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2.1 SWRL
Design Strategies

Sun, Wind, Rain & Light
Architectural Design Strategies

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R.G.CHAN & ASSOCIATES
ARCHITECTS ENGINEERS ENVIRONMENTAL PLANNERS
888 City Camp Road Baguio City, 2600 Philippines

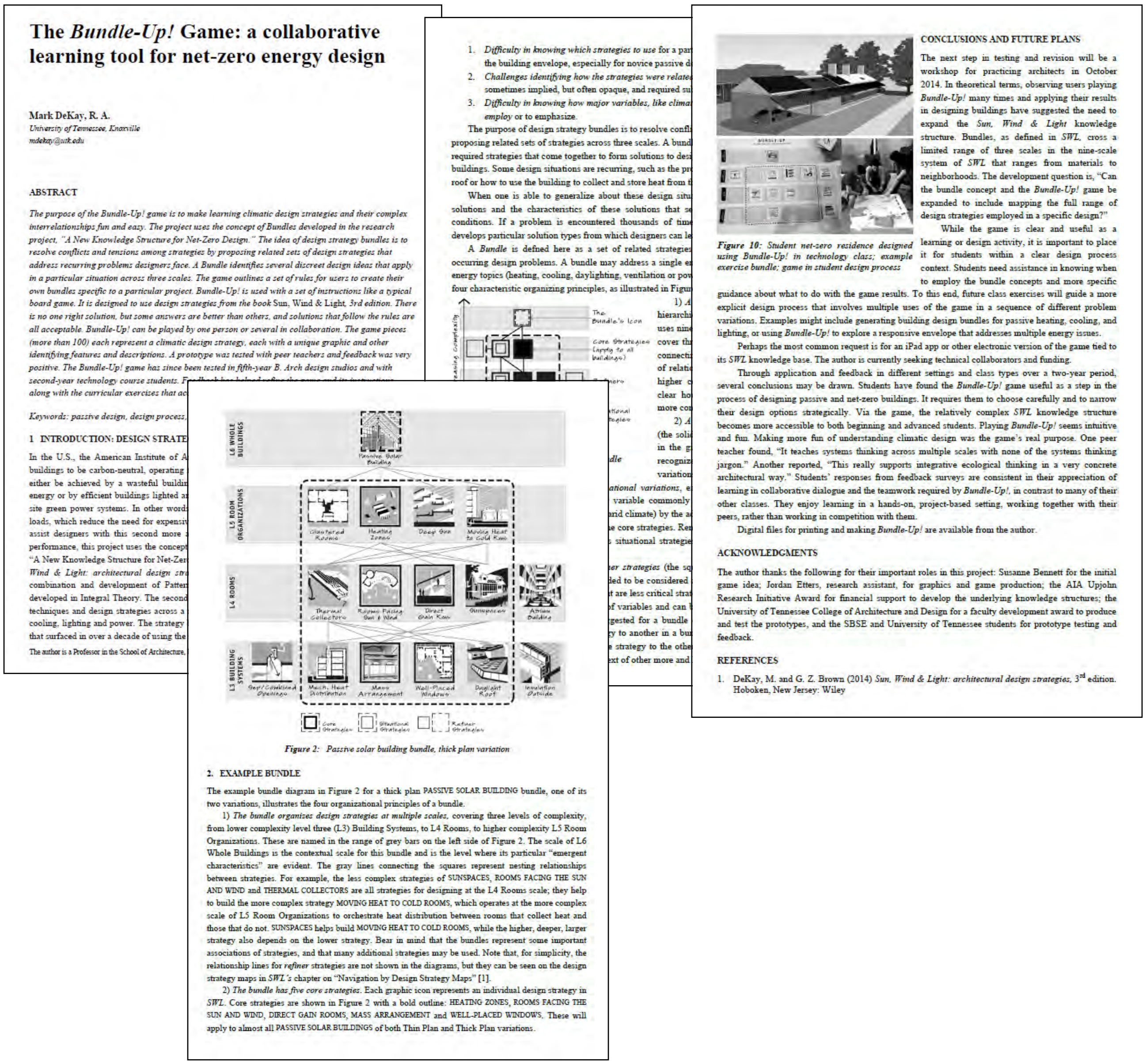
Table of Contents

ABOUT THE SERIES

This pdf file-binding is part of the
NZB.RGChan.Series on foundational researches undertaken by
R.G.CHAN & Associates for in-house office use, towards
systematic steps for Net Zero Building Design of projects.

Contextualization

This report draws inspiration from the documentation on the "Bundle-Up!" Game: a collaborative learning tool for Net-Zero Energy Design by Archt. Mark DeKay. The game is designed to use strategies from the book Sun, Wind & Light, 3RD Edition.



The *Bundle-Up!* Game: a collaborative learning tool for net-zero energy design

Mark DeKay, R. A.
University of Tennessee, Knoxville
mdekay@utk.edu

ABSTRACT

The purpose of the Bundle-Up! game is to make learning climatic design strategies and their complex interrelationships fun and easy. The project uses the concept of Bundles developed in the research project, "A New Knowledge Structure for Net-Zero Design." The idea of design strategy bundles is to resolve conflicts and tensions among strategies by proposing related sets of design strategies that address recurring problems designers face. A Bundle identifies several discreet design ideas that apply in a particular situation across three scales. The game outlines a set of rules for users to create their own bundles specific to a particular project. Bundle-Up! is used with a set of instructions like a typical board game. It is designed to use design strategies from the book Sun, Wind & Light, 3rd edition. There is no one right solution, but some answers are better than others, and solutions that follow the rules are all acceptable. Bundle-Up! can be played by one person or several in collaboration. The game pieces (more than 100) each represent a climatic design strategy, each with a unique graphic and other identifying features and descriptions. A prototype was tested with peer teachers and feedback was very positive. The Bundle-Up! game has since been tested in fifth-year B. Arch design studios and with second-year technology course students.

Figure 2: Passive solar building bundle, thick plan variation

2. EXAMPLE BUNDLE

The example bundle diagram in Figure 2 for a thick plan PASSIVE SOLAR BUILDING bundle, one of its two variations, illustrates the four organizational principles of a bundle.

1) *The bundle organizes design strategies at multiple scales,* covering three levels of complexity, from lower complexity level three (L3) Building Systems, to L4 Rooms, to higher complexity L5 Room Organizations. These are named in the range of grey bars on the left side of Figure 2. The scale of L6 Whole Buildings is the contextual scale for this bundle and is the level where its particular "emergent characteristics" are evident. The gray lines connecting the squares represent nesting relationships between strategies. For example, the less complex strategies of SUNSPACES, ROOMS FACING THE SUN AND WIND and THERMAL COLLECTORS are all strategies for designing at the L4 Rooms scale; they help to build the more complex strategy MOVING HEAT TO COLD ROOMS, which operates at the more complex scale of L5 Room Organizations to orchestrate heat distribution between rooms that collect heat and those that do not. SUNSPACES helps build MOVING HEAT TO COLD ROOMS, while the higher, deeper, larger strategy also depends on the lower strategy. Bear in mind that the bundles represent some important associations of strategies, and that many additional strategies may be used. Note that, for simplicity, the relationship lines for *refiner* strategies are not shown in the diagrams, but they can be seen on the design strategy maps in *SWL's* chapter on "Navigation by Design Strategy Maps" [1].

2) *The bundle has five core strategies.* Each graphic icon represents an individual design strategy in *SWL*. Core strategies are shown in Figure 2 with a bold outline: HEATING ZONES, ROOMS FACING THE SUN AND WIND, DIRECT GAIN ROOMS, MASS ARRANGEMENT and WELL-PLACED WINDOWS. These will apply to almost all PASSIVE SOLAR BUILDINGS of both Thin Plan and Thick Plan variations.

Figure 10: Student net-zero residence designed using Bundle-Up! in technology class; example exercise bundle; game in student design process

CONCLUSIONS AND FUTURE PLANS

The next step in testing and revision will be a workshop for practicing architects in October 2014. In theoretical terms, observing users playing *Bundle-Up!* many times and applying their results in designing buildings have suggested the need to expand the *Sun, Wind & Light* knowledge structure. Bundles, as defined in *SWL*, cross a limited range of three scales in the nine-scale system of *SWL* that ranges from materials to neighborhoods. The development question is, "Can the bundle concept and the *Bundle-Up!* game be expanded to include mapping the full range of design strategies employed in a specific design?"

While the game is clear and useful as a learning or design activity, it is important to place it for students within a clear design process context. Students need assistance in knowing when to employ the bundle concepts and more specific guidance about what to do with the game results. To this end, future class exercises will guide a more explicit design process that involves multiple uses of the game in a sequence of different problem variations. Examples might include generating building design bundles for passive heating, cooling, and lighting, or using *Bundle-Up!* to explore a responsive envelope that addresses multiple energy issues.

Perhaps the most common request is for an iPad app or other electronic version of the game tied to its *SWL* knowledge base. The author is currently seeking technical collaborators and funding.

Through application and feedback in different settings and class types over a two-year period, several conclusions may be drawn. Students have found the *Bundle-Up!* game useful as a step in the process of designing passive and net-zero buildings. It requires them to choose carefully and to narrow their design options strategically. Via the game, the relatively complex *SWL* knowledge structure becomes more accessible to both beginning and advanced students. Playing *Bundle-Up!* seems intuitive and fun. Making more fun of understanding climatic design was the game's real purpose. One peer teacher found, "It teaches systems thinking across multiple scales with none of the systems thinking jargon." Another reported, "This really supports integrative ecological thinking in a very concrete architectural way." Students' responses from feedback surveys are consistent in their appreciation of learning in collaborative dialogue and the teamwork required by *Bundle-Up!*, in contrast to many of their other classes. They enjoy learning in a hands-on, project-based setting, working together with their peers, rather than working in competition with them.

Digital files for printing and making *Bundle-Up!* are available from the author.

ACKNOWLEDGMENTS

The author thanks the following for their important roles in this project: Susanne Bennett for the initial game idea; Jordan Etters, research assistant, for graphics and game production; the AIA Upjohn Research Initiative Award for financial support to develop the underlying knowledge structures; the University of Tennessee College of Architecture and Design for a faculty development award to produce and test the prototypes, and the SBSE and University of Tennessee students for prototype testing and feedback.

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1. DeKay, M. and G. Z. Brown (2014) *Sun, Wind & Light: architectural design strategies*, 3rd edition. Hoboken, New Jersey: Wiley

Our localization of the Game-Bundle is our own design, where we incorporate precipitation/rainfall data, which we reconcile as a dominant weather element that must be included to guarantee a holistic analysis towards Net Zero Building Design. As such, we have renamed our system as SWRL (Sun, Wind, Rain, and Light) to parallel the source reference on SWL (Sun, Wind, & Light).

Localizing climate zones

Identifying the climate type is the key in creating custom bundles for a selected location. By using Köppen climate, the climate zones of the Philippines as well as its priorities for heating and cooling strategies.

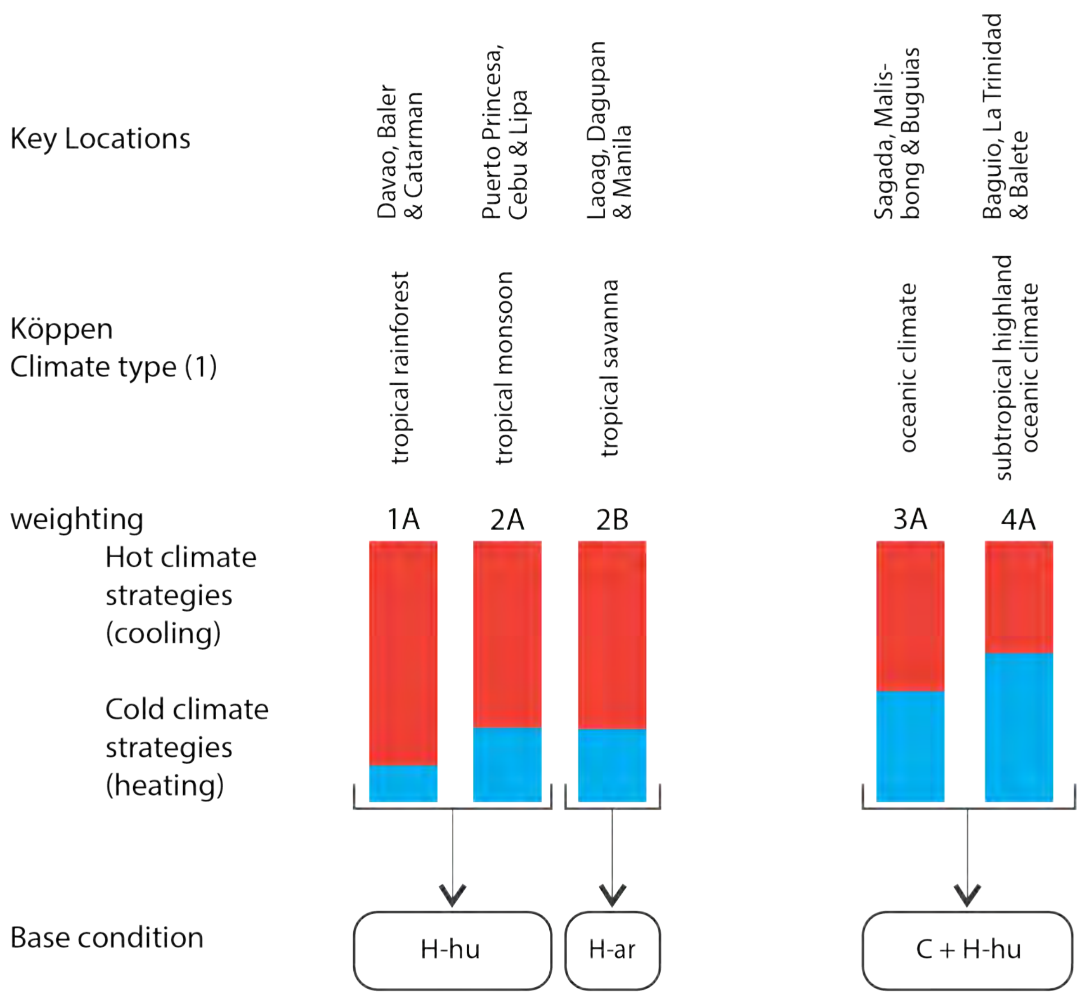


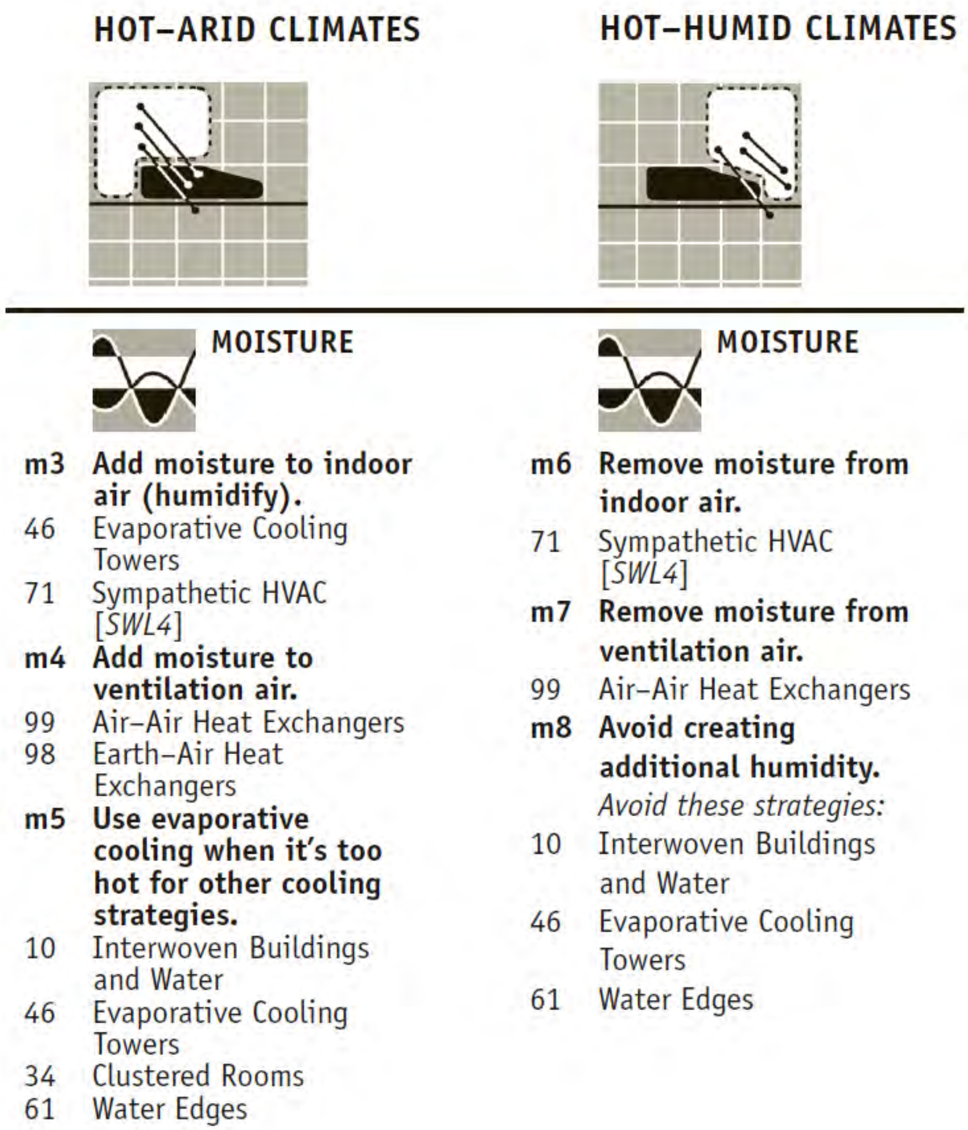
Figure 1.0 Climate Zones and Their Priorities to Heating and cooling strategies

(1) See Köppen Climate in the Philippines map

From Figure 1.0, the climate type of the Philippines can be further group according to their energy priorities, thus producing three general climate types:

1.) Hot-humid
2.) Hot-arid
3.) Mixed –humid

In the *strategies by climate type and energy intentions,* SWL point out that **MOISTURE** control is the design issue to address in all climate type of the country. Even hot-arid (Tropical Savanna) climate in the Philippines is still characterized by oppresive humidity. Excessive precipitation and high humidity due to high temperature and surface evaporation were the cause of moisture in the tropics. Therefore design strategies must prioritize removing moisture from indoor air and protecting the structure from the rain.



Additional strategy

To create a bundle that will function for the tropical climate in the Philippines additional design strategy for rain control must be integrated. **This additional strategies however, does little effect on net-zero intentions and will be beneficial for maintenance and utilies.**

Driving Rain

Driving rain is typically the largest source of moisture for the above-grade building enclosure. Hence, control of rain penetration and absorption is a fundamental function of the building enclosure, and a major part of its moisture control functions (Straube, 2011)

Pitched Roof

L3 Building systems

The purpose of a roof is to keep natural elements away from a building's interior space. Traditional houses not only in the Philippines but also in the neighbouring countries use high pitch slope to keep the water away from the building.

Slope – Gravity is the main factor in shedding away precipitation. Water reaches the ground more easily on a steeply sloped roof. The minimum slope a roof can have is determined by local building codes. Usually it is around 2%. Even the flattest roof needs to have some amount of slope (Blankenbehler, 2015)

Flashing on walls and windows

L2 Elements

Flashing – Avoid flat areas on the roof at all costs.

Flashing is an anti-corrosive metal piece that surrounds any penetration in the roof or any transition between materials, and it is sealed sufficiently to prevent leakage. Careful overlapping is also necessary with flashing. Consider that snow may build up in these tight areas and leech up the flashing. Research proper details for flashing and counter-flashing, as this is the primary culprit of roof leaking, and make sure it is appropriate for the roof material and design condition.

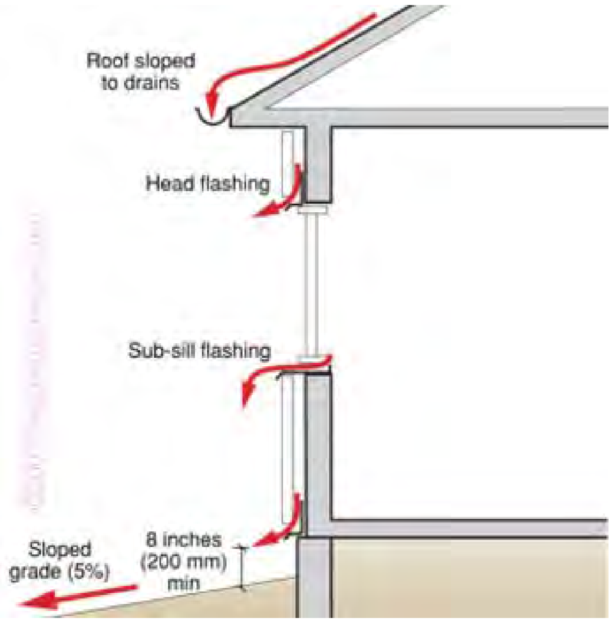


Figure 2.0 Flashing location retrieved from buildingscience.com

Vented airspace

L3 Elements

A vented airspace also allows for both some degree of pressure moderation. Pressure moderation is the term given to the mechanism whereby wind pressure differences across the cladding are reduced by connecting an air space behind the cladding with the wind-induced pressure acting on the exterior. (see DOUBLE SKIN from SWL for additional benefits of vented airspace)

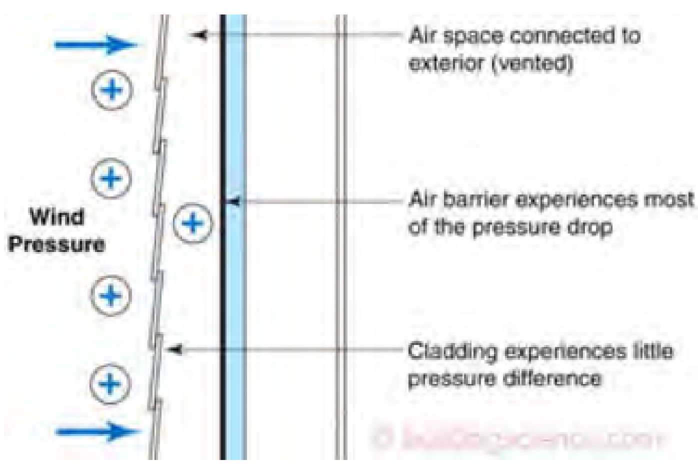


Figure 2.0 Pressure on ventilated wall retrieved from buildingscience.com

By reducing air pressure differences across the cladding, rain will not be forced across openings by this force, while the standard features of capillary break, drainage, and flashing deal with the other rain penetration forces. If the air pressure is completely eliminated, the process is termed pressure equalization.

Reusing Rain Water

Impluvium

L5 Room organization (refiner)

Roman buildings collected rain water and stored it for future use. Sloped roof surfaces directed rain water toward the central atrium. It dripped into the building, onto a porous regressed surface. Here, it filtered through gravel and sand into a cistern basin. The drip of the water provided visual and audible grandeur from winter storms. The filtering gravel cleaned the water and made it suitable for human use. In summer months, evaporation of the water will cool the entire building. This Impluvium water system was efficient, and it was an excellent use of this important natural resource.

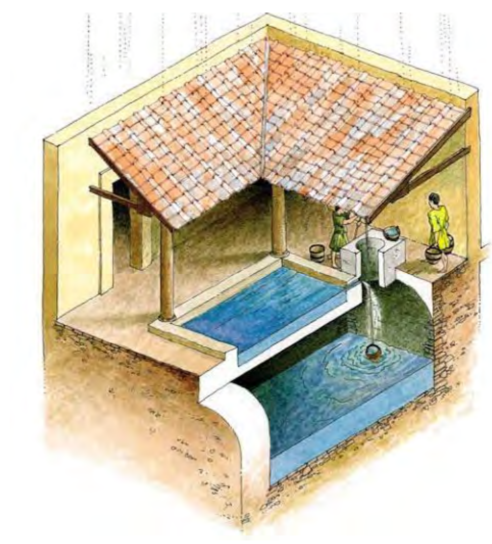


Figure 3.0 Roman Impluvium

This strategy must be utilized with caution since evaporative cooling must be avoided if the climate have relative high humidity.

Customizing bundle

In SWL navigation by scale and energy topic, it already provided bundles that address the need for cooling. For creating a custom bundle, we use **B6 passively cooled building** as a based structure. The bundle passively cooled building already has variation of hot-humid climate and hot-arid climate shown below.

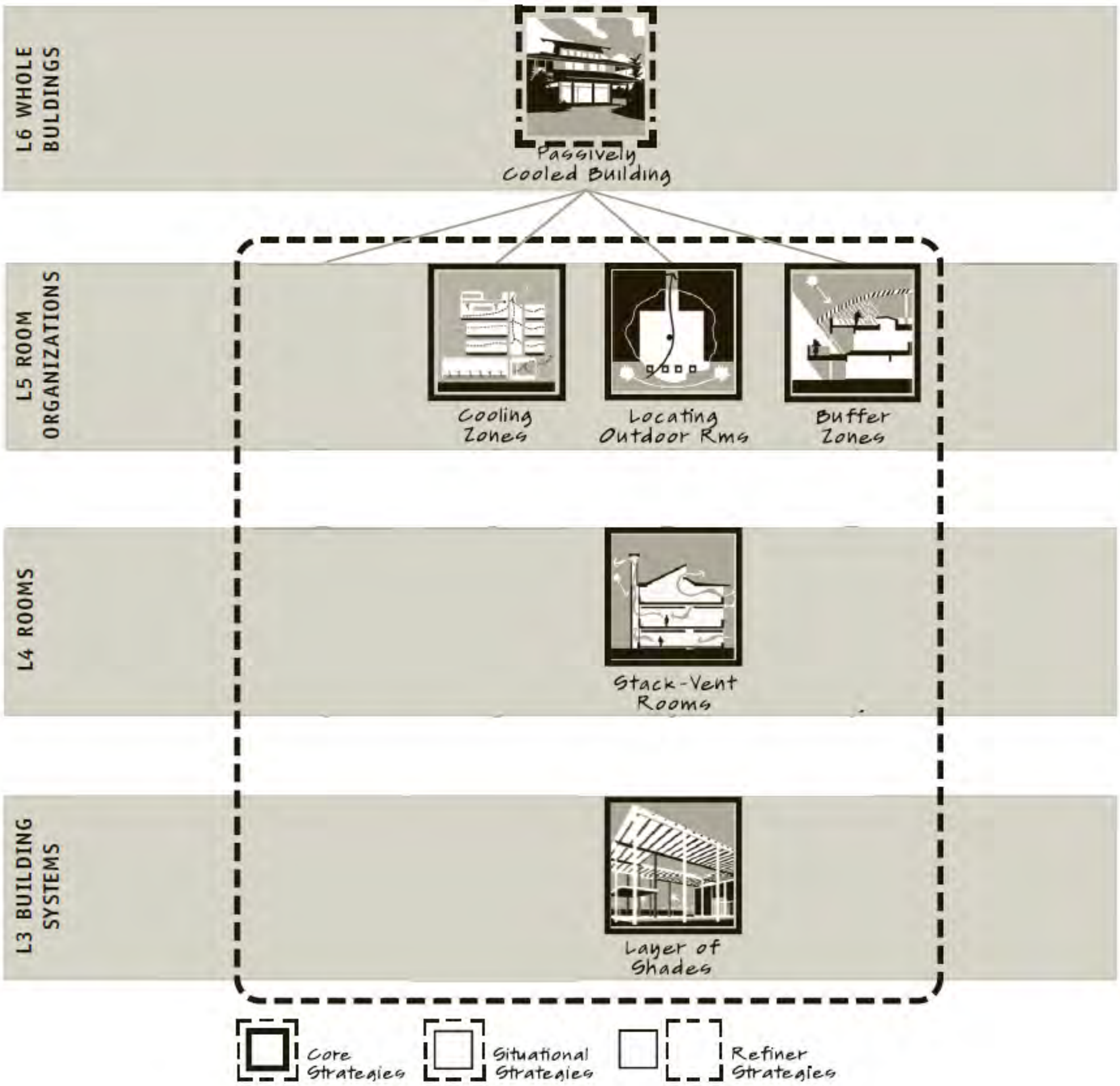


Figure 4.0 Core strategies ofPassively cooled building: Hot-Humid Climate bundle

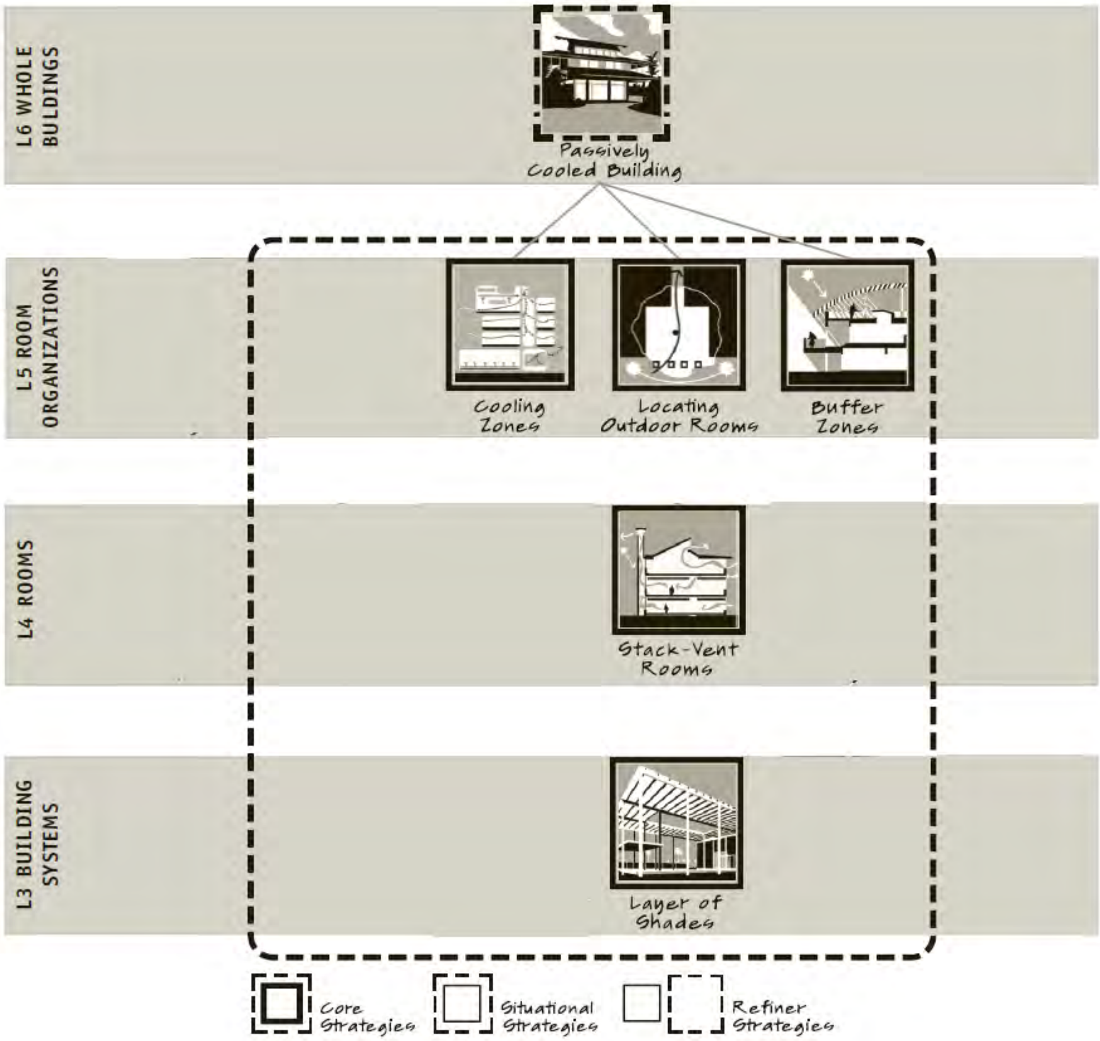


Figure 5.0 Core strategies of Passively cooled building: Hot-Arid Climate bundle

For customizing these bundles, we disregard strategies that are not a core strategy for the mean time. Then add rain and moisture design strategies as situational strategy.

PROPOSED BUNDLE

Passively cooled building: Hot-humid climate bundle

Climate: Tropical forest, Tropical Monsoon, Oceanic Climate,

Key locations: Baler, Lipa, Puerto Princesa, Cebu, Davao

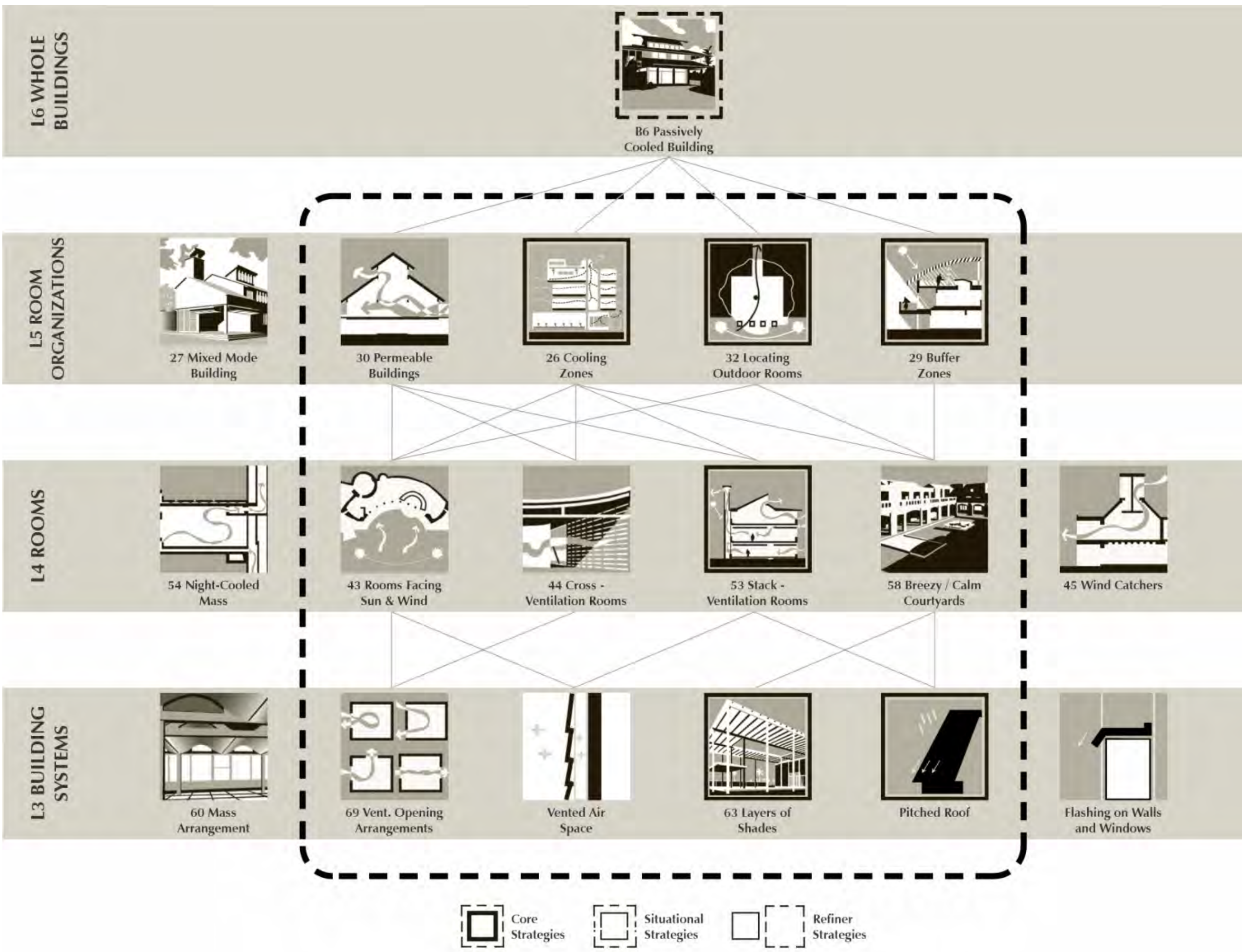


Figure 5.0 Modified Passively cooled building: Hot-Humid Climate bundle

Passively cooled building: Hot-Arid Climate bundle

Climate: Tropical savanna

Key locations: Laoag, Dagupan, Manila

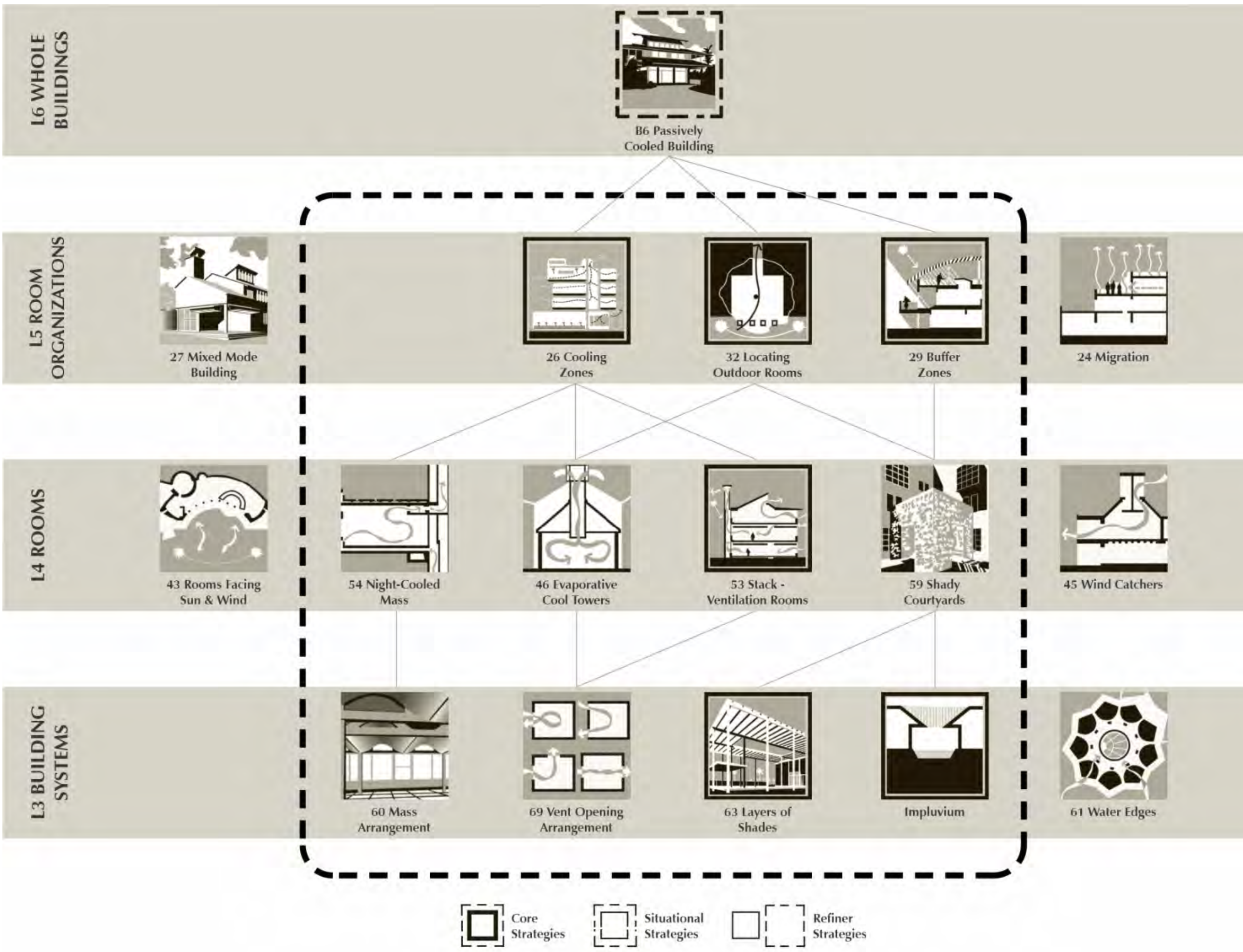


Figure 6.0 Modified Passively cooled building: Hot-Arid Climate bundle

CORE STRATEGIES

Locating Outdoor Rooms – Outdoor rooms expand the living space and allow places for MIGRATION. They may support associated occupied floor areas inside the envelope. Designers can ask, "What spaces (such as circulation or morning meeting) can happen in unconditioned outdoor spaces?" This strategy directs the designer to consider the combination of wind and sun directions when locating outdoor rooms. For example, in a hot climate, when the summer sun and wind come from the same direction, admitting the breeze rules, and the designer must admit wind first and provide structured or landscaped shade to minimize harsh sun.

Buffer Zones – Some rooms can tolerate temperature swings and can be located between the more protected rooms and undesired heat sources, often the eastern or western sun, or the roof. These spaces can be used as thermal buffer zones between the more extreme outside conditions and spaces that need somewhat more careful temperature control.

Cooling Zones – If parts of the building can be cooled during only a portion of the day, or with a passive strategy or with a low-energy cooling system such as evaporative cooling, then the overall energy for cooling will be significantly reduced. This strategy directs the designer to consider arranging spaces that have similar cooling needs and occupant schedules together in zones of the plan or section. Its consideration begins with ENERGY PROGRAMMING. If these spaces are in the same zone, they can employ the same energy efficient design strategies to maintain the space's comfort. In ENERGY PROGRAMMING, spaces are categorized by allowable temperature range, internal rate of gain and occupant density.

Stack-Ventilation Rooms – In almost all climates natural ventilation will provide some or all the cooling for some portion of the cooling season or for some portion of the day. It is like throwing money away not to employ it. In a significant number of climates, the wind is calm for portions of the day, so CROSS-VENTILATION, while effective when the wind blows, does not always work. In most cooling climates, temperatures during the summer afternoon will be too hot for the outside air to provide much cooling. In such cases, NIGHT-COOLED MASS strategies will often work well, but winds tend to be most calm at night. For all these reasons, we recommend stack-ventilation for almost all passively cooled buildings. This strategy directs the designer to consider the sectional quality of the building to enhance this gravity-driven ventilation system. In a room cooled by stack-ventilation, warm air rises, exits through openings at the top of the room, and is replaced by cooler air entering low in the room.

Layer of Shades – One of the greatest design opportunities in hot climates is to expand the idea of the envelope from a thin construction (conceptually a line) to a broader spatial zone of elements. Solar heat gain on the roof is greatest in the middle of the day, when the sun is overhead in summer. In most hot climates, the sun is high enough in the sky for much of the day that a horizontal structure of overhead elements is effective at shading outdoor spaces, roofs, or entire buildings (except in the early morning and evening, where vertical shades or adjacent buildings [SHARED SHADE] would be more effective). This strategy gives recommendations for the size and location of overhead shades. On east and west walls in very hot climates, consider the related DOUBLE SKIN MATERIALS strategy.

Pitched roof –In hot-humid climate in the tropic, driving out moisture is a major concern. Sloped roof lets water reach the ground more easily and avoid moisture to stack in the building. Steep slope roof in traditional house in the tropics are also used to achieve STACK-VENTILATION.

Vented Airspace – By reducing air pressure differences across the cladding, rain will not be forced across the openings by this force, while the standard features of capillary break, drainage and flashing deal with the other rain penetration forces. This strategy is supported by FLASHING ON WALLS AND WINDOWS. A vented airspace also allows for both some degree of pressure moderation. Pressure moderation is the term given to the mechanism whereby wind pressure differences across the cladding are reduced by connecting an air space behind the cladding with the wind-induced pressure acting on the exterior.

SITUATIONAL STRATEGIES

Variations based on Hot-Humid and Hot-Arid Climate

Hot-Humid Situational Strategies

Permeable Buildings –Because humid climates depend so greatly on ventilation by cooling, it is critical to promote both cross- and stack-ventilation by making plans and sections open as a pathway for air.

Cross-Ventilation Rooms – More than arid climates, humid climates can use wind-driven cross-ventilation when the wind is available. Wind driven ventilation is, in general, more effective than stack-ventilation. However, because the wind is not always available, most humid climate buildings should also design for STACK-VENTILATION ROOM.

Rooms facing the sun and wind – to support cross-ventilation, face inlets towards the prevailing breezes and be aware of secondary wind directions [WIND ROSE]. Cross-ventilation outlets and stack ventilation outlets should face *away* from the prevailing wind.

Breezy Courtyards – A fully enclosed courtyard is one of the least comfortable outdoor spaces in a humid climate. It cannot be cooled by the breeze and air becomes stagnant. Therefore, like indoor rooms, outdoor rooms and courts used in the hot season can be designed with shade and partial enclosure that promotes good ventilation.

Ventilation Openings Arrangement – A good cross-vented plan only works if the ventilation apertures are placed so that all the floor space is cooled by moving air and there are no dead air zones. Similarly, an elegant stack-ventilation section cannot work for cooling if the openings are misplaced for a full-coverage air flow path through each space.

Hot-Arid Situational Strategies

Shady Courtyards – offer a respite from intense sun. Their proportions are biased toward shade rather than wind, as in hot-humid climates.

Evaporative cooling towers – not a viable option in an already humid climate, work well in arid conditions by using gravity to drive air flow without wind or fans and to cool and humidify the air. They can cool when air is much too hot for natural ventilation cooling alone.

Night-cooled mass rooms– are a great fit in arid climates where temperature ranges tend to be high and straddle the comfort zone. This is a good combination with evaporative cooling which can be used to supplement mass cooling or can be used during the day, depending on conditions.

Mass arrangement – assures that thermal mass for cooling is located where it can absorb the most heat during the day and give that heat up to ventilation air during the night. The location of massive and non-massive elements can be major driver of building order.

Impluvium – supports evaporative cooling through storing rainwater in an open court during rainy season then cools the air through evaporation during summer season.

Mixed-Humid Climate Bundle

Climate type: Subtropical highland oceanic climate & Oceanic Climate

Key locations: Baguio, La Trinidad, Sagada

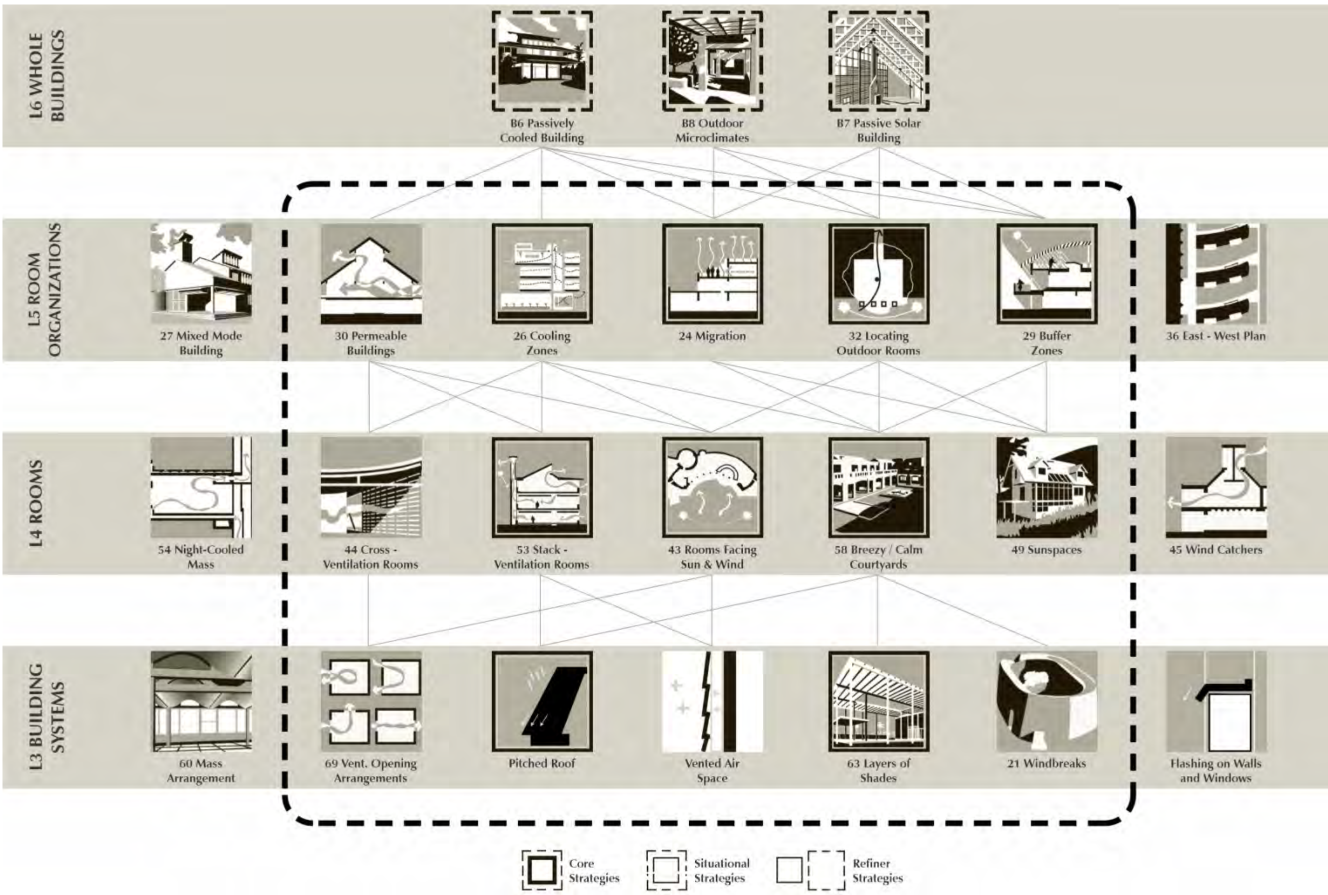


Figure 6.0 Modified Passively cooled building: Mixed-Humid Climate bundle

CORE STRATEGIES

Locating Outdoor Rooms – Outdoor rooms expand the living space and allow places for MIGRATION. They may support associated occupied floor areas inside the envelope. Designers can ask, "What spaces (such as circulation or morning meeting) can happen in unconditioned outdoor spaces?" This strategy directs the designer to consider the combination of wind and sun directions when locating outdoor rooms. For example, in a hot climate, when the summer sun and wind come from the same direction, admitting the breeze rules, and the designer must admit wind first and provide structured or landscaped shade to minimize harsh sun. Buildings can create series of different microclimates around them because they block sun and wind. It is the most fundamental move that places-built form and open space relative to each other. It recognizes that the microclimate around buildings is impacted by the buildings themselves. They create shade or reflect sun; they block wind or intensify it. Outdoor rooms can be located to make use of this fact.

Migration – Migration is often a good strategy because it is difficult to design a single outdoor space that is comfortable in all conditions. This strategy suggests creating multiple spaces designed to create different conditions (such as a summer room and a winter room) that allow users to move between them and find conditions that suit them. Another variation is to create a gradient of conditions in a single space, such as full sun, partial shade and full shade. Given that people have different thermal tolerances and preferences, each will fi nd the combination of conditions that best suits that individual.

Buffer Zones – Some rooms can tolerate temperature swings and can be located between the more protected rooms and undesired heat sources, often the eastern or western sun, or the roof. These spaces can be used as thermal buffer zones between the more extreme outside conditions and spaces that need somewhat more careful temperature control.

Create a third condition of tempering between inside and outside that reduces thermal stresses on the indoor space and can provide for occupied spaces at the edge of buildings, which are more comfortable than being in the open. BUFFER ZONES can be used for both cold and hot conditions.

Cooling Zones – If parts of the building can be cooled during only a portion of the day, or with a passive strategy or with a low-energy cooling system such as evaporative cooling, then the overall energy for cooling will be significantly reduced. This strategy directs the designer to consider arranging spaces that have similar cooling needs and occupant schedules together in zones of the plan or section. Its consideration begins with ENERGY PROGRAMMING. If these spaces are in the same zone, they can employ the same energy efficient design strategies to maintain the space's comfort. In ENERGY PROGRAMMING, spaces are categorized by allowable temperature range, internal rate of gain and occupant density.

Stack-Ventilation Rooms – In almost all climates natural ventilation will provide some or all the cooling for some portion of the cooling season or for some portion of the day. It is like throwing money away not to employ it. In a significant number of climates, the wind is calm for portions of the day, so CROSS-VENTILATION, while effective when the wind blows, does not always work. In most cooling climates, temperatures during the summer afternoon will be too hot for the outside air to provide much cooling. In such cases, NIGHT-COOLED MASS strategies will often work well, but winds tend to be most calm at night. For all these reasons, we recommend stack-ventilation for almost all passively cooled buildings. This strategy directs the designer to consider the sectional quality of the building to enhance this gravity-driven ventilation system. In a room cooled by stack-ventilation, warm air rises, exits through openings at the top of the room, and is replaced by cooler air entering low in the room.

Breezy and Calm Courtyards – Breezy and calm courtyards help the designer determine the dimensions of open spaces, such as courtyards, based on whether wind is an asset or a liability. Breezy courts are relatively wide and permeable, while calm courts are more protected.

Rooms facing the Sun and Wind – Rooms facing the sun and wind applies equally to indoor and outdoor rooms. If a partially enclosed outdoor room is to be ventilated, it needs both inlets facing the wind and outlets away for the wind. If an outdoor room is to receive sun, building massing cannot block the sun reaching the ground. This strategy is often at odds with rigid formal symmetry that creates mirrored orientations.

Layer of Shades – One of the greatest design opportunities in hot climates is to expand the idea of the envelope from a thin construction (conceptually a line) to a broader spatial zone of elements. Solar heat gain on the roof is greatest in the middle of the day, when the sun is overhead in summer. In most hot climates, the sun is high enough in the sky for much of the day that a horizontal structure of overhead elements is effective at shading outdoor spaces, roofs, or entire buildings (except in the early morning and evening, where vertical shades or adjacent buildings [SHARED SHADE] would be more effective). This strategy gives recommendations for the size and location of overhead shades. On east and west walls in very hot climates, consider the related DOUBLE SKIN MATERIALS strategy.

Separated or Combined Openings – Because ventilation apertures may be larger than solar or daylight apertures, and because there are so many places they are required to be, consider whether in some cases, ventilation openings may be handled separately, thus avoiding over lighting or overheating from glazed apertures.

SITUATIONAL STRATEGIES

Permeable Buildings –Because humid climates depend both cross- and stack-ventilation by making plans and sections open as a pathway for air.

Cross-Ventilation Rooms – More than arid climates, humid climates can use wind-driven cross-ventilation when the wind is available. Wind driven ventilation is, in general, more effective than stack-ventilation. However, because the wind is not always available, most humid climate buildings should also design for STACK-VENTILATION ROOM.

Sunspaces – Sunspaces are also spaces that can be inhabited during certain periods and are a special case of buffer zone. Sometimes their temperature is above the comfort zone (such as in the middle of a sunny day), sometimes within the comfort zone (such as on a winter morning) and sometimes below the comfort zone (typically, at night). However, the sunspace will always be warmer than the colder outdoor temperatures in winter and will have a daily temperature variation that is greater than indoors but less than outdoors.

Windbreaks – Windbreaks are especially important in outdoor microclimates when the temperatures are cool. The BIOCLIMATIC CHART assumes that when conditions fall within the comfort zone, that the wind is blocked. If it is not, there is a cooling effect and even mild conditions can be experienced as cold. Windbreaks can be buildings, walls, fences, or vegetation; in any variety, they help build WINTER COURTS and calm courts [BREEZY AND CALM COURTYARDS].

Ventilation Openings Arrangement – A good cross-vented plan only works if the ventilation apertures are placed so that all the floor space is cooled by moving air and there are no dead air zones. Similarly, an elegant stack-ventilation section cannot work for cooling if the openings are misplaced for a full-coverage air flow path through each space.

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