

1. WHOLE BUILDING DESIGN

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Overview of Whole Building Design

Hawaii’s climate presents unique challenges and opportunities to designers of commercial buildings. In most of the United States it is taken for granted that heating and/or cooling systems will be installed. But in Hawaii designers often have a choice of using either air conditioning or natural ventilation in a building. There are many successful examples of both strategies.

Whether a building is naturally ventilated or air conditioned, the odds of success improve dramatically if the project team employs an integrated design — or *whole building design* — approach. This is especially true when considering a building’s energy efficiency. The operating costs of energy-consuming systems such as lighting and air conditioning are highly dependent on the architectural design. For example, a well-shaded building will not only consume less energy but will likely have a smaller and less expensive cooling system. With adequate attention to cross-ventilation design, the building may need no cooling at all. In addition, a well-designed fenestration system will reduce the need for electric lighting and save large amounts of energy.

From an energy efficiency perspective, the following design issues should be addressed at the same time and as early as possible in the design process:

- Solar control strategy
- Daylighting and visual comfort strategy
- Thermal comfort strategy
- Special indoor environment requirements
- Air quality strategy

Sometimes design strategies may seem to be in conflict with one another. For example, using reflective glass for solar control limits

the amount of visible light available for daylighting. Natural ventilation for thermal comfort may not always maintain the indoor temperature and humidity necessary for special equipment. But if these issues are considered early in the design process, then conflicts can be resolved and energy-efficient design options can be developed.

These general design strategies influence many specific design decisions, including:

- Siting and orientation (although there is not always much choice in Hawaii because land is scarce and views are a high priority)
- Building form (shape, number of stories)
- Fenestration design (glass type, window area, shading design, operability)
- Roof construction and surface type
- Lighting system design (luminaire type, controls)
- Mechanical system type (including ceiling fans)
- Interior space zoning
- Material selection (moisture resistance, light color, thermal mass)

The remaining sections of this chapter discuss important whole building design issues and describe design alternatives and recommendations.

Whole Building Design and Construction Process

In the traditional design process, lack of communication among the designers sometimes leads to lost savings opportunities. In some cases, efficient HVAC equipment cannot be accommodated unless considered early in the schematic design phase (or even earlier, in the budgeting phase). Sometimes there is not enough design time budgeted at the beginning of the project to evaluate design alternatives.

While there is no single “best” design process, several steps can help ensure a successful project.

Energy Efficiency Budget

In the planning process, provide a budget for design coordination and evaluation of energy efficiency alternatives. Depending on the project’s size, this could range from \$5,000 to \$50,000. In addition, the inspections and functional testing required for proper

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building commissioning cost roughly \$0.25 per square foot of floor area.

Integrated Design Meeting #1

At the beginning of schematic design, hold a meeting between the architect, mechanical designer, electrical designer, lighting designer, owner/tenant, and other consultants. Consider including utility personnel to take advantage of their expertise and incentive programs.

At this meeting discuss design strategies for energy efficiency. The list of design issues in this chapter (for example, solar control strategy, daylighting and visual comfort strategy, etc.) could serve as a framework for the meeting.

The meeting should result in a list of potential strategies and design goals. Some issues will require further evaluation.

Evaluation of Alternatives

Following the initial meeting, evaluate design alternatives. A little extra investment at this point can save a lot later on. This step may involve simulations or engineering calculations. Thermal simulations can predict the performance of building form options or air conditioning system choices. Daylighting simulation can predict illumination levels. Rough cost estimating is important to determine the lifecycle cost of design alternatives.

Integrated Design Meeting #2

Hold a second integrated design meeting before finalizing the schematic design. This meeting can be used to select design alternatives and to communicate the design approach and important features to the whole team.

Design Development Review

Arrange for a plan and specification review before the end of design development to ensure that the design strategies are implemented properly. The project manager or construction manager should formally track the status of energy efficiency measures.

Construction Documents Review

Review construction documents to ensure that the plans and specs clearly state the contractors' responsibilities for installation and testing of efficiency measures.

Submittals Review

During the construction phase, review contractor submittals to ensure proper performance of efficiency measures. This step is critical because some substitutions may not be equal in ways that are not immediately obvious (for example, the substituted equipment may not be compatible with other controls).

Construction Inspection

Inspection is an obvious step and is a normal part of any construction project. However, specific inspection of energy-

efficient equipment does not always occur. Conduct an inspection to confirm that controls are installed as specified and that sensors are located so they will give accurate readings.

**Functional
Performance
Testing**

A formal testing process is extremely valuable. When buildings are first occupied, the building systems seldom function as their designers' intended. Using the building's maintenance staff to debug problems and address occupant complaints can be very costly. Many of these problems could be eliminated by testing system performance before occupancy.

Solar Control Strategy

To achieve a comfortable and energy-efficient building in Hawaii, controlling the amount of sunlight and heat from the sun that enters the building is key. Good solar control offers several benefits:

- Lower energy cost
- Smaller and less expensive cooling system
- Greater occupant comfort because of cooler interior surfaces
- More usable interior space because of improved comfort near windows

Effective solar control is not always easy or inexpensive. Fortunately, several strategies work well. This section provides an overview of alternatives and discusses some whole building design implications. **More details on many of these strategies may be found in the specific guidelines in this document.**

Orientation

Proper orientation is the most important strategy. Whenever possible, limit the amount of window and wall area on the east and west facades. Sunlight is easier to control on the north and south sides of a building.

Fixed Shades

The best strategy for solar control in Hawaii is to keep direct sunlight off the windows. Overhangs are typically the best choice and are especially effective on the north and south facades. The combination of overhangs and vertical fins can nearly eliminate direct solar gain for most of the year. See the Energy-Efficient Windows Guidelines for details.

Operable Shades

Automatic or manually controlled operable shades can replace or supplement fixed shades. When the sun is obscured by clouds or is on the other side of the building, operable shades can be adjusted to allow more light into the space and to give occupants a better view. However, operable shades are less likely to provide

full long-term energy efficiency benefits compared to fixed shades because operable shades require more maintenance and their effectiveness depends on occupant behavior.

Exterior shades provide greater solar control because they block more heat from entering the building. However, interior shades may last longer, especially in areas close to the ocean or subject to harsh weather.

Windows

Windows are critical in the battle against the sun. A designer's first choice should be to minimize the amount of direct solar radiation that reaches the windows. If direct sunlight can be kept off the windows, then inexpensive clear or lightly tinted glass can be used. However, if it is not possible to completely shade the windows from direct sunlight, then solar-control glazing should be specified.

The most important glazing characteristic for windows in Hawaii is solar heat gain coefficient (SHGC). A low SHGC can be provided through several different technologies:

- *Heat-absorbing tints.* These tints are available in a range of colors. Some tints, typically blue or green in color, offer better visible light transmittance while providing equal or better solar control than gray or bronze tints. Consider using these blue or green tints in daylighting designs. All heat-absorbing tints get hot in direct sunlight — an important consideration for buildings where occupants sit close to windows.
- *Heat-reflecting coatings.* Several types of coatings are available. Some appear reflective; others are designed to reflect as much heat as possible while also appearing as clear as possible. The latter type of coating is called "spectrally selective" and is the best choice for simultaneously providing daylight and solar control.
- *Laminates.* These consist of plastic films sandwiched between two sheets of glass. Both heat-absorbing and heat-reflecting films are available. Heat-absorbing glass can be used to create the laminated glass sheet, providing further solar control.
- *Films.* Plastic films similar to those used to create laminated glass can be applied to the surface of the glass after the window is installed. This should be considered only as a retrofit measure because the exposed film is not as durable as glass.

In colder parts of the world, U-factor (an indicator of insulating performance) is often considered the most important feature of a window. Low U-factor is achieved using measures like multi-pane

windows, infrared reflecting coatings and inert gas fill in glazing cavities. In Hawaii, where the difference between outdoor and indoor temperatures is small, U-factor is not an important issue.

Cool Roof

After windows, the roof is the next most significant path for solar heat to enter a building. As with windows, several effective solar control strategies are available. The first is to prevent solar heat from ever being absorbed by the roof surface. A "cool roof" surface is typically a white material that reflects solar radiation (high reflectance) and reradiates heat to the cool sky (high emissivity). Cool roof materials include white single-ply membranes, white liquid-applied coatings and white painted metal or tile.

A second solar control option is a radiant barrier, a reflective sheet with a low-emissivity surface that prevents radiant heat transfer between a hot roof and the surfaces below. For details, see the Cool Roofs Guidelines.

Finally, insulation also reduces heat gain through the roof. Foam board and fiberglass batts are two common materials. Cellulose spray-in insulation is also effective; many spray-in cellulose products are made primarily from recycled paper, an added environmental benefit.

Walls

As with windows, the first choice for controlling heat gain through a wall is shading. If shading is not possible, consider a light-colored exterior wall, radiant barrier, insulation and/or thermal mass to reduce heat flow. As with windows, the primary source of cooling load through walls in Hawaii is not high outdoor temperature. Rather it is solar radiation hitting the wall and heating the wall's surface. Therefore, a white uninsulated wall can be as effective as a dark wall with insulation.

Landscaping

Landscaping can provide excellent solar control. Place trees and shrubs in strategic locations, especially on the east or west sides where they can block morning and afternoon sun. But even if plants do not directly shade a building, they can help keep the local environment cooler. Pay special attention to shading asphalt roads and parking lots.

Integrated Design Conflicts

Designing for good solar control involves several tradeoffs and potential synergies. These are a few of the potential conflicts to consider when choosing an appropriate strategy.

Solar Control vs. Daylighting

Providing more daylight can conflict with the goal of reducing solar heat gain. However, well-designed shades can block much solar gain while also improving daylight penetration into the building. In addition, spectrally selective glazings can provide a low SHGC while also offering good visible light transmittance.

Solar Control vs. Hurricane Safety

Window overhangs or vertical fins might increase wind pressure on building walls during a storm. Extra structural measures may be necessary.

Solar Control vs. Allowable Building Floor Area

Overhangs or lanais are sometimes counted toward the allowable floor area of a building, thereby reducing the amount of interior floor area allowed.

Solar Control vs. Maintenance

Exterior shades should be designed to allow access for window washing. Measures to discourage roosting birds might also be considered.

Integrated Design Benefits

Good solar control provides benefits that affect many aspects of the building's design and operations, including:

Air Conditioning Zoning

Fewer air conditioning zones may be necessary if windows are effectively shaded because cooling loads will vary less between orientations.

Air Conditioning Capacity

An important benefit to solar control is smaller cooling loads and smaller and less expensive cooling equipment.

Dehumidification Performance

Typically, air conditioning equipment must be sized to meet peak solar loads through windows. If the windows are well shaded, then the equipment can be smaller and run at a more constant load. Not only does the equipment run more efficiently, but it also provides better dehumidification performance and better comfort.

Occupant Comfort

Hot surfaces cause comfort problems for occupants. Therefore, solar control at the roof, walls and windows improves occupant comfort.

Daylighting and Visual Comfort Strategy

Lighting accounts for about 40% of the energy cost for commercial buildings in Hawaii, and most of that lighting energy is consumed during daylight hours. Therefore, buildings designed to take advantage of daylight provide dramatic energy savings.

Several daylighting strategies are available, and more than one may be applied in a single project. Two broad categories of daylighting design are toplighting and sidelighting. Toplighting employs skylights or roof monitors to illuminate a space from above. Sidelighting designs use daylight from windows.

To be effective, a daylighting design must consider visual comfort. If glare is excessive, occupants may resort to using window shades, which may reduce the energy savings of the daylighting design.

To take advantage of the potential energy savings, the designers must develop a daylighting strategy early in the design process. Once decisions such as the number of stories and basic floor plan are made, many daylighting options may be eliminated.

Design team collaboration is critical to successful daylighting design. The architect, lighting designer and electrical engineer all play important roles and need to work together.

The success of a daylighting design often lies in the design details. Analysis tools such as physical models or computer simulations are very useful for selecting window size, shading configurations and space layouts. These tools can predict illumination levels and identify glare or daylight distribution problems.

Building Form

The most basic design decisions have a big impact on daylighting potential. Single-story buildings have the greatest number of options: they can take advantage of toplighting, sidelighting or both. Multi-story buildings can achieve nearly complete daylighting through several means. A narrow floor plan, like that of many high-rise hotels, allows most indoor space to be illuminated by sidelighting. A courtyard or atrium can also allow daylight to reach interior zones of lower floors.

Space planning should account for uses that benefit from daylighting and those that don't. Most general office, medical examination, retail and educational spaces benefit from daylight access. Seldom-occupied spaces, such as storage rooms, can be given lower priority. Some types of work that are best performed with lower illumination levels will receive less benefit from daylighting. However, with careful design, even spaces with critical computer-intensive tasks can successfully employ daylighting.

Orientation

Orientation has an impact on daylighting effectiveness. As with solar shading design, daylight is more easily controlled on the north and south sides of a building. Whenever possible, the long sides of a building should face north and south, minimizing the east and west exposures. Good daylighting design is more difficult on the east and west sides because of glare created by direct sunlight in the morning and afternoon.

Skylights

Overhead skylights can be a very cost-effective means of providing pleasant and even illumination to an interior space. And in a single-story building, skylights can meet all the daytime lighting needs. Skylights are common in large spaces such as warehouses and factories, but they have also been used with great success in smaller spaces such as offices and classrooms. See the Daylighting Guidelines for details.

Windows

It's usually desirable to provide separate vision fenestration (windows that provide views) and daylighting fenestration (glass that provides daylighting). Vision glass should have lower light transmission to reduce glare and maintain the visual comfort of occupants close to the window. Daylighting glass, positioned higher on the wall, should transmit more visible light to provide better daylight penetration for occupants further from the window. Refer to the Daylighting Guidelines for more information.

Lightshelves and Other Shading Devices

Lightshelves or similar shading devices help improve the daylighting performance of windows. A good shade design serves two purposes: it blocks direct sunlight penetration and reflects diffuse light deeper into the room. See the Daylighting Guidelines for more information.

Controls

For a daylighting design to save energy, some form of electric lighting control is necessary. There are several control options; the best choice depends on the space type, the size of the space, and the type of lamp being controlled. See the Daylighting Guidelines.

Costs and
Benefits

Manual control is the simplest approach. However, occupant control is unlikely to achieve consistent and lasting savings, especially in larger buildings. Small, owner-occupied buildings are the best candidates for manual lighting control.

Automatic dimming control is the most desirable option for continuously occupied spaces such as offices. Dimming controls are least distracting and are therefore most likely to be accepted by occupants.

Automatic On/Off or multiple-step control is the best choice for spaces that are intermittently occupied, such as warehouses, workshops or similar spaces. Automatic On/Off control provides good energy savings while being relatively inexpensive.

Some daylighting design options can add significant cost to the project, but daylighting's many benefits should be considered before rejecting daylighting based solely on first-cost concerns. For example, a design that allows daylight to reach all parts of the building may result in less floor area than a square floor plan that fills up the lot and has large interior spaces. But that extra cost could be worth the additional benefits. Besides saving lighting energy, a building designed for daylighting may also be able to save energy by employing natural ventilation because occupied spaces are likely to be close to openings. Even without natural ventilation, daylighting can lead to cooling energy savings because of the reduced heat gain from lights. And tenants often favor daylit spaces, increasing the value of the building.

Productivity can also be a powerful — and perhaps the most valuable — benefit to good daylighting design. The value of a mere 1% increase in occupant productivity far outweighs the investment cost for better daylighting and controls. Recent studies have shown that schoolchildren learn faster in a daylit environment.¹ Other studies seem to show improved sales in daylit retail stores; further studies are underway to verify this effect.² These study results indicate that energy savings are just a small part of the total benefits of good daylighting design.

¹ Heschong Mahone Group, *Daylighting in Schools*, and *Skylighting and Retail Sales* (Pacific Gas & Electric Company, 1999). Available at www.pge.com/pec/daylight.

² *Productivity and Interior Environments* studies now being conducted by Heschong Mahone Group for the New Buildings Institute's *Integrated Energy Systems: Productivity & Building Science* program, a project of the State of California PIER Program. For more information, go to www.newbuildings.org/pier.

Thermal Comfort Strategy

Thermal comfort depends on several factors, including air temperature, relative humidity, air movement and the temperature of surrounding surfaces. Therefore, several approaches to maintaining comfort are possible.

Natural Ventilation

From an energy efficiency and air quality perspective, natural ventilation is usually the best choice. Natural ventilation should be considered in all spaces without special indoor environment constraints (see Special Indoor Environment Requirements section). Of course, the feasibility of natural ventilation also depends on the building location.

For a successful naturally ventilated building, designers need to pay greater attention to the surroundings. Obstructions, landscaping and microclimate issues are important. Nearby sources of noise or dust can also be a constraint.

The Natural Ventilation Guidelines discuss thermal comfort and natural ventilation strategies.

Ceiling Fans

Ceiling fans are an effective way to provide comfort through air movement. See the Natural Ventilation Guidelines for ceiling fan design guidelines.

Mechanical Cooling

Mechanical cooling and dehumidification can ensure comfort for the majority of occupants. But no single condition is acceptable to all people, so even a well-designed mechanical system will not provide perfect comfort.

If choosing air conditioning for all or a portion of a building, consider the following:

- *Low supply air temperature.* By operating at a lower supply air temperature — closer to 50°F rather than 55°F leaving the cooling coil — dehumidification performance improves. And if humidity control is required, then less reheat energy will be necessary. Use a low approach coil (typically larger) to achieve the lower supply air temperature without necessarily reducing chilled water temperature.
- *Dual-path air handler.* Condition outside ventilation air (where much of the system's latent moisture-load comes from) separately from return air. Cool the outside air as low as is feasible to extract as much moisture as possible. Then provide additional cooling to the relatively dry return air if more cooling is necessary. See the Dehumidification Guidelines for details.

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- *Humidity control.* Use measures such as heat pipes and run-around coils to avoid using a reheat coil. See the Dehumidification Guidelines.
- *Careful load calculation and equipment sizing.* If specifying packaged, direct expansion cooling equipment (as opposed to chilled water cooling), be especially careful not to oversize the cooling capacity. In addition, consider a unit with a refrigerant subcooling option to improve the dehumidification capacity. See the HVAC Guidelines for recommendations regarding packaged air conditioners.

Hybrid Design

Many successful designs employ natural ventilation and air conditioning in separate portions of the same building. For example, spaces with very high equipment loads or occupant density can be mechanically cooled, while areas such as open offices, private offices, corridors and lobbies can be naturally ventilated. A good hybrid design requires careful space planning from the start.

Building Envelope

Regardless of the choice of natural or mechanical ventilation, the building shell should be designed to prevent the occupants from being exposed to hot interior surfaces. Insulation reduces the interior wall and ceiling temperatures. Window shading, coated glass or both help keep windows cool. Avoid tinted glass where it will be exposed to direct sunlight. Tinted glass absorbs solar radiation and can reach very high temperatures, causing discomfort for people close to the windows.

Special Indoor Environment Requirements

The choice between natural ventilation and air conditioning depends in part on whether natural ventilation can provide acceptable indoor conditions. One important consideration is human comfort, but another is the environment necessary for the operation of equipment or for other indoor space functions.

Office Equipment

Electronic equipment is designed for operation within certain temperature and humidity limits. Some electronic devices will malfunction if they get hot. Therefore it is important to make sure that any equipment located in a naturally ventilated space will tolerate temperatures of 80°F to 90°F.

Natural ventilation is not a problem for typical personal computers; they are rated to operate in temperatures as high as 95°F and relative humidity as high as 90%.

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*Table 1-1.
Operating
temperature and
relative humidity
(RH) range for
selected office
equipment.
Source:
Manufacturers'
product literature.*

Product	Temperature Range °F	RH Range (non- condensing) %RH
Desktop Computers		
Power Mac G4	50 – 95	5 – 95%
iMac	50 – 95	5 – 95%
Power Mac G4 Cube	50 – 95	5 – 95%
HP Desktop (Brio)	41 – 95	15 – 85%
HP Desktop (Vectris)	41 – 95	8 – 85%
Laptop Computers		
iBook	50 – 95	20 – 80%
PowerBook G4	50 – 95	20 – 80%
Dell Inspiron	41 – 95	10 – 90%
Printers		
HP Copyjet	59 – 95	30 – 80%
HP Deskjet	59 – 95	20 – 80%
Xerox Desktop Laser	50 – 90	15 – 85%
IBM Laser	60 – 90	20 – 80%
Epson Inkjet	50 – 95	20 – 80%
Copy Machines		
Xerox 2510	60 – 90	15 – 85%

Some paper may curl at high humidity and affect printer or copier performance. These problems may be minimal if the paper is not subject to changing conditions. For copiers and printers located in naturally ventilated spaces, store the paper under the same conditions.

Refrigerated equipment may develop condensation on its surface if it is not well insulated. Water coolers, refrigerators and vending machines could be affected.

Medical Facilities

Some spaces within hospitals and other medical facilities may require pressurization controls to prevent contamination between rooms. Mechanical ventilation and cooling may be required for those areas, limiting the potential application of natural ventilation.

Medical electronics may be sensitive to temperature and humidity. Manufacturer specifications should be checked when natural ventilation is considered.

Laboratories

Some laboratories require exhaust systems to remove potential contaminants. The changing pressure due to natural ventilation could interfere with the safe operation of fume hoods.

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**Libraries &
Museums**

Some materials such as books and other paper documents require low humidity to prevent damage. Art and artifacts may also require conditions not attainable through natural ventilation.

Retail Spaces

Spaces with many refrigerated cases are not good candidates for natural ventilation because the humidity can create condensation problems.

Indoor Air Quality Strategy

Good indoor air quality is best achieved through a system approach that considers:

- ventilation,
- moisture control,
- reduction of indoor pollution sources, and
- monitoring and maintenance.

Ventilation

For naturally ventilated buildings the most important issue is the location of nearby exterior pollution sources. Obvious sources include roads, parking lots, dusty fields, agricultural areas and some commercial or industrial activities.

Ventilation is traditionally employed as an indoor air quality solution for air-conditioned buildings. However, ventilation alone cannot guarantee a healthy building, and high ventilation rates raise energy costs.

Moisture Control

Good moisture control in the roof, walls and floors is important to prevent mold growth. Careful design of the air conditioning system can also improve dehumidification to inhibit mold growth.

Indoor Pollution

To improve indoor air quality, reducing indoor pollution sources is critical. Choose furniture and finishings with low emission rates of toxic chemicals. Ensure that air from storage spaces for chemicals and cleaning materials is directly exhausted to the outside. It is also a good idea to exhaust air from areas with photocopiers or printers.

**Monitoring &
Maintenance**

Regular cleaning and maintenance of air conditioning equipment is essential. Cooling coils are nearly always host to mold growth in Hawaii, and can be sources of odor and health problems. Maintenance options include thoroughly cleaning the coils (preferably twice each year), or installing ultraviolet lamps in the air handlers to inhibit mold growth. See the HVAC Guidelines.

Specific Building Type Issues

Different building types present different opportunities for energy efficiency. This section highlights important issues for a number of commercial and institutional building types.

Office Buildings

Solar Control



Windows are the critical element in office solar control. Proper orientation and exterior shading are the preferred approach. Otherwise, glazing with low solar transmission is appropriate (but also remember light transmission for daylighting). See the Energy-Efficient Windows Guidelines for recommendations.

The roof is also important, especially for low-rise offices. See the Cool Roofs Guidelines.

Daylighting and Visual Comfort

Daylighting is ideal for offices, saving both lighting and cooling energy. Both sidelighting (through windows and clerestories) and toplighting (via skylights) are applicable. See the Daylighting Guidelines.

Wherever possible, try to keep the building depth narrow (under 40 feet) to allow for good daylighting and improve natural ventilation opportunities. A relatively high ceiling — 10 to 12 feet — will also improve daylight penetration and natural ventilation.

Lighting design also offers an excellent savings opportunity for offices. Consider suspended direct/indirect fixtures and appropriate (low) ambient illumination. See the Electric Lighting Guidelines.

Use occupancy sensors for lighting control.

Thermal Comfort

Natural ventilation works for offices in Hawaii, especially if supplemented with ceiling fans. If there's critical equipment or materials that require special environmental conditions, consider designing the building with a small air-conditioned room in the

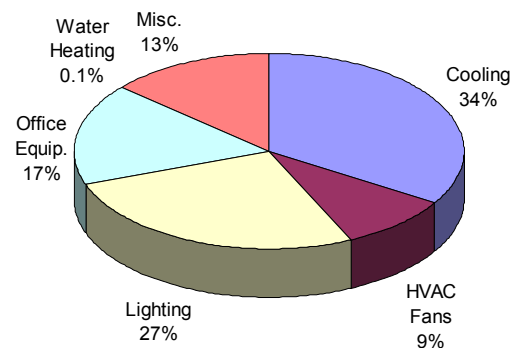


Figure 1-1. Energy consumption for typical Hawaii office building; total 23 kWh/yr-ft².

building core instead of conditioning the whole building. See the Natural Ventilation Guidelines.

Otherwise use a variable-air-volume air conditioning system to provide fan power savings and superior dehumidification performance compared to a constant-air-volume system. In addition, consider a dual-path system that cools ventilation air separately from return air and further improves dehumidification. See the HVAC and Dehumidification Guidelines.

Indoor Air Quality

Natural ventilation can often provide excellent indoor air quality. Otherwise, consider a demand-controlled ventilation system that varies the amount of outside ventilation air depending on the number of occupants. Also consider UV lamps in air handlers to inhibit mold growth. See the HVAC Guidelines.

Retail Buildings



Solar Control

For many retail buildings, especially “big box” stores, the roof is the main path for solar heat to enter the building. See the Cool Roofs Guidelines for recommendations.

Daylighting and Visual Comfort

Lighting is usually the biggest energy consumer in retail buildings (except for grocery stores, where refrigeration is also significant). Therefore, special attention to lighting design is critical. Minimize the use of incandescent lamps, using them only for accent lighting. See the Electric Lighting Guidelines.

Skylights are a great choice for many retail spaces, providing lighting savings as well as excellent color rendition. See the Daylighting Guidelines for recommendations.

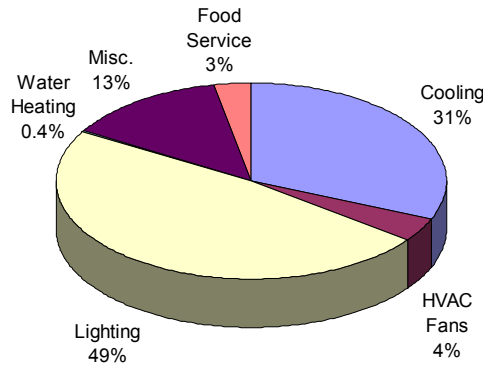
Thermal Comfort

If air conditioning is necessary, then a dual-path system may be appropriate, especially for spaces with refrigerated cases because the lower humidity will help prevent condensation.

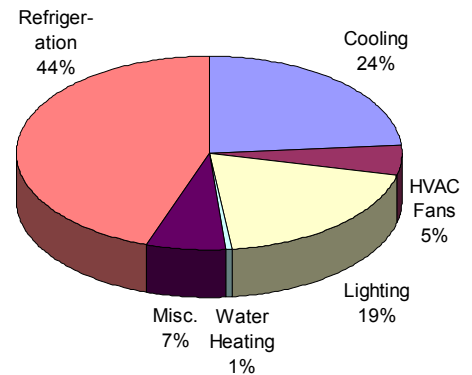
Also consider variable-air-volume controls to minimize fan energy and improve dehumidification.

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*Figure 1-2 (left).
Energy
consumption for
typical Hawaii
retail facility
(excluding
grocery); total
26 kWh/yr-ft².*



*Figure 1-3 (right).
Energy
consumption for
typical Hawaii
grocery building;
total
53 kWh/yr-ft².*



Indoor Air Quality

Consider UV lamps in air handlers to inhibit mold growth on cooling coils.

Other Savings Opportunities

Recover heat rejected from refrigeration and air conditioning systems for water heating.

School Buildings

Solar Control



School buildings in Hawaii are typically naturally ventilated. Therefore, solar control is critical for comfort. Proper orientation is important, and window shading is common and highly desirable. In addition, a cool roof—such as a white roof combined with a radiant barrier—is necessary to help keep the classrooms cool and comfortable.

Daylighting and Visual Comfort

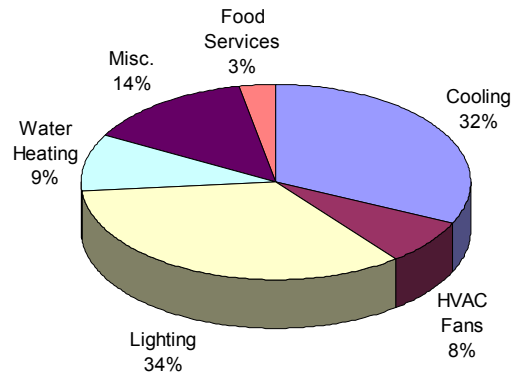
Daylight has been shown to improve learning performance. Therefore, classrooms, gyms and multipurpose rooms are excellent candidates for daylighting design using windows and skylights. See the Daylighting Guidelines for details.

Lighting design is another big savings opportunity in schools. A high ceiling provides multiple benefits, allowing pendant-mounted direct/indirect lighting and improving daylight distribution and thermal comfort. See the Electric Lighting Guidelines for design and lighting control recommendations.

Figure 1-4. Energy consumption for typical Hawaii school; total 9 kWh/yr-ft².

Thermal Comfort

Natural ventilation should be the first choice for classroom comfort. Otherwise, if outdoor noise or pollution don't allow the windows to stay open, then a dual-path air conditioning system is an excellent choice because classrooms have high outside air ventilation rate requirements due to high occupant density. See the Dehumidification Guidelines for more information.



Indoor Air Quality

Natural ventilation is the best choice, assuming that outdoor air quality is reasonable. If air conditioning is installed, then humidity control is important. The system should be carefully designed so that it is not any larger than necessary. An oversized system cycles on and off more frequently and dehumidification performance degrades.

Health Care Buildings



Solar Control

Health care buildings often have less window area than other commercial building types, but high performance windows are still likely to be cost effective for solar control, especially if windows have little exterior shading.

Daylighting and Visual Comfort

Many parts of health care facilities can be effectively illuminated using daylight, with task lighting used for critical tasks. Lighting controls should include occupancy sensors in private office spaces and exam rooms.

Thermal Comfort

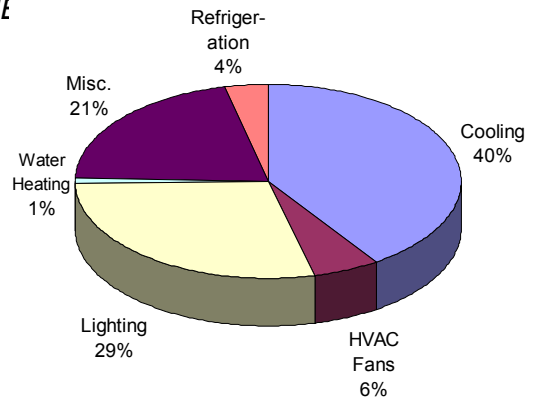
Cooling is a major energy consumer in many health care facilities because many spaces use 100% outside air for ventilation (no recirculated air). In addition, some spaces such as operating rooms also require humidity control. The Dehumidification Guidelines provide recommendations for energy-saving systems such as heat pipes and run-around coils.

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Figure 1-5. Energy consumption for typical Hawaii health care building; total 25 kWh/yr-ft².

Indoor Air Quality

Humidity control is important for good indoor air quality. It's especially challenging in facilities that operate 24 hours per day, as do many health care buildings. The problem is that moisture must be removed from the ventilation air even at night when the air temperature is relatively low and cooling requirements inside the building are lower. In a conventional system the ventilation air is cooled to low temperature, perhaps 50°F to 55°F, to remove moisture and then reheated to avoid overcooling the building. The process of cooling and reheating can be energy intensive. Therefore, it is important to consider the energy-saving dehumidification techniques described in the Dehumidification Guidelines.



Another source of air quality problems can be mold growing on the damp cooling coils. UV lamps inside the air handlers can help keep coils clean. More intense levels of UV light can be used to kill microbes in the air as it flows through the air handler to help prevent the spread of diseases such as tuberculosis.

Hotels

Solar Control

The main challenge for solar control in hotels is providing complete window shading while also maintaining views. As much as possible, windows should be facing north or south. And balconies should be designed to keep the sun off the windows at all times (which is very difficult for east and west-facing windows). If complete shading is not possible, then consider high performance low-e windows that have low solar transmission while maintaining good views. See the Energy-Efficient Windows Guidelines for details.



Daylighting and Visual Comfort

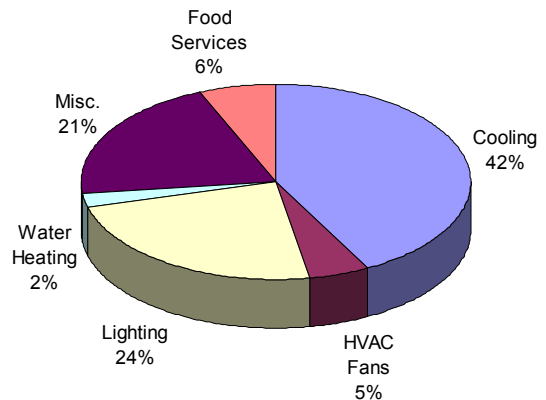
Hotel guest rooms typically have adequate window area for daylighting illumination. To optimize light distribution within the room, use light-colored interior surfaces. For low-rise hotels, consider small skylights in bathrooms.

Avoid the use of energy-intensive incandescent lighting. Modern compact fluorescent fixtures can provide good color rendition, lower energy consumption, and much longer life.

Figure 1-6. Energy consumption for typical Hawaii hotel; total 16 kWh/yr-ft².

Thermal Comfort

Design for natural ventilation, allowing the guests to easily shut off cooling and rely on cross ventilation and ceiling fans for comfort. If air conditioning is installed, use magnetic switches on balcony doors to shut off cooling to a room when the door is open. Also consider an energy management system that reduces cooling demand by automatically raising the temperature in vacant rooms.



For ballrooms and meeting rooms, use controls to vary the amount of outdoor air ventilation depending on occupancy. See the HVAC Guidelines.

Indoor Air Quality

Moisture control is the primary air quality issue in hotels. Ventilation air delivered to guest rooms should be dehumidified.

Other Savings Opportunities

Hotels are an excellent application for using heat recovered from the cooling system to heat water. Heat rejected by water chilling equipment can be very effectively recovered using heat pump water heaters.

Restaurants



Solar Control

As with most other building types, attention to the windows and the roof is important for solar control. Consider operable exterior shades for east- or west-facing glazing.

Daylighting and Visual Comfort

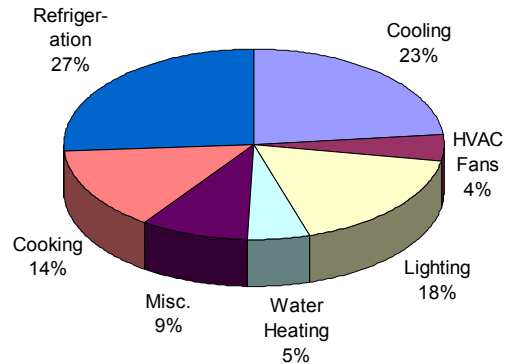
For general ambient light, use full-size or compact fluorescent lighting. Limit the use of incandescent (including halogen) lamps to accent lighting.

Figure 1-7. Energy consumption for typical Hawaii restaurant; total 53 kWh/yr-ft².

Thermal Comfort

In many cases, cross ventilation and ceiling fans can provide comfort in dining rooms and cooling should not be necessary. Otherwise, it is important to pay attention to air conditioner sizing. A restaurant can have highly variable cooling loads because the number of occupants varies over the day.

Therefore, good comfort requires that the system operate over a wide range of cooling loads while still providing good humidity control. Consider a dual-path system for humidity control and demand control for outside air volume. See the Dehumidification and HVAC Guidelines.



Kitchen comfort can be a significant energy issue. Providing air conditioning to the kitchen can be very costly due to the large heat sources and the large volume of exhaust air. Before providing air conditioning to the kitchen, it is important to carefully design the exhaust system so that the majority of air that is exhausted is drawn directly from outdoors and introduced to the space directly in front of the range hoods. See the Kitchen Exhaust Makeup section of the HVAC Guidelines.

Indoor Air Quality

Design and commission the kitchen exhaust system to ensure that the kitchen is negatively pressurized relative to the dining room. And, as described in the proceeding discussion of thermal comfort, design the cooling system to operate over a wide range of cooling conditions.

Other Savings Opportunities

Heat recovery from the cooling system or refrigeration system for water heating may be cost effective.

Commissioning

Increasingly, building owners are recognizing that building commissioning is an important strategy for achieving lasting energy savings. Commissioning is a type of quality assurance program used to verify that building systems work together efficiently, effectively and as intended in the design specifications. Commissioning can give the building owner confidence that the

designers and contractors have done the work the owner hired them to do. Without a formal commissioning process, building owners may find themselves dealing with costly and frustrating system problems well after construction is complete and the building contractors have moved on to other projects.

Not only does commissioning help ensure that a new building is performing optimally when delivered to the owner, it also improves the chances that the building will continue to operate as intended.

Commissioning Agent

The commissioning process starts with a commissioning agent (CA), who is engaged by the building owner to manage the commissioning and to act as an advocate for the owner. It's important that the CA be independent and under direct contract to the owner, not under contract to other members of the design and construction team.

The owner should hire a commissioning agent as early as possible in the project. Part of the CA's job is to identify the commissioning responsibilities of each member of the design and construction team so that this information can be included in each team member's contract.

Commissioning Plan

In a written commissioning plan, the CA identifies the systems to be commissioned, describes the scope of the commissioning process, lays out a commissioning schedule, and defines the testing and reporting procedures that are integral to the commissioning process.

Most commissioning plans include the following important elements:

- *Installation checks.* Ensure that specified equipment and accessories are installed.
- *Performance checks.* Verify and document that systems are performing as intended, and that sensors and other control devices are properly calibrated.
- *Documentation.* Ensure that all required documentation has been provided, such as a statement of the design intent and operating protocols for all building systems.
- *Manuals and training.* Prepare operation and maintenance (O&M) manuals and provide training to the building operations staff.

- *Monitoring.* Conduct ongoing monitoring after the building is occupied to ensure that equipment and systems continue to perform as expected.

Verification and Testing

Although any building system can be commissioned, the most important systems that should be commissioned are the mechanical, electrical and life safety systems. Throughout the construction process, the CA verifies that the systems are being installed as specified, identifies any problems related to that particular system or its interaction with other systems, and makes recommendations to the owner for correcting those problems.

Functional tests, a key part of commissioning, help ensure that systems are working together as intended. The CA develops written protocols for these tests, ensures that they are properly conducted, documents the results, and reports the findings to the building owner.

Commissioning Report

The Building Commissioning Association recommends that every commissioning process be thoroughly documented with a commissioning report that includes:

- An assessment of the systems' operating condition when the functional tests are conducted;
- Problems discovered and the steps taken to correct them;
- Uncorrected operational problems that the owner decided to accept;
- Functional test procedures and results;
- Reports documenting all commissioning activities as they progress; and
- A description and estimated schedule of any deferred testing.

Properly implemented, commissioning will ensure that a new building starts its life at the highest performance level possible.

Resources

For more information about building commissioning:

U.S. Department of Energy, Office of Building Technology, State and Community Programs,
www.eren.doe.gov/buildings/comm_energyeff.html

Building Commissioning Association, www.bcx.org