Volume 8

VIOLETA MASTRONARDI
MI ZHOU

AIR MOVE-MENT & TEMPERA-TURE CON-TROL

AIR MOVEMENT & TEMPERATURE CONTROL

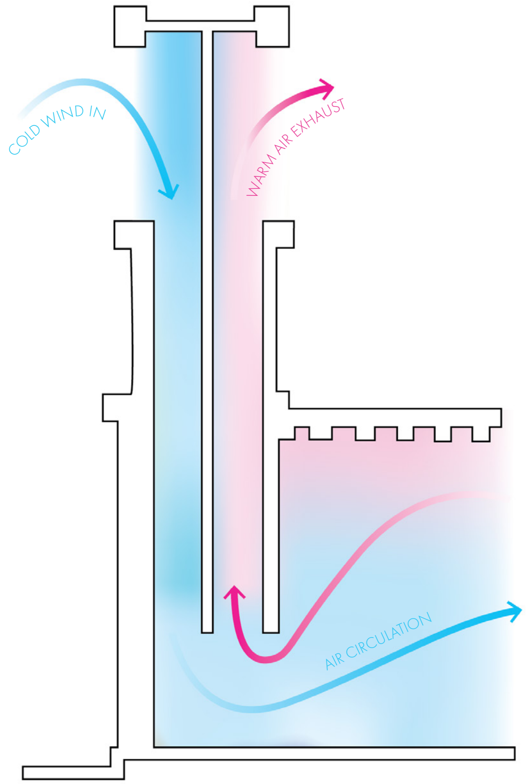
This book compiles design strategies for passive cooling and thermal regulation, showing how architecture can achieve comfort by engaging environmental forces rather than mechanical systems. Organized around the four classical elements, it presents principles through which buildings interact with climate.

Air explores systems like windcatchers, stack effect, atrium exhaust, and cross-ventilation that guide airflow. Water includes cooling towers, PDEC systems, stepwells, and courtyard fountains that use evaporation and humidity for cooling. Earth covers thermal mass, sod roofs, and earth-sheltering techniques leveraging the ground's insulation. Fire, understood as solar radiation, encompasses brise-soleil, radiant barriers, double roofs, shutters, and double-skin façades that mediate heat gain.

Rooted in vernacular wisdom yet reinterpreted in contemporary practice, these techniques reveal how resource-conscious traditions can inspire sustainable design, positioning architecture in dialogue with natural forces.

- Violeta Mastronardi, Mi Zhou

AIR
WINDCATCHERS



Qatar University, designed by Kamal El-Kafrawi, integrates more than 2,000 modular wind catchers across its hexagonal concrete units, making it one of the largest contemporary applications of this vernacular technology. These elevated, chimney-like towers are strategically oriented to capture prevailing Gulf breezes, channeling cool air down vertical shafts into shaded courtyards. Inside, adjustable dampers, sensors, and internal divisions guide and regulate airflow, while the system simultaneously exhausts hot air through opposing vents, creating a continuous cycle of natural ventilation. By combining traditional badgir principles with modern controls, the university achieves large-scale passive cooling suited to Doha's desert climate.

Dowlat-Abad Garden

Yazd, Iran, 1747–1750. Mohammad Taghi Khan Bafqi.

Iran Paradise. (2020, October 27). Dowlat Abad Garden. Iran Paradise.

Dowlat-Abad Garden in Yazd integrates a monumental wind catcher, the tallest in Iran, as both a climatic device and architectural centerpiece. The tall, conical tower captures breezes from any direction and channels them down internal shafts, where air passes over water basins (traditionally known as qanats) and through shaded channels. Evaporation, combined with the thermal inertia of thick adobe walls, cools the air before it circulates through the pavilion's lower levels. Even in still conditions, the tower functions as a solar chimney: warm air rises and escapes, drawing cooler air in. Together, these strategies provide natural ventilation and passive cooling, ensuring comfort within the arid desert climate while symbolizing a cultural design.

HISTORICAL PRECEDENT

Qatar University

Doha, Qatar, 1992. Kamal El-Kafrawi.

Aga Khan Trust for Culture. (n.d.). Qatar University, Kamal El-Kafrawi, Doha, Qatar. In Archnet.

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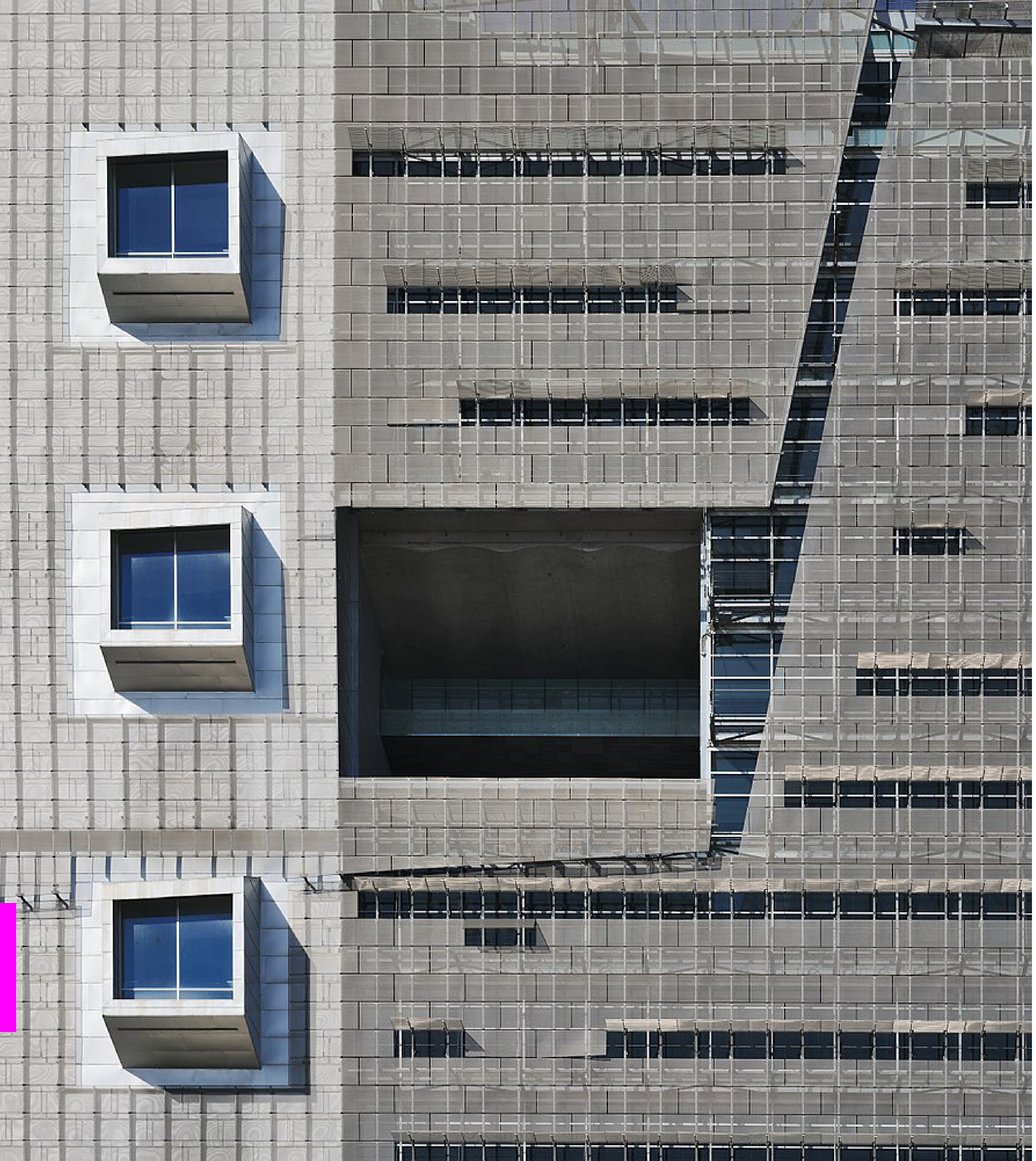
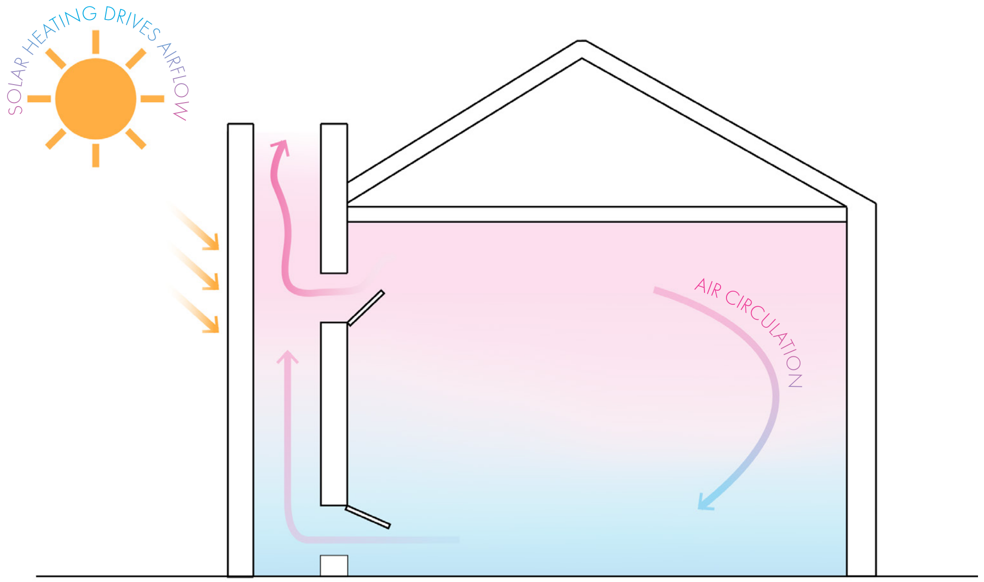
CONTEMPORARY REINTERPRETATION



AIR
STACK EFFECT



The stack effect is a passive ventilation process driven by temperature and density differences between indoor and outdoor air. As warm air inside a building becomes lighter, it rises naturally and exits through high-level openings such as clerestories, vents, or atria. This upward movement creates a negative pressure at lower levels, drawing cooler, denser air inside through openings near the ground. The continuous cycle helps flush out heat, regulate interior temperatures, and maintain fresh air circulation without reliance on mechanical systems.

Great Mosque of Córdoba

Córdoba, Andalusia, Spain, 784–786 CE, Abd al-Ramān I (Patron).

Iran Paradise. (2020, October 27). Dowlat Abad Garden. Iran Paradise.

The Great Mosque of Córdoba integrates the stack effect by combining large interior spaces, massive masonry walls, and strategically placed openings. The hypostyle hall's tall double arches and high ceilings encourage hot air to rise, while small, regular window-lattices in the upper walls and chapels allow it to escape. This upward movement draws in cooler air from shaded courtyards and lower openings, creating continuous airflow that circulates through the sanctuary. Thick stone and brick walls add thermal inertia, stabilizing temperatures, while the absence of direct sunlight preserves the dim, intimate atmosphere desired for worship. In this way, passive ventilation maintains comfort in Andalusia's climate.

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Doha, Qatar, 1992. Kamal El-Kafrawi.

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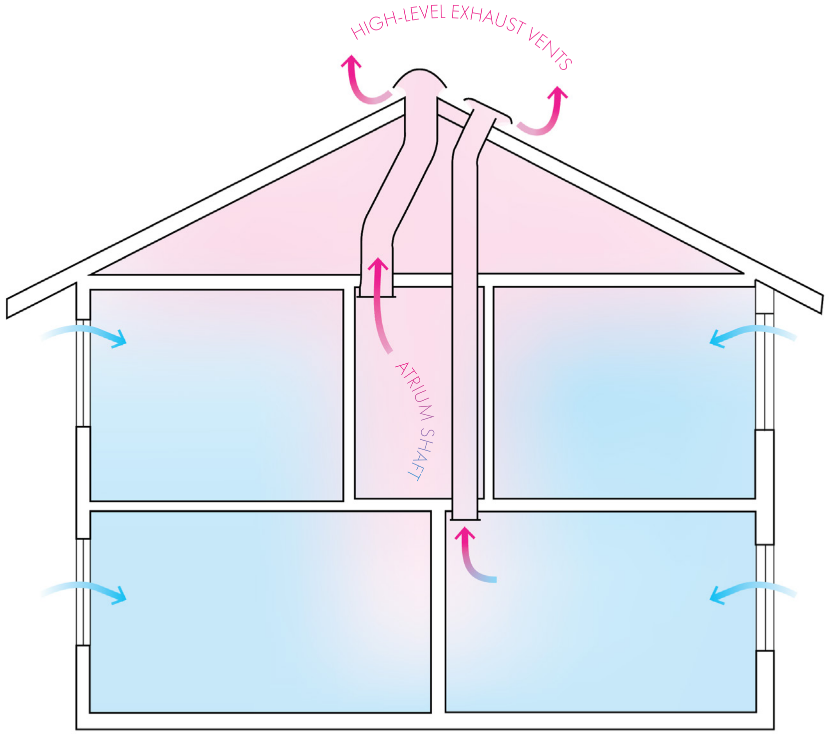
AIR
ATRIUM EXHAUSTS



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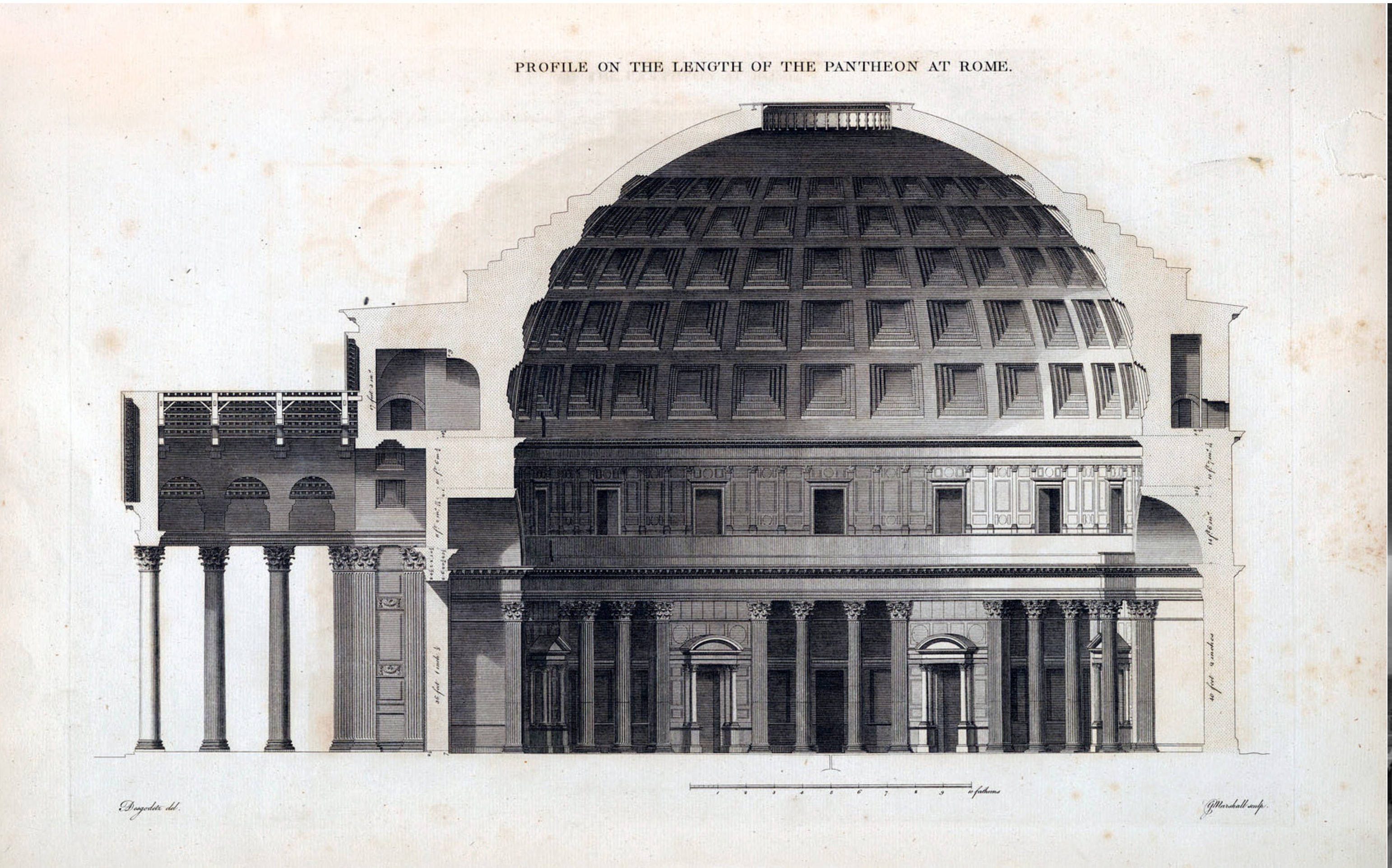
Pantheon

Rome, Italy, 27 BCE, Marcus Agrippa (Original patron).



Palladio, A. (1570/ 1997). I quattro libri dell'architettura (I quattro libri dell'architettura di Andrea Palladio: Venezia 1570) [Plans and sections of the Pantheon]. Venice, Italy: Marsilio.

The Pantheon uses its vast atrium-like volume and central oculus that creates a passive cooling effect. Warm air generated inside rises naturally toward the dome and escapes through the oculus, while cooler, denser air is drawn in at lower levels through the entrance and subtle wall inlets. The thick masonry walls further stabilize temperatures by absorbing heat during the day and releasing it slowly at night. Together, these elements establish a continuous cycle of natural ventilation that keeps the interior relatively cool despite Rome's summer heat.

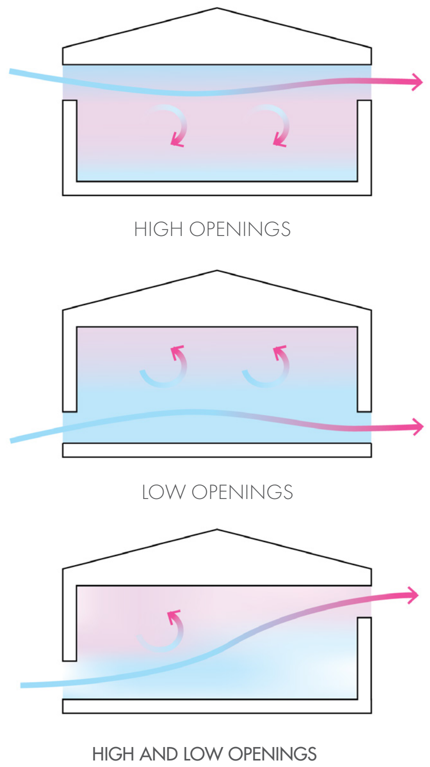
Ford Foundation Building

New York, United States, 1967. Kevin Roche, John Dinkeloo.

Stoller, E. (Photographer). (n.d.). Ford Foundation Building, New York City [Photograph]. Esto.

The Ford Foundation Building employs a twelve-story glass atrium as both a social space and a passive environmental system. Acting as a giant thermal chimney, the atrium captures solar heat, causing interior air to warm and rise. This buoyant air is vented through adjustable openings at the top of the structure, while cooler, denser air is drawn in at lower levels, creating a continuous cycle of natural ventilation. The surrounding offices benefit from this airflow, as the atrium moderates temperature swings and reduces reliance on mechanical cooling. The atrium is both a climatic regulator and an architectural centerpiece.

AIR
CROSS-VENTILATION



Cross ventilation is a passive cooling strategy that relies on the natural movement of air through a building to reduce indoor heat. By placing operable openings, such as windows, vents, or doors, on opposite or adjacent walls, air flows laterally across interior spaces, driven by pressure differences created by wind or temperature. This continuous exchange flushes out warm, stagnant air and replaces it with cooler outdoor air, improving comfort and air quality. Cross ventilation minimizes reliance on mechanical cooling while fostering a direct connection between architecture and climate.

Bahay Kubo

Philippines. Vernacular Filipino architecture.

Perez, R. T., Formoso, B. C., Zialcita, F. N., & Tinio, M. A. (1989). Folk architecture (p. [insert page number if available]) [Photograph of traditional Filipino house, the "bahay kubo"]. Quezon City, Philippines: GCF Books.

The Bahay Kubo, or nipa hut, is the archetypal form of traditional Filipino vernacular architecture, developed in response to the hot, humid, and storm-prone climate of the tropical Philippines. Typically elevated on stilts to avoid flooding and promote airflow beneath the floor, the lightweight bamboo-and-thatch dwelling is designed on the principle of cross-ventilation. Large operable windows are distributed on all sides, while the open-plan interior allows air to circulate freely across the single room. Breezes entering from one side can exit through the opposite openings, carrying heat and humidity out of the living space. These features create a cool, breathable environment without mechanical cooling, making the Bahay Kubo a highly efficient and sustainable response to the tropical setting.

HISTORICAL PRECEDENT

Commerzbank Tower

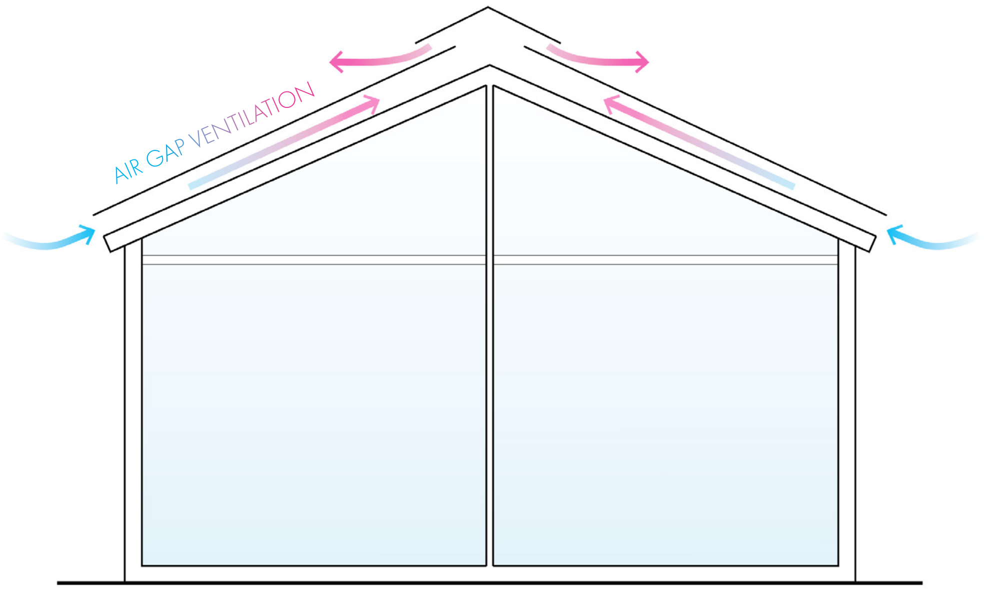
Frankfurt, Germany, 1997. Foster + Partners.

Wolf, T. (2019, July 10). Commerzbank Tower, Frankfurt, Germany, with Taunusturm and Omniturm [Photograph]. © Thomas Wolf, www.foto-tw.de . Licensed under CC BY-SA 3.0 DE.

The Commerzbank Tower integrates cross ventilation as a defining feature of its high-tech environmental design: shaped around a central triangular plan with sky gardens carved into its form, the tower allows offices to remain only one room deep, ensuring that each workspace has access to operable windows. These openings draw in fresh air from the exterior, while opposite sides of the floorplate permit warm air to exit, establishing continuous cross-flow. The sky gardens act as intermediate lungs, distributing air and light deep into the building, while the double-skin façade regulates solar gain and acoustic performance.

CONTEMPORARY REINTERPRETATION

AIR
DOUBLE-ROOFS



Double roofs are a passive cooling design technique in which two roof layers are separated by a ventilated cavity. The outer layer absorbs or deflects solar radiation, while the air gap allows heat to dissipate before it reaches the inner roof. This buffer zone reduces thermal transfer, stabilizes indoor temperatures, and promotes airflow through convection. Double roofs effectively moderate heat gain in hot climates without reliance on mechanical cooling.

Malay Houses/Kampung Houses

Southeast Asia, 19th century, Collective vernacular tradition

Ahlan Malaysia TM. (n.d.). [Photograph of traditional Malay house architecture] [Photograph]. Ahlan Malaysia TM.

Traditional Malay houses are elevated timber structures designed for tropical climates, integrating double roofs as a passive cooling technique. Their steeply pitched thatch roofs create a ventilated cavity between the outer covering and the inner ceiling, allowing hot air to rise and escape beneath the ridge. This layered system shades the interior while promoting continuous air circulation, reducing heat gain and maintaining thermal comfort. Combined with stilts, open walls, and wide eaves, the double roof exemplifies a holistic vernacular response to heat and humidity.

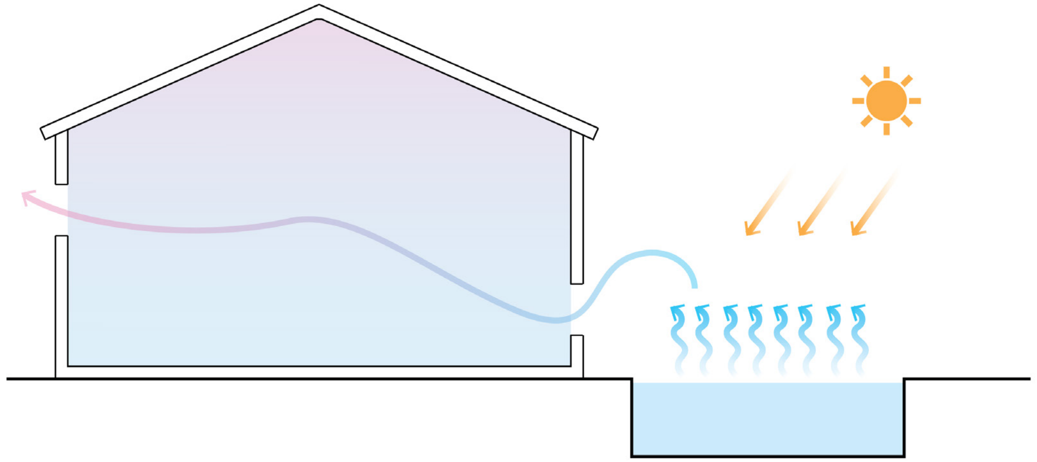
Gando Library Extension

Gando, Burkina Faso, 2008. Diébédo Francis Kéré

Ouwerkerk, E. J. (Photographer). (2008). School extension, Gando, Burkina Faso, by Kéré Architecture [Photograph].

The Gando Library Extension employs a double roof system as a key passive cooling strategy in response to the region's hot, arid climate. A lightweight metal canopy is raised above the primary earthen roof, creating a ventilated cavity that shades the structure and allows hot air to dissipate before reaching the interior. This air buffer reduces solar heat gain while encouraging convection, keeping indoor spaces cooler and more comfortable. Combined with thick earthen walls for thermal mass and strategically placed openings for airflow, the double roof leverages vernacular wisdom and innovative design to achieve sustainable, climate-responsive architecture.

WATER
WATER FEATURES



Water features provide natural cooling through evaporation and convection. Falling or circulating water absorbs heat and lowers surrounding air temperature, creating a more comfortable microclimate. The process also adds humidity, balancing dry indoor air and supporting nearby plants. In closed-loop systems, collected rainwater is filtered and reused, reducing energy and water waste.

Salsabil/Salasabil/Shadirwan

Middle East & North Africa, 8th–19th centuries. Vernacular

Perez, R. T., Formoso, B. C., Zialcita, F. N., & Tinio, M. A. (1989). Folk architecture (p. [insert page number if available]) [Photograph of traditional Filipino house, the "bahay kubo"]. Quezon City, Philippines: GCF Books.

Salsabils or shadirwans are stepped or inclined fountains that spread water across a broad surface. Salsabils were historically used as passive cooling devices in Islamic and Persian architecture. By maximizing the surface area of flowing water, they accelerate evaporation, which absorbs heat from the surrounding air and lowers indoor temperatures. When integrated into courtyards, palaces, or mosques, this evaporative cooling provided relief in hot, arid climates without mechanical systems. In addition, these water features also produced a steady sound of flowing water, which masked speech and helped prevent eavesdropping. Thus, they functioned both as environmental regulators and as subtle instruments of social privacy.

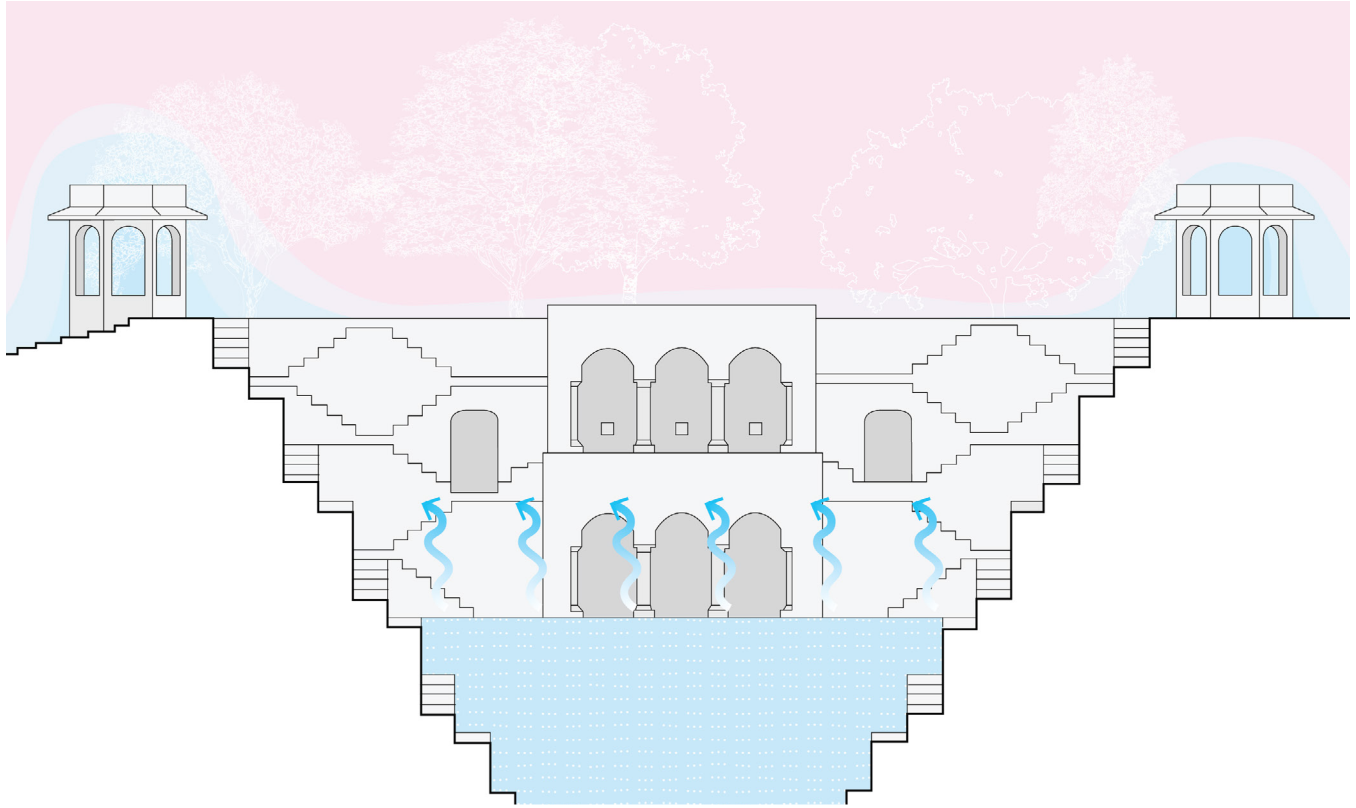
Jewel Changi Airport

Changi, Singapore, 2019. Moshe Safdie

Hursley, T. (Photographer). (2019). Jewel Changi Airport, Changi, Singapore [Photograph].

The Rain Vortex at Jewel Changi Airport, the world's tallest indoor waterfall at 40 meters, is both a dramatic centerpiece and a passive environmental device. The falling water naturally humidifies the vast air-conditioned space, maintaining comfort for people and plants in the Forest Valley. Its constant downward motion creates convective air currents that mix interior air and reduce stagnant, warm zones. The system is closed-loop—rainwater collected from the roof is filtered and recirculated, minimizing energy and water waste.

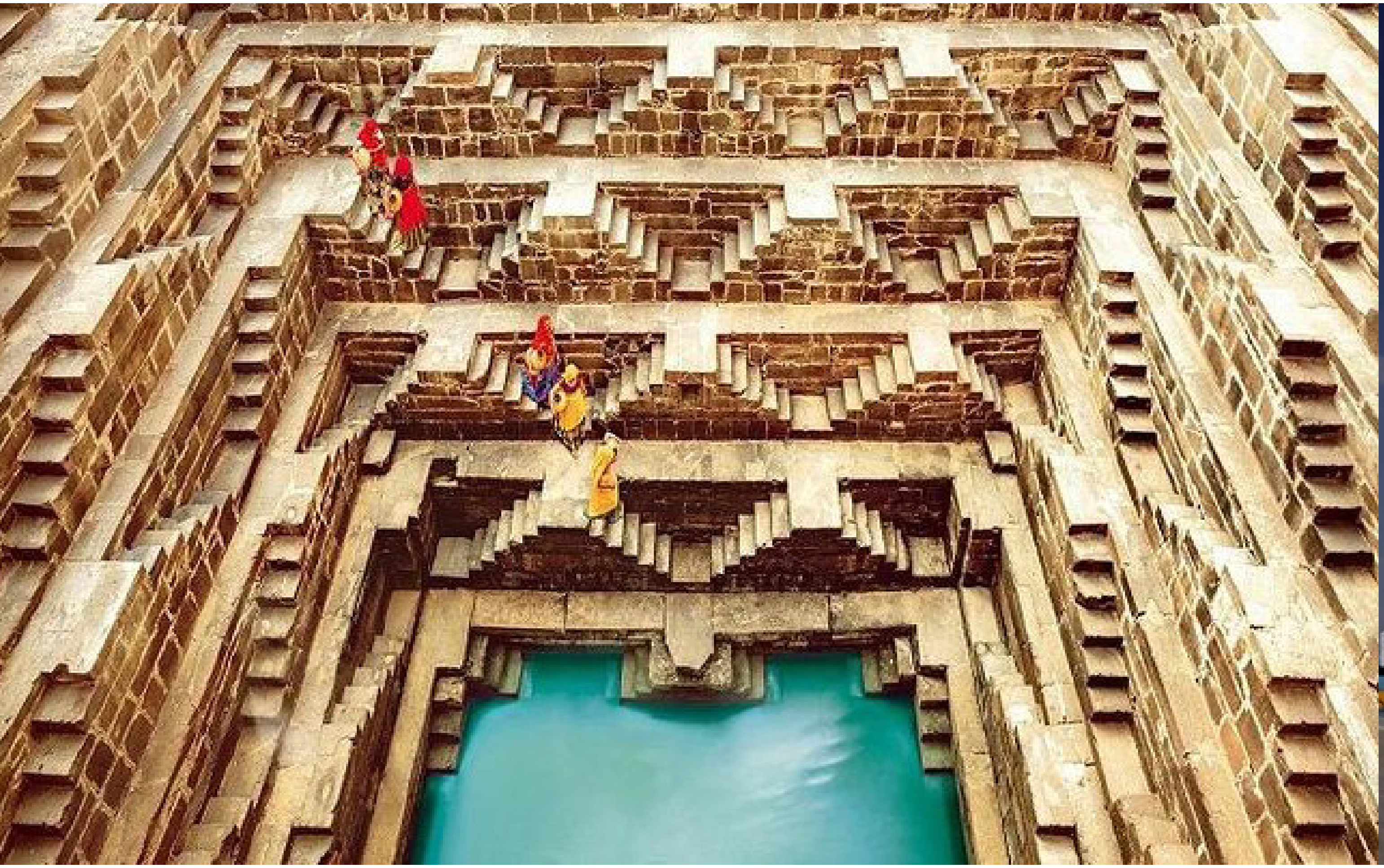
WATER
STEPWELLS



Stepwells are traditional subterranean water structures found primarily in India, designed to provide reliable water access and passive cooling in hot, arid climates. Built from stone or brick, they descend deep into the earth through a series of terraces, steps, and landings that lead to a central water reservoir. Their sunken form creates shaded, insulated spaces where temperatures remain significantly cooler than the surrounding environment. Beyond their utilitarian function, stepwells often served as social and cultural gathering places.

Chand Baori

Jaipur, India, 9th century CE. Vernacular Indian stepwell architecture.



Wu, M. (Photographer). (n.d.). Chand Baoli step well, Jaipur, India [Photograph].Shutterstock.

The Chand Baoli stepwell engages in passive cooling by using its deep, symmetrical stepped design to moderate temperature. The descending steps lead to a pool of stored water that remains cool even in extreme heat, while the high stone walls and narrow shafts limit direct sunlight and create shaded microclimates. As air passes over the cool water surface, it loses heat through evaporation, lowering the surrounding temperature. This combination of evaporative cooling, shading, and thermal mass turned the stepwell into both a vital water reservoir and a naturally cooled gathering space for the community.

Pearl Academy of Fashion

Jaipur, India, 2008. Morphogensis.

Fanthome, A. J., & Sumner, E. (Photographers). (2008). Pearl Academy of Fashion, Jaipur, India [Photograph]. Morphogenesis / Architonic.

The Pearl Academy of Fashion reinterprets the traditional stepwell as a central device for passive cooling and social space. Inspired by Rajasthan's historic baolis, the architects carved a vast subterranean courtyard beneath the building, where sunken steps lead down to shaded gathering areas. This recessed void is naturally cooler than the surface, and by channeling prevailing breezes across pools of water, it generates evaporative cooling that lowers ambient temperatures. The heavy stone construction and earth-sheltered depth provide additional thermal insulation, while the perforated jaali screens above filter sunlight and allow hot air to rise and escape.

EARTH
THERMAL MASS

The Effectiveness of Some Common Materials

Material	Specific heat capacity	Thermal conductivity	Density	Effectiveness
water	4200	0.6	1000	high
stone	1000	1.8	2300	high
brick	800	0.73	1700	high
concrete	1000	1.13	2000	high
unfired clay bricks	1000	0.21	700	high
dense concrete block	1000	1.63	2300	high
gypsum plaster	1000	0.5	1300	high
aircrete block	1000	0.15	600	medium
steel	480	45	7800	low
timber	1200	0.14	650	low

Source: http://www.greenspec.co.uk/building-design/thermal-mass/

Thermal mass refers to the ability of a material to absorb, store, and release heat over time, acting as a natural moderator of temperature fluctuations. Materials with high thermal mass, such as stone, adobe, concrete, or earth, slowly absorb heat during the day to prevent interiors from overheating and release it gradually as temperatures drop at night. This delayed thermal response stabilizes indoor conditions and reduces reliance on mechanical heating and cooling. In both vernacular and contemporary sustainable architecture, thermal mass is a key passive design strategy for achieving comfort in climates with pronounced diurnal temperature swings.

Great Mosque of Djenné

Djenné, Mali, 13th century. Koi Konboro (Patron)

Morris, J. (2003). [Description of the photograph] [Photograph]. In Butabu: Adobe architecture of West Africa (p. [insert page number]). New York, NY: Princeton Architectural Press.

The Great Mosque of Djenné is the largest adobe brick structure in the world and a landmark of Sahelian architecture. Constructed of sun-dried banco mudbrick coated in mud plaster, its walls up to 60 centimeters thick serve as massive thermal buffers against the intense Sahelian climate. By absorbing heat during the day and slowly releasing it at night, the building's heavy thermal mass stabilizes indoor temperatures and reduces daily extremes. This passive cooling strategy ensures a comfortable interior environment despite the region's harsh heat.

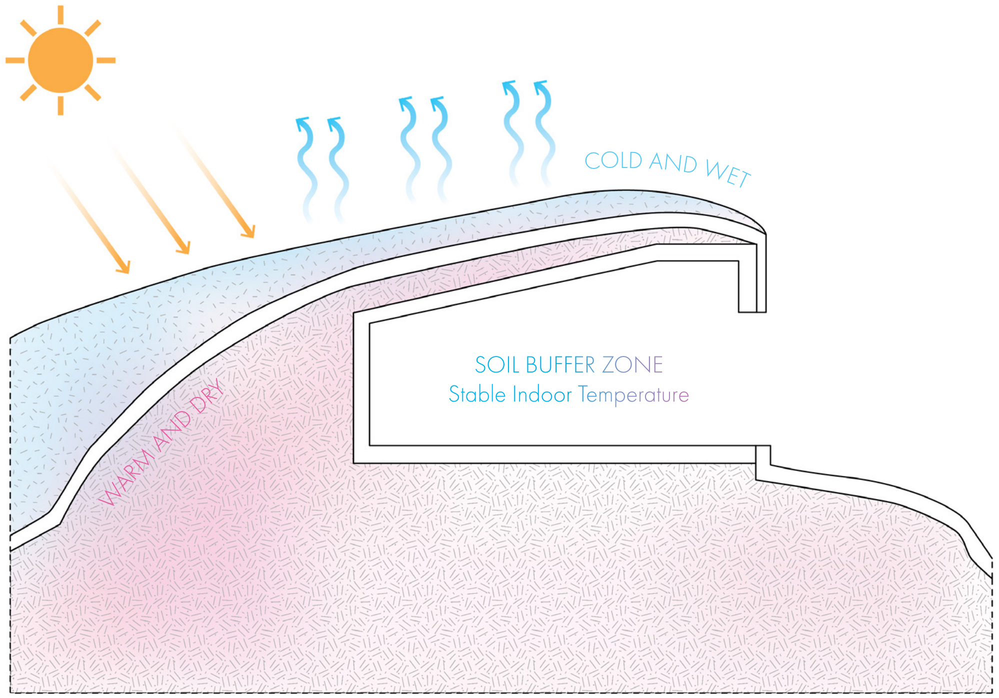
Gando Teachers' Housing

Gando, Burkina Faso, 2004. Diébédo Francis Kéré

Ouwerkerk, E.-J. (Photographer). (2004). Gando Teachers' Housing, Gando, Burkina Faso [Photograph]. Courtesy of Kéré Architecture.

The Gando Teachers' Housing integrates heavy thermal mass as a primary strategy for passive cooling in the hot, arid Sahelian climate. Constructed with thick walls of locally produced clay bricks, the housing absorbs heat during the day, preventing excessive interior temperature rise, and releases it gradually at night when outdoor temperatures drop. This thermal inertia creates a stable indoor environment. Combined with shaded outdoor spaces and natural cross-ventilation, the use of massive earthen construction allows the buildings to remain comfortable without mechanical cooling, continuing a vernacular tradition of climate-responsive architecture.

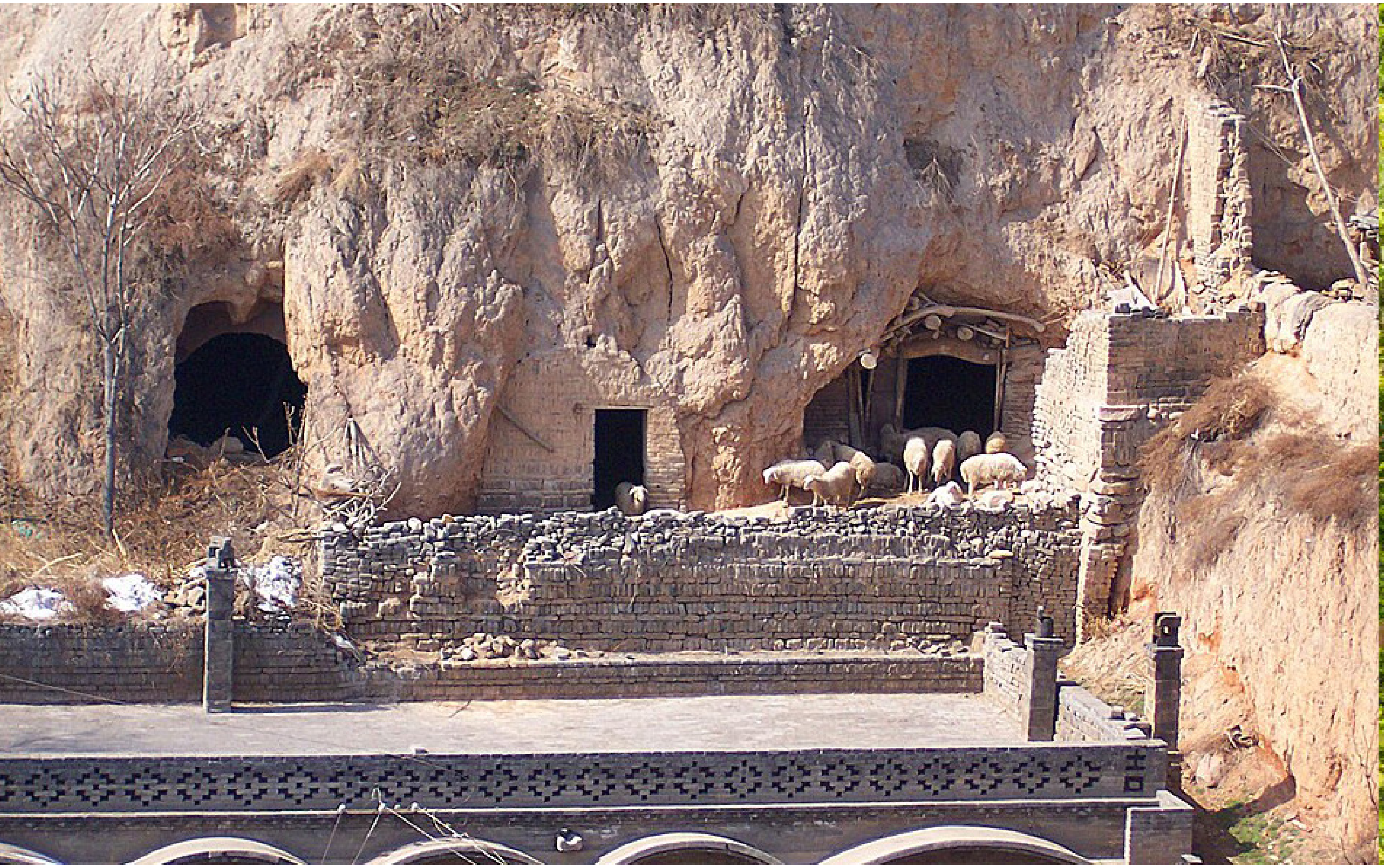
EARTH
EARTH SHELTERING



Sod roofs are a traditional Northern European roofing technique, especially common in Scandinavia, where a thick layer of soil and vegetation is laid over birch bark or wooden planks. The sod provides thermal mass and natural insulation, buffering interiors against summer heat and winter cold. Vegetation on the roof further reduces heat gain through evapotranspiration, while the soil layer stabilizes interior temperatures by storing and slowly releasing heat. Sod roofs are durable, low-maintenance, and ecologically integrated, and integrate local, renewable materials.

Yaodong

Northern China, 7th century CE. Vernacular dwellings.



Meier, & Poehlmann. (2006, February). Traditional cave houses and barns, Wang Family Grand Courtyard, Lingshi County, Shanxi Province, China [Photograph].

Carved into the thick loess soil of northern China, yaodong are traditional cave dwellings that use earth-sheltering to create naturally temperate interiors. Their thick earthen walls and underground orientation stabilize indoor climates, staying cool in the hot summers and warm in the harsh winters of the plateau. Arranged in courtyards or dug into hillsides, yaodong represent a sustainable adaptation to local geography and climate, housing millions of people for over a millennium.

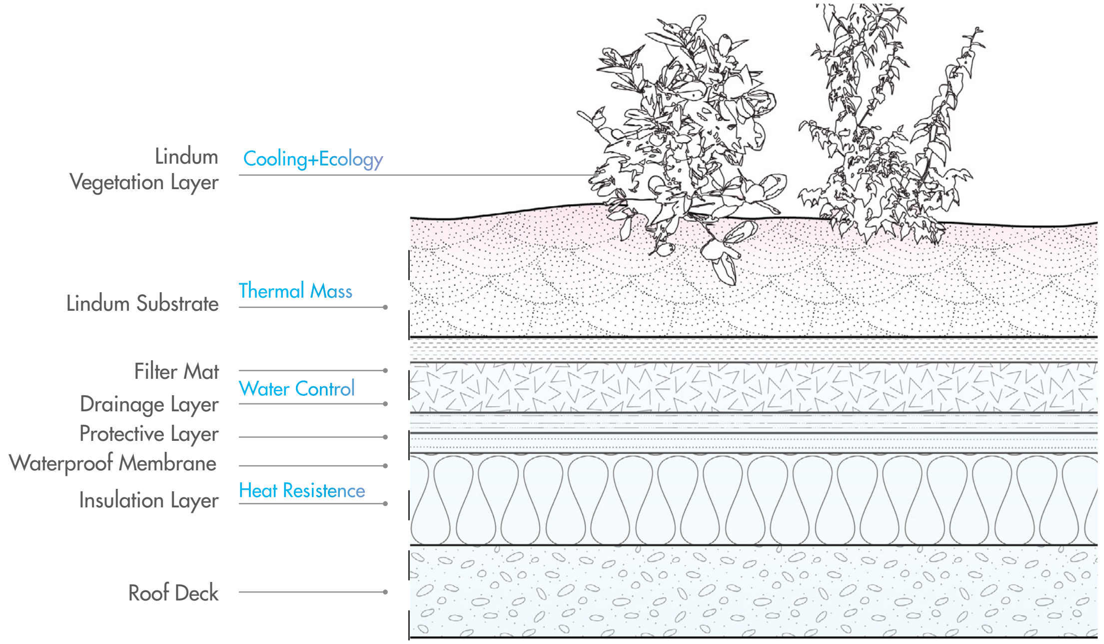
Library in the Earth,

Kisarazu, Japan, 2022. Hiroshi Nakamura & NAP Architects.

Fujii, K. (Photographer). (2022). Library in the Earth, Kisarazu, Japan [Photograph]. TOREAL / Hiroshi Nakamura & NAP.

Buried within a hollowed hillside, The Library in the Earth is enveloped by layers of soil that act as a massive thermal buffer, absorbing heat in summer and releasing stored warmth in winter. This stable subterranean environment keeps indoor temperatures naturally moderated throughout the year, reducing reliance on mechanical air conditioning. By integrating the landscape itself as insulation, the library transforms earth into an active climatic device, demonstrating how architectural form can harmonize with natural thermal regulation.

EARTH
SOD ROOF



SOD ROOF — ONE EXAMPLE OF LAYERED ASSEMBLY

Sod roofs are a traditional Northern European roofing technique, especially common in Scandinavia, where a thick layer of soil and vegetation is laid over birch bark or wooden planks. The sod provides thermal mass and natural insulation, buffering interiors against summer heat and winter cold. Vegetation on the roof further reduces heat gain through evapotranspiration, while the soil layer stabilizes interior temperatures by storing and slowly releasing heat. Sod roofs are durable, low-maintenance, and ecologically integrated, and integrate local, renewable materials.

Scandinavian Log Buildings

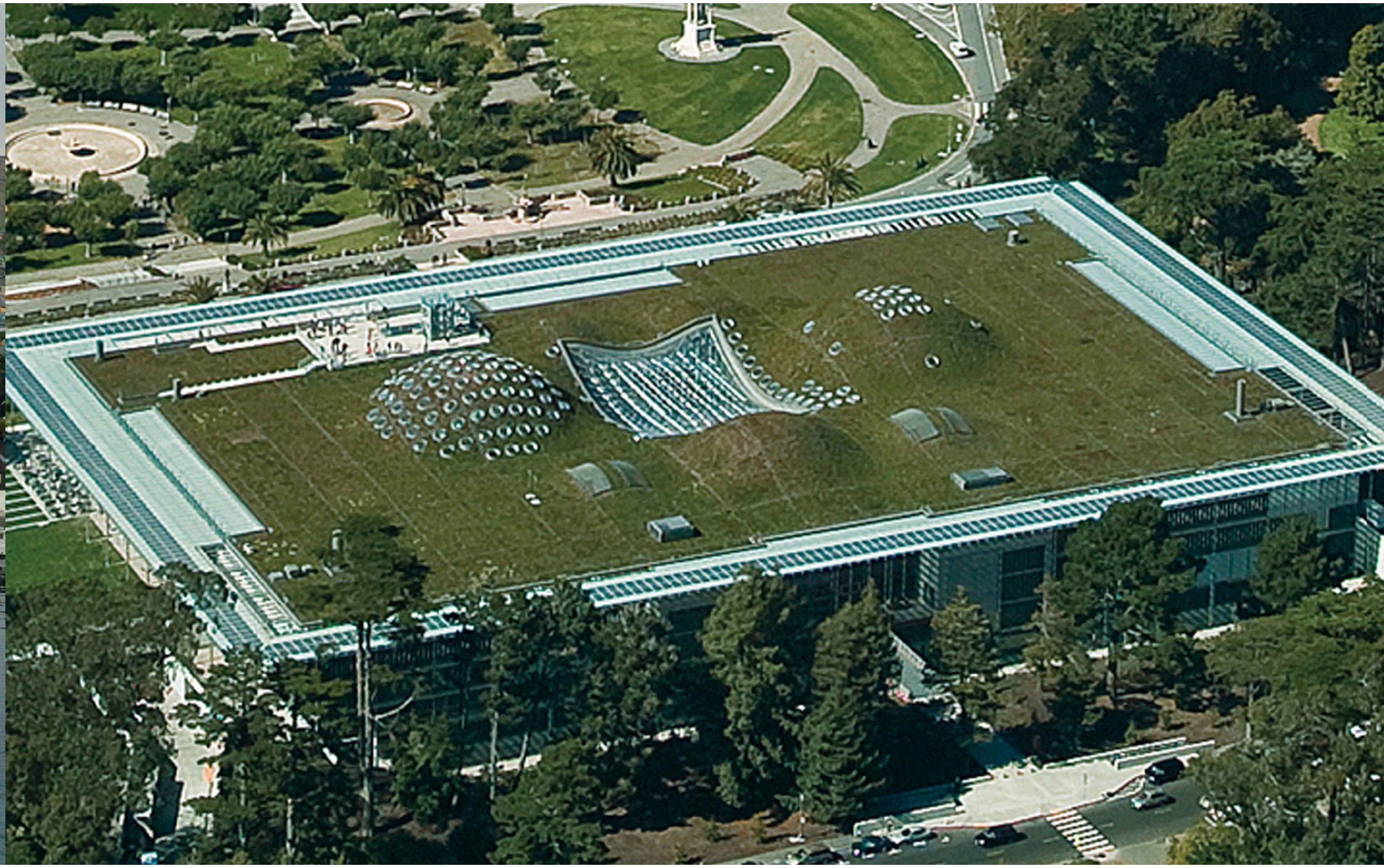
Oslo, Norway, 1894 (Norsk Folkemuseum). Vernacular timber construction

Christensen, E. (2004, October 30). Street on Tinganes, old town of Tórshavn, Faroe Islands [Photograph].

Sod roofs are a collective Scandinavian vernacular tradition developed to adapt to the region's variable climate. Built by layering birch bark for waterproofing and thick sod for insulation, these roofs provided high thermal mass that buffered interiors from heat gain in summer and heat loss in winter. The vegetation layer absorbed solar radiation and reduced surface temperatures through evapotranspiration, while the soil's mass stabilized indoor conditions by storing and slowly releasing heat. In the Faroes, where strong winds, heavy rainfall, and cool temperatures dominate, thick sod roofs layered over birch bark or wooden planks provide excellent insulation and weather protection.

California Academy of Sciences

San Francisco, United States, 2008. Renzo Piano

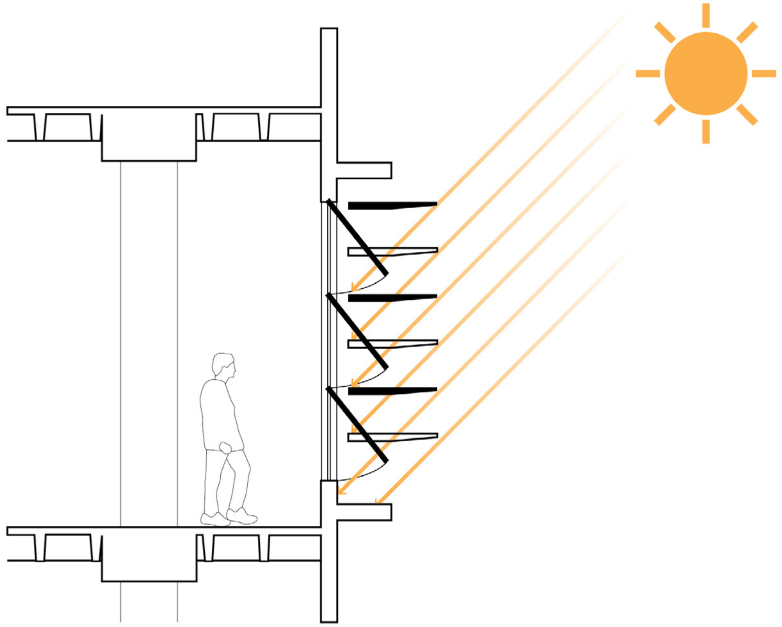


Griffith, T. (Photographer). (2008). California Academy of Sciences, San Francisco, United States, by Renzo Piano Building Workshop and Stantec Architecture [Photograph]. Arquitectura Viva.

The California Academy of Sciences employs a living sod roof as a passive cooling device. Its undulating, 2.5-acre green roof is covered with native plants rooted in a thick soil layer that insulates the building and moderates interior temperatures. By absorbing solar radiation and lowering roof-surface heat through evapotranspiration, the vegetated roof reduces the urban heat island effect while cutting the cooling demand inside. The soil's thermal mass further stabilizes diurnal temperature swings, allowing the building to remain cooler during hot days.

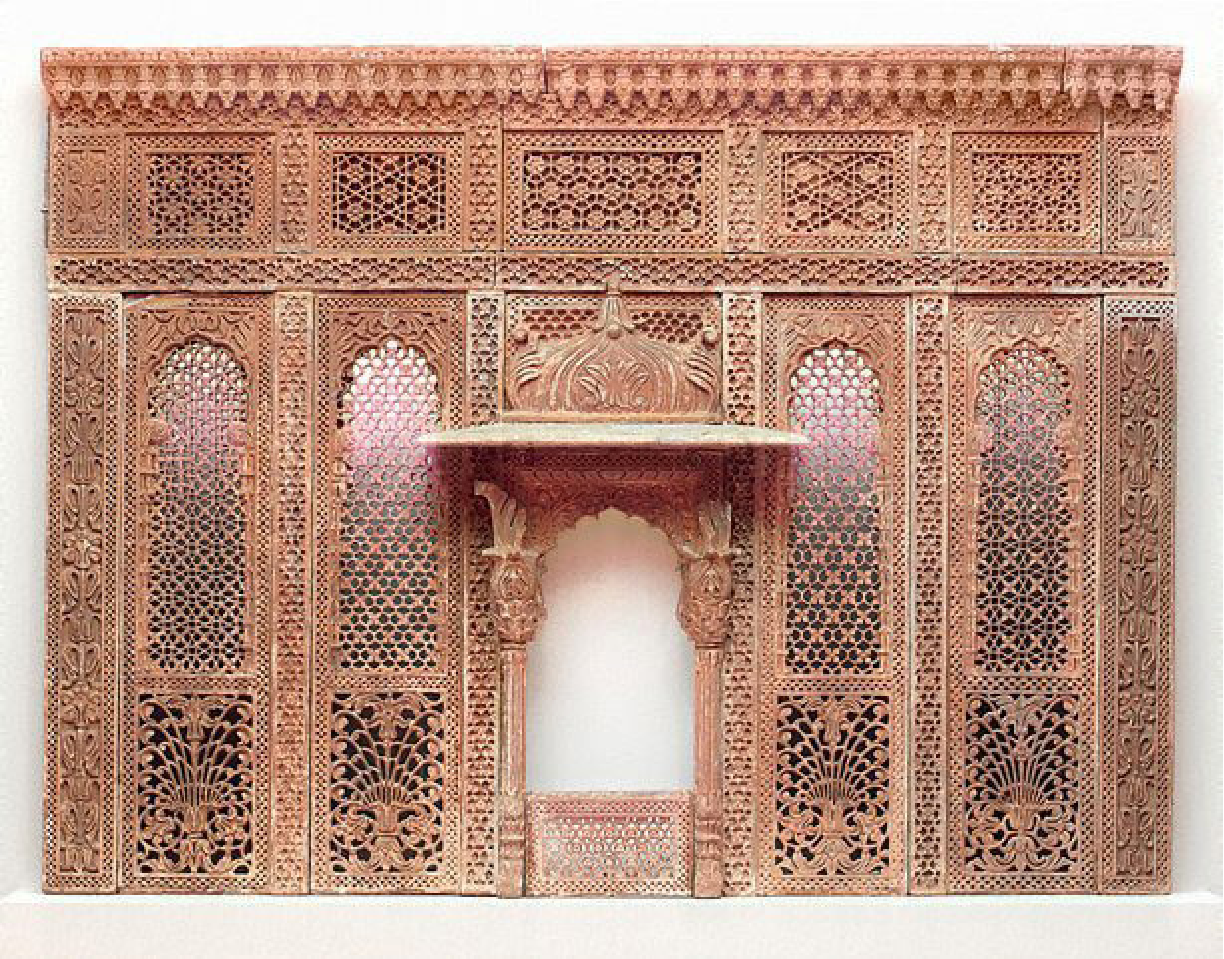
FIRE

BRISE-SOLEIL



Brise-soleil is a "sun breaking" architectural device consisting of fixed or movable shading elements, such as louvers, fins, or perforated screens, positioned on a building's façade to control solar radiation. By blocking high-angle sun while allowing diffuse light and ventilation, brise-soleil reduce heat gain and glare, lowering cooling loads and improving interior comfort. Originating in vernacular precedents like jali screens and mashrabiyas, the concept was reinterpreted in modern architecture. Today, they remain a widely used passive strategy for climate-responsive design.

Jali Screens
India, 13th-18th CE, Collective vernacular tradition.



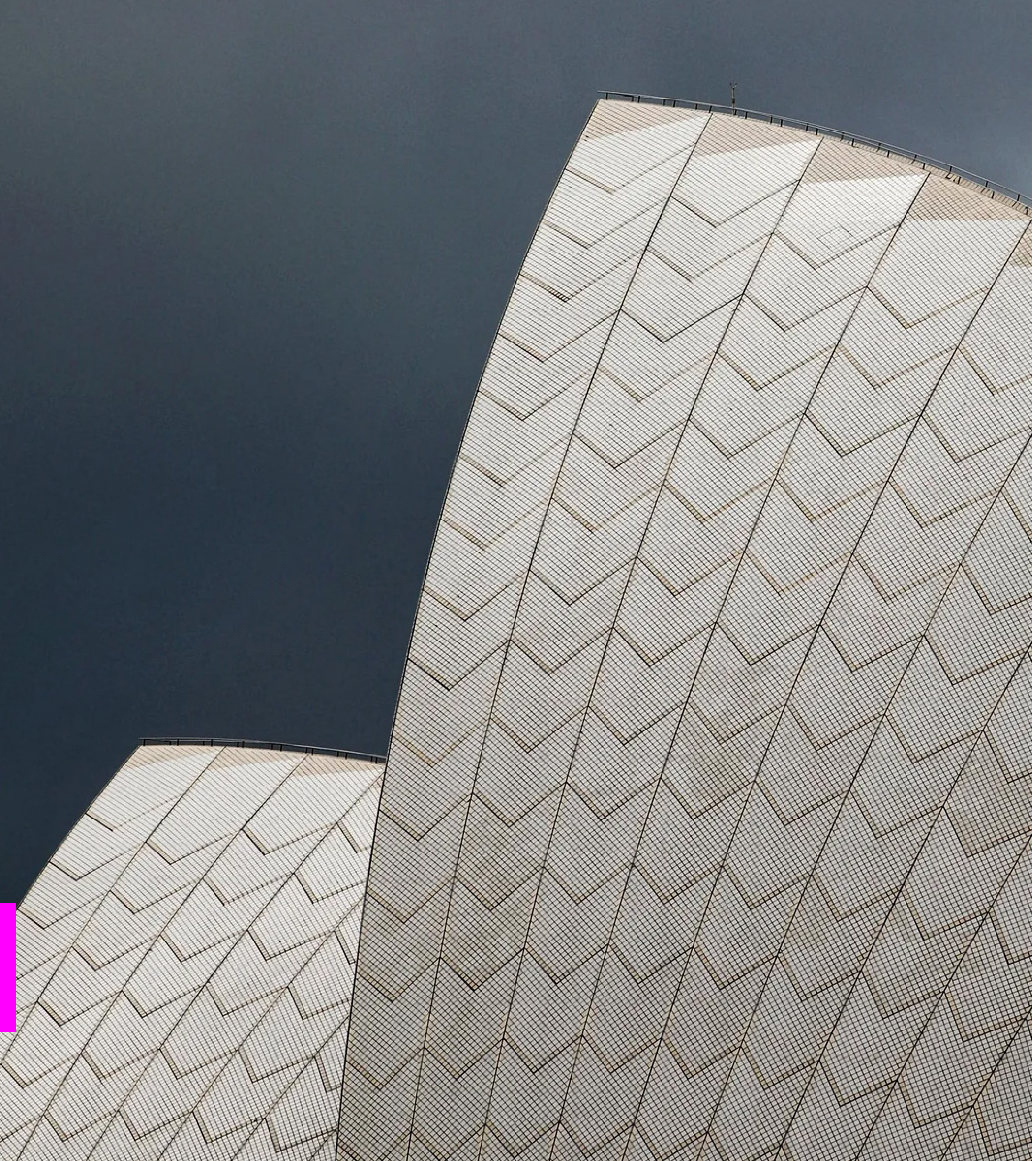
Jali Zaroka, unknown artist, Jaisalmer, Rajasthan, India, 18th century. Yellow sandstone, 222 × 287 cm. Collection: Margaret Hannah Olley Art Trust, 1998 (Accession no. 220.1998).

Jali screens a tradition of the Indian subcontinent, are intricately carved perforated stone or lattice screens that became prominent during the Sultanate and Mughal periods. Serving as an early form of brise-soleil, they filter intense sunlight, reduce heat gain, and promote ventilation while maintaining privacy. Beyond their environmental function, jali exemplify the integration of ornament and climate-responsive design, merging structural utility with cultural and aesthetic expression.

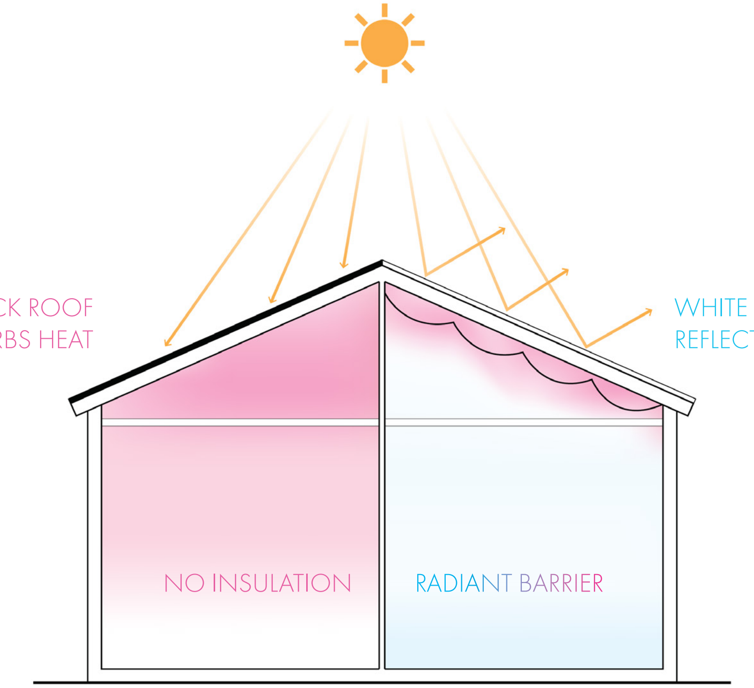
Institut du Monde Arabe
Paris, France, 1987. Jean Nouvel.

Romero, F. (2015, November 8). Institut du Monde Arabe (Arab World Institute), Paris, France, by Architecture-Studio and Jean Nouvel (1981–1987) [Photograph]. Wikimedia Commons.

The south façade of the Institut du Monde Arabe reinterprets the vernacular mashrabiya as a high-tech brise-soleil. The curtain wall is fitted with 240 light-sensitive diaphragms, each composed of metallic apertures resembling camera lenses. These motorized elements open and close in response to daylight intensity, filtering sunlight and reducing solar heat gain while preserving views and admitting diffuse light. Functioning simultaneously as shading device, climate regulator, and ornamental screen, the kinetic façade exemplifies how a brise-soleil can merge environmental performance with cultural symbolism in contemporary architecture.



FIRE
RADIANT BARRIERS



Radiant barriers are surfaces designed to reflect, rather than absorb, solar radiation, thereby reducing heat gain within a building. They typically take the form of light-colored or reflective roofs, walls, and high-albedo finishes, which deflect a significant portion of incoming sunlight. By lowering surface temperatures and minimizing the transfer of radiant heat indoors, these finishes help stabilize interior conditions and lessen cooling loads. Found in both vernacular traditions and modern sustainable design, radiant barriers exemplify a simple yet highly effective passive strategy for controlling solar heat.

Santorini Houses

Santorini, Greece,18th century, Collective vernacular tradition

Brothers Travel Santorini. (n.d.). [Photograph of white houses in Santorini, Greece] [Photograph]. Brothers Travel Santorini.

Evolving as part of Cycladic architecture, these whitewashed dwellings are an example of the vernacular use of radiant barriers to regulate climate. Their lime-plastered walls, painted in bright white, reflected intense solar radiation and reduced heat gain within interiors. The practice became codified in the 1930s under the Metaxas regime, when laws required Cycladic houses to be limewashed for both sanitary reasons as lime's high alkalinity provided antimicrobial protection during outbreaks of cholera and tuberculosis, and for climatic benefit, stabilizing interior comfort in the hot, sun-drenched Aegean.

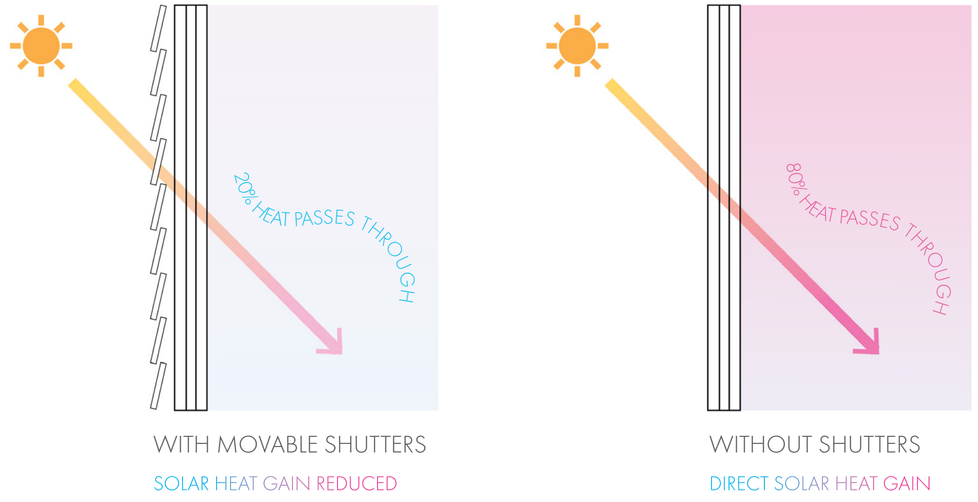
Sydney Opera House

Jørn Utzon, Sydney, Australia, 1973

Vissel, J. (Photographer). (1973). Sydney Opera House, Sydney, Australia [Photograph]. ArchDaily.

The Sydney Opera House integrates a radiant barrier strategy through the careful design of its iconic roof shells. Clad in over a million white ceramic tiles in two finishes: matte "snow" and glossy "ice". The sails are engineered to reflect rather than absorb Sydney's intense sunlight. This dual texture captures brilliance under changing skies while reducing heat gain, ensuring that much of the solar radiation is deflected outward. As a result, the light-colored cladding not only enhances the building's shimmering presence on the harbor but also passively contributes to maintaining cooler interior spaces by minimizing heat absorption.

FIRE
MOVABLE SHUTTERS



Movable shutters are a passive cooling technique that regulate solar gain, ventilation, and thermal comfort by allowing occupants to adjust building openings in response to changing conditions. Mounted externally or internally on windows, shutters can be closed during the hottest parts of the day to block direct sunlight and reduce heat gain, while their operability permits controlled airflow when partially opened. At night or during cooler periods, they can be fully opened to promote cross-ventilation and flush out warm interior air. By combining shading and air control in a simple, adaptable device, movable shutters provide a flexible means of moderating temperature without mechanical systems.

Amado & Shoji Sliding Panels
Japan, Edo Period, Collective vernacular tradition.

Ktmchi. (2013, October 14). Shoji sliding doors in the Rinshunkaku at Sankei-en (Important Cultural Property), Yokohama, Japan [Photograph]. Wikimedia Commons.

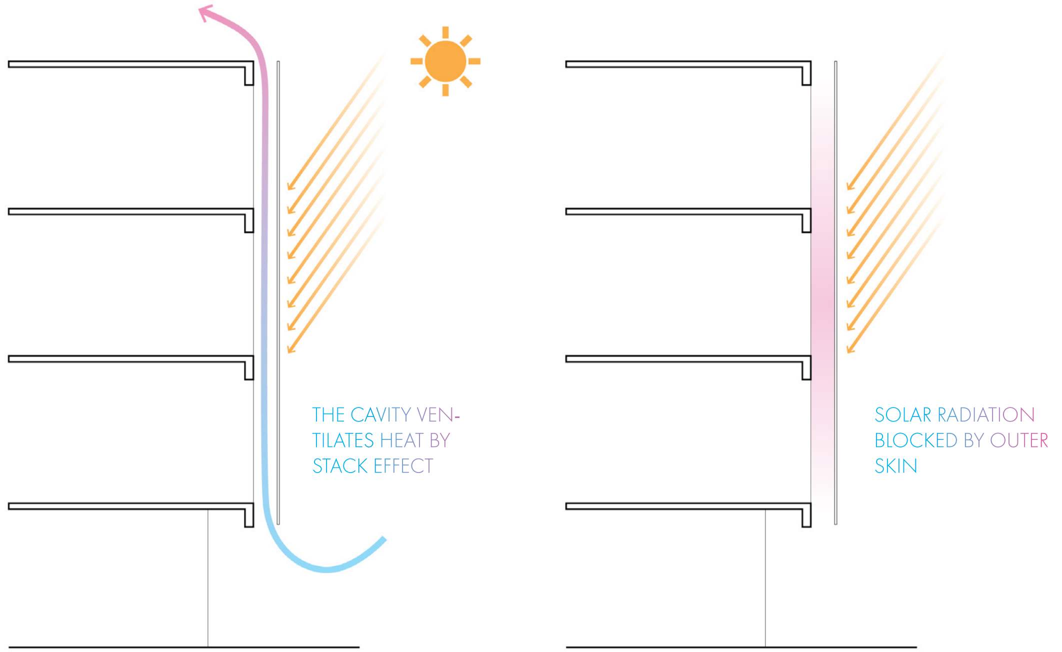
Amado and shoji sliding panels in traditional Japanese architecture exemplify the use of movable shutters as passive cooling devices. Shoji are lightweight wooden lattice frames covered with translucent paper, positioned inside to diffuse sunlight, reduce glare, and allow air to circulate freely while maintaining privacy. Amado, by contrast, are heavy opaque wooden or metal panels mounted on the exterior, slid shut during storms or intense heat to block solar gain and insulate interiors. Used together, the two layers form an adaptable façade system: shoji modulate light and air, while amado provide thermal protection and security when needed.

One Ocean Pavilion
Yeosu, South Korea, 2012. SOMA Architecture.

soma architecture. (n.d.). One Ocean pavilion, Yeosu, South Korea [Photograph]. Architizer. https://architizer.com/projects/one-ocean/

The One Ocean Pavilion integrates movable shutters as a dynamic passive design system. Its façade is composed of kinetic louvers that open and close in response to sun, wind, and programmatic needs, functioning like a contemporary version of shutters. By adjusting their position, the shutters control solar heat gain, reduce glare, and allow natural ventilation, creating a continuously adaptable envelope that responds to shifting environmental conditions. This kinetic skin demonstrates how movable shading devices can merge performance, flexibility, and architectural expression in a high-profile, climate-responsive building.

FIRE
DOUBLE SKIN FAÇADE



Double-skin façades function as passive cooling systems that mitigate solar radiance by creating a ventilated cavity between two layers of the building envelope. The outer skin absorbs or reflects sunlight, while the air gap prevents direct heat transfer to the interior. Warm air within the cavity rises and is vented through stack effect, reducing surface temperatures and cooling the inner layer. This buffer zone not only improves thermal comfort but also decreases reliance on mechanical cooling, making double-skin façades an effective strategy for energy-efficient, climate-responsive design.

Architecture of Bedford Park (Victorian Cavity Walls)

United Kingdom, 18th century, Collective tradition.

Ktmchi. (2013, October 14). Shoji sliding doors in the Rinshunkaku at Sankei-en (Important Cultural Property), Yokohama, Japan [Photograph]. Wikimedia Commons.

The Bedford Park Estate is often cited as one of the earliest developments in Britain to employ the Victorian cavity wall, a direct precursor to the modern double-skin façade. Instead of relying on traditional solid masonry, its houses were built with two parallel brick leaves separated by an air cavity. This gap reduced moisture penetration and created a thermal buffer, improving comfort in damp and variable climates. While not glazed like contemporary double façades, the system established the principle of a layered building envelope with an intermediate air space, an innovation that foreshadowed the environmental strategies of later modernist architecture.

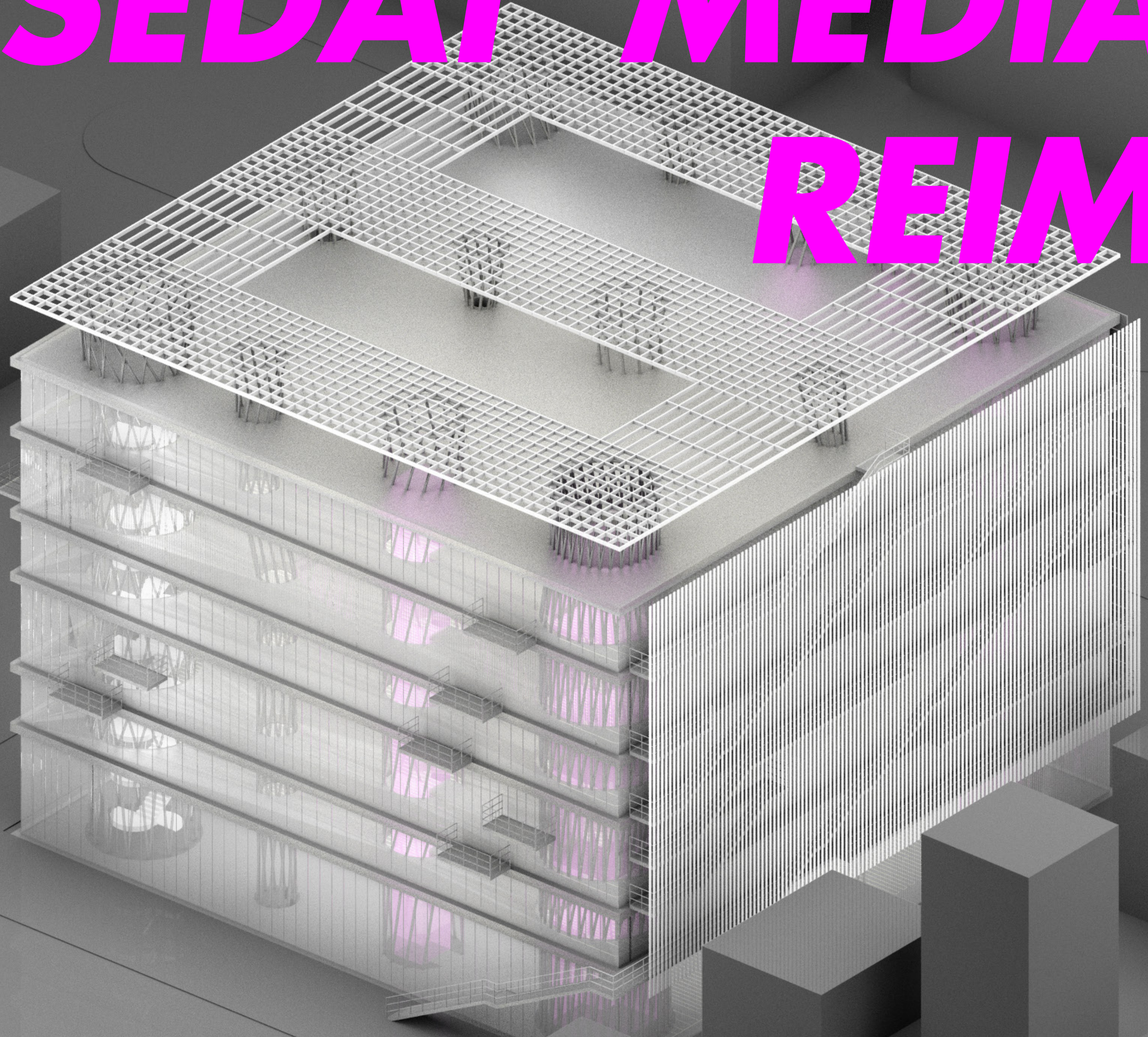
30 St Mary Axe ("the Gherkin")

London, United Kingdom, 2004. Foster + Partners.

Bryant, R. (Photographer). (2003). 30 St Mary Axe "The Gherkin," London, United Kingdom, by Foster + Partners [Photograph]. Foster + Partners.

The Gherkin integrates a contemporary double-skin façade as a passive environmental system. Its exterior envelope consists of an inner layer of glazing and an outer skin separated by a ventilated cavity, within which blinds and shading devices are housed. This cavity moderates solar heat gain, provides insulation, and allows natural air circulation between the two layers. Combined with the building's spiraling atria, the façade supports cross-ventilation and enhances the stack effect, drawing fresh air through the offices while expelling warm air upwards. In this way, the double-skin system not only reduces reliance on mechanical cooling but also becomes integral to the tower's high-performance sustainable design.

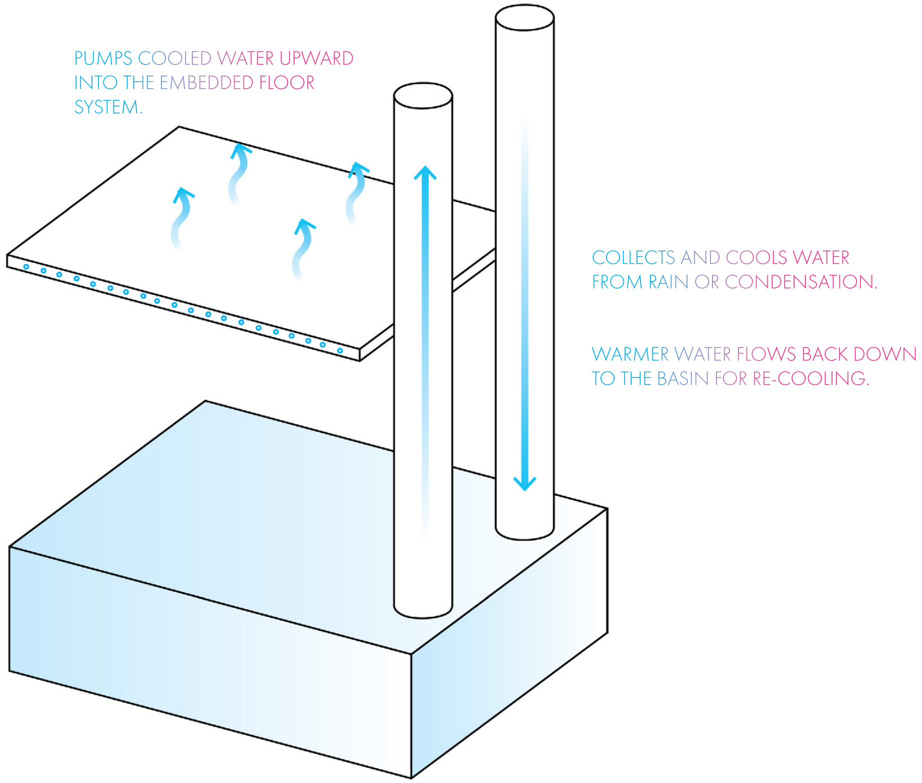
SEDAI MEDIATHEQUE REIMAGINED



This reinterpretation of Toyo Ito's Sendai Mediatheque transforms the building's transparent structure into an integrated environmental network. Instead of treating air and water as invisible utilities, the design makes them performative and spatial. A series of vertical towers collect rainwater and channel it into a radiant cooling system embedded within concrete slabs, where water circulates through concealed tubes to absorb heat and moderate interior temperature. These towers also operate as air stacks, connecting to curved plenums that guide airflow through each floor. As warm air rises, cooler air drawn from shaded lower areas replaces it, generating a continuous convective loop that reduces mechanical dependence.

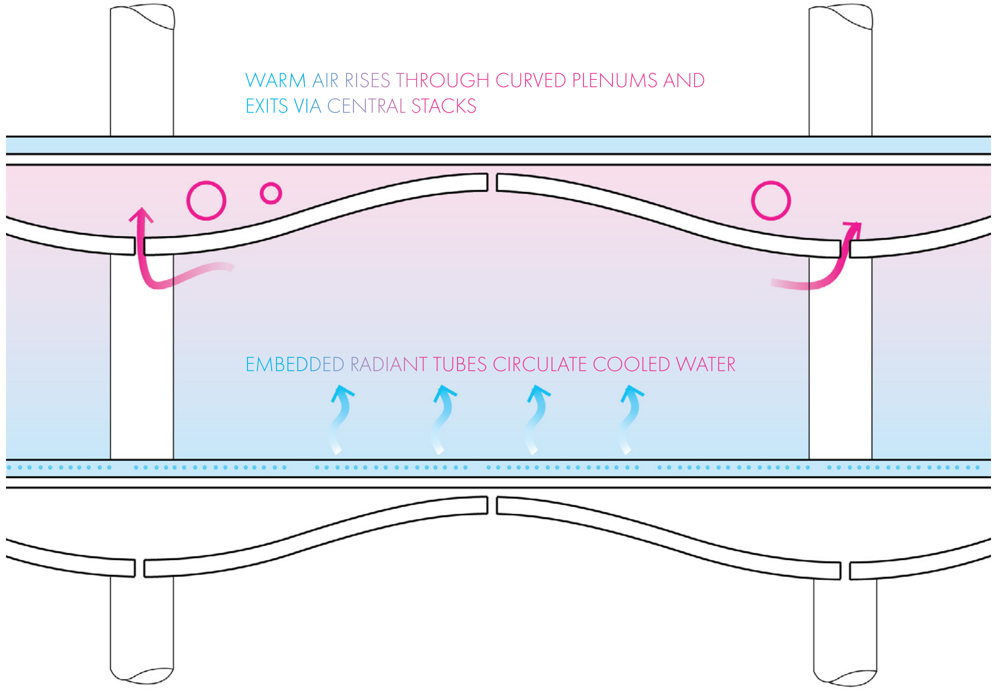
The architecture thus evolves from a purely visual framework into a climatic machine—where transparency is redefined not only by light but by the movement of air and water. By integrating environmental systems into the building's structure, the reimagined Mediatheque becomes both an infrastructural organism and an experiential atmosphere.

WATER
RADIANT COOLING NETWORK

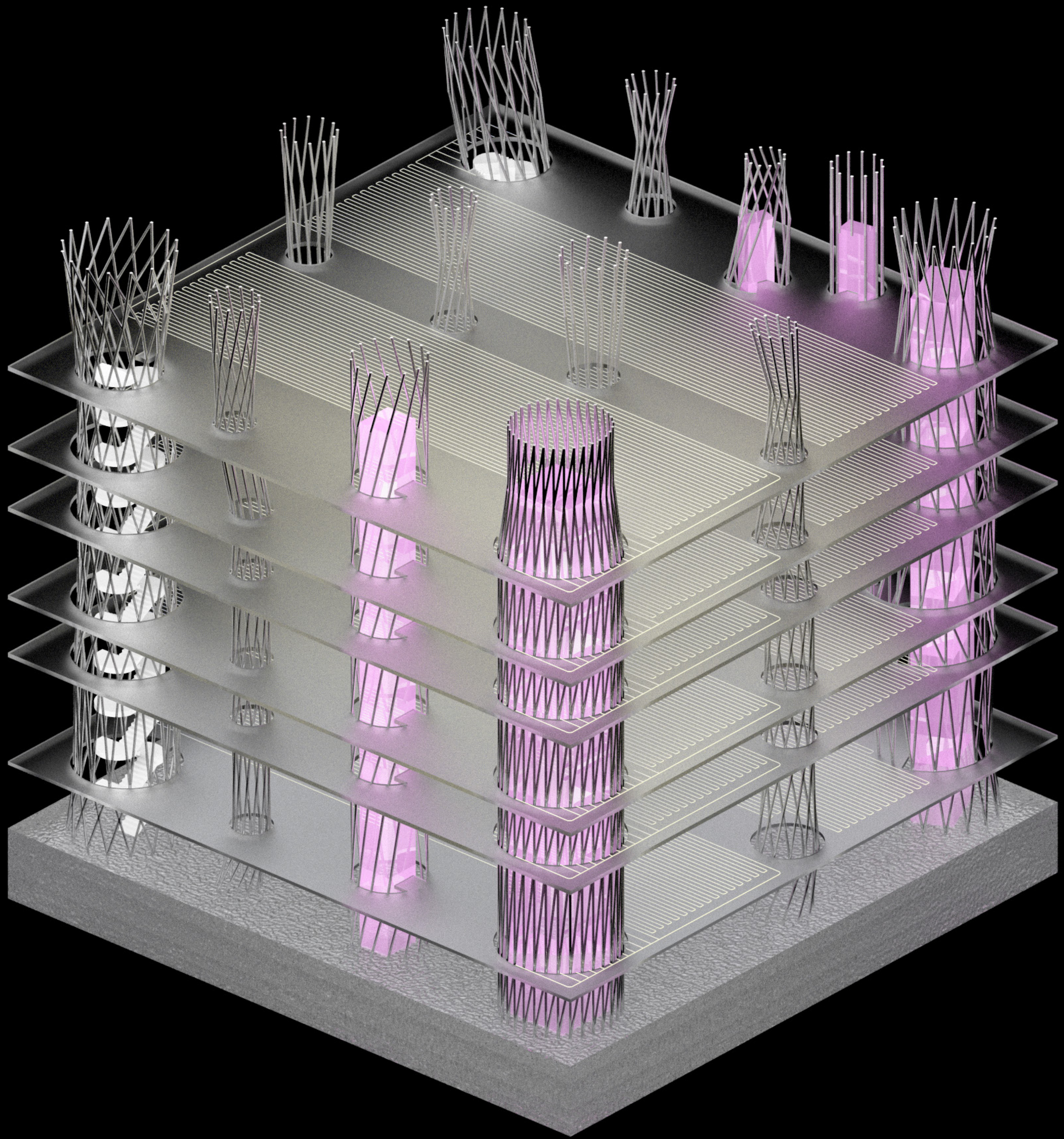


The radiant cooling network operates through a closed-loop system that circulates cool water within the concrete slabs. As water moves through embedded tubes, it absorbs heat from the interior environment and returns to the basin for re-cooling. This process stabilizes indoor temperature by reducing radiant heat and maintaining comfort without relying on mechanical air conditioning. The continuous flow of water through supply and return channels transforms the structure into a thermally active surface — one that cools quietly and efficiently, integrating environmental performance directly into the building's material system.

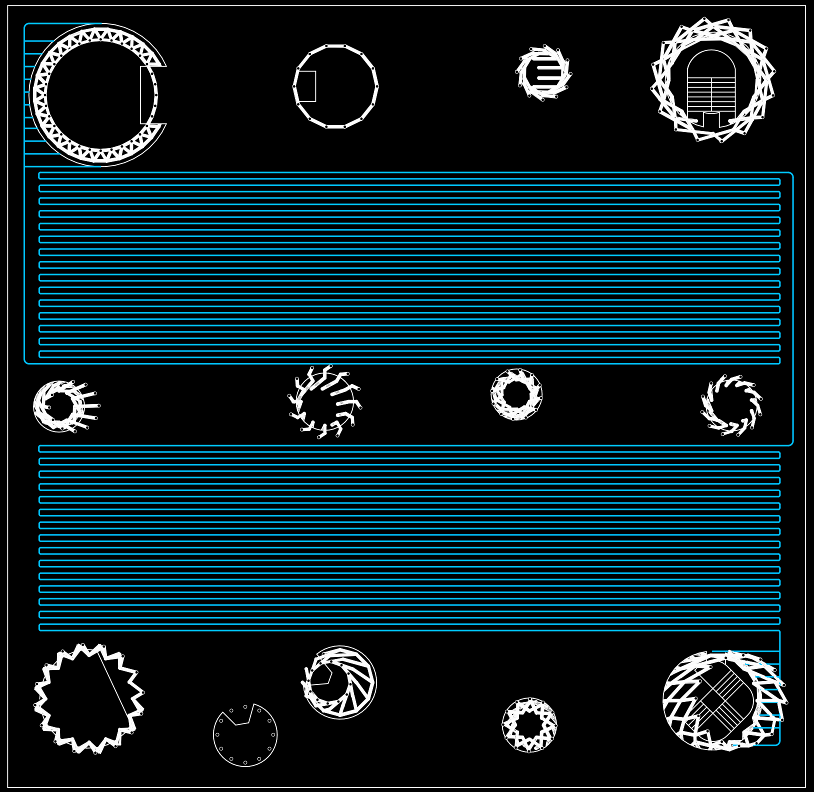
AIR
VERTICAL STACKS CONNECTING PLENUM SYSTEM



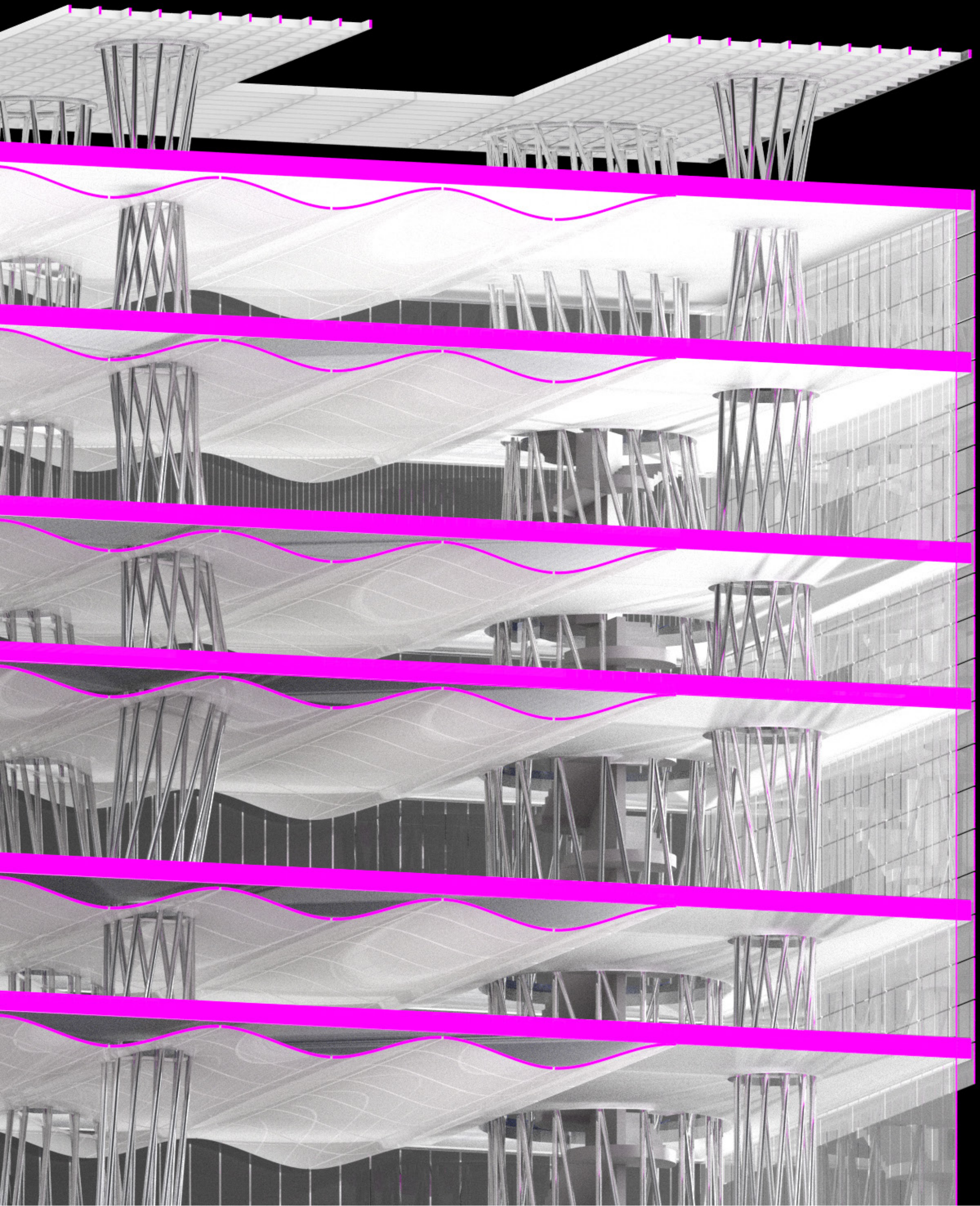
Curved plenums align through each floor, connecting to vertical stacks that activate the natural stack effect. Warm air rises through the curved ceiling channels and exits via the towers, while cooler air from shaded zones and water-cooled slabs is drawn upward to replace it. This continuous convective loop balances temperature and air pressure across the building, reducing dependence on mechanical systems. The plenum's curvature guides airflow smoothly, enhancing circulation and stratification. Working together with the radiant cooling network, the system transforms the structure into a responsive thermal organism that breathes and moderates its own environment.



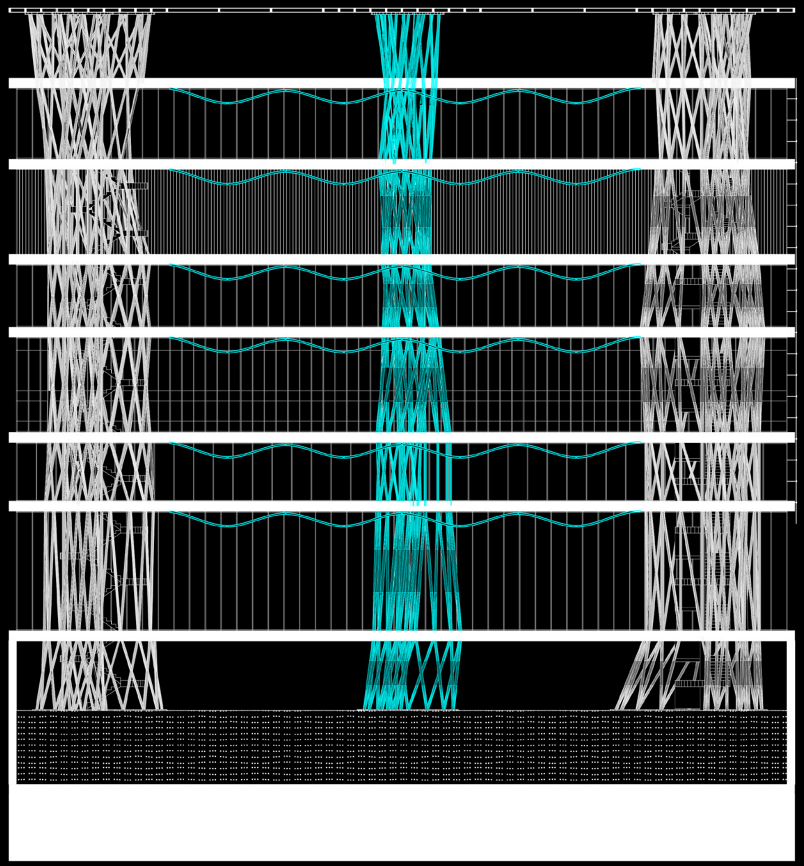
WATER
RADIANT COOLING NETWORK



This system integrates water circulation directly into the building's structure, using embedded tubes within concrete slabs to absorb and dissipate heat. Rainwater collected from rooftop funnels is stored and recirculated through these radiant networks, allowing surfaces to act as thermal regulators. As water flows, it draws excess heat away from occupied spaces and releases it through vertical cooling shafts, creating a passive system that stabilizes indoor temperature and reduces the need for mechanical cooling.

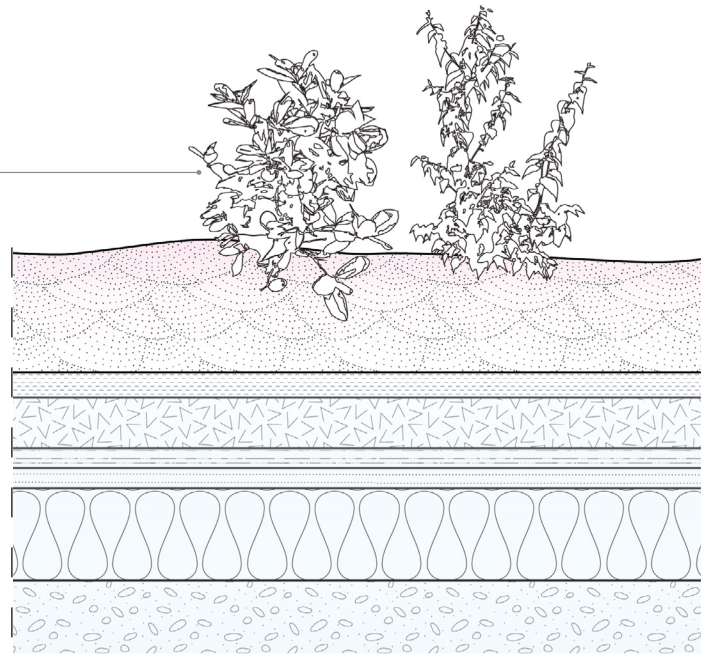


AIR
STACK EFFECT



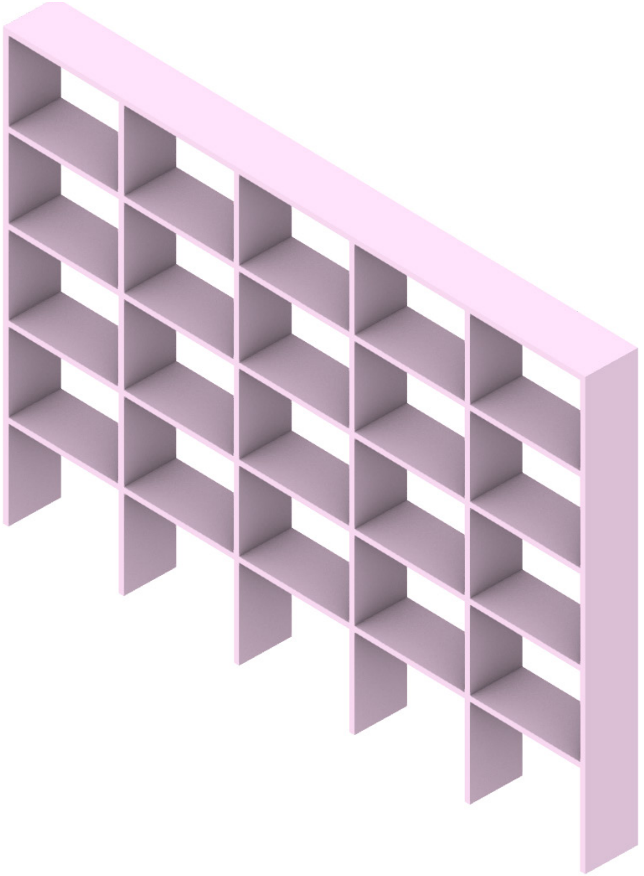
Curved plenums align vertically through the building and connect to the central stacks. Warm air rises along these plenum curves and is drawn upward through the stack, while cooler air from shaded lower levels replaces it. This continuous convection loop enhances natural ventilation, stabilizes indoor temperature, and reduces reliance on mechanical cooling.

This cube system integrates design devices corresponding to the four elements as adaptable strategies that can be applied to almost any building typology. For the Earth element, a sod roof utilizes its natural thermal mass to stabilize indoor temperatures across seasons, while its vegetation layer sequesters carbon and enhances biodiversity, improving the building's overall environmental footprint. The Air element is expressed through a double-skin façade composed of operable double-paned glazing; the air cavity between panes provides insulation, while controlled openings enable cross-ventilation and natural airflow throughout the interior. Under the Fire element, a free-standing brise-soleil is positioned along the south-facing façade, filtering intense solar radiation while preserving daylight and outward views. Finally, the Water element is activated through a closed hydronic loop connected to a nearby water source, using a heat exchanger to circulate cooled or warmed water through radiant slabs, thus maintaining comfortable temperatures year-round. Together, these systems demonstrate how architecture can harmonize with natural forces, transforming elemental phenomena into integrated environmental design.

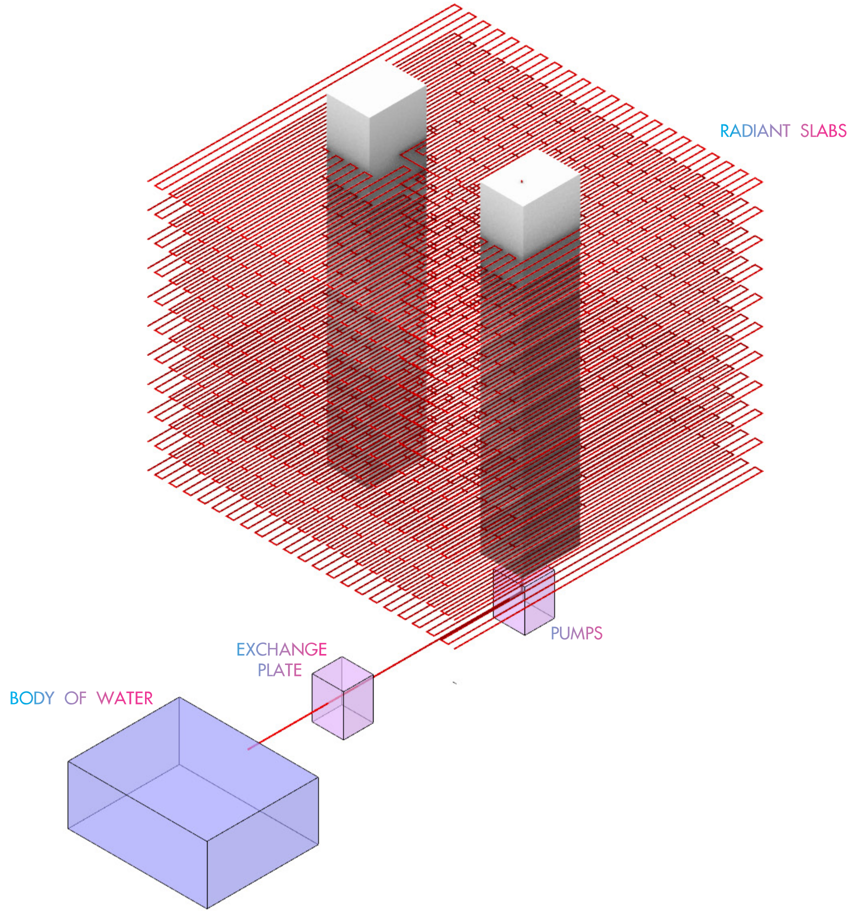


SOD ROOF — ONE EXAMPLE OF LAYERED ASSEMBLY

Rooted in Scandinavian and North Atlantic vernacular traditions, sod roofs combine the thermal mass of soil with the evaporative cooling of vegetation, forming a layered system as insulation. The thick substrate absorbs heat during the day and releases it gradually at night, moderating indoor temperatures and reducing mechanical cooling demand. Meanwhile, native or adaptive plant species promote evapotranspiration, which further cools the air above the roof and improves local microclimates. In addition to its climatic benefits, a sod roof supports biodiversity, filters rainwater, and sequesters carbon, turning an architectural surface into an active ecological device.



Inspired by Le Corbusier's Casa Curutchet in La Plata, the use of an independent brise-soleil system positioned before the sun-exposed façade, typically south-facing in the Northern Hemisphere, offers a highly adaptable solar control strategy. This secondary architectural skin filters sunlight, blocking direct solar radiation while admitting diffused, softer light into interior spaces. The system reduces glare, mitigates overheating, and preserves outward views, all while maintaining visual permeability. By standing slightly detached from the building envelope, the brise-soleil creates a ventilated buffer zone that prevents heat buildup on the façade, much like a double-skin cavity but expressed as a sculptural, tectonic layer.



When a building is sited near a body of water, it can harness that proximity through a hydronic cooling loop, an energy-efficient system that transfers heat from the building into the cooler water source. In this setup, river water is drawn through screened intake pipes to a plate heat exchanger in the building's basement. There, heat is transferred to the river water from a closed internal loop of treated water that circulates throughout the building via vertical shafts or cores to feed fan-coil units or radiant slabs. As the treated water absorbs indoor heat, it returns to the exchanger to be cooled again, establishing a continuous cycle of thermal exchange. While this constitutes a mechanical cooling system, it dramatically reduces the energy intensity of conventional chillers by relying on the natural thermal stability of the water body.