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A Guideline Report on Sustainable Design, Equipment for New Health Care Facilities.

Editorial

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ACRONYMS

HVAC	Heating Ventilation And Air Conditioning
HDDs	Heating Degree Days
CDDs	Dooling Degree Days
IPU	Inpatient Unit
SHGC	Solar Heat Gain Coefficient
U-factor	Thermal Transmittance
SRI	Solar Reflectance Index
WWR	Window-To-Wall Ratio
VT	Visible Transmittance
LSG	Light-To-Solar Gain
FFR	Floor Area Ratio
PF	Projection Factor
ASF	Reference Architectural Shading Factors
LED	Light Emitting Diode
CRI	Colour Rendering Index
ACH	Air Changes Per Hour
ER	Emergency Room
ERV	Energy Recovery Ventilator
COP	Coefficient Of Performance
EER	Energy Efficiency Ratio
VSD	Variable Speed Drive
VRF	Variable Refrigerant Flow
SCOP	Seasonal Coefficient Of Performance
IPLV	Integrated Part-Load Value
NPLV	Non-Standard Part Load Value
WSHP	Water Source Heat Pump
GSHP	Ground Source Heat Pump
EC M	Electronically Commutated Motor
AC	Alternating Current
FCU	Fan Coil Unit
SFU	Supply Fixture Unit
PPR	Polypropylene
FSTC	Food Service Technology Center

01

INTRODUCTION

1.
INTRODUCTION

Resource-intensive facilities and technical systems are an integral part of hospitals and health care facilities. They include demanding thermal comfort requirements, rooms kept at different air pressure, the need for sufficient cleanliness, year-round fresh air, substantial hot water and power requirements supported by a reliable energy supply, robust fire protection, vertical transport systems, and much more.

In line with the energy strategic report prepared for public hospitals, this guide provides various energy efficiency considerations for the construction of new health care facilities. It is hoped that new buildings in health-care that may be constructed in the future will take into account these considerations.

The strategy begins with a robust passive design and an efficient building envelope that decreases the demand for energy, whereas the second part of this report aims to minimize energy needs through efficient building services (active systems).

02

ARCHITECTURAL ASPECT

2.

ARCHITECTURAL ASPECT

Thinking about a health care facility's architectural design early on plays an important role in the building's energy efficiency and helps to reduce energy consumption, lower energy bills, and reduce impacts on the environment. Architectural design determines the structure, interior spaces, and exterior skin of the building.

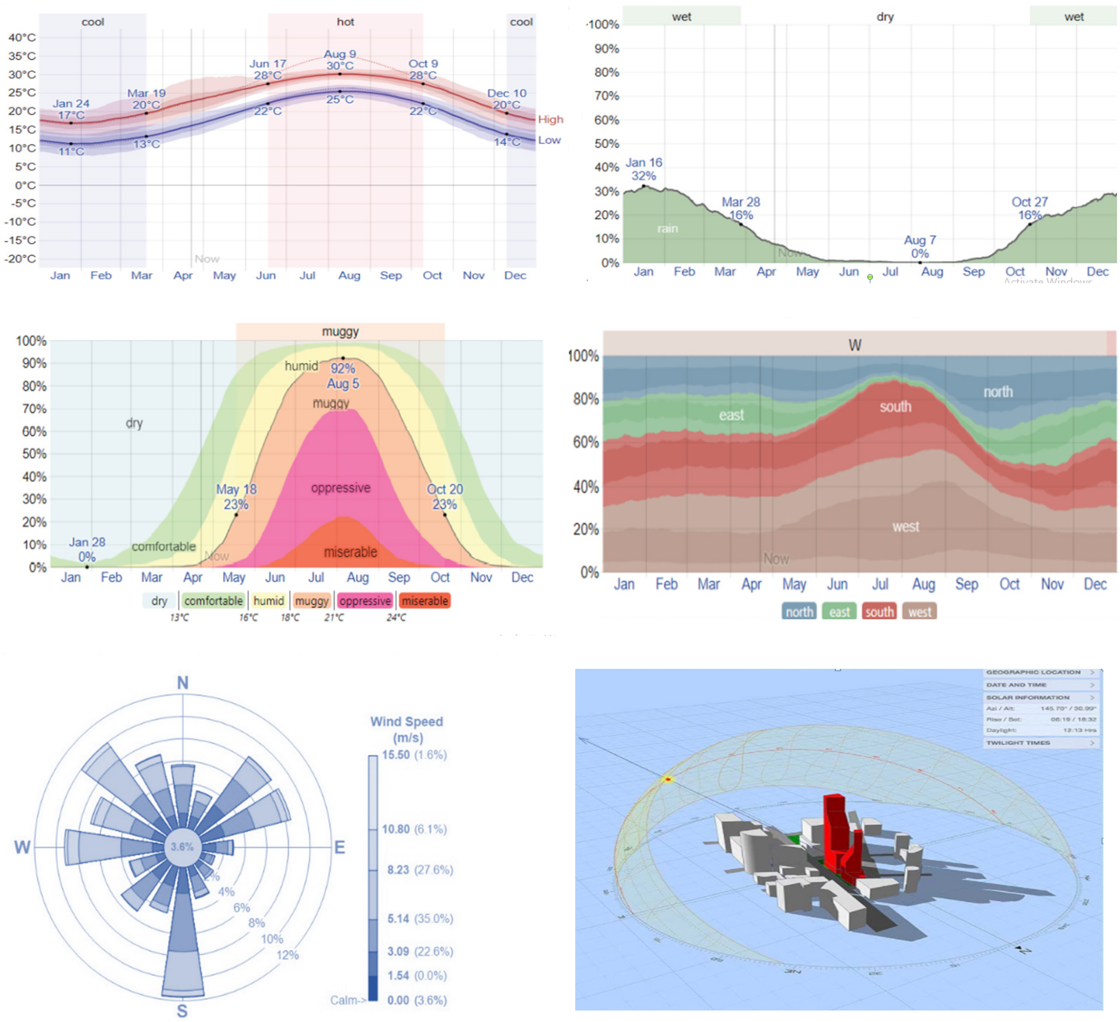
Many design features affect the energy performance of a building. These features include building location in terms of climatic region; patterns of use, shape, size, number of floors, and orientation of the building massing; the resultant active mechanical and electrical systems for ventilating, heating, cooling, and lighting; and controls that integrate the passive and active systems and that provide users and operators feedback on the building's actual performance relative to its expected performance. The following sections present each of these issues in detail.

2.1. Siting and Climate

The location of the building determines the microclimate conditions that play an important role in a building's energy efficiency, such as sun radiation and angles, air temperature, air circulation and prevailing winds, humidity levels, all of which affect the energy costs and impact the energy performance of the building.

The site of the building and distance between other buildings are among the most important design parameters, affecting the amount of sun radiation and air circulation velocity around buildings. For this reason, the site of the building should be determined to maximize benefit, for example, from renewable energy resources such as the sun and wind. Figure 1 shows examples of the siting analysis features and components performed for orientation and building design configuration purposes.

Figure 1: Siting analysis data



Top: Average high and low temperatures (left); daily chance of precipitation (right)
Centre: Time spent at various humidity levels (left); wind direction (right)
Bottom: Wind speed (left); sun radiation angle analysis (right)

Moreover, heating and cooling demands in health care facilities are highly affected by the climatic zone corresponding, notably:

- Intensity and length of the heating season represented by heating degree days (HDDs).
- Intensity and length of the cooling season represented by cooling degree days (CDDs).
- Consistent intensity of the sun’s energy represented by annual solar radiation.
- Worst case for removal of airborne moisture (i.e., humidity) represented by the design dew-point temperature.
- Ability of the air to engage in evaporative cooling represented by the design wet-bulb temperature.

In combination, these variables show that distinct patterns emerge with regards to climate types, each of which has particular energy impacts on building design and operation. Lebanon can be divided into four primary climate zones for the specification of design criteria. Figure 2 and Table 1 show these climate zones with their corresponding CDDs and HDDs.

Figure 2: Lebanese climatic zones

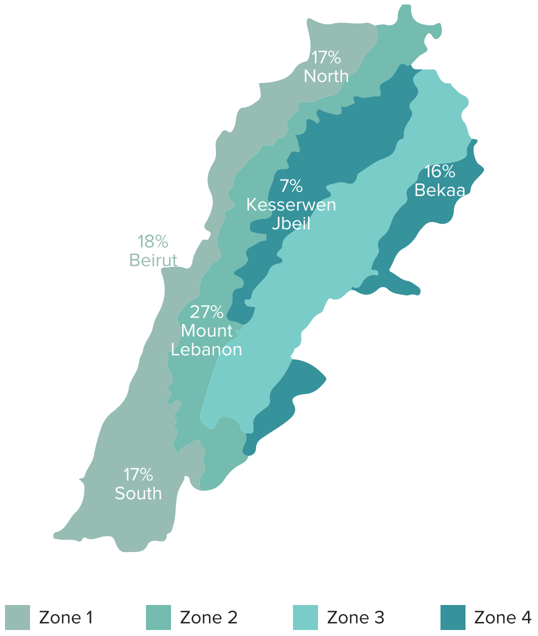


Table 1: Climatic zones in Lebanon with corresponding CDD and HDD

Zone	Description	Reference weather station	Characteristic HDD	Characteristic CDD
1	Coastal	Beirut	379	882
2	Western Mid-Mountain	Qartaba	1,514	105
3	Inland Plateau	Zahle	1,600	390
4	High Mountain	Cedars	3,330	-

(Source: MoE/GEF/UNDP (2015), "Energy consumption in the commercial and institutional sector")

No single design strategy applies to all these climate combinations. Each set of climate combination needs to be analysed separately. Therefore, it is important for the design team to determine the unique characteristics of the climate closest to the site.

It is not possible to present every design strategy for each climate, but some common and fundamental principles apply, such as the sensible and latent loads due to people, since occupant density and hours of occupation are assumed to be climate independent. Typically, the lighting power levels are the same, but the energy use for lighting changes with location due to the available daylighting.

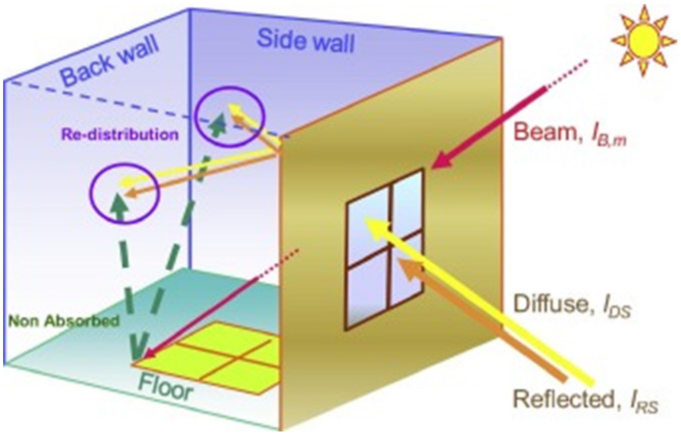
2.2. Orientation

The orientation of hospital buildings not only affects their energy performance but also the patients' healing process, stress levels, and comfort. Orientation of the facility should take into consideration two factors: daylight and natural ventilation.

2.2.1. Daylight

As such, building orientation, the placement and proportioning of fenestration, and the design of shading and daylight control façade systems have a critical effect on the ability of a design to provide useful daylight to perimeter zones and to maintain energy-efficient operation for cooling and heating. A good daylighting solution requires the simultaneous examination of the building configuration and internal space planning (Figure 3) so to maximize the amount of normally occupied space that has access to daylight for ambient illumination. This analysis must also include an assessment of the space's ability to maintain heat gain criteria for minimizing cooling energy and maximizing the potential for solar heating during cold periods.

Figure 3: Glazing solar heat gain analysis and simulation



(Source: https://www.sciencedirect.com/science/article/pii/S0306261915001233)

East- and west-exposed spaces provide the highest amount of daylight in sunny climates but are critical to shading. The illumination of the sun on east and west surfaces is essentially the same, except for local diurnal cloudiness variability, local vertical obstructions that may shade these surfaces unequally, and the timing of the diurnal pattern of daylight. Accordingly, the west exposure needs to be critically evaluated and better be avoided since it commonly contributes most to the peak or design cooling load.

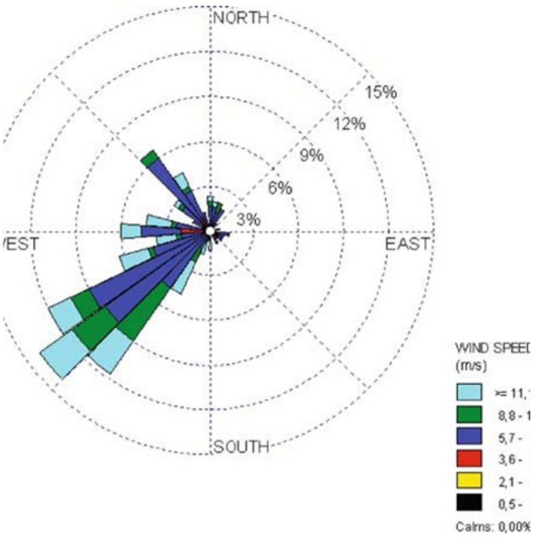
South-facing orientations have the greatest peak solar intensity and the least variation in sun angle of any vertical surface. Therefore, the best orientation for facilities in Lebanon is on the North-South axis, with the longest façade facing the south . This orientation permits the healthcare facility to maximize the solar gains during the cold season extending over seven months, and at the same time harvest the daylight from the north which helps to reduce the cooling load during summer and provides a better glare control.

Illumination or skylighting through the roof can be a great daylighting asset, but the horizontal solar flux is the largest on these horizontal surfaces in the summer when cooling loads are quite likely to be problematic. Therefore, considering the potential solar heat gain is critical if flat skylights are being considered.

2.2.2. Natural ventilation

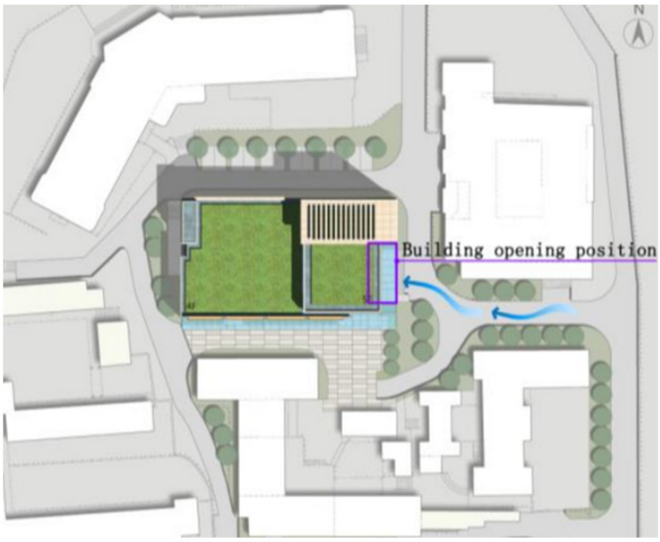
Health care buildings have numerous highly technical spaces that require strict temperature control or high ventilation rates for infection control. This often leads to design solutions where façades are sealed, and where centralized mechanical ventilation is used to supply and extract air. However, these facilities can benefit from natural ventilation if designed properly to harness summer winds for better indoor ventilation and to decrease cooling loads; while in winter, to block infiltration of cold air, especially for the inpatient and outpatient departments. Lebanon features south-west winds in summer and north winds in winter as shown in Figure 4.

Figure 4: Lebanon wind rose



In evaluating the building orientation, special attention should be given to the direction of winds. If wind blows over the building from the front side directly, a large area behind the building would get very little natural wind. If the wind blows over the building at an angle, the situation will improve remarkably. In this range, the architectural complex can effectively use the natural ventilation in summer and shield the north cold wind in winter with the north building. Figure 5 provides an example of a building orientation simulation.

Figure 5: Building orientation simulation

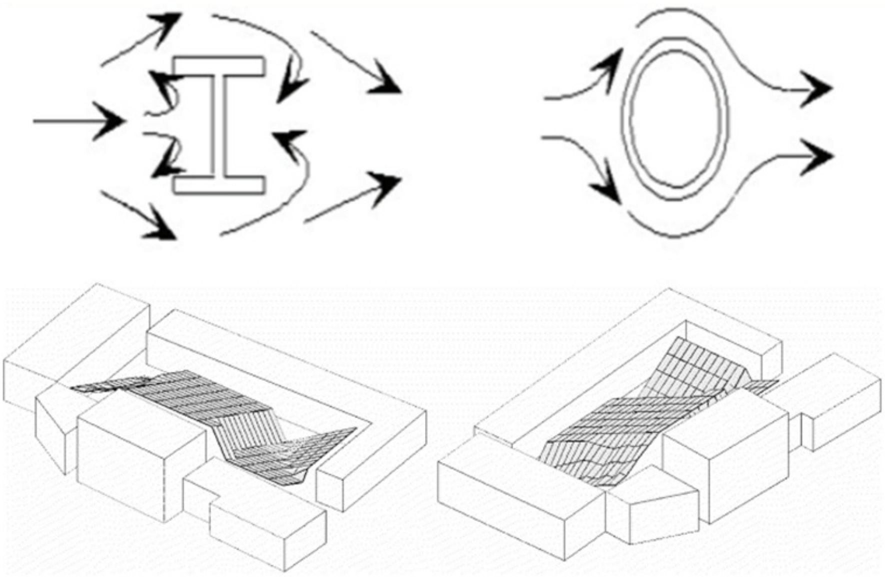


2.3. Configuration and built area

The basic shape of the building has a fundamental impact on the daylighting potential, the building's transfer characteristics, and its overall energy use. How new hospitals are positioned and configured can improve energy efficiency. Before considering mechanical systems, the focus should be on reducing the load as much as possible through passive architectural strategies. Certain building shapes are conducive to energy conservation, such as a compact footprint, especially when oriented properly.

Sometimes, though, the configuration can be as an H-shape or a C-shape, including a courtyard, which allows daylight opportunities. These configurations can also provide innate shading opportunities delivered by the building itself just from its geometry (Figure 6).

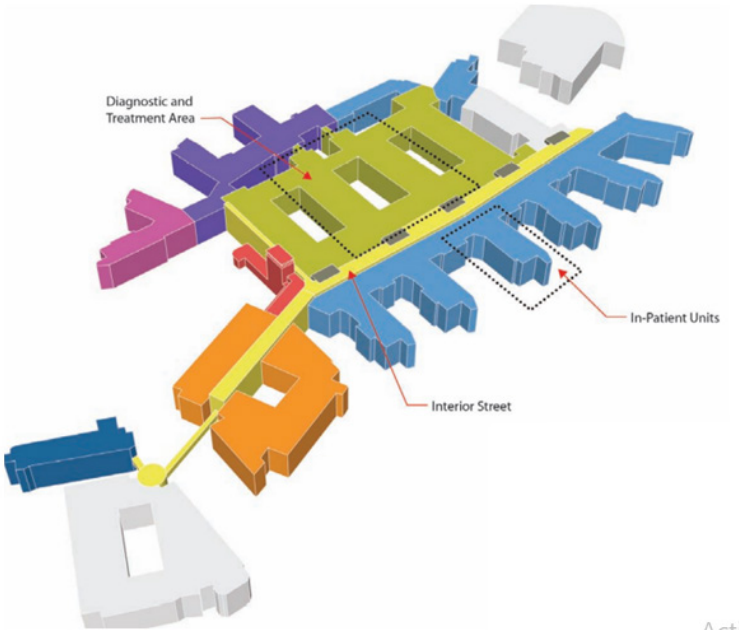
Figure 6: Building geometry and configuration examples



The prescriptive recommendations presented in this report are based on a standard hospital form with a deep and rectangular shape.

The inpatient unit (IPU) zone shown in Figure 7 is traditionally the zone with the most aggressive and well-documented daylighting goals. Therefore, the IPU's building mass has the greatest amount of surface area for transmission of light and heat. This zone is made up of patient rooms, corridors, nursing and semi-private caregiver stations, and service spaces for patient support and storage. Traditionally, the IPUs are stacked in multi-story configurations that are 4–4.5 metres, floor-to-floor, and with the patient rooms in a racetrack form around the core spaces.

Figure 7: Hospital Building Configuration

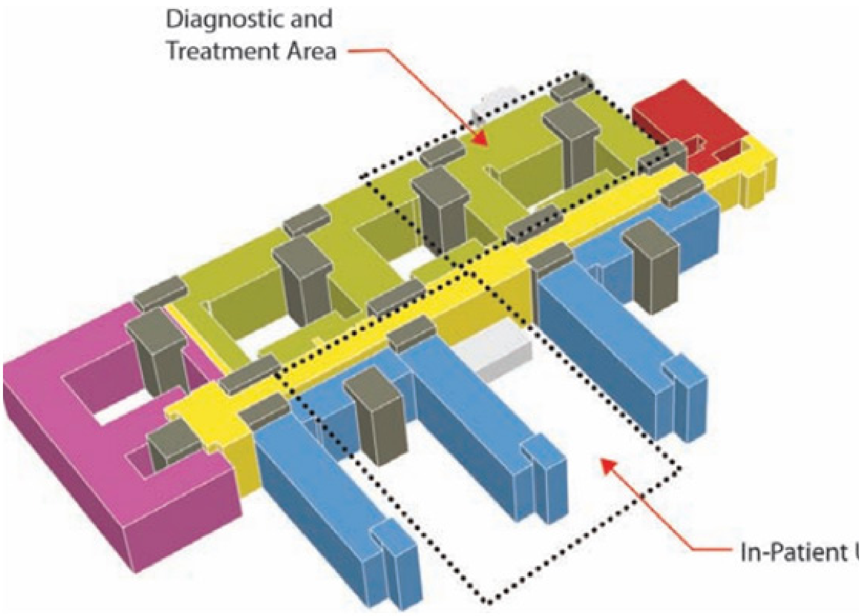


The traditional configuration provides the opportunity for a day-lighted perimeter of patient rooms, depending on the exact configuration of the patient suite, with particular care taken to locate the toilet room on the corridor wall or within a shared interstitial zone. With some attention to the design of the toilet room and the amount, position, and shading of the glazing, these perimeter zones can be well day-lighted up to about 6 metres from the window wall. This traditionally leaves the corridors and caregiver areas without access to daylight.

Reconfiguring the building to provide daylight to caregiver spaces, as well as to patient rooms, is an energy performance challenge for this zone.

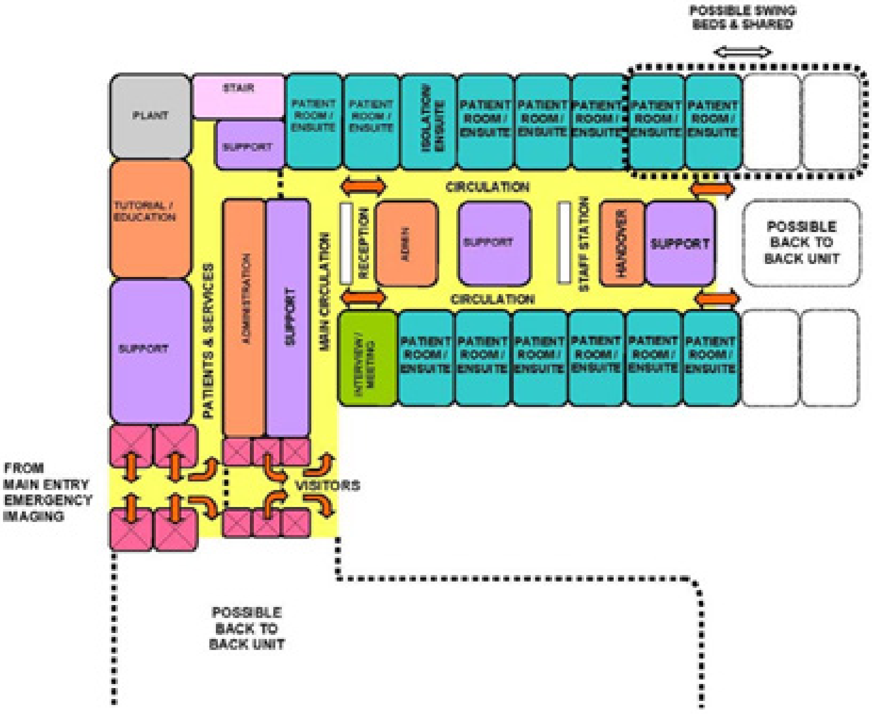
Daylight is provided in various models by one of these configurations:
(1) Reconfiguring the patient tower into a finger plan of double-loaded corridors, with core caregiver functions moved to the junction of the ward corridor and a corridor connecting several nursing units on the same floor level as seen in Figure 8.

Figure 8: Finger Plan configuration



(2) Reconfiguration into a larger racetrack, where the entire building takes on a “U” or “O” shape and where the sides of the plan are double-loaded corridors with caregiver spaces allocated to the corridor knuckles and spread along the corridor (Figure 9).

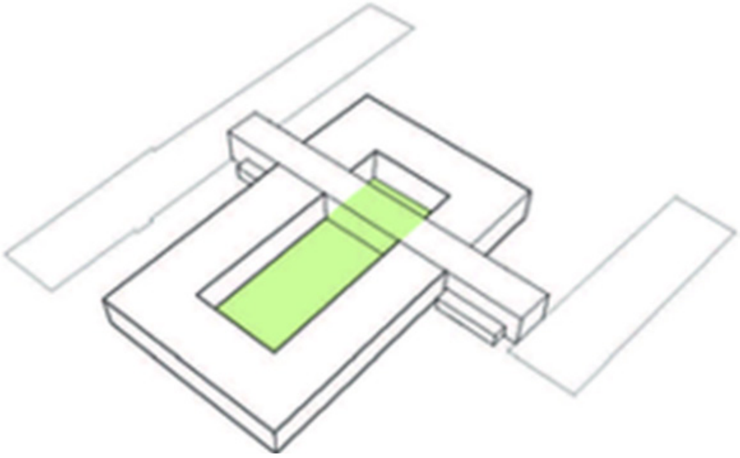
Figure 9: Double Corridor - Racetrack Model



The insertion of plan-enclosed courtyards (Figure 10) is a strategy that achieves both density and daylight in buildings of most types and is the best way to increase daylighting in the interior space. Buildings of this style usually have a shallow depth and can absorb natural light to a considerable extent. There should be enough courtyard space between buildings to get more southward natural light. In addition, lower buildings should be placed in the southern part of the building complex in controlling the overall height of buildings. This configuration allows the retention of a simple overall plan shape, allow departments to vary around their corners, front, and back; and to allow treatment and service spaces to be shared at the back-of-house departments. Atriums and other core lighting strategies may also be introduced into more compact building forms to achieve a similar effect.

Less compact forms increase a building's daylighting potential, but they also may magnify the influence of outdoor climate fluctuations. Greater surface-to-volume ratios increase conductive and convective heat transfer through the opaque building envelope; and, of greatest concern, the potential for massive radiant solar heat gains via unshaded glazing. Therefore, it is critical to assess the daylighting characteristics of the building form in combination with the shading of all glazing surfaces and the heat transfer characteristics of the building envelope to optimize overall building energy and daylighting performance.

Figure 10: Enclosed courtyard configuration



Built area

The first item to address in building design is the built area. There is a drive to minimize built square footage, and the entire team should review the actual requested occupancies to determine if space can be shared for uses otherwise listed separately;

- Shared conference or lounge spaces can reduce the redundancy of built space while encouraging interdepartmental cooperation.
- Space planning to reduce circulation space and lobby size by merging them with other functions or limiting or controlling the scope of their energy use under low-occupancy conditions.

The second major item is to address the architectural configuration of the building. Façade square footage represents a source of conductive heat loss or heat gain as the outdoor air temperatures fluctuate; therefore, the larger the amount of façade area, the greater this impact. Additionally, most façades for hospitals contain windows for the benefit of the patients and staff. Glazing is a poorer insulator than most opaque constructions and should be reviewed regarding its placement and size. Daylighting and natural ventilation are possible within about 7.6 metres of a façade, a value that may govern the depth of footprints for which greater connectivity to the outdoors is desired.

Beyond the impact on the interior floor plate, the shape of the building also informs where and how the building self-shades and begins to inform where glazing can be most effectively placed. As mentioned earlier, in Lebanon glazing those points towards the north captures sky-reflected daylight with minimal solar heat gain, making it the ideal source of even light. Eastern and western glazing is affected by low-angle sun throughout the year, which can cause glare and thermal discomfort if not mitigated properly. Lastly, southern façades with glazing benefit from overhangs to reduce solar load during the summer season. The following sections need to be designed carefully:

Patient rooms and recovery areas

Patient rooms by nature require quality views and daylight. Lighting level requirements are typically low and daylight control is driven by the patients' health condition and individual needs. Prioritizing response to patient needs makes patient rooms an unreliable space for the maximization of daylight, making it unsuitable as a source for daylight harvesting and energy savings.

Diagnostic and treatment spaces

Typically dominated by planning criteria, such as circulation distance, proximity, and adjacency requirements, operating rooms and procedure rooms are often located at the core of a deep floor plate with no access to views and daylight. Breaking up the diagnostic and treatment block requires careful planning, however locating these spaces on the building perimeter for daylighting and views is feasible without surrendering flexibility.

Staff areas (exam rooms, nurse stations, and offices)

Locating staff spaces on the building perimeter is essential for staff performance and requires a design strategy that dovetails with the effort to save energy through reduction of electric light and cooling loads.

Public spaces (lobbies, reception, waiting areas, and transitional spaces)

These spaces provide the best opportunity for high ceilings with high, large-scale fenestration, and they offer the largest potential for daylight harvesting and energy savings.

The following recommendations apply to spaces that are not located on the building perimeter but will allow for additional energy savings if they are designed to follow specific rules:

Internal corridors

In single-story buildings or on top-level floors, where side lighting is not available, top lighting should be used to provide daylight for corridors and contiguous spaces. Make sure that nurse stations, which are frequently placed in niches of circulation areas, and waiting areas have access to daylight and views.

Conference rooms

Conference rooms are densely populated spaces that build up high interior heat loads for only a limited period of time. When located on the perimeter, the interior loads and solar radiation penetrating the perimeter wall accumulate, leading to the escalation of peak loads and oversizing of HVAC systems. As a strategy to minimize peak load, conference rooms should be located on north façade perimeters only or inboard, avoiding west, south, and east-facing perimeter walls. This approach is supported by prioritizing perimeter space for permanently occupied spaces, which make better use of daylight and views than conference rooms, which remain unoccupied for much of the time.

Inboard vs outboard patient toilet rooms

Most inpatient units are designed around a patient-room module that positions the patient toilet room in one of three ways: adjacent to the interior corridor (inboard), adjacent to the exterior wall (outboard), or nested with the toilet for the adjacent patient room. Inboard and outboard layouts can use either a same-handed or opposite-handed approach. Many factors contribute to the design decision; each facility should evaluate carefully based on patient population, acuity level, values, and operational practices. Major considerations typically include the following:

- Nurses' ability to view patients from the corridor
- Direct access from the patient bed to the patient toilet via a handrail along the wall
- Efficient use of space and efficient provision of care within the patient and toilet rooms
- Views from the patient bed to the outdoors

Nested conditions are less favourable in some facilities because they can require more square footage and do not allow for same-handed rooms. An outboard toilet is often favoured by staff because it can provide the most expansive view from the corridor to the patient's bed. However, this condition reduces the amount of exterior wall available for the window, which limits opportunities for daylight and views and potentially reduces the area within the patient room intended for use by family members. Inboard or nested options, on the other hand, offer the full length of patient-room exterior wall.

For some projects, canting the conventional inboard option as shown in Figure 11 provides nurses with an adequate view from the corridor while optimizing the family zone, the patient view to the outdoors, and the adjacency of the patient bed to the toilet room. From an energy-efficiency perspective, a smaller window may be preferred. However, views to the outdoors, and especially views to nature, have been proven to improve health outcomes [Ulrich 2008].

Figure 11: Patient room layout examples: Inboard same handed (top) and outboard opposite handed (right)

The best balance is to provide a window that shows expansive views but not to extend the glazing to the floor and ceiling, staying within the window-wall-ratio recommendations shown in Table 2.

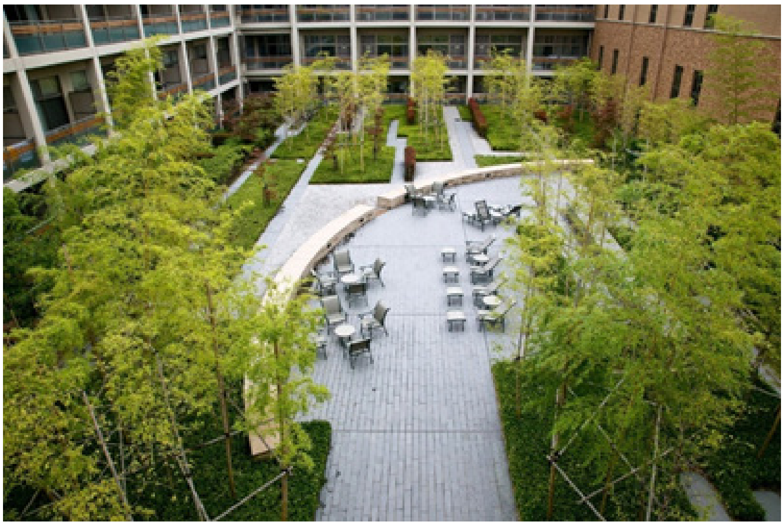
Table 2: Thermal Standard For Buildings in Lebanon. Reference Window to Wall Ratio

Climatic Zone	Maximum Reference Window to Wall Ratio
Zone 1: Coastal	0.21
Zone 2: Western Mid-Mountain	0.20
Zone 3: Inland Plateau	0.19
Zone 4: High Mountain	0.20

2.4. Surroundings

Gardens and landscaping are an aesthetic enhancement and promote the wellness of patients in hospitals. People exposed to plants have higher levels of positive feelings (pleasantness, calm) as opposed to negative feelings of anger and fear. Several studies show that recovery from stress is faster and ends when patients are exposed to the natural environment than any other form of artificial environment. With a growing understanding of the importance of the physical environment for the quality of hospital care, as well as for the health and safety of patients and staff, the outdoor spaces of hospitals, especially in rural areas and in greener areas, are considered a productive addition to reserved interior spaces to treat the patient (an example is shown in Figure 12).

Figure 12: Garden landscaping



Outdoor as well as indoor spaces of health care structures are understood as crucial to patients' physical, psychological, and social recuperation and wellness, appropriately designed active and passive hospital landscapes enhance patients' interaction with nature and so reduce stress, facilitating interaction with others in ways compatible with and complementary to those found in the urban environment.

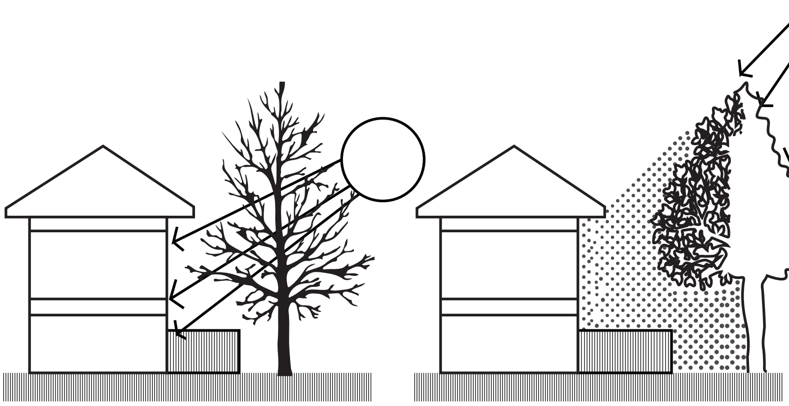
Gardens and other forms of landscaping provide many benefits, which can be grouped under three headings:

1. Psychological
2. Physical
3. Social

The benefits that vegetation brings to buildings are multiple when integrated in an appropriate way, such as enclosed vertical gardens or vegetal covers. These systems intervene in the bioclimatic behaviour of buildings, improving their performance. Vegetation improves the quality of a building and its energy efficiency, among other benefits.

Moreover, the large crowns of the trees provide shade in the summer and offer shelter in the winter; they can also help change the local climate and lower the air temperature. During the winter it protects from wind and humidity. In summer, it protects against excessive heating of interior spaces by blocking solar radiation (Figure 13). However, when relying on landscape elements for shading, be sure to consider the cost of landscape maintenance and upkeep on life-cycle cost.

Figure 13: Greenery shading in winter (left) and summer (right)



Deciduous trees allow sun to warm building in winter

Deciduous trees provide shade in the summer

Adjacent taller buildings and trees, shrubs, or other plantings effectively shade glass on south, east, and west façades. For south-facing windows, remember that the sun is higher in the sky during the summer, so shading plants should be located high above the windows to effectively shade the glass. Also, be careful to not block south light that is being counted on for daylighting. While the shading effect of plants can reduce energy consumption, it does not affect equipment size. The sizing of HVAC equipment relies on the solar heat gain coefficient (SHGC) of the glass and shading system only. The glazing of fully shaded windows can be selected with higher SHGC ratings without increasing energy use. The solar reflections from adjacent buildings with reflective surfaces (metal, windows, or especially reflective curtain walls) should be considered in the design. Such reflections may modify shading strategies, especially on the north façade.

2.5. Building envelope

The building envelope is a major component of the facility’s energy performance and the physical separator between a conditioned and an unconditioned environment. Its function is mainly to resist heat, cold, and noise transfers. The envelope includes all elements of the outer shell to maintain a dry, heated, or cooled indoor environment and facilitate its climate control. It is considered inefficient when it allows high rates of heat transfer between interior spaces and the outdoor environment. Eliminating heat gain and heat loss completely is not possible, but this can be minimized to improve efficiency. Useful design includes specific practices based on the type and specs of the envelope.

The envelope is characterized by the opaque components and fenestration. Improvements should be considered for reduced thermal transmittance (i.e., U-factors), use of thermal mass, and control of solar heat gains.

Recommended upgrades to the opaque elements, such as the roofs/ceilings, walls, and foundations, include increased insulation to lower U-factors and/or additional thermal mass for roofs and walls. Adding cool roofs with high reflectivity in most climates is often found to be a direct benefit to reducing energy associated with cooling.

2.5.1. Opaque envelope components

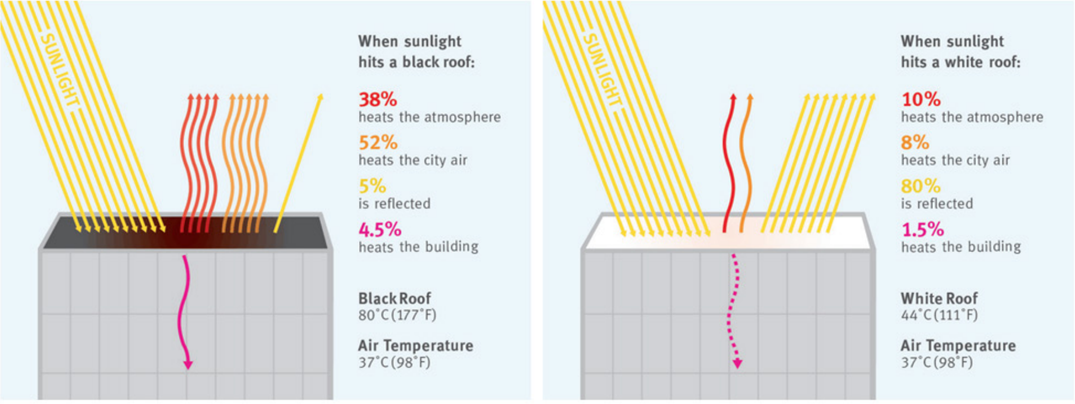
It is important to adequately insulate all walls, roofs, and floors for the particular climate zone so as to provide comfort and energy efficiency and to pay special attention to roofs that are particularly vulnerable to solar gain in summer and to heat loss in winter.

2.5.1.1. Roofs

Cool roofs

A cool roof is a roofing system that delivers higher solar reflectance (SRI= 78 and higher), which is expressed by the ability to reflect the visible, infrared, and ultraviolet wavelengths of the sun, thus reducing heat transfer to the building. Moreover, it can provide a higher thermal emittance (the ability to radiate absorbed or non-reflected solar energy) than standard roofing products. Historically, cool roofs have been either white or some other lighter shade colour. The differences between traditional and cool roof concepts are depicted in Figure 14.

Figure 14: Traditional roof (left) versus cool roof concept (right)

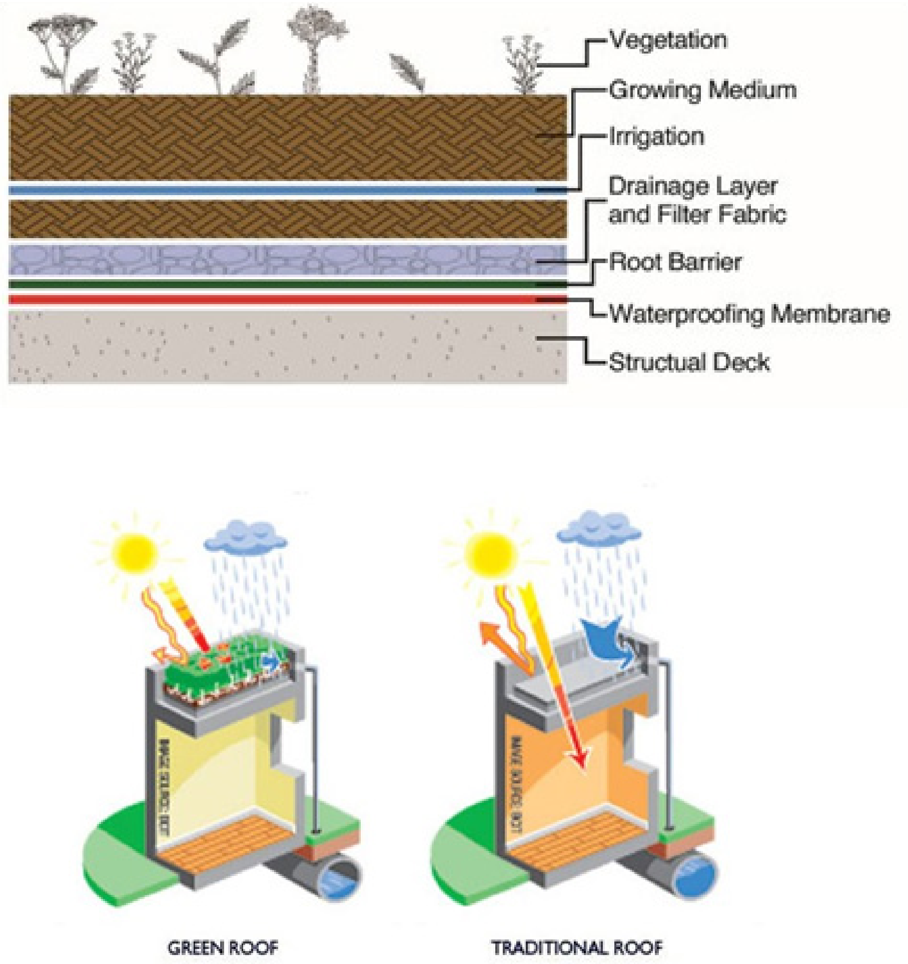


In the heat of the full sun, the surface of a black roof can increase temperature by more than 38 C° above the ambient temperature. This increase can contribute to a greater use of cooling energy as well higher utility bills, higher peak electricity demand, reduced indoor comfort conditions, increased air pollution, and higher maintenance costs.

Green roof

A green roof system is an extension of the existing roof that involves high quality waterproofing, a root repellent system, a drainage system, filter cloth, a lightweight growing medium, and plants (as shown in Figure 15), which serve as a contained green space on top of the building facility.

Figure 15: Green roof section (top) and green roof vs. traditional roof (bottom)



Green roofs offer many advantages for the building envelope design. Most importantly it enhances the aesthetics of the built environment, especially in urban areas, prolonging the service life of HVAC systems through the decrease of use, retaining precipitation water, and decreasing runoffs. In urban areas they reduce noise pollution as well, since they absorb noise from vehicles and other elements. They also prevent the bounce of sound waves on the surface of the building façades, thus acting as acoustic screens. Green roofs can cool the building during the summer months and reduce the urban heat island effect enhanced by black rooftops.

In terms of energy efficiency, the greater insulation offered by green roofs can reduce the amount of energy needed to moderate the temperature of a building, as roofs are the site of the greatest heat loss in the winter and the hottest temperatures in the summer.

Roof insulation entirely above deck

The implementation of a continuous insulation – also known as insulation entirely above deck – is especially efficient because no framing members are involved, and hence the possibility of thermal bridges or short circuits to bypass the insulation are reduced. When two layers of continuous insulation are used in this construction, the board edges should be staggered to reduce the potential for convection losses or thermal bridging as shown in Figure 16.

Thermal bridges are places in the building envelope where there is a higher heat loss compared to surrounding building components. This is an insulation fault which occurs when there is a gap between insulation materials and structural surfaces. Usually, they are located at the junction points of different structures; consequently, the main thermal bridges in a building are found at the junctions of walls and floors, walls and cross walls, walls and roofs, etc. If an inverted or protected membrane roof system is used, at least one layer of insulation is placed above the membrane and a maximum of one layer is placed beneath the membrane. Table 3 below provides the recommended thermal transmittance values for roofs per the Lebanese Climatic Zones to be used in the design of new healthcare facilities.

Figure 16: Continuous roof insulation schematic

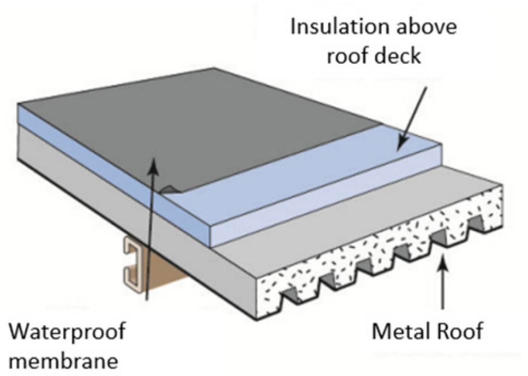


Table 3: Recommended Thermal Transmittance Values for roofs per climatic zones

Climatic Zone	Maximum U-value (W/m2.K)
Roof	
Zone 1: Coastal	0.71
Zone 2: Western Mid-Mountain	0.55
Zone 3: Inland Plateau	0.55
Zone 4: High Mountain	0.55

(Source: Thermal standard for buildings in Lebanon, 2010)

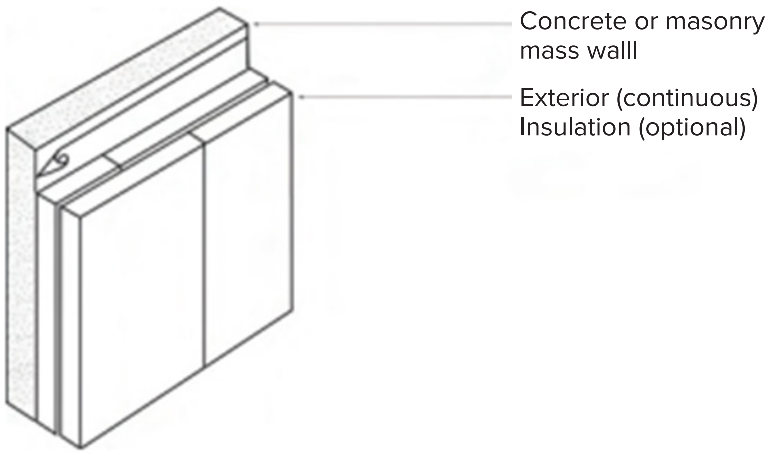
2.5.1.2. Walls

Mass walls

A wall is defined as a mass wall when its heat capacity exceeds 39.75 W/m2. K. Heat capacity or the Specific Heat Capacity of a material is the amount of heat needed to raise the temperature of 1kg of the material by 1K (or by 1°C). A good insulator has a higher Specific Heat Capacity because it takes time to absorb more heat before it heats up (temperature rising) to transfer the heat. High Specific Heat Capacity is a feature of materials providing thermal mass, which is the ability of a material to absorb, store, and release heat.

In the case of a masonry wall, insulation may be placed either on the inside or the outside (see Figure 17). When insulation is placed on the exterior, rigid continuous insulation is recommended. On the other hand, when insulation is placed on the interior, a furring or framing system may be used. The greatest advantages of a mass wall can be obtained when insulation is placed on the exterior in order to absorb heat from the interior spaces and release it later in the evening.

Figure 17: Mass Wall

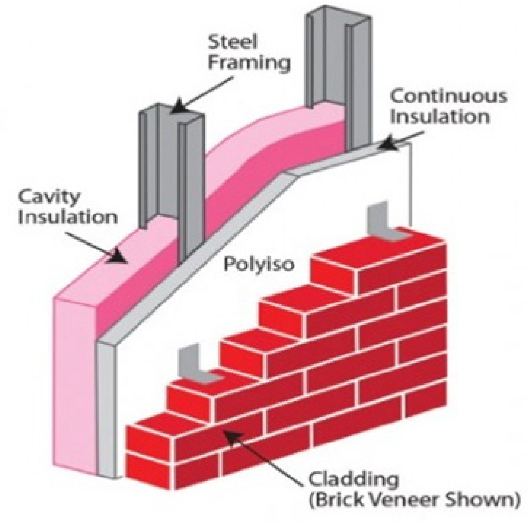


The thermal mass of a building (typically contained in the building envelope) absorbs heat during the day and reduces the magnitude of indoor air temperature swings and peak cooling loads. Moreover, it transfers some of the absorbed heat into the night hours. The cooling load can then be covered by passive cooling techniques (natural ventilation) when the outdoor conditions are more favourable. Thermal mass has also a positive effect on thermal comfort. High-mass buildings decrease the interior air and wall temperature offsets, which increases thermal comfort.

Steel framed walls

Cold-formed steel framing members may be a strong, durable framing material, but it is also a thermal conductor. When not properly insulated, steel allows heat – and associated energy – to travel through the frame. which increases the energy costs and can cause thermal bridges to the cavity insulation. Therefore, it is recommended to add exterior foam sheathing as a continuous insulation to upgrade the wall's thermal performance as seen in Figure 18.

Figure 18: Steel framed



Below-grade walls

Insulation, when recommended, may be placed either on the inside or the outside of the below-grade wall as shown in Figure 19. If placed on the exterior of the wall, rigid continuous insulation is recommended. If placed on the interior of the wall, a furring or framing system is recommended.

Figure 19: Below-grade wall insulation

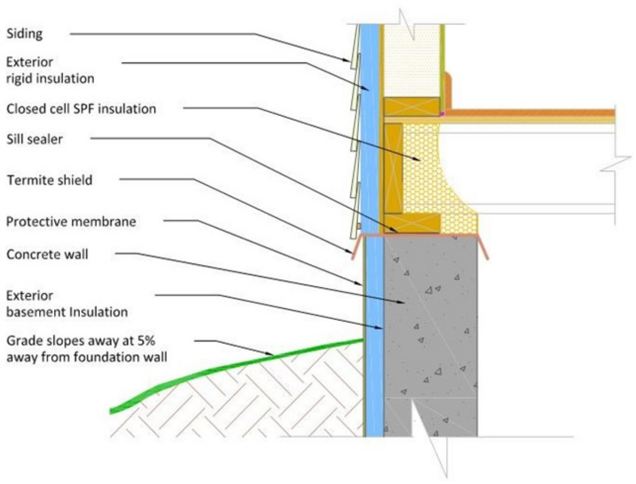


Table 4 indicates the recommended thermal transmittance - u values for walls corresponding to each climatic zone.

Table 4: Recommended Thermal Transmittance Values for walls per climatic zones

Climatic Zone	Maximum U-value (W/m2.K)
Wall	
Zone 1: Coastal	1.26
Zone 2: Western Mid-Mountain	0.65
Zone 3: Inland Plateau	0.65
Zone 4: High Mountain	0.57

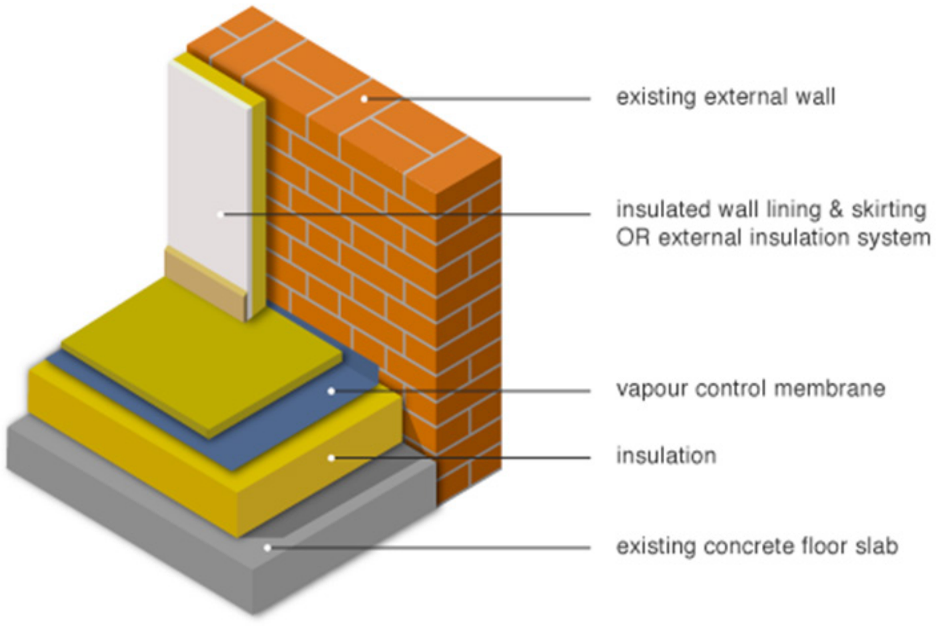
(Source: Thermal standard for buildings in Lebanon, 2010)

2.5.1.3. Floors

Mass floors

Adequate floor insulation should be continuous and either integral to or above the slab. This can be achieved by placing high-density extruded polystyrene above the slab with either plywood or a thin layer of concrete on top (Figure 20). Placing insulation below the deck is not recommended due to losses through any concrete support columns or through the slab perimeter. It is also not recommended in departments enclosing heavy machinery or heavy biomedical equipment. These heavy loads will result in higher applied loads and load bearings on a smaller area of insulation under the screed.

Figure 20: Floor above the slab insulation



Metal joist or wood joist/wood frame

Insulation should be installed parallel to the framing members and in intimate contact with the flooring system supported by the framing member in order to avoid the potential thermal short-circuiting associated with open or exposed air spaces. Non-rigid insulation should be supported from below. The following table presents the maximum U-values recommended for exposed and semi-exposed floors. An exposed floor is a ground floor in direct contact with the exterior air, while a semi-exposed floor is a ground floor above a non-air-conditioned space. Table 5 presents the recommended u-values for floors per climatic zone.

Table 5: Recommended Thermal transmittance values for floors per climatic zones

Climatic Zone	Maximum U-value (W/m2.K)	
	Exposed Floor	Semi-exposed floor
Zone 1: Coastal	1.70	2.00
Zone 2: Western Mid-Mountain	0.70	1.20
Zone 3: Inland Plateau	0.70	1.20
Zone 4: High Mountain	0.66	1.00

Slab-on-ground floors, unheated

The following recommendation is limited to slabs on ground constituting the floors of conditioned spaces only. In these cases, slabs on ground are to be insulated under the outside perimeter of the slab with a specified width of thermal insulation having the required thermal resistance (R value) as presented in Table 6.
The thermal resistances presented in Table 6 are exclusively for the insulation material of the slab composition and should specifically exclude internal air films as well as the thermal resistance of the ground.

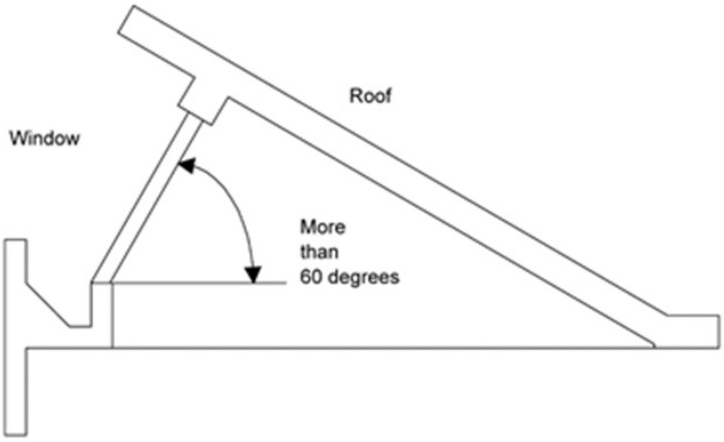
Table 6: Reference Thermal Resistance and width of thermal insulation for slab on grade per climatic zone

Climatic Zone	Minimum Thermal Resistance (m2.K/W)	Insulation Width (m)
Zone 1: Coastal	NR	NR
Zone 2: Western Mid-Mountain	0.75	1.00
Zone 3: Inland Plateau	1.00	1.25
Zone 4: High Mountain	1.25	1.50

2.5.1.4. Vertical fenestration

Fenestration refers to the light-transmitting areas of a wall or roof, windows, and skylights but also to glass doors, glass block walls, and translucent plastic panels. Vertical fenestration includes sloped glazing with slopes equal to or more than 60° from the horizontal (Figure 21).

Figure 21: Vertical fenestration schematic



If it slopes less than 60° from the horizontal, the fenestration falls in the skylight category. The selection of high-performance window products should be considered separately for each orientation of the building and for daylighting and viewing functions. The following design practices are recommended.

Fenestration has a major impact on architectural appearance, energy savings potential, and the improved health and wellbeing of building occupants. Therefore, considerable attention should be given to fenestration design to ensure proper balance of the goals for heating, cooling, daylighting, and views. Envelope design should include glazing only where necessary to provide an appropriate level and quality of daylight and views. However, areas of high glazing, if implemented to improve access to daylight, should be qualitatively weighed against the potential increased HVAC energy use due to larger window area or increased solar heat gain coefficient. The more that glazing is introduced into a façade, the higher its performance needs to be to achieve required energy savings.

The following components should be studied for vertical fenestrations in building envelope.

Window-to-wall ratio

The window-to-wall ratio (WWR) is the percentage resulting from dividing the total glazed area of the building by the total exterior wall area. A WWR selected between 20 percent and 40 percent, in addition to specific vertical fenestration performance values lead to an appropriate balance of the window area and improve the glazing performance.

Careful attention should also be paid to glare, a form of visual discomfort usually caused by the difference in relative brightness between interior surfaces, including computer screens, and the outdoors as viewed through the window. Glare is especially challenging in direct low-to-medium-angle sunlight. Use of exterior shading, such as overhangs on the south façade, can help control both solar heat gains and glare. The recommended values for U-factor and solar heat gain coefficient contribute towards the 30 percent savings target of the entire building energy consumption.

A reduction in the overall WWR will also save energy, especially if glazing is significantly reduced on the east and west façades. Reducing glazing on east and west façades for energy reduction should be done while maintaining consistency with needs for view, daylighting, and passive solar strategies. The maximum reference WWR is presented in Table 7. This ratio was determined from a review of the current average fenestration ratio of existing buildings in Lebanon and the economics of using improved glazing and architectural shading devices to control the solar cooling load and to optimize the beneficial solar heat gain during the heating season.

Table 7: Reference Maximum WWR

Climatic Zone	Maximum Reference Window to Wall Ratio
Zone 1: Coastal	0.21
Zone 2: Western Mid-Mountain	0.20
Zone 3: Inland Plateau	0.19
Zone 4: High Mountain	0.20

(Source: Thermal standard for buildings in Lebanon, 2010)

Visual transmittance

Utilizing daylight in place of electrical lighting significantly reduces the internal loads and saves cost on lighting and cooling power. The higher the visible transmittance (VT), the more energy that can be saved. The amount of light transmitted in the visible range affects the view through the window, glare, and daylight harvesting. For the effective utilization of daylight, high VT glazing types (0.60 to 0.70) should be used in all occupied spaces. VTs below 0.50 appear noticeably tinted and dim to occupants and may degrade luminous quality. However, lower VTs may be required to prevent glare, especially on the east and west façades or for higher WWRs. Lower VTs may also be appropriate for other conditions of low sun angles or light-coloured ground cover (such as snow or sand), but adjustable blinds should be used to handle intermittent glare conditions that are variable. High continuous windows are more effective than individual vertical slot windows for distributing light deeper into the space and provide greater visual comfort for the occupants.

Solar heat gain coefficient

The solar heat gain coefficient (SHGC) is the fraction of solar radiation admitted through a window, door, or skylight that can be transmitted directly and/or absorbed, and subsequently released as heat inside a space. The lower the SHGC, the less solar heat it transmits and the greater its shading ability. Therefore, it is important to consider the SHGC of the glazing when designing the vertical fenestration in a hospital envelope as they can substantially increase the cooling loads during hot months.

Glazing

For north- and south-facing windows, select windows with low solar heat gain coefficients (SHGC) and an appropriate visible transmittance (VT). These characteristics are captured in the light-to-solar gain (LSG) ratio, which is the ratio of VT to SHGC. The higher the LSG, the better the glazing is at admitting visible light without additional thermal gain. A glazing system with LSG > 1.5 will provide a good balance between daylighting and thermal control.

Certain window coatings, called “selective low-e” (Figure 22) transmit the visible portions of the solar spectrum selectively and reject the nonvisible infrared sections. These glass and coating selections are important to providing a balance between visible light and solar heat gain. The placement of the coating on the glazing panes is dependent on whether the objective is to prevent heat loss in cold climates or to reduce external heat gain in hot climates. Table 8 provides the maximum thermal transmittance allowable for vertical glazing components based on climatic zones.

Figure 22: selective low e glazing

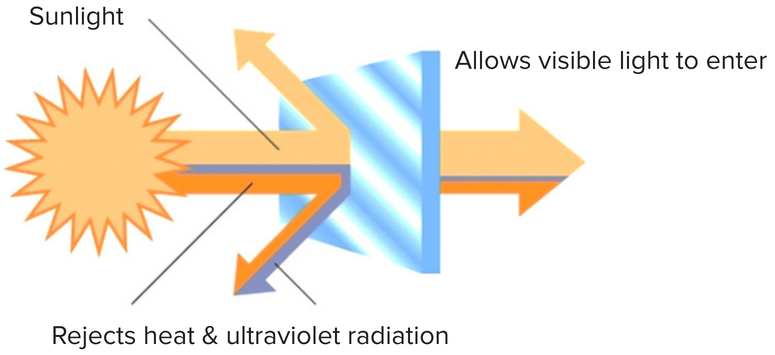


Table 8: Recommended / Reference Maximum thermal Transmittance for vertical glazing

Climatic Zone	Maximum U-value (W/m².K)
Vertical Glazing	
Zone 1: Coastal	6.2
Zone 2: Western Mid-Mountain	4.3
Zone 3: Inland Plateau	4.3
Zone 4: High Mountain	2.8

Operable versus fixed windows

Operable windows shown in Figure 23 play a significant role in the design of health care facilities in terms of occupant comfort. However, although operable windows offer the advantage of personal comfort control and beneficial connections to the environment, individual operation of the windows can backfire on the HVAC system settings and requirements and increase the energy use. Advanced energy buildings with operable windows should strive for a high level of integration between envelope and HVAC system design.

The envelope should be designed to use natural ventilation with operable openings to make use of cross ventilation. Second, the mechanical system should use interlocks on operable windows to ensure that the HVAC system responds by shutting down in the affected zone if the window is opened. The window interlock zones need to be designed to correspond as closely as possible to the HVAC zone affected by the open window.

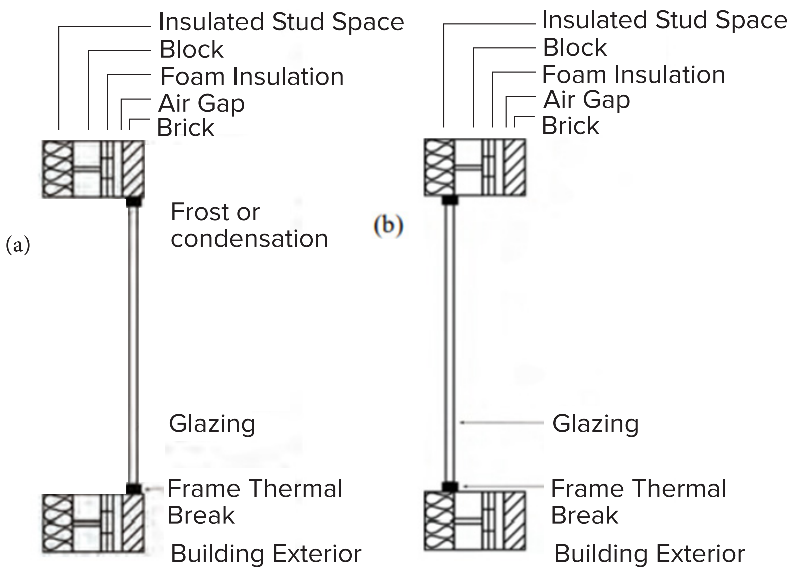
Figure 23: Operable versus fixed windows

Continuous insulation to avoid thermal breaks

Thermal bridging is the interruption of the insulation layer, which creates a higher heat transfer at the connection of different building elements such as floor-wall and window-wall connections. Thermal bridges may cause condensation and mold problems. In well-insulated buildings, the percentage of losses due to thermal bridges becomes high (more than 30 percent), compared to the losses through the envelope. Therefore, in energy-efficient buildings, thermal bridges need to be avoided.

Windows installed out of the plane of the wall insulation (Figure 24 a) are a common source of envelope thermal breaks. Installing the fenestration outside the plane of the wall insulation defeats the thermal break in the window frame. In cold climates this causes condensation and frosting. The normal solution is not to rebuild the wall but to blow hot air against the window to increase the interior surface temperature of the frame and glazing, which increases the temperature difference across the glazing and reduces the interior film coefficient from 0.68 to 0.25. Fenestration should be installed to align the frame thermal break with the wall thermal barrier (Figure 24 b). This will minimize thermal bridging of the framing due to fenestration projecting beyond the insulating layers in the wall.

Figure 24: Thermal break (a) at window frame and (b) in window frame aligned



Tables 9 through 12 indicate the reference WWR, thermal transmittance values of building envelope components, and the Solar Heat Gain Coefficients (SHGC) in the four Lebanese climatic zones.

Table 9: Recommended WWR, U-values, and SHGC values climate zone 1

Window to Wall Ratio WWR (%)	U-value Roof W/m2.K	U-value Wall W/m2.K	U-value Windows W/m2.K	SHGC
≤15%	0.71	1.26	5.8	North: NR All: NR
16-25%	0.71	1.26	5.8	North: NR All: 0.7
26-35%	0.71	1.26	4.0	North: 0.7 All: 0.6
36-45%	0.71	1.26	3.3	North: 0.7 All: 0.34
Skylight			**U-value Skylight W/m2.K**	**SHGC**
≤2%			5.8	0.4
2.1-5.0%			5.8	0.2

(Source: Thermal standard for buildings in Lebanon, 2010)

Table 10: Recommended WWR, U-values, and SHGC values climate zone 2

Window to Wall Ratio WWR (%)	U-value Roof W/m2.K	U-value Wall W/m2.K	U-value Windows W/m2.K	SHGC
≤15%	0.63	0.77	4.0	North: NR All: NR
16-25%	0.63	0.77	4.0	North: NR All: 0.7
26-35%	0.55	0.57	2.6	North: 0.6 All: 0.5
36-45%	0.55	0.57	1.9	North: 0.5 All: 0.4
Skylight			**U-value Skylight W/m2.K**	**SHGC**
≤2%			4.0	0.4
2.1-5.0%			3.3	0.2

(Source: Thermal standard for buildings in Lebanon, 2010)

Table 11: Recommended WWR, U-values, and SHGC values climate zone 3

Window to Wall Ratio WWR (%)	U-value Roof W/m2.K	U-value Wall W/m2.K	U-value Windows W/m2.K	SHGC
≤15%	0.63	0.77	4.0	North: NR All: NR
16-25%	0.63	0.77	4.0	North: NR All: 0.7
26-35%	0.55	0.57	2.6	North: 0.6 All: 0.5
36-45%	0.55	0.57	1.9	North: 0.5 All: 0.34
Skylight			**U-value Skylight W/m2.K**	**SHGC**
≤2%			4.0	0.4
2.1-5.0%			3.3	0.2

(Source: Thermal standard for buildings in Lebanon, 2010)

Table 12: Recommended WWR, U-values, and SHGC values climate zone 4

Window to Wall Ratio WWR (%)	U-value Roof W/m2.K	U-value Wall W/m2.K	U-value Windows W/m2.K	SHGC
≤15%	0.55	0.57	4.0	North: NR All: NR
16-25%	0.55	0.57	3.3	North: NR All: 0.7
26-35%	0.49	0.50	2.6	North: 0.6 All: 0.5
36-45%	0.49	0.50	1.9	North: 0.5 All: 0.4
Skylight			**U-value Skylight W/m2.K**	**SHGC**
≤2%			3.3	0.4
2.1-5.0%			2.6	0.2

(Source: Thermal standard for buildings in Lebanon, 2010)

2.5.1.5. Doors

The baseline standards classify doors as either swinging or non-swinging. Non-swinging doors are called roll-up doors. The prescriptive U-factor requirements depend on the door type, so this input affects the baseline building criteria.

Opaque, swinging

A U-factor of 0.37 corresponds to an insulated double-panel metal door. A U-factor of 0.61 corresponds to a double-panel metal door. If at all possible, single swinging doors should be used. Double swinging doors (Figure 25) are difficult to seal at the centre of the doors unless there is a centre post. Double swinging doors without a centre post should be minimized and limited to areas where width is important. Vestibules or revolving doors can be added to further improve energy efficiency.

Figure 25: Single (left) and double (right) swinging doors

Opaque, roll-up or sliding

Roll-up or sliding doors (Figure 26) are recommended to have R-4.75 rigid insulation or meet the recommended U-factor. When meeting the recommended U-factor, the thermal bridging at the door and section edges is to be included in the analysis. Roll-up doors that have solar exposure should be painted with a reflective paint (or should be high emissivity) and should be shaded.

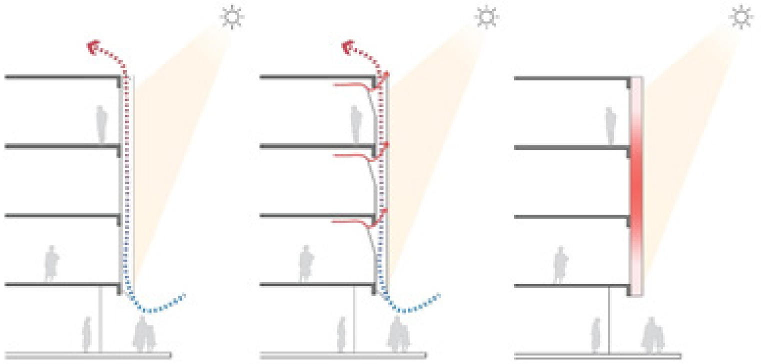
Figure 26: Sliding door

2.5.1.6. Built-in architecture

The double skin is a regular building with an architectural built – in complex shading system placed in front of the regular skin / layer of the building. The cavity formed between these two layers act as insulation against extreme temperatures, winds, and sound, improving the building's thermal efficiency for both high and low temperatures. The airflow through the intermediate cavity can occur naturally or be mechanically driven, and the two glass layers may include sun protection devices. Double skin façades provide thermal and acoustic comfort, are able to reduce the cooling heating requirements of a building as they are adaptable to cooler or warmer weather, and they limit the need for window specific technologies.

In cold climates, the air buffer works as a barrier to heat loss. Sun-heated air contained in the cavity can heat spaces outside the glass, reducing the demand for indoor heating systems. While in hot climates the cavity can be vented outside the building to mitigate solar gain and decrease the cooling load. Excess heat is drained through a process known as the 'chimney effect' shown in Figure 27, whereby differences in air density create a circular motion that causes warmer air to escape. As the air temperature in the cavity rises, it is pushed out, bringing a slight breeze to the surroundings while isolating against heat gain.

Figure 27: Chimney effect in double skin façades

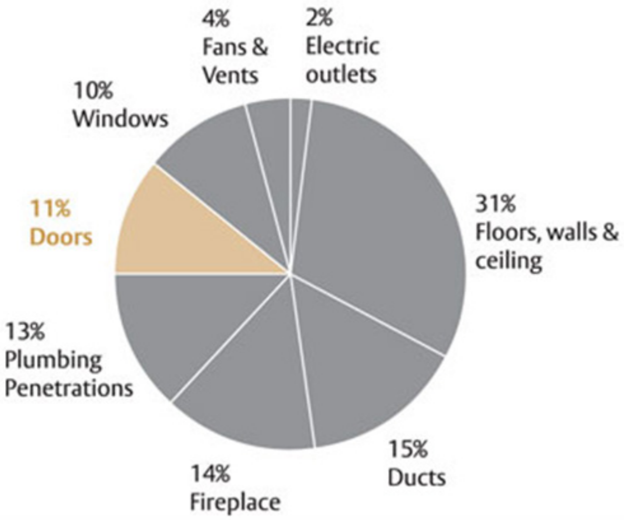


Overall, double-skin façades design and placement depend heavily on external conditions (solar radiation, external temperature, etc.) that directly influence internal comfort and user quality of life. Therefore, careful design is essential for each case, requiring detailed knowledge of solar orientation, context, local radiation, temperature conditions, building occupancy, and much more.

2.5.1.7. Air infiltration control

As shown in the Figure 28, approximately 40 percent of all air infiltration comes from the building envelope, of which floors, walls, and ceiling take up to 31 percent, followed by windows at 10 percent, and doors at 11 percent. Therefore, the building envelope should be designed and constructed with a continuous air barrier system to control air leakage into or out of the conditioned space and should extend over all surfaces of the building envelope (at the lowest floor, exterior walls, and ceiling or roof). An air barrier system should also be provided for interior separations to maintain adequate temperature or humidity levels. If possible, a blower door test should be used to depressurize the building and to find leaks in the infiltration barrier.

Figure 28: Air infiltration percentages by building envelope component



The energy savings of air tightening measures affect the consumption of electricity as well as gas, diesel, and biomass as shown in the table below, as this measure can significantly reduce the cooling and / or heating demand. Table 13 provides indication of average savings per climatic zone resulting from air tightening.

Table 13: Indication of average energy savings and simple pay back times for air tightening

Air Tightening	Climatic Zone 1	Climatic Zone 2	Climatic Zone 3	Climatic Zone 4
Electricity savings (kWh/ year)	190 - 300	100 - 200	200 - 200	100 - 10
Diesel/gas/ biomass savings (Loil eq/year)	10 - 20	40 - 60	60 - 100	80 - 130
Simple Pay Back Time (years)	0.7 - 5	0.5 - 3	0.3 - 2	0.3 - 2

(Source: "High Level Energy Efficiency Guidelines for Building Reconstruction and Upgrades in Lebanon," Greenfield Cities, LCEC & Energy Transition Facility, June 2021)

2.6. Daylighting

General principles

Daylighting strategies drive the building's shape and form and need to be considered in the structural, mechanical, electrical, and architectural designs. Daylighting can increase the energy performance of the building by impacting the size and costs.

Providing daylight is fundamental for a healing environment, as it makes a key contribution to energy-efficient and eco-effective health care design. While the most valuable asset of daylight is its free availability, the most difficult aspect is its controllability as daylight changes during the course of the day. Daylighting is more of an art than a science, and it offers a broad range of technologies that provide glare-free balanced light, sufficient lighting levels, and good visual comfort.

Daylighting will only translate into savings when electrical lighting is dimmed or turned off and is replaced with natural daylight. Effective daylighting uses natural light to offset electrical lighting loads. When designed correctly, daylighting lowers energy consumption and reduces operating and investment costs, such as:

- Reduced electricity use for lighting and peak electrical demand
- Reduced cooling energy and peak cooling loads
- Reduced fan energy and fan loads
- Reduced maintenance costs associated with lamp replacement
- Reduced HVAC equipment and building size and cost

However, to achieve this reduced cooling, the following criteria must be met:

- High-performance glazing to meet lighting design criteria and block solar radiation
- Effective shading devices, sized to minimize solar radiation during peak cooling times
- Electric lights, through the use of photo sensors, automatically dimmed or turned off

The case for daylighting reaches far beyond energy performance alone. Indoor environmental quality not only benefits the patients and their healing process but also has a significant impact on the performance of the care-giving staff by reducing medical errors.

Most daylighting strategies are generic and apply to health care facilities just as they do to other building types.

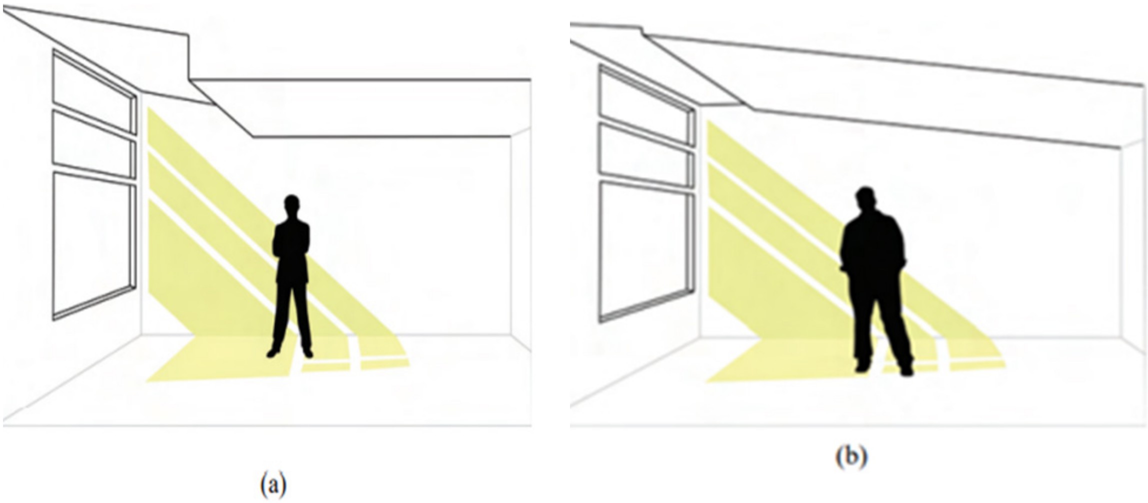
2.6.1. Side lighting

For side lighting, daylight penetrates the interior space through windows below ceiling height. To achieve uniformity in daylighting, horizontal strip windows are often used to compare with individual windows. Moreover, to provide a greater depth of penetration of daylight into the interior space, window openings should be located higher on the wall. When designing side lighting, it is also recommended to build separate windows for viewing out the building and for daylighting. Here are some side lighting techniques.

Ceiling and window height

For good daylighting, a minimum ceiling height of 2.7 m is recommended. In public spaces such as waiting areas and lobbies, which extend to greater depth, ceiling height (at least partially) should be 3 to 3.6m. When daylighting is provided exclusively through sidelighting, it is important to elevate the ceiling on the perimeter and extend glazing to the ceiling. Additional reflectance to increase lighting levels can be achieved by sloping the ceiling up towards the outside wall: (Fig 29 - a) raised ceiling at façade and (Fig 29 - b) sloped ceiling at façade.

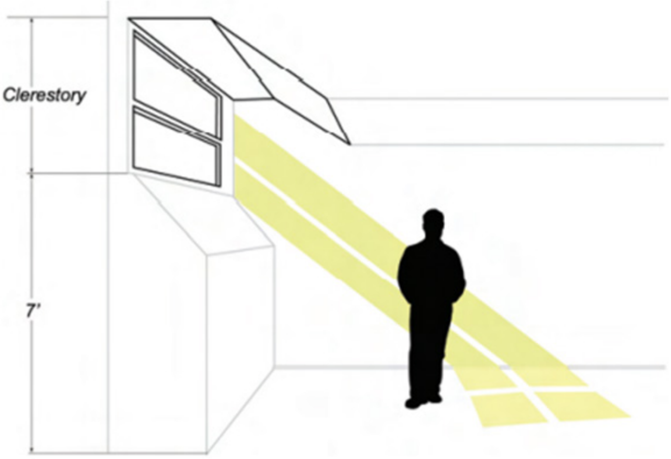
Figure 29: Raised ceiling (a) versus sloped ceiling (b)



Clerestory window

In cases where it is not possible to place windows in exterior walls, clerestory windows (Figure 30) or window bands should be considered for daylighting. Daylight delivered above 2.1m at clerestory level delivers the highest illuminance level available through sidelighting.

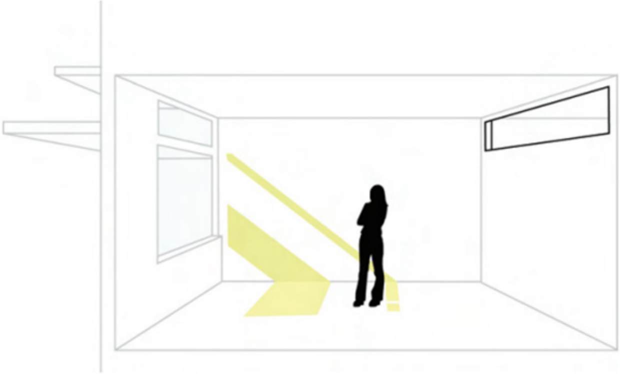
Figure 30: Clerestory window



Borrowed light

Borrowed light (Figure 31) is an effective strategy to deliver daylight to corridors that are located behind spaces on the building perimeter, where the corridor wall frequently blocks and prevents daylight from entering deeper into the building. The corridor partitioning wall provides significant opportunities to daylight in the corridor through borrowed light. The corridor partitions should be designed with clerestory windows or window bands for perimeter spaces with a dept-to-height ratio no greater than 2.5:1.

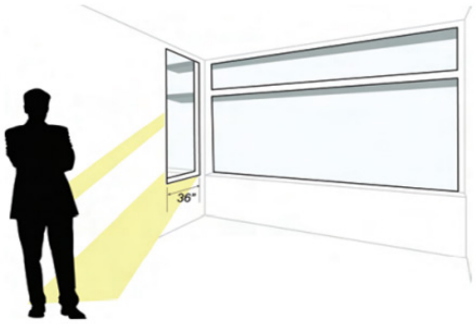
Figure 31: Borrowed light schematic



Wall-to-wall windows

Raising the window levels to ceiling level is the first priority for deepening daylight penetration. However, to balance light levels in the room and to mitigate contrast, it is equally important to maximize the window width. By extending the window width from wall to wall as shown in Figure 32, the adjacent partitioning walls receive greater exposure and act as indirect sources of daylight while also achieving greater depth of daylight penetration. Even more daylight and a wider range of view can be gained by making the first 0.6m and 0.9m of the cellular partitioning walls (i.e., where they meet the perimeter wall) transparent.

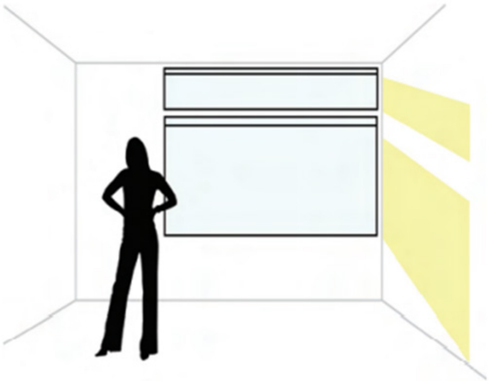
Figure 32: Wall to Wall Windows



Punched windows

When window size is limited and ‘punched’ windows can not be avoided, special care should be taken in placing the aperture to avoid high contrasts and low visual comfort. To ensure that daylight is maximized and light levels are distributed evenly, the window aperture should align with one of the partitioning walls (Figure 33). This will mitigate contrast differences, maximize the depth of daylight reach, and make the space appear larger.

Figure 33: Punched Windows



2.6.2. Top lighting

Top lighting draws from a zenithal skylight, which makes top lighting the most effective source of daylight. The difference between side and top lighting is simple: side-lighting products face the horizon while top-lighting products face the sky. Side lighting from windows and doors provides daylight and solar energy along the perimeter of a building. Therefore, it requires smaller apertures than side lighting to achieve the same level of light.

In health care facilities, top lighting is recommended for use in occupied spaces that have no access to sidelight and is best used in circulation areas and contiguous spaces that are used for nurse stations and waiting areas or lobbies. Top lighting in circulation areas needs careful coordination with overhead ductwork and lighting. Top lighting is a highly effective strategy that not only provides excellent daylight and way finding support but also saves energy for electrical lighting however it can present several limitations. The limitation of top lighting is that it can be used in single-story designs only or on the top floors of multi-story designs and has insulation problems. Two types of top lighting are used: Rooftop monitors and skylights.

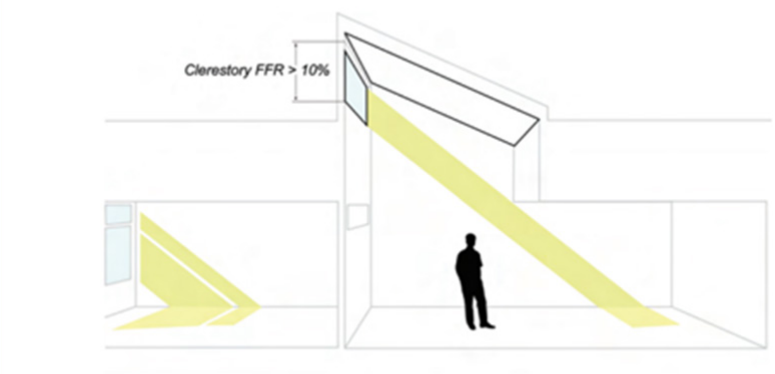
Rooftop Monitors

Rooftop monitors are typically the top lighting strategy best suited for healthcare applications. The monitor's vertical glazing delivers excellent quality daylight, and delivers it specifically to the monitor's orientation (which is important for good controlling of the daylight). It is recommended for Roof monitors not face east or west. South orientation is possible if appropriately sized overhangs are included, but undesired solar heat gain is blocked most effectively when the monitors face north.

Rooftop monitors follow a recommended Fenestration to Floor Area Ratio (FFR) of 10% of vertical glazing which is sufficient to achieve good quality daylight levels and to switch off electrical lighting during daytime and under partially cloudy sky conditions (Figure 34).

When the monitor faces south, the glazing area is typically 25% less than when it faces north to provide the same amount of daylighting.

Figure 34: Rooftop Monitors



Skylights

Skylights (Figure 35) are a powerful source of daylight; however, these openings present their own challenges in terms of water insulation, high solar heat gains, direct beam radiation, and glare. Applications in health care facilities should be considered with great care and only if north-facing glazing façades are not deemed feasible. Work spaces need to be shielded from direct sun, as diffusing skylights can cause glare. To overcome these problems, the use of light-reflecting baffles and/or diffusing glazing to control direct sun is needed.

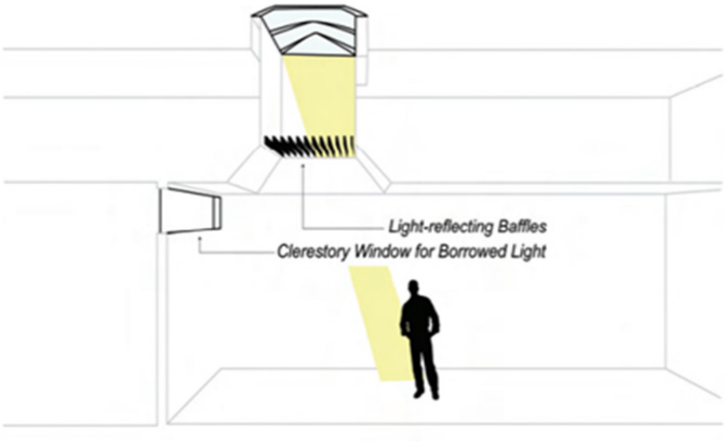
To overcome the unwanted effects of skylights, it is recommended to use skylights with low overall thermal transmittance (U factor) to reduce the thermal heat gains during the hot seasons. Also, insulate the skylight curb above the roof line with rigid continuous insulation and shade skylights with exterior/interior sun control devices such as screens, baffles, or fins.

Active skylights, by contrast, have a mirror system within the skylight that tracks the sun and are designed to increase the performance of the skylight by channeling the sunlight down into the skylight well. Some of these systems also attempt to reduce the daylight ingress in the summer months, balancing daylighting with cooling loads.

Tubular daylight devices are another type of toplighting device. These devices employ a highly reflective film on the interior of a tube to channel light from a lens at the roof, to a lens at the ceiling plane. Tubular daylight devices tend to be much smaller than a typical skylight, yet still deliver sufficient daylight for the purpose of dimming the electric lighting.

Daylight redirection devices take incoming direct beam sunlight and redirect it, generally onto the ceiling of a space. These devices serve two functions: glare control, where direct sun is redirected away from the eyes of occupants, and daylight penetration, where sunlight is distributed deeper into a space that would not be allowed otherwise. Daylight redirection devices generally take one of two forms: a large horizontal element, or louvered systems. Horizontal daylight redirection devices are often called lightshelves.

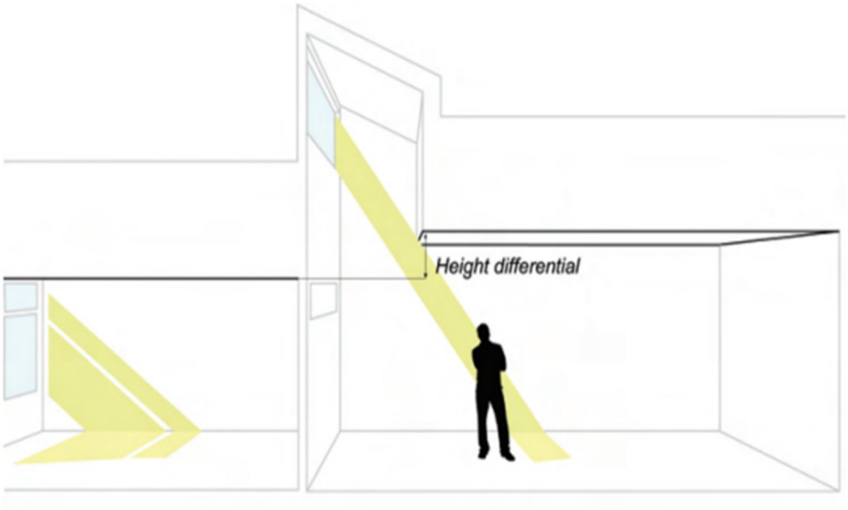
Figure 35: Skylights



Use ceiling height differentials

Differences in floor-to-floor height offer useful opportunities for daylighting. Differentials in ceiling height (Figure 36) as a result of programmatic requirements provide cost-effective opportunities to implement daylight through top lighting.

Figure 36: Ceiling Height Differentials



2.6.3. Shading systems

Lebanon is located at about 34 degrees Latitude, which makes it heavily exposed to the sun. Therefore, the elimination of uncontrolled, direct beam radiation is essential for good daylight quality in health care design to positively impact the patient and staff areas. Direct beam radiation causes thermal discomfort and glare, which are critical to avoid in all patient and staff spaces but less critical to avoid for some public spaces and corridors. Strategies should be used that bounce, redirect, and filter sunlight so that direct radiation does not enter the space.

Shading systems are designed to reduce solar radiation. In most cases, however, they also inadvertently cause loss of valuable daylight. As a result, the electric lights are switched on during the peak time of day, causing cooling load and power consumption to peak and driving HVAC sizing excessively/uncontrollably. This explains why in the process of developing a shading strategy it becomes inevitable to acknowledge and include daylighting as an integral component of the system.

The effectiveness of shading systems varies widely and depends on the system’s ability to adapt to changing conditions. To that end, dynamic systems that operate on demand and track the path of the sun are significantly more successful than static/fixed systems.

Shading type selection

To obtain the best overall performance results, the selection of the right shading type should be based on considerations concerning both heat load and the ability to facilitate daylight and views. There are six shading types to choose from, as discussed in the following. However, in all climate zones except the high mountain area, it is recommended to use horizontal shading devices on south façades and vertical shading devices on east and west façades.

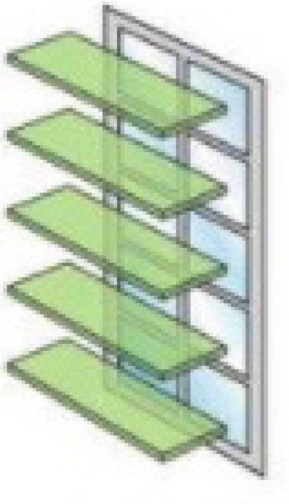
Fixed external shading

Solar heat gain is most effectively controlled when penetration is blocked before entering the building. One disadvantage of exterior shading systems can be the accessibility issues for maintaining and cleaning the façade. Fixed devices are designed to perform best at peak hours, but work significantly less effectively outside the optimized time range. There are different configurations of exterior shading:

Horizontal devices

Overhangs, soffits, awnings, and trellises respond well to steep solar angles and work best on south-facing façades. Passive solar gains are possible in winter; however, additional interior shading will be required to counter glare. A projection factor of 0.5 is typical. Overhangs are most effective and economical when located directly above the glass and continue beyond the width of the window.

Figure 37: Horizontal



Overhangs requirement

Important energy savings are realized when sun penetration is blocked before it enters the windows. Horizontal overhangs at the top of the windows are most effective for south facing façades. In this case, horizontal overhangs should continue beyond the width of the windows to shade them. Vertical fins oriented slightly north are most effective for east- and west-facing façades. The projection factor (PF) of the architectural shading device is calculated as below.

PF overhangs = A/B

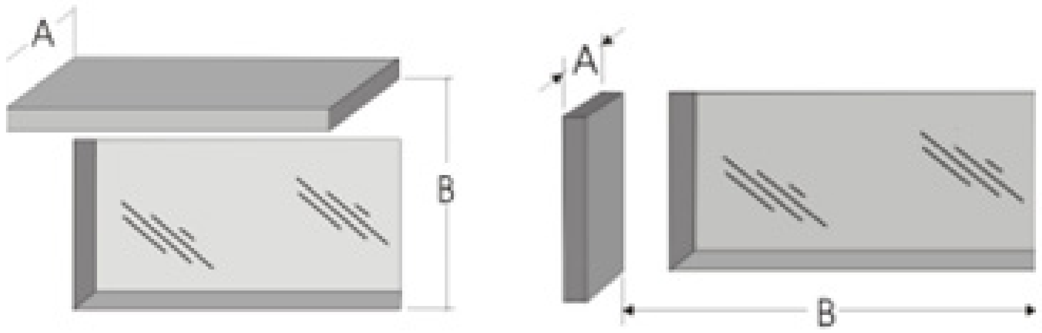
A: Horizontal extension of the overhang from the vertical wall plane that contains fenestration (m).

B: Distance between the bottom edge of the fenestration and the bottom edge of the overhang (m).

PF fins = A/B

A: Horizontal extension of the fin from the vertical wall plane that contains fenestration (m).

B: Distance between the farthest side of the fenestration to the face of fin closest to the fenestration (m).



When both overhangs and fins are used simultaneously, the projection factors for the overhangs and fins should be calculated separately using the formulas provided above. Then the appropriate architectural shading factor should be selected from Table 14. If the projection factor ranges in Table 14 do not exactly fit the proposed ratios of fins and overhang, then the value with the closest fit to the projection factor of the overhang should be used.

Table 14: Recommended / Reference Architectural shading factors (ASF)

PF - Overhangs	ASF per Orientation			
	N	NE,NW	E,W	S,SE,SW
0.05≤ PF<0.15	0.24	0.43	0.74	0.89
0.15≤ PF<0.30	0.23	0.4	0.68	0.8
0.30≤ PF<0.50	0.21	0.34	0.57	0.64
0.50≤ PF<0.70	0.19	0.31	0.49	0.54
0.70≤ PF<0.90	0.18	0.28	0.43	0.46
0.90≤ PF<1.25	0.17	0.26	0.38	0.41
PF≥1.25	0.16	0.24	0.31	0.34

PF - Fins	ASF per Orientation			
	N	NE,NW	E,W	S,SE,SW
0.05≤ PF<0.15	0.23	0.42	0.76	0.92
0.15≤ PF<0.25	0.20	0.38	0.71	0.85
0.25≤ PF<0.35	0.19	0.35	0.67	0.78
PF≥0.35	0.17	0.32	0.63	0.74

PF – Fins and Overhangs	ASF per Orientation			
	N	NE,NW	E,W	S,SE,SW
Overhangs 0.05≤ PF<0.35 Fins 0.05≤ PF<0.15	0.20	0.35	0.63	0.72
Overhangs 0.30≤ PF<0.60 Fins 0.15≤ PF<0.30	0.15	0.26	0.47	0.50
Overhangs 0.60≤ PF<1.05 Fins 0.30≤ PF<0.50	0.11	0.17	0.30	0.27
Overhangs PF≥1.05 Fins PF≥0.50	0.08	0.11	0.17	0.13

(Source: Thermal standard for buildings in Lebanon, 2010)

Vertical devices

Vertical screens or horizontal louvers configured in vertical arrays work when oriented south, west, or east.

Dynamic shading systems

Dynamic or operable systems (Figure 38) are the most effective shading devices available, as they do not have to compromise on one single position for minimizing heat gain and maximizing daylight. The most common technologies used are louvered systems and fabric-based roller shades, which are able to reduce solar heat gain by as much as 80–90 percent while simultaneously allowing for daylight and views. Operable systems are motorized and controlled either manually or automatically, and can be driven by solar tracking technology.

Figure 38: Dynamic shading device

On the exterior, operable systems are less commonly used than fixed systems, due to higher maintenance and vulnerability in windy conditions. Ideally, best applications are found in double-skin façade systems, a rapidly emerging technology, where accessibility is easier and weather protection allows for more lightweight solutions (Figure 39).

Figure 39: Exterior Operable shading device

Interstitial systems

Integrated with the insulated glazing unit, operable louvers are located between the glass panes. Louvers are rotated, raised, and lowered electrically (Figure 40). This clean, tidy solution with good accessibility lends itself to application in health care environments.

Figure 40: Operable louvres located between glass

Internal shading systems

Fixed interior shades or operable roller shade systems (Figure 41) are typically used for filtering light to mitigate glare or to ensure thermal comfort against direct solar radiation that has escaped the exterior shading devices. Internal shades use fabrics with various levels of transmissivity to reduce heat radiation and provide thermal comfort and glare protection.

Using internal shading alone, without automated daylight control systems, should not be a primary strategy for improving energy performance. They can, however, be used for improving thermal comfort. Interior light shelves can also act as internal shades, but they are not a recommended choice in health care facilities due to cleanability issues.

Figure 41: Internal shading system

2.7. Artificial Lighting – Electric Lighting

Energy-efficient lighting in a health care setting is possible without sacrificing the visual needs and comfort of patients and caregivers. There are also potentially beneficial health effects of exposing patients and staff to daylight in many settings. When properly designed, a positive synergy of energy conservation and improved health is possible.

2.7.1. Light-coloured interior finishes

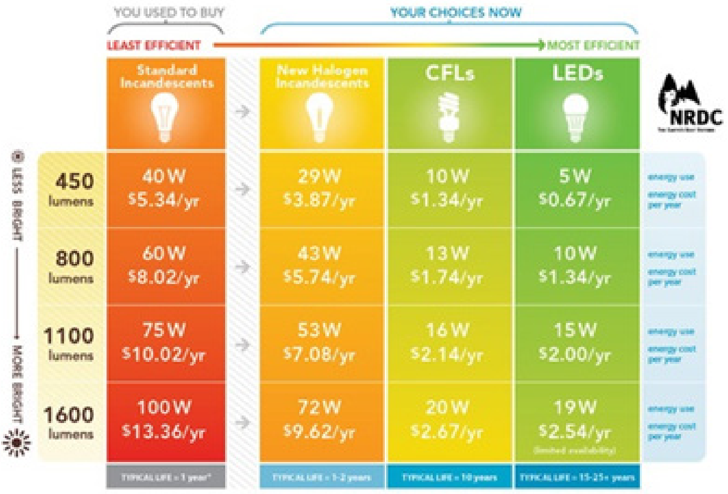
For electrical lighting to be most efficient, spaces must have light-coloured finishes. Ceiling reflectance should be at least 85 percent for direct lighting schemes and preferably at least 90 percent for indirect and daylighting schemes. This generally means using high-performance white acoustical tile or high-reflectance white ceiling paint on hard surfaces. For daylighting schemes, the average reflectance of the walls should be at least 50 percent, and for the portions of the wall adjacent to the daylighting aperture and above 2.1 metres high it should be 70 percent. This generally means using light tints for the wall surface, as the lower reflectance typical of doors, trim, and other objects on the walls will reduce the average. Floor surface reflectance should be at least 20 percent, for which there are many suitable surfaces.

The shape and finish of the ceiling should also be considered. A flat or gradually sloped ceiling is the most efficient; steep sloping ceilings and exposed structures, even if painted white, may have significantly lower reflectance.

2.7.2. LED lighting

LED lighting uses up to 50 percent less energy than incandescent bulbs (Figure 42). At low power levels, the difference is even larger. Bright LED flood lamps, for example, use only 11 to 12 watts while creating a light output comparable to a 50-watt incandescent bulb. Hence, it is recommended to install LED lighting rather than incandescent, compact fluorescent, linear fluorescent, or metal halide.

Figure 42: LED versus other lighting choices

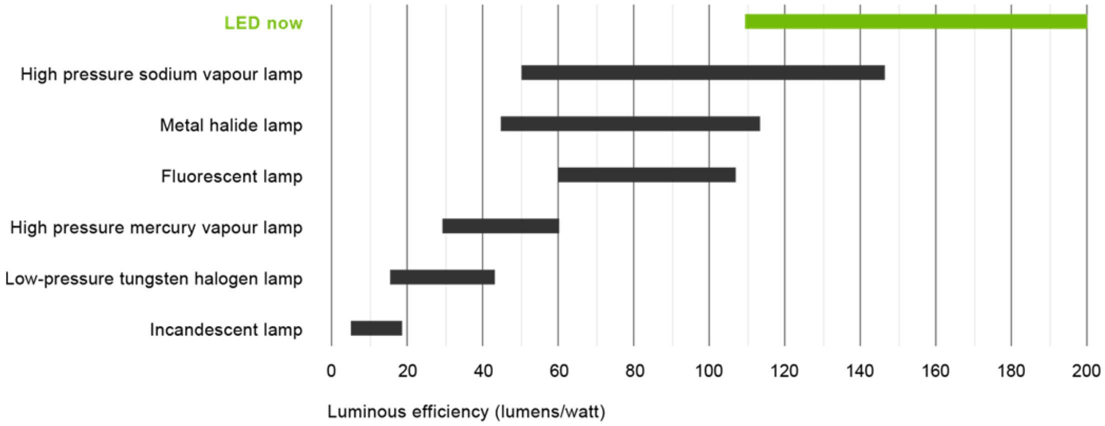


	Standard Incandescents	New Halogen Incandescents	CFLs	LEDs	
450 lumens	40 W $5.34/yr	29 W $3.87/yr	10 W $1.34/yr	5 W $0.67/yr	energy use energy cost per year
800 lumens	60 W $8.02/yr	43 W $5.74/yr	13 W $1.74/yr	10 W $1.34/yr	energy use energy cost per year
1100 lumens	75 W $10.02/yr	53 W $7.08/yr	16 W $2.14/yr	15 W $2.00/yr	energy use energy cost per year
1600 lumens	100 W $13.36/yr	72 W $9.62/yr	20 W $2.67/yr	19 W $2.54/yr (limited availability)	energy use energy cost per year
	TYPICAL LIFE = 1 year*	TYPICAL LIFE = 1-2 years	TYPICAL LIFE = 10 years	TYPICAL LIFE = 15-25+ years	

LED is the only light source that satisfies all the criteria in terms of efficiency, colour rendering index, correlated colour temperature, and lamp life.

As Figure 43 shows, LED fixtures offer the best lighting technology available in terms of efficacy, with energy savings in the range of 30–90 percent. Moreover, LED bulbs have a longer lamp life (40,000 to 60,000 hours).

Figure 43: Lighting technology efficacy (lumens/watt)



Adequate lighting levels are crucial in health care facilities, as they have a direct impact on patient health and mood and also on limiting energy consumption. Table 15 presents the ASHRAE Standard 90.1–2004 of the recommended minimum illumination (Lux) levels in hospitals. The following values can easily be met by LED fixtures.

Table 15: Illumination levels in hospitals (ASHRAE/IESNA Standard 90.1.)

Area	Recommended Min. Illumination (Lux)
Bathroom	100 - 150
Entrance-Hall	200
Consultation room	100
Corridor, General	300
Ward	150 - 300
Delivery Room	400
Diagnostic X ray, Work place	300
Doctors' office	300
Enquiry office	500
Nursing station (Day)	300
Nursing station (Night)	30 - 100
Kitchen	300
Laboratory, Pathology	300 - 500
Maternity Department	400
Operating Theatre	10,000 - 50,000
Store	100
Pharmacy	300
Scrub room, operating rooms	300
Mortuary	200

Moreover, LED lighting has an excellent colour rendering index (CRI), reaching 70 to 100 CRI, which makes them suitable for use in health care facilities and very effective in improving the medical diagnosis of patients.

Finally, it is important to provide lighting with a well correlated colour temperature (Table 16) to provide comfort, which is also a characteristic of LED technologies.

Table 16: Colour temperature ranges

Temperature (K)	Colour	Description
2,000 - 3,500	Orange/Yellow	Ultra Warm or Warm White
3,500 - 5,000	Paper White	Natural/Neutral White
5,100 - 6,500	Bluish White	Cool White

(Source: Montes de Oca, 2017)

2.7.3. Exit signs

Use LED exit signs or other sources that use less than 5 W per face. The selected exit sign and source should provide the proper luminance to meet all building and fire code requirements.

2.8. General lighting control strategies

To maximize the energy performance of a facility, lighting control strategies should be adopted to optimize how lights are turned on, when and how lights are turned off, and the output level of the lights whenever they are operating. The optimum electric light level in a given space is dependent on the task or activity in the space, the user's personal preference or desired aesthetic, and the amount of daylight in the space. Typically, the highest potential for lighting energy savings in a hospital is to adjust the lighting to optimum levels whenever the lights are turned on. Another prime light control strategy for most public spaces, corridors, waiting rooms, etc. is daylighting control, where electric light levels are automatically adjusted to supplement the available daylight in a space throughout the day.

2.8.1. Occupancy-based control

Use occupancy sensors in all common areas that are not regularly occupied, including but not limited to: parking spaces; common lobbies, circulation areas, and stairs; all exam and treatment rooms; staff support spaces for nutritional care; medication areas; clean and soiled utility rooms; offices; mechanical rooms; restrooms; and storage rooms. Unless otherwise recommended, occupancy sensors should be set for medium to high sensitivity and a 15-minute time delay (the optimum time to achieve energy savings without excessive loss of lamp life). In high-performance integrated lighting control systems, motion sensors can also be used in spaces that have little if any traffic during late-night hours. If light levels are automatically dimmed late at night, motion sensors can be used to raise light levels in public corridors, waiting rooms, and other spaces whenever someone approaches and occupies the space.

2.8.2. Wall controlled dimming and switching

In patient care spaces, the controls for switching and dimming of the lighting system (and motorized window shades, if provided) should be readily accessible by patients, their families, and support staff. In these applications, low-voltage multifunction wall controls with appropriate labelling should be considered. In non-patient-care areas, the controls should be located where they are easily accessible and understandable by the caregiving staff.

In general use spaces, lighting should be controlled by a time-of-day scheduling system or occupancy sensors. Wall controls should be provided for manual override and should be placed in remote locations for use by the staff only.

2.8.3. Time clock control

In some common spaces, such as waiting rooms, time-of-day scheduling controls can be used to ensure that lights are on when desired and are reduced or turned off after hours when not required. In spaces that have significant daylighting, such as an entry lobby, time-of-day scheduling can be used to reduce the artificial lighting output or turn off some interior lights during the day.

For exterior lighting, use an astronomical time switch with an exterior photocell for all exterior lighting. Turn off exterior lighting not designated for security purposes when the building is unoccupied. If a building energy management system is being used to control and monitor mechanical and electrical energy use, it can also be used to schedule and manage outdoor lighting energy use.

2.8.4. Daylight harvesting control

In atriums, lobbies, waiting rooms, corridors, open-office and administration areas, and other appropriate spaces, automated daylight harvesting controls that are able to dim or switch electric lighting in response to changing daylight availability can be used to regulate the output of electric lights to optimize the quality of the visual environment while saving significant amounts of energy. Daylight harvesting controls may be considered in patient room applications, especially for the lighting zones nearest the windows. However, patient control of their environment is an overriding priority, and automatic controls should not override the ability to manually control the lights. This makes the potential energy savings challenging to quantify.

2.9. Plug and phantom loads

Plug loads are devices or appliances that plug into a 120/208 volt receptacle. Some plug loads in a medical facility may include computers, DVD players, VCRs, printers, scanners, copiers, fax machines, radios, microwaves, coffee pots, desktop lights, stoves, refrigerators, vending machines, smart boards, vocational equipment and tools, soda machines, drinking fountains, and many other devices.

Phantom loads, also known as 'standby power' or 'leaking electricity', are when a device consumes energy even when the switch indicates the device is off. Equipment with electronic clocks or timers or remote controls, portable equipment, and office equipment with wall cubes (small boxes that plug into an AC outlet to charge cell phones or provide power to computers) all have phantom loads. Phantom loads can consume up to 5 percent of an electrical plug load. To reduce plug and phantom loads, consider controlling the top outlet of each duplex outlet in selected locations with the occupancy sensor used to control the lighting in the room. The best direct way to control these loads is to unplug them when not in use. In lieu of directly unplugging the item, all these items can be plugged into a power strip that is switched off at the end of each day, over the weekend, and during holidays and vacations. Create a personal appliance policy and conduct constant energy awareness training on equipment and appliance use.

Each hospital should develop an equipment management plan along the following lines:
1. Use laptops as much as possible because they are more efficient than desktops. Recommended minimum number of laptops is two thirds of all computers.
All others should be mini desktop computers.
2. Specify all computers, other equipment (e.g., vending machines with LED) and appliances as ENERGY STAR® rated.
3. Install network controls with power saving modes and monitoring during unoccupied hours or an IT power management programme (e.g., to switch off screens in outpatient areas at night).
4. Install time switches in water coolers, coffee makers, small appliances to ensure automatic shut off during unoccupied hours.

03

HVAC

3.

HVAC

The mission of health care facilities is to provide an environment for healing patients. HVAC systems must support this primary mission and be dependable day to day, hour to hour. The challenge is how to provide reliable systems that meet all of the various health care-specific criteria and use less energy.

Based on the ASHRAE 90.1 standard for new buildings, mechanical equipment and systems serving the heating, cooling, or ventilating needs of new buildings shall comply with the requirements as described in Section 6.2 of the ASHRAE 90.1 standard. Although many types of HVAC systems could be used in health care facilities, it is assumed that one of the following types is to be used to reduce energy use compared to the baseline systems.

3.1. Load calculations

It is important to start the HVAC design by properly calculating the heat and cooling loads for each hospital to determine an optimized HVAC system in terms of sizing and application. Accurate equipment sizing is crucial to reduce utility costs and improve dehumidification performance:

- The design cooling and heating loads must be calculated in accordance with generally accepted engineering standards and handbooks.
- Safety factors should be applied cautiously to prevent oversizing of compressors and other types of equipment to prevent inefficiencies. Oversized compressors, for example, have limited ability to reduce capacity at part-load conditions, which can cause short cycling. This in turn limits the system’s ability to dehumidify and causes large changes in Saturated Air Temperature, which may affect occupant comfort.
- Cooling and heating load calculations must include the conditioning of outdoor air as well as lighting and plug loads.

Below are various components that can create heat gains/losses and affect the load calculations:

- Heat gains or losses by the walls: Walls of the conditioned space gain or lose heat by conduction. The amount of heat depends on the wall material and its thermal conductivity value, as well as its alignment with the sun direction.

- Heat gains or losses by roof and partitions: If the roof is exposed directly to the sun, it absorbs maximum heat. If there is another room above the air-conditioned space, then the amount of heat gained by the roof reduces. The heat gains and losses by the partitions of the conditioned space depend upon the type of partition.

- Heat gains or losses by the windows: Windows are directly exposed to the surrounding environment, and heat from the sun enters the room by radiation. If there are sufficient curtains on the windows and an external awning, the amount of heat gained by radiation reduces. The type and U-value of the window glass also affects the amount of heat gained through the windows by radiation.

- Heat generated by occupants: The people inside the space in question generate lots of heat. It is important to take into consideration the level of activity of these occupants as heat dissipated from working people is higher than from sitting people.

- Heat generated by electrical equipment: Heat generated by electrical appliances and equipment such as lights, motors, coffeemakers, electronic equipment, biomedical equipment, etc. should also be considered for heat load calculations, which is also called cooling load calculations.

- Heat gains or losses from outside air: Depending on the seasons, outside air can be at a greater or lower temperature than the room temperature. When this air comes inside the room, it brings in a certain amount of heat or it causes a loss of heat.

3.2. Air ventilation

3.2.1. Ventilation requirements

Ventilation air assists in maintaining acceptable indoor air quality and offsets the amount of exhausted air to maintain building pressure. It is air induced into the building either naturally (via open windows) or by mechanical means. Project teams and health care organizations need to select an appropriate balance between ventilation and energy that best aligns with the goals of the project.

A first step is determining the ventilation code or set of criteria that will be used for the design. For example, outpatient diagnostic and treatment facilities have different ventilation criteria and standards than surgical suites and hospitals. The most common term used to refer to the amount of outside air that needs to be introduced into a building is Air Changes per Hour (ACH). The ACH can vary widely depending upon what is going on inside the building. The following Tables are the ventilation requirements for areas affecting patient care in hospitals in compliance with the ANSI/ASHRAE/ASH Standard 170-2021 for Ventilation in Health Care Facilities, taken from "Guidelines for Environmental Infection Control in Health -Care Facilities" (2003).

Surgery and critical care

Area designation	Minimum air changes of outdoor air per hour	Minimum total air change per hour
Operating/surgical cystoscopic rooms	3	15
Delivery room	3	15
Recovery room	2	6
Critical and intensive care	2	6
Newborn intensive care	2	6
Treatment room	–	6
Trauma room	3	15
Anaesthesia gas storage	–	8
Endoscopy	2	6
Bronchoscopy	2	12
ER waiting rooms	2	12
Triage	2	12
Radiology waiting rooms	2	12
Procedure room	3	15

Nursing

Area designation	Minimum air changes of outdoor air per hour	Minimum total air change per hour
Patient room	2	6
Toilet room	-	10
Newborn nursery suite	2	6
Protective environment room	2	12
Airborne infection isolation room	2	12
Isolation alcove or anteroom	-	10
Labour/delivery/recovery	2	6
Labour/delivery/ recovery/ postpartum	2	6
Patient corridor	-	2

Ancillary/Radiology

Area designation	Minimum air changes of outdoor air per hour	Minimum total air change per hour
X-ray (surgical/critical care and catheterization)	3	15
X-ray (diagnostic & treatment)	-	6
Darkroom	-	10

Laboratory

Area designation	Minimum air changes of outdoor air per hour	Minimum total air change per hour
General	–	6
Biochemistry	–	6
Cytology	–	6
Glass washing	–	10
Histology	–	6
Microbiology	–	6
Nuclear medicine	–	6
Pathology	–	6
Serology	–	6
Sterilizing		10
Autopsy room11	–	12
Non-refrigerated body-holding room	–	10
Pharmacy	–	4

Diagnostic and treatment

Area designation	Minimum air changes of outdoor air per hour	Minimum total air change per hour
Examination room	–	6
Medication room	–	4
Treatment room	–	6
Physical therapy and hydrotherapy	–	6
Soiled workroom or soiled holding	–	10
Clean workroom or clean holding	–	4
Pharmacy	–	4

Sterilizing and supply

Area designation	Minimum air changes of outdoor air per hour	Minimum total air change per hour
ETO-sterilizer room	–	10
Sterilizer equipment room	–	10

Central medical and surgical supply

Area designation	Minimum air changes of outdoor air per hour	Minimum total air change per hour
Soiled or decontamination room	–	6
Clean workroom	–	4
Sterile storage	–	4

3.2.2. Exhaust air

Exhaust air systems in health care facilities are typically more extensive than those in other types of facilities to provide both odour and infection control. In many cases, the amount of air exhausted from a room is chosen to create negative air pressure relative to the adjacent rooms, lowering the potential for airborne transmission of odour and contaminants.

The following from ASHRAE/ASHE Standard 170 lists rooms that require exhaust:
- ER waiting
- Triage
- ER decontamination
- Radiology waiting
- Toilet room
- Airborne infection isolation room
- Physical therapy
- Bathing room
- Locker room
- Darkroom
- Bronchoscopy
- Sputum collection

- Medical gas storage
- Pentamidine administration
- Laboratory
- Endoscope cleaning
- Hydrotherapy
- Sterilizer equipment room
- Soiled or decontamination areas
- Ware washing
- Laundry
- Soiled linen sorting storage
- Linen and trash chute room
- Janitor closet or room
- Hazardous material storage

The following are some requirements on how to save energy in exhaust systems:

- Provide motorized dampers that open and close with the operation of the fan.
- Locate the damper as close as possible to the duct penetration of the building envelope to minimize conductive heat transfer through the duct wall and avoid having to insulate the entire duct.
- For fans that are interlocked with air handling systems, be sure to keep the exhaust fans off and dampers closed during unoccupied periods, even if the HVAC system is operating to maintain setback or setup temperatures.
- Consider designing exhaust ductwork to facilitate recovery of energy from Class 1 and Class 2 (e.g., restroom) exhaust air (ASHRAE Standard 62.1-2007).

3.2.3. Exhaust air energy recovery

Exhaust ductwork should incorporate heat recovery from exhaust air. Heat recovery systems pre-heat incoming cold air as it enters the ventilation system using treated warm exhaust air as it leaves the building. For reasons of hygiene, heat recovery from exhaust air from labs, fume hoods, nuclear medicine, or vivarium and autopsy spaces should not be incorporated.

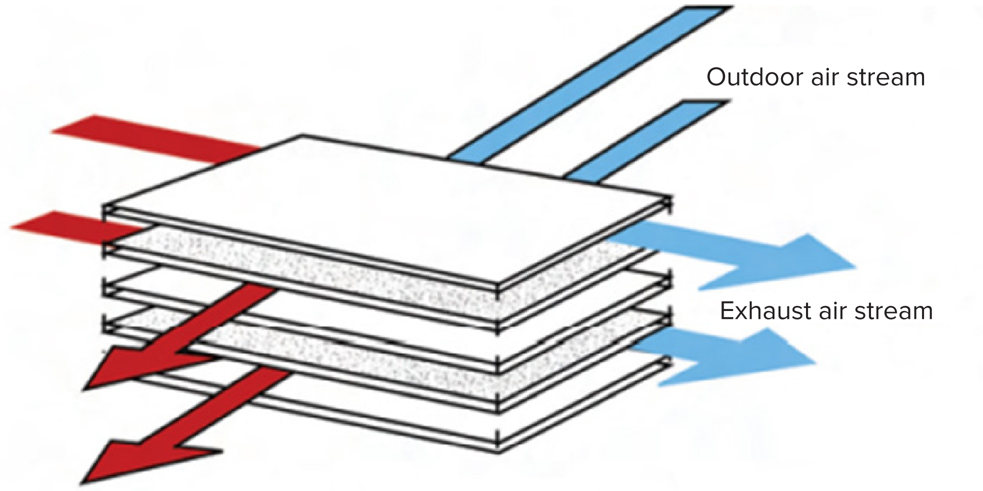
With the use of an enthalpy wheel, exhaust air recovery systems can reduce the humidification and dehumidification load by transferring moisture from exhaust air to dry outdoor air or by transferring moisture from humid outdoor air to exhaust air. It is recommended to select HVAC systems that use exhaust air energy recovery that account for only a partial reduction in the outdoor air heating and cooling loads caused by the energy recovery equipment.

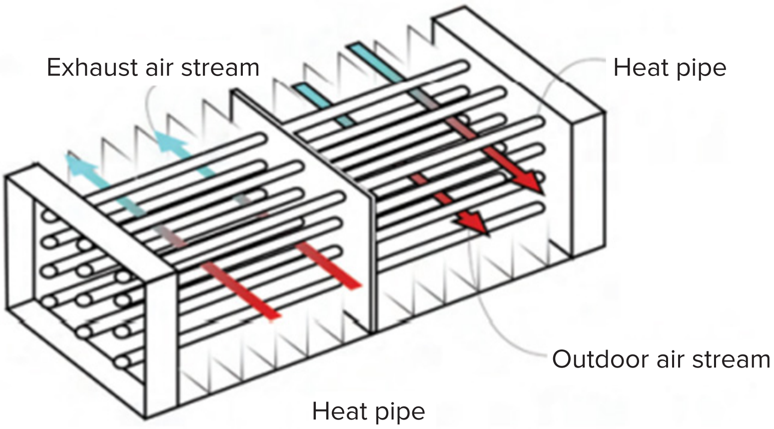
Common examples of energy recovery devices include coil loops (run-around loops), fixed-plate heat exchangers, heat pipes, and sensible energy rotary heat exchangers or sensible energy wheels. An exhaust-air energy recovery device can be packaged in a separate energy recovery ventilator (ERV) or a dedicated outdoor air unit that conditions the outdoor before it enters the air-conditioning unit, or the device can be integral to the air-conditioning unit.

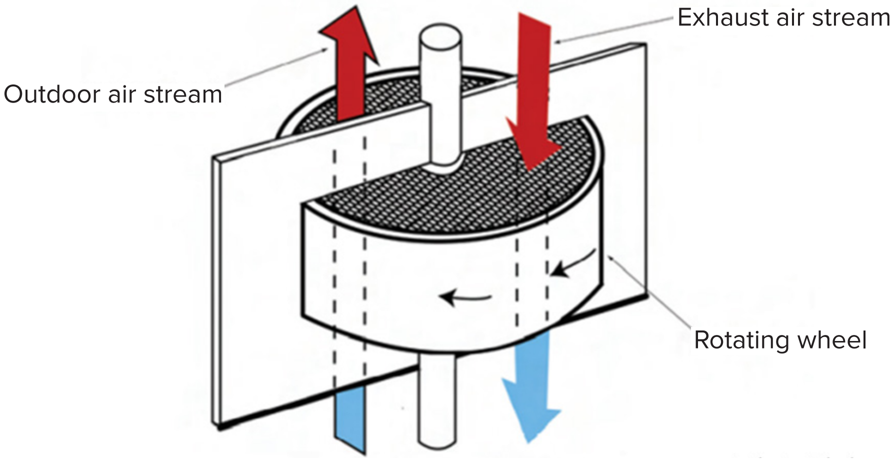
For maximum benefit should be considered:

- The system should be provided with as close to balanced outdoor and exhaust airflows as is practical, taking into account the need for building pressurization and any exhaust that cannot be ducted back to the energy recovery device. Exhaust for energy recovery may be taken from spaces requiring exhaust (using a central ducted exhaust system for each unit) or directly from the return airstream (as with a unitary accessory or integrated unit).
- Where an air-side economizer is used along with an ERV, add bypass dampers (or a separate outdoor air path) shall be added to prevent airflow through the recovery device, thereby reducing the air-side pressure loss during economizer mode.
- The ERV should be turned off during Economizer mode to avoid adding heat to the outdoor airstream.
- Where energy recovery is used without an air-side economizer, the ERV should be controlled to prevent the transfer of unwanted heat to the outdoor airstream during mild outdoor conditions.
- Caution should be exercised when applying rotating wheel type recovery devices (Figure 44) to critical care spaces because of the controversial concern about the possibility of cross contamination of dirty exhaust air to the clean air side of the device. This type of device is not recommended for exhaust from isolation rooms or other locations where infectious patients may be housed, because of the potential for cross-contamination of exhaust air into the outdoor airstream.

Figure 44: Cross-flow fixed plate heat exchanger, heat pipe, rotary heat exchanger (wheel)







3.3. Energy efficient HVAC systems

3.3.1. Chilled-water system

Central cooling and heating systems are recommended in large hospital buildings and complexes where there is a high density of energy use. Surgical areas typically have a central air handling system, as no fan-coils or room HVAC equipment are allowed in surgical areas for hygienic reasons. Typical means of production of cold water for these systems include water-cooled chillers, water circulation pumps, cooling towers, heat recovery systems, and equipment fans. When considering a central chiller plant, refer to Table 17 for minimum recommended efficiencies.

Table 17: Minimum equipment cooling, heating, and ventilation efficiency

	All Zones
Water-cooled chillers	6.5 COP
Cooling tower	VSD on fans
Air-cooled chiller efficiency	Meet or exceed ASHRAE/IES Standard 90.1 (ASHRAE 2016b) requirements: <150 tonnes; 10.1 EER; 13.7 IPLV @ AHRI conditions. <150 tonnes; 12.2 EER; 15.5 NPLV @ 55°F chilled water temperature VSD compressor control
Water circulation pump CHW	VSD & >16 W/gpm

(Source: "Energy and Resource Efficiency in Hospitals and Healthcare Facilities," 2021)

Very small systems with a total system pumping power of 10 HP or less may be designed for constant flow, but the use of modulating control valves and variable frequency drives should be considered for both energy reduction and controllability reasons.

3.3.2. Variable refrigerant flow

When considering small health care facilities, it is recommended to employ variable refrigerant flow (VRF) systems, which vary the flow of refrigerant to indoor units based on demand. This ability to control the amount of refrigerant that is provided to fan-coil units located throughout a building makes the VRF technology ideal for applications with varying loads or where zoning is required. VRF systems are available either as heat pump systems or as heat recovery systems for those applications where simultaneous heating and cooling is required. In addition to providing superior comfort, VRF systems offer design flexibility, energy savings, and cost-effective installations.

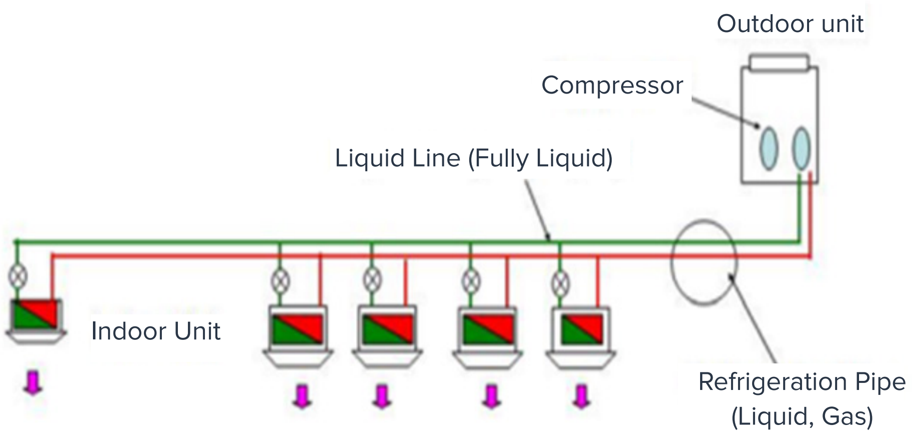
In a VRF system, multiple indoor fan-coil units may be connected to one outdoor unit. The outdoor unit has one or more compressors that are inverter driven, so their speed can be varied by changing the frequency of the power supply to the compressor. As the compressor speed changes, so does the amount of refrigerant delivered by the compressor. Each indoor fan-coil unit has its own metering device that is controlled by the indoor unit itself, or by the outdoor unit. As each indoor unit sends a demand to the outdoor unit, and the outdoor unit delivers the amount of refrigerant needed to meet the individual requirements of each indoor unit (Figure 45).

In terms of hospitals, three micro-environments need special heating or cooling requirements:

- Administrative areas;
- Office areas,
- Critical care environments, such as isolation rooms, surgery centres, etc.

All these areas require high air changes per minute in order to be in compliance with the regulations. For a hospital to have accreditation it must prove it has an HVAC system that can provide sterile air and very close temperature and humidity control.

Figure 45: Variable refrigeration flow system schematic



Cooling Mode: Expansion = Indoor Unit Liquid Line + Condensed Liquid

Heating Mode: Expansion = Outdoor Unit Liquid Line + Condensed Liquid

All VRF systems provide energy savings by varying compressor speed and matching the output of the system as closely as possible to the load. In addition, VRF systems do not experience the same energy losses as systems that move conditioned air through ductwork. However, differences in design in the available outdoor units will influence the efficiency level that is achieved. Table 18 presents the design requirements for VRF air conditioners.

Table 18: Electrically operated variable refrigerant flow air conditioners - Minimum efficiency requirements (ASHRAE Standard 90.1)

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Conditions	Minimum Efficiency
VRF air conditioners, air cooled	< 65,00 BTU/h	All	VRF multi-split system	13.0 SEER
	>= 65,00 BTU/h and <135,000 BTU/h	Electric resistance (or none)	VRF multi-split system	11.2 EER 3.1 IEER (before 2017) 15.5 IEER (as of 2017)
	>= 135,000 BTU/h and <240,000 BTU/h	Electric resistance (or none)	VRF multi-split system	11.0 EER 12.9 IEER (before 2017) 14.9 IEER (as of 2017)
	>= 240,000 BTU/h	Electric resistance (or none)	VRF multi-split system	10.0 EER 11.6 IEER (before 2017) 13.9 IEER (as of 2017)

3.3.3. Heat pumps

Water source heat pump

In water source heat pump systems (WSHP), a separate WSHP is used for each thermal zone. The components are factory designed and assembled and include a filter, fan, refrigerant-to-air heat exchanger, compressor, refrigerant-to-water heat exchanger, and controls (see Figure 46).

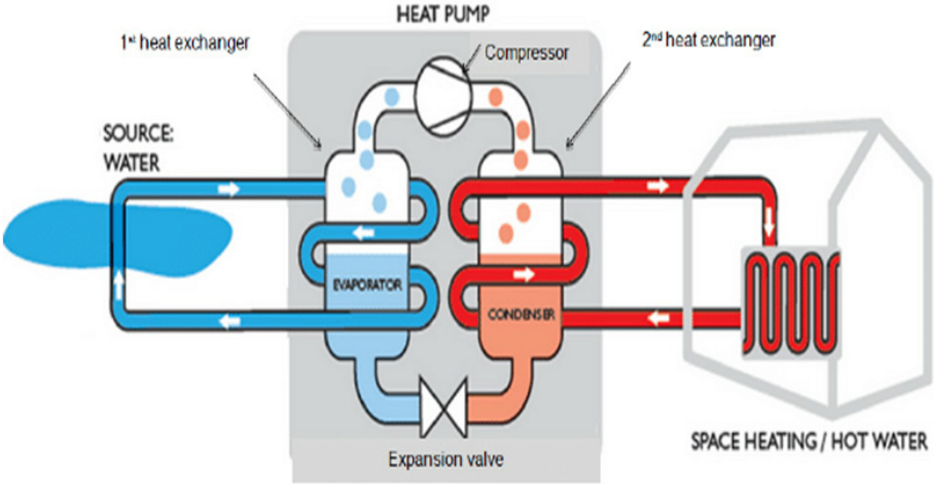
The refrigeration cycle is reversible, allowing the same components to provide cooling or heating. The equipment should be located to meet the acoustical goals of the space; permit access for maintenance; and minimize fan power, ducting, and wiring. This may require that the WSHPs be located outside of the space.

WSHP systems are applied in four common configurations:

- Fluid-cooler and boiler systems
- Ground-loop systems with tubing located in vertical wells
- Pond systems with tubing at the bottom of a pond
- Hybrid systems that use a fluid cooler to minimize the cost of the well field,

In traditional WSHP systems, all the heat pumps are connected to a common water loop. A cooling tower (or fluid cooler) and a water boiler are also installed in this loop to maintain the temperature of the water within a desired range, typically between 15.5°C and 32°C.

Figure 46: Water source heat pump



For water source heat pumps utilizing a building water loop, a minimum efficiency required is based on the size of the equipment, as outlined in Table 19.

Table 19: Minimum water source heat pump efficiency requirements (ASHRAE Standard 90.1)

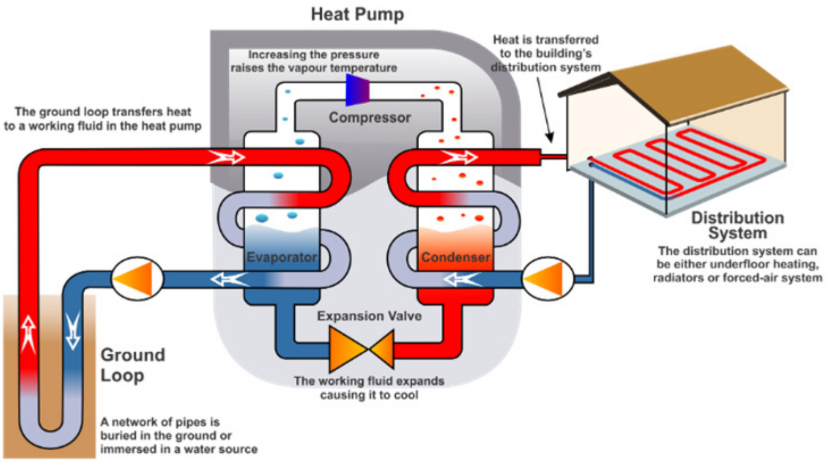
Equipment Type	Size Category	Subcategory or Rating Conditions	Minimum Efficiency
Water source (heating mode)	< 135,000 Btu/h (cooling capacity)	680F entering water	4.3 COP
	≥135,000 Btu/h and < 240,000 Btu/h (cooling capacity)	680F entering water	2.9 COP
Water source (cooling mode)	≥65,000 Btu/h and < 135,000 Btu/h	860F entering water	13.0 EER
Water source water-to-water (cooling)	< 135,000 Btu/h	860F entering water	10.6 EER
Water source water-to-water (heating mode)	< 135,000 Btu/h (cooling capacity)	680F entering water	3.7 COP

A variation of this system takes advantage of the earth's relatively constant temperature and high heat capacity and uses the ground instead of the cooling tower and boilers.

Ground source heat pump

Ground source heat pump (GSHP) systems (Figure 47) primarily do not reject heat; they store it in the ground for use at a different time. During the summer the heat pumps extract heat from the building and transfer it to the ground. When the building requires heating, this stored heat is transferred from the ground to the building. This offers the potential to reduce (or often eliminate) the energy used by a cooling tower and/or boiler.

Figure 47: Ground source heat pump



Larger hospitals which have great cooling needs most of the time may be better served by pond systems that reject heat in a better manner than absorbing it. Well systems can present some limitations when there's a great difference between their net heat gain and losses, as the net energy transfer must be done through the perimeter of the well field which is limited by the relatively low conductivity of the ground.

Outdoor air is conditioned and delivered by a separate, dedicated ventilation system. This may involve ducting the outdoor air directly to the inlet or outlet duct for each heat pump, delivering it in close proximity to the heat pump intakes, or ducting it directly to the occupied spaces. Depending on the climate, the dedicated outdoor air system may include components to filter, cool, heat, dehumidify, and/or humidify the outdoor air. In many applications, some form of heat recovery is used to reduce the energy associated with tempering (or reheating) the dehumidified outdoor air. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE Standard 90.1) includes minimum efficiency requirements for ground source heat pumps (Table 20).

Table 20: Minimum ground source heat pump efficiency requirements (ASHRAE Standard 90.1)

Equipment Type	Size Category	Subcategory or Rating Condition	Efficiency
Ground source (cooling mode)	< 135,000 Btu/h	77ºF entering water	14.1 EER
Ground source (heating mode)	< 135,000 Btu/h (cooling capacity)	32ºF entering water	3.2 COP

3.3.4. Fan coils

Non-surgical areas may be HVAC treated with many different systems, such as the fan-coil system with fresh air served from an all-fresh air–air handling unit with heat recovery. Fan coils are typically installed in each conditioned space (often under the window), in the ceiling plenum above the corridor (or some other noncritical space), or in a closet adjacent to the space.

As shown in the Figure 48, the system typically receives chilled and hot water from a chiller with or without cooling tower, boiler or heat pump and water circulation pumps. Cooling is provided by a centralized water chiller, while heating is provided by either a centralized boiler or by electric resistance heat located inside each fan coil. As with the previous recommendation, Table 21 includes the minimum energy efficiency requirement for these systems.

Figure 48: Fan coil Unit system schematic

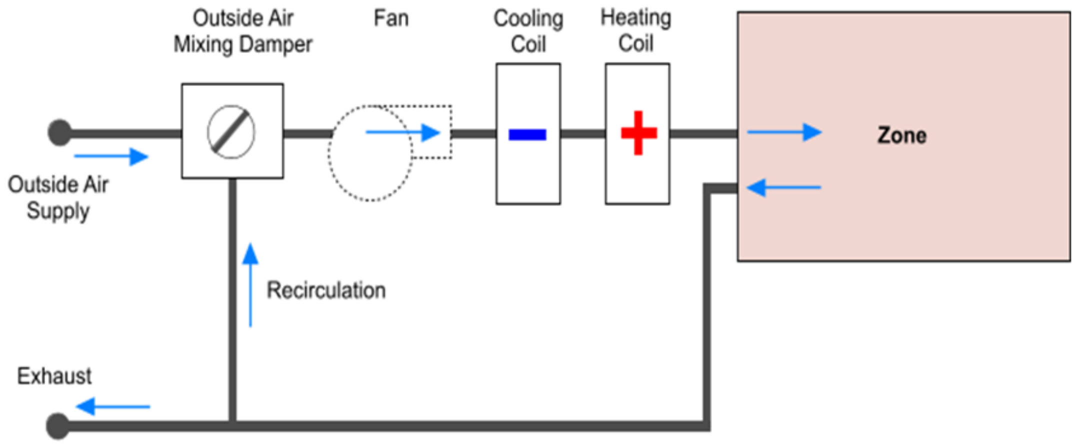


Table 21: Minimum system efficiency

Climatic Zone	All zones
Fan coil efficiency	<0.3 W/cfm at design
Air handling heat recovery min fan efficiency	Recommended specific fan power 1.7
Boiler efficiency	Over %92 efficiency
Water-cooled chillers	6.5 COP
Cooling tower	VSD on fans
Air-cooled chiller efficiency	Meet or exceed ASHRAE/IES Standard 90.1 (ASHRAE 2016b) requirements: <150 tonnes; 10.1 EER; 13.7 IPLV @ AHRI conditions. <150 tonnes; 12.2 EER; 15.5 NPLV @ °55F chilled water temperature VSD compressor control

(Source: “Energy and Resource Efficiency in Hospitals and Healthcare Facilities,” 2021)

Outdoor air is conditioned and delivered by a separate dedicated ventilation system. This may involve ducting the outdoor air directly to each fan coil or ducting it directly to the occupied spaces.

For fan coil units, the dedicated outdoor air system should be designed to dehumidify the outdoor air so that it is dry enough to offset the latent loads in the spaces. This helps avoid high indoor humidity levels without additional dehumidification enhancements in the fan coil units (FCUs). Alternatively, fan coils could be equipped with multiple-speed or variable-speed fans for improved part-load dehumidification (this is only possible in spaces where there is no minimum air change rate requirement); or reheat coils (much less energy efficient) could be added for direct control of space humidity. Recovered heat, such as condenser or solar heat, can be used when using reheat.

Many areas of health care facilities are required to maintain humidity levels below 60 percent RH, especially operating theatres according to ASHRAE/ASHE Standard 170. For FCUs, the dedicated outdoor air system should be designed to dehumidify the outdoor air enough to offset the latent loads. This helps avoid high indoor humidity levels without additional dehumidification enhancements in the FCUs. If the outdoor air requirement is low and/or the space latent loads are high, the dedicated outdoor air source may be required to supply air at a lower dew point than traditional systems, either by overcooling and using recovered energy for reheat (if needed) or by employing desiccant technology.

It is recommended to use high efficiency electronically commutated (EC) fan motors, which offer comparatively low energy consumption and higher efficiency compared to Alternating Current (AC) induction motors. Claims suggest Electronically Commutated fan coil units use up to 70 percent less energy than traditional products, and that a specific fan power of 0.3Watts/liter/second or lower can be achieved (compared to a specific fan power of 0.7Watts/liter/second for an Alternating Current fan coil unit) with the introduction of the Electronically Commutated motor.

3.4. Ductwork design, construction, and insulation

Good duct design practices result in lower energy use. Low pressure loss and low air leakage in duct systems are critical to lowering overall fan energy. Designers should re-evaluate fitting selection practices using the ASHRAE duct fitting database, which contains more than 220 fittings that can significantly affect pressure loss.

Poor fan performance is most commonly caused by improper outlet connections, non-uniform inlet flow, and/or swirl at the fan inlet. Look for ways to minimize the fan/duct system interface losses, referred to as the system effect losses. The use of flexible duct should be limited because these ducts will use more fan energy than a metal duct system.

All supply and return ducts installed as part of an HVAC air distribution system should be thermally insulated in accordance with Table 22. The following ductwork should be insulated (as defined by ASHRAE/IESNA Standard 90.1):

- All supply air ductwork
- All outdoor air ductwork
- All exhaust and relief air ductwork between the motor-operated damper and penetration of the building exterior
- All ductwork located in unconditioned spaces or outside the building envelope
- All ductwork located in attics, whether ventilated or unventilated
- All ductwork buried either outside the building or below floors

In addition, all airstream surfaces should be resistant to mold growth and erosion according to the requirements of ASHRAE Standard 62.1.

Table 22: Minimum duct insulation R-values, combined heating and cooling supply ducts and return ducts (ASHRAE Standard 90.1)

Climate Zone	Exterior	Unconditioned Space *	Indirectly Conditioned Space**	Buried
1 and 2	R-1.06	R-0.62	none	R-0.62
3 and 4	R-1.41	R-0.62	None	R-0.62

** Includes crawlspaces, both ventilated and non-ventilated.*

*** Includes return air plenums with or without exposed roofs above.*

Insulation R-values, measured in m2 K/W, are for the insulation as installed and do not include film resistance. The required minimum thickness does not consider water vapour transmission and possible surface condensation. Where exterior walls are used as plenum walls, wall insulation shall be required by the most restrictive condition of Section 6.4.4.2 or Section 5 of the ASHRAE standards. Insulation resistance measured on a horizontal plane in accordance with ASTM C518 at a mean temperature of 23.9°C at the installed thickness.

3.5. Zoning

Zoning is using separate air systems for different departments, which may be indicated to:
1- Compensate for exposures because of orientation or for other conditions imposed by the building configuration
2- Minimize recirculation between departments
3- Provide flexibility of operation
4- Simplify provisions for operation on emergency power
5- Conserve energy

Ducting the air supply from several air-handling units into a manifold gives central systems some standby capacity. When one unit is shut down, air is diverted from noncritical or operated areas to accommodate critical areas that must operate continuously. This or other means of standby protection is essential if the air supply is not to be interrupted by routine maintenance or component failure.

Separating supply, return, and exhaust systems by department is often desirable, particularly for surgical, obstetrical, pathological, and laboratory departments. The desired relative balance in critical areas should be maintained by interlocking supply and exhaust fans. Thus, exhaust should cease when supply airflow is stopped in areas otherwise maintained at positive or neutral pressure relative to adjacent spaces. Likewise, supply air should be deactivated when exhaust airflow is stopped in spaces maintained at a negative pressure.

04

PLUMBING AND HOT WATER

4.
PLUMBING AND HOT WATER

This guide covers systems that use oil for generating Hot water in addition to the use of solar or site-recovered energy (including heat pump water heaters). These systems may be used to achieve 30 percent (or greater) energy savings over ASHRAE/IESNA Standard 90.1. Many factors come into play in making a decision of the most efficient system, including availability of service, installation cost, utility costs, operator familiarity, and the impact of source energy use. Efficiency recommendations are provided to allow for choice.

4.1. Sizing and location

The water heating system should be sized to meet the anticipated peak hot water load, stated both in gallons per minute (gpm) and gallons per hour (gph). Plumbing codes include a supply fixture unit (SFU) sizing method that yields peak building gpm. In the SFU method, each hot-water-using fixture or appliance is assigned an SFU value.

The SFU values are totalled for the entire building, and then a diversity factor is applied to arrive at expected peak gpm. Where instantaneous water heaters are used, sizing is based on peak gpm. If peak gpm can be met, instantaneous water heaters will have excess capacity at all other lower demand periods. Storage type water heaters are sized using the manufacturer’s published first-hour delivery capacity, which is a combination of storage capacity and recovery capacity. If a storage water heater system can meet the largest hourly demand, the storage water heaters will have excess capacity at all other lower demand periods. Hourly hot water demand is calculated by assigning each hot-water-using fixture an expected hourly usage and then applying a diversity factor. For both instantaneous and storage type systems, timing of peak functional area usage should be analysed. For example, peak kitchen or laundry hot water use may not coincide with peak shower demand. Water heater capacity may be reduced based on this analysis. Health care facilities cannot operate without hot water. Should a facility be forced to close because of a lack of hot water, unacceptably high losses, both in revenue and reputation, would be incurred. Because of this, diversity must be evaluated and included in the design. At least two water heaters should be in the base design. Common diversity factors would be 50 percent, 100 percent, or N+1.

Health care facilities have a relatively high density of hot-water-using plumbing fixtures, located throughout the building, so it is usually not possible to locate the water heater satisfactorily close to all hot water demand points. Because of high service hot water usage and many demand points, health care facilities typically use a recirculating service hot water system. One notable exception is a multi-suite medical office building where, to simplify the lease, each tenant is held responsible for his or her own service hot water needs.

If a recirculating service hot water system is used, the optimum water heater location is at the building water service entrance, near the water softeners (if required), minimizing overall piping costs. Due to the premium cost for space at a water entrance room, another common location is in a remote mechanical room (a penthouse for example). Combustion air and flue gas exhaust venting requirements for gas water heaters need to be reviewed and for aesthetic reasons may dictate the location. Heat tracing on hot water supply piping may be used to satisfy code or user requirements, and advantages are noted for future remodelling projects. Disadvantages of heat tracing include maintenance and limited product lifetime. Heat tracing lends itself to longer ‘dead-legs’ and, where waterborne bacterial control is an issue, heat tracing applications should be carefully reviewed.

4.2. Energy efficient systems

4.2.1. Heat pump

In general, hospital hot water systems operate 24 hours a day all year round. Heat-pump hot water systems use a refrigeration cycle to extract heat from the surrounding air. They then use a heat exchanger to heat water in an insulated storage cylinder. These systems work in a similar way to reverse-cycle air conditioners when run on a heating cycle, but heat water instead of the air inside your home. Unlike solar hot water systems, heat-pump systems do not have an electric or gas boosting system. But they do use electricity to operate the evaporator fan and compressor when they are heating water. These systems typically use around 60–75 percent less electricity than a conventional electric hot water system because the electricity is used to operate the heat pump and does not heat the water directly with an element.

Heat pumps are by far more efficient than boilers, which significantly reduces the energy demand. Energy demand is also reduced thanks to the higher efficiency of a heat pump relative to a boiler.

Table 23 indicate performance requirements for a heat pump by ASHRAE 90.1 standard.

Table 23: Performance requirements for water heating equipment (heat pump)

Equipment Type	Subcategory or Rating Condition	Size Category (Input)	Performance Required
Electric water heaters	≤24 amps and ≤ 250 volts	Heat pump	0.93-0.00132V EF

To achieve energy efficiency, it is recommended to use domestic hot water heat pumps with a Seasonal Coefficient of Performance (SCOP) of 2.33.

4.2.2. High-efficiency oil condensing boilers

High-efficiency oil condensing boilers usually operate at about a 95% efficiency level and can achieve a 98% efficiency levels in some cases. When boilers are used, consider specification of 'point of use' water heaters rather than central heating systems to avoid energy losses from long pipework runs.

By converting fuel oil into heat, oil condensing boilers are highly efficient. They extract nearly all of the heat contained in the flue gases, turning this into additional heating energy and therefore minimizing waste.

Table 24 presents the minimum efficiency requirements for oil fired boilers from ASHRAE 90.1 standard (Table 6.8.1–6)

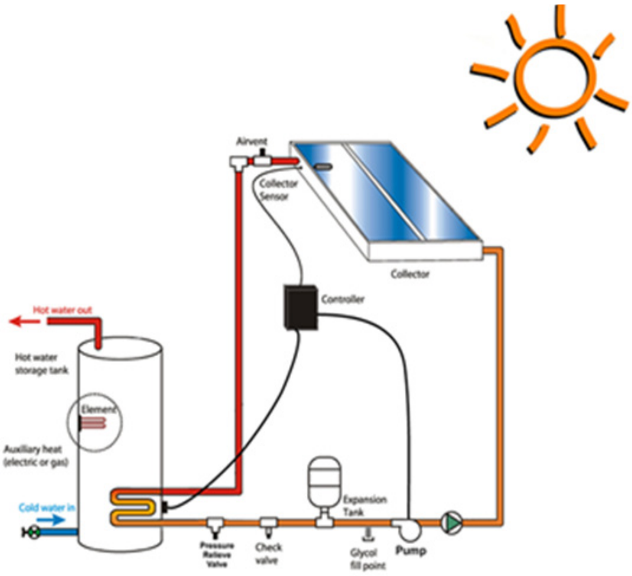
Table 24: Oil-fired boilers – minimum efficiency requirement

Equipment Type	Subcategory or Rating Condition	Size Category (Input)	Minimum Efficiency	Efficiency as of 3/2/2020
Hot water Boiler	Oil fired	< 300,000 BTU/h	84 % AFUE	84 % AFUE
		≥ 300,000 BTU/h and ≤2,500,000 BTU/h	82 % Thermal efficiency	82 % Thermal efficiency
		≥ 2,500,000 BTU/h	84 % combustion efficiency	84 % combustion efficiency

4.2.3. Solar water heater

Essentially a solar water heater system uses the sun to heat water in collectors mounted on a roof or some raised south-facing façade (Figure 49). The heated water is then stored in a tank not unlike a conventional electric or gas water heater tank. Solar water heating systems consist of a solar collector and a storage tank connected by two pipes. In the solar collector, the sun's energy is converted to heat in the liquid in the solar collector's channels. This liquid transports the heat through a pipe to the storage tank, where the heat is transferred to the water in the heat exchanger.

Figure 49: Solar water heater schematic



The points below describe the main activities required for the installation of new solar water heating systems.

- Supply and installation of solar panels
- Supply and installation of circulating pumps
- Supply and installation of booster filling pump with pressure kit
- Supply and installation of differential controller with all necessary sensors
- Supply and installation of data logger with online monitoring system
- Supply and installation of copper pipes
- Supply and installation of pipes insulation
- Supply and installation of pipes insulation with aluminum jacketing
- Supply and installation of PPR (Polypropylene) cold pipes
- Supply and installation of an uninterruptible power supply
- Supply of solar panels as spare parts
- Supply of safety valves as spare parts

- Supply of circulating pump as spare parts
- Supply of temperature sensors as spare parts
- Supply of antifreeze glycol as spare parts

The solar collectors should be installed on a concrete flat roof area and unshaded south exposure. The steel structure should have a tilt angle ranging between 30° and 45°.

4.3. Piping insulation

All pipes installed as part of a cooling, heating, or service hot water distribution system must be thermally insulated in accordance with Table 25 to achieve energy efficiency.

Table 25: Minimum pipe insulation thickness (ASHRAE Standard 90.1)

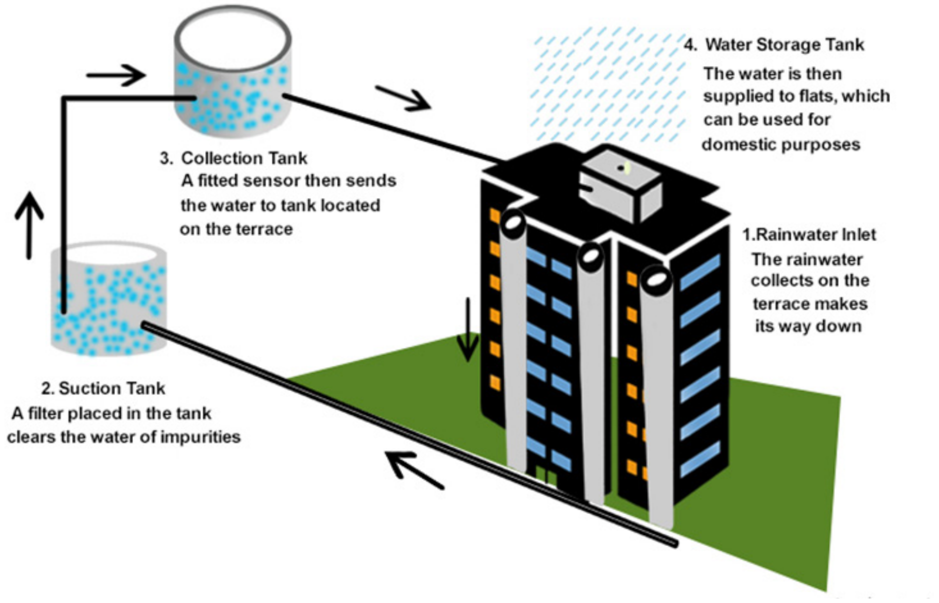
FLUID OPERATING TEMPERATURE RANGE (F°)	INSULATION CONDUCTIVITY			NOMINAL PIPE DIAMETER (in inches)				
				<1		1 to <1.5		1.5 to <4
	Conductivity (in Btu-in/h per ft2 (°F)	Mean Rating Temperature (°F)		INSULATION THICKNESS REQUIRED (in inches)				
Space heating, service water heating systems (steam, ,steam condensate, refrigerant, space heating service hot water)				Minimum pipe insulation required (Thickness in inches or R-value)				
Above 350	0.32-0.34	250	Inches	4.5	5	5	5	5
			R-value	R37	R41	R37	R27	R23
251-350	0.29-0.32	200	Inches	3	4	4.5	4.5	4.5
			R-value	R24	R34	R35	R26	R22
201-250	0.27-0.30	150	Inches	2.5	2.5	2.5	3	3
			R-value	R21	R20	R17.5	R17	R14.5
141-200	0.25-0.29	125	Inches	1.5	1.5	2	2	2
			R-value	R11.5	R11	R14	R11	R10
105-140	0.22-0.28	100	Inches	1	1.5	1.5	1.5	1.5
			R-value	R7.\	R12.5	R11	R9	R8

FLUID OPERATING TEMPERA-TURE RANGE (C°)	INSULATION CONDUCTIVITY			NOMINAL PIPE DIAMETER (no inches)						
				<1		1 to <1.5		1.5 to <4	4 to<8	8 and larger
	Conductivity (in Btu-in/h per ft^2 (°F)	Mean Rating Temperature (°C)		INSULATION THICKNESS REQUIRED (in inches)						
Space cooling systems (chilled water, refrigerant, and brine)										
5-15	0.21-0.27	23	Inches	0.5	0.75	0.5	0.75	1	1	1
			R-value	R3	R6	R3	R5	R7	R6	R5
Below 5	0.20-0.26	10	Inches	1		1.5		1.5	1.5	1.5
			R-value	R8.5		R14		R12	R10	R9
These thickness are based on energy efficiency considerations only. Issues such as water vapor permeability or surface condensation sometimes require vapor retarders or additional insulation										

4.4. Rainwater harvesting

Rainwater harvesting (see Figure 50) in health care facilities has the potential to save thousands of litres of water every year, which can result in substantial cost savings and contribute to alleviating storm water run-off.

Figure 50: Rainwater harvesting schematic



Systems supplying water for toilet flushing in the health care market are always designed with the ultimate safety in mind. UV filtration is used, with ultra-fine particle filters. Multiple break tanks are often used to deliver the water so there is absolutely no loss of service should any maintenance work need to be carried out. Several types of rainwater harvesting systems are possible:

- **Water butt**
  - This is the most basic form of rainwater harvesting where water collects in the container from the drain pipes and/or natural rainfall.

- **Direct-pumped**
  - Submersible – Mostly used for domestic purposes, the pump is located within the storage tank and is pumped directly to the water closets or other fixtures and appliances.
  - Suction – This type of system is commonly used in health care facilities where the pump system is kept within a control unit (e.g., utility room) and a draw-line pulls water from the storage tank directly to the water closets or other fixtures.

- **Indirect gravity**
  - With this arrangement, water is pumped to a high-level tan (header tank) and then allowed to supply the outlets by gravity alone. The pumps will only be required when the tank needs filling.

- **Indirect pumped**
  - This system first pumps the harvested water to a tank that can be located at any level in the facility. Then a booster pump is used to provide a pressurized supply, which can be tailored to suit the floor and pressure demands of the facility.

- **Gravity only**
  - This system is only possible where the storage tank can be located below the level of the gutters, yet higher than the outlets that it will supply. Only the power of gravity is needed to feed collected and filtered water, making it a desirable and ultra-energy efficient option.

The following components are needed for wain water harvesting.

a. Leaf separator and mosquito proofing

- Filters are needed to prevent sediment build-up and clogging from large debris, such as leaves and twigs. All downpipes from the roof to the rainwater tanks must be provided with a self-cleaning leaf separator and all inlet pipes must be equipped with screens.
- All overflow pipes from cisterns or storage tanks must be secured with mosquito screens and affixed with tie straps or clamps.
- The use of non-corrosive or non-deteriorating materials must be considered in Lebanon’s tropical climate. Vinyl-coated screens work well and do not corrode.

- Pipe inlets into storage tanks must be properly sealed with silicone to prevent mosquito infestation.

b. First flush diverters: Also known as a roof washer, this system diverts the first flow of water away from the rainwater catchment system to ensure cleaner water into the tanks.

c. UV disinfection: If the rainwater is required to be of a potable standard or where there is a risk of contamination, this is usually done using ultra-violet light treatment coupled with additional fine sediment filtration.

d. Gutter systems

- To collect rainwater efficiently, the guttering system must be both well designed and well maintained.
- Trapezoidal or K-style guttering systems provide the greatest capacity for water catchment.

e. Water level indicators: There are two basic water level indicator mechanisms:

- A pulley and rope mechanism requires an extra hole in the tank for the rope, so care must be taken to prevent mosquitoes entering/leaving by adding a rubber seal around the punctured hole through which the rope fits tightly.
- A second method involves a clear tube attached at the bottom of the tank and visible on the outside, with a red floater to indicate water level. However, there is the risk that if the tube becomes damaged the tank could empty. Also, the tube might develop algae growth and the floater might then get stuck. Using a tight-fitting floater is needed; otherwise mosquitoes will breed in the tube.

f. Maintenance of components:

- Once adequate filtration is present, sediment build-up will be minimal and maintenance times will be reduced as a result.
- Filter cleaning will need to be completed at regular intervals and should include annual cleaning of down spout and gutter screens. Pump filters should also be thoroughly cleaned yearly.

g. Water storage tanks

- The tank size is important given that a larger tank can potentially store more water after a downpour but will incur a higher initial cost, and for much of the time it will be only partly full. It may also place limitations on the property, especially for above-ground tanks, and may not be aesthetically pleasing.
- The smaller the roof size and the lower the annual rainfall, the less the volume of water to be collected. For facilities with no beds, a minimum of 10 imperial gallons per square foot of roof catchment area times three days for capacity may be used to adequately size the storage tanks. This information can be compared with water data collected and analysed and/or water usage calculations of the facility.

- The placement of water tanks is critical, especially when they must be located below the guttering system. Another concern is the weight of the water tanks and the structure available the handle the weight. A roof void may seem to be an ideal location but may not be structural feasible, keeping in mind that every 1,000 litres of water weighs one ton.
- Proper overflow drainage from the water storage tanks must be considered to prevent erosion.
- Tank security is important when it is exposed to high winds, potential theft, and contamination. A cable assembly of vertical restraints can provide seismic and wind restraint; and the tank can be enclosed in a concrete structure or secured by adequate fencing to deter theft.

4.5. Water efficiency

In addition to rainwater harvesting, it is important to find energy efficient practices to save on water consumption. Hospitals are water-intensive facilities that use water for cooling equipment, plumbing fixtures, landscaping, and medical process rinses. Operational costs and environmental impacts are highly influenced by water use; thus, implementing water-efficient practices is crucial to achieve savings of up to 20 percent with little or no investment cost required.

Hospital facility managers can benefit from employing water-efficient practices through operational improvements and upgraded equipment. For example, high-performing equipment and fixtures are now available that use at least 20 percent less water than standard models.

Sanitary fixtures should comply with all of the following:

- Install WaterSense labelled showerheads, toilets, bathroom faucets, and flushing urinals where appropriate. WaterSense labelled products have been independently certified to be at least 20 percent more water-efficient and perform as well or better than standard models.

- Check automatic sensors on faucets, toilets, and urinals to ensure they are operating properly and avoid unnecessary water use. The automatic shutoff mechanism also reduces the risk of sink overflow due to a faucet being left on either inadvertently or deliberately. Automatic faucets are water-saving devices that help save 70 percent of the water that would otherwise be unused. Other benefits of automatic faucets include inhibiting the spread of germs that are known to thrive on faucet handles, as well as helping to prevent or mitigate scalding incidents caused by hot water.

05

ELECTRIC EQUIPMENT

5.

ELECTRIC EQUIPMENT

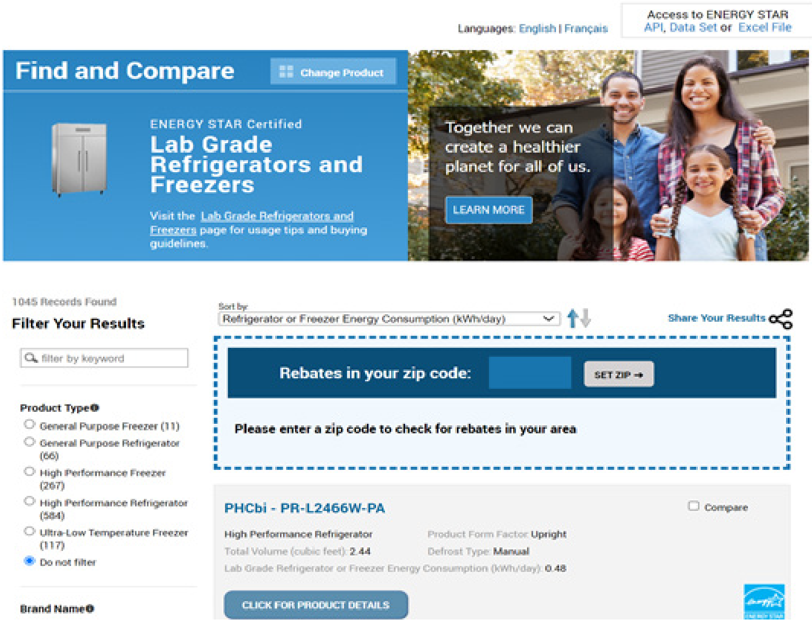
5.1. Medical equipment

Health care facilities include various kinds of equipment contributing to different processes within the same building. Some of this equipment may be for dietary purposes, office use, and data centres. Other equipment performs medical functions, either directly (as in an imaging machine) or indirectly (as in a sterilizer). There is also an overlap between process loads and plug loads (infusion pumps, otoscopes, blood pressure cuffs, monitoring equipment, computers used for electronic health records that also plug into 120 V receptacles).

Where appropriate, use energy control methods for these loads. In addition, consider the following measures:

- Do not use once-through water cooling for equipment; a large percentage of overall energy use goes towards processes related to potable water.
- Do not use film systems for imaging equipment.
- For all medical and other kinds of equipment that are not associated with HVAC systems, and for which no ENERGY STAR® label is available (Figure 51), use only equipment that is among the 25th percentile of lowest energy consumers for that class of equipment. Compare equipment performance using continuous (or standby) mode electrical energy consumption and heat rejection.

Figure 51: ENERGY STAR® energy comparison website for lab grade refrigerators and freezers



Languages: English | Français

Access to ENERGY STAR API, Data Set or Excel File

Find and Compare

Change Product

ENERGY STAR Certified

Lab Grade Refrigerators and Freezers

Visit the Lab Grade Refrigerators and Freezers page for usage tips and buying guidelines.

Together we can create a healthier planet for all of us.

LEARN MORE

1045 Records Found

Filter Your Results

filter by keyword

Product Type

○ General Purpose Freezer (11)
○ General Purpose Refrigerator (66)
○ High Performance Freezer (267)
○ High Performance Refrigerator (584)
○ Ultra-Low Temperature Freezer (117)
● Do not filter

Brand Name

Sort by: Refrigerator or Freezer Energy Consumption (kWh/day)

Share Your Results

Rebates in your zip code: SET ZIP →

Please enter a zip code to check for rebates in your area

PHCbi - PR-L2466W-PA ☐ Compare

High Performance Refrigerator
Product Form Factor: Upright
Total Volume (cubic feet): 2.44
Defrost Type: Manual
Lab Grade Refrigerator or Freezer Energy Consumption (kWh/day): 0.48

CLICK FOR PRODUCT DETAILS

- Select the devices that match the needed workflow of the hospital.
- Do not oversize the needed specs of the equipment by more than 30 percent of the actual need as laboratory equipment is in continuous evolution.
- Select laboratory, blood bank, and pharmacy refrigerators and freezers that are classified A+ or above for a better energy consumption.
- Select X-ray machines that are approved as high efficient equipment with recent improved technologies that consume less energy than older versions
- Install a central steam boiler and connect sterilizers without internal steam generators.
- Avoid oversized and undersized sterilizers and washers.
- Create charging docking stations for drug pumps, ECG machines, and ventilators inside each department to centralize and optimize the power management of these devices when not used.

5.2. High-performance kitchen equipment

While most outpatient health care facilities do not have a full-service commercial kitchen, the small hospitals included in the scope of this guide will have various components of a full commercial kitchen. The general strategy for minimizing energy use in commercial kitchens includes the following steps.

Minimize exhaust and ventilation energy use:

Design the exhaust ventilation system with proper layout of cooking equipment and the proper hood design to minimize total airflow while still providing sufficient exhaust flow.

After minimizing ventilation needs, consider variable-speed exhaust hood flow systems. The specification of the exhaust hood within the design of a commercial kitchen typically falls under the scope of the food service consultant, whereas the design and specification of the ductwork, exhaust fan, and makeup air side of the system falls under the mandate of the mechanical engineer. This requires sufficient collaboration and communication between the food service consultant and the mechanical engineer.

Additional opportunities can include makeup air energy recovery. A number of resources are available from the Food Service Technology Center (FSTC) with links and guidance on efficient design for commercial kitchens. The FSTC is the industry leader in commercial kitchen energy efficiency and appliance performance testing. The following design guides provide additional guidance for energy efficiency, specifically for the kitchen ventilation system:

- Design Guide 1: Improving Commercial Kitchen Ventilation System Performance – Selecting and Sizing Exhaust Hoods. Design Guide 1 covers the fundamentals of kitchen exhaust and provides design guidance and examples.
- Design Guide 2: Improving Commercial Kitchen Ventilation System Performance – Optimizing Makeup Air. Design Guide 2 augments Design Guide 1, with an emphasis on the makeup air side of the equation.

Select energy-efficient kitchen equipment

Energy efficient equipment selection include:

- Cooking equipment – including dishwashers, freezers (solid door), fryers, hot food holding cabinets, ice machines, refrigerators (solid and glass door), and steamers – should be specified ENERGY STAR® rated or an equivalent internationally recognized standard (e.g., EU energy labelling).
- Select low-flow hot water fixtures to minimize both water use and hot water energy use.
- Refrigeration equipment should have at least 15cm insulation on low-temp walk-in equipment, insulated floor, LED lighting, floating-head pressure controls, liquid pressure amplifier, subcooled liquid refrigerant, and evaporative condenser.
- Exhaust hoods should include long overhangs, local air supply compensation and be variable air volume type. Exhaust flow to vary based on cooking activity level (e.g., steam sensor).

5.3. High-performance laundry equipment

The size of textile care operations can vary greatly between the types and sizes of health care facilities they are designed to support. Hospitals have significant laundering needs that usually run about 2 percent of their total operating budget. Tunnel washers, ironers with feeders and folders, washers with high-speed extract, ozone laundry systems, water reuse systems, and improved linen management systems can all significantly lower water, energy, labour, and linen replacement costs. New technology, better management, and larger state-of-the-art equipment can use far less water and energy to clean linen, as compared to older, traditional laundering methods.

Conventional commercial washers consume approximately 37.5 litres of hot water per kg of laundry processed. New water-conserving commercial washers consume approximately 7.5 litres of hot water per kg of laundry. These improvements in washer efficiency will add up to sizable water and energy savings over time.

Ozone laundry washing systems can dramatically reduce the amount of water and energy used for textile care each day. Ozone and its derivatives are powerful oxidizers that replace many of the chemicals normally used in traditional laundering methods. Water must be cold for ozone to dissolve into it, and the colder the water is, the more efficiently it works. These rules are what provide the exceptional energy savings that can be delivered by an effective ozone laundry system.

Another important characteristic of commercial washers is the amount of water removed or extracted during the spin cycle. Extraction efficiency is a function of the gravitational force (g-force) generated in the washer drum. Standard washers generate a g-force of only about 85g. High-performance washers generate over 350g. Water retained after extraction in a traditional slow-speed (85g) machine is roughly 87.5 percent of the dry weight of the laundry. Washers with high-speed extract can reduce the water remaining in the linen to around 50 percent of the dry weight. The use of ozone and the elimination of many of the traditional chemicals in the wash can enhance extraction efficiency and reduce water weight retention even further.

It takes approximately 2,000 BTUs to evaporate one pound of water. Therefore, the more water removed from the linen before it goes into the ironer or dryer, the more energy saved drying the linen. Shorter dryer cycles equate to substantial energy savings. On average, high-performance washers use about 25 percent more electricity than standard slow-speed extract washers, but they more than make up for this increased electricity use by offsetting hot water and drying energy use. In general, because dryers are direct-fired appliances, sending both heated air and products of combustion through the bin containing the clothes to be dried, there are very few efficiency differences among them. Adding insulation to a dryer will help retain heat and lower energy consumption, and microprocessor-controlled timers and moisture sensors can prevent over drying and save a substantial amount of energy over time. The key to reducing dryer energy consumption the most is to reduce the retained moisture content of the linen before it is put through the dryer cycle.

5.4. ENERGY STAR® equipment

For all equipment being purchased for the building for which ENERGY STAR® (Figure 52) qualified equipment is available, the project should include only ENERGY STAR® qualified equipment.

The following equipment mentioned in Table 26 and appliances that are commonly found in health care facilities have ENERGY STAR® labels.

Table 26: Energy Star Equipment

Product	Items
Appliances	• Battery chargers • Clothes washers • Dishwashers • Refrigerators and freezers • Water coolers • Ice makers
Heating and Cooling	• Air-source heat pumps • Boilers • Central air conditioners • Ceiling fans • Dehumidifiers • Furnaces • Geothermal heat pumps • Programmable thermostats • Fans
Electronics	• Cordless phones • Combination units (TV/VCR/DVD) • DVD products • Audio • Televisions • VCRs
Office Equipment	• Computers • Copiers • Fax machines • Laptops • Mailing machines • Monitors • Multifunction devices • Printers • Scanners
Lighting	• LED • Ceiling fans

Commercial Food Service	• Commercial fryers • Commercial hot-food holding cabinets • Commercial solid-door refrigerators and freezers • Commercial steam cookers
Other Products	• Transformers • Vending machines

Figure 52: ENERGY STAR® label