Passive Cooling in a Warming Planet

Climate Responsive Design, Smart Controls and Active Occupants

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Arcadis / Cal Poly Pomona

OUTLINE

Design with Climate

- Mid-twentieth century Los Angeles
- Workflow and tools
- Middle East
- Northern Italy

Smart Passive Cooling: Improving Performance of Passive Systems

- Cooling with air
- Cooling with the sky
- Cooling with water

Integrating Systems

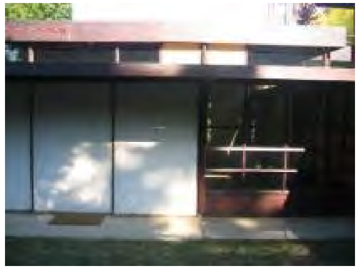
Conclusions

1

Design with Climate:

Mid-twentieth Century Los Angeles
Case Study House program

Early 20th century architecture in Los Angeles connected with climate.



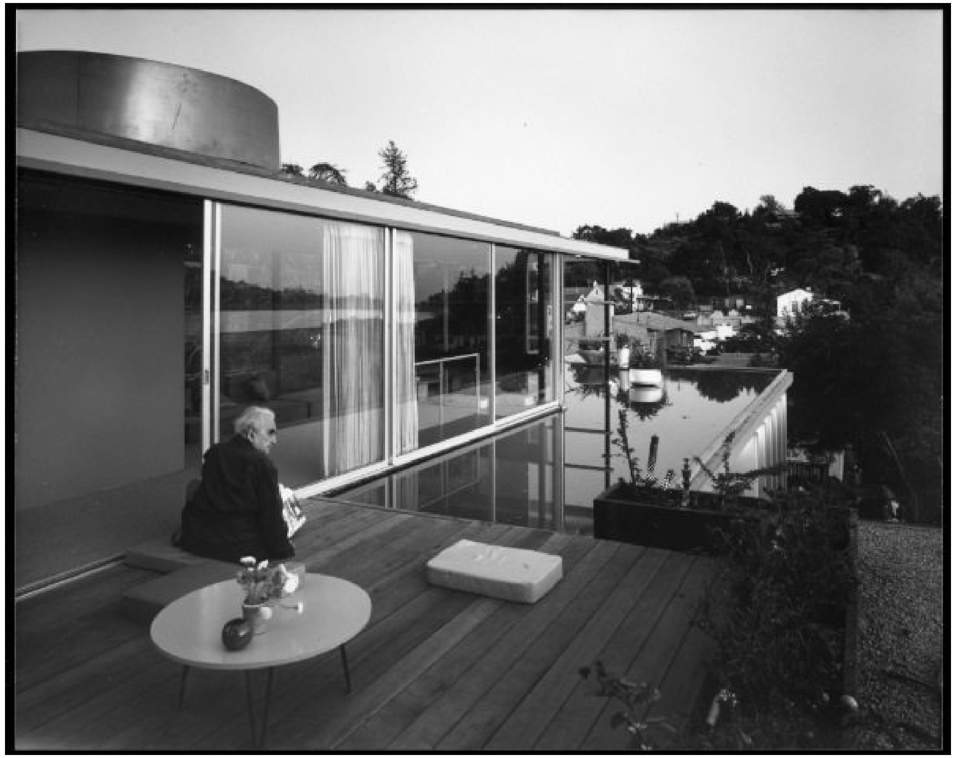
Indoor / Outdoor

R. Schindler 1921

Using a consistent four-foot module and standardized “Slab-Tilt” wall construction, Schindler created a building in which no two spaces are alike while at the same time seamlessly integrating indoors and out, creating, in his words, “A Real California Scheme.”

VDL Research House

Richard Neutra built the VDL house in 1932, designed for his office and two families on a 60 x 70 ft lot. In 1939, as his family expanded, he built a garden house in the back lot. A fire in 1963 burnt the house and left the garden house and basement of the original house. Richard and his son and partner redesigned the main house. Two floors were added above the basement. They applied what they had learned about sun louvers, water roofs, nature-near, and physiologically motivated design.



VDL Research House

Solar geometry and natural ventilation

NATURAL VENTILATION: cooling breezes from silverlake reservoir

VDL GARDEN HOUSE

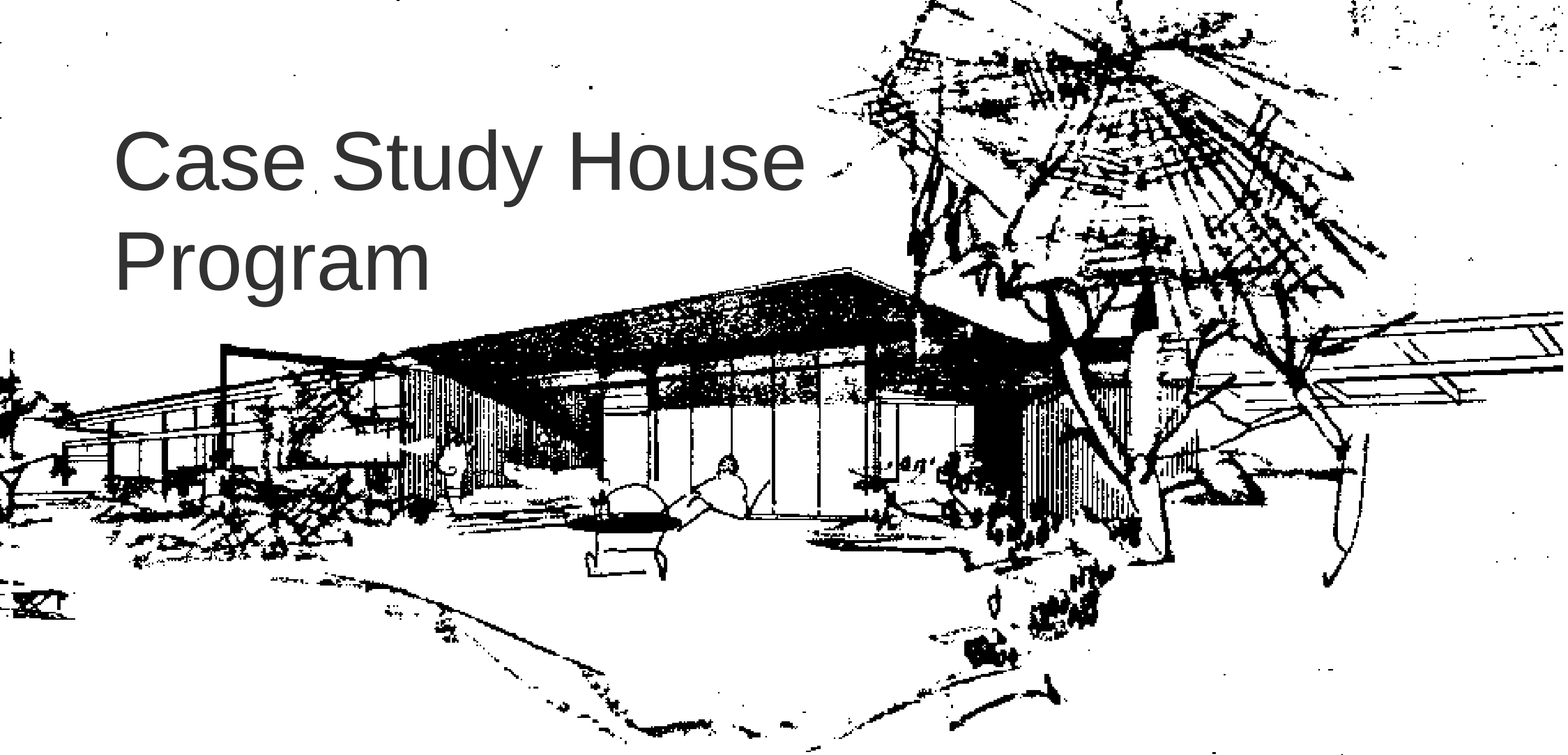
…and this connection was further explored in mid century architecture

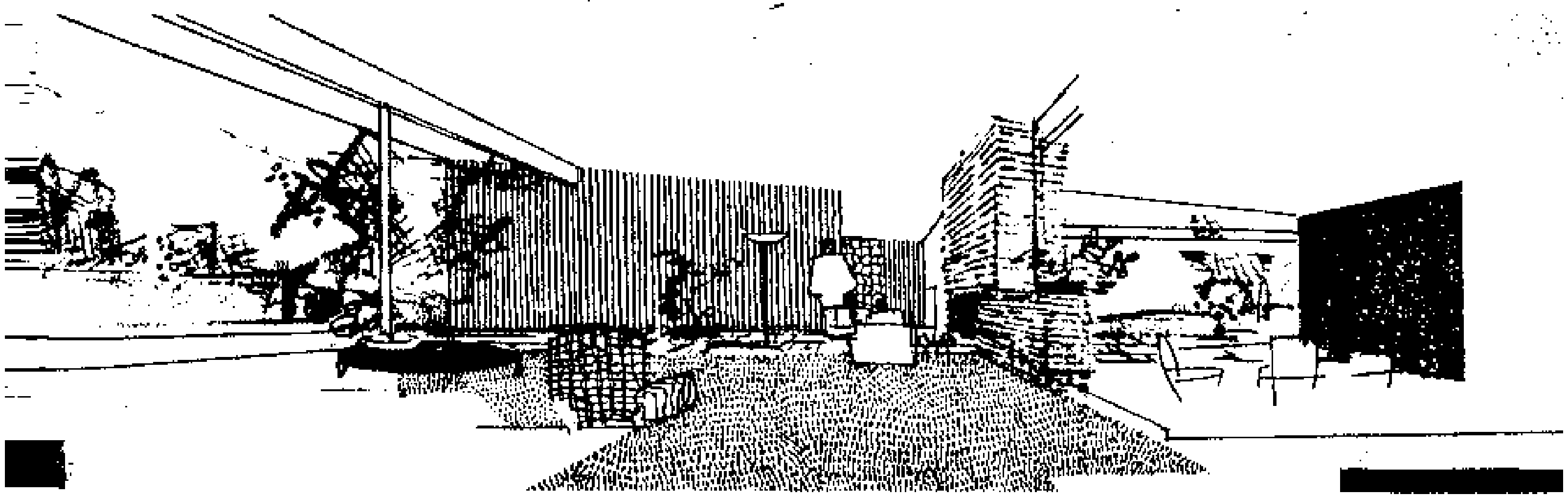
…by the Case Study House Program

One of Southern California's most significant contributions to modern Architecture was the Case Study House program sponsored by John Entenza's Art & Architecture magazine between 1945 and 1966. During this time thirty-six experimental prototypes were designed and many of them built.

The importance of climate in the design of these houses has been discussed by some authors such as Ester McCoy "…it was the California sun rather than the hearth that was at the base of the Case Study houses."

Case Study House Program



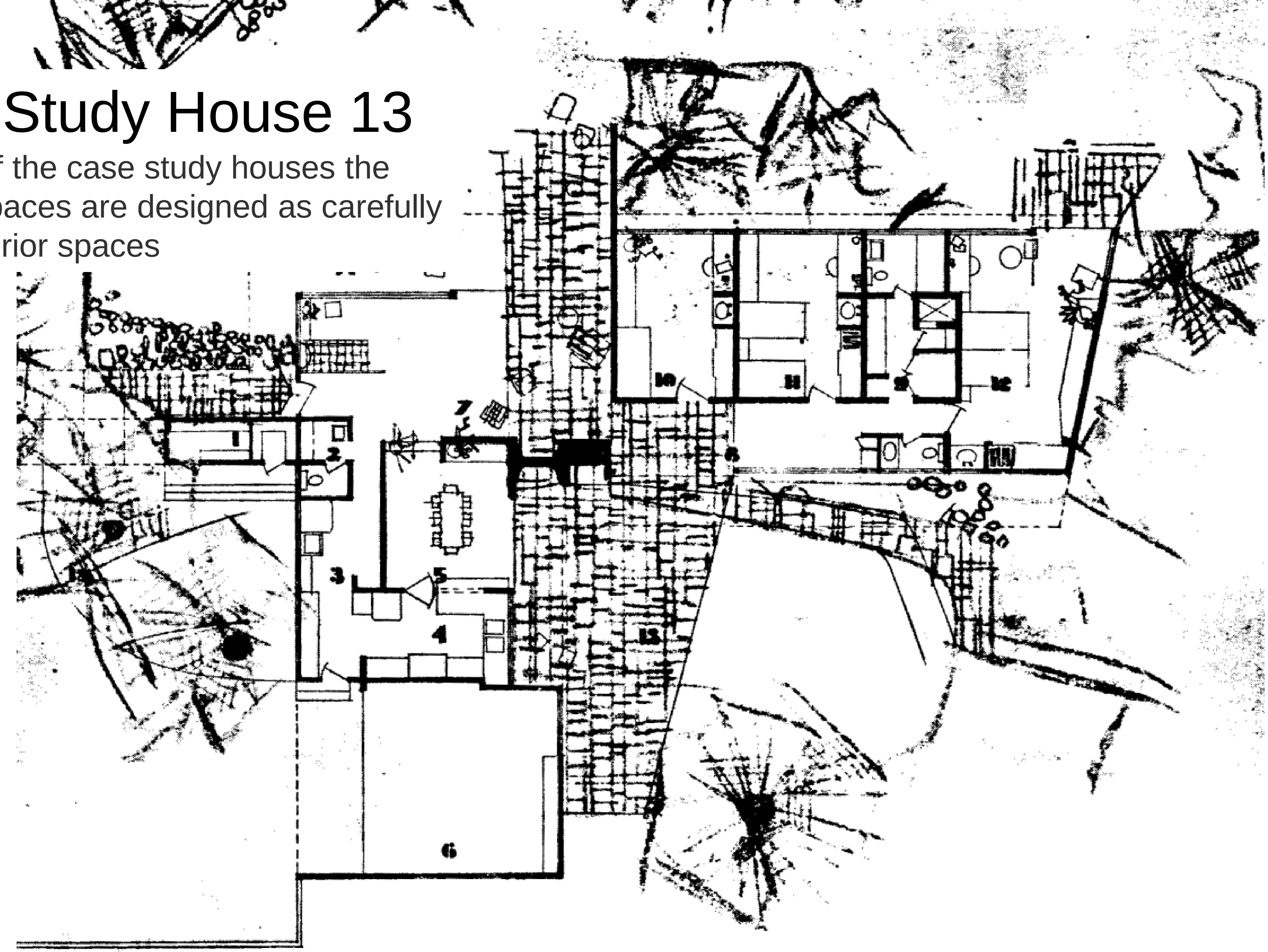


The idea of **creating a free flow of activity between indoor and outdoors** was strongly encouraged by “contemporary” architects, particularly those working in the west coast of the USA (Jackson, 1994:80). Living outdoors – and partially outdoors – was an important principle in most of the Case Study Houses.

There was a consciousness of the mild southern Californian climate, which determined an important component of outdoor living

Case Study House 13

In many of the case study houses the exterior spaces are designed as carefully as the interior spaces



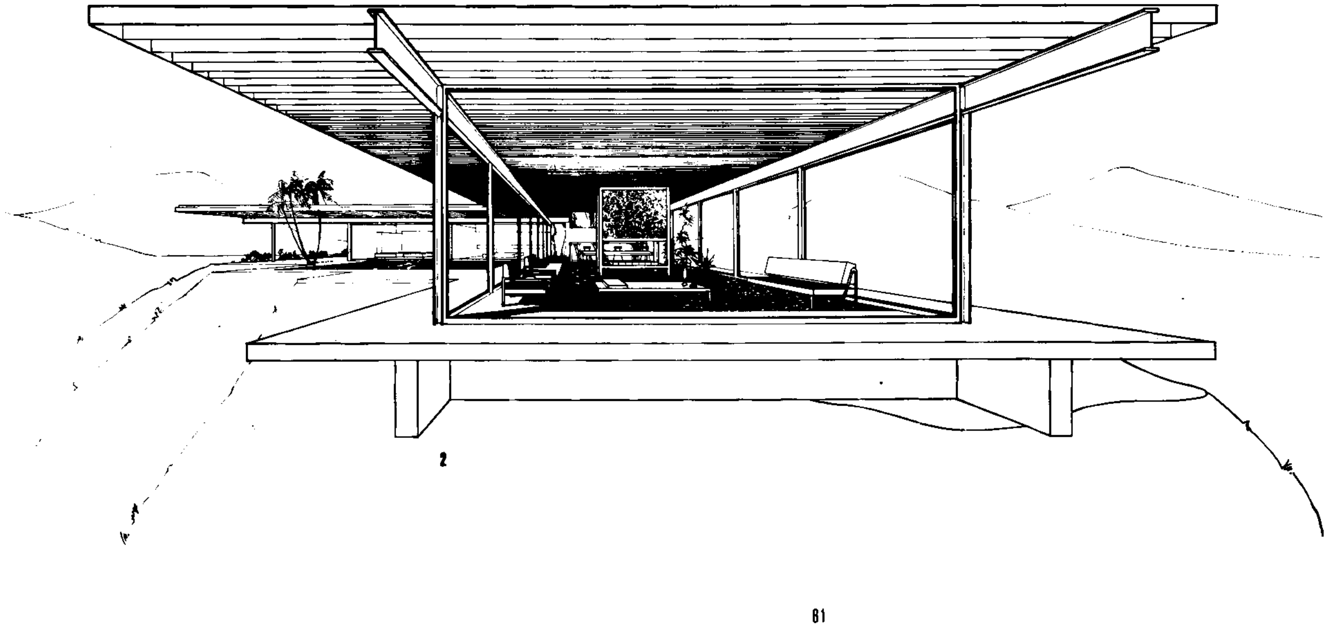
We see this in three examples of mid 20th century architecture in Los Angeles.

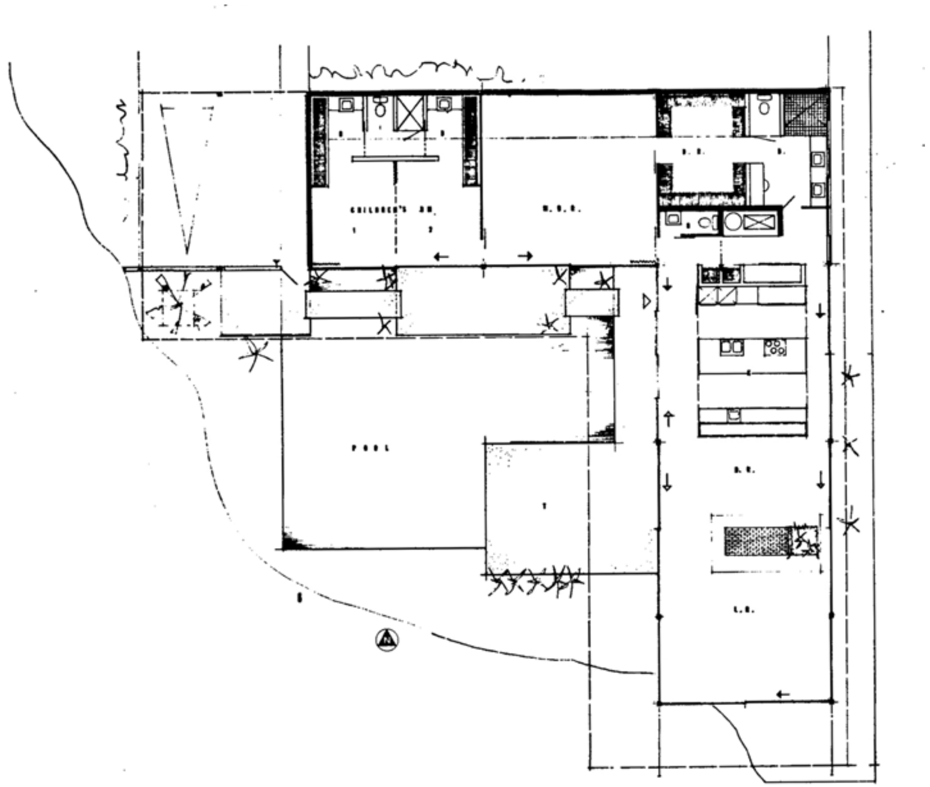
Case Study House 22

Case Study House 22
With its pool and panoramic view across the city, is probably the archetypal Southern Californian “good-life” house and is now a protected Los Angeles County architectural landmark.

Photograph Julius Shulman

Cross Ventilation





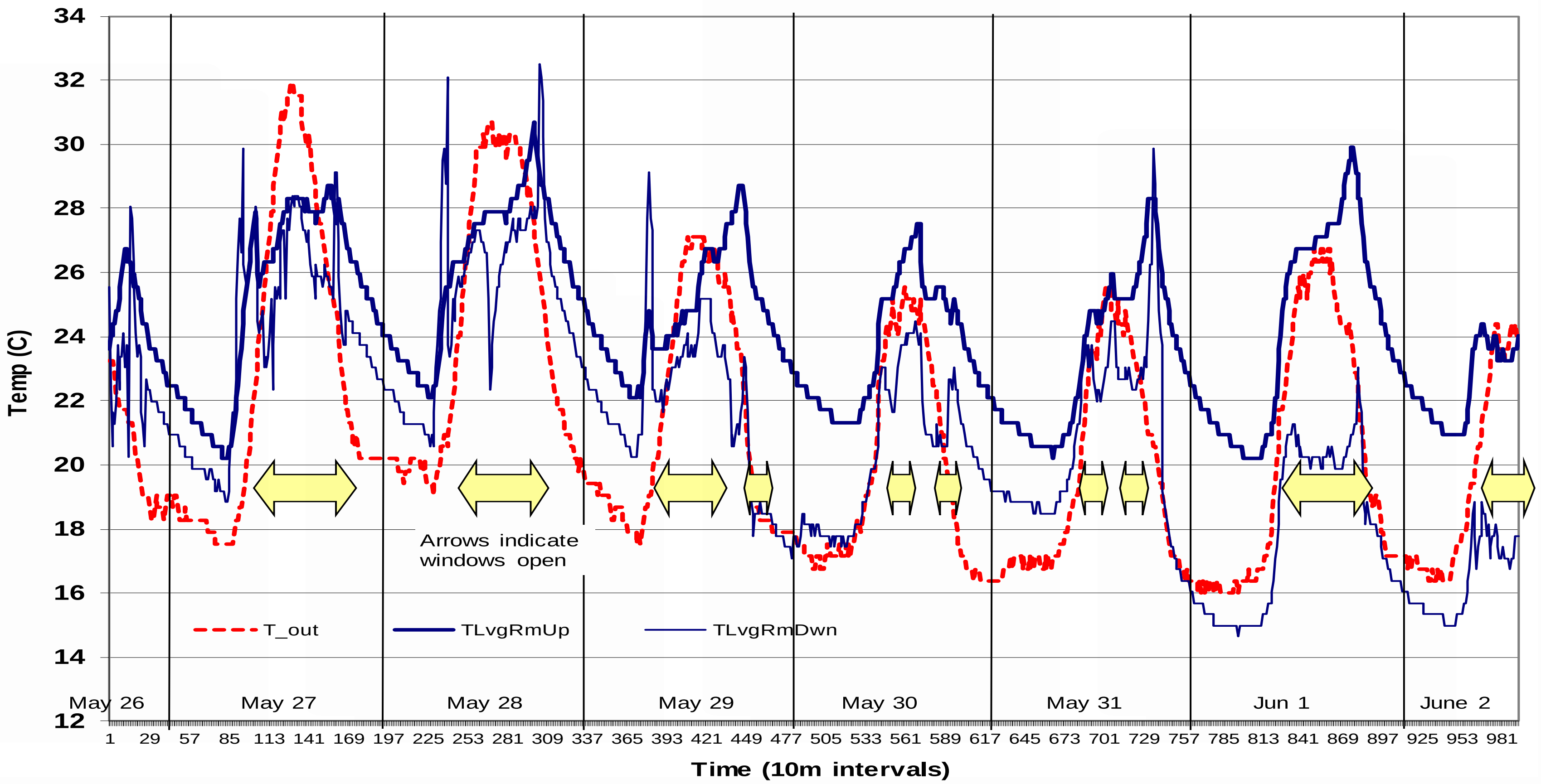
The layout of Case Study House 22 consists of two wings forming an “L” at 90 degrees to each other and about the same size. This simple form with 20 feet wide pavilions permits all spaces to be easily cross ventilated

Indoor / Outdoor Relationship

The separation between interior and exterior areas was taken to the extreme and blurred until it virtually disappeared.

Photograph Julius Shulman

Indoor and Outdoor Temperatures



The author did a study in which Mrs. Stahl keep track of the operation of the windows. This was compared to indoor and outdoor data loggers. Mrs. Stahl said, "just opening the sliding door for a couple of feet generates a nice breeze". During the summer, the windows were generally opened in the morning, around 8:00 AM, and closed around 8:00 PM, so daytime ventilation prevents the building from overheating. During the winter the windows are opened for shorter times during the day if there is overheating on sunny days. During the measuring period the temperature inside the building followed the outside temperature quite closely when windows were open and was higher when they were closed.

Case Study House 22

The Stahl family lived in this house for more than 40 years since its construction in 1960. Mrs. Stahl managed indoor temperature by opening and closing the sliding doors. They did not have air conditioning, and they only felt uncomfortable when the hot Santa Ana breezes flowed from the desert which was not for more than several days a year. An afternoon breeze generally cooled the air from inside the house while at the same time it was strong enough to achieve comfort ventilation.

Photograph Tim Sakamoto

Case Study House 22

The Stahl family understood how their house worked, and opened and closed the windows accordingly, cooling or heating as desired, and achieving an intimate house-dweller-environment relationship.

Case Study House 22 demonstrates that the occupant of a house can achieve optimum thermal performance by doing more than turning a thermostat on or off.

Photograph Tim Sakamoto

Schrage House

Designed in 1951 by R. Soriano
Lived by Steven and Marian Dodge

Marian and Steve Dodge, have occupied it for more than 30 years. The changes in lifestyle over the years have been accommodated with adaptations to the prototypical way of life for which the house was initially designed. The building has had the capacity to adapt to those changes

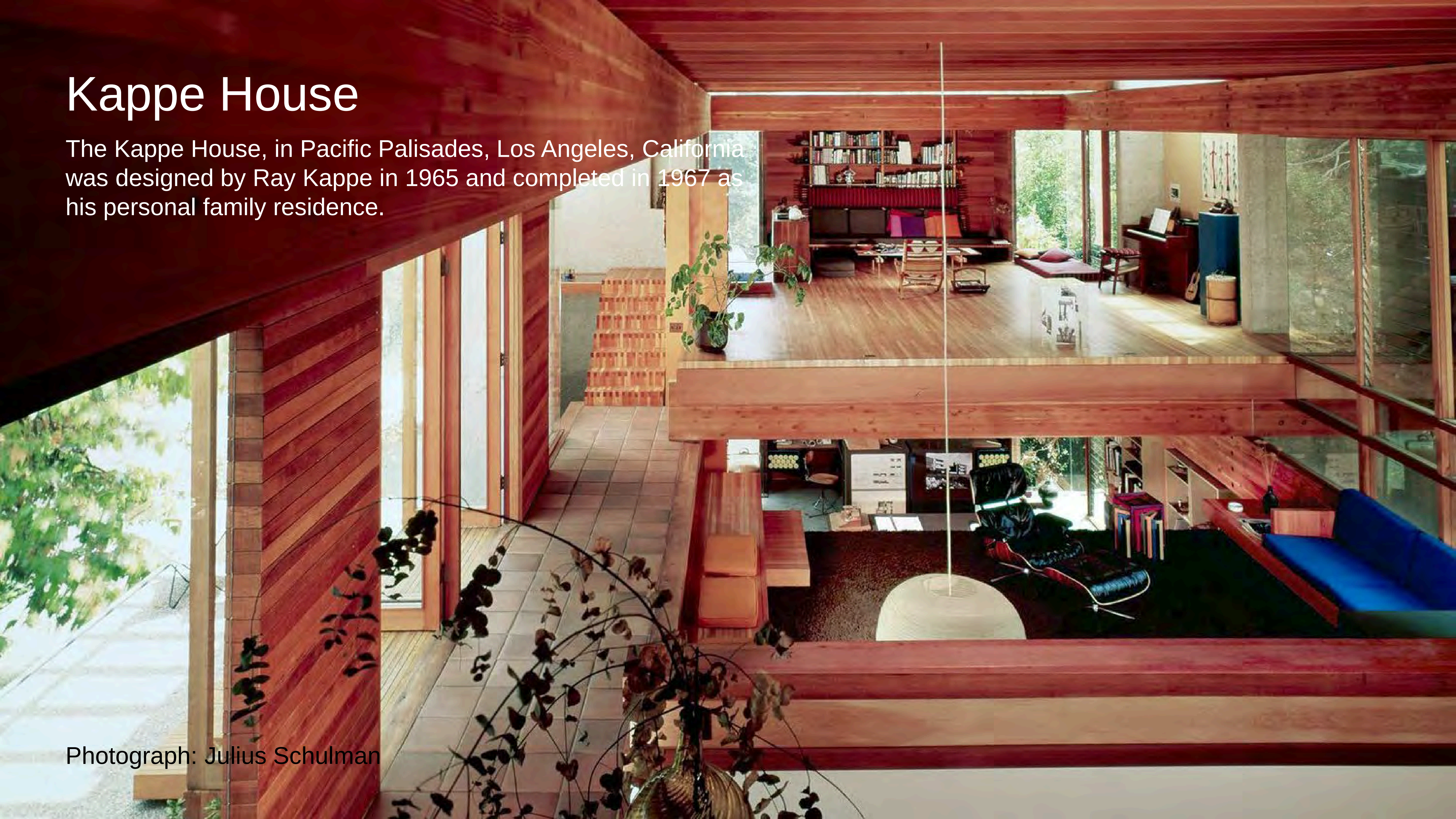
Schrage House

Today’s tools make it possible to simulate, understand and control energy performance in housing, although effective application of that information calls for active participation on the part of a responsible user. There is current research directed towards the role of occupants in large buildings such as offices. **This paper demonstrates that occupant appreciation and understanding of the living spaces clearly seems to be a factor in the successful implementation of transformation, usage and maintenance measures.**

Carmen Alonso, Pablo La Roche & Ignacio Oteiza (2016): Occupants and energy performance: the Schrage House, Architectural Science Review, DOI: 10.1080/00038628.2016.1205472

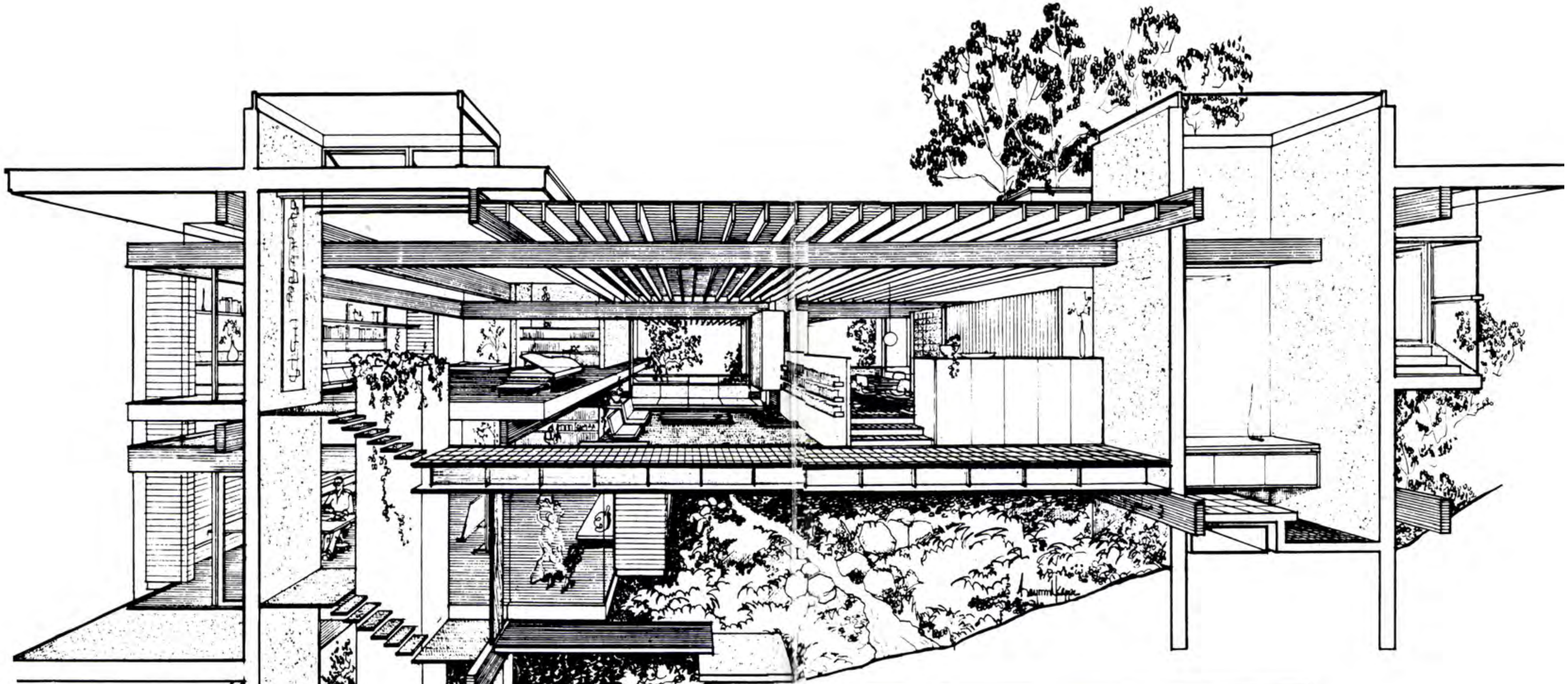
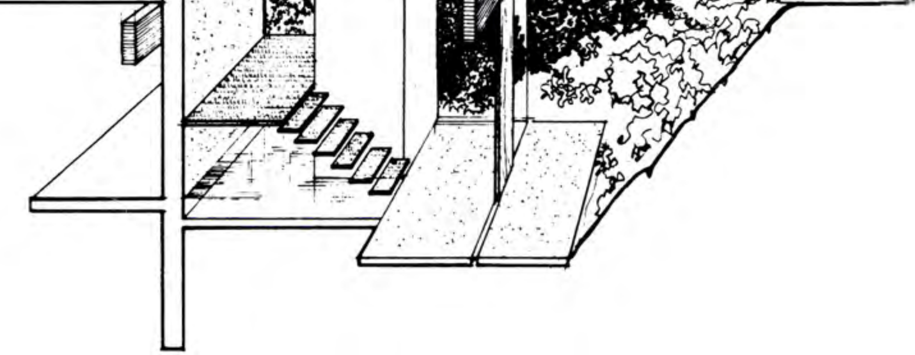
Kappe House

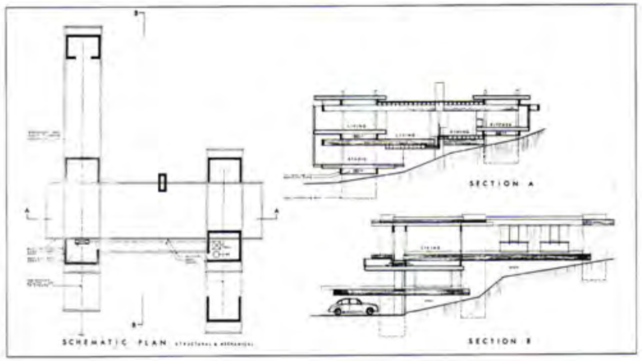
The Kappe House, in Pacific Palisades, Los Angeles, California was designed by Ray Kappe in 1965 and completed in 1967 as his personal family residence.



Photograph: Julius Schulman

Photograph: Tim Sakamoto

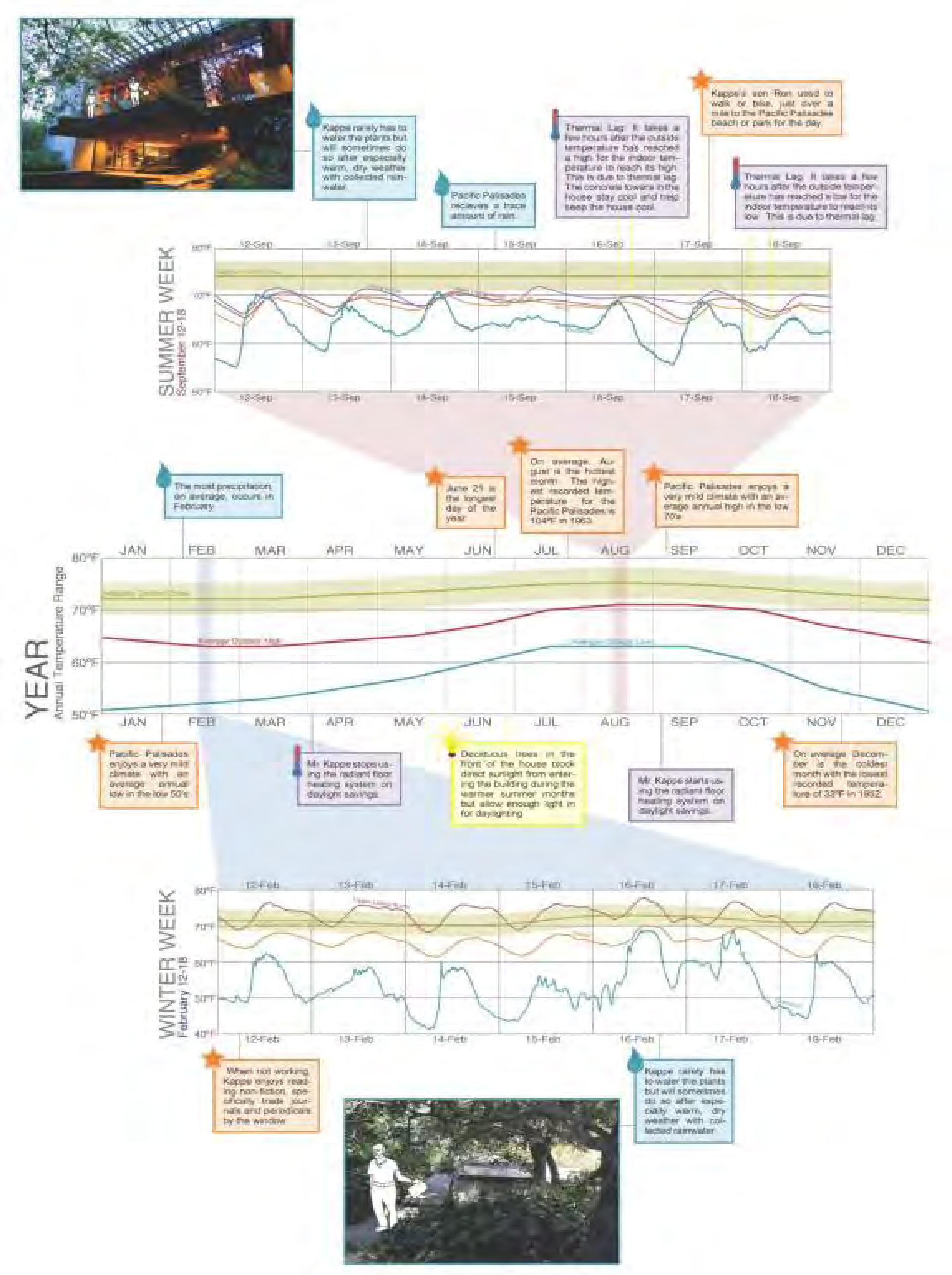



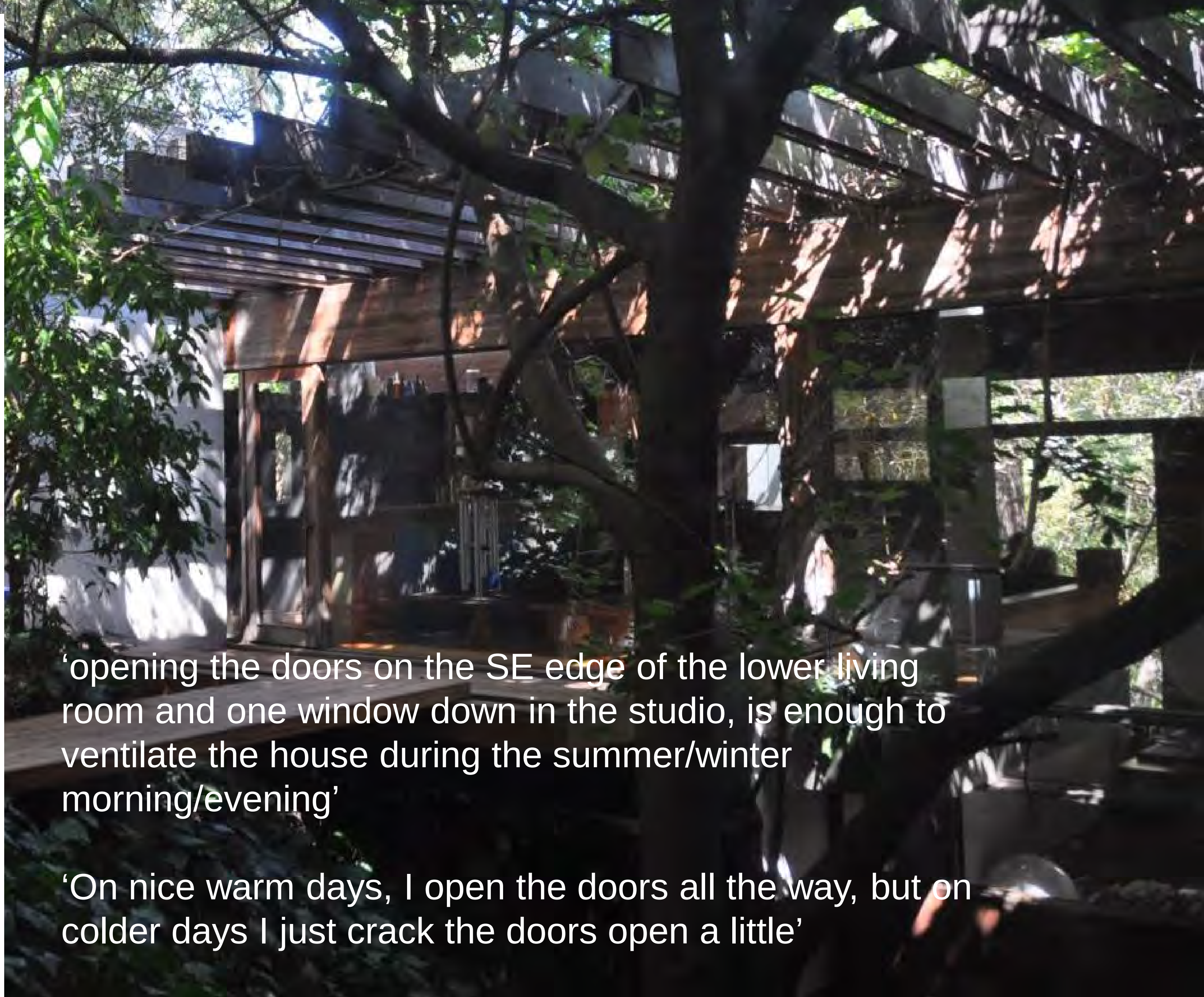


6

5 Main section
6 Schematic plan and sections

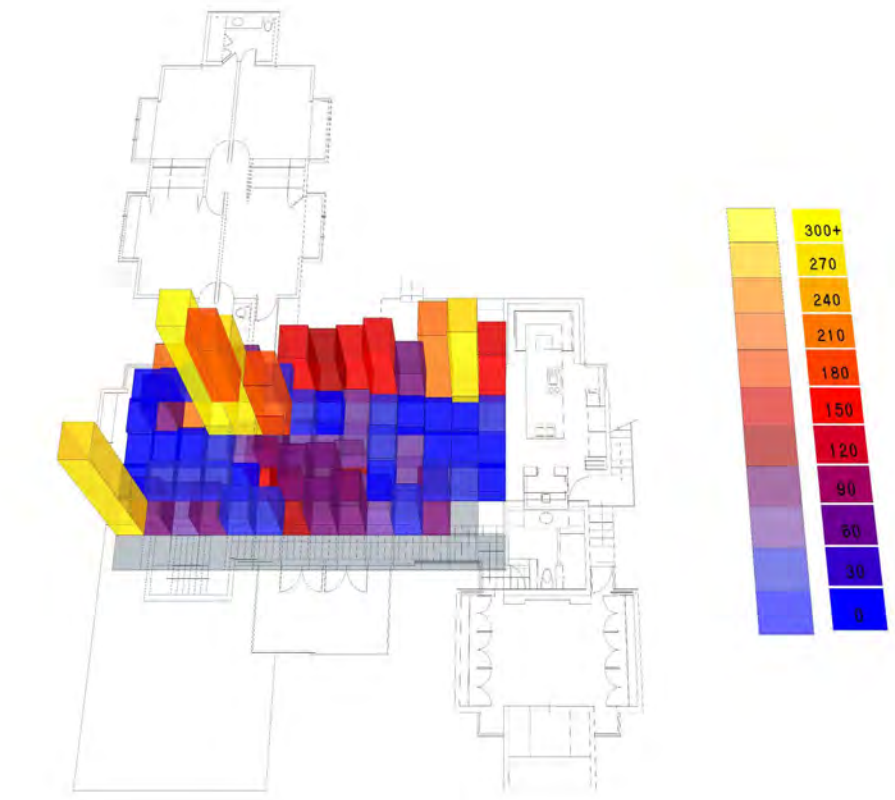
We interviewed Ray Kappe to understand how he lived his house and operated it as a response to the climate around it.





‘opening the doors on the SE edge of the lower living room and one window down in the studio, is enough to ventilate the house during the summer/winter morning/evening’

‘On nice warm days, I open the doors all the way, but on colder days I just crack the doors open a little’



We put all of this in the exhibit Technology and Environment: The Postwar House in Southern California, which I co-curated at Cal Poly Pomona in 2013 and part of the Getty's Pacific Standard Time Presents architecture series

……The room on energy is particularly thorough -- a reminder of how few of the shows in the architecture series have directly addressed ecology or sustainability……

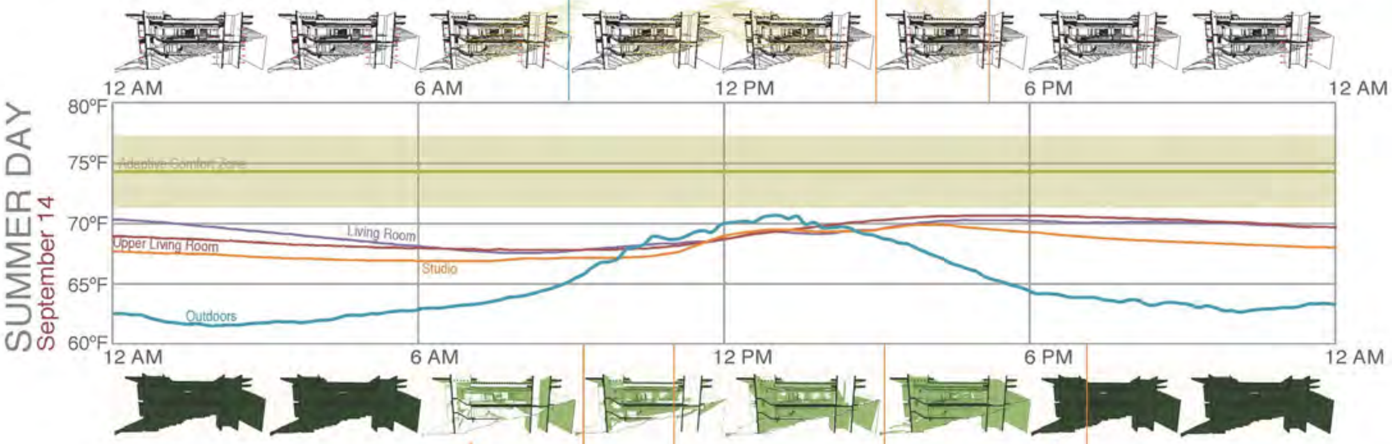
Los Angeles Times Architecture Critic Christopher Hawthorne (2013/07/11)

The south-east facing doors on the living room are cracked opened to allow for natural ventilation.

The pool is almost entirely heated with a solar hot water heater in the summer.

Kappe goes swimming everyday in the late afternoon around 3-4

When Kappe is not working he likes to sit in the living room and enjoy the view, watching the sun change and night coming in. He can see east and west, the play of light and shadows.

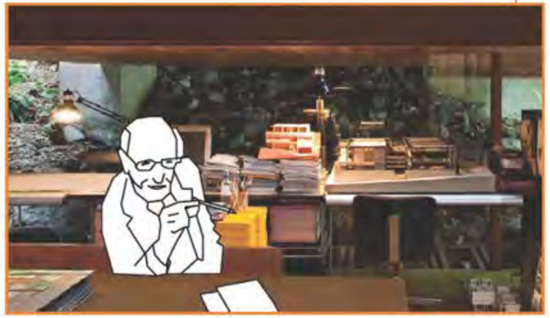


Kappe works in his studio throughout the morning, often drawing.

Kappe meets with clients in his studio.

When Kappe is not working he likes to sit in the living room and enjoy the view, watching the sun change and night coming in. He can see east and west, the play of light and shadows.

Kappe eats dinner with family, on occasion dining outside.



SUMMER THERMAL STRATEGIES

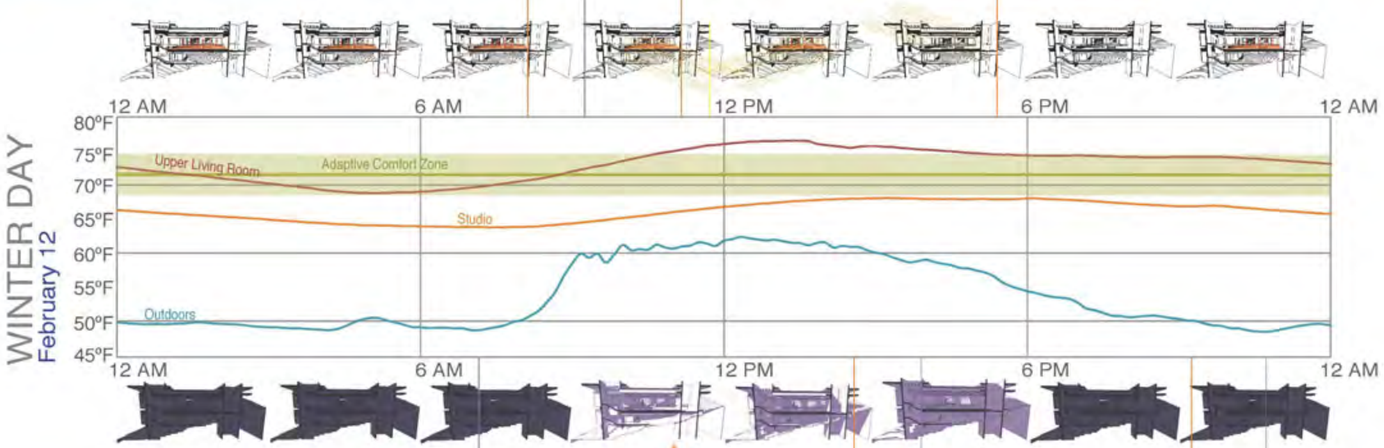
- Shading by trellises and leafy trees during warm parts of day
- Thermal massing of concrete towers provide moderation of temperatures
- Ventilation from doors on SE edge of living room and studio windows on warm days
- Louvered windows in bedrooms and living room opened for cross ventilation
- Solar hot water heater provides heating to outdoor swimming pool
- Evaporative cooling effect from stream under living area
- Trees and slope shelter the house from sun
- Trees create a micro-climate that shades and humidifies the air through transpiration
- No mechanical air conditioning system is used

While the house heats up in the morning, Kappe and Shelly make coffee and enjoy breakfast above radiant floors.

The south-east facing doors on the living room are cracked opened to allow for natural ventilation.

Mr. Kappe meets wth clients in his studio.

When Kappe is not working he likes to sit in the living room and enjoy the view, watching the sun change and night coming in. He can see east and west, the play of light and shadows.



Kappe wakes up and sets the thermostat to 70ºF.

Mr. Kappe goes swimming everyday in the late afternoon around 3-4.

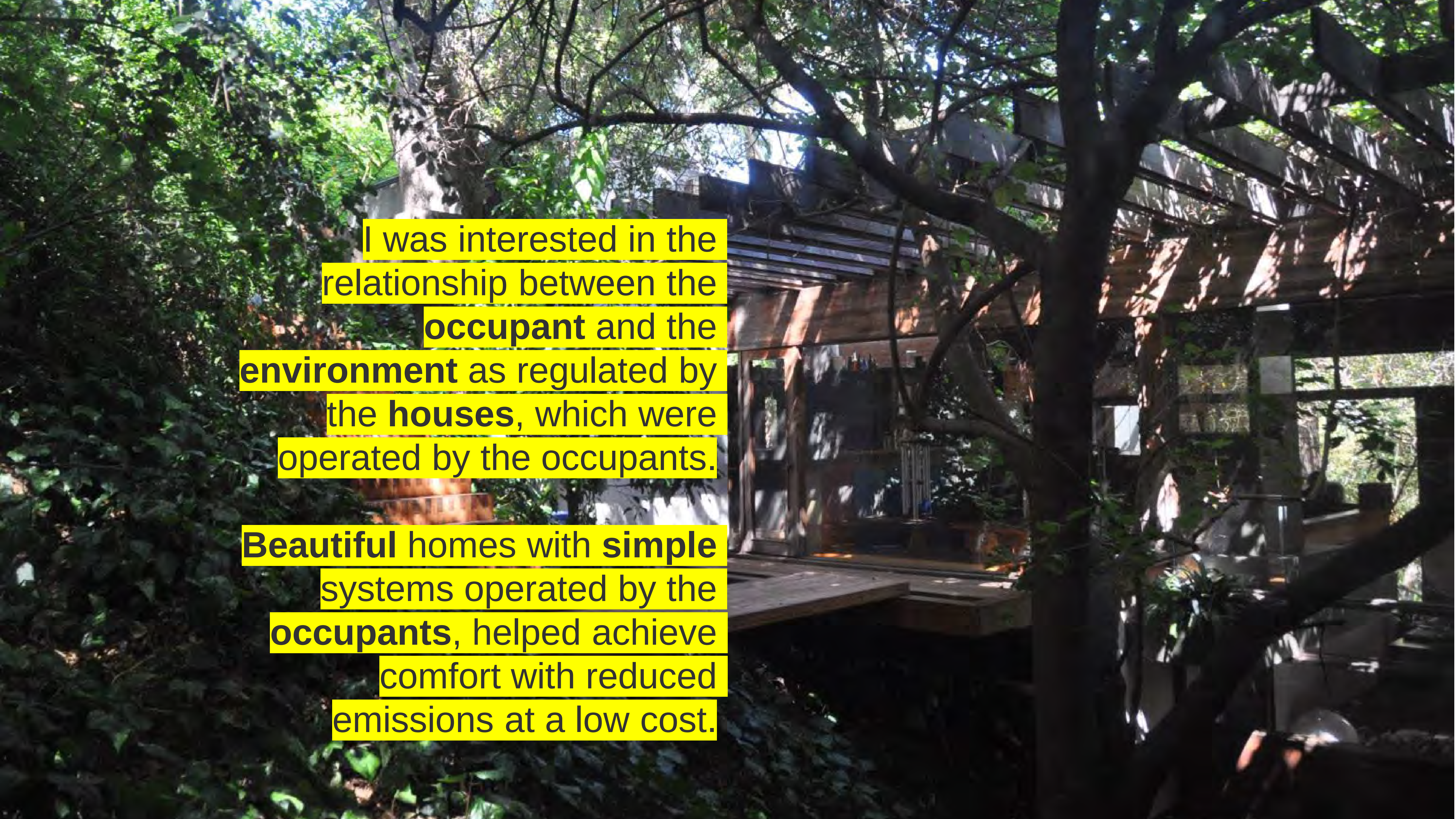
The southeast facing doors on the living room are fully opened during the hottest part of the day.

Overnight the thermastat is set to 64ºF.

Kappe spends time with Shelly in the living room. They used to keep warm and relax by the fireplace, but the fireplace now reduces the indoor air quality.

WINTER THERMAL STRATEGIES

- Leaves fall off of trees, providing more direct solar gains into house
- Direct solar gains through Southeast windows around living area to warm space
- Windows in studio & living area cracked for ventilation on colder days
- Trees and slope shelter the house from cold wind
- Radiant floor heating system uses natural gas, warm air rises from floor to heat space
- The windows of the house recieve very little direct sun because of the vegetation and the topography of the site. Decidous trees in the front yard loose their leaves in the winter and allow solar heat gain through the SE glass doors off of the living room in the mornings.



I was interested in the relationship between the **occupant** and the **environment** as regulated by the **houses**, which were operated by the occupants.

Beautiful homes with **simple** systems operated by the **occupants**, helped achieve comfort with reduced emissions at a low cost.

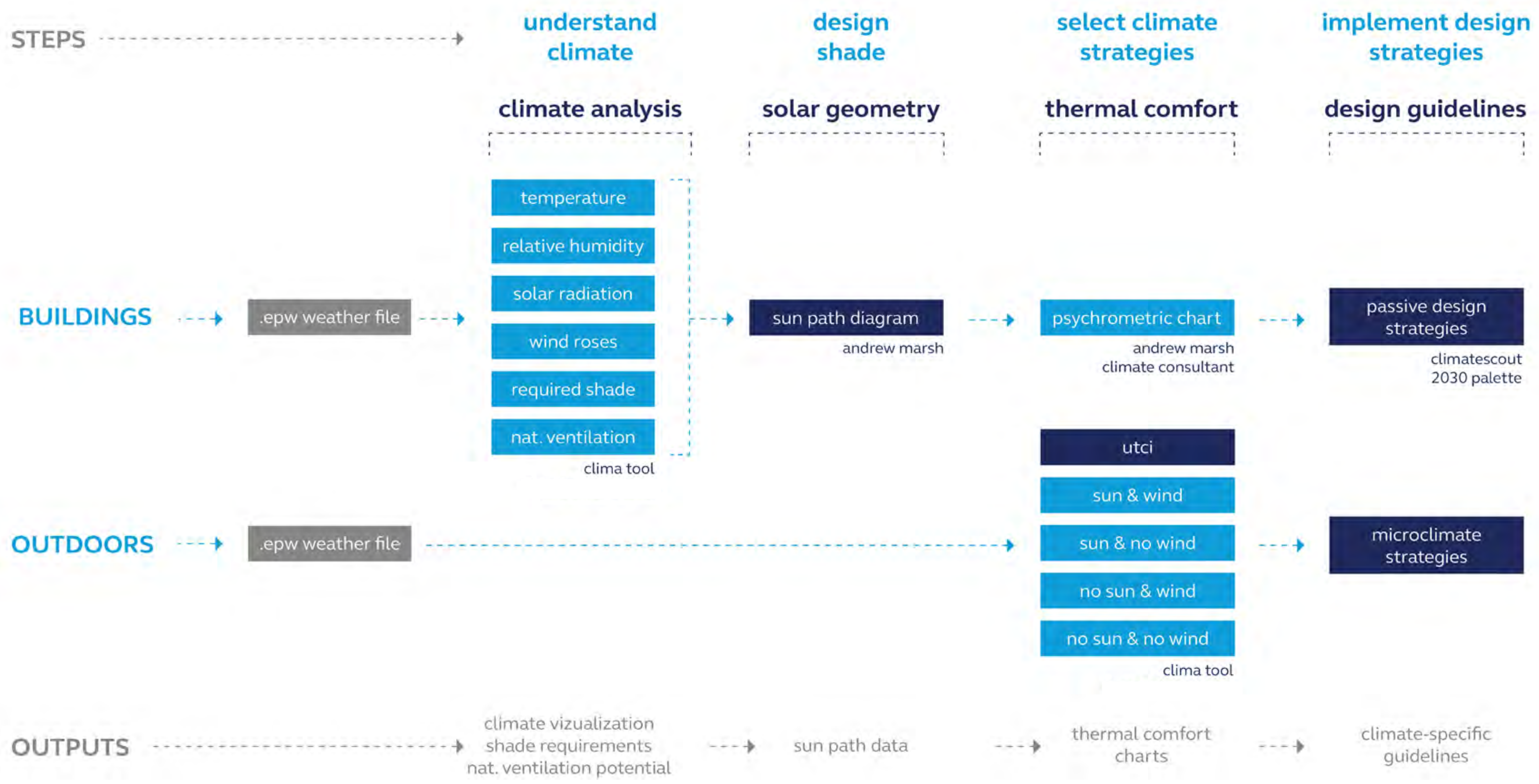
Principle

We should design buildings that are loved by occupants, are simple to operate, and respond to climate.

Architecture is important.

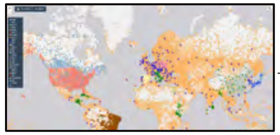
2
Design with Climate:
Workflow and Tools

Process


STEPS
understand climate
design shade
select climate strategies
implement design strategies
climate analysis
solar geometry
thermal comfort
design guidelines
BUILDINGS
.epw weather file
temperature
relative humidity
solar radiation
wind roses
required shade
nat. ventilation
clima tool
sun path diagram
andrew marsh
psychrometric chart
andrew marsh
climate consultant
passive design strategies
climatescout
2030 palette
OUTDOORS
.epw weather file
utci
sun & wind
sun & no wind
no sun & wind
no sun & no wind
clima tool
microclimate strategies
OUTPUTS
climate vizualization
shade requirements
nat. ventilation potential
sun path data
thermal comfort charts
climate-specific guidelines

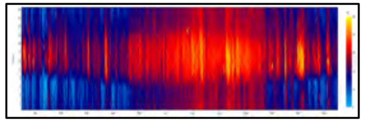
Process

BUILDINGS

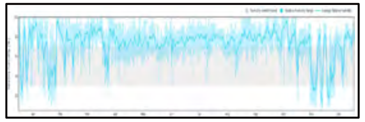


.epw weather file

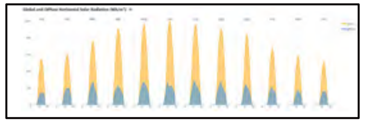
climate analysis



temperature

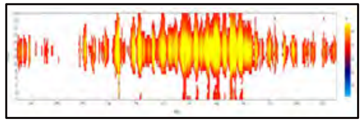


relative humidity

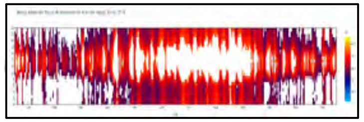


solar radiation

wind direction



shade requirement

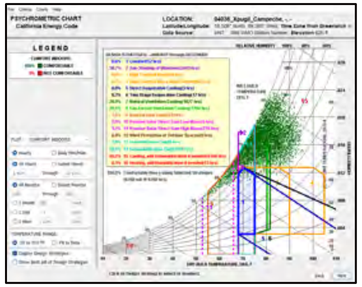


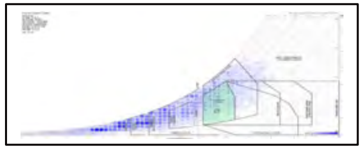
natural ventilation potential

solar geometry

sun path diagram

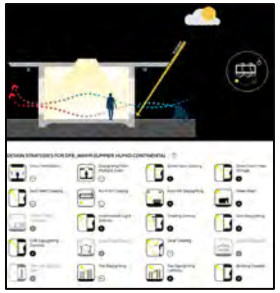
thermal comfort climate strategies



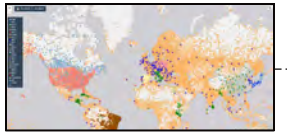


psychrometric chart

building strategies

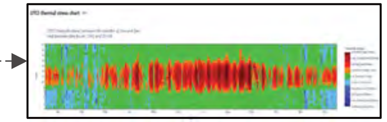


OUTDOORS

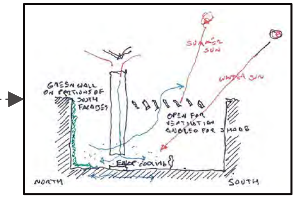


.epw weather file

sun & wind
sun & no wind
no sun & wind
no sun & no wind



UTCI



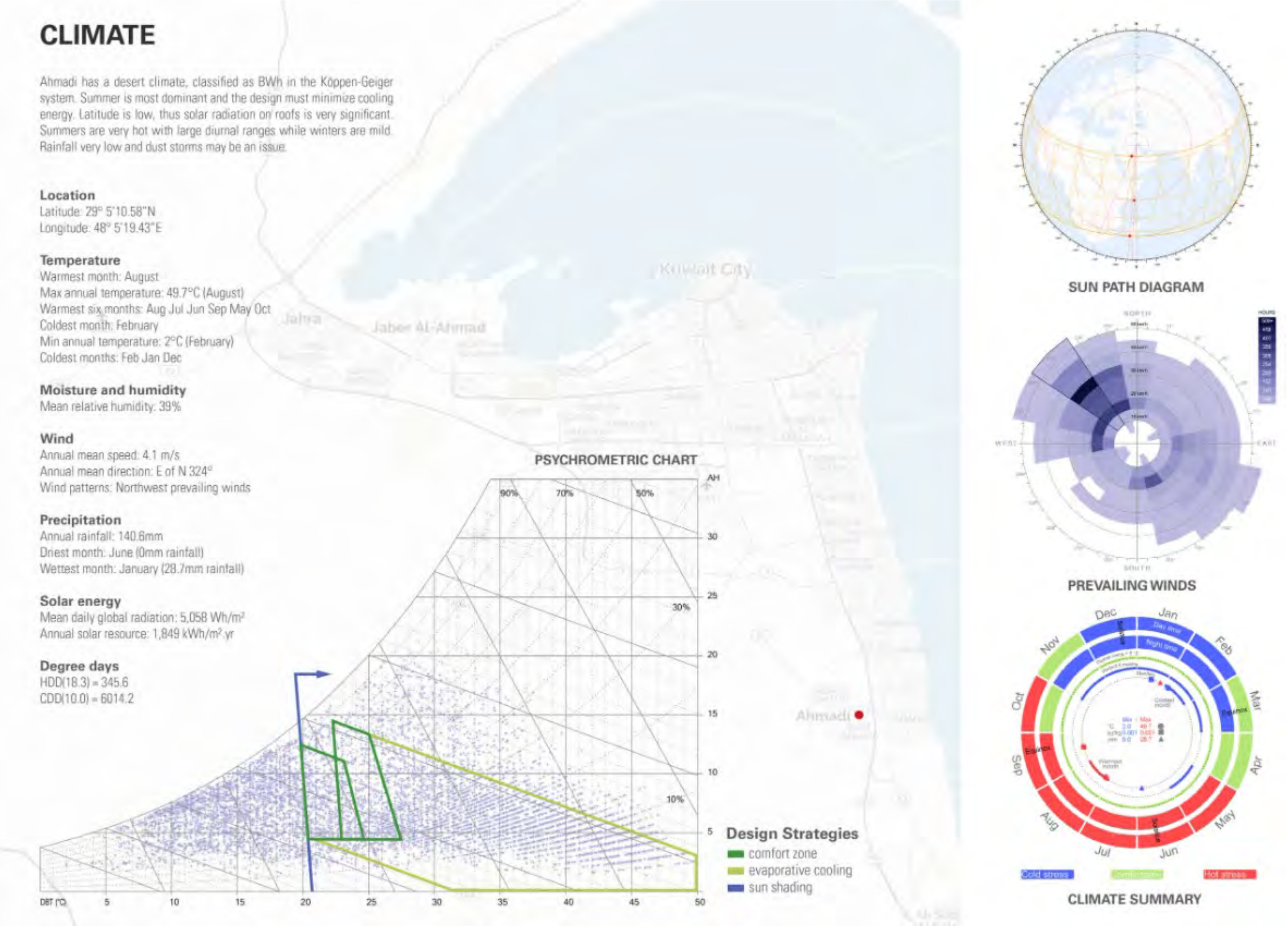
climate analysis | understand climate

Climate Files

Climate analysis uses information from the weather file to determine the architectural design strategies that are most effective to harness natural forces through building design.

In architectural design, climate graphs and charts are useful because they permit us to quickly understand climate variables.

https://www.ladybug.tools/epwmap/

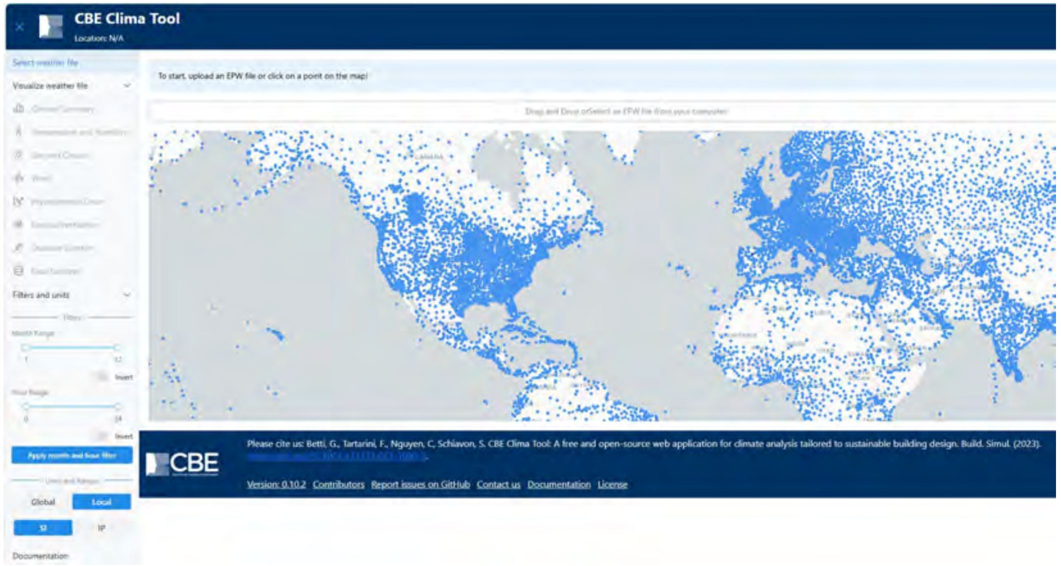


Climate / CBE Clima Tool

https://clima.cbe.berkeley.edu/

The CBE Clima Tool is free and open-source web application for climate analysis tailored to sustainable building design.

It analyzes climate data for over 27,500 global locations using EnergyPlus or user-uploaded EPW files.[1,2]



[1]https://doi.org/10.1007/s12273-023-1090-5

[2]https://cbe-berkeley.gitbook.io/clima

Climate / Temperature & Relative Humidity

Comfort metrics

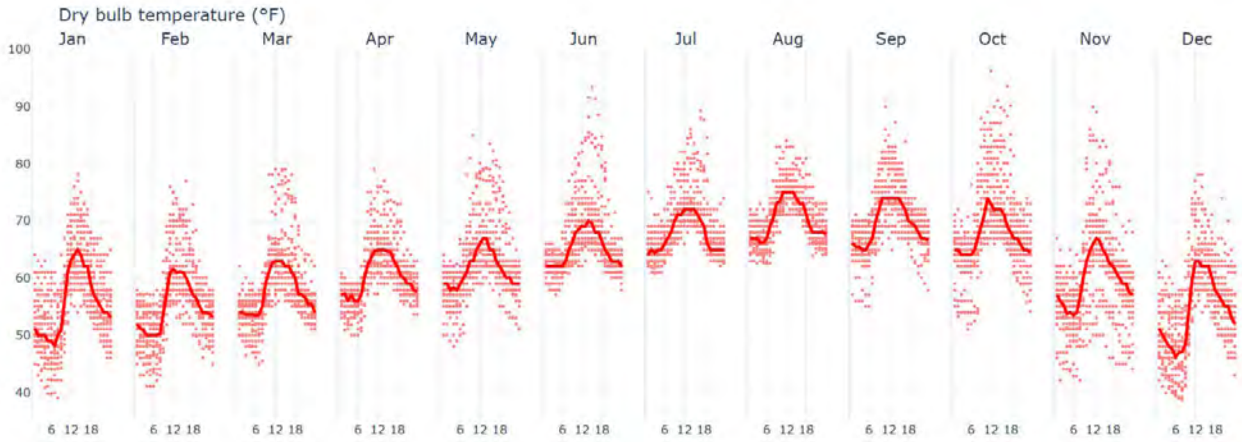
Dry bulb temperature

Relative humidity

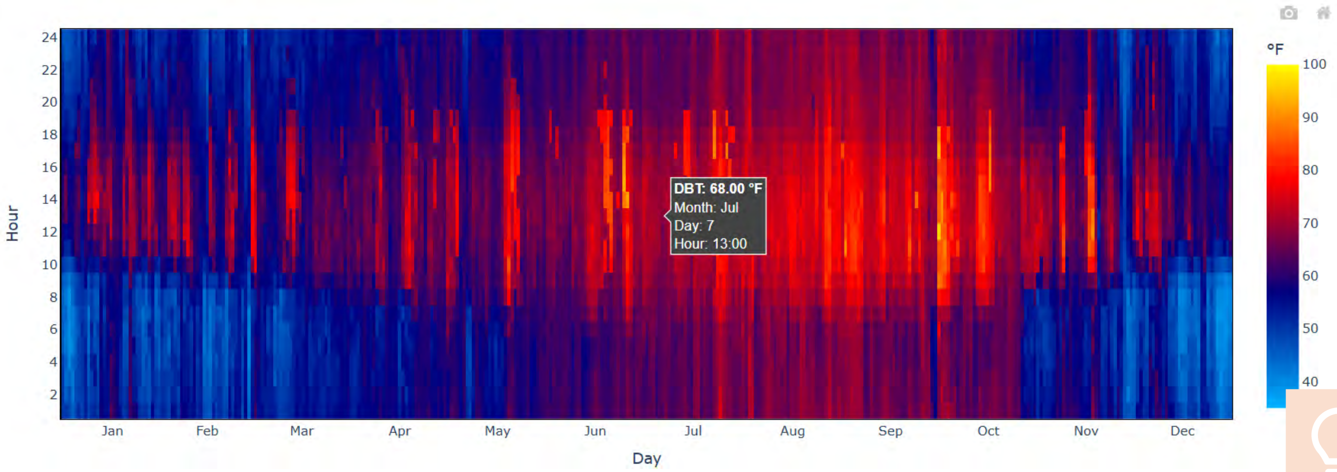
Climate / Temperature

You can better understand temperature and humidity dynamics over the year by examining the daily chart, the corresponding heatmap and monthly descriptive statistics.

Daily chart



Heatmap chart

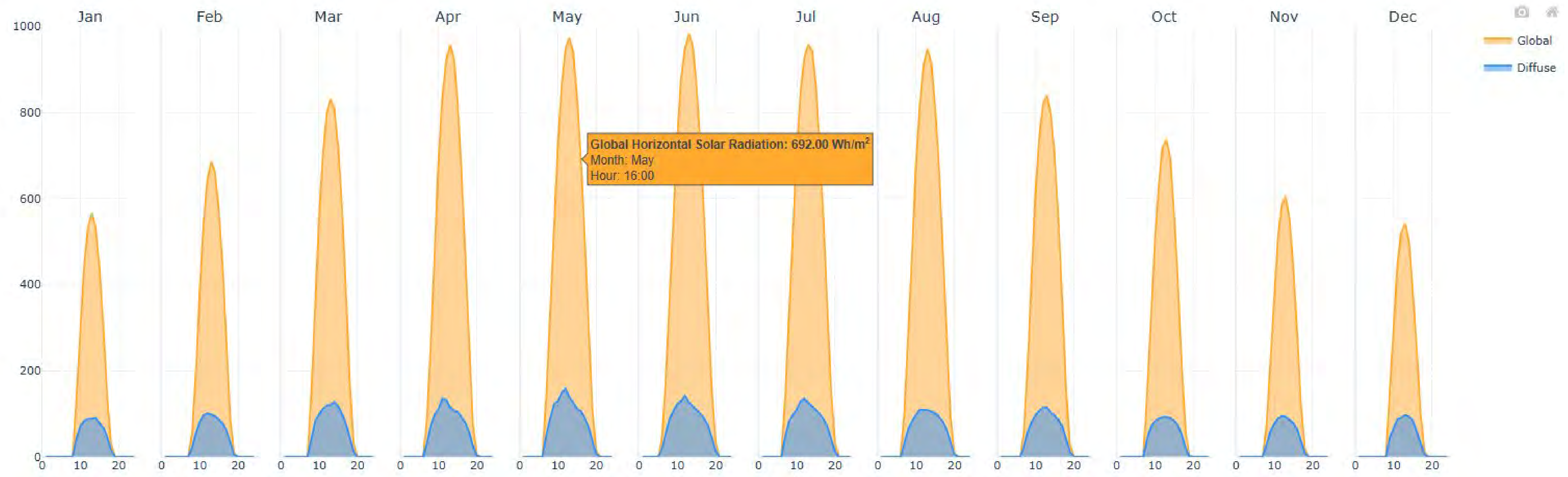


Descriptive statistics

month	mean (°F)	std (°F)	min (°F)	1% (°F)	25% (°F)	50% (°F)	75% (°F)	99% (°F)	max (°F)
Jan	56.4	7.3	39	42.1	50.7	55.9	61	73.6	78.1
Feb	55.8	6.7	41	43	51.1	55	59	73.9	77
Mar	58	5.9	45	46.9	54	57	61	77.9	79
Apr	60.7	4.8	50	51.4	57.2	60.1	63	75	79
May	62.2	5.8	48	50	59	61	64.9	79.6	84.9
Jun	66.1	5.5	57	57.9	62.1	64.9	68	84.7	93.4
Jul	68.5	4.8	60.8	61.8	64.9	68	71.1	84	89.2

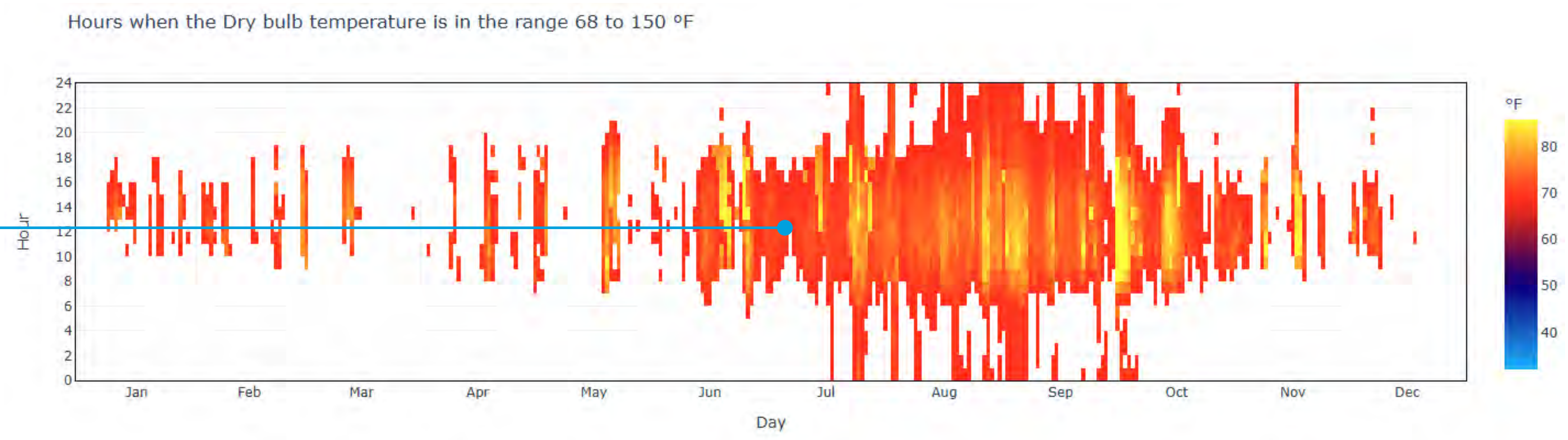
Climate / Solar Radiation

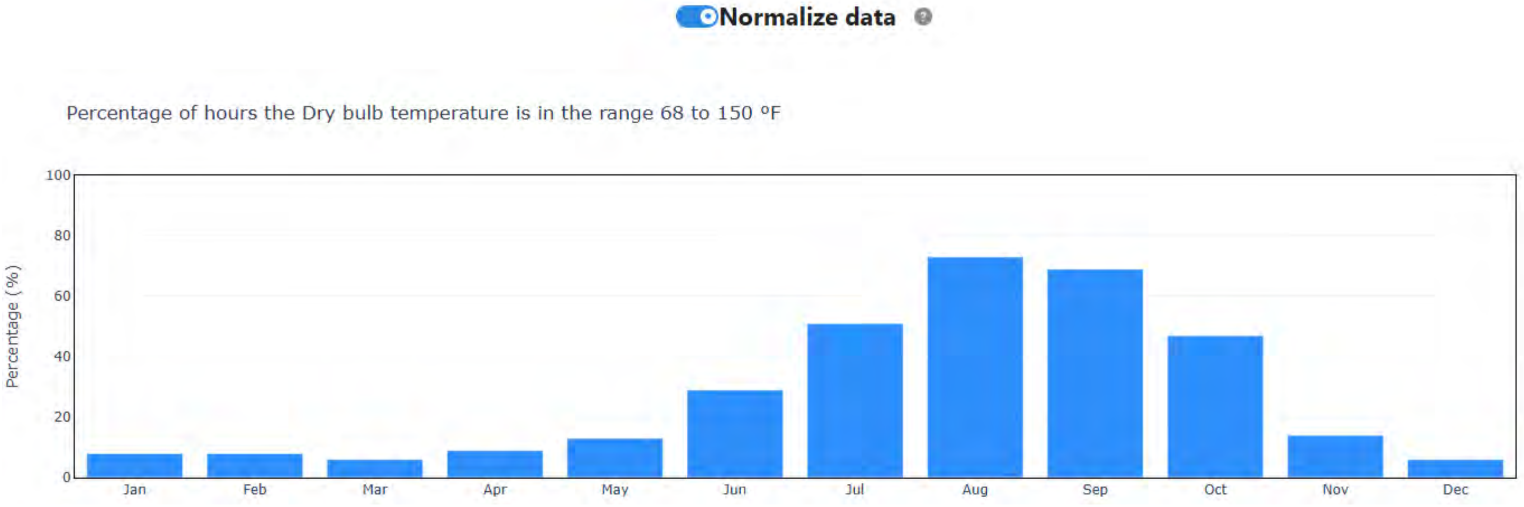
Global and Diffuse Horizontal Solar Radiation (Wh/m²)



Shade Required

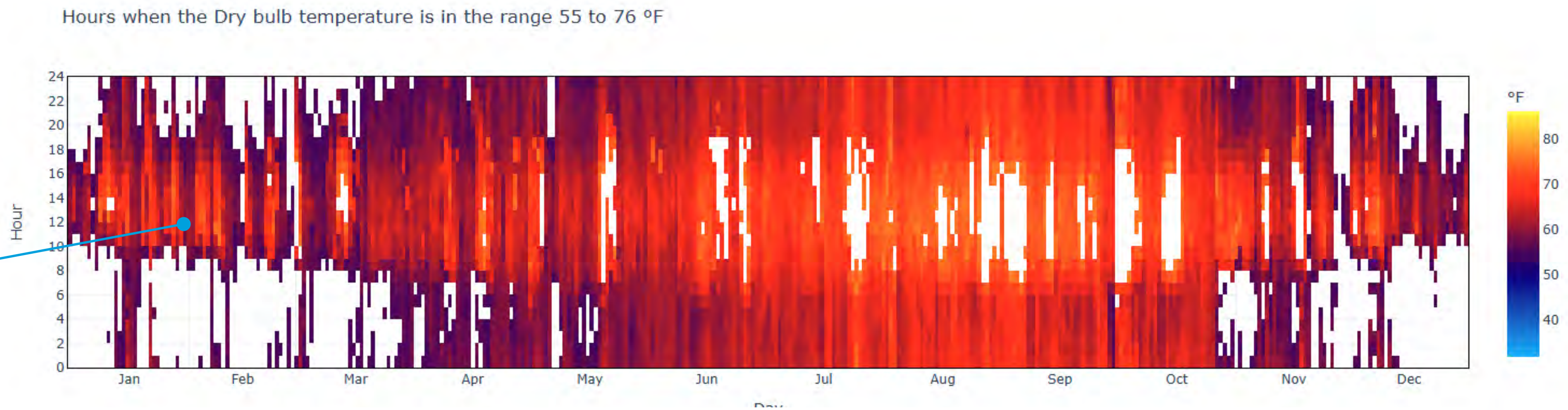
The colored area indicates time of the year when temperatures are higher than 68°F and shade will be required to make indoor spaces more comfortable. Screenshot the top table and summarize your findings.

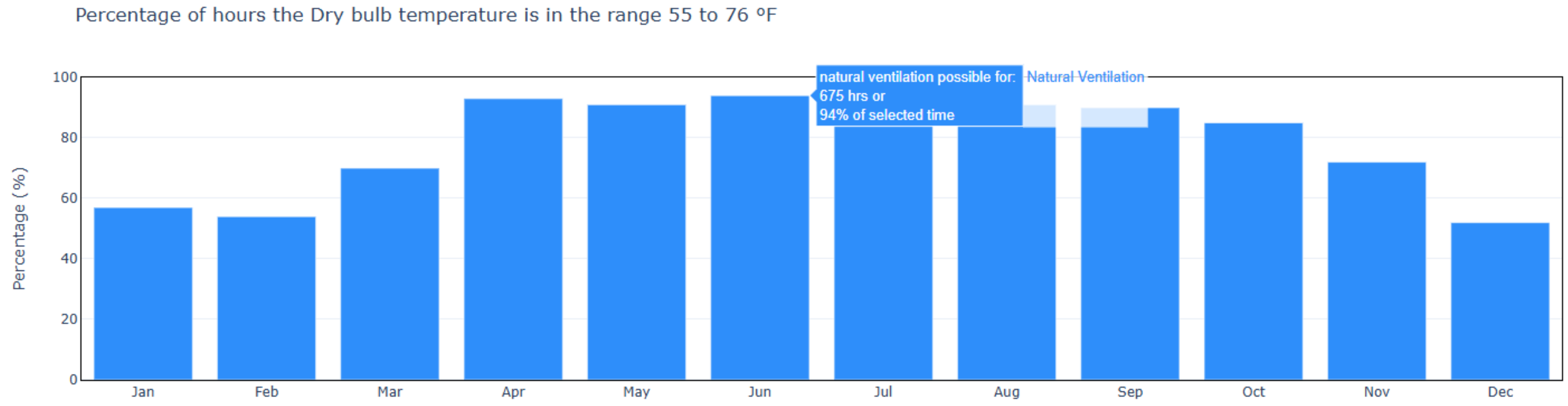




Potential for Natural Ventilation

The colored area indicates when natural ventilation can provide thermal comfort.

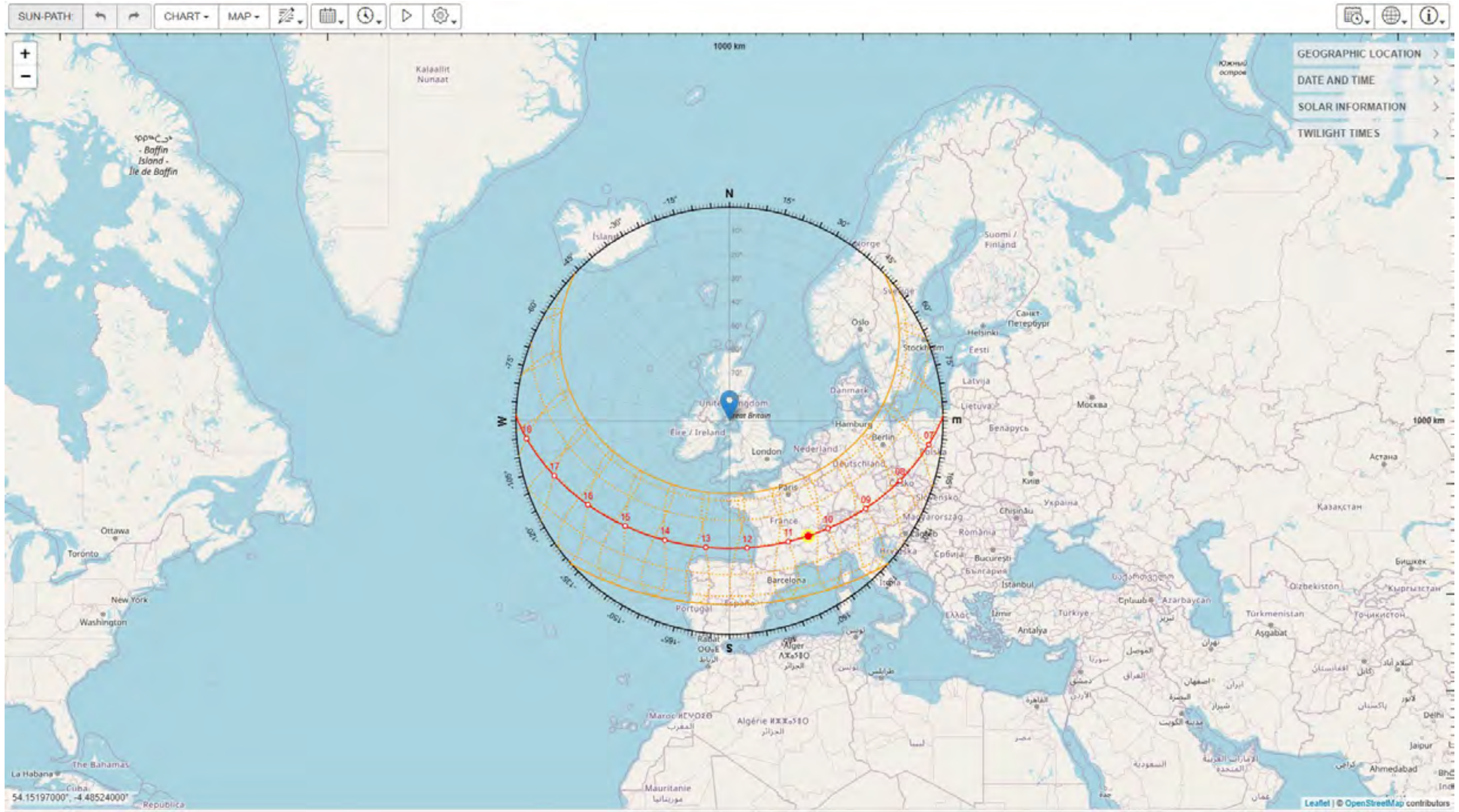




Solar Geometry

Sun-Path on Map is an app developed by Andew Marsh that overlays a dynamic 2D sun-path diagram on a location in earth using a map and automatically adjusting for location.[1]

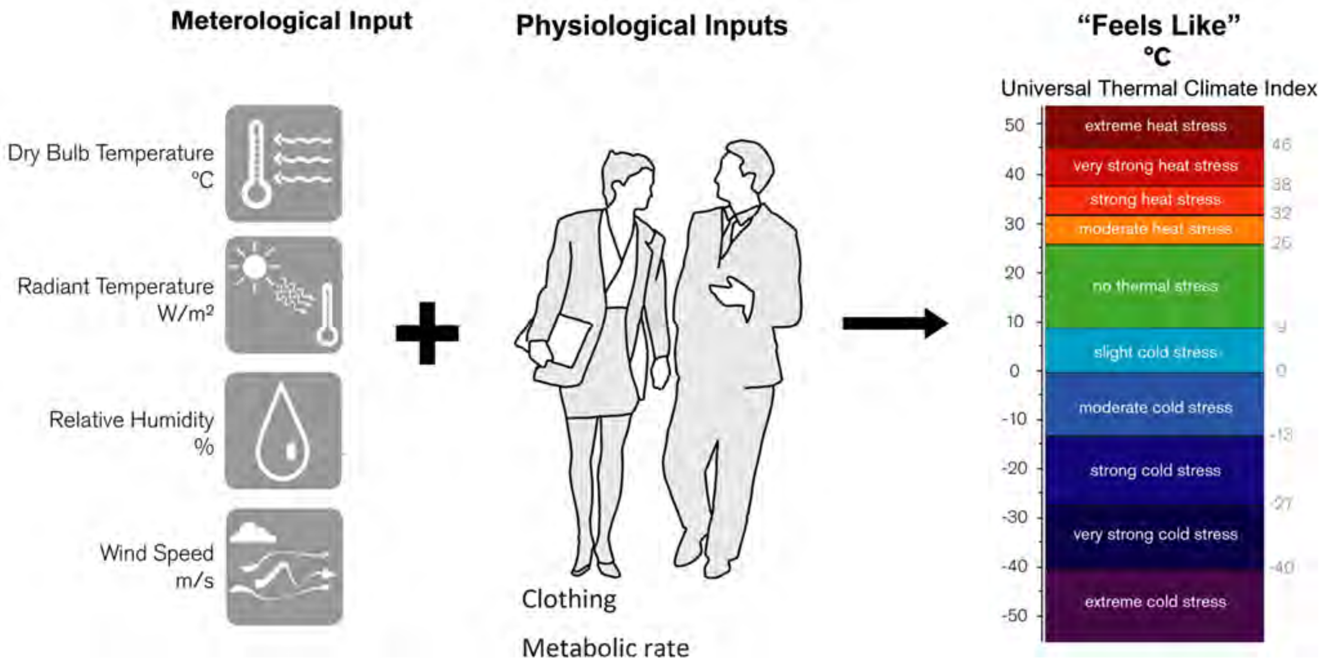
Click here to access the tool: https://drajmarsh.bitbucket.io/sunpath-on-map.html



[1]AJM - Sun-Path on Map

Outdoor Comfort / UTCI

The Universal Thermal Climate Index (UTCI), introduced in 1994, aims to be the measure of human physiological reaction to the atmospheric environment.[1]

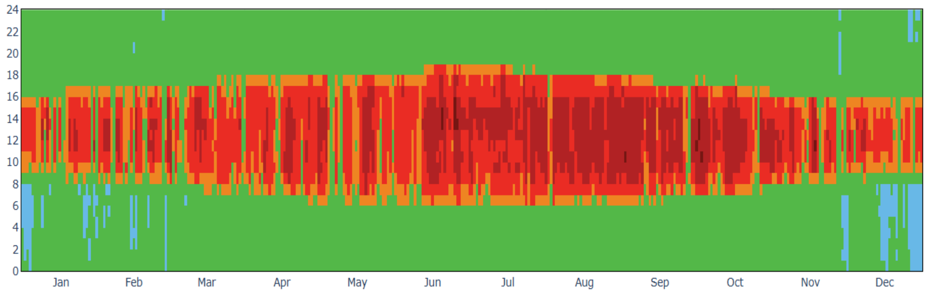


[1] Outdoor Comfort | CBE Clima Tool

Outdoor Comfort / UTCI

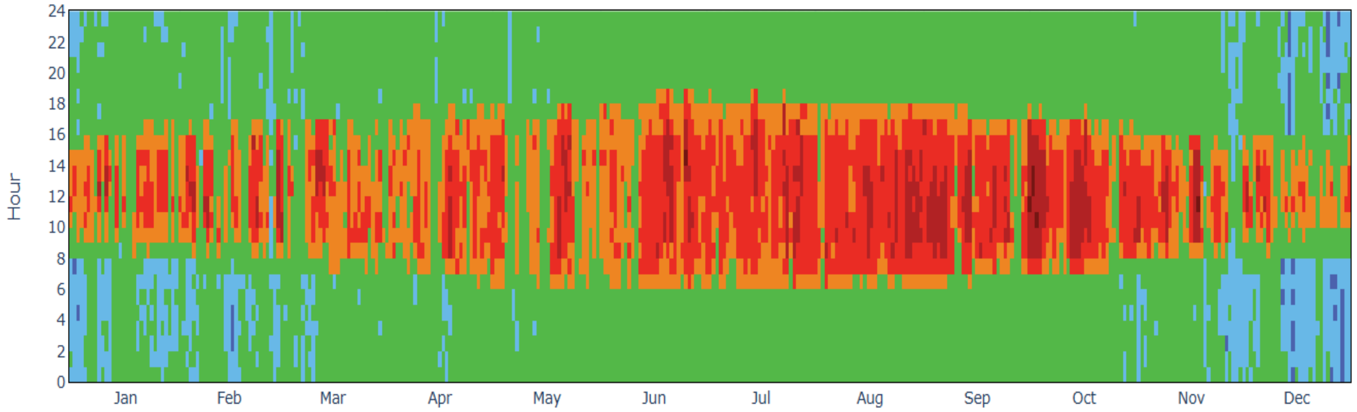
Compare with the other three options, sun no wind; no sun wind; no sun no wind. These indicate presence or absence of air movement and shade.

The combination with more hours in green is the best one.

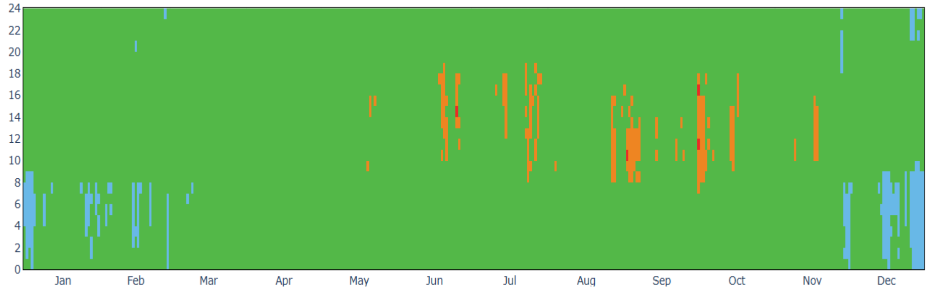


Sun & No Wind

No Sun & Wind



Sun & Wind



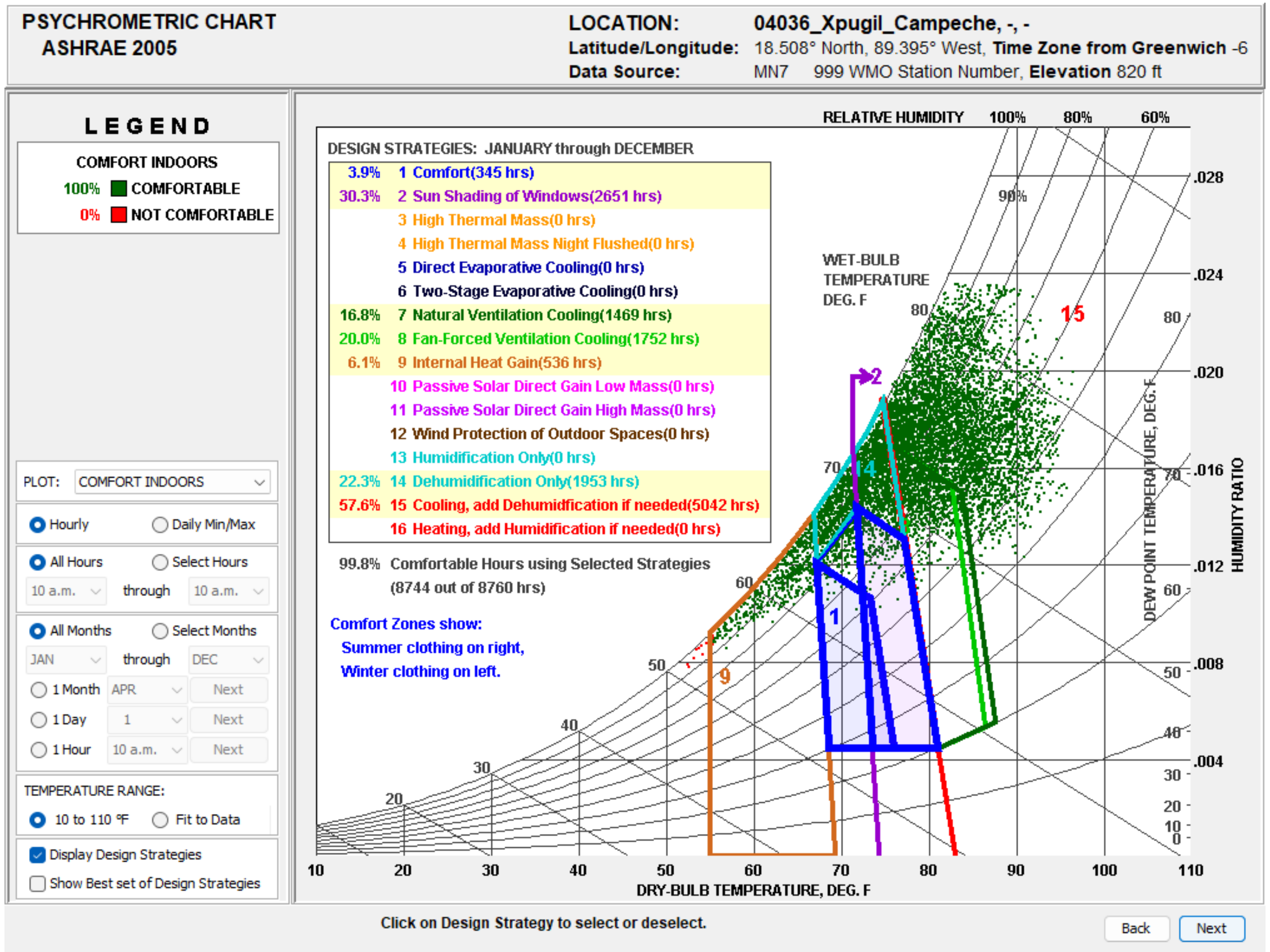
No Sun & No Wind

design | implement climate strategies

Climate Strategies / Climate Consultant

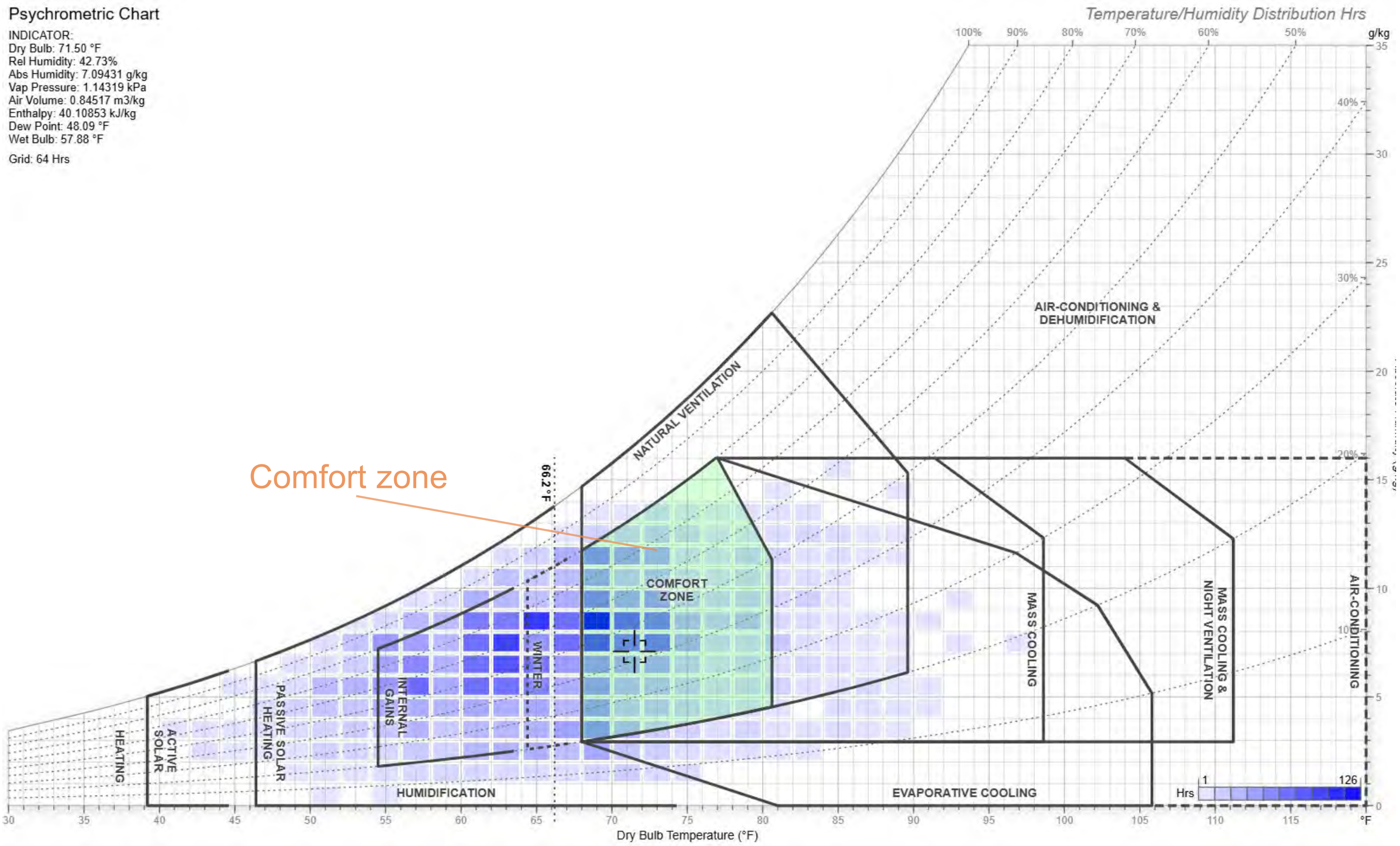
Download at:

https://www.sbse.org/resources/climate-consultant



Climate Strategies / Building Bioclimatic Chart

https://andrewmarsh.com/software/psychro-chart-web/



Design Guidelines / Arcadis CLIMATESCOUT

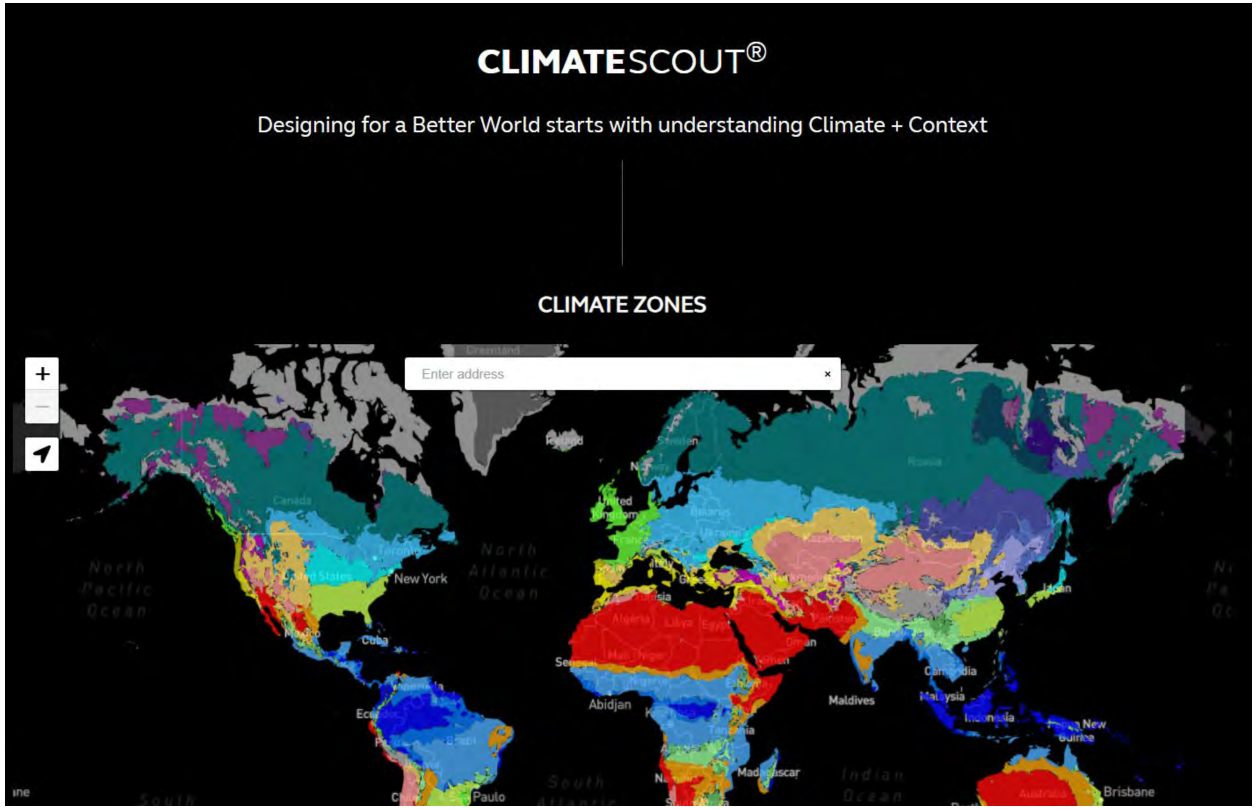
CLIMATE SCOUT® helps its users to design buildings that uniquely respond to a site by providing climate-specific design advice linked to operational carbon intensity goals at the earliest stages of concept design.

To achieve this, it uses:

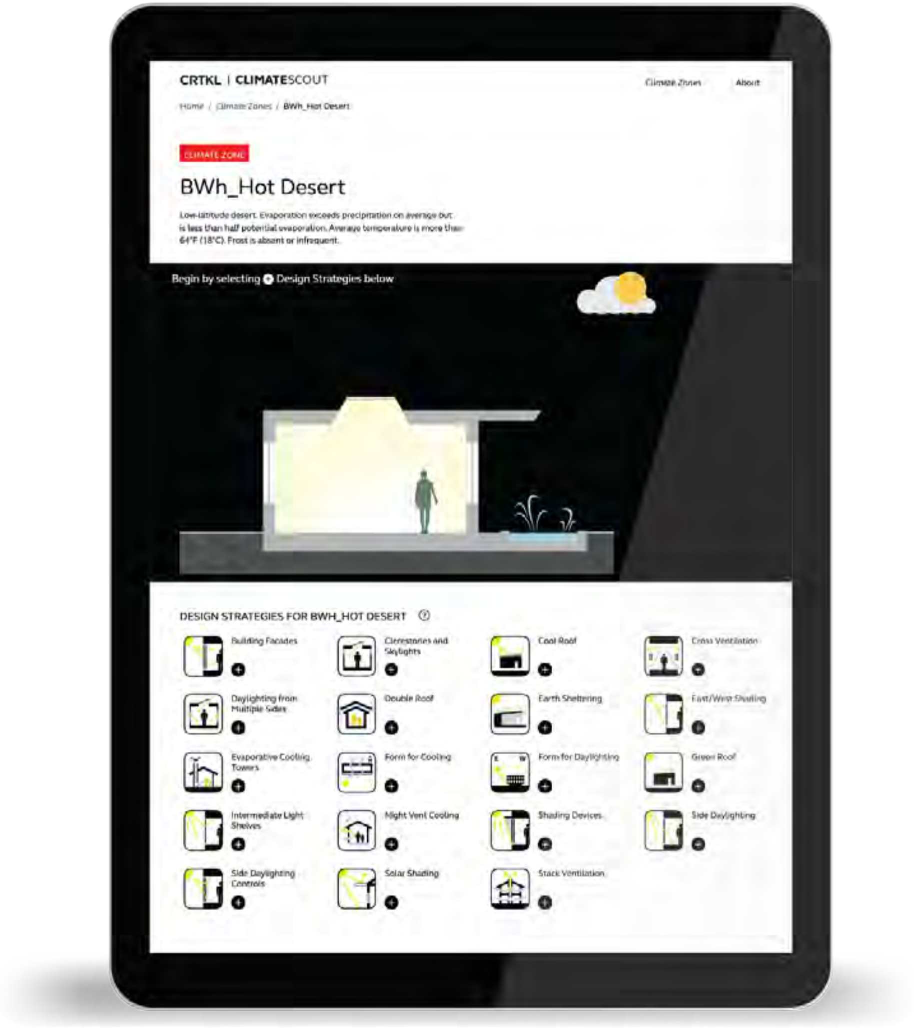
- Köppen-Geiger climate classification,
- Building scale design strategies from Architecture 2030's Palette
- Grid Carbon Intensity Data.

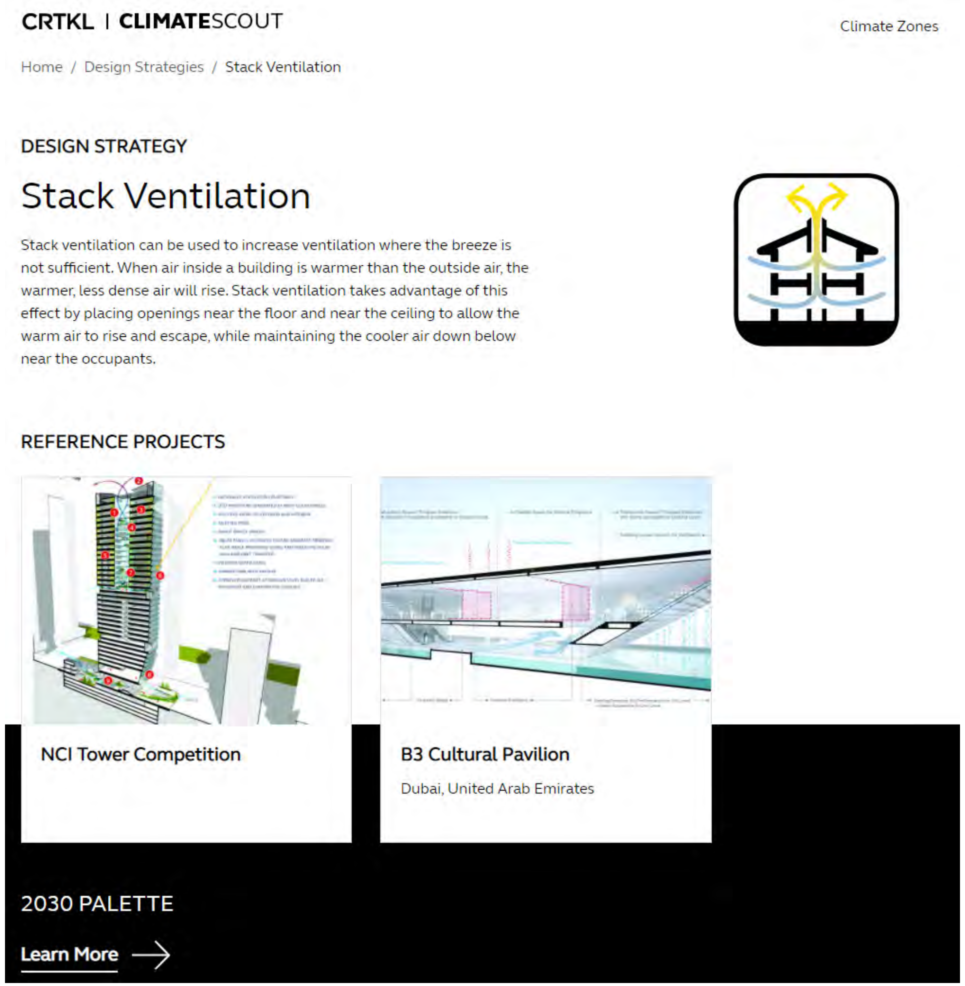
Click here to access the tool:

https://climatescout.arcadis.com/



Design Guidelines



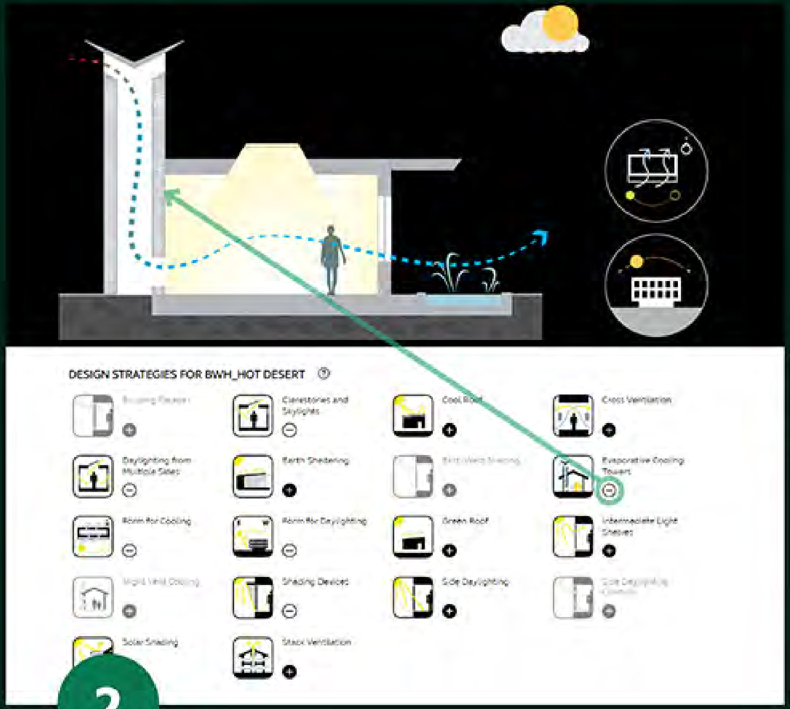



CRTKL | CLIMATESCOUT
Climate Zones
About
CLIMATESCOUT
Desiging for a Better World starts with understanding Climate + Context
CLIMATE ZONES

1

When accessing the site, **select the appropriate climate zone by clicking on the map or choosing from the list below.** In the Köppen-Geiger climate type, you can find climate data and descriptions for most cities.

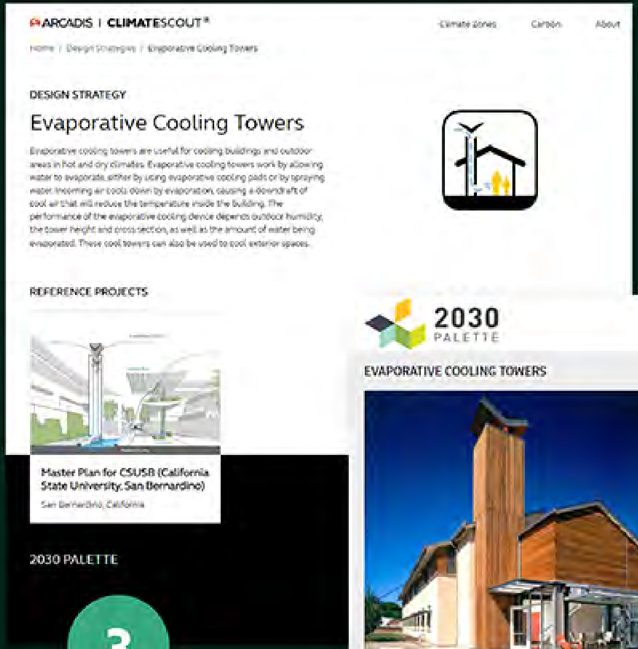
Selecting the climate prompts a new screen with a building section to overlay chosen design strategies.



2

Using the icon's plus symbol populates the strategy in the diagram. You can select as many of the strategies in any combination until satisfied with the results. You will be able to export this image to a report of your initial site analysis.

You can also click directly on each strategy icon to learn more and see Arcadis project examples of its implementation.

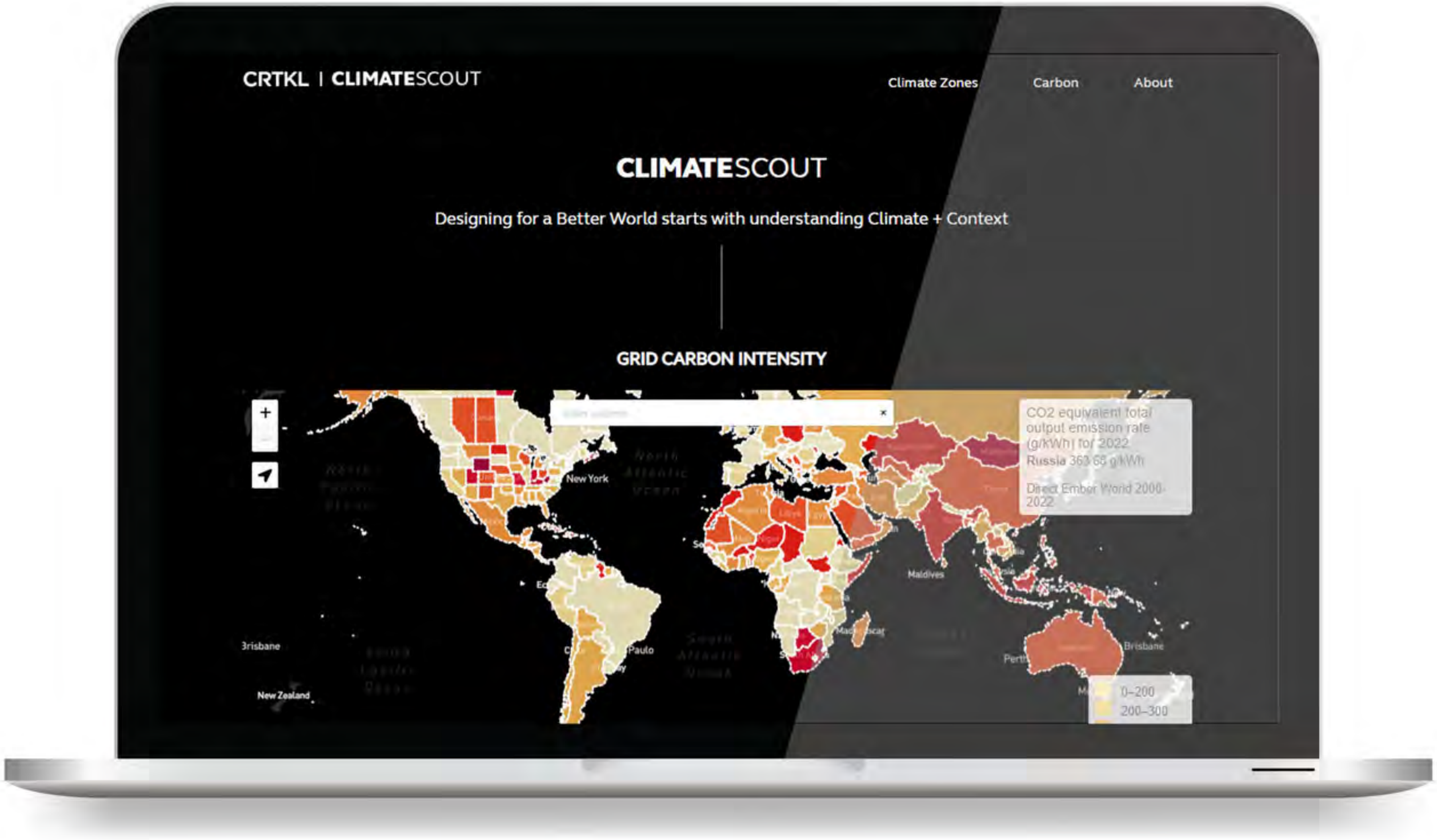


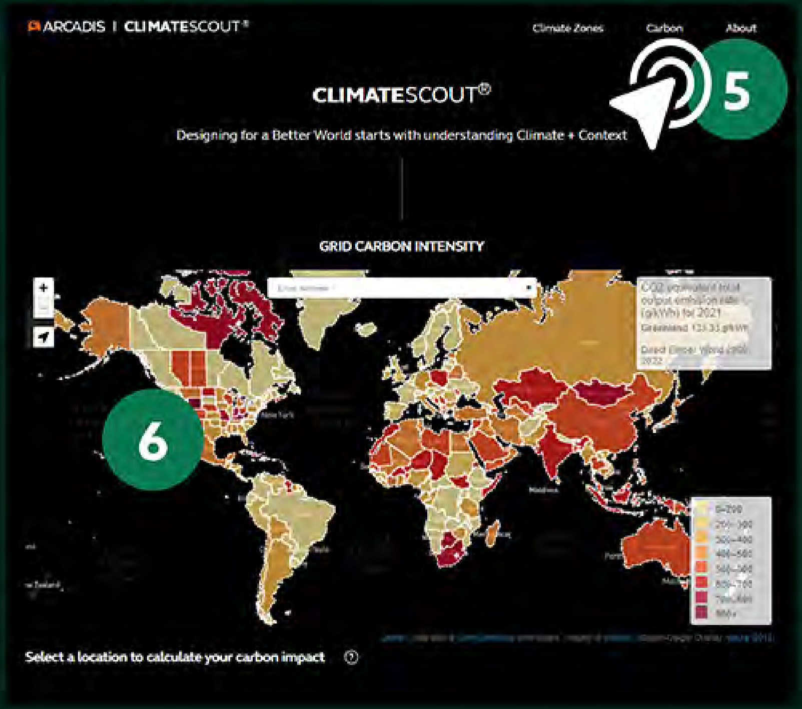
3

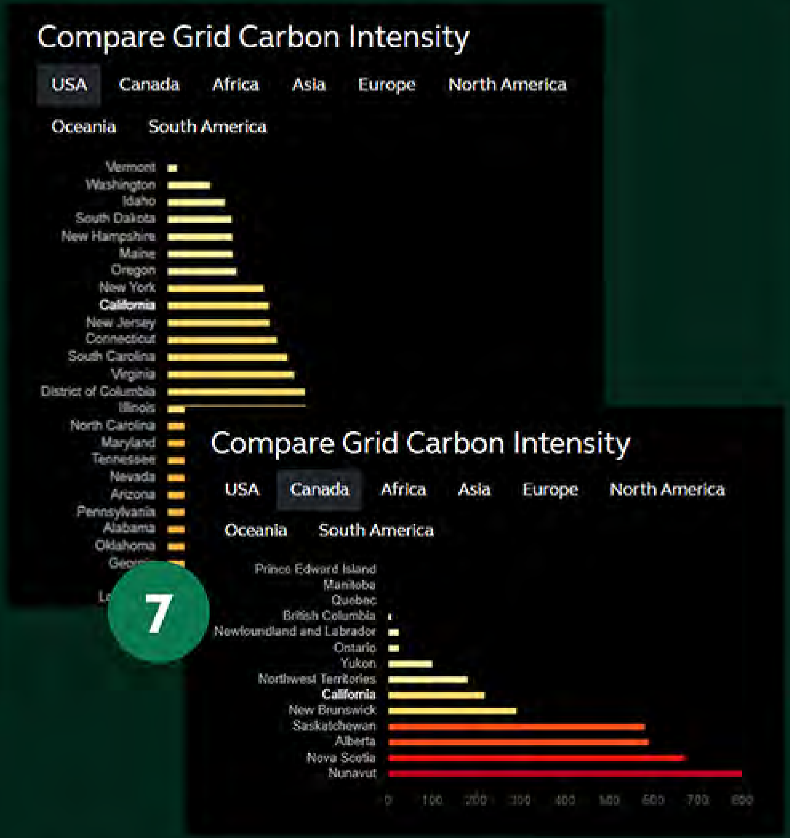
4

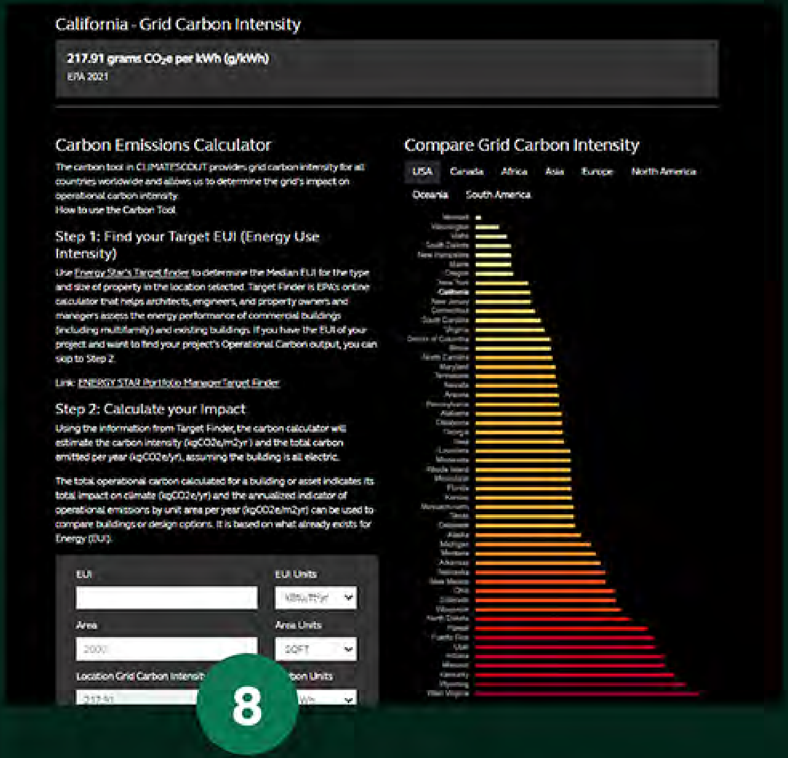
This page also directly links to the same strategy in the 2030 palette, where more information resides on strategy implementation.

We have also evaluated and omitted combination options that would not work in "a real-world" situation due to design interference or other technicalities.


CRTKL | CLIMATESCOUT
Climate Zones
Carbon
About
CLIMATESCOUT
Designing for a Better World starts with understanding Climate + Context
GRID CARBON INTENSITY
New York
Maldives
Brisbane
New Zealand
0–200
200–300







Clicking on the Carbon tab at the top of the page will prompt the **grid carbon intensity page.** In this page, you can select any state in the United States, any province in Canada or any country in the world to find out their carbon intensity.

On the right of the page, you can **compare the grid carbon intensity** of your location to different countries in the world.

Selecting a location prompts a **Carbon Emission Calculator.** With the Target EUI (Energy Use Intensity) and the area of your project, **the carbon calculator will estimate the carbon intensity (kgCO2e/m2yr) and the total carbon emitted per year (kgCO2e/yr)**, assuming the building is all electric.

CLIMATESCOUT

CLIMATESCOUT connects climate data directly to architectural design decisions, making climate-responsive design more accessible and actionable. It helps designers understand that building performance and carbon emissions are strongly influenced by local climate conditions, reinforcing the need for climate-specific strategies early in design

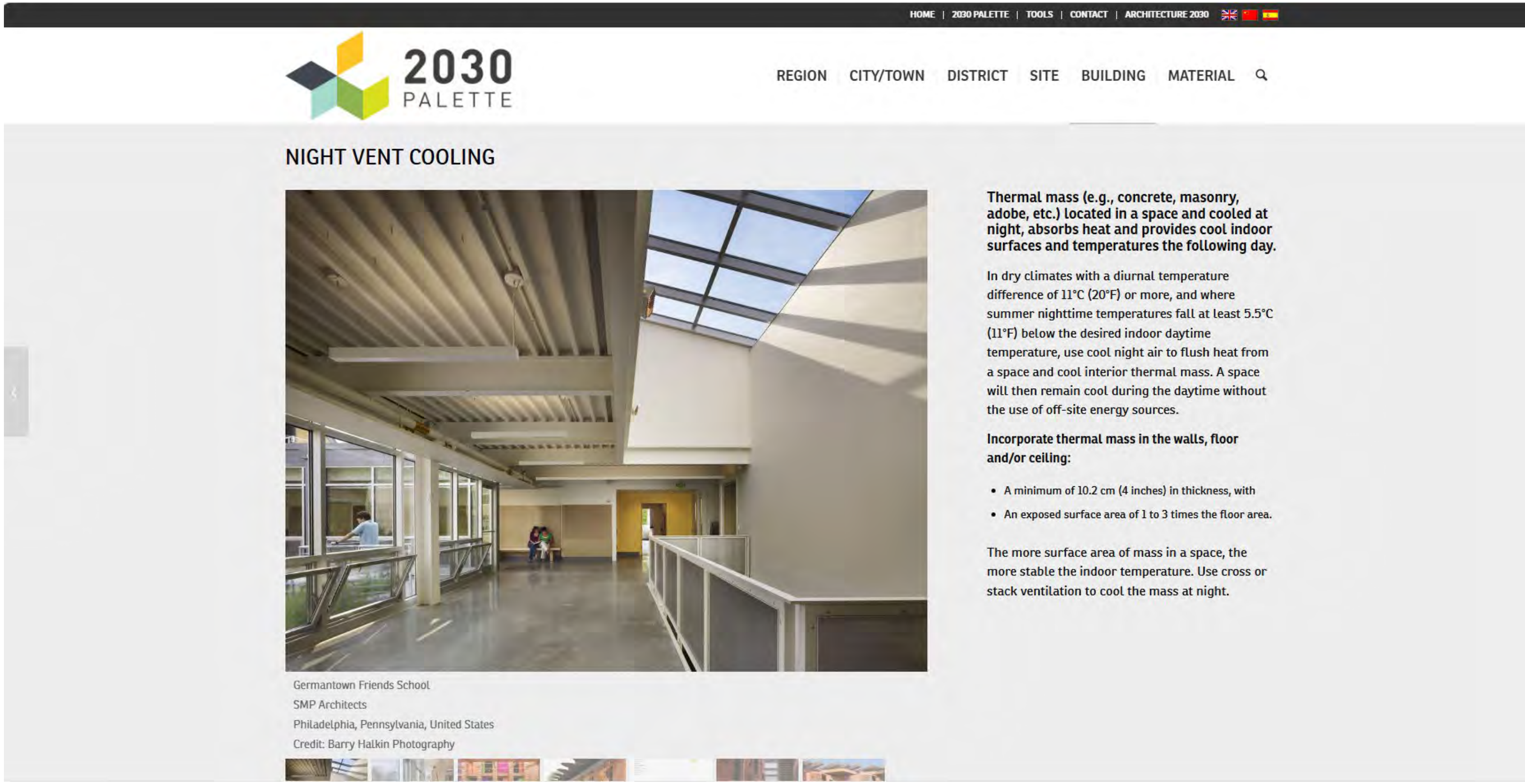
How it’s useful for low-carbon design

- **Translates climate into design strategies** - Uses Köppen-Geiger climate zones to recommend appropriate passive and building-scale strategies
- **Integrates passive design early** - Identifies strategies such as shading, natural ventilation, massing, and daylighting tailored to specific climates
- **Reduces operational carbon** - Supports climate-appropriate solutions that lower heating, cooling, and lighting loads, directly impacting energy use
- **Provides visual, interactive feedback** - Allows teams to overlay strategies and see how they work together in a building section, improving early decision-making
- **Bridges tools and workflows** - Combines climate analysis with Architecture 2030 strategies in one platform, making it easier to apply sustainable design principle

Architecture 2030 Palette

The 2030 Palette is a free online platform that succinctly puts the principles and actions behind carbon neutral and resilient built environments at the fingertips of designers, planners, builders, and policymakers worldwide. The swatches, or sustainable design strategies, address energy consumption and greenhouse gas emission at all scales – from regional and city planning to building details.

https://2030palette.org/



Architecture 2030 Palette

2030 PALETTE

REGION CITY/TOWN DISTRICT SITE BUILDING MATERIAL

EVAPORATIVE COOLING TOWERS

Global Ecology Center, Carnegie Institution for Science
EHDD
260 Panama Street, Stanford, California, United States
Credit: Mert Carpenter Photography

In hot-dry climates, evaporative cooling towers will cool outdoor air and circulate it to a space or building.

Evaporating water at the top of a cooling tower creates a downdraft of cooler air that can then be circulated to a specific space or area. The amount of cool air from the tower is dependent on outdoor humidity, the height of the tower, and the amount of water being evaporated.

Configure an evaporative cooling tower:

- A minimum of twice the height of the space to be cooled, with
- A cross-sectional area of approximately
  - 3 m2 (33 ft2) for residential applications
  - 6 m2 (64 ft2) for commercial applications

The higher the tower, the greater the amount of air delivered. Make the area of the outlet opening (delivering the cooled air) as large as the cross-section of the cooling tower.

TOOLS + RESOURCES

BOOKS

- Climate Considerations in Building and Urban Design. Baruch Givoni.
- The Green Studio Handbook. Alison G. Kwok and Walter T. Grondzik.
- Sun, Wind and Light: Architectural Design Strategies, Third Edition. Mark DeKay and G. Z. Brown.
- Passive Low Energy Cooling of Buildings: Baruch Givoni.
- Carbon-neutral Architectural Design. Pablo La Roche.

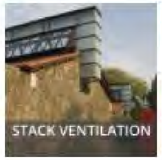
PUBLICATIONS

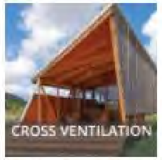
- Energy and Buildings: Refining the use of evaporation in an experimental down-draft cool tower

TOOLS

- U.S. Department of Energy: Energy Plus
- cove.tool

RELATED SWATCHES





Principle

Climate analysis is a powerful early phase integrative design tool.

3

Design with Climate:

Middle East
Arcadis

Principle

Different seasons require different strategies.

Section 4
Design with Climate:
Northern Italy
Arcadis

Section 5
Smart Passive Cooling
Improving passive systems

Lack of cooling kills, but so does providing inefficient, polluting cooling.

Passive Cooling Systems

Passive cooling systems will cool the building by transferring energy to natural heat sinks such as the **air, water, earth, or outer space**. Implementation of these systems in buildings reduces the energy needed for cooling.

Passive cooling systems use a fraction of the energy at a fraction of the cost of mechanical cooling systems.

...passive cooling technology must become central to climate adaptation.

Passive cooling technologies reduce heat and solar gains in buildings and public spaces while dissipating excess heat. This approach could reduce impacts of mechanical air conditioning, which has environmental impacts and consumes electricity, contributing to peak demand and grid stress.

Santamouris, M., Vasilakopoulou, K. Passive cooling for the built environment. *Nature Reviews Clean Technologies* (2026). https://doi.org/10.1038/s44359-026-00177-y

The goal:
To make passive cooling more accessible, providing a viable low carbon, alternative path for cooling.

When possible, generating income that stays in the community.

Smart Passive Cooling Systems

Three smart passive cooling systems developed and tested by the author are presented. These systems provide cooling using different heat sinks:

- Air
- Water
- Sky

Their performance is enhanced with smart controllers that operate responding to real time measurements in the building and weather.

They can reduce operational and embodied emissions.

1. Cooling with air

The atmosphere provides a powerful medium for heat transfer, primarily through convection. Cooling by ventilation to the atmosphere is probably the simplest way to remove heat from buildings, as comfort or night ventilation. Comfort ventilation provides direct well-being by air movement through the body, evaporating sweat and cooling the skin. Night ventilation cools the thermal mass of the building with outside air. During the daytime, the cooled mass acts as a heat sink, reducing the rate of indoor temperature rise.

Smart Ventilation and Shading System

With Murray Milne at UCLA

Smart Ventilation and Shading System

Operation Rules

The microcomputer-controlled thermostat controls the fan and blind so that they adjust the air changes and radiation into the cells.

Equation (1) for air movement

If $T_o < T_i$ and $T_i > Cf_{low}$ then FAN ON else FAN OFF

where

T_o = outside temperature

T_i = indoor temperature

Cf_{low} = comfort low (18.33°C) can be adjusted

If it is cooler outside than inside and indoor temperature is higher than lower range of comfort low, then provide ventilation, otherwise, no ventilation.

Equation (2) for solar control

If $T_p > T_o$ and $T_i > Cf_{low}$ then SHADE ON else SHADE OFF

where

T_p = Temperature south facing exterior plate

T_o = outside temperature

T_i = indoor temperature

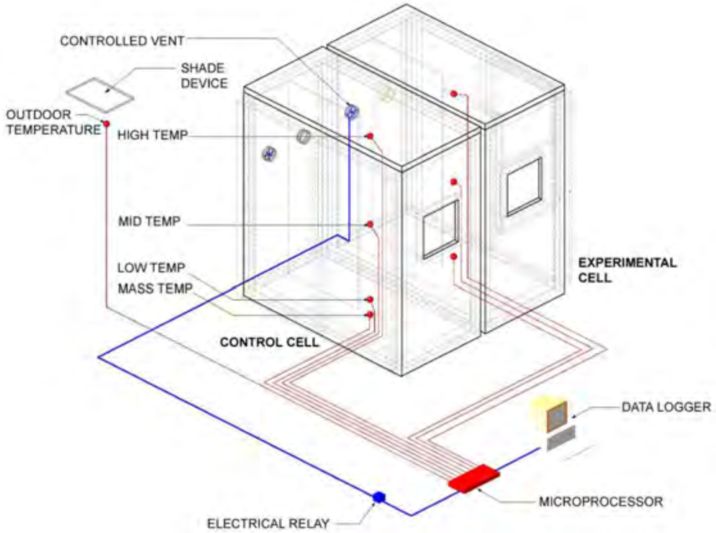
Cf_{low} = comfort low (18.33°C) can be adjusted

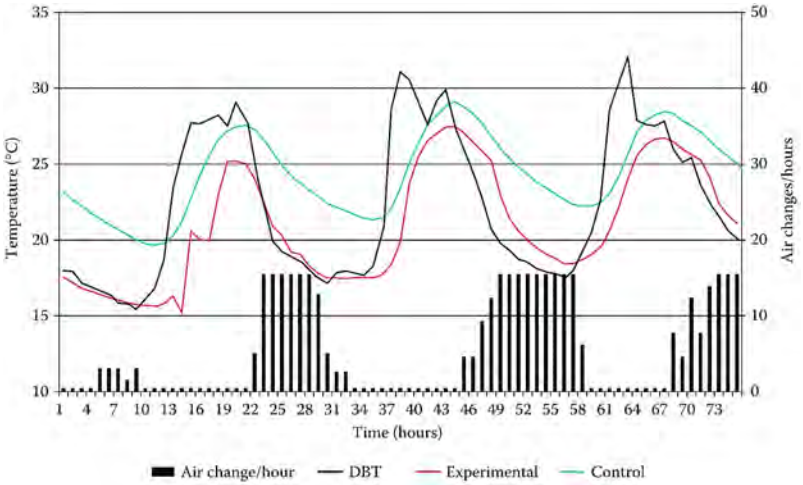
If surface temperature and indoor temperature are higher than lower range of comfort low, then provide shade, otherwise, no shade.

Smart Ventilation System

Operation

The system ventilates the cell when needed to cool the interior mass while maintaining comfort. It operates an exhaust fan that regulates the air flow according to predetermined rules (selective ventilation).

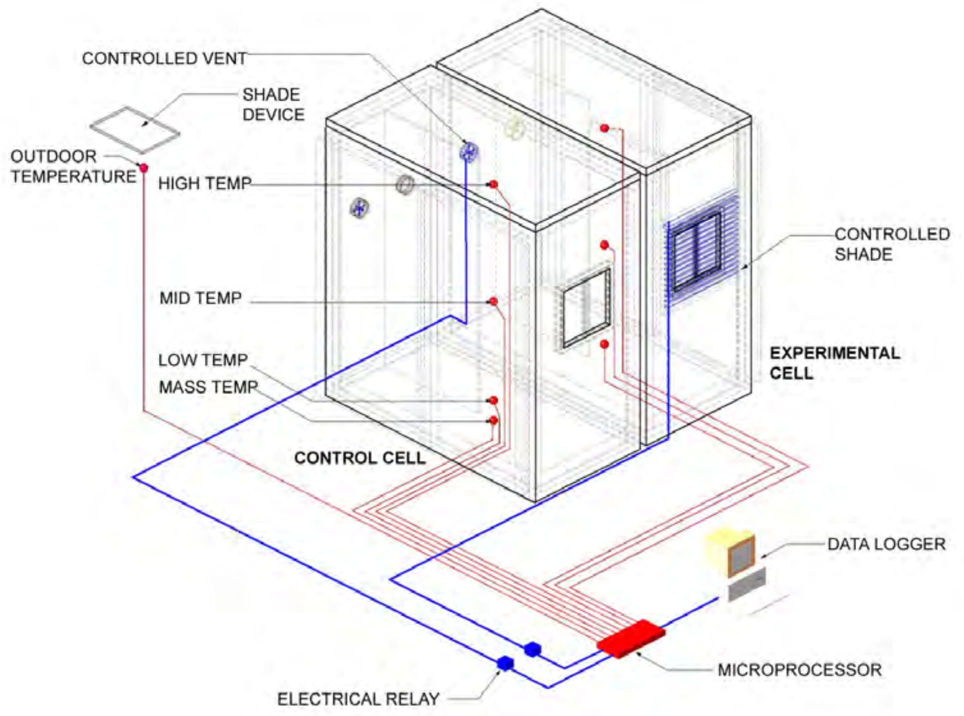


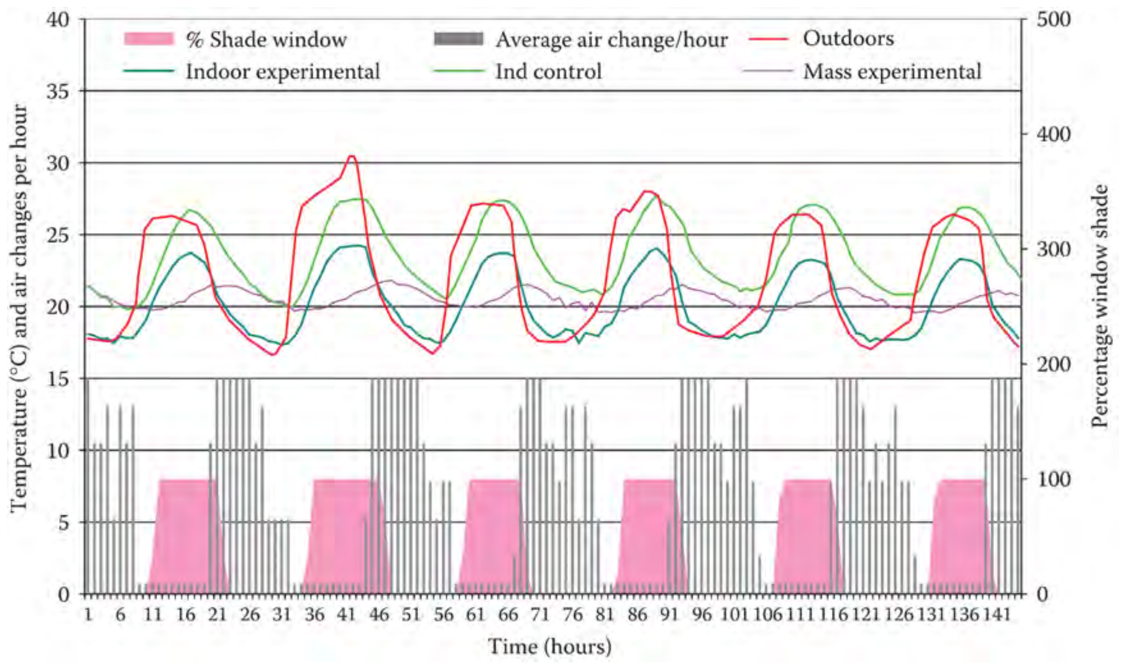


Smart Ventilation and Shading System

Microcmputer Operated

The microcomputer-controlled thermostat controls the fan and a blind so that they adjust the air changes and radiation into the cells according to rules.





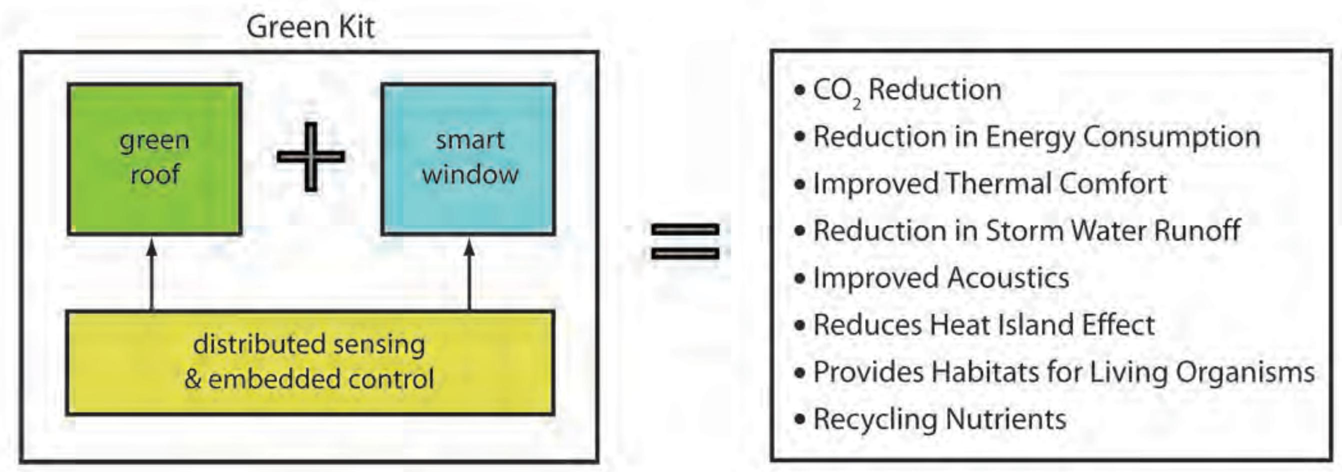
Cooling with air

Teaching

GreenKit Modular window

“The Green Kit: A Modular, Variable Application System for Sustainable Cooling,” developed by architecture and engineering students, combined modular green surfaces and passive ventilation with computer controls to optimize the performance of these proven low-tech cooling strategies.

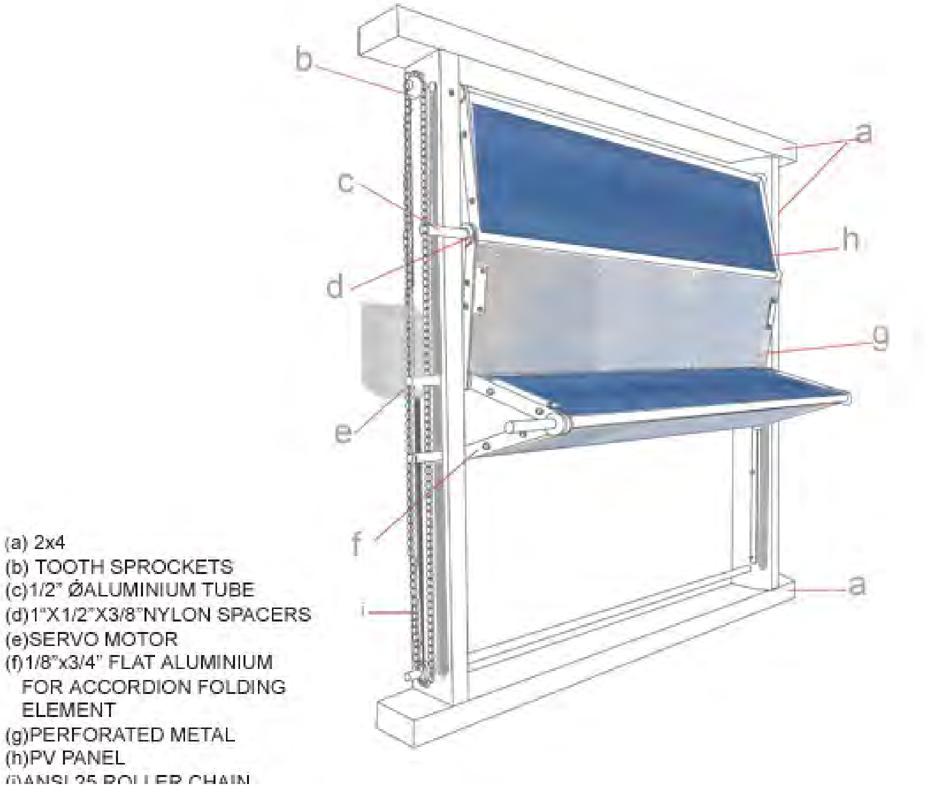
It essentially was a smart window plus a green roof, with distributed sensing and embedded control. The resulting technology enabled dynamic management of ventilation and sun control in response to changing environmental conditions in real time.



GreenKit Modular window

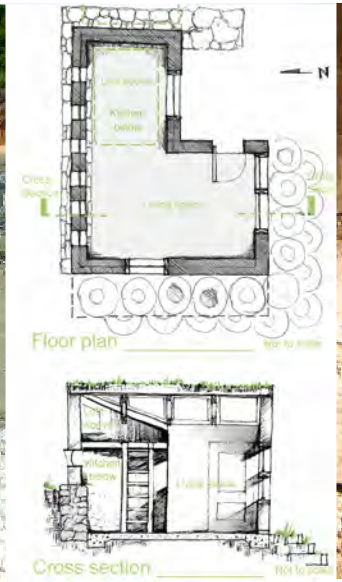
Different prototypes were developed and tested.

GreenKit Modular window



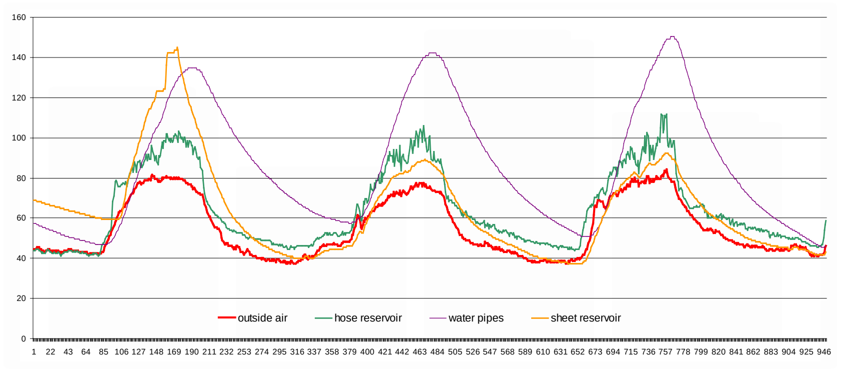
Tijuana Affordable Housing Project

This project explored the development of sustainable technologies for low-cost housing in Tijuana, integrating, design, construction and research in one project.



Tijuana Affordable Housing Project

Cal Poly Pomona students worked with Corazon, a U.S. non-profit organization with the mission to serve Mexican border communities through an active home-building program, educational programs, and other community development activities.



Papercrete walls

The soil generated from the grading process could be used in the walls, while rock also from the grading can be used to fill gabion units used for both walls and retaining walls. After several tests, walls were built with papercrete, a mixture of Portland cement, earth, and shredded waste newsprint. A tow mixer with a 150-gal capacity was used to mix these and the papercrete pulp was poured into the walls. This material was easily cut with a chainsaw.

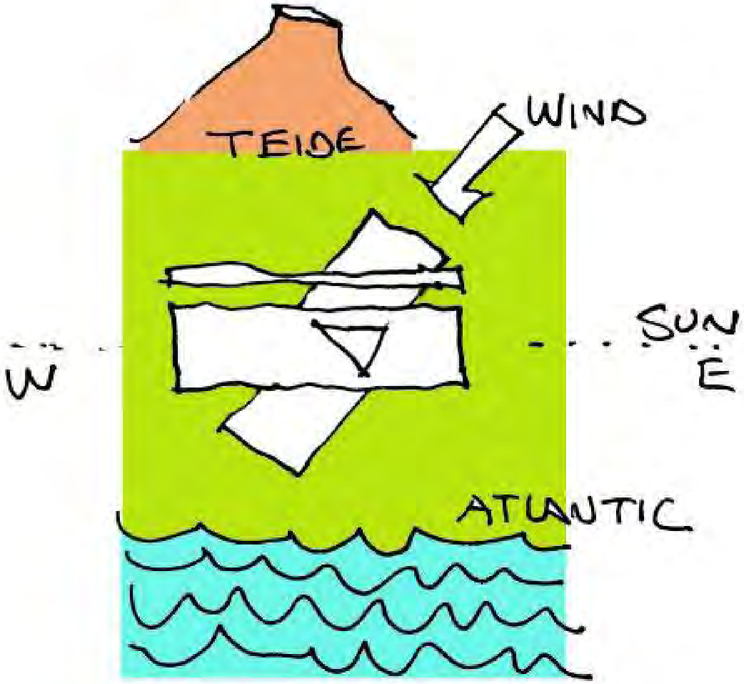
Cooling with air

Practice

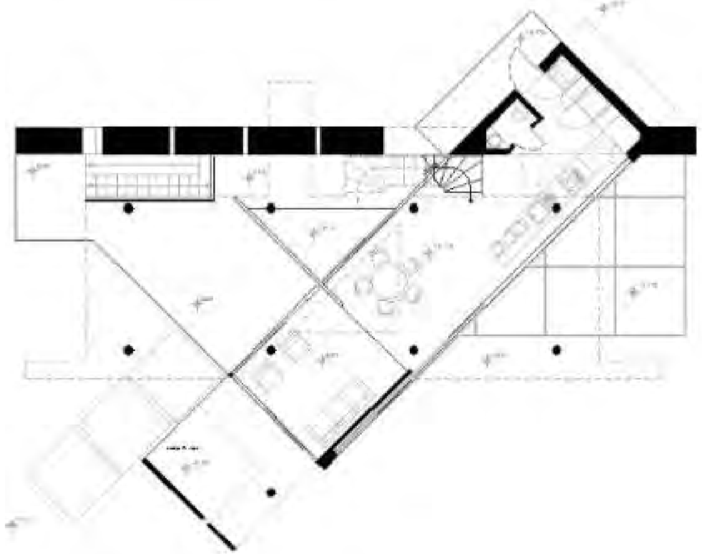
To inhabit the Device:
A Net Zero Energy Home in Tenerife Spain

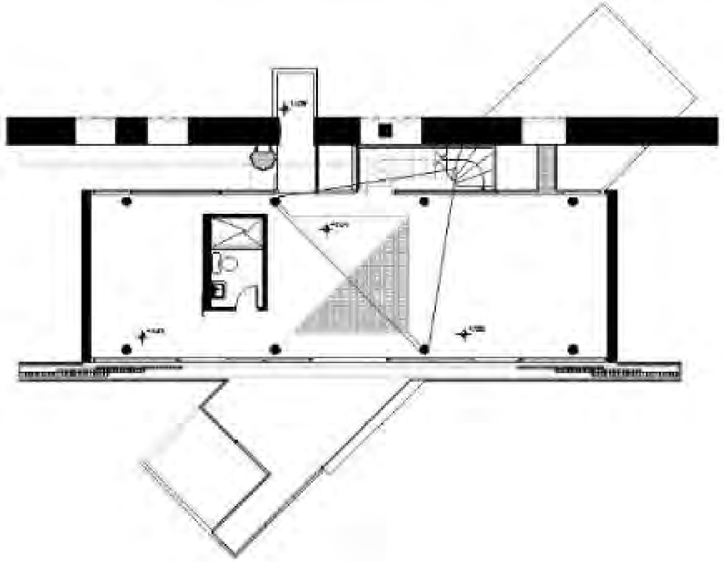
La Roche, Mustieles, Oteiza

Responds to the Sun and the Wind

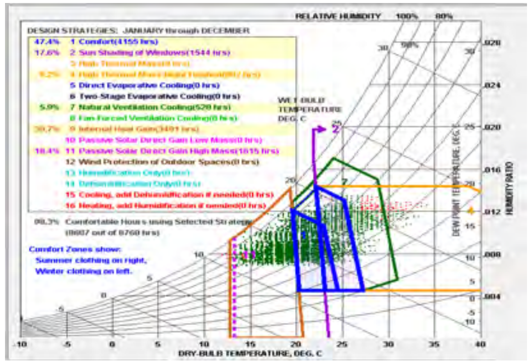


Connects with the sun,
wind and nature.

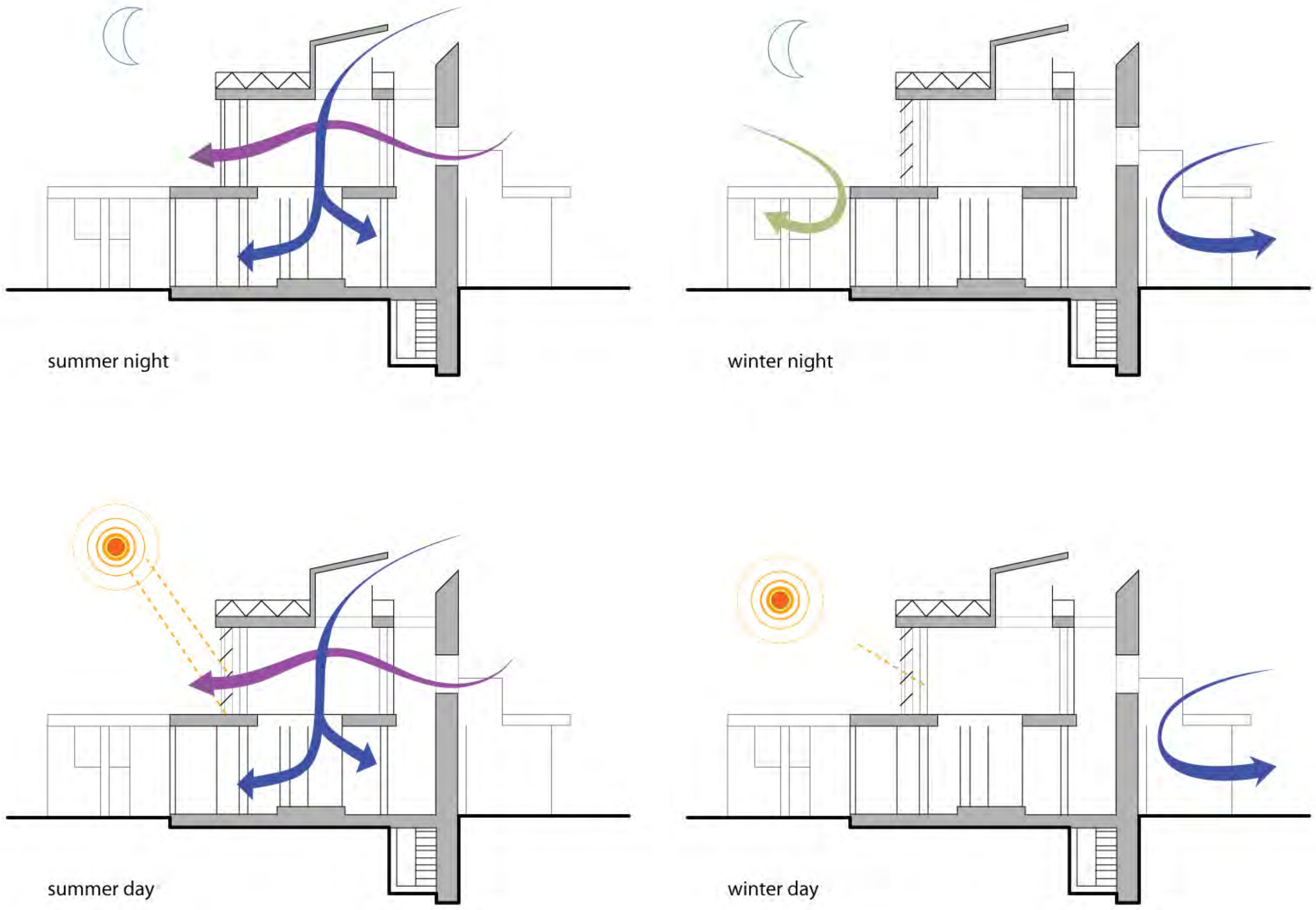




Bioclimatic Design



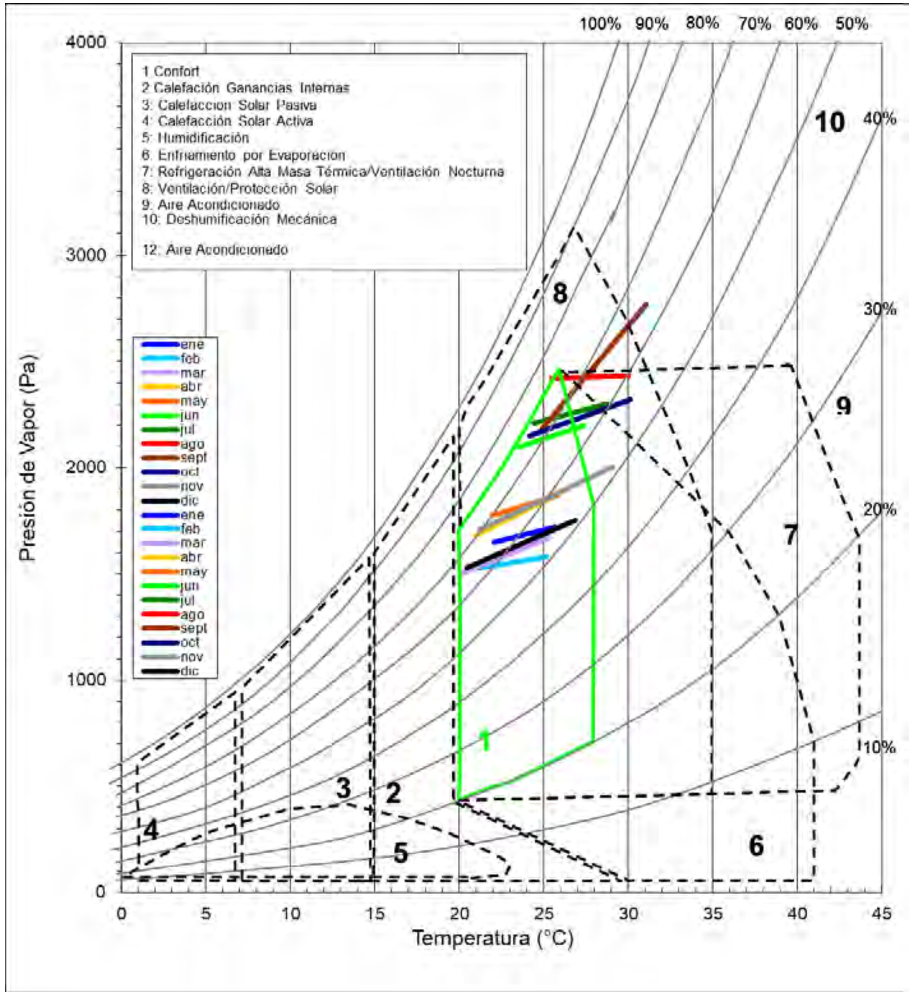
The building was designed to harness the natural forces: the sun and the air movement.



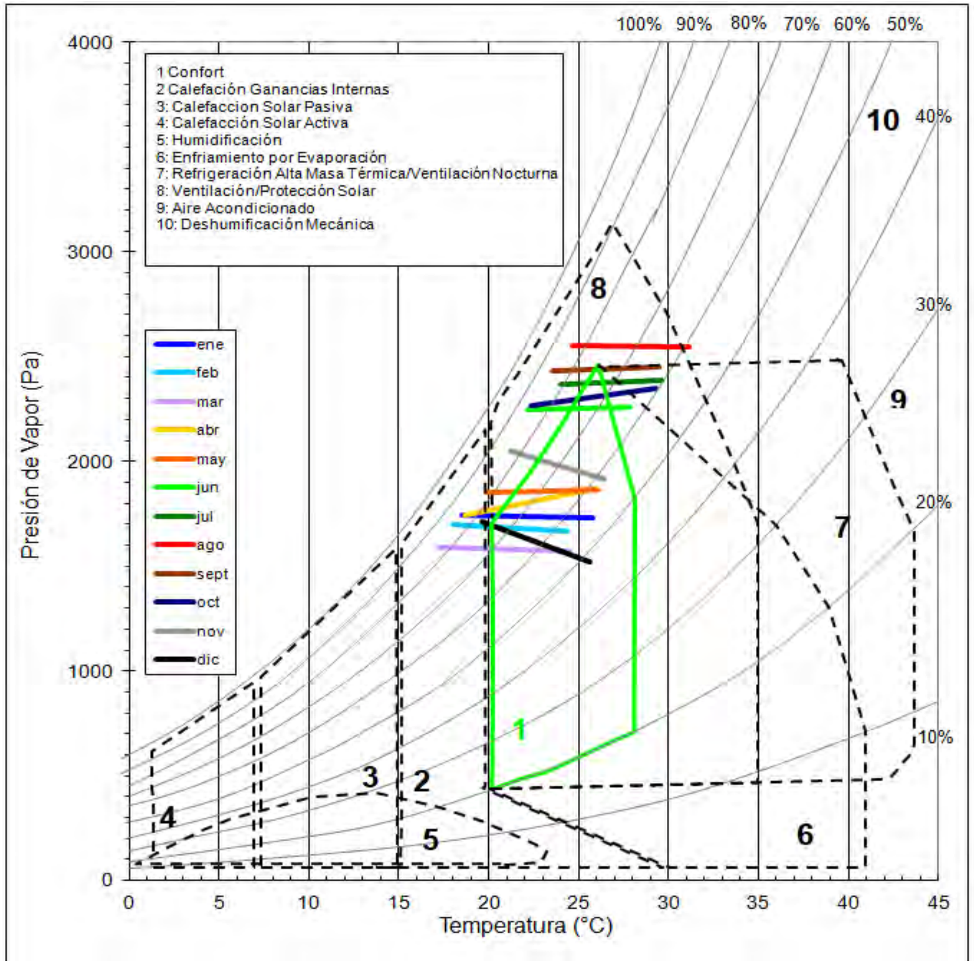

...and lets the air move through



Data Collected



Monthly temperature & humidity inside the house



Monthly temperature & humidity outside the house

The psychrometric charts, show that temperatures and humidity in 2016, inside the house, are mostly within the comfort zone with the exception of August and September, when they are in area 8 and air movement will provide thermal comfort.

2. Cooling with the sky

The sky provides the ultimate continuous heat sink to maintain the Earth’s thermal equilibrium. All bodies radiate and absorb energy to the sky at the same time, usually at different rates and wavelengths. Any ordinary surface that “sees” the sky loses heat by emitting longwave radiation, and at night, buildings can lose more heat than they gain by radiation.

Smart Radiant Cooling System.

With Baruch Givoni at UCLA

Smart Radiant Cooling System

Control Rules

The microcomputer-controlled thermostat operates the radiant panel.

If $T_{surf} < T_i$ and $T_{surf} < T_o$ and $T_i > Cf_{low}$ then PANEL OPEN else PANEL CLOSED

Where:

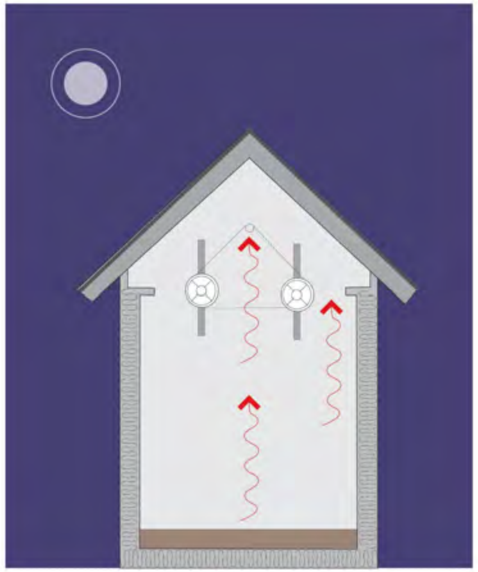
- Tsurf = Temperature of external metal plate
- T_o = Outdoor dry-bulb temperature
- T_i = Indoor Temperature of the Test Cell
- Cf_{low} = Lower limit of the comfort zone

If the metal roof temperature is lower than both the indoor and outdoor temperature and indoor temperature is higher than the lower band of comfort, then open panels for radiant cooling, otherwise close the panels.

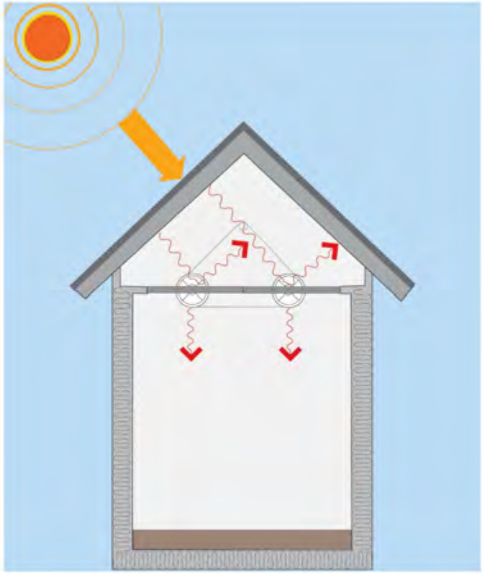
Smart Radiant Cooling System

Operation

In this system, operable hinged aluminum foil interior plates, under a metal roof, painted white to reduce its absorptivity and increase its emissivity, reduce daytime heating while allowing radiant night cooling opening the louvers. The rotation of the insulating ceiling panels between the horizontal (closed) and vertical (open) positions was achieved by an electromechanical system under computer control, first open at sunset and closed at sunrise and then opened using different rules. The ceiling panels can also be operated manually.



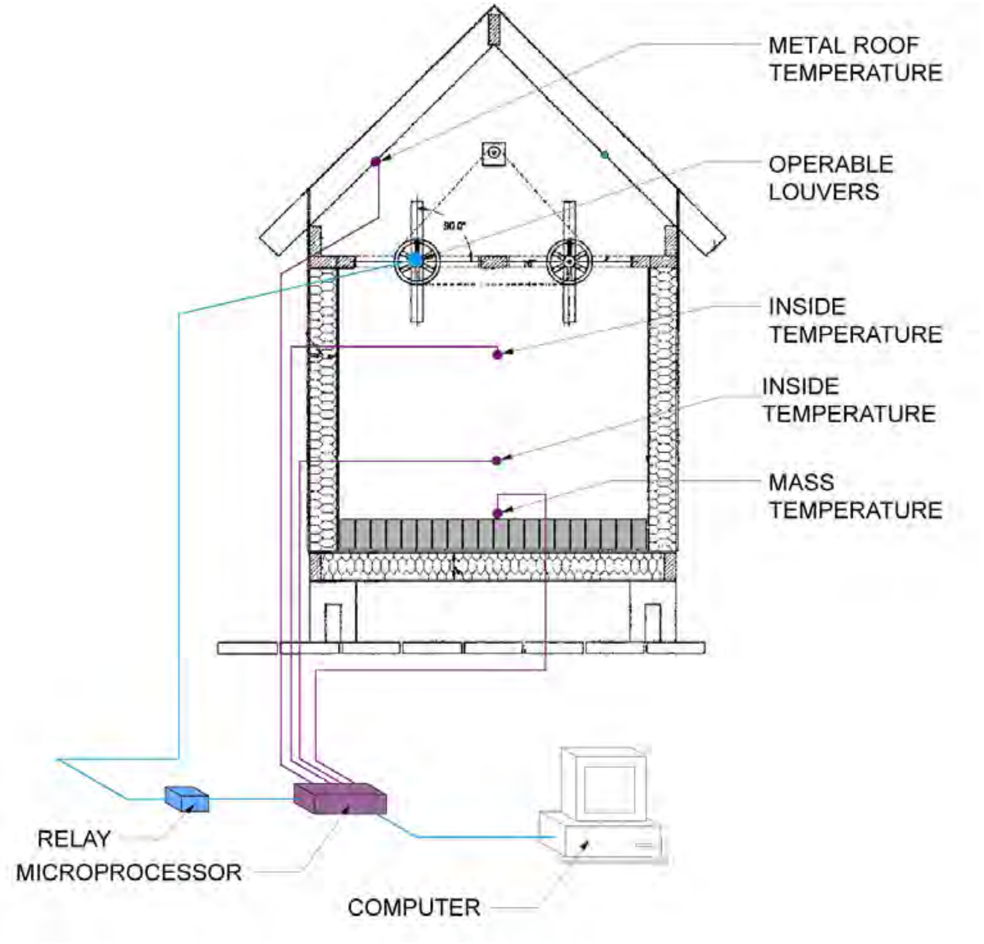
Night

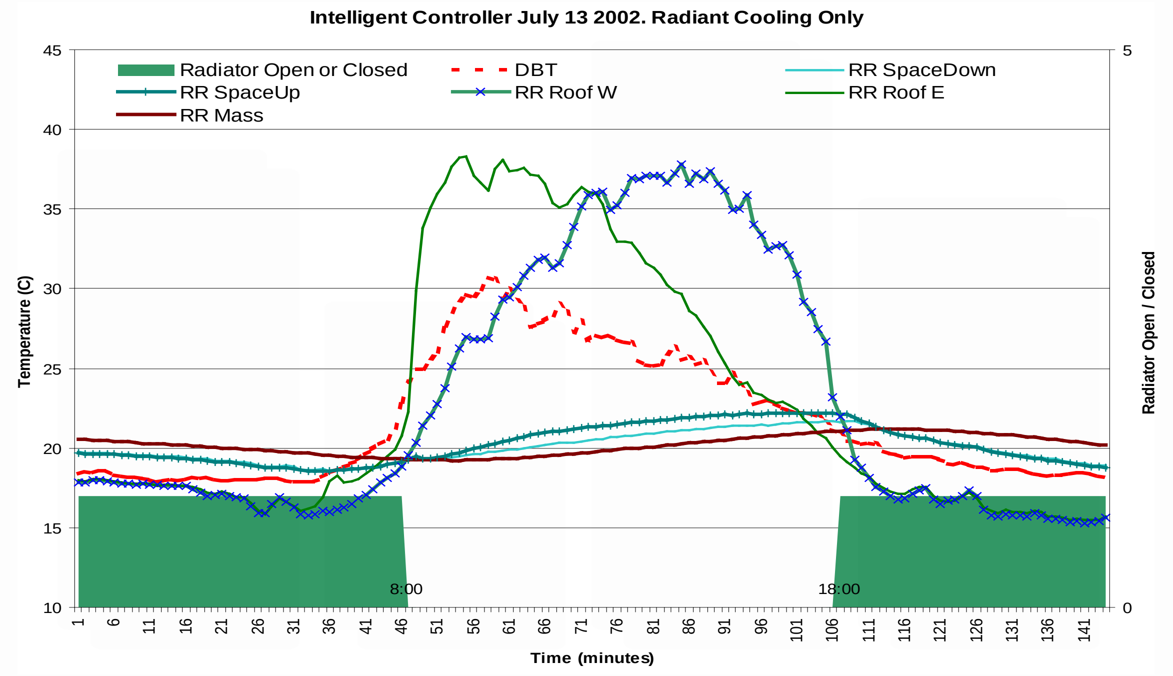


Day

Smart Radiant Cooling System.

Results



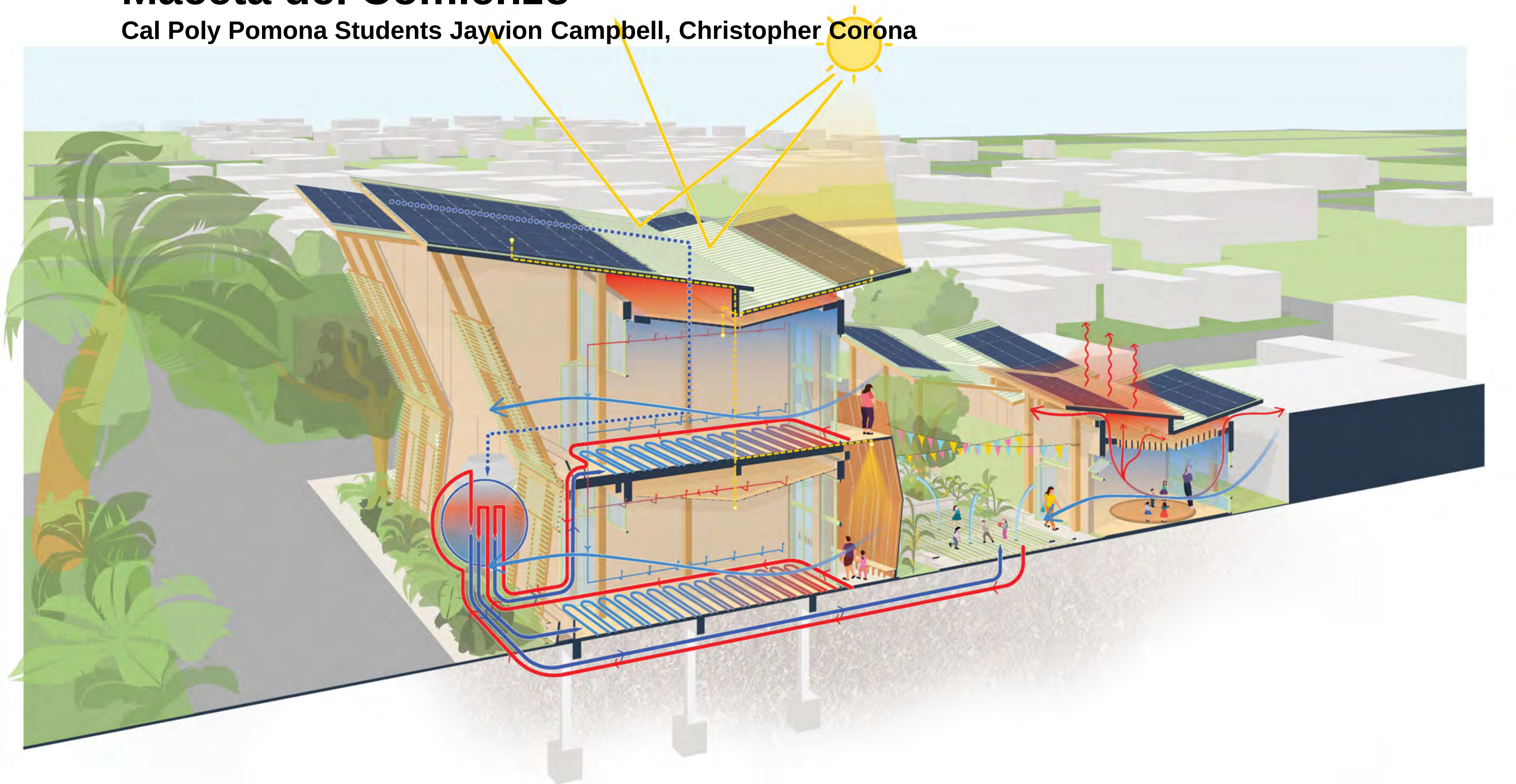


Cooling with the sky

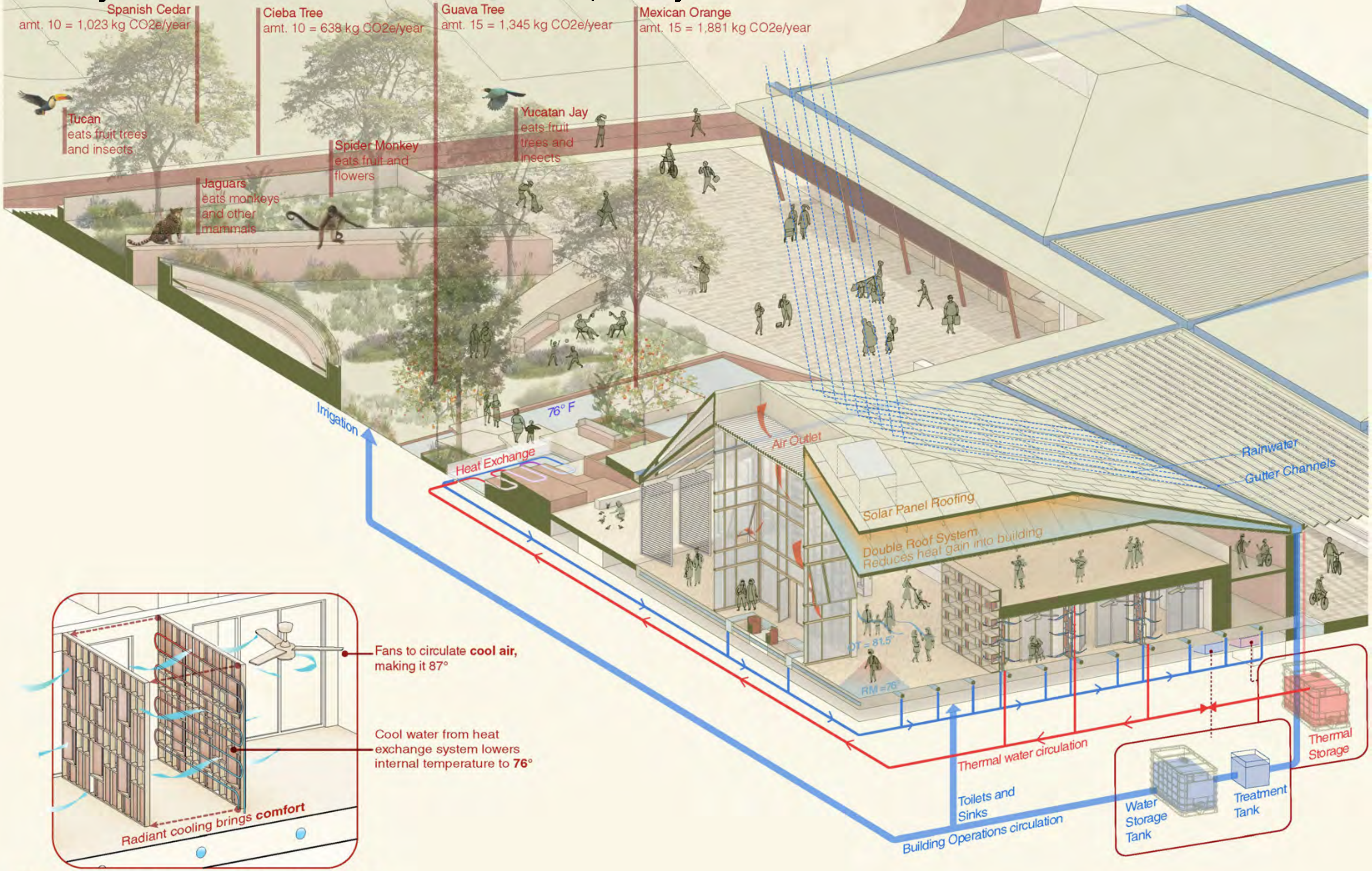
Teaching

Maceta del Comienzo

Cal Poly Pomona Students Jayvion Campbell, Christopher Corona



Cal Poly Pomona Students Ana Sofia Botero, Sandy Cruz



The Living Wall : Radiant Airflow Shelf Wall

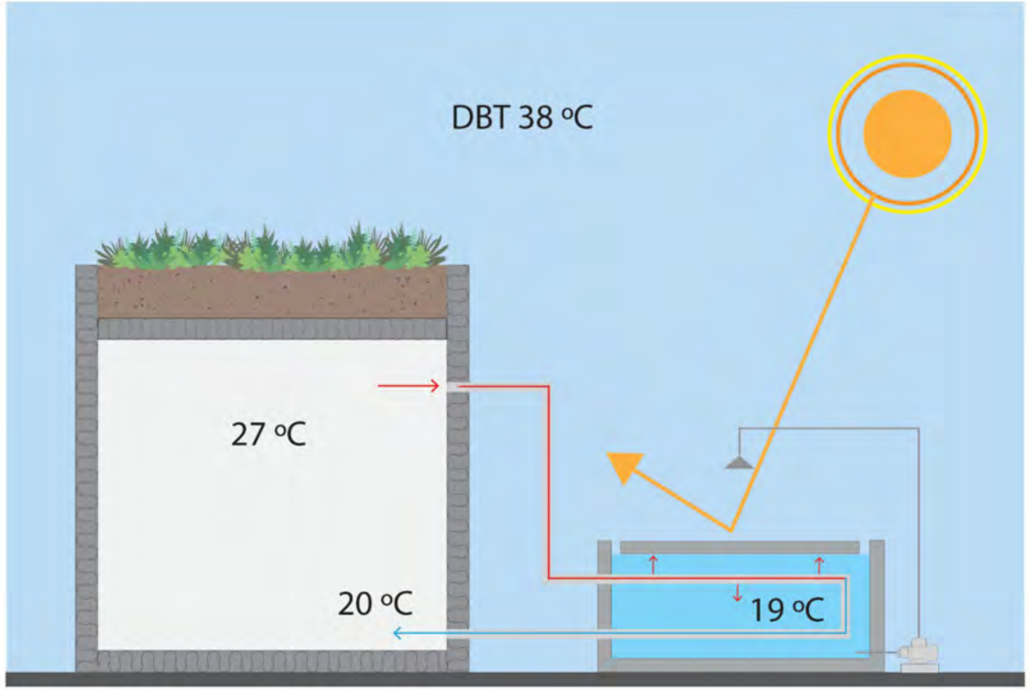
3. Cooling with water (and air and the sky)

Even though the heat sink ultimately is the air, in this evaporative cooling system water is an important cooling and transport component of the system.

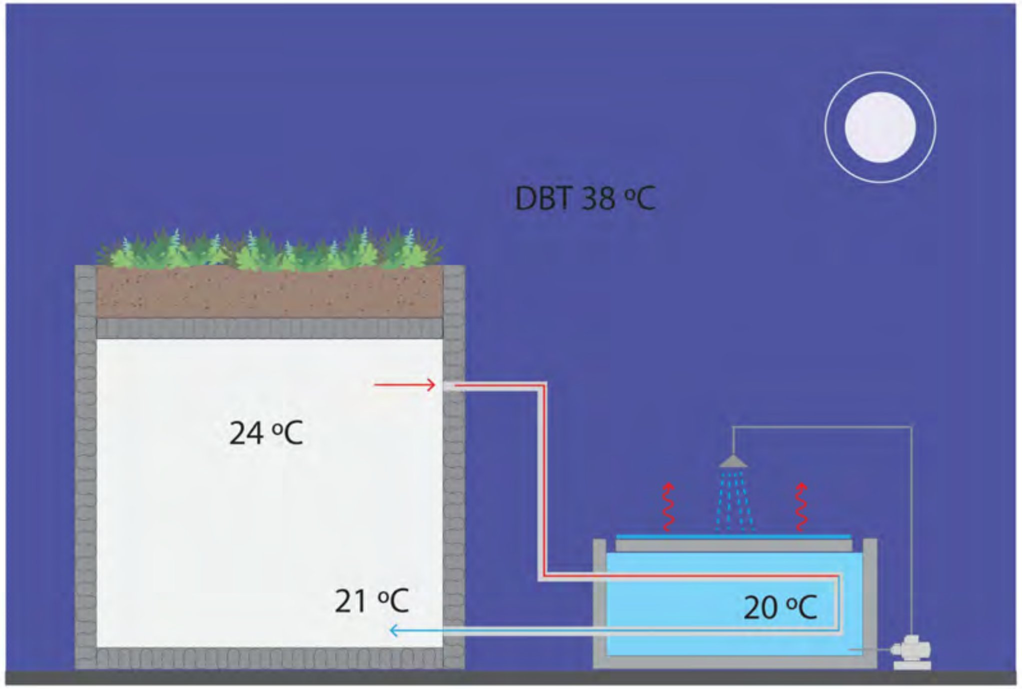
Water-to-air Heat Exchanger with Living Roof

With J.M. Almodovar & Jason Yeom

A Water to Air Heat Exchanger, WAHE provides cooling and reduces energy consumption with a water pond as a heat sink. During the daytime, the pond is insulated from the heat, while during the night the water spray is turned on and cools the water by evaporation and by radiation to the night sky, cooling the water in the tank. During the whole day, the air moves through the underwater pipes, which act as a heat exchanger, releasing heat from the air to the water and lowering its temperature. This cool air then cools the test cell.



Day



Night

Water-to-air Heat Exchanger with Living Roof

Cal Poly Pomona University

Water-to-air Heat Exchanger with Living Roof

Control Rules

The microcomputer-controlled system controls the pump, so it provides radiant and evaporative cooling during the night.

If T_{surf} < T_o and T_i > Cf_{low} then PUMP ON else OFF

where

- **T_{surf} = Temperature of the external metal plate**
- **T_o = Outdoor dry-bulb temperature**
- **T_i = Temperature in test cell**
- **Cf_{low} = Lower limit of the comfort zone**

If the exterior roof surface above the pump is lower than the outdoor temperature and indoor temperature is higher than the lower band of comfort, then turn the pump on for radiant and evaporative cooling of the water.

Water-to-air Heat Exchanger with Living Roof

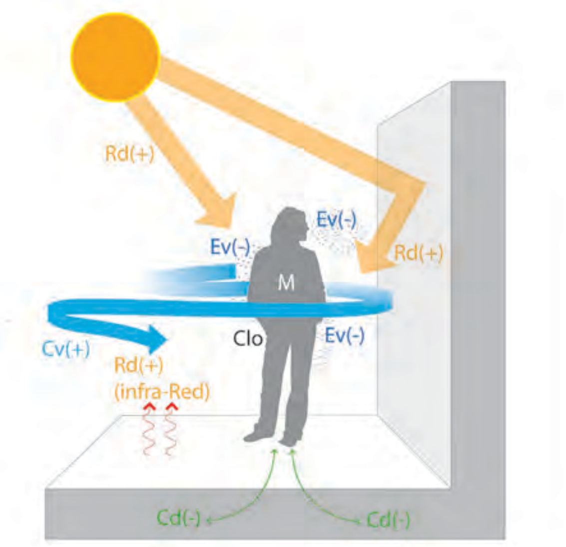
Cal Poly Pomona University

Images of the System at the Lyle Center in Cal Poly Pomona

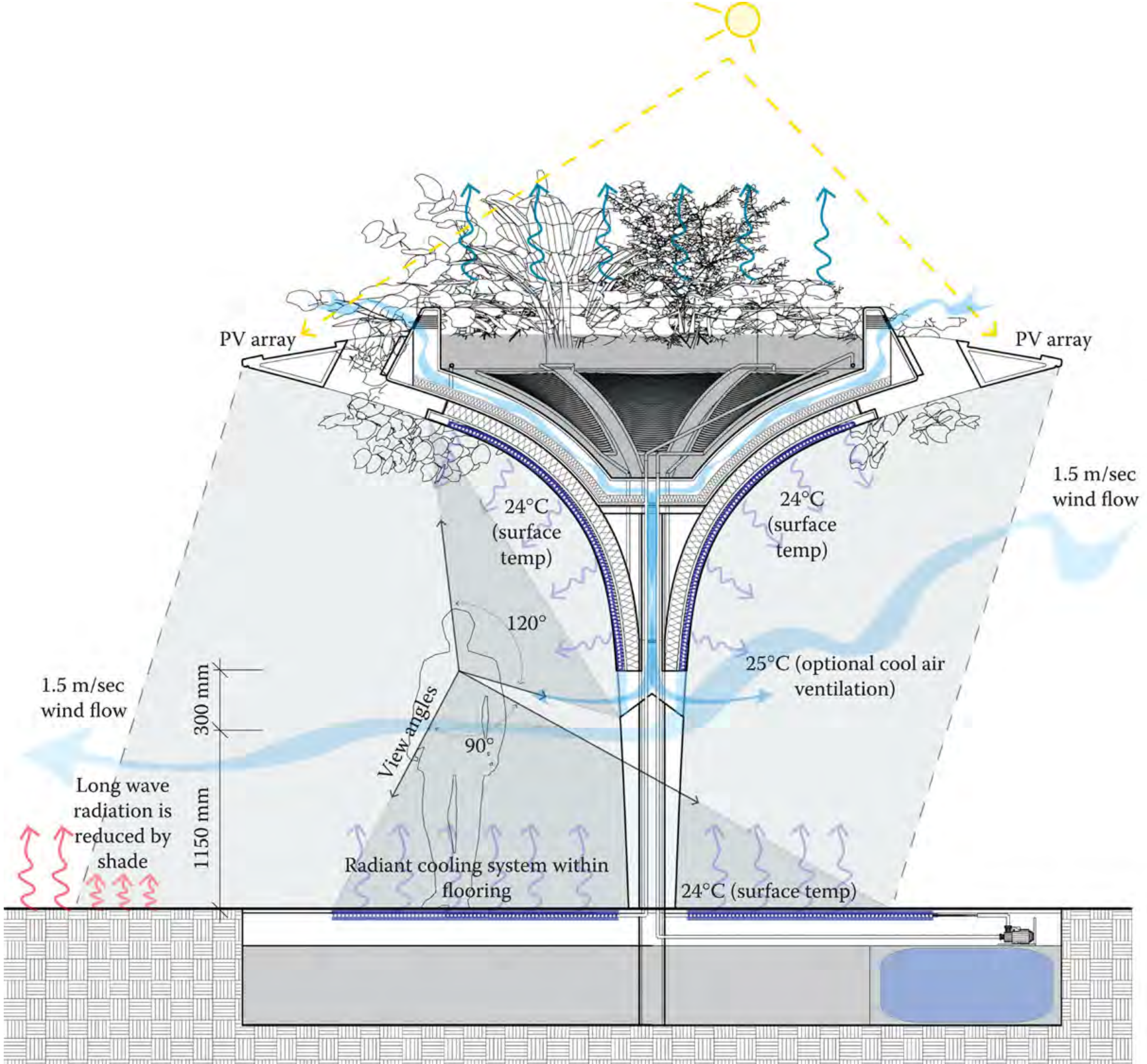
Cooling with water (and air and the sky)

Practice

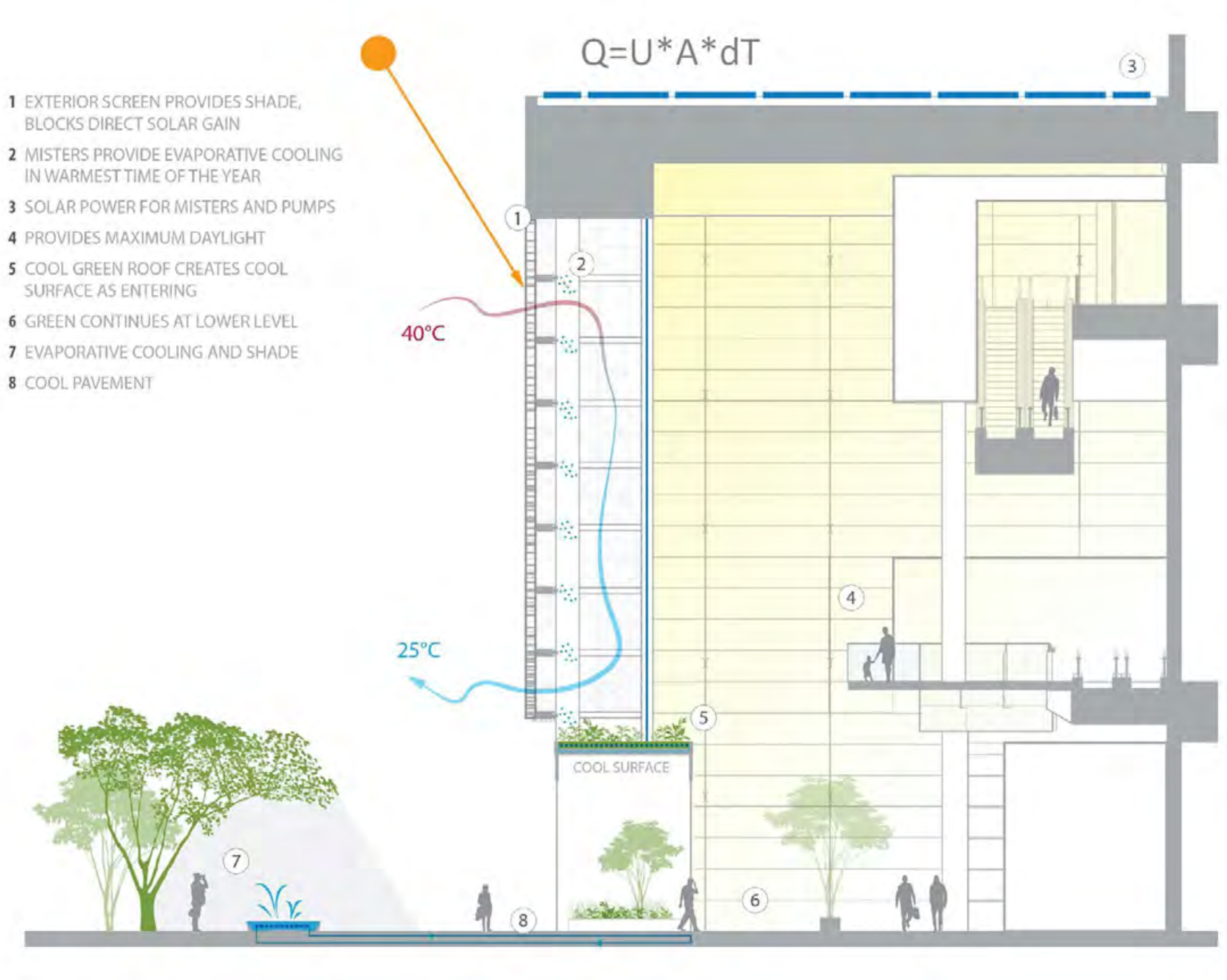
The Xylem / Arcadis



The Xylem improves outdoor thermal comfort by implementing four outdoor cooling strategies: a large canopy for shading, promoting natural ventilation, a vegetated roof for thermal mass, and water circulation for radiant cooling.



Retail and Entertainment Center at Al Khirian, Kuwait

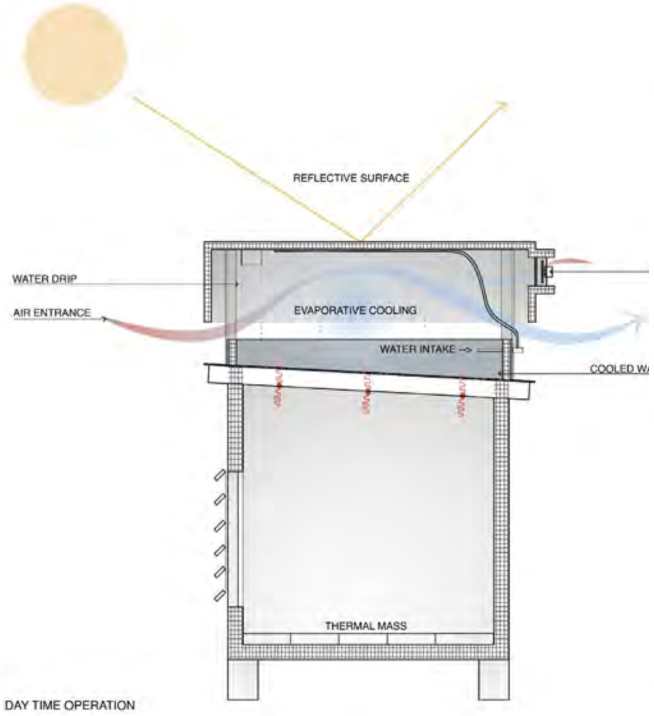


Cooling with water (and air and the sky)

Teaching

Covered Roof Pond

Alexia Orozco & Marco Espinoza



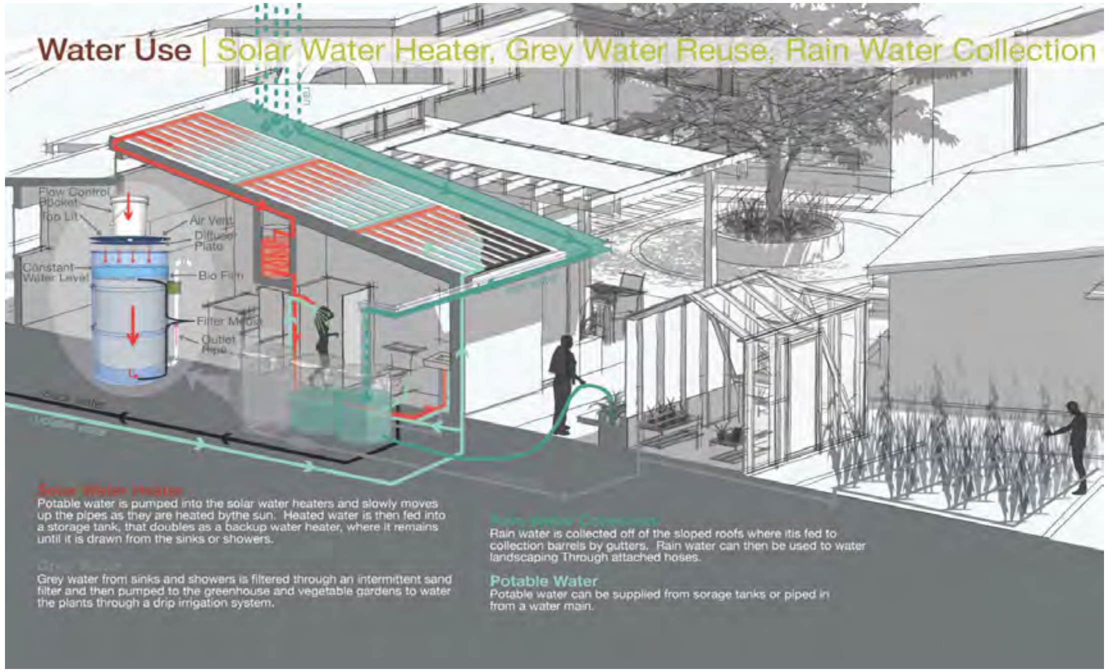
Community Center, Tecate, Mexico

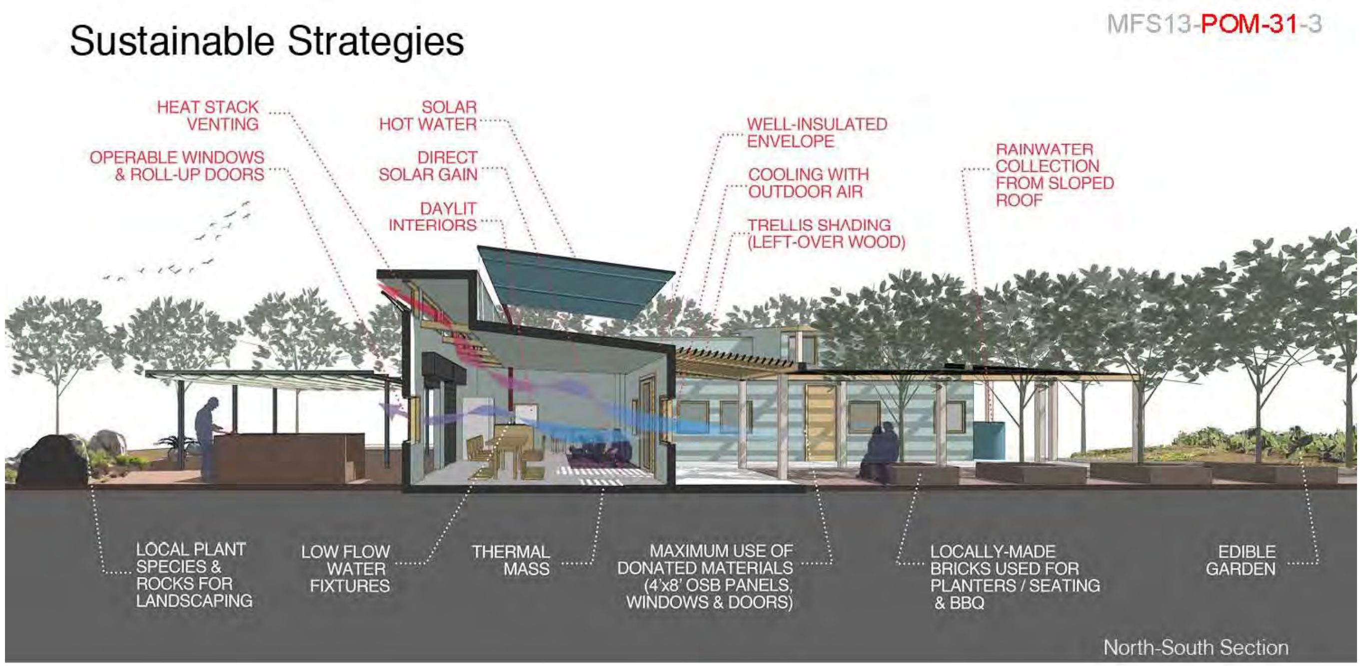
Corazon is a non-profit based in California that does work in Mexico. They wanted to build the center in phases, so the students proposed a group of buildings that could be built independently by the community, volunteers, and students.

Students in the studio designed the center with active participation from Corazon volunteers and the community. They met with the community in Mexico, which shared their desires and aspirations with them. Corazon staff participated in the studio reviews and provided input during the design process. All student projects proposed using local materials and passive low-tech strategies to achieve thermal comfort.

Corazon selected one of the student projects for construction, and the project evolved as the construction progressed. Some of the systems were also refined and tested on site.

Student Designed





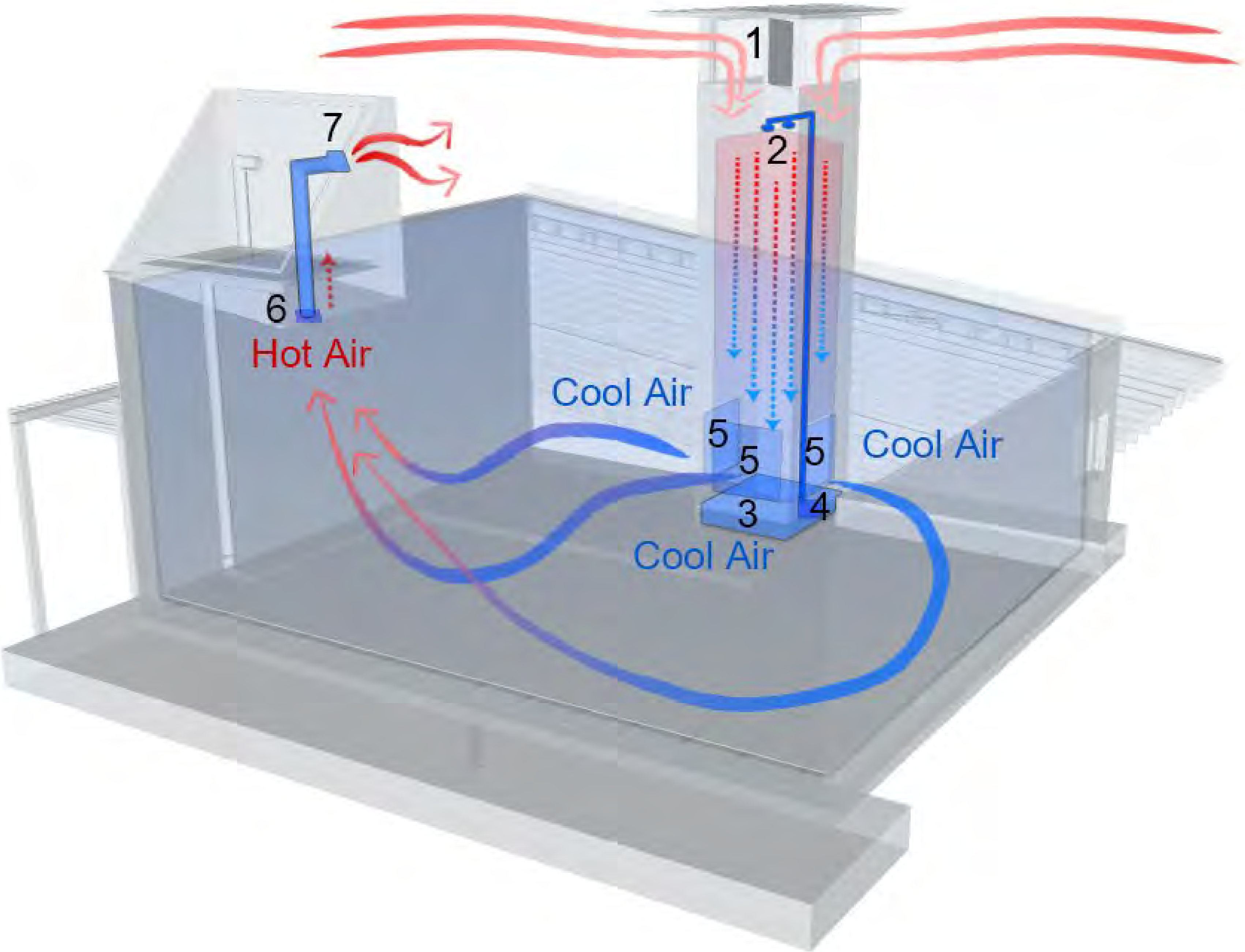
With community participation

Volunteer and community built

Volunteer and community built

Cool Tower

Cooling in Summer



1. Wind Scoop
2. Shower Head
3. Water Tank
4. Water Pump
5. Ventilation Window
6. 6' Duct Fan
7. Outlet

Principle

Understand concepts for creative problem solving.

Think passive, use the building.

6

Integrating Systems

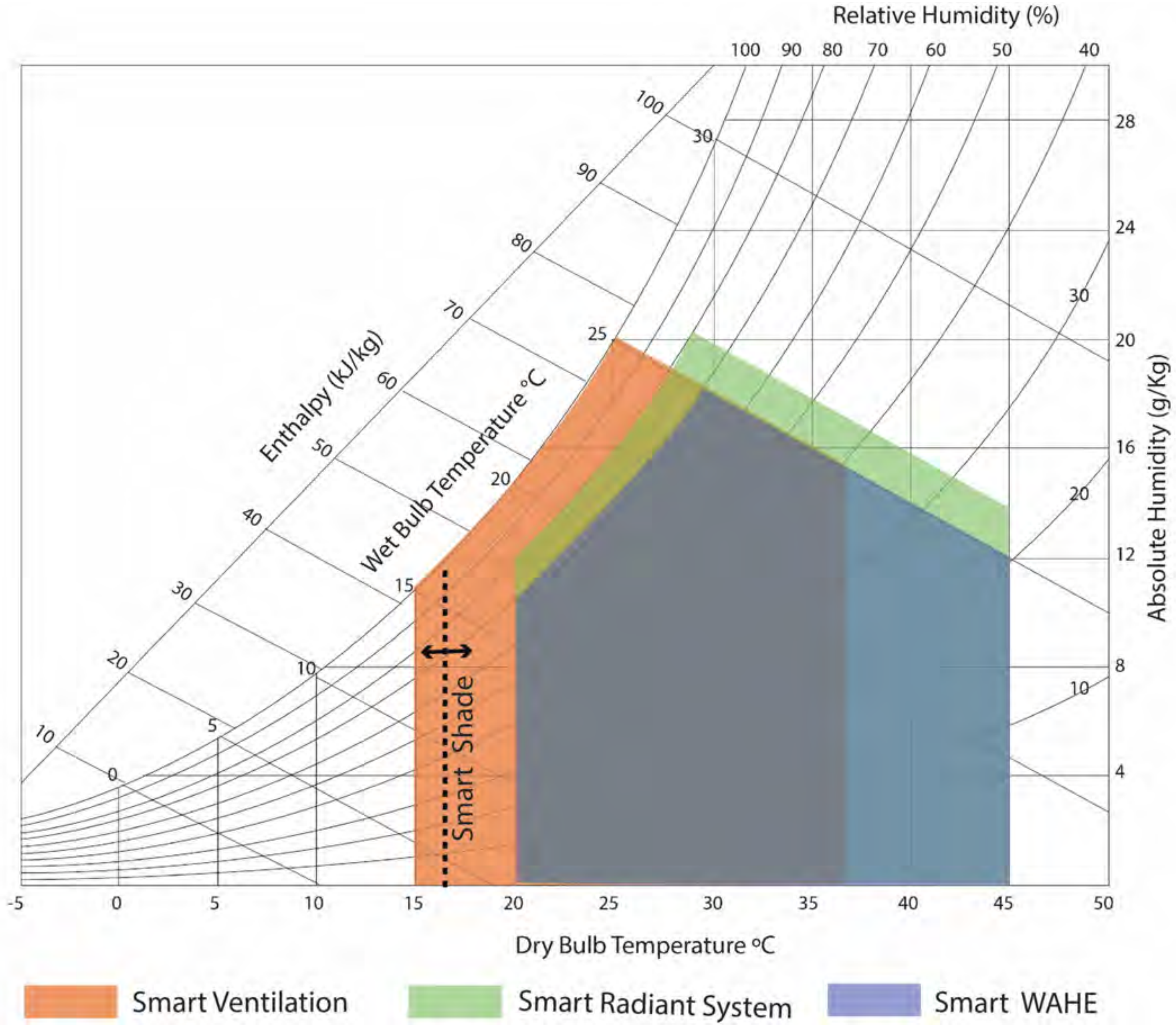
Maximizing Performance under Different Conditions

Climate Applicability of the three Systems

The table shows the three cooling systems tested with their heat sinks and climate applicability. Solar control will make these systems operate better.

The psychrometric chart shows the climate applicability of the three systems based on Givoni's bioclimatic strategies. The systems should be tested during different periods to determine these zones with more precision.

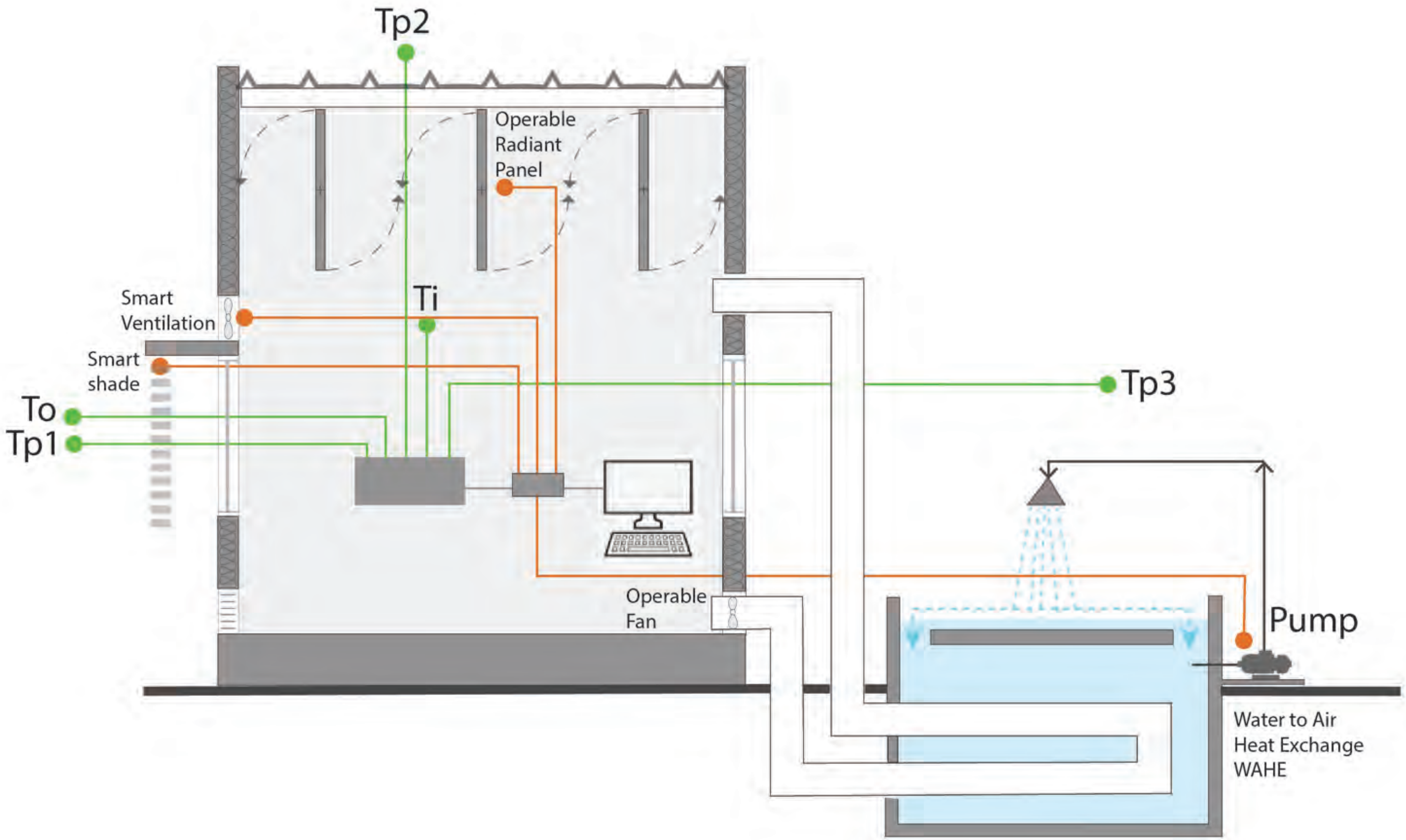
Cooling System or Strategy	Heat Sink	Climate Applicability
Smart Ventilation	Ambient Air	Hot to temperate climates with different levels of humidity
Smart Radiant	Sky and upper atmosphere	Hot and dry climates & summers with clear night skies
Smart Water to Air Heat Exchanger	Evaporation, Ambient Air and sky upper atmosphere	Hot and dry climates to mixed humid climates



Combining Sensors and Controllers

Combining several of these systems with sensors and controllers will provide more cooling than implementing them separately.

The image shows how these could work. The different temperature sensors are in green and the sensors that control fans and pumps in orange.



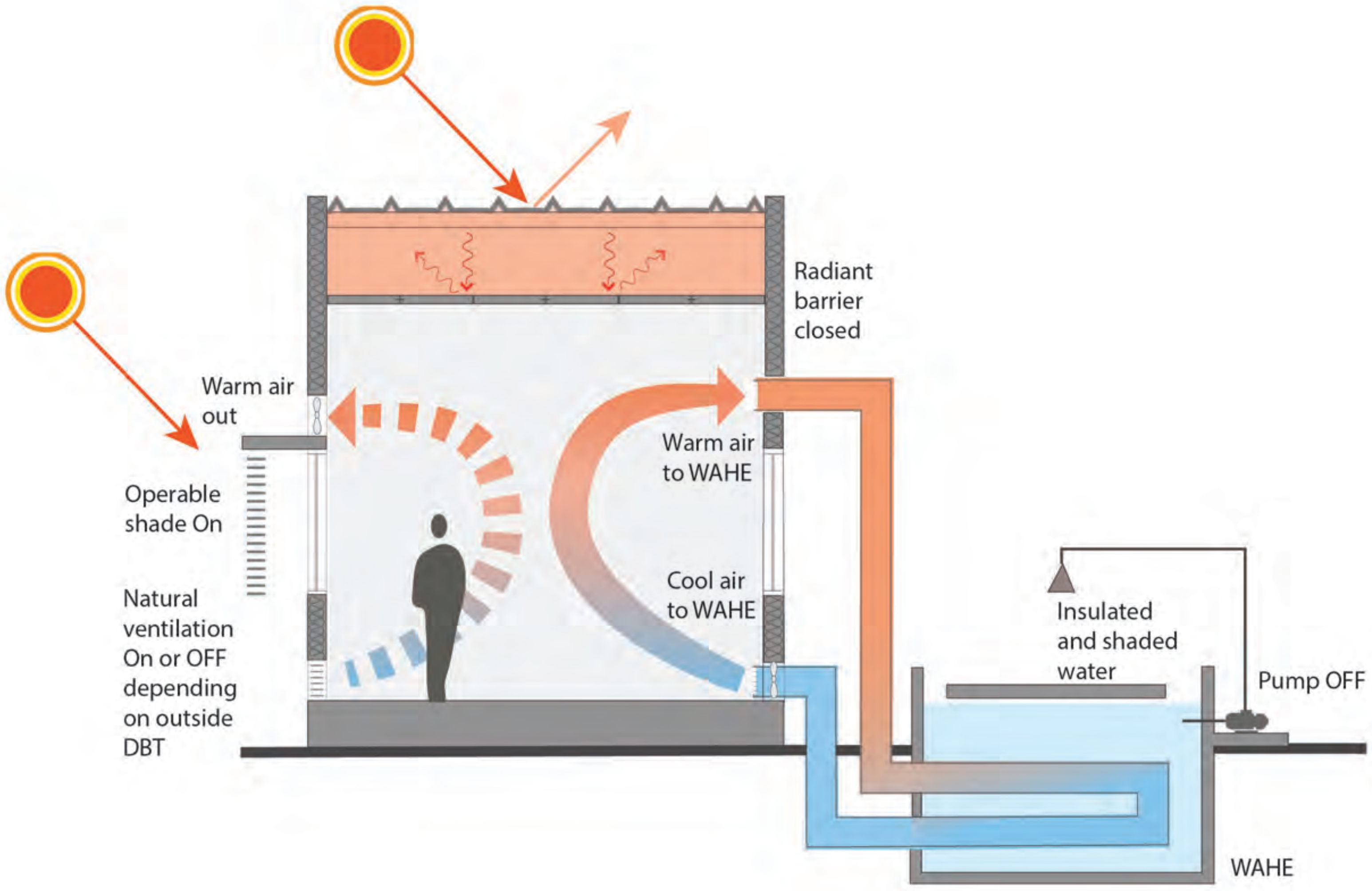
Smart Passive Cooling: Day

The smart ventilation system provides cool air from the exterior when it is cooler outside then inside and the indoor temperature is higher than the lower range of comfort low.

The blinds close if the temperature of the façade surface sensor and the indoor temperature are higher than the lower range of comfort low.

The radiant system closes the panels during the daytime.

The WAHE cools continuously day and night.



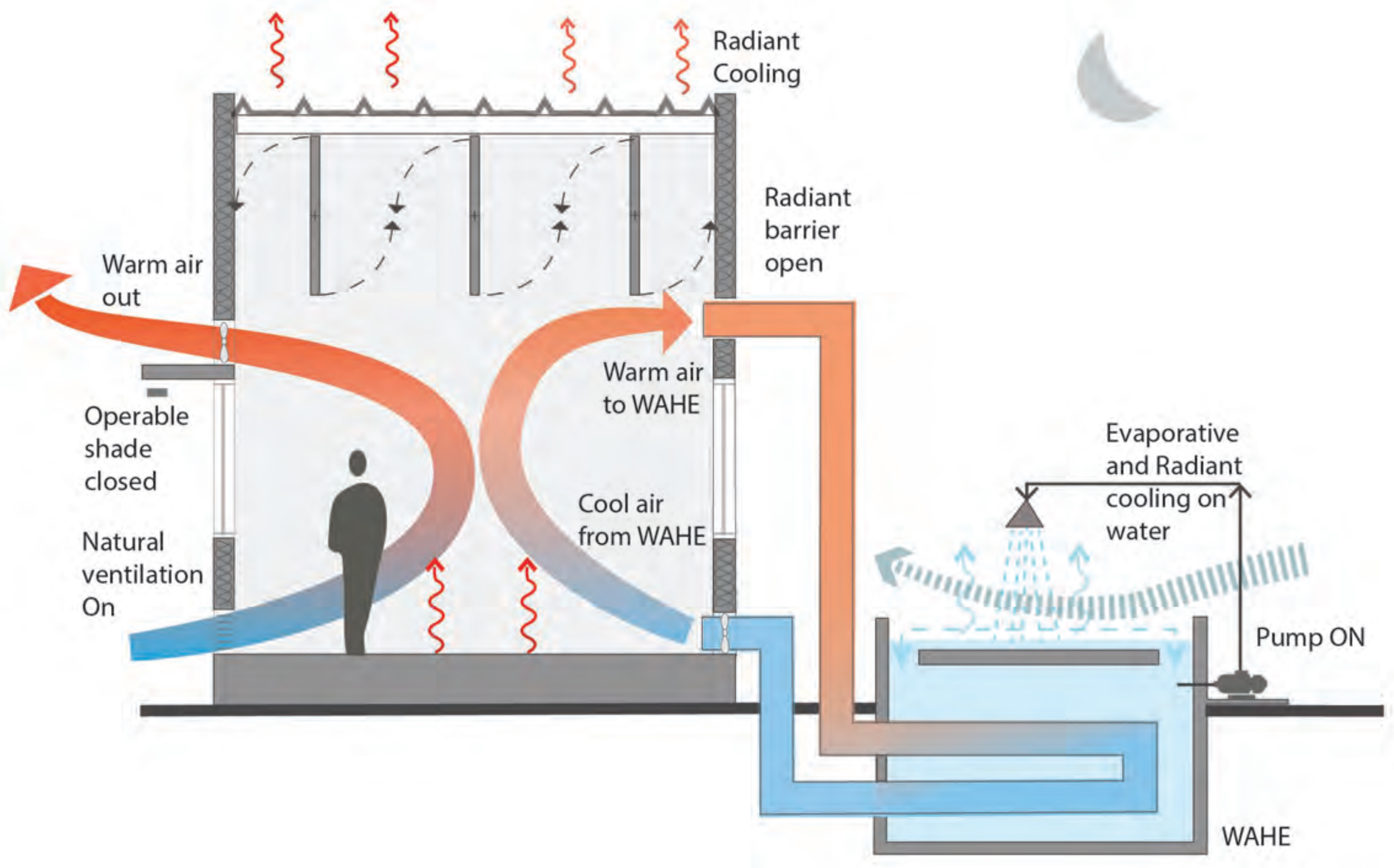
Smart Passive Cooling Night

The smart ventilation system provides cool air from the exterior when it is cooler outside than inside and indoor temperature is higher than the lower range of comfort.

The radiant system opens the panels at night when the metal roof temperature is lower than both indoor and outdoor temperatures and indoor is higher than the lower band of comfort.

WAHE cools continuously day and night.

The pump is turned on for radiant and evaporative cooling of the water in the pond If exterior roof surface temperature is lower than outdoor temperature and indoor is higher than the lower band of comfort.This is usually at night.



Principle

Embrace technology when it improves performance.

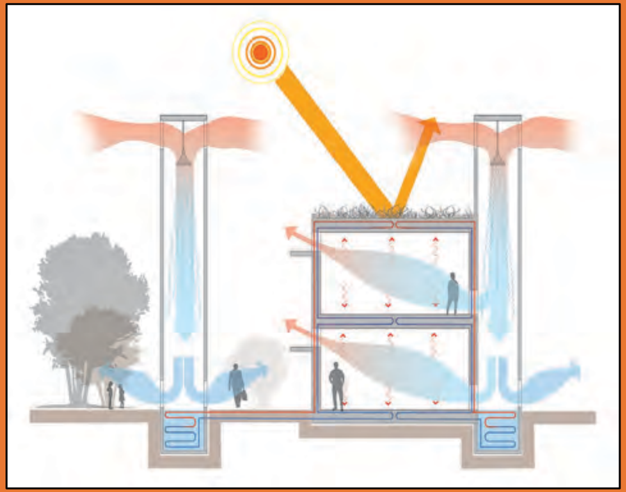
7
Conclusions

Implementing Passive Cooling Systems

It is possible to improve the performance of passive systems to facilitate their implementation.

- Active (smart) occupants
- Simple systems
- Integrated into beautiful architecture

+



- Smart controls
- Passive design
- Climate appropriate
- Using local technology and materials

=

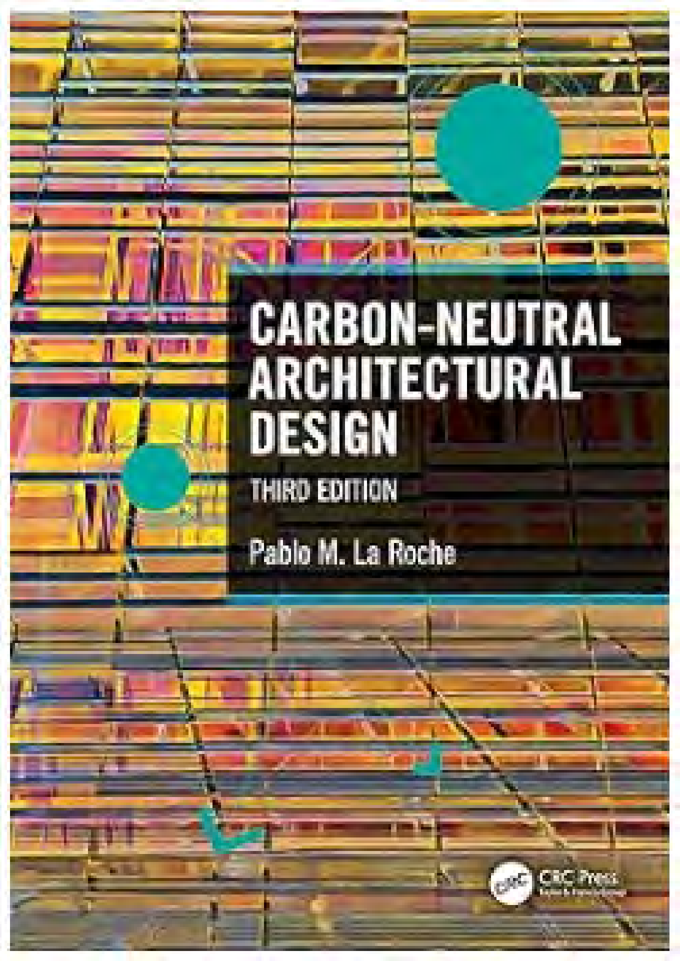
LOW CARBON ARCHITECTURE

“Buildings should be smart but simple to operate, letting nature do the work as much as possible, with a gentle touch from humans. Sensors measure indoor and outdoor conditions to manage the building’s skin and achieve thermal, visual, and acoustic comfort, working with minimum use of mechanical systems.”

La Roche, P., *Indigenous Knowledge, Innovation, and Climate Change*, Op/Positions. Technology Architecture + Design, Issue 9:2, Special edition, Innovation (2025)

Acknowledgements

To the many faculty and students that I have had the pleasure of working with in these projects.



More in the 3rd edition of my Book Carbon Neutral Architectural Design

Routledge: https://www.routledge.com/

Code: ADC26 for 30% discount

Also, available in online bookstores such as **www.amazon.com/**

Carbon-Neutral Architectural Design
This seminal book is a comprehensive and indispensable resource for architects, designers, and building professionals. Written in clear and accessible language, it explores cutting-edge building strategies, including climate adaptation, mitigation and resilience, site design, building form and envelope design, and passive and nature-based cooling, heating, and daylighting. This book is more than just a resource; it is a call to action, driving real-world change in the built environment on a global scale. Design the future, it's happening now, and it's carbon neutral.

Edward Mazria FAIA FRAIC
Founder of Architecture 2030
Recipient of the 2021 AIA Gold Medal

The book by Pablo M. Roche is among the very rare documents that addresses the topic in such a complete, scientific and precise way. It provides the proper knowledge in a very well organised and comprehensive manner and succeeds to inform and educate the reader on everything he needs to know about modern ecological, bioclimatic and zero carbon buildings. It is highly recommended to all building professionals and students.

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Anita Lawrence Chair High Performance Architecture
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Thank you