained.

Appendix B: Resources

Section I

Atlas of Hawaii. Second Edition. University of Hawaii Press, Honolulu 1983.

Section II

Ceiling Insulation for Your Home. Developed by Eley Associates for DBEDT, 1998. www.state.hi.us/dbedt/ert/rf_insul.html.

Environmental Design & Construction, September/October 1999, p 44.

Richmond-Powers, Marc, *Tips to Keep Your Attic Cool*, Austin American Statesman. www.greenbuilder.com.

Green Seal Web site: www.greenseai.org.

The House in the Sun Solar Conscious Architecture for Hawaii and the Tropics. Consumer Education Project of Hawaii, Department of Education State of Hawaii, 1979. p32,38.

Sustainable Building Sourcebook: Radiant Barrier and Ridge-and-Soffit Venting. www.greenbuilder.com.

Wasley H. James & Michael Utzinger. *Vital Signs Glazing Performance*. Johnson Controls Institute, School of Architecture and Urban Planning University of Wisconsin, 1996. p3-4, 10-11.

Section III

EnergyStar® web site: www.energystar.gov.

Green Seal web site: www.greenseal.org.

Consumer Guide to Home Energy Savings, 7th edition, by Alex Wilson, Jennifer Thorne, and John Morrill. Published by the American Council for an Energy-Efficient Economy, Washington, DC, 2000.

The Health House Workbook: A Homeowner's Manual for Building a Healthier Home. Published by the American Lung Association, 490 Concodia Avenue, St. Paul, MN 55103. 651-227-8014. www.healthhouse.org.

Section IV

Ceiling Insulation for Your Home. Developed by Eley Associates for DBEDT, 1998. www.state.hi.us/dbedt/ert/rf_insul.html.

Cooling Our Communities: A Guidebook on Tree Planting and Light-Colored Surfacing. Berkeley Lab Report LBL-31587, January 1992. To order, write to: Superintendent of Documents, Attn: New Orders, P0 Box 371954, Pittsburgh, PA 15220 and request GPO Document Number 055-000-00371-8.

Cooling Your Home Naturally. United States Department of Energy, National Renewable Energy Lab, Technical Information Program, 1996.

Energy Tips & Choices: A Guide to an Energy Efficient Home. HEI Companies, June 1998. This excellent resource provides tips on what to look for when shopping for household appliances and other energy using equipment. Oahu 543-7511; Maui 871-2323; Hawaii 969-0137.

Have Some Energy on the House ... Solar. DBEDT, 1997. Questions and answers on solar water heating and how to purchase one from a reputable dealer.

Hawaii Model Energy Code Application Manual" DBEDT, 1994. Hawaii's MEC is not adopted universally for residential use, but this is a valuable guidance document. www.hawaii.gov/dbedt/ert/mec.

Hawaii Model Energy Code (MEC) Overview, Residential and Commercial Buildings. DBEDT, 1993. www.hawaii.gov/dbedt/ert/model_ec.html.

Hawaii Model Energy Code (MEC) Low-Rise Residential Requirements for Air-Conditioned Homes. DBEDT, 1993.

Residential Efficient Water Heating Program. Hawaiian Electric Company, Inc., 1997.

Guide to Resource-Efficient Building in Hawaii, Hawaii Advanced Building Technologies Training (HABIT) Program. DBEDT, 1999. 808-587-3804.

A Green Hawaii: Sourcebook for Development Alternatives. 1992. Honolulu: Na Kane 0 Ka Malo Press.

Environmental Building News. A leading newsletter of the green building industry. For subscription information, contact Environmental Building News, 122 Bridge St., Suite 30, Brattleboro, VT 05301. 802-257-7300. E-mail: ebn@ebuild.com.

Green House Hawaii Project. Provides lists of earth friendly products and materials and offers a traveling exhibit of materials. See the DBEDT Clean Hawaii Center web site (www.state.hi.us/dbedt/ert/chc/index.html) for materials list and exhibit schedule.

Green Spec: The Environmental Building News Product Direct and Guideline Specifications. Organized by building divisions, provides model specifications environmentally friendly product ideas for each division. Published by *Environmental Building News* (see above).

A Contractor's Waste Management Guide: Best Management Practices and Tools for Job-Site Recycling and Waste Reduction in Hawaii. Prepared by O'Brien & Company for DBEDT, 1999. www.state.hi.us/dbedt/ert/cwmg/index.html.

National Association of Home Builders Research Center. Conducts research on aspects of green building and sponsors an annual green building conference. For information, contact the NAHB Research Center at 400 Prince George's Blvd., Upper Marlboro, MD 20774-8731. 301-249-4000. www.nahbrc.org.

Appendix C: Bibliography

Section II

ASHRAE Handbook of Fundamentals, 1989.

Environmental Design & Construction. September/October 1999. p44.

Green Seal, Energy Star Homes Project: www.greenseal.org.

Wasley H. James & Michael Utzinger. Vital Signs Glazing Performance. Johnson Controls Institute, School of Architecture and Urban Planning University of Wisconsin, 1996. p10-11.

Section III

Energy star website: www.energystar.gov.

Energy Tips & Choices. Hawaiian Electric Company. p12.

Environmental Building News Vol. 5 number 3 May/June 96. p11.

EPRI Journal. November/December 1997. p17.

Garrett, Doug. "Service Your Air Conditioner for Summer Comfort" Austin American Statesman. City of Austin Green Builder Program. www.greenbuilder.com.

Green Seal Web site: www.greenseal.org.

Lam,W., C., 1986, *Sunlighting, As Formgiver for Architecture* Van Nostrand Reinhold CO.

Leslie P. Russell and Kathryn M. Conway. The Lighting Pattern Book for Homes. Lighting Research Center Troy, New York 1993. p203.

Moore, F., 1993, *Environmental Control Systems-Heating, Cooling and Lighting* First edition, McGraw Hill, Inc.

PG&E Major Appliance Energy Guide. 1996.

Pita, G. Edward. Air Conditioning Principles and Systems, An Energy Approach. Prentice-Hall, Inc. Englewood Cliffs, New Jersey. 1989. p328-329.

Sustainable Building Sourcebook: Ductwork. www.greenbuilder.com.

Swisher, M.E., Debbie Roos, Arlene Z. Stewart. Build Green & Profit: Advanced Concepts Participant Guide Lighting. University of Florida Extension 1999. p7.

Townsend, A.K. The Smart Office. Olney, MD: Gila Press, 1997. p125.

Build Green & Profit: Advanced Concepts Participant Guide. University of Florida Extension Service, 1999. p16-26.

Energy Star Homes Project, Discover Ducts, April 1997. www.greenseal.org.

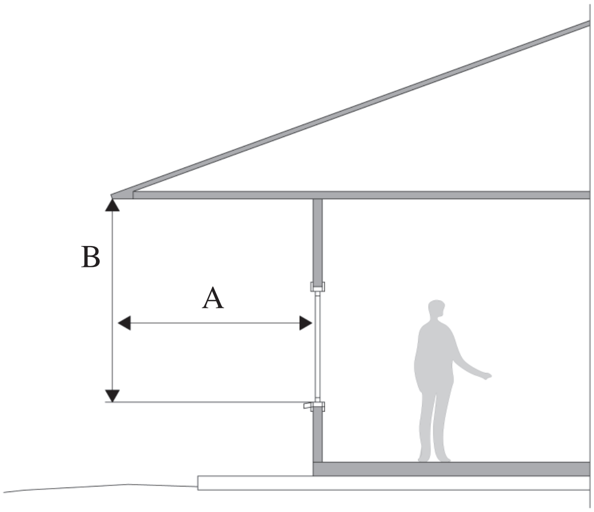
Appendix D: Shading Formulas

The Projection Factor (PF) is an index of the size of a shading device relative to the window it is protecting. The PF helps to determine how well a window will be shaded.

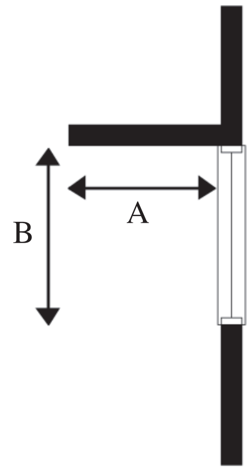
For horizontal shading devices, the PF is the distance that the overhang projects past the surface of the glass (A), divided by the distance from the bottom of the window to the bottom of the overhang (B).

For vertical shading devices, the PF is the distance the fin projects from the wall (A), divided by the distance from the far window jam to the fin (B). The fin should also extend above the window head a distance at least equal to the side fin projection.

For best results in both cases, you want the PF to be 0.5 to 1.0 (with 1.0 providing the most protection all year round).



Projection factor for horizontal shading devices



Projection factor for vertical shading devices (plan view)

Appendix E: Operations and Maintenance

Introduction

A home that is built to high energy-efficiency standards will *be* energy-efficient only to the extent that you, the homeowner, operate your home in an energy efficient manner and keep your equipment well maintained. Besides conserving energy and reducing your energy bills, proper maintenance keeps equipment running well and extends its service life, reducing repair and long term replacement costs as well.

To help you operate and maintain the equipment in your home to peak energy-efficiency, this appendix provides:

- "Do's and Don'ts" for operating the equipment in your home in an energy-efficient manner.
- Maintenance guidelines for air conditioners, hot water heaters, and major appliances.

To properly operate and maintain your equipment, it is important to understand how the equipment or system works. Be sure to review information provided by the manufacturer. And if there is a conflict between manufacturer's operational or maintenance recommendations and these general guidelines, *follow the manufacturer's recommendations*.

Operating Do's and Don'ts

Air Conditioners

The best way to conserve energy and the life of your air conditioning equipment is to use air conditioning only when natural ventilation is inadequate. Here are some ways to minimize the need for air conditioning in your home.

Do's	Don'ts

• Use natural or forced ventilation at night, while keeping the house closed up tight during hot days.
• If your air conditioner has an outside air option, use it sparingly.
• Always keep all doors and windows closed when operating an air conditioner.
• Use ceiling fans to increase your comfort range. (You will probably be comfortable with the thermostat set at about 78^{0}F. You will save 3% to 5% on air conditioning costs for each degree that you raise the thermostat.)
• Reduce humidity to increase comfort. (For example, use a bathroom exhaust fan when you shower.)
• Diligently perform recommended periodic maintenance to keep your system running at peak efficiency.
• Reduce the cooling load:
  • Consider additional landscaping to provide additional shading for east and west windows.
  • Use energy efficient lighting and appliances.
  • Add insulation and sealant around doors and windows.
	• Don't cool unoccupied rooms (but don't shut off too many registers with a central system either, or the increased system pressure may harm the compressor).
	• Don't operate a whole-house fan or window fans while using the air conditioner.

Operating Tips for Window Air Conditioners

Do's	Don'ts
• Set your thermostat as high as comfortably possible. • On very humid days, set the fan speed on low. With the slower air speed through the cooling equipment, the unit will remove more moisture from the air and provide better cooling. • Use an interior fan to help distribute the cooled air. With improved air movement, thermostats can be set at higher without affecting comfort.	• Don't set your thermostat at a colder setting than normal when you turn on your air conditioner. It will not cool your home any faster and could result in excessive cooling and higher utility bills.

Appliances

Refrigerator / Freezer

Do's	Don'ts
• Keep your freezer full. A full freezer will perform better. If your freezer isn't full, fill plastic containers with water and freeze them. • Clearly mark items for quick retrieval. • Turn off empty freezers/refrigerators. You can always turn that unused freezer or second refrigerator when it is needed again. • Unplug unused freezers/refrigerators and remove the door to be sure children cannot be accidentally trapped inside.	• Don't put hot foods directly in the refrigerator or freezer. Allow them to cool to room temperature first.

Dishwashers

Do's	Don'ts
• Use energy-saving cycles whenever possible. • Use the no-heat air-dry feature on your dishwasher. If your dishwater does not have this feature, simply turn off the dishwasher at the end of the wash cycle and open the door to allow the dishes to air dry. • Load the dishes according to manufacturer's instructions and wash only full loads. • If your dishwasher has an accessible filter (at the bottom of the dishwasher), clean it regularly to keep the machine running efficiently.	• Don't pre-rinse your dishes. Scrape off the food and liquids, and the dishwasher will do the rest. If you must pre-rinse, use cold water.

Stoves / Ovens

Do's	Don'ts
• Use microwaves for cooking and reheating small quantities of food. A conventional, full-size oven will consume over five times the electricity for comparable heating. • Use crock-pots and pressure-cookers for appropriate foods. They consume substantially less energy than conventional stove top and oven methods. • Keep burner pans clean. Shiny surfaces will reflect more heat back up to the pan. • Use the smallest pan possible and match the pan size to the element size. • Use copper bottomed pans, which heat faster. • For all but gas stoves, it is important to use flat-bottomed pans to maintain good, efficient contact between the pan and the heating element. • Defrost frozen foods in the refrigerator before cooking to reduce cooking time (and energy use). • Preheat your oven only if you need to, and keep the preheat time to a minimum. • Keep the oven door closed during baking. • If making more than one pan at a time, stagger them so they don't interfere with free air movement. • Use glass or ceramic pans in ovens and reduce the temperature about 25^0 F. Your food will heat just as quickly. • If you have a self-cleaning oven, use the feature after baking to avoid re-heating just for cleaning. • Keep your microwave clean. Clean surfaces allow more efficient microwave cooking.	• Don't lay foil on the oven baking racks. This interferes with air circulation and extends baking times. • Don't overcook. Use meat thermometers and timers to monitor cooking.

Clothes Washers / Dryers

Do's	Don'ts
• Use lower temperatures for washing. • Wash only full loads whenever possible. • When drying, separate your clothes and dry similar types together. • Use the automatic drying feature, if your dryer has one, instead of the timer. • Clean the dryer filter after each use. • Periodically check the outside dryer exhaust vent. Make sure it is clean and that the flapper on the outside hood opens and closes freely. • In good weather, hang your clothes outside to dry. Solar drying is free!	• Don't overdry your clothes. Take clothes out while they are still slightly damp to minimize ironing (another big energy-user). Overdrying is also hard on your clothes and shortens their life. • Don't add wet times to a load that is already partially dry. • Don't overload or underload your dryer. Drying small loads wastes energy. Overloading causes wrinkling and uneven drying.

Maintenance

This section provides general guidelines for routine maintenance of air conditioners, water heaters, and major appliances.

Air Conditioners

<u>Central Air Conditioners and Split Systems</u>

Monthly

- Clean or replace the air filters
- Check the area around the unit and clear away any debris. Leaves and trash can block the vents and prevent interfere with air circulation. Blockages will cause the system to run longer, increasing utility bills and maintenance costs.

Yearly
Have a licensed technician service the system once a year. The technician should:

- Check the coolant level. A system that is 10% low on coolant will cost 20% more to operate. If a system is leaking coolant (freon) by law the leak must be fixed before any more freon can be added. Freon is a chlorofluorocarbon (CFC) and will damage the earth's ozone layer if released into the atmosphere.
- Clean the condenser coils
- Check the amp draw on the compressor
- Oil the fan motors
- Check the belts
- Make sure the operating pressures and temperatures are at the manufacturers specified levels.[1]

Inspect the ductwork for central systems to make sure it is airtight and in good condition.

- Have a contractor repair any disconnected, leaky, or damaged ducts. If air is leaking out of your system you are paying to cool spaces you are not using.

Note: Be sure to check customer references before hiring a contractor to perform duct cleaning or other service.

Window Air Conditioners

Monthly
- Clean or replace the air filters. Keeping the filter clean can lower your air conditioner's energy consumption by 5% to 15%.
- Make sure the drain channels are clear. Clogged drain channels will prevent the air conditioner from reducing humidity, and the resulting excess moisture may discolor your walls or carpet. Channels can usually be cleared by passing a stiff wire through them.

Yearly
- Inspect the seal between the air conditioner and the window frame. Holes in the seal will allow cool air to escape from your home.

Water Heaters

All Water Heaters

Once
- Wrap pipes with a diameter equal to or less than 2 inches with insulation of R-4 or greater. Pipes with a diameter of more than 2 inches should be covered with insulation of R-6 or greater.
- Adjust the water heater's thermostat to 120°F unless dishwasher does not have a booster heater.
- Install a heat trap above the water heater. A heat trap is a piping arrangement that prevents hot water from rising up in the pipes, thereby minimizing standby losses.
- For electric water heaters, install a timer that can automatically turn the hot water off at night and on in the morning. A simple timer can pay for itself in less than a year. OR, enroll in a utility electric demand control program using larger storage capacity tanks and timers to limit heating hours to low electric energy use periods (for example, at night and on Sundays, when most businesses are closed).
- For solar water heating systems, install a backup storage tank with an R-value of at least 16. If less, externally wrap backup storage tanks with insulation of R-12 or greater.

Conventional Water Heaters

Every Three Months

- Drain a quart of water from the tank. This removes sediments in the tank that will decrease the water heater's efficiency.

Solar Hot Water Heaters

Be sure to ask your general contractor or solar installer for a maintenance guidelines and schedule when your system is installed. Your contractor should be able to describe to you the unit's basic operating principles. If you understand how your system operates, most maintenance is a simple matter. If you prefer to hire a solar professional, most offer routine maintenance services at reasonable fees.

Every Three Months

- Flush your storage tank. The normal pressure from a city or county water system is sufficient for the flushing. Small bits of debris from your water supply or solar system can collect at the bottom of the tank, and can affect the function of your pump and valves. A water filter on your incoming supply line can be very effective at removing grit and silt from your water supply. If you do have a filter, include changing the filter cartridge on your regular maintenance schedule.

Annually

- Visually inspect your solar system, especially the equipment, such as the collectors, which are always exposed to the elements. Confirm that the sensor is still weather-tight (if you have an AC forced-circulation system.)
- Look for evidence of leaks.
- Examine the pressure-relief valve and air vent on the pipes exiting the collector to ensure that they're operable and not corroded. If there is water dripping from your pressure-relief valve, replace it.
- If there is dirt on the collector glass, rinse it off or clean with mild soap and water. Do this when the glass is cool, on a cloudy day or early in the morning.
- Examine the pipe insulation. It will break down when exposed to ultraviolet radiation, and should be protected from the sun. It can be painted, wrapped in reflective duct tape, or otherwise covered with an ultraviolet-resistant seal. Repaint or re-seal as necessary.
- Monitor the pump's operation (for a forced-circulation system). It should cycle off and on several times during a normal day, and you should have plenty of hot water.
- Check the mounting structure that supports the collectors to make sure it's in good condition. The metal should be solid and not corroded, and the wood should be sound, with no rot or damage. There should be a two-inch air space between the collectors and the roof. Make sure no leaves or other debris are trapped (which can contribute to rot or corrosion) and that no other unwanted material is present (wasp nests, for example).
- The roofing penetrations—where the mounting structure is fastened to your roof system—must also be checked. Often, a simple but effective fastener like a six- or eight-inch lag bolt holds the collector mount to a rafter or perlon. A roofing compound (or "tar") can be added at the point of penetration to renew the seal, and is easy to apply with a caulking gun.
- Flush your storage tank. The normal pressure from a city or county water system is sufficient for the flushing. Small bits of debris from your water supply or solar system can collect at the

bottom of the tank, and can affect the function of your pump and valves. A water filter on your incoming supply line can be very effective at removing grit and silt from your water supply. If you do have a filter, include changing the filter cartridge on your regular maintenance schedule.

Anode Replacement (Every Four to Six Years)

- Check to see if your system runs hot (with tank temperatures consistently over 150°F). The standard industry recommendation is to replace your anode if the tank temperature runs between 130°F and 160°F, which normally means an anode replacement every four to six years.

- Because the hexagonal head of the rod is sometimes beneath the exterior shell of the tank and use of an impact wrench may be required, this job is often difficult for the do-it-yourselfer. Consider hiring a plumber or solar installer to replace your anode.

Whenever You're Away

If no one will be home to use hot water for an extended period—say, a week or more—take steps to ensure that system temperatures don't get too high while you're gone.

- *For forced-circulation systems*. Before you leave, set the pump switch to "ON" and turn off the back-up heating element. When you are at home, the pump switch will normally be set to "Automatic." When the switch is ON, the pump will run continuously. While this does use additional electricity (about the same as a light left on for security reasons), it keeps the tank from overheating. The water should be fairly warm when you return and will heat rapidly once the back-up is turned back on.

OR

- *All solar systems*. Cover the solar collectors. Some solar companies have frames with shading screens that fit over the collectors.

Appliances

<u>Refrigerator/Freezer</u>

Semi-Annually (Every Six Months)

- Check the door seals. The door seals or gaskets can deteriorate, greatly increasing energy consumption. To check, put a dollar bill in the door as your close it. If it is not held firmly in place, the seals may be defective. If so, check with your dealer. New seals are expensive. If the seal needs replacement, it may be time to think about replacing the refrigerator/freezer with a new, higher-efficiency model.
- Check the temperature. The refrigerator compartment should be kept between 36°F and 38°F, and the freezer compartment should be kept between 0°F and 5°F. Keeping the settings just 10°F lower than these recommended temperatures can increase energy use by 25%.
- Check for location and clearance. Is your refrigerator in the sunlight or next to your stove or dishwasher? If so, it has to work harder to maintain cool temperatures. Move it to a cooler

location if possible. Also make sure than air can circulate freely around the condenser coils. If air flow is blocked, energy consumption will increase.

- Check the power-saver switch. Some refrigerator models are equipped with wall heaters to prevent outside condensation. On newer units, you can turn off this energy-consuming features. Unless you have noticeable condensation, keep the power-saving switch on the power-saving setting.
- Check for the need to defrost. If you have a manual defrost refrigerator or freezer, defrost on a regular basis to prevent build up of ice on the coils inside the unit.
- Vacuum the coils. Vacuuming the coils periodically keeps them free of dust and debris that can affect their operational efficiency.

[1] Garrett, Doug. "Service Your Air Conditioner for Summer Comfort" Austin American Statesman. City of Austin Green Builder Program. www.greenbuilder.com.

Appendix F: Equivalencies for Energy Star® Homes in Hawaii

Homes without Air Conditioning

Homes without air conditioning participating in the solar domestic water heating programs of HECO, MECO, and HELCO comply with the requirements of the ENERGY STAR® Homes Program. A post-installation inspection is required.

Homes with Air Conditioning

New homes with air conditioning that are built to the *Hawaii Model Energy Code – Low Rise Residential Requirements for Air Conditioned Homes* can also be ENERGY STAR® compliant if the additional measures are implemented from one of the following option packages below:

Option 1 (Homes with Standard Windows and Ducts in Unconditioned Space):

1. Use double pane windows with total unit solar heat gain coefficient (SHGC) less than or equal to 0.55 (for example, clear, Low-e, or tinted). Total window area must be less than 18% of the conditioned floor area, and less than 62.5% of the total window area can be oriented on the south and west sides combined.
2. Use a programmable thermostat.
3. Use a minimum 12 SEER air conditioner.
4. Have duct unions and joints thoroughly and completely sealed with mastic and fibrous tape and verify with a visual inspection.

Option 2 (Homes with Standard Windows and Ducts in Conditioned Space):

1. Use double pane windows with total unit solar heat gain coefficient (SHGC) less than or equal to 0.55 (for example, clear, Low-e, or tinted). Total window area must be less than 22% of the conditioned floor area, and less than 62.5% of the total window area can be oriented on the south and west sides combined.
2. Use a programmable thermostat.
3. Use a minimum 12 SEER air conditioner.

Option 3 (Homes with High Performance Windows and Ducts in Unconditioned Space):

1. Use double pane windows with total unit solar heat gain coefficient (SHGC) less than or equal to 0.40 (for example, Low-e, or tinted). Total window area must be less than 25% of the conditioned floor area, and less than 62.5% of the total window area can be oriented on the south and west sides combined.
2. Use a programmable thermostat.
3. Use a minimum 12 SEER air conditioner.
4. Have duct unions and joints thoroughly and completely sealed with mastic and fibrous tape and verify with a visual inspection.

Note: With all options, a post-installation inspection is required.

Appendix G: Utility Co-Payments

Hawaiian Electric Co., Inc. (HECO)

Residential Efficient Water Heating Program
Financial Co-Payment Levels*
Effective 4/20/00

Technology		Retrofit	New Construction
Solar Water Heating System		$500	$1,000
Heat Pump Water Heater		$175	$300
High-Efficiency Electric Water heater	EF**		
35 gal. tank or less	0.94	$40	$60
36-45 gal. tank	0.93	$40	$60
46-64 gal. tank	0.92	$50	$80
65 gal. tank	0.91	$50	$80
66 gal. tank or greater	0.88	$70	$80
Tank and Timer			
80+ gal. tank with timer	0.88	n/a	$270***

* Co-payment levels are subject to change without notice.
** EF ratings are minimums based on most recent GAMA certified ratings.
*** Customers who have an 80+ gallon tank installed with a load control timer are eligible to receive a $5.00 per month credit on their electric bill.

Hawaiian Electric Light Co., Inc. (HELCO)

Residential Efficient Water Heating Program
Financial Co-Payment Levels*
Effective 5/01/00

Technology		Retrofit	New Construction
Solar Water Heating System		$1,000	$1,000
Heat Pump Water Heater		$175	$300
High-Efficiency Electric Water heater	EF**		
35 gal. tank or less	0.94	$40	$60
36-45 gal. tank	0.93	$40	$60
46-64 gal. tank	0.92	$50	$80
65 gal. tank	0.91	$50	$80
66 gal. tank or greater	0.88	$70	$80

* Co-payment levels are subject to change without notice.
** EF ratings are minimums based on most recent GAMA certified ratings.

Maui Electric Company, Ltd. (MECO)
Residential Efficient Water Heating Program
Financial Co-Payment Levels*
as of 11/01/98

Technology		Retrofit	New Construction
Solar Water Heating System		$1,000	$1,000
Heat Pump Water Heater		$275	$725
High-Efficiency Electric Water heater	EF**		
35 gal. tank or less	0.94	$40	$60
36-45 gal. tank	0.93	$40	$60
46-65 gal. tank	0.92	$50	$80
66 gal. tank or greater	0.88	$70	$80

* Co-payment levels are subject to change without notice.
** EF ratings are minimums based on most recent GAMA certified ratings.

Kauai Electric
Energy Wise Residential Retrofit Program

Summary of Residential Water Heating Incentive Rebates (July 2000)

Cost/Benefit Assessment and Recommendations
Kauai Electric's Energy Wise residential program starts with a home visit to any household that heats water with a conventional electric heater or a solar system with an electric backup. During the home visit, the energy auditor checks the water heating system and where appropriate, installs energy-saving showerheads, faucet aerators, and tank wraps. Water heater temperature settings may be lowered. Heavily used incandescent lighting may be replaced with compact fluorescent lamps. These are provided at no cost to the customer.

During the home visit, the auditor also gathers information about the household occupancy, their hot water use, and the feasibility of installing a heat pump or solar water heating system (space and insolation factors). This information is compared with the household's historic energy use taken from the bill history of that account. If the estimated lifetime savings for an installation is equal to or greater than the estimated cost of a system, a recommendation and offer for an incentive rebate is mailed to the customer, with an explanation of procedure and a list of participating installation contractors. Incentive rebates are offered only when the maximum allowable cost for a solar water heating system is greater than $3,268 or if the maximum allowable cost for a heat pump is greater than $2,400.

Owner Occupant
When the customer is an owner-occupant, the incentive rebate is 45% of the installation cost, which cannot exceed the maximum allowable cost.

Income-Qualified or Rental Unit
When the customer qualifies under federal income guidelines, or when the customer is a tenant and the landlord is willing to participate, the incentive rebate is 70% of the installation cost, which cannot exceed the maximum allowable cost.

New Construction
When a house is being built for an owner-occupant (not speculative construction), and the owner is intending to install regular electric water heating (the hose is wired for an electric water heater—no pre-existing gas piping or solar water heating plumbing), a review for cost effectiveness of a solar water heating system is made using estimates of water heating energy requirements based on household size. If cost effective, the incentive rebate is 80% of the maximum allowable cost less $500 (to account for the conventional electric water heater the customer would have otherwise installed).

General Comments
Although customers are not required to get multiple bids, they are encouraged to do so because they will still pay for most of the installation cost.

In addition, Hawaii State energy income tax credits of 35% of the customer's portion may apply.

Calculations for Solar Hot Water Savings – Approximations – Oahu (Source: DBEDT)

Adjusted Solar Hot Water System Cost

System Installed Cost	$4,000
Utility Rebate	-500
	$3,500
Tax Credit (35%)	-1,225
Adjusted Cost	$2,275

Solar Hot Water Savings After 20 Years

Yearly savings ($626/yr.)	$12,520
HECO Rebate	500
Tax Credit	$1,225
Total	$14,245

Solar Hot Water Monthly Savings

Assumptions:

- 100kWh per person per month for water heating.
- 14.5 cents per kWh electricity cost.
- Solar hot water provides 90% of hot water needs.

Calculation:

100kWh x $0.145 = $14.50 per person per month.

$14.5 x 4 people = $58 per month.

$58 x 12 months = $696 per year.

$696 x 90% = $626.40

Appendix H: Certification Programs and Other Resources

Reputable certification programs help identify environmentally preferable products. Suppliers have recognized the importance of increasing the credibility of environmental claims and have begun to certify those claims using industry or independent certification programs. Independent programs will provide the most objective documentation. Two programs that certify energy-efficient building products include:

- Green Seal: Green Seal standards are based on environmental protection. They focus on reduced air and water pollution, reduced consumption of energy and other resources, protection of wildlife and habitats, reduced packaging, quality, and performance, 202-588-8400, www.greenseal.org.
- Energy Star®: A program of the federal government, manufacturers are allowed to use the Energy Star® label only if the product meets certain energy efficiency levels developed by either the U.S. Environmental Protection Agency or U.S. Department of Energy, 888-STAR-YES, www.energystar.gov.

"Branding" the Extra Value of an Energy-Efficient Home

- The EPA's Energy Star® performance standards for homes in Hawaii (see Appendix F for Hawaii equivalencies) documents your home's energy performance for the purpose of Energy Efficient Mortgage qualification *and* helps you "brand" your home(s) as extra energy-efficient. The Energy Star® program provides builders enrolled in the program with marketing materials. For more information: 888-STAR-YES, www.energystar.gov.
- The National Home Builders Association Research Center recognizes high energy-efficient performers through its annual "Energy Value Housing Award" program. 800-638-8556, ext. 6192, www.nahbrc.org, or e-mail at evha@nahbrc.org.
- On May 15, 2001, a model demonstration home built to the State's *Energy Efficiency Guidelines* (see page 3) was dedicated as the First Hawaii BuiltGreen™ Home in the state (see Appendix I for Case Study). That means it not only met the intent of the *Guidelines*, but it met a set of "green" criteria developed by the Building Industry Association of Hawaii (BIA) in partnership with government and utility representatives. These criteria were reviewed and approved by developer members of the BIA. The Hawaii BuiltGreen™ program is a voluntary program where home projects are certified by the builder to include energy efficient, materials efficient, improved air quality, and site protection features. For more information about the program, please call the BIA-Hawaii at 847-4666.

Energy-Efficient Product Directories

Several good directories identify environmentally preferable products. Those that address energy efficiency include:

- *REDI Guide (Resources for Environmental Design Index)*, web database, diskette, or printed handbook. Available from Iris Communications, Eugene, OR, 800-346-0104, or at www.data.oikos.com/products.

- *Consumer Guide to Home Energy Savings*, by Alex Wilson, Jennifer Thorne, and John Morrill. Available from the American Council for an Energy-Efficient Economy, Washington, DC, 202-429-0193, or at www.aceee.org.

Energy Efficient Financial Incentives

Contact your local utility for information on current utility rebates for solar water heater systems:

- Hawaiian Electric Company (Oahu): 947-6937.
- Hawaii Electric Light Company (Big Island): 969-0127.
- Kauai Electric: 246-8280.
- Maui Electric Company (toll free): 1-888-632-6786.

For more information on the State Income Tax Credits for solar water heater and other energy systems, call the State Department of Taxation, 587-4242 (Neighbor Islands toll-free, 1-800-222-3229).

Appendix I: Case Study – Model Demonstration Home

The First Hawaii BuiltGreen™ Home and Oahu's First Energy Star® Home*

- Energy Efficiency
- Comfort without air conditioning
- Environmentally responsible/HABiT (Hawaii Advanced Building Technologies Training Program) construction practices

Project Description

The First Hawaii BuiltGreen™ Home was designed for the State Department of Hawaiian Home Lands in a cooperative project supported by the U.S. Department of Energy, DBEDT, DHHL, the Honolulu Chapter/AIA, Building Industry Association of Hawaii, Honsador Lumber Corporation, and HECO. The home incorporates affordable techniques derived from the State's *Energy Efficiency Guidelines* and the HABiT guide to provide energy efficiency and comfort without air conditioning. It was built in Waianae Valley, Oahu, and dedicated on May 15, 2001. The following are some basic facts about the Home:

A. Incorporated the money-saving "Three Big Bang Technologies":
   1. HECO-approved solar water heater
   2. Radiant barrier
   3. Natural ventilation

B. Cost: Under $128,000 (not including the land); land area: 8,146 sq. ft.
4-bedroom, 2 1/2 bath

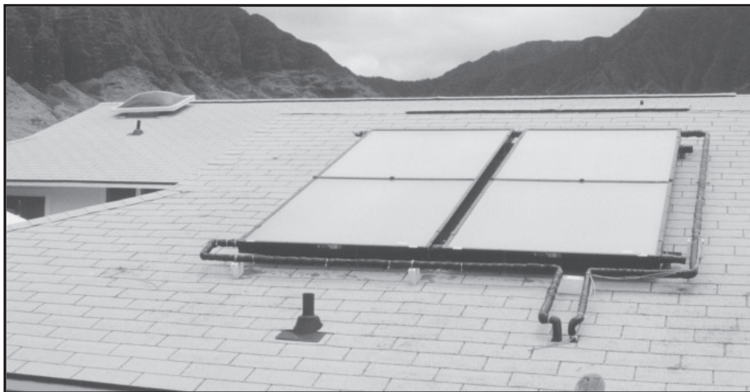
Interior floor area:	1,259 sq. ft.
Covered lanai & entry porch:	106 sq. ft.
Garage	
Laundry & half bath:	108 sq. ft.
<u>Parking area:</u>	<u>372 sq. ft.</u>
Total:	1,845 sq. ft.

Construction:
Commencement: February 2001 Completion: May 2001

Project Partners:
- U.S. Department of Energy
- State Department of Business, Economic Development & Tourism
- State Department of Hawaiian Home Lands
- Honsador Lumber Corporation
- Building Industry Association of Hawaii
- Honolulu Chapter, American Institute of Architects
- Hawaiian Electric Company, Inc.

Special Features
Energy efficiency, comfort, value, and environmentally responsible building strategies used in the design and construction of the First Hawaii BuiltGreen™ Home include:

1. Orientation of the house on the lot to minimize solar heat gain and improve exposure to trade winds and cross ventilation.
2. Light colored roofing to reduce solar heat gain.
3. Roof ridge and soffit vents to vent heat from attic spaces.
4. Polyethylene bubble insulating radiant barrier in the attic.
5. Radiant barrier bonded to particle board roof sheathing.
6. Polyethylene bubble insulating radiant barrier in walls exposed to high sun levels.
7. Generous eaves for window and wall shading.
8. Shading of south-facing walls by the carport and of the east wall by the entry porch.
9. Light colored finishes on the exterior to reduce heat gain.
10. Generous window openings with window selected to provide ample light and ventilation while reducing heat gain on the west side of the house.



Above: Venting skylight on leeward side of the roof draws out hot air. Solar panels, shown on the carport roof, help to reduce utility bills by about 40%, saving about $626 per year.

Above: Astro-E was draped from the rafters and nailed outside the studs. The radiant barrier reflects the sun's heat, helping the home to be comfortable without air conditioning.

Below: The Building Industry Association of Hawaii, the developer of the Hawaii BuiltGreen™ Home, received a $1,000 rebate check from HECO. L-R: Karen Nakamura, BIA Executive Director; Audrey Hidano, BIA Past President; Randy Lau, BIA President; and Jackie Mahi Erickson, HECO Vice President.

Right: Light-colored interiors and ceiling fans helped to keep the home cool. Large windows provide natural ventilation and daylighting.

11. Ventilating skylight to remove heat and improve lighting and air circulation in the hall way.
12. Louvered doors at some bedrooms to improve air circulation.
13. Open living, dining, kitchen area floor plan with the kitchen located on the leeward side of the house to improve air circulation and the removal of kitchen heat and humidity from the home.
14. Front screen door so that the front door can be left open for improved ventilation.
15. Screened operable glazing at the kitchen door for improved ventilation.
16. Ceiling fans to improve comfort on warm days.
17. Stove venting to remove cooking heat.
18. Location of the laundry in the carport to remove heat and humidity from the house.
19. HECO-approved solar hot water heater.
20. Microwave oven to reduce conventional oven use.
21. New generation high efficiency refrigerator.
22. Light colored finishes in interior spaces to increase the efficiency of daylighting.

23. Use of fluorescent lighting wherever possible, including the provision of compact fluorescent bulbs in recessed ceiling lights in the hallway.
24. Raised pier foundations to provide cooling air flow under the home and easy visual inspections to reduce the risk of ground termite infestation.
25. Use of cast concrete caps on concrete masonry unit columns and footing piers to reduce the risk of ground termite infestation.
26. Use of borate treated lumber and wood products.
27. Use of recycled plastic materials (Trex®) that resist rot and termites for deck surfaces.
28. Use of oriented strand board for roof sheathing.
29. Roof and floor plan dimensions scaled to fit standard material sizes to reduce waste.
30. Provision of generous hall, bathroom and door widths to improve accessibility and ease of use.
31. Use of recycled, crushed concrete for fill material under the garage and driveway slabs.
32. Spreading of excavated soil on the site to reduce hauling costs.
33. Implementation of a construction waste management program during the construction process.
34. Use of carpet with recycled content.

* ***Energy Star® Homes****: Non-air-conditioned new homes with an Hawaiian Electric Company-approved solar water heating system qualify for an Energy Star® Mortgage, which provides home owners with increased buying power. Call HECO (947-6937) for more information.*