Urban Solarium

Thermal Performance in Boston

by Juliet Chia-Wen Hsu

Bachelor of Arts, in Architecture
University of California – Berkeley, 2002

Submitted to the Department of Architecture, February 2012
in partial fulfillment of the requirements for the degree of
Master of Architecture at the Massachusetts Institute Of Technology

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Abstract

This thesis addresses the issue of energy efficiency through the lens of thermal performance in the context of urban housing in the city of Boston. Located in the historic brick row house neighborhood of the South End, the project utilizes brick for its inherent property of high heat capacity – a material's ability to store radiant energy and release it later due to the temperature difference between day and night – as a thermal battery for heating and cooling domestic spaces.

In Boston where the temperature frequently goes below freezing in winter time, this thesis challenges existing housing typologies by incorporating thermal mass as a passive solar strategy at the scale of an entire structure. The urban solarium produces an interstitial zone in housing that promotes a new lifestyle by bringing together thermal performance and urban farming.

Thesis Supervisor: Joel Lamere
Title: Lecturer, Architectural Design

Acknowledgements

To my advisory committee: Thank you Joel, for your comments, suggestions, and guidance throughout this entire process. To John, for your invaluable insight and advice. To Yung Ho, for making time and your words of wisdom.

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To my classmates and friends at MIT: for the laughs, coffee runs, and late night camaraderie, and most of all for being a part of this roller coaster ride.

To Jack, thank you for being my rock and for motivating me to go to MIT. I would not have been able to finish without your unconditional support and encouragement.

To my family and friends, for your love and support during this incredible journey!

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INTRODUCTION

House : Experimentation

The single-family housing typology had long been a codified space with specific sets of rules and regulations. As family structures and lifestyles evolved, resulting in programmatic changes; the house nevertheless has remained a laboratory for experimentation of emerging disciplinary developments. To operate in the realm of domestic architecture, one must understand the house not only as an intimate landscape, but also as an artifact of culture with larger ramifications. The instrumentality of the house therefore lies in its easy relation to the general public beyond the discourse of architecture.

Historical precedents of collective experimentations in the single-family housing typology ranges from Weissenhof siedlung in Stuttgart, Germany in 1920's to the Case Study Houses in Los Angeles, California of the postwar era. As communities of houses, both movements proved to be didactic. In the former, Mies van der Rohe, Le Corbusier, Walter Gropius and others combined "mixed-income residences to advocate modernism's social potential during a time of housing shortages" and in the latter, Richard Neutra, Charles and Ray Eames, Eero Saarinen, and others "constructed daring examples of affordable modern homes for a country immersed in a building boom". What then, is the proper expression of housing experimentation for today?

House : Nature

From John Ruskin's notion of habitation in the landscape to Le Corbusier's Five Points of Architecture, the relationship between the house and its surrounding environment had shifted. Modernism's quest for transparency lead to an increased exchanged between the inhabitant and its habitat in terms of accessibility as well as visibility. In Los Angeles, California, the production of the Case Study Houses and the collective incorporation of the open floor plan, a sequence of continuous volumes that culminates in a variety of indoor and outdoor spaces. In contemporary practices of architecture, a similar desire to connect to the landscape remains, more so than ever it is revealed in the area of the envelope. Not only are traditional materials appropriated, new materials explored, a crop of hybrid materials are also currently available for architects to deploy.

House : Envelope

Recent developments in the realm of surface and envelope research often manifests in one of two scales – standalone installations or full-scale implementation at the size of a stadium, shopping mall, and a variety of large-scale civic buildings that "do not require any relationship between inside and outside." These objects, consumed in the format of books and magazine photo or on websites, are often considered to be beyond the reach of the general public. Therefore, projections of the latest technological advancements in the realm domestic architecture is eminent in order to reach a broader demographic.

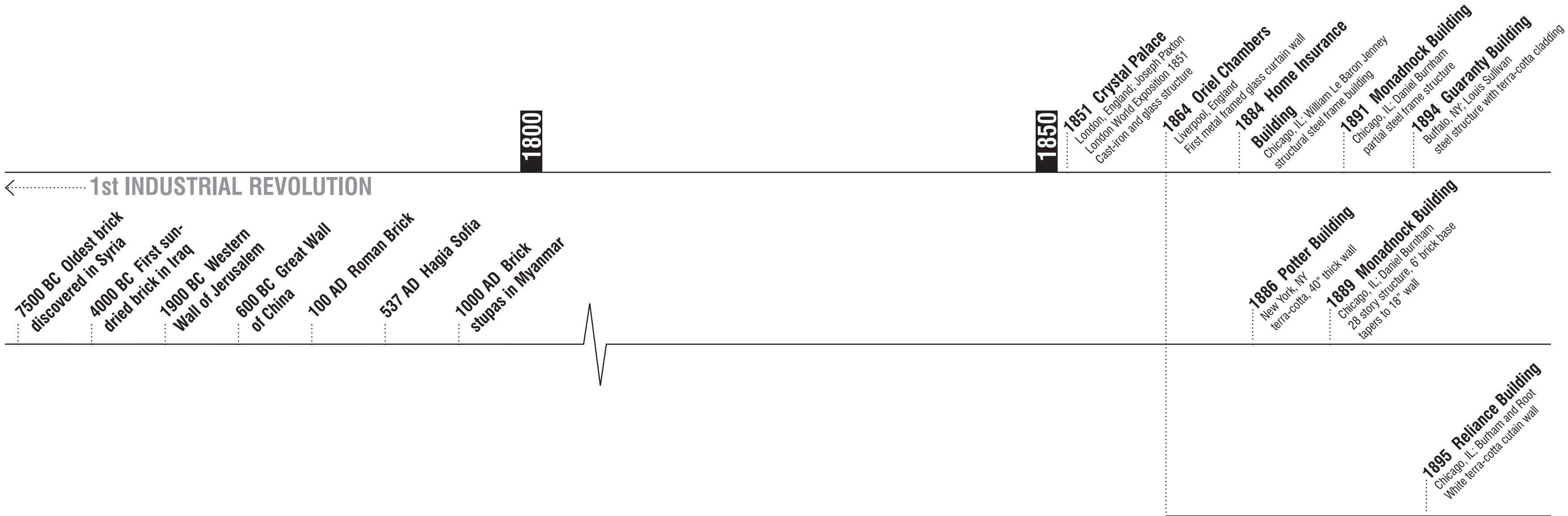
To situate the discussion of the house as an envelope, one can begin the discourse from the thick to the thin, from poché space in Roman architecture to Gottfried Semper's theory of original enclosure, as textile or woven mat between poles. Furthermore, the tension between ornament and function will find relevance in both Adolf Loos' argument of Ornament and Crime as well as Venturi Scott Brown's theory of the decorated shed . According to K. Michael Hays, "the experience of the [new] architectural envelope is no longer distinctive but is now part of an aesthetic experience that is diffused through and saturates every part of our lives." While technology have afforded us digital tools to aid in both the design (software) and the fabrication (hardware) of new envelopes, these digital tools have yet to permeate the canonical means and methods of standard residential construction.

House : Materiality

Furthermore, the current state of discourse on material and envelope has remained at the level of producing architectural phenomenon through the manipulation of opacity, translucency, and textures. The shifted focus from "static material properties to dynamic material behaviors" at the level of academic research has captured the attention and sparked interest in the discipline of architecture. The changing nature of material through the fourth dimension of time demands a radical transformation that will require a new architectural paradigm. Concerns of sustainability and issues of ecology are often brought into question when evaluating new materials and new methods of production and application. The embodied energy of material production is just as important as the effects that it produces.

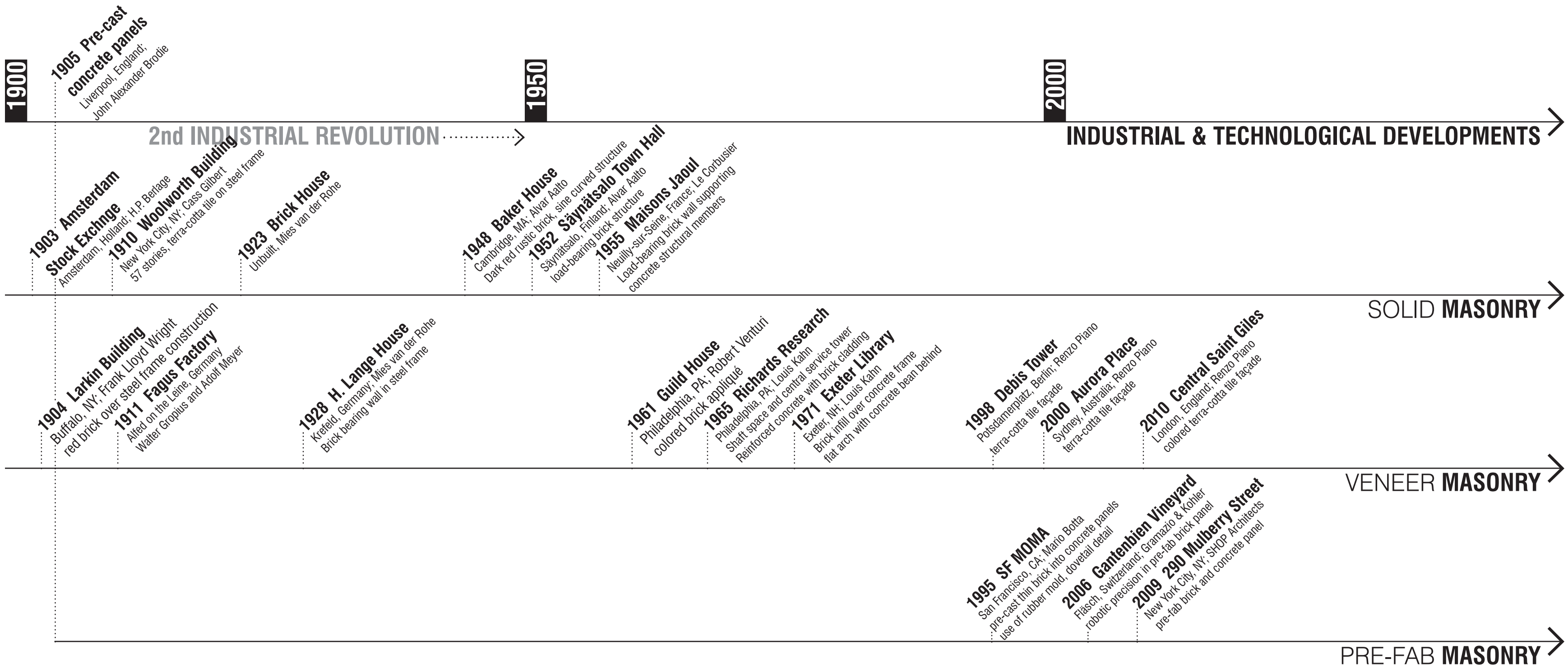
Passive strategies that engage the local climate, mediation of air and lighting condition, as well as seasonal changes typically have been incorporated into standard architectural practices today. However, work remains in the architectural invention and application of active strategies such as local electric generation, responsive materials, and embedded intelligence in interactive systems. This new crop of performance driven materials and its application will be the subject that occupies a new generation of architectural practices.

In conclusion, this thesis intends to catalogue the current state of material practices and address issues of the ever diminishing wall thickness. The house is at once an experiment, a place for nature, an expression of tectonics (envelope), that which is measured through its engagement of materiality. Energy production, material efficiency and efficacy can be addressed simultaneously through alternative modes of material application.


1800
1850
1st INDUSTRIAL REVOLUTION
7500 BC Oldest brick discovered in Syria
4000 BC First sun-dried brick in Iraq
1900 BC Western Wall of Jerusalem
600 BC Great Wall of China
100 AD Roman Brick
537 AD Hagia Sofia
1000 AD Brick stupas in Myanmar
1851 Crystal Palace
London, England; Joseph Paxton
London World Exposition 1851
Cast-iron and glass structure
1864 Oriel Chambers
Liverpool, England
First metal framed glass curtain wall
1884 Home Insurance Building
Chicago, IL; William Le Baron Jenney
structural steel frame building
1891 Monadnock Building
Chicago, IL; Daniel Burnham
partial steel frame structure
1894 Guaranty Building
Buffalo, NY; Louis Sullivan
steel structure with terra-cotta cladding
1886 Potter Building
New York, NY
terra-cotta, 40" thick wall
1889 Monadnock Building
Chicago, IL; Daniel Burnham
28 story structure, 6' brick base
tapers to 18" wall
1895 Reliance Building
Chicago, IL; Burham and Root
White terra-cotta cutain wall

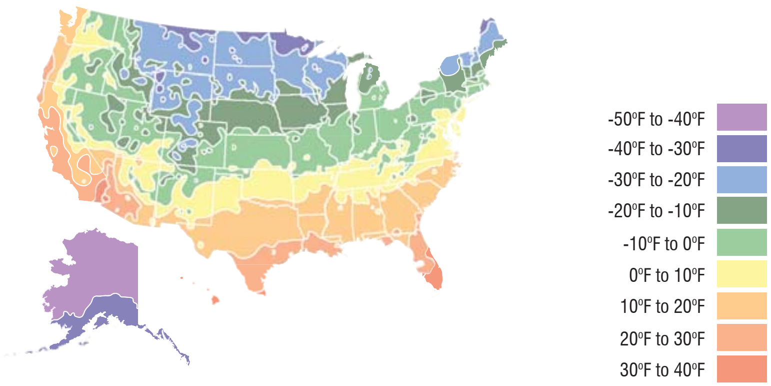

GUILD HOUSE

INDUSTRIAL TIMELINE OF **MASONRY STRUCTURE**

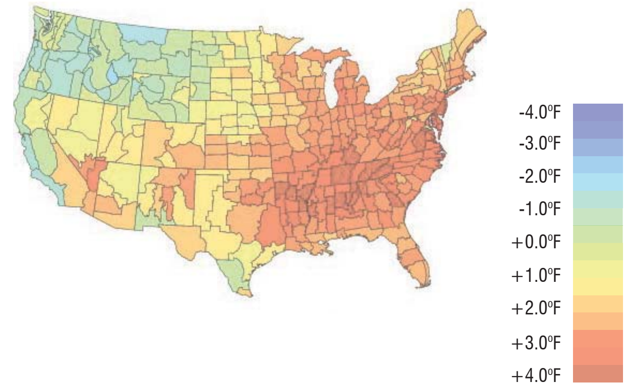


RESEARCH

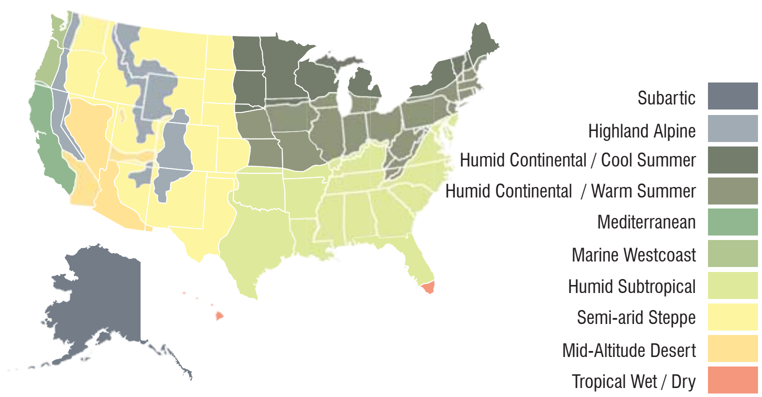
>US Weather Condition



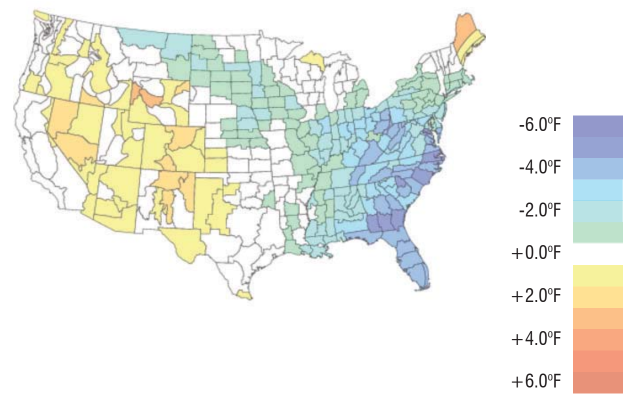
US Temperature Zones
Avg Annual Min Temperatures



US Temperature Anomalies
Summer 2010 (vs 1950 - 1995 avg)

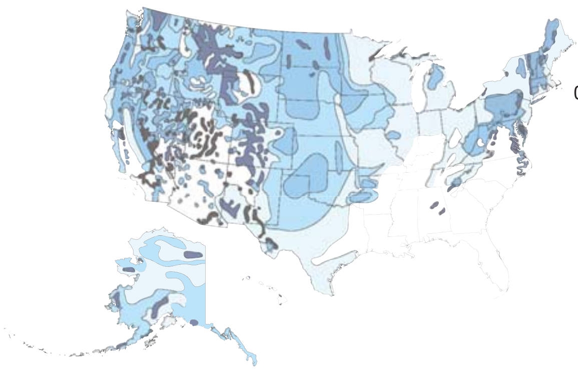


US Climate Zones



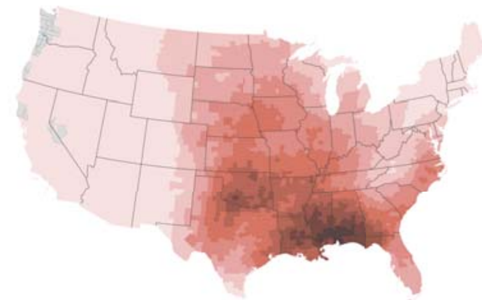
US Temperature Anomalies
Winter 2010 (vs 1971 - 2000 avg)

Source: NOAA / ESRL PSD and CIRES-CDC



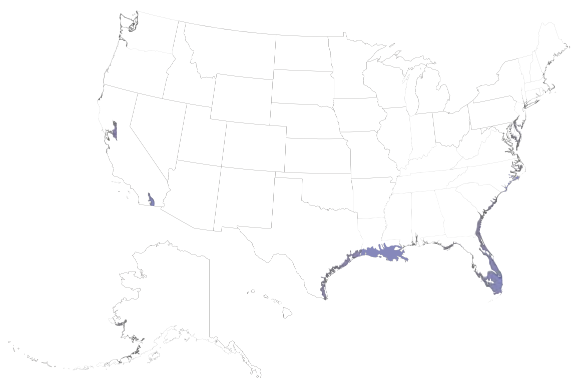
Class	Wm²	m/s	mph
0	0	0	0
1	200	5.6	12.5
2	300	6.4	14.3
3	400	7.0	15.7
4	500	7.5	16.8
5	600	8.0	17.9
6	800	8.8	19.7
7	2000	11.9	26.6

US Wind Map
Wind Power | Energy Resource

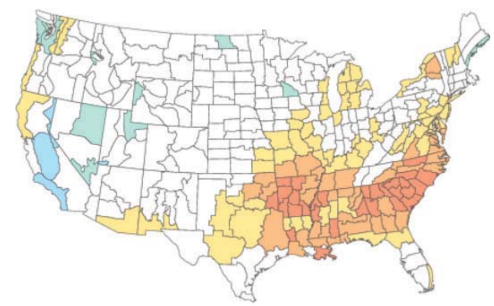


1
3
4
7
9
11
13
15
>15

US Tornado Map
Annual Frequency |1999 - 2008



US Flood Map
2080 Projected Mapping
Sea Level Rise & Storm Surge

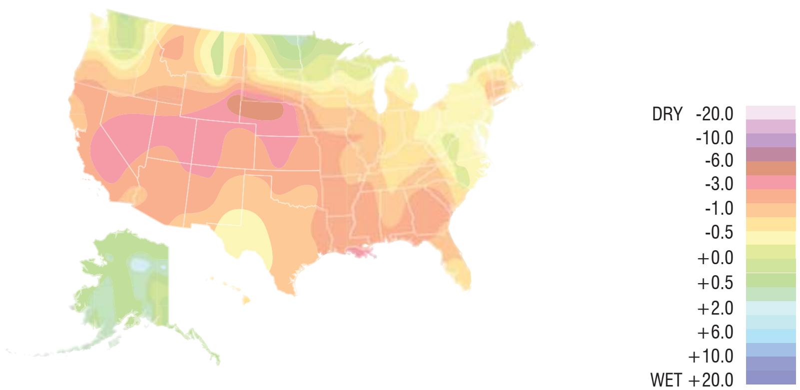


-8.0”
-6.0”
-4.0”
-2.0”
+0.0”
+2.0”
+4.0”
+6.0”
+8.0”

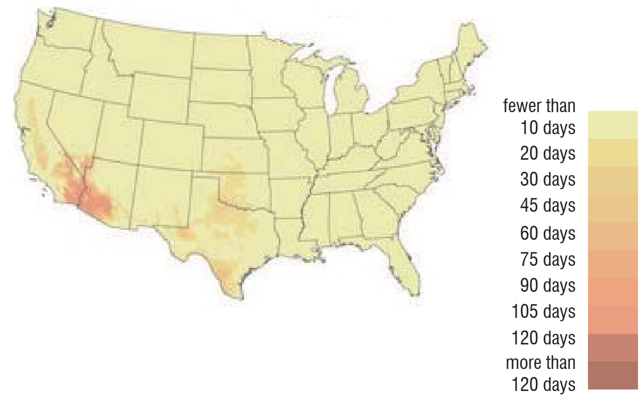
US Percipitation Anomalies
Winter 2010 (vs 1970 - 2000 avg)

Source: NOAA / ESRL PSD and CIRES-CDC

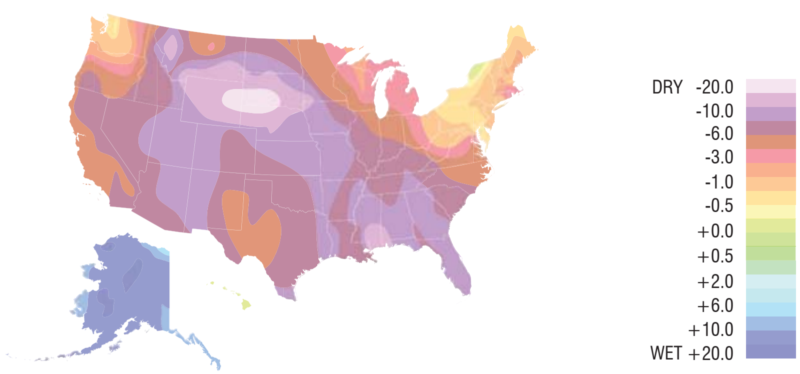
>US Weather Condition



US Drought Zones
2000 - 2009 SC-PDSI

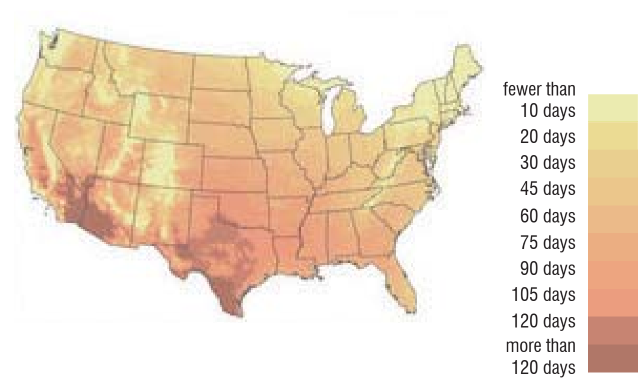


US Heat Wave Zone
Number of Days Exceeding 100ºF



US Drought Zones
2090 - 2099 SC-PDSI
Projected Mapping

Source: Wiley Interdisciplinary Review | onlinelibrary.wiley.com/doi/10.1002/wcc.81/abstract

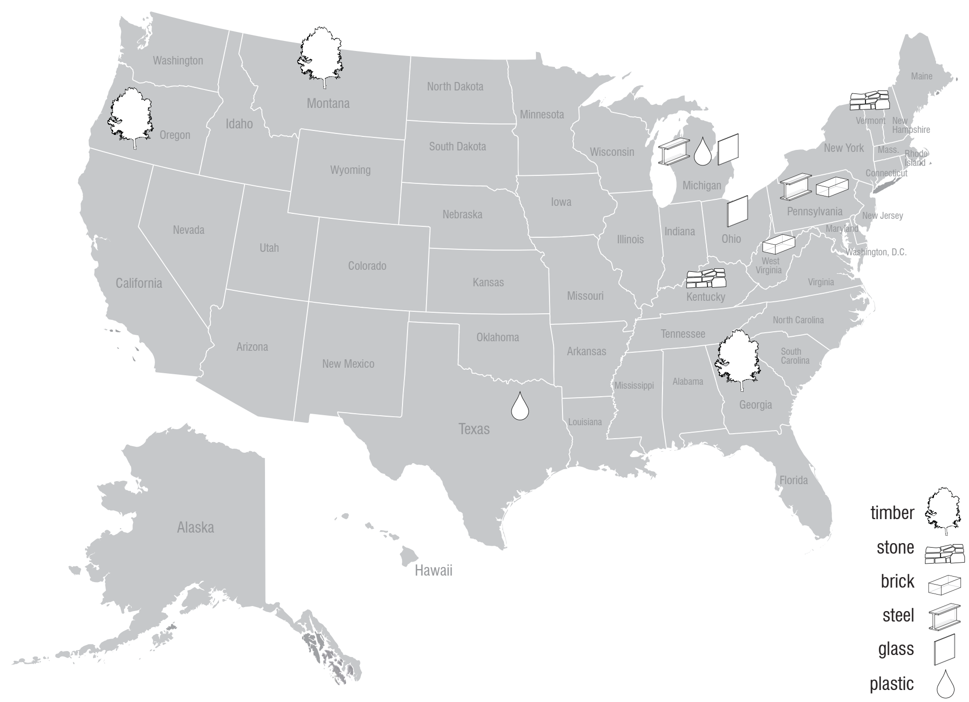


US Heat Wave Zone
Number of Days Exceeding 100ºF
2080 Projected Mapping

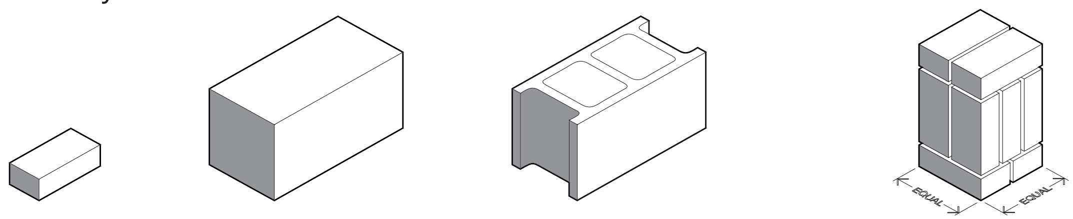
Source: US Global Change Research Program |www.globalchange.gov

>US Industrial Zone

	Boston	Humid Continental / Warm Summer	82°F	65°F	36°F	22°F
Timber	Oregon	Marine Westcoast	80°F	56°F	45°F	34°F
	Montana	High Alpine	83°F	52°F	29°F	**9°F**
	Georgia	Humid Subtropical	88°F	67°F	50°F	29°F
Stone	Kentucky	Humid Subtropical	87°F	62°F	43°F	25°F
	Vermont	Humid Continental / Cool Summer	94°F	70°F	58°F	33°F
Brick	Pennsylvania	Humid Continental / Warm Summer	85°F	62°F	37°F	20°F
	West Virginia	Humid Continental / Warm Summer	83°F	64°F	39°F	22°F
Steel	Michigan	Humid Continental / Warm Summer	83°F	65°F	32°F	21°F
	Pennsylvania					
Glass	Michigan					
	Ohio	Humid Continental / Warm Summer	85°F	63°F	31°F	16°F
Plastic	Texas	Humid Subtropical	**95°F**	74°F	54°F	34°F
	Michigan					

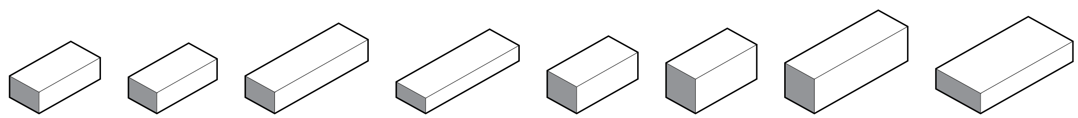


>Masonry Unit

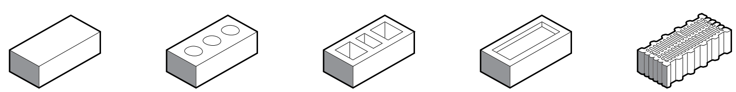


BRICK | STONE | CONCRETE BLOCK

HEADER | ROWLOCK | SAILOR | SOLDIER | STRETCHER | SHINER

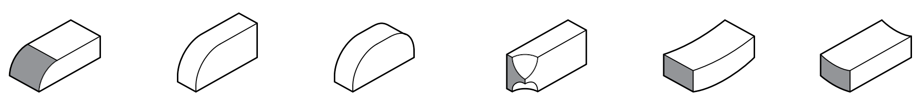


STANDARD | ENGINEER | NORMAN | ROMAN | MODULAR | ECONOMY | UTILITY | SCR

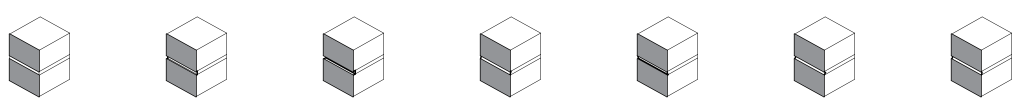


SOLID | CORED | HOLLOW | FROGGED | INSULATED

PLINTH HEADER | PLINTH STRETCHER | PLINTH EXTERNAL RETURN | CANT STOP | DOUBLE CANT | SADDLEBACK COPING

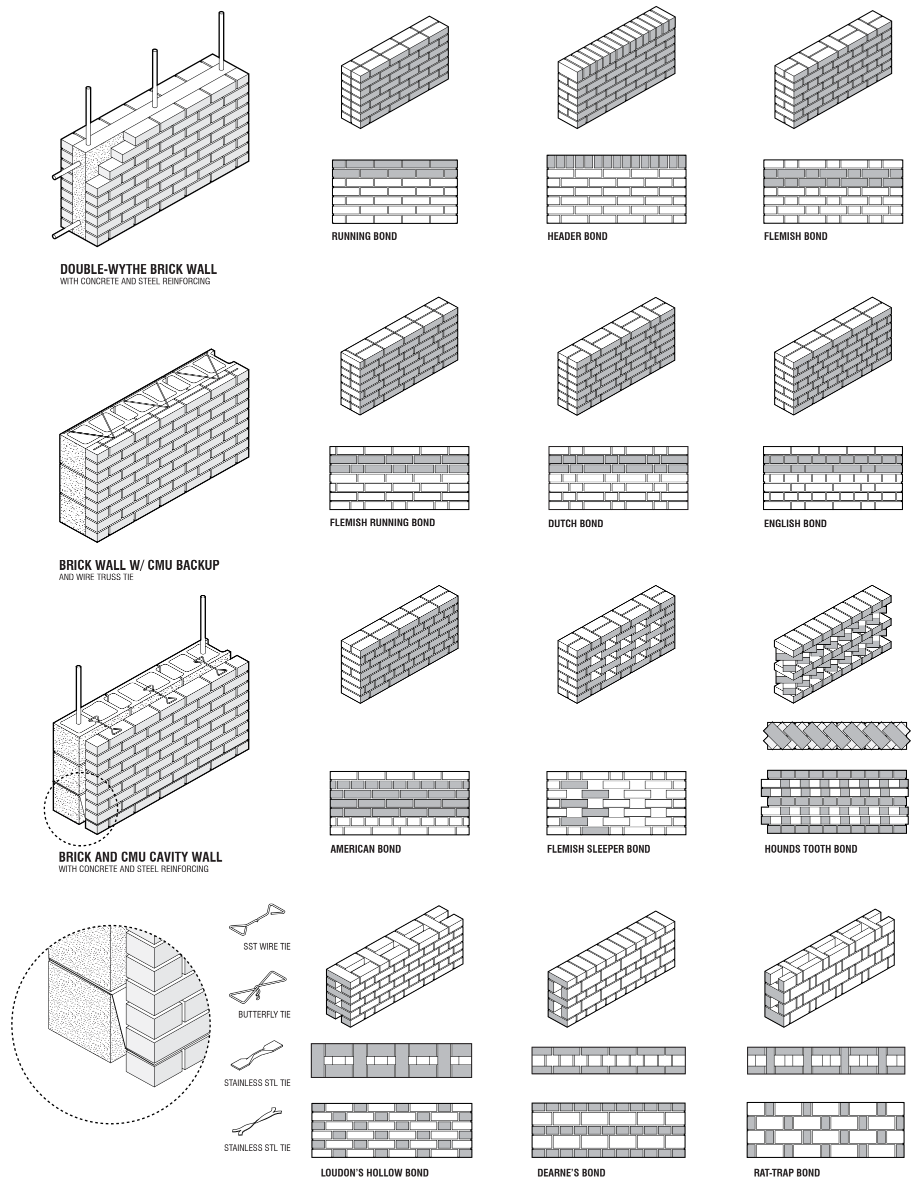


BULLNOSE HEADER | SINGLE BULLNOSE | DOUBLE BULLNOSE | BULLNOSE ON END STOP | RADIAL STRETCHER | RADIAL HEADER

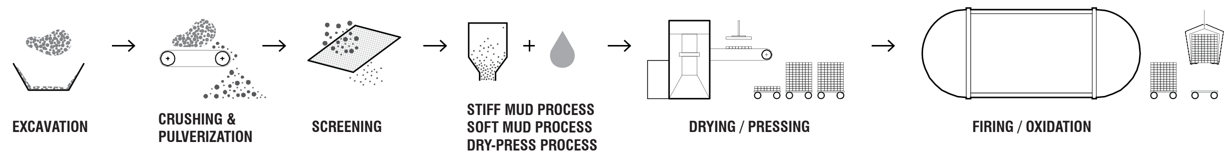


SOLID | CORED | HOLLOW | FROGGED | INSULATED | INSULATED | INSULATED

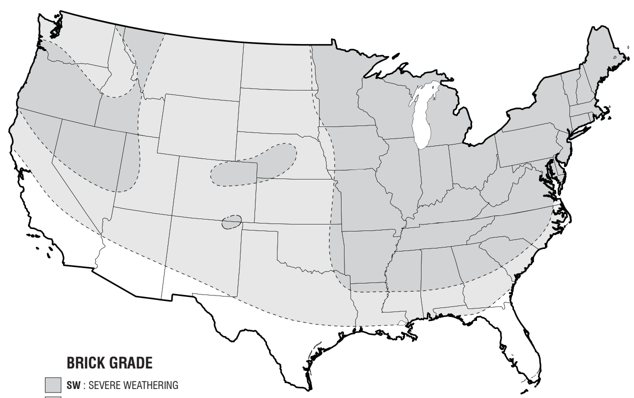
>Masonry Construction



>Brick Manufacturing Process



>US Climate Zones



BRICK GRADE

- **SW** : SEVERE WEATHERING
- **MW** : MODERATE WEATHERING
- **NW** : NEGLIGIBLE WEATHERING

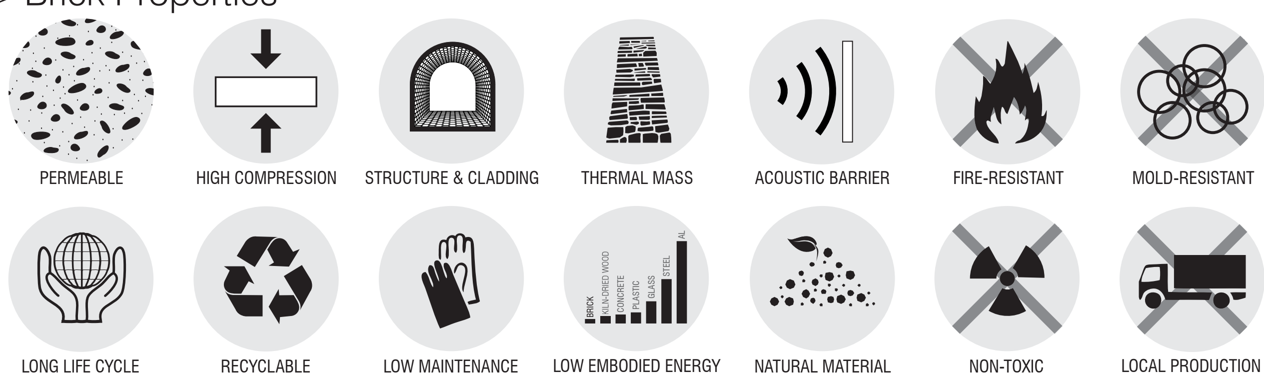
BRICK TYPES

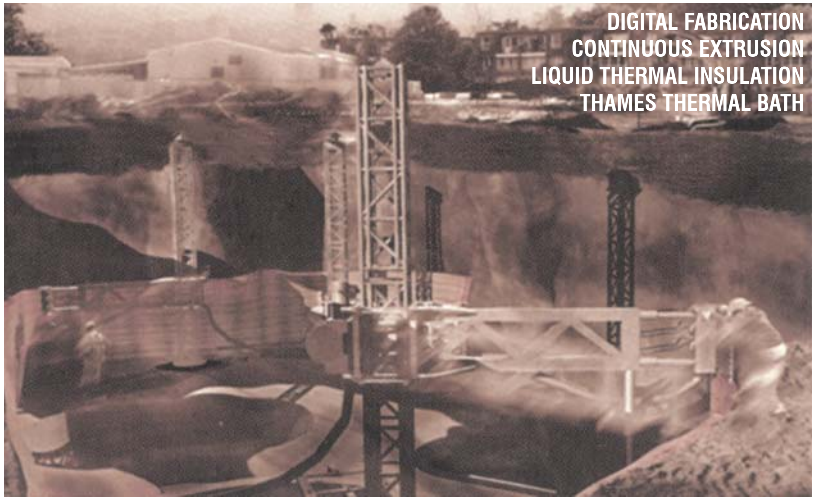
- **FBS** : GENERAL USE EXPOSED EXT & INT (DEFAULT)
- **FBX** : SPECIAL USE EXPOSED EXT & INT, HIGHER DEGREE OF PERFECTION (MIN VARIATION)
- **FBA** : SPECIAL USE EXPOSED EXT & INT, NON-UNIFORM IN SIZE, COLOR, & TEXTURE

>Brickmaking

Images from *Brick: A World History* by James W.P. Cambell

>Brick Properties

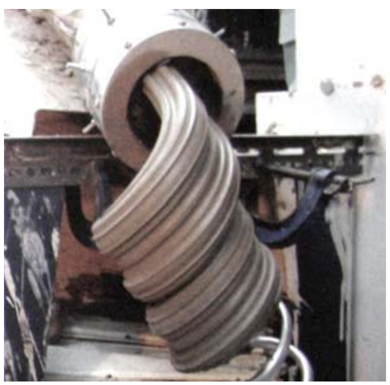


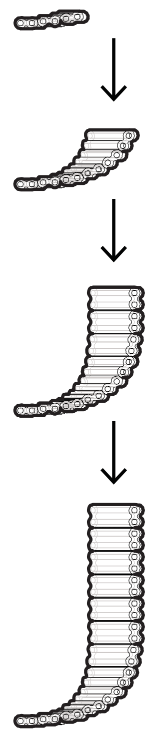


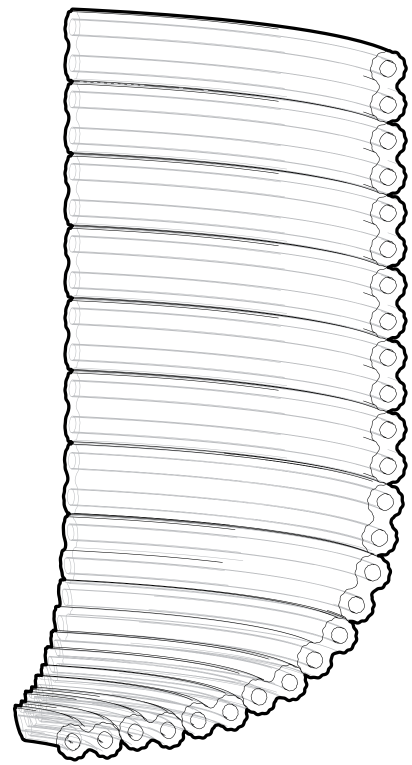
>Precedents

2010
TERRA THERMA
The Bartlett : Peter Webb & Mick Pinner

This project aims to rethink clay and the building components that are made from it. With the aid of digitally controlled tools, it investigates methods to extrude, manipulate and fire clay in the making of a building skin that is termperature and humidity controlled. When fired, clay vitrifies, changing state from clay into ceramic / brick. The result is a material with a hard, porous structure that has a high resistance to weathering. High in compression, it is initially bluish in color and becomes brown when wethered.



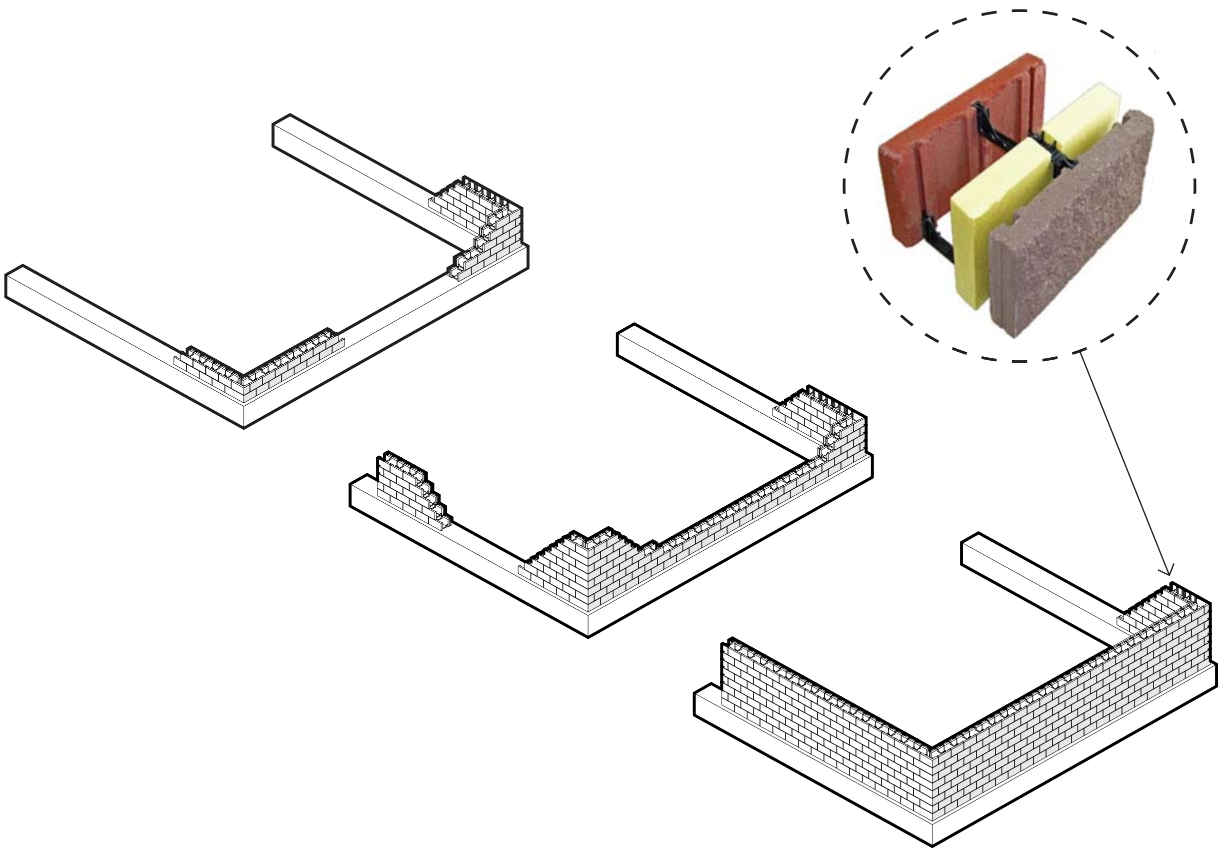




>Precedents

2008
ONE STEP BUILDING SYSTEM
PENTSTAR: JOHN SPAKOUSKY & PAUL SPAKOUSKY

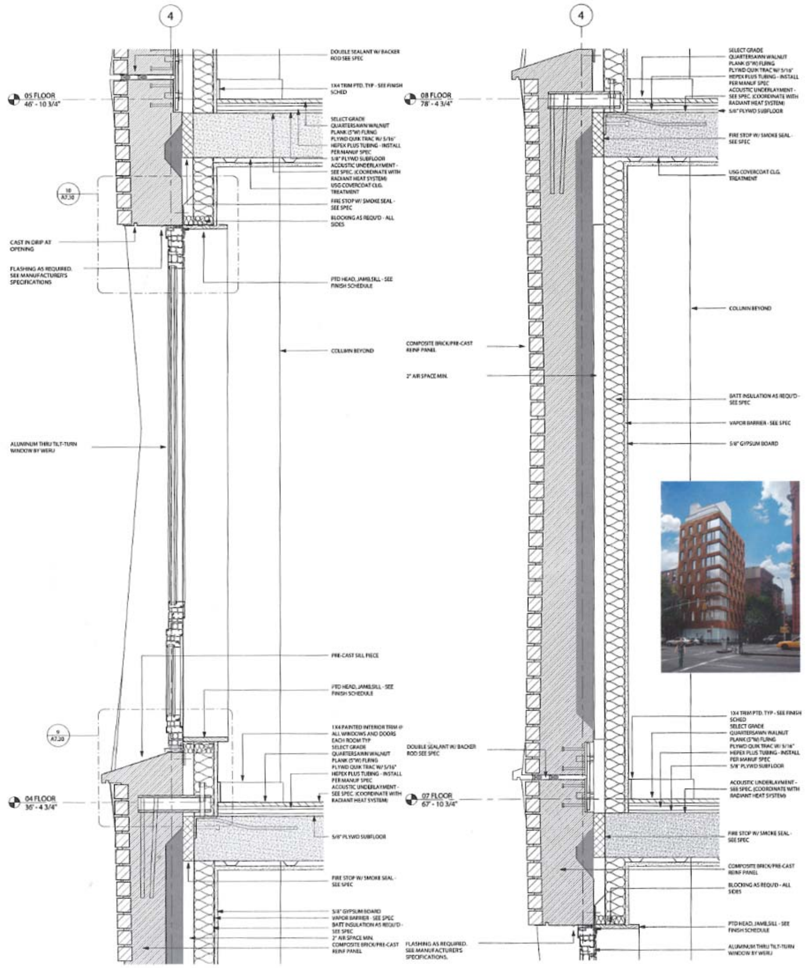
A holistic, high-performance building product that address the entire exterior structure of a wall. The system's concrete form masonry units (CFMUs) allow the shell of a building to be constructed using only one product, one trade organization, and one step in construction sequence. CFMU incorporates high R-value, low conductivity, and dense thermal mass - all of which combine to significantly reduce heating and cooling costs. The CMFU includes a 5 layer moisture-blocking system, preventing water leakage, condensation, and black mold.

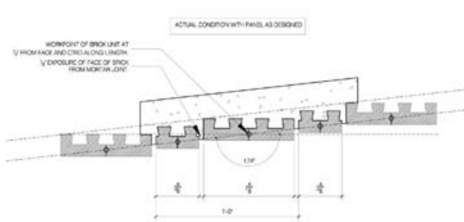


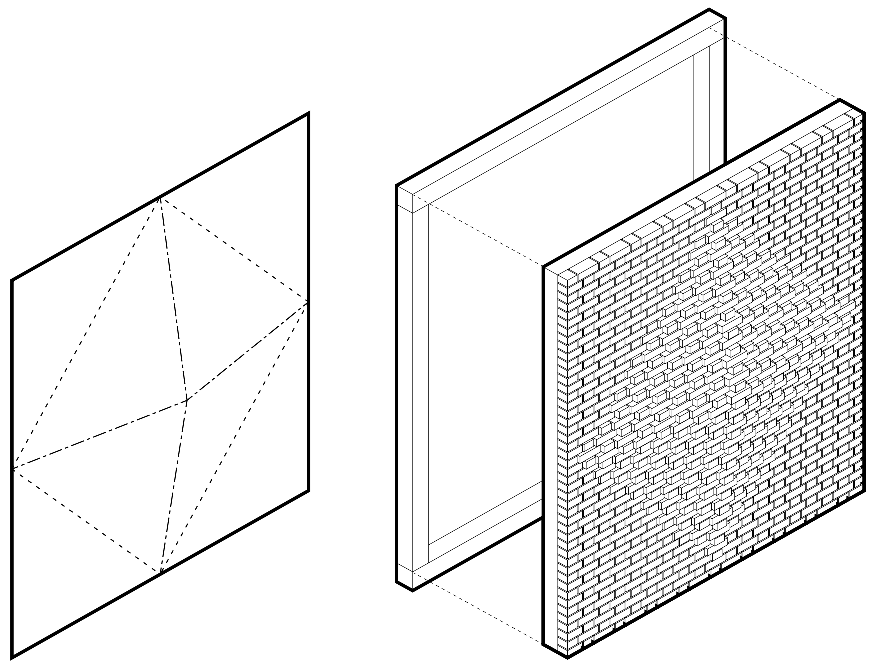
>Precedents

2009
290 MULBERRY STREET
SHOP ARCHITECTS

The project is defined by its context and by reinterpreting the zoning and building code regulations. The masonry enclosure was developed as a contemporary response that does not attempt to imitate the past. Using a corbelling technique, the brick façade projects beyond the property line as allowed by the code for classical ornamentation. Customized precast brick panels were designed to achieve maximum effect at minimum cost. The building is veiled by a textured wrapper in contrast to the simplicity of the interior.



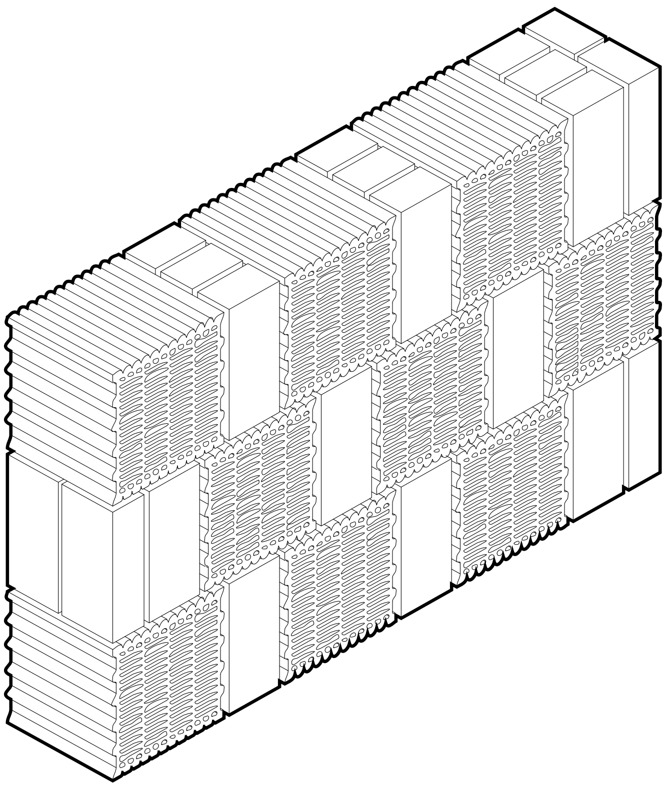


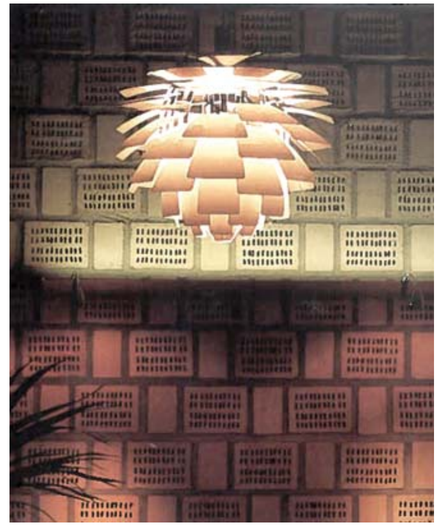


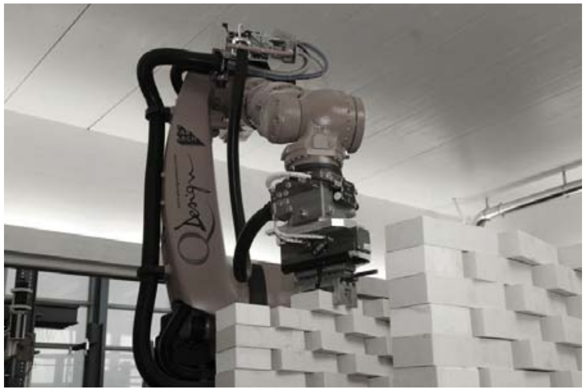
>Precedents

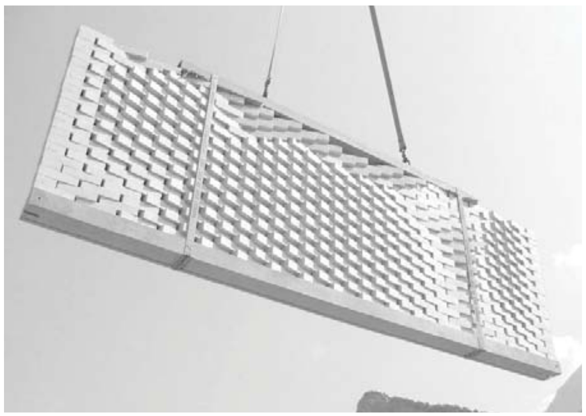
1992
CRYSTALLOGRAPHIC DATA CENTER
ERIC CHRISTIAN SORENSEN

The Crystallographic Data Center holds a database for the identification of organic and inorganic compounds from the results of spectroscopy. The basic requirements of this building were for a quiet working environment for the researchers. In the interior, acoustic bricks laid in Flemish bond provide an interesting texture and pattern while absorbing majority of the noise. Furthermore, carpeted floors and timber acoustic ceilings help to dampen the noise. The exterior shell of the building is clad in Danish brick to provide additional thermal mass.





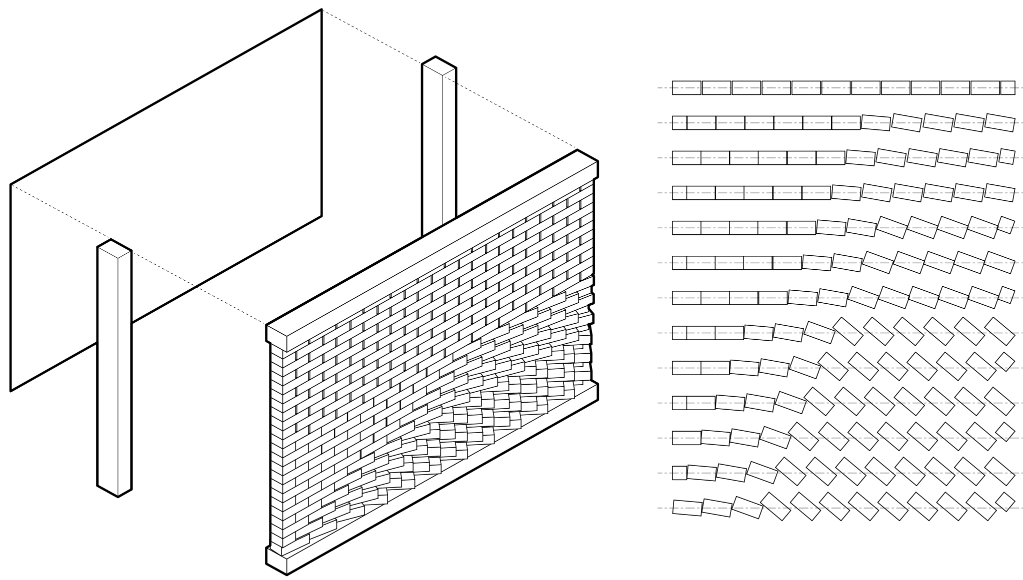




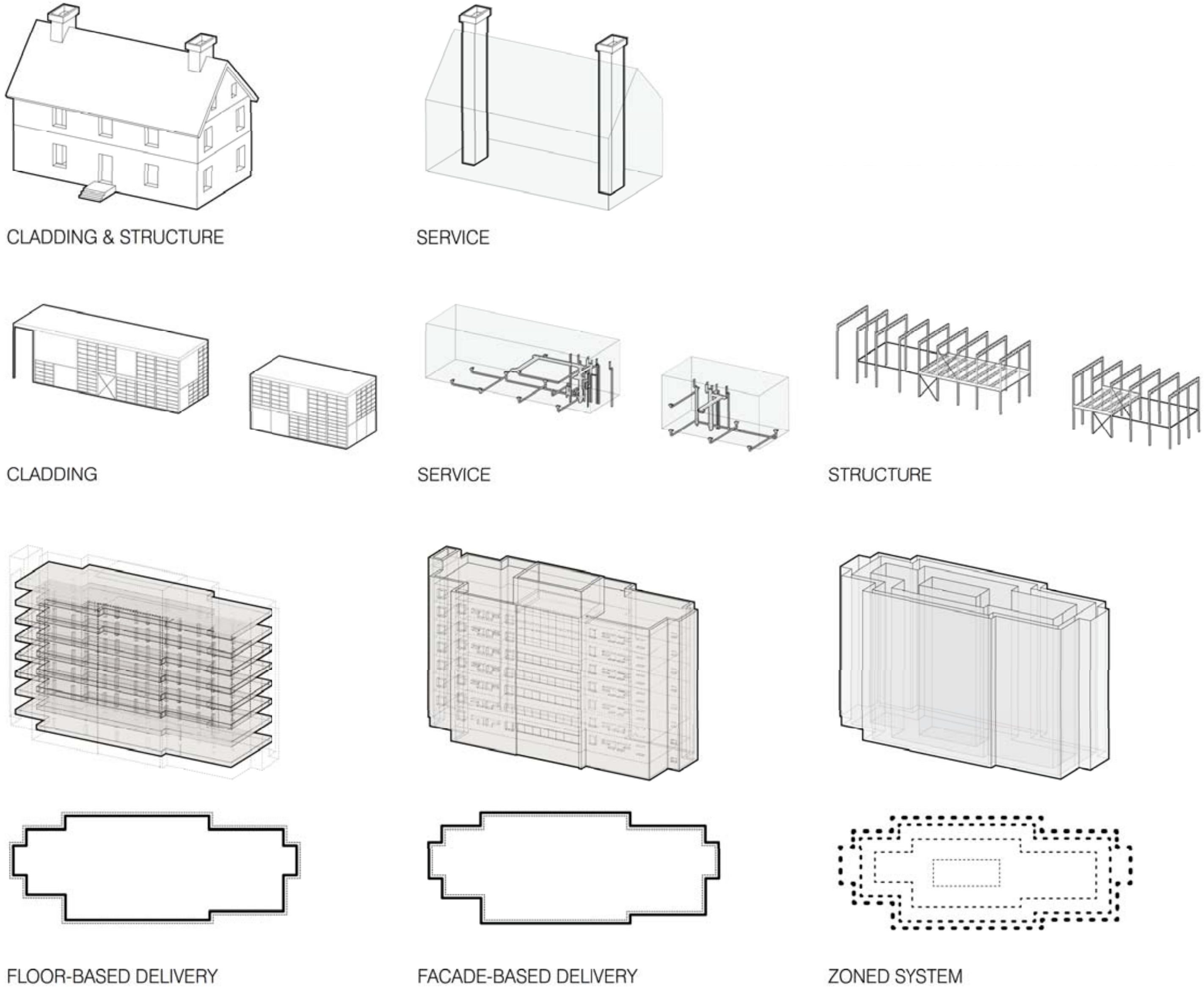
>Precedents

2006
GANTENBIEN VINEYARD FACADE
GRAMAZIO & KOHLER

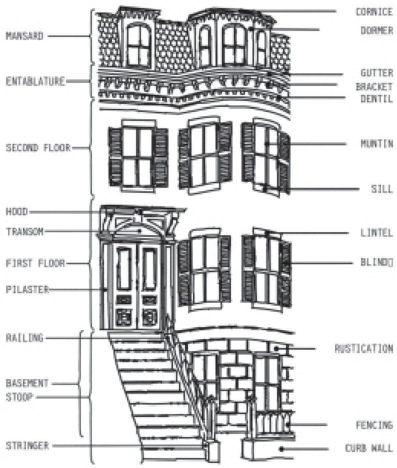
Masonry is used on the facade for its ability to buffer temperature, as well as filtering direct sunlight for the fermentation room. Using a robotic production developed at ETH, each brick is laid precisely according to programmed parameter. An appearance of plasticity is achieved based on the movement of the observer and of the sun over the course of the day. Joints between the bricks were left open to create transparency and allow daylight to penetrate the hall and into the building. Polycarbonate panels are installed on the inside.



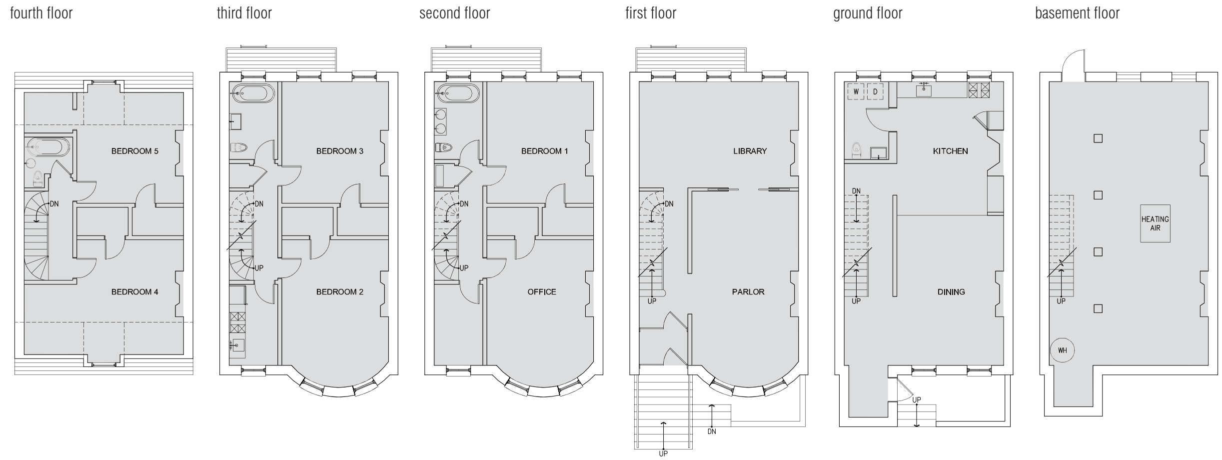
>Building Classification



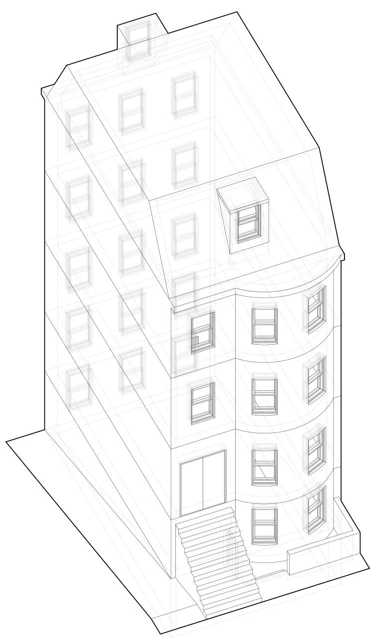
>South End Row House

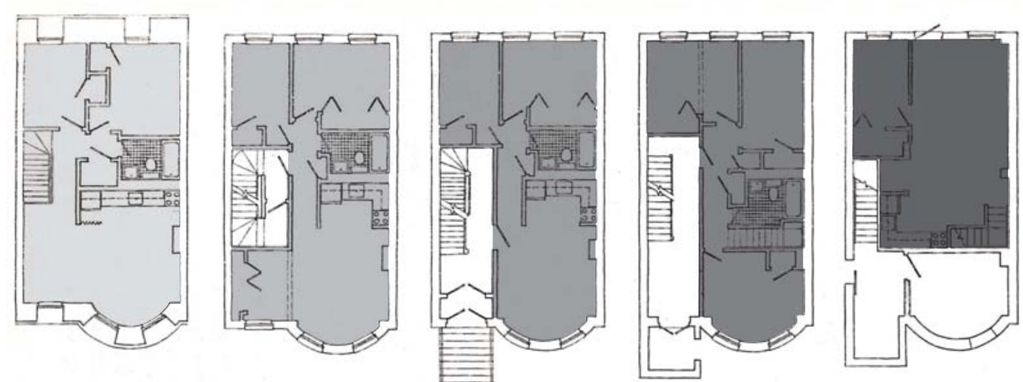


bow front row house



1800s historic plan
single family residence





boston housing authority
multi-family rehabilitation

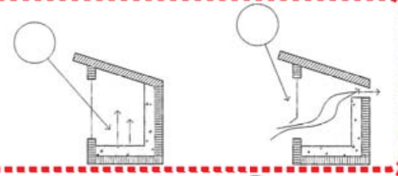
>Passive Solar

organization of architectural building elements based on thermal principles

HEATING **COOLING**

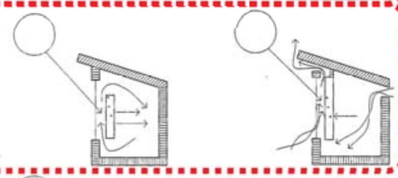
direct gain / loss
winter : south glazing for solar radiation to space beyond
summer : natural or induced ventilation to cool space

DIRECT SYSTEM



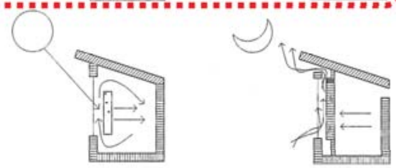
thermal storage wall
energy to wall via conduction, wall to space via radiation
winter : thermal energy from wall is vented to space by a convective heat flow (trombe wall)
summer : shading & ventilation

INDIRECT SYSTEM - Mass



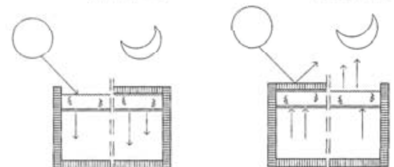
thermal storage wall - water
energy is absorbed by contained water
released slowly back into the interior
potential corrosion, bacteria, and algae growth
freeze protection when maybe required

INDIRECT SYSTEM - Water



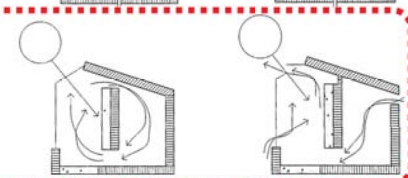
liquid storage in the ceiling or roof
winter : expose liquid during daytime to absorb solar energy, cover liquid at night to radiate energy into interior
summer : reverse, daytime cover liquid to absorb heat from interior, expose liquid at night radiate heat to sky

INDIRECT SYSTEM - Roof Pond



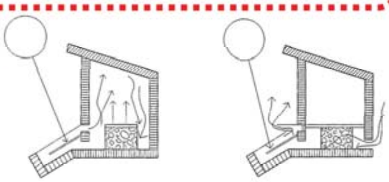
winter : heat can be drawn from sunspace, possible to overheat on clear winter days due to large glazed area
summer : shading required, sunspace used tc induce convection flow from exterior

ISOLATED SYSTEM - Sunspace



natural convection system, rise and fall of heated and cooled air without mechanical assistance
winter : collector surface heated by sun, warm air rises, cool air returns to storage bottom, heat stored in thermal mass
summer : collector may be used as thermal chimney, warm air rises, induce precooled air from ground & thermal storage

ISOLATED SYSTEM - Thermosiphon



LESS USER CONTROL
LARGE DIRUNAL SWING

MORE USER CONTROL
SMALL DIRUNAL SWING

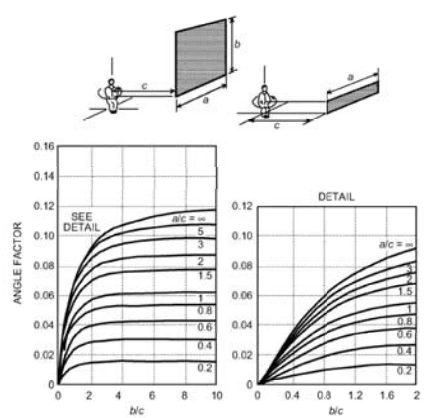
>Thermal Comfort

human satisfaction with the thermal environment

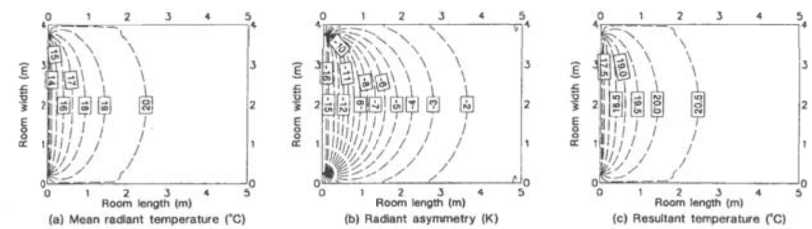
HUMAN : Clothing
Activity

CLIMATE : Air Temperature
Mean Radiant Temperature
Operative Temperature
Relative Humidity

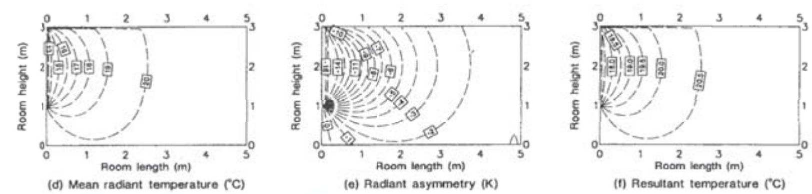
MICRO CLIMATE : Air Movement / Velocity
Radiant Asymmetry



ANGLE FACTOR / VERTICAL SURFACE



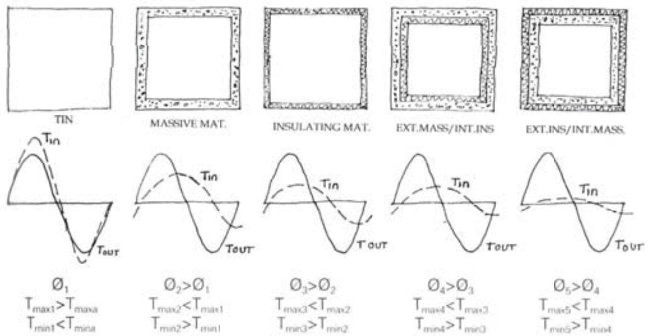
PLAN - MEAN RADIANT TEMPERATURE



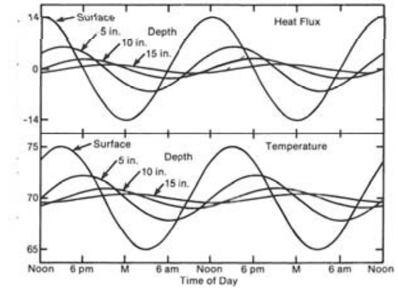
SECTION - MEAN RADIANT TEMPERATURE

effective for material with high heat capacity, moderate conductance, moderate density, high emissivity

DAILY TEMPERATURE FLUCTUATION



HEAT FLUX & TEMPERATURE OF VARYING THICKNESS



RULE OF THUMB

cold climate : brick thickness 4" - 16"
mild climate : brick thickness 1.5" - 2"

1 SF glazing to 6 SF exposed masonry

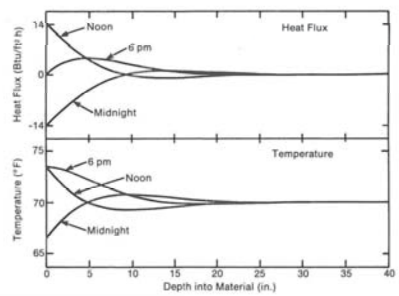
winter : maintain 68°F over 24 hr period on avg sunny day

	THICKNESS					
MATERIAL	4"	8"	12"	16"	20"	24"
BRICK	-	24°	11°	7°	-	-

Thermal Storage Wall Indirect Solar Gain

INTERIOR TEMPERATURE FLUCTUATIONS

HEAT FLUX & TEMPERATURE AT VARYING TIME OF DAY



THERMAL STORAGE

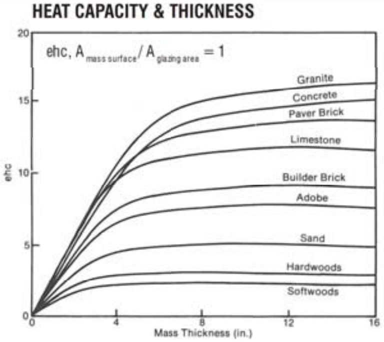
$Q = C_p \cdot \rho$

where: *Q is heat stored*
C_p is specific heat
ρ is density

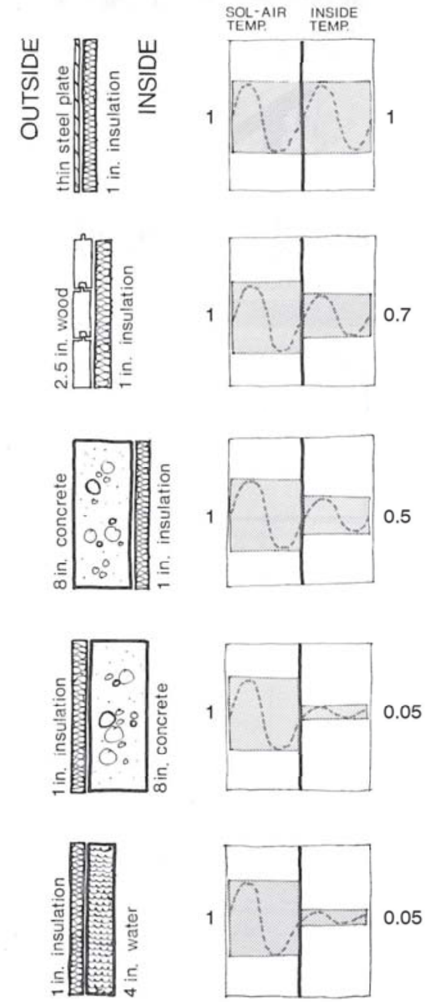
Q_{Brick} = (0.22 BTU / lb - °F)(137 lb / ft³)
Q_{Brick} = 30 BTU / ft³ - °F

Material	C_p *(Btu/lb-°F)*	ρ *(lb/ft³)*	Q (Btu/ft³-°F)
Wood	0.57	27	15.4
Steel	0.12	489	58.7
Glass	0.18	154	27.7
Concrete	0.156	144	22.4
Brick	0.22	137	30.1
Water	1.0	62.3	62.3

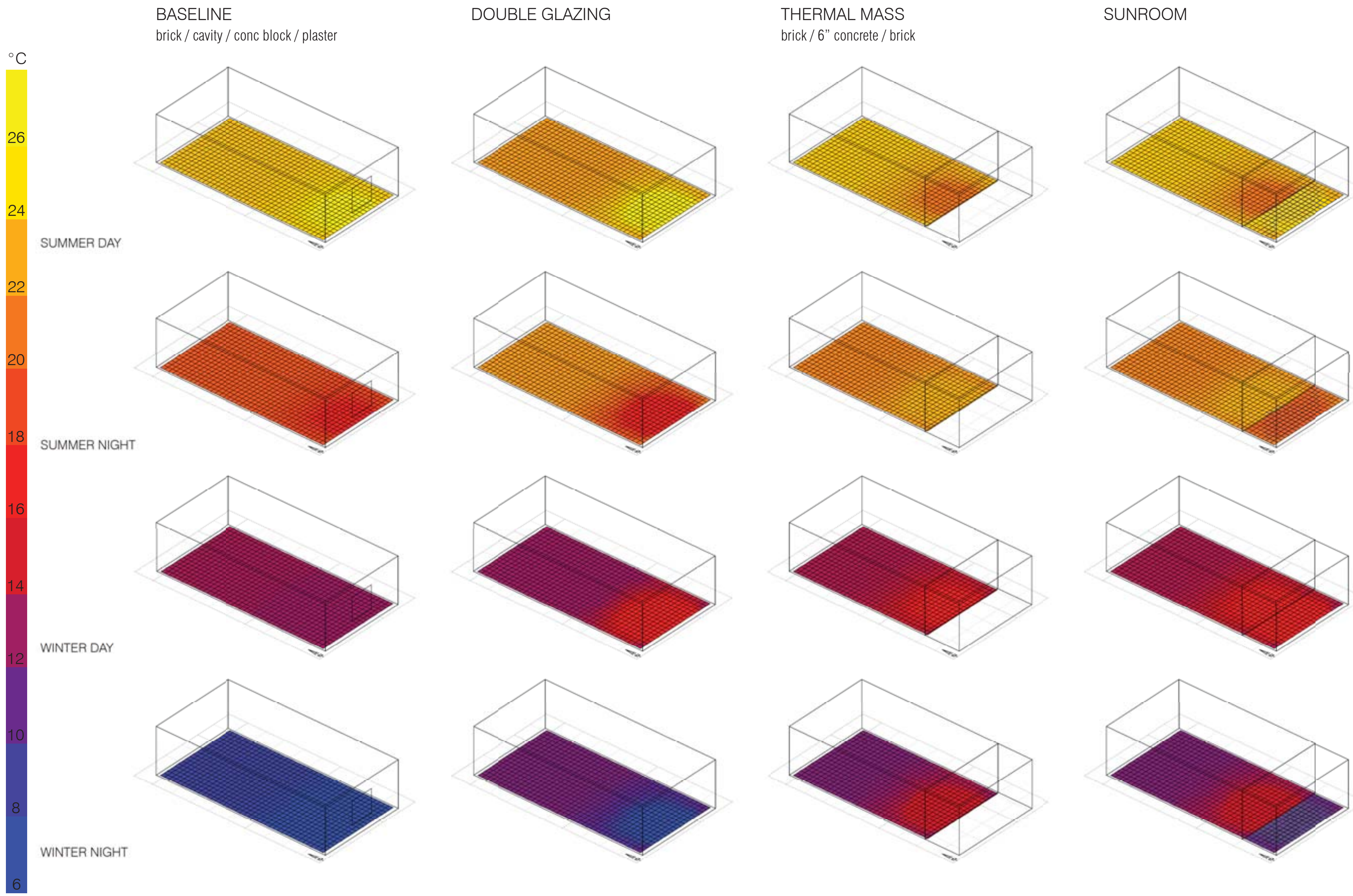
HEAT CAPACITY & THICKNESS



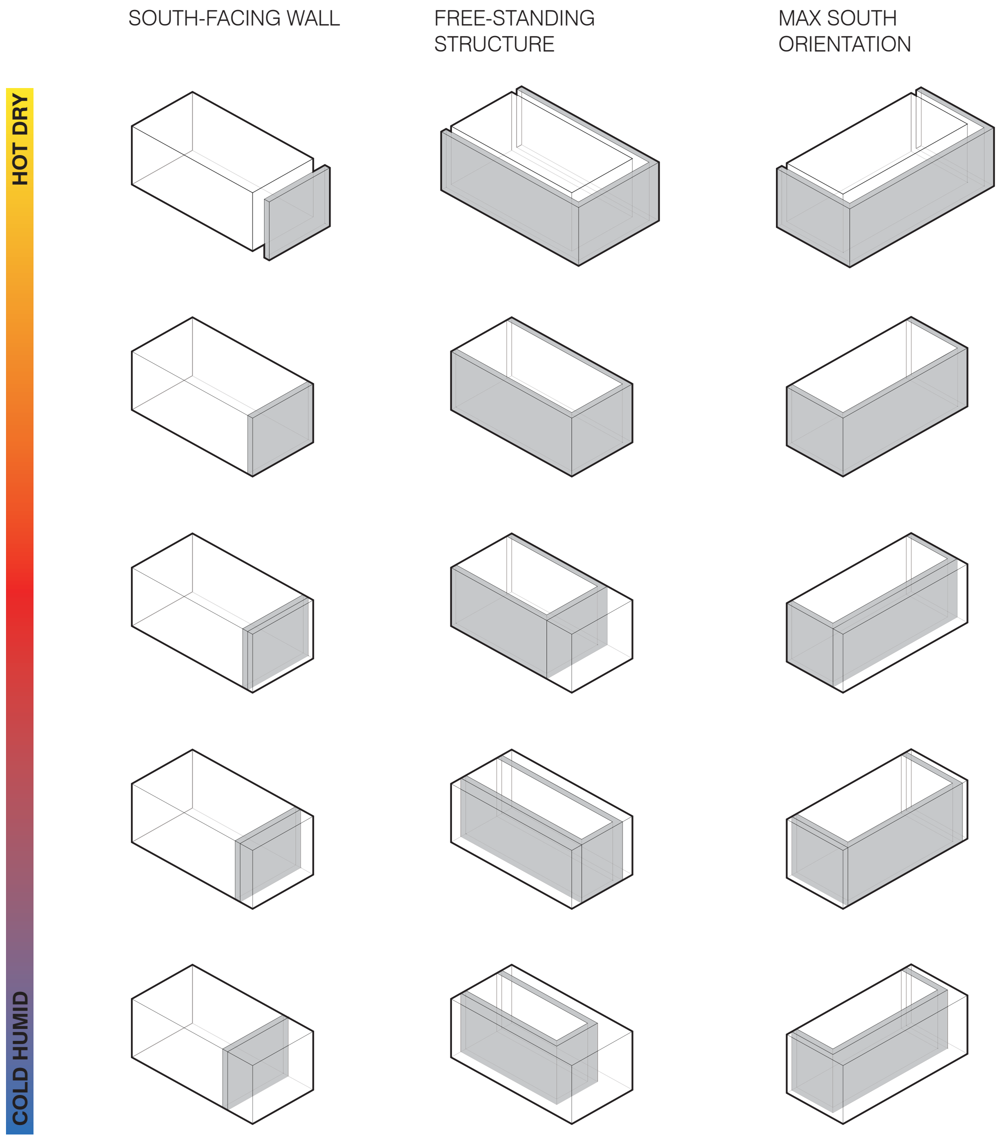
MASS VS INSULATION



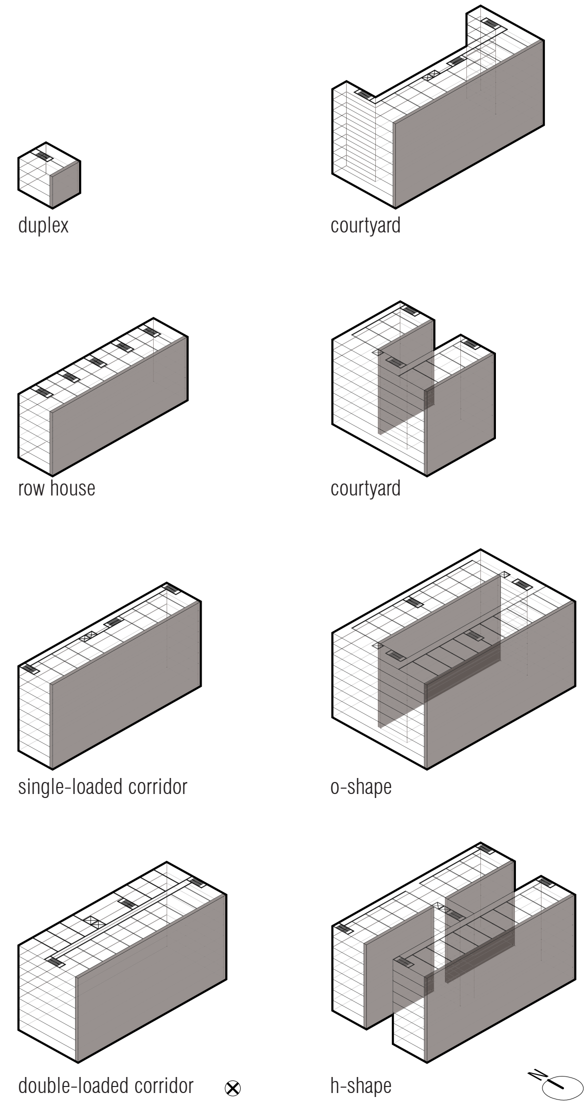
>Mean Radiant Temperature Mapping



>Unit Typology



>Building Typology



DESIGN

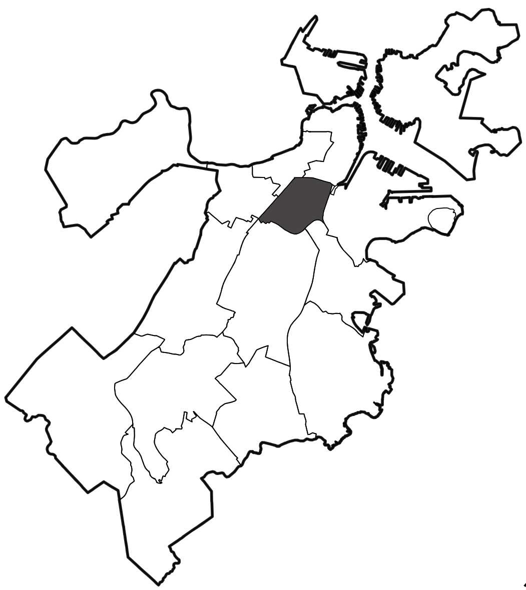
>Boston's South End

Boston's South End is built upon a former tidal marsh, part of a larger land fill project from the 1830s to the 1870s. The neighborhood consists mostly of mid-nineteenth century brick bow front row houses of mixed residential and commercial use. Designed to emulate the wealthy residential district of London, the neighborhood incorporates public squares, rectilinear gardens, and broad tree-lined English avenues. An influx of immigrant and working class populations soon settled in the South End and created an impoverished district amidst the Victorian architecture. Many of the South End's upper class residents abandoned the neighborhood and favored other areas such as Back Bay and Beacon Hill. By the late 1960s and 1970s urban renewal lead to the area's revival and many home owners moved back due to the affordability of housing in the South End. Since the 1980s an effort has been made to preserve the South End's historic and architectural attributes as well as the creation of affordable housing to help retain the neighborhood's ethnic diversity. Today, the South End is a Boston Landmark District and is listed on the National Register of Historic Places.

>Boston South End

Located in the heart of the South End neighborhood, the project site is the Rutland Washington Community Garden protected by the South End / Lower Roxbury Open Space Land Trust. Washington Street, a high-traffic four-lane wide road, is to the southeast of the lot, while Rutland Street, a smaller two-lane residential road is its southwest.

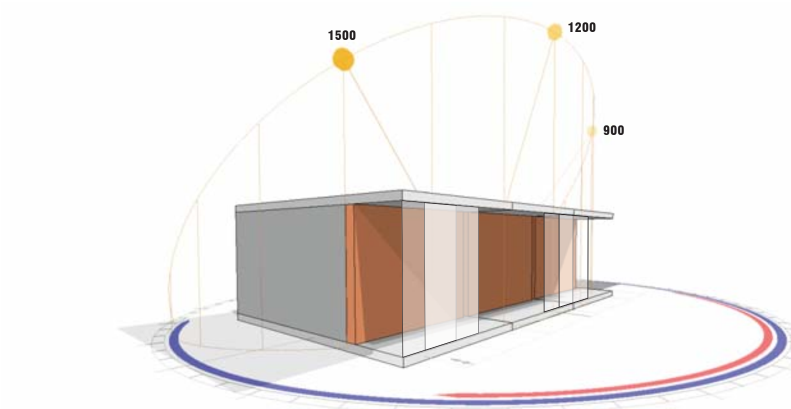
(RIGHT) This map documents existing public housing projects and identifies all open space, including public parks, parking areas, and open lots. Potential sites for this project are specified as south-facing lots with direct solar access.



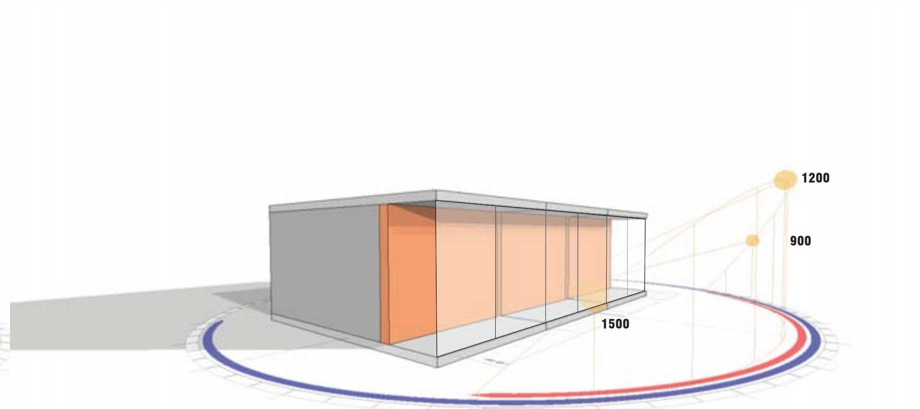
>Sun Study

(TOP) During summer time, the solar room protects the thermal mass wall from overheating with its deep floor overhang. In winter time, the low sun angle penetrates the solar room and provides direct solar gain on the masonry wall.

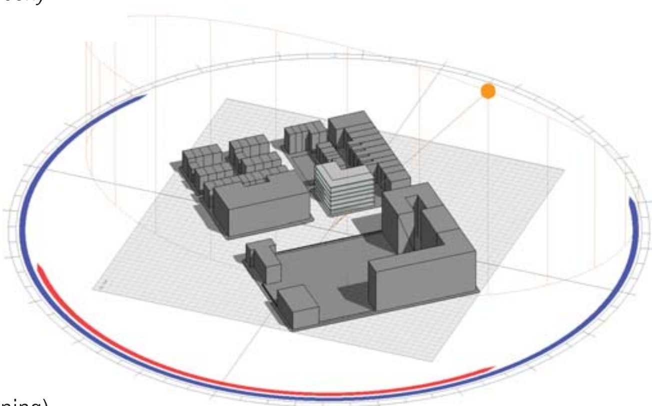
(BOTTOM) On the southeast façade of the corner lot, the project has year-round direct solar exposure. While the southwest corner of the project is occasionally blocked by shadows casted from adjacent building in summer mornings and winter afternoons.



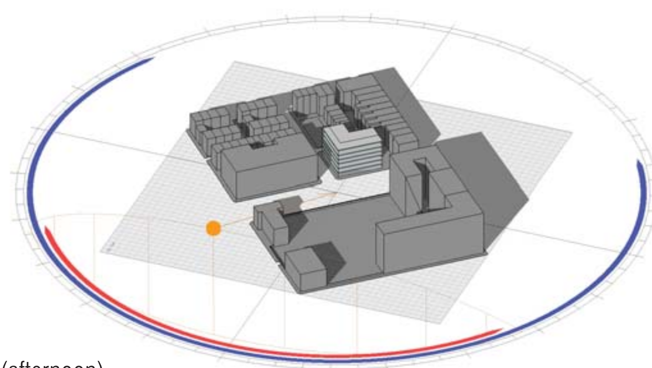
SUMMER SOLAR ROOM
self shading balcony



WINTER SOLAR ROOM
direct solar gain



SUMMER (morning)
southwest corner shaded



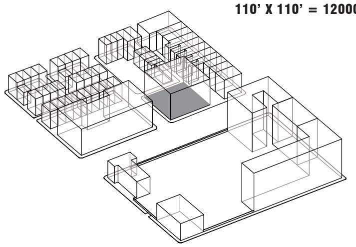
WINTER (afternoon)
southwest corner shaded

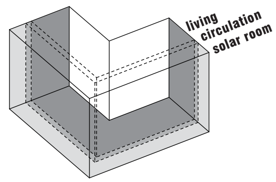
>Massing Strategy

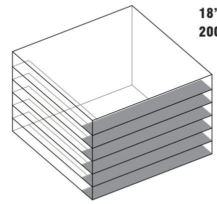
(TOP & CENTER) The project is set up as a series of zones with different levels of thermal comfort: the solar room, circulation, and living spaces. The solar rooms are programmed as urban gardens and shaped according to sunlight and shadow studies. The thermal mass wall is rotated 45 degrees for direct southern exposure and pleated to increase surface area.

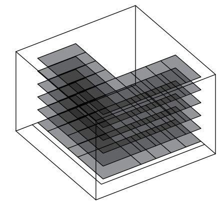
(BOTTOM) In winter daytime, direct solar gain heats up air in the solar room creating a greenhouse scenario. Thermal energy is absorbed by thermal mass wall via conduction. In winter evening, the solar room provides both radiant and convection heat delivered into the living space through operable vents.

DEVELOPMENT SCENAIRO

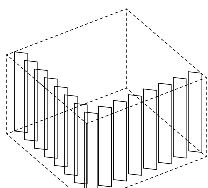


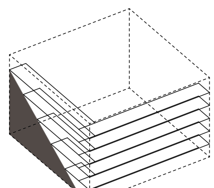


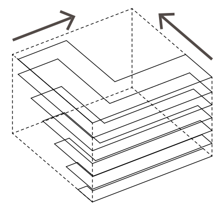


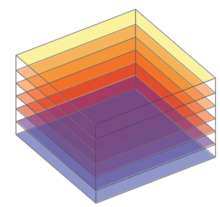


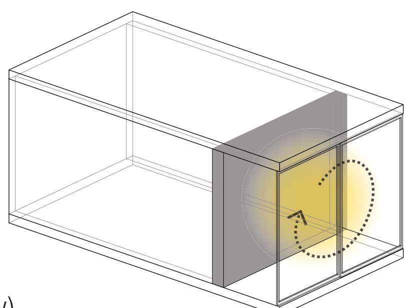
SOLAR STRATEGY

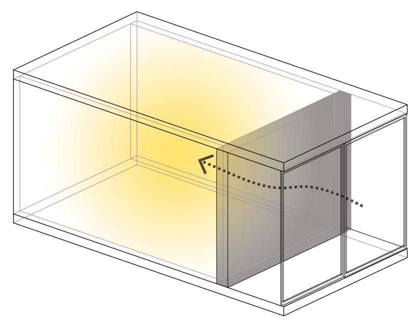

direct south exposure / thermal mass


shadow from adjacent structure

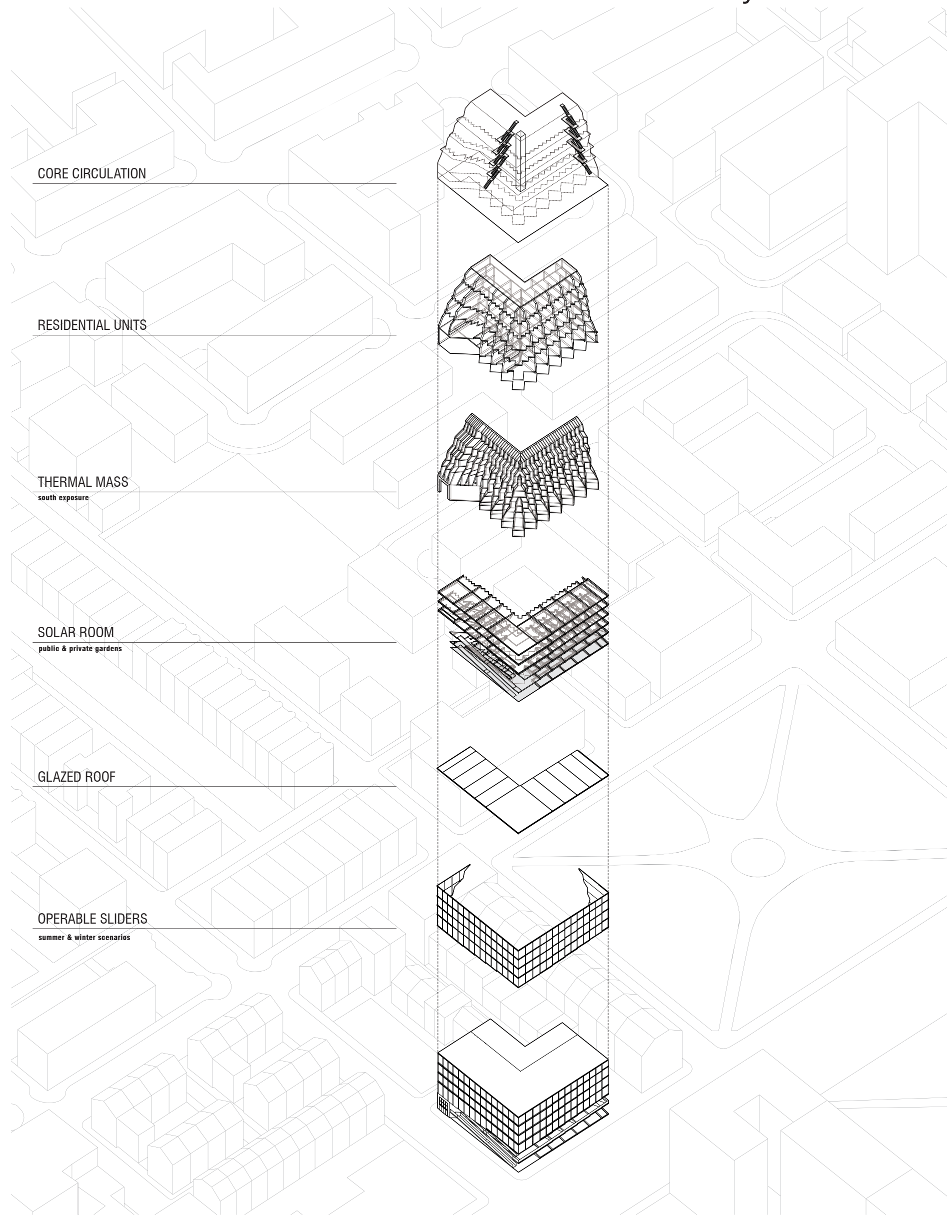

max garden area / terrace


temperature difference per floor


WINTER (day)
solar gain raises room temperature


WINTER (night)
warm air pushed into living space through vents

>Systems Axon

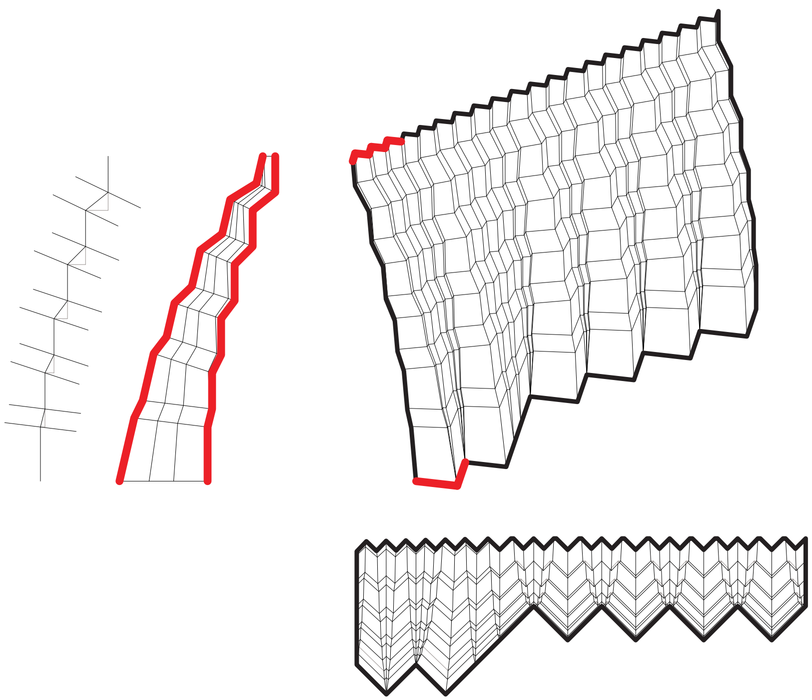


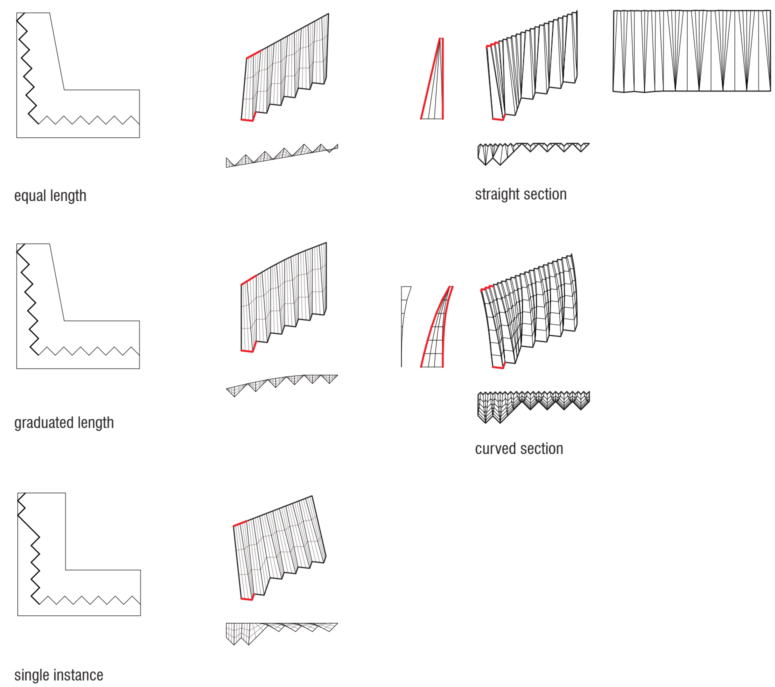
(LEFT) Southeast elevation rendering in winter. View from Washington Street towards Rutland Street and downtown.

(RIGHT) The project is a layering of systems. The solar room is protected with large sliding doors that are to remain open in the summer to promote air circulation and to prevent overheating. During winter time, the sliders will be closed to create a greenhouse scenario for raising room air temperature using passive solar strategy. The masonry wall behaves much like a thermal battery, absorbing radiant energy during daytime and releasing it later due to diurnal swing. In night time, warm air from the solar room is delivered into the residential units through operable vents.

>Wall Geometry

(LEFT) The wall geometry was further developed to accommodate a single instance on the southwest corner where the building is generally in shadow. Different iterations were studied to transform the thermal mass wall from its 10 feet set back towards aligning with the exterior of the floor plate.

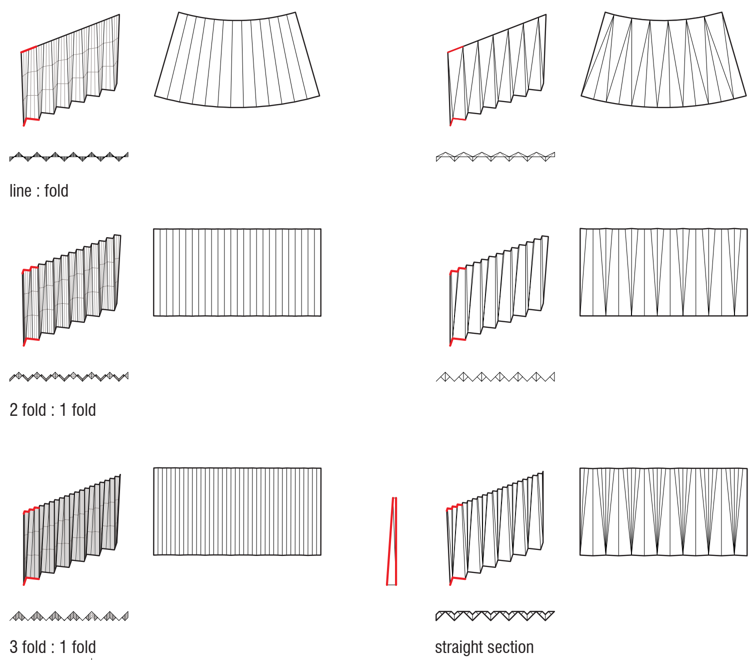


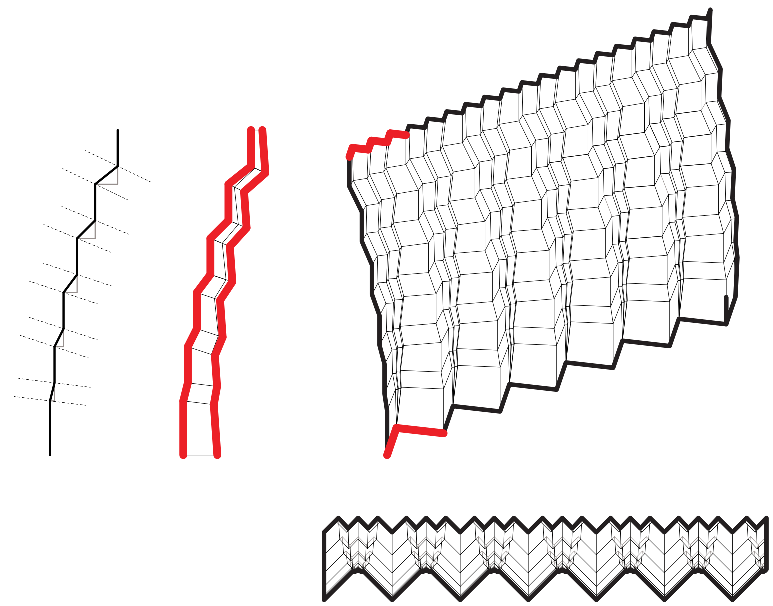


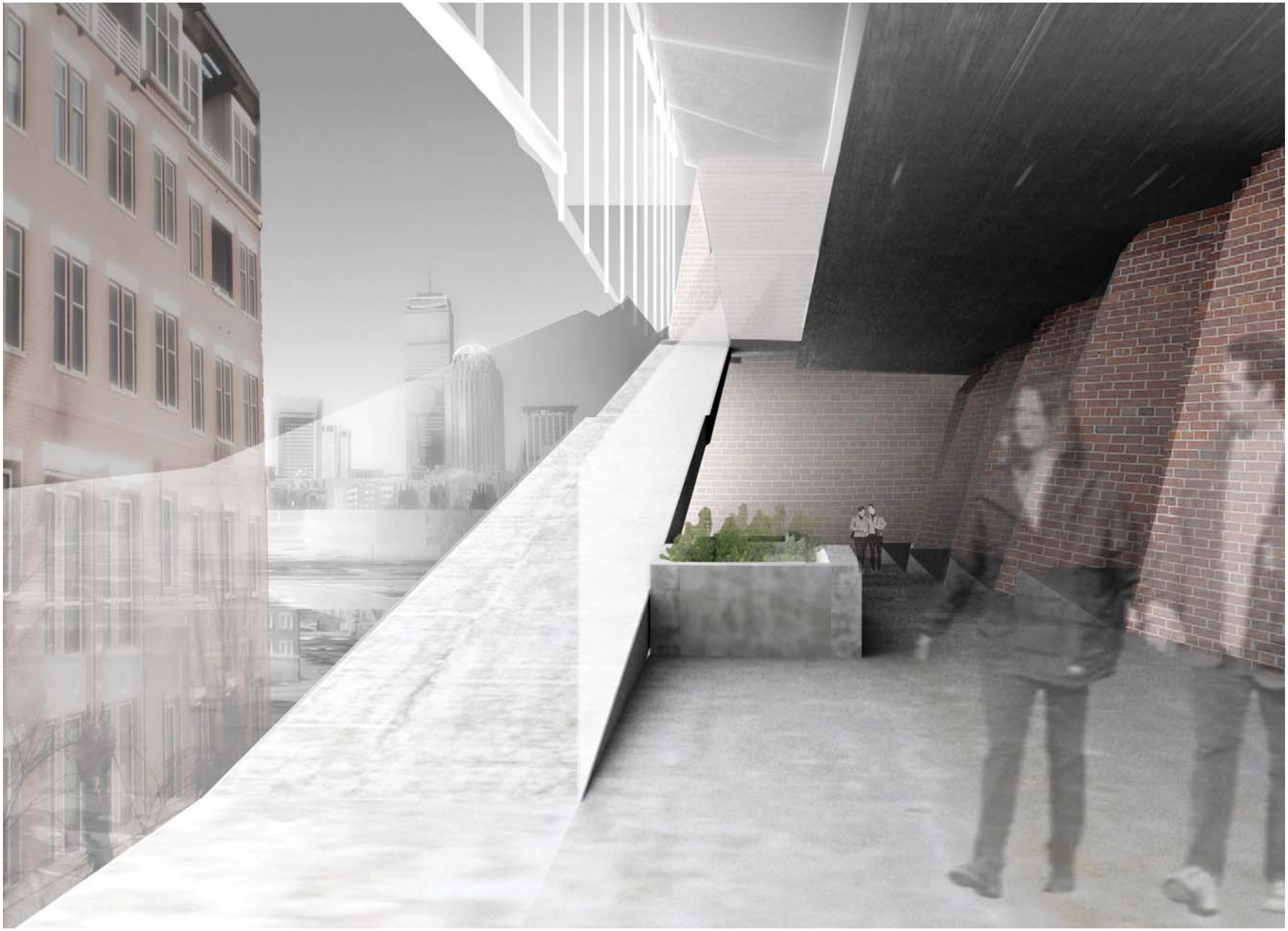
>Wall Geometry

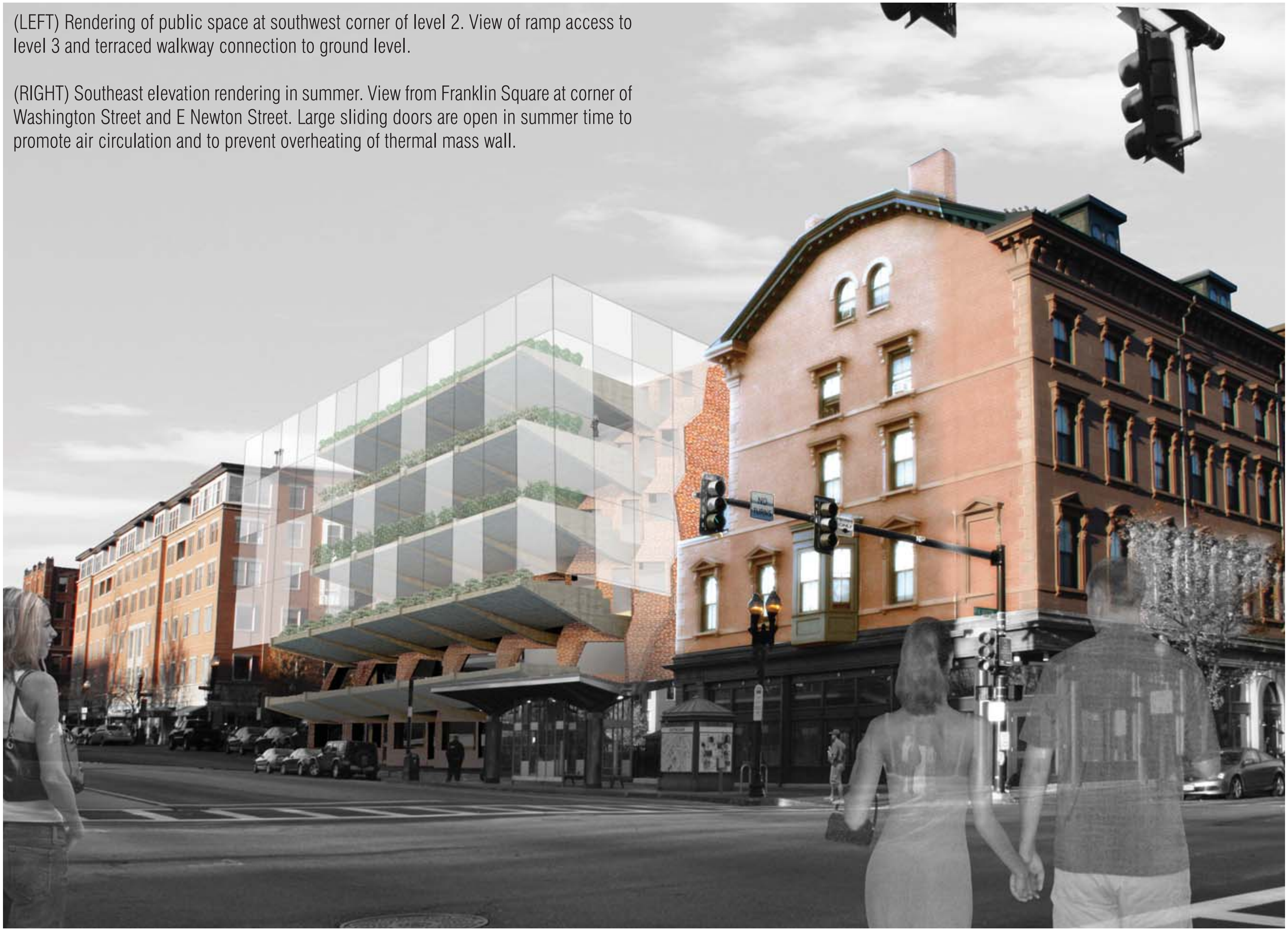
(LEFT) Geometry of the thermal mass wall was studied to maximize surface area in relation to entry sequences. Over six stories the wall transforms from a single V-shape fold to a straight section, a single fold to a double fold, and finally a single fold to triple fold. At the ground floor the wall is a single fold, each segment is 9 feet in length and the V-shape forms a generous entry area for the apartment unit. On the top floor the wall is a triple fold, each segment is 3 feet in length, which is the minimum clearance necessary for an entry door.

(RIGHT) In subsequent iteration of the wall geometry, the thermal mass wall steps back to allow for deeper solar rooms. Pleating in the vertical section is coordinated with entry door height – the thermal mass wall remains vertical from floor to top of entry door and folds back to span the distance to the wall above.



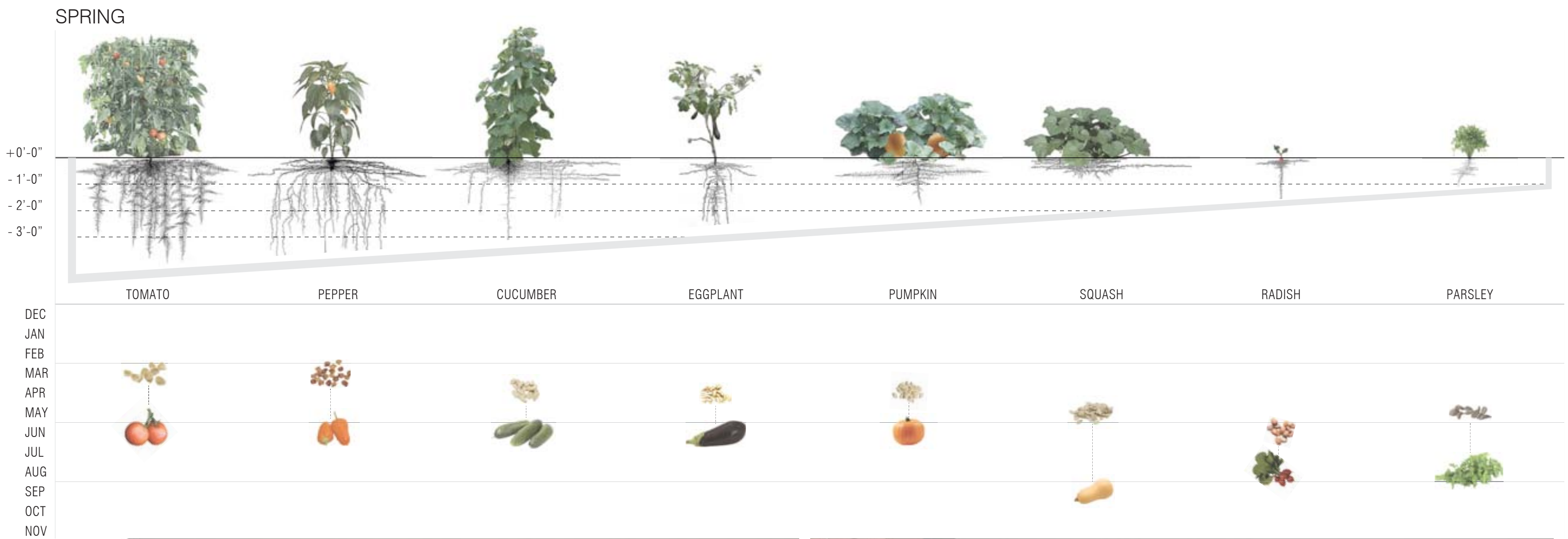


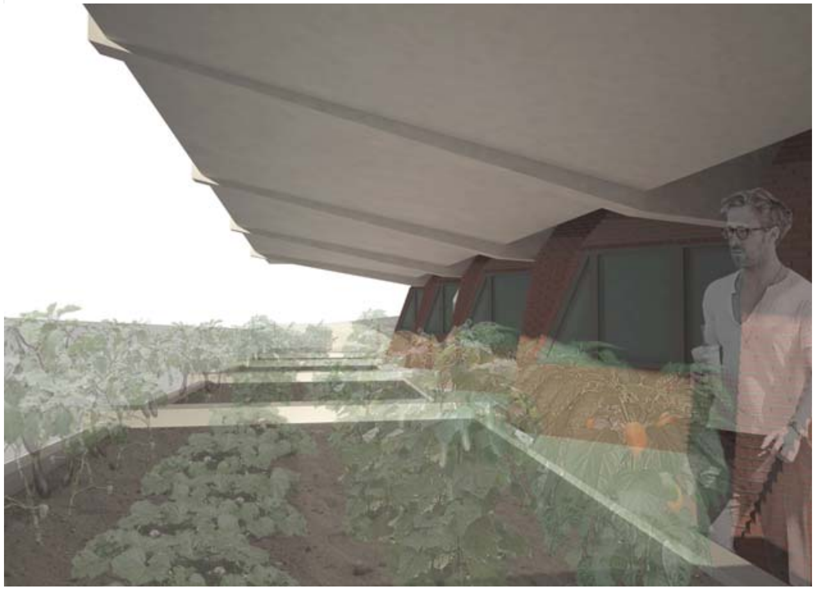




(LEFT) Rendering of public space at southwest corner of level 2. View of ramp access to level 3 and terraced walkway connection to ground level.

(RIGHT) Southeast elevation rendering in summer. View from Franklin Square at corner of Washington Street and E Newton Street. Large sliding doors are open in summer time to promote air circulation and to prevent overheating of thermal mass wall.

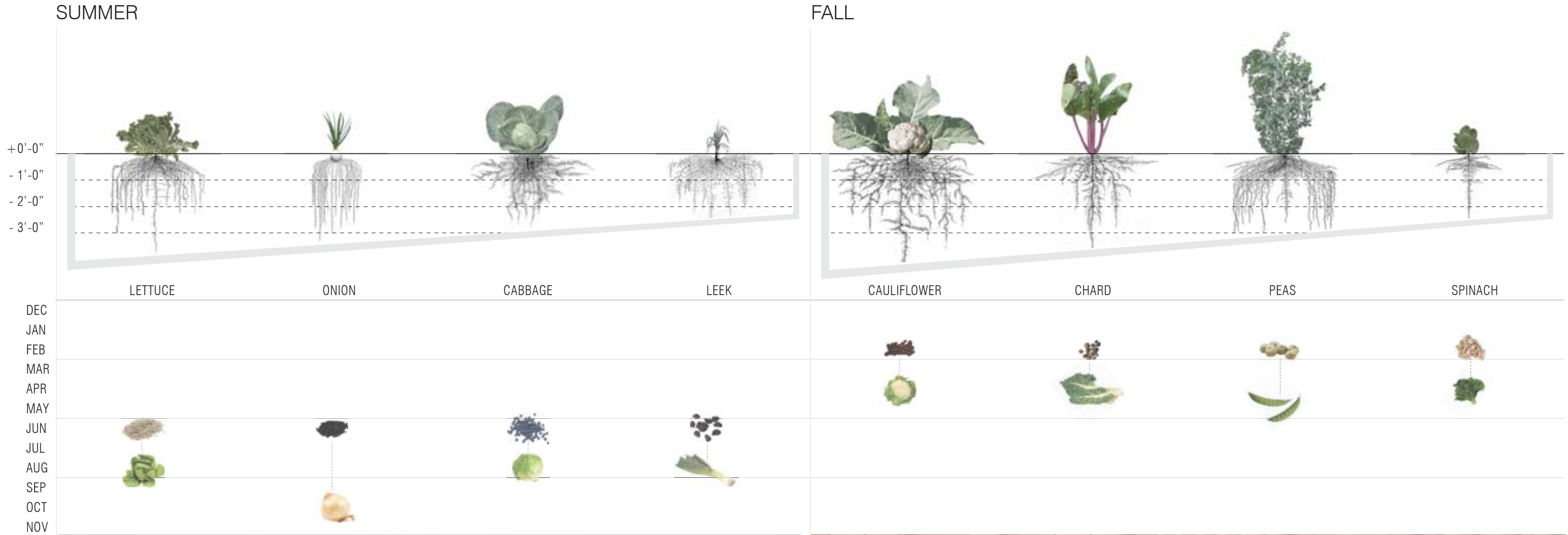




Level 2. Spring time vegetables in solar room along southeast façade.

Level 3. Spring time vegetables in solar room along southeast façade.

>Solarium Planting Schedule

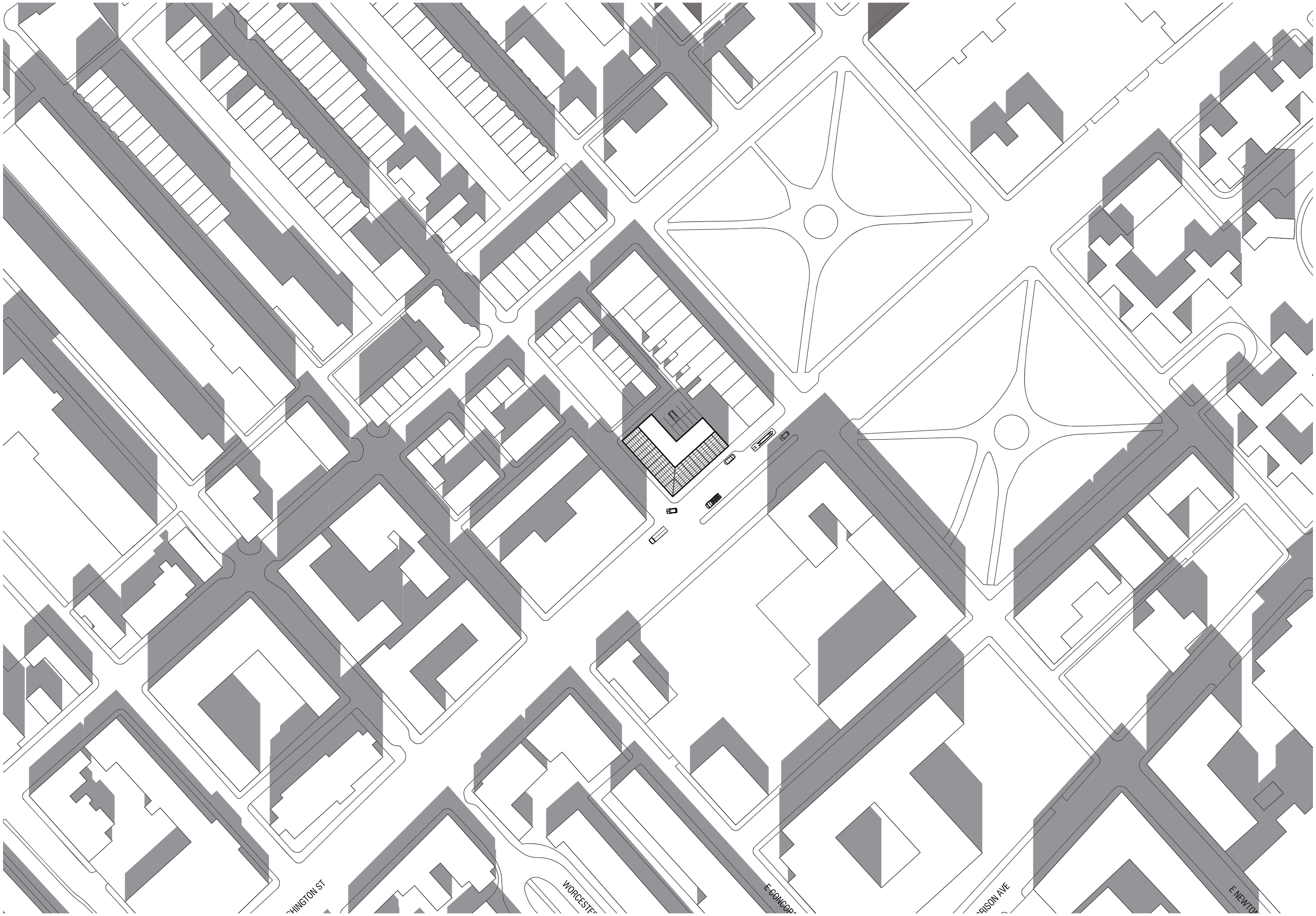


Level 6. Summer time vegetables in solar room along southeast façade.

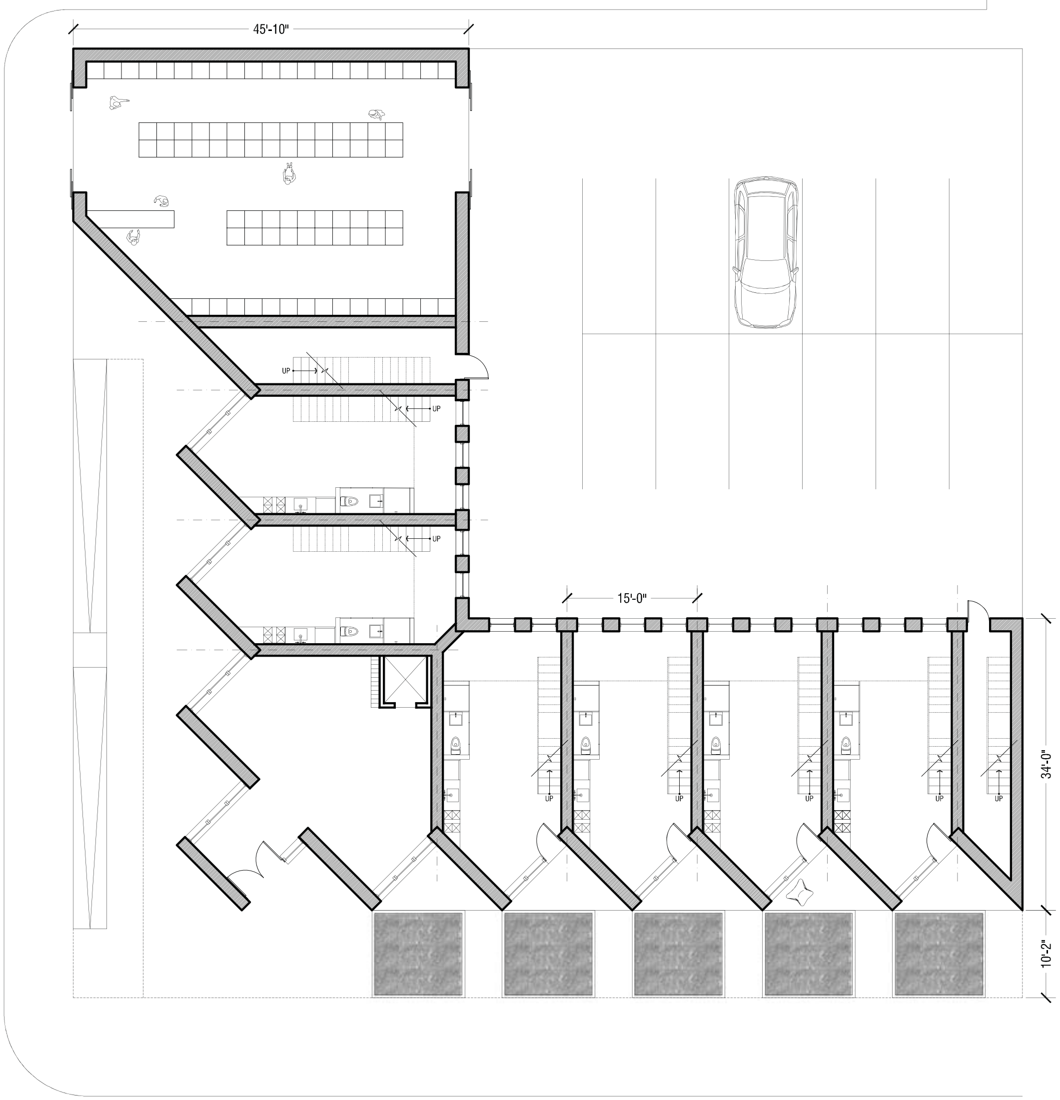
Level 6. Winter time residential interior, view of solar room through glazing.

Southwest elevation rendering along Rutland Street. View of market façade stepping out from setback area to align with exterior edge of floor plate.

>Site Plan

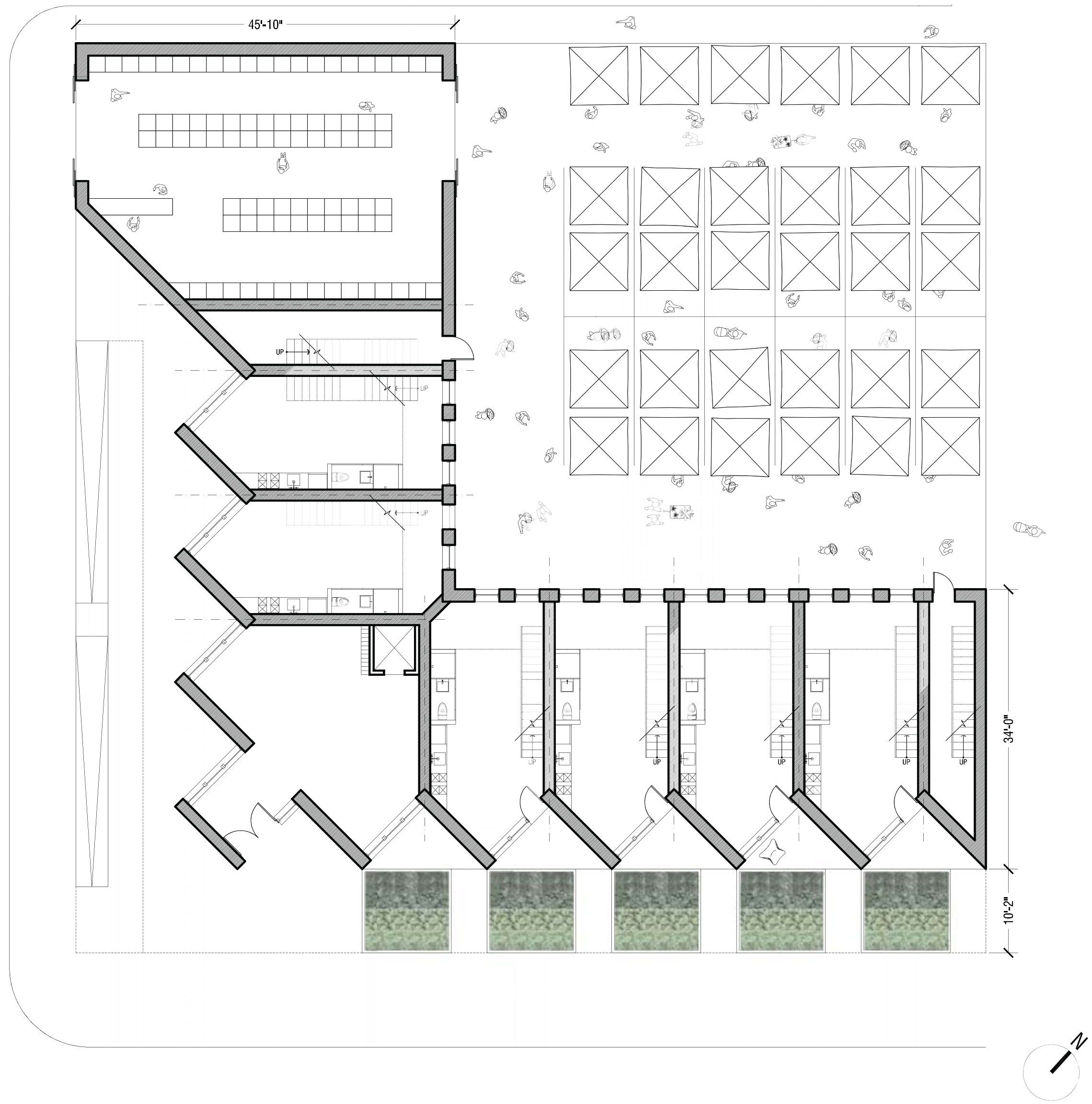


>Floor Plan
ground level : winter & spring

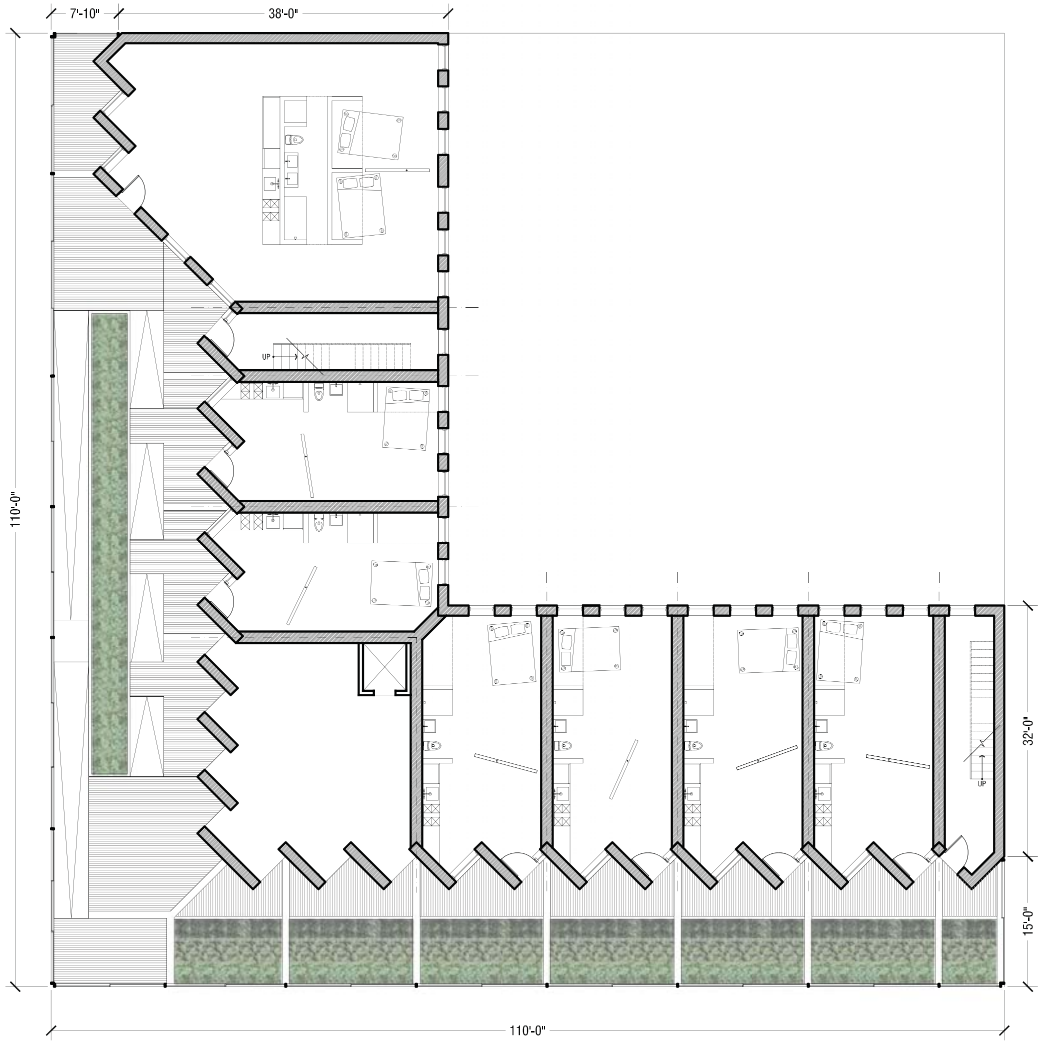


>Floor Plan

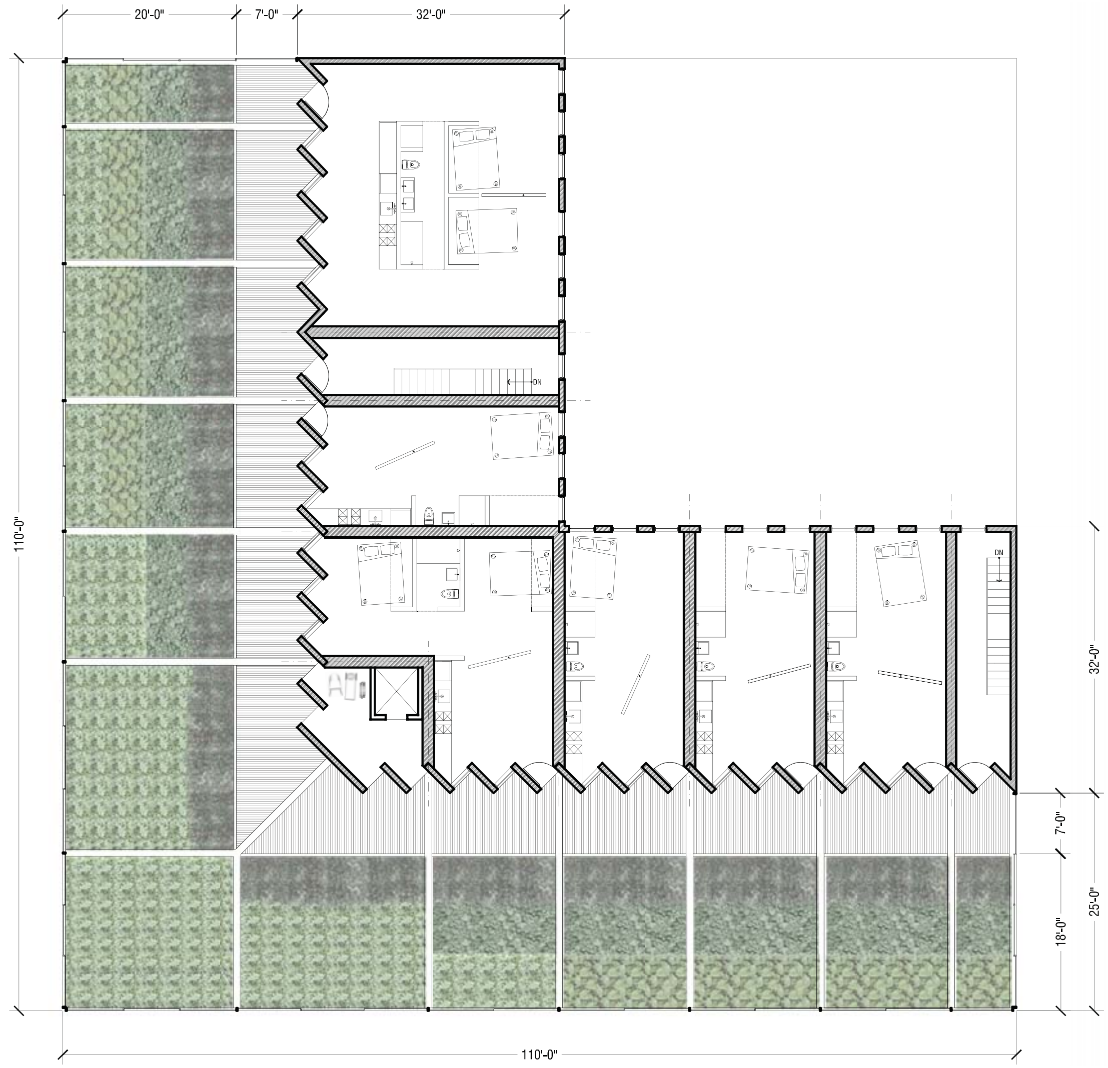
ground level : summer & fall : farmers market scenairo



>Floor Plan
level 3

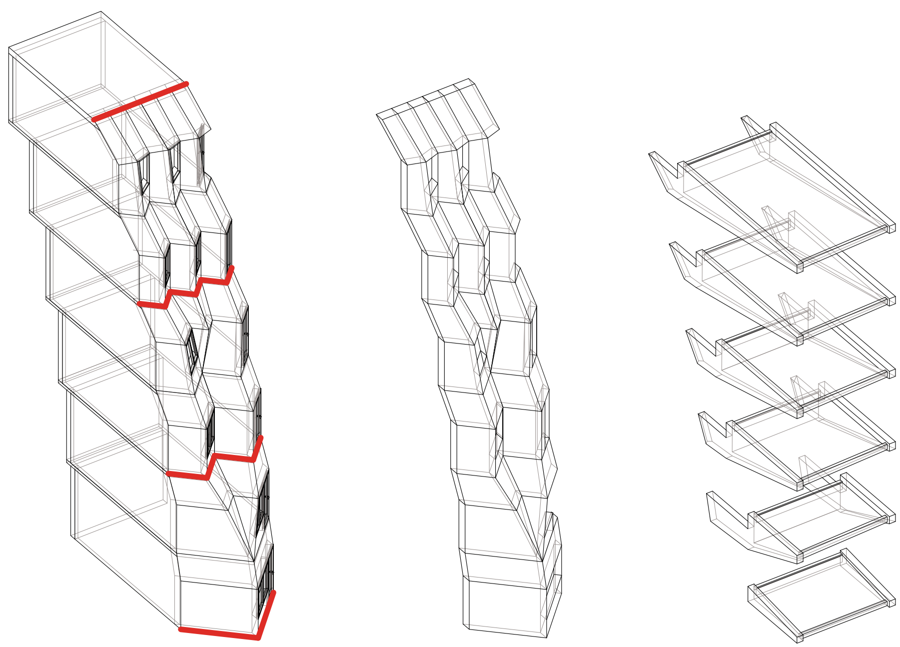


>Floor Plan
level 6



>Unit Detail

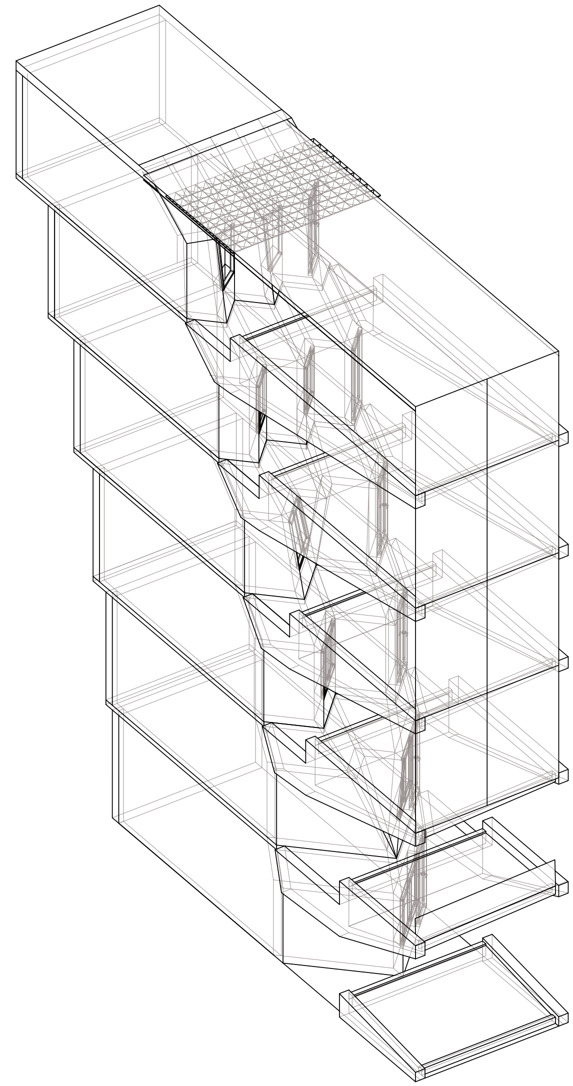
Transformation of the thermal mass wall from ground level (single V-shape fold) to level three (double fold), to level five (triple fold), and eventually resolving as a straight wall segment on the roof. Also, as the thermal mass wall steps back to allow for deeper solar rooms, the depth of planting trays increased from 10' to 18' deep.



RESIDENTIAL UNITS

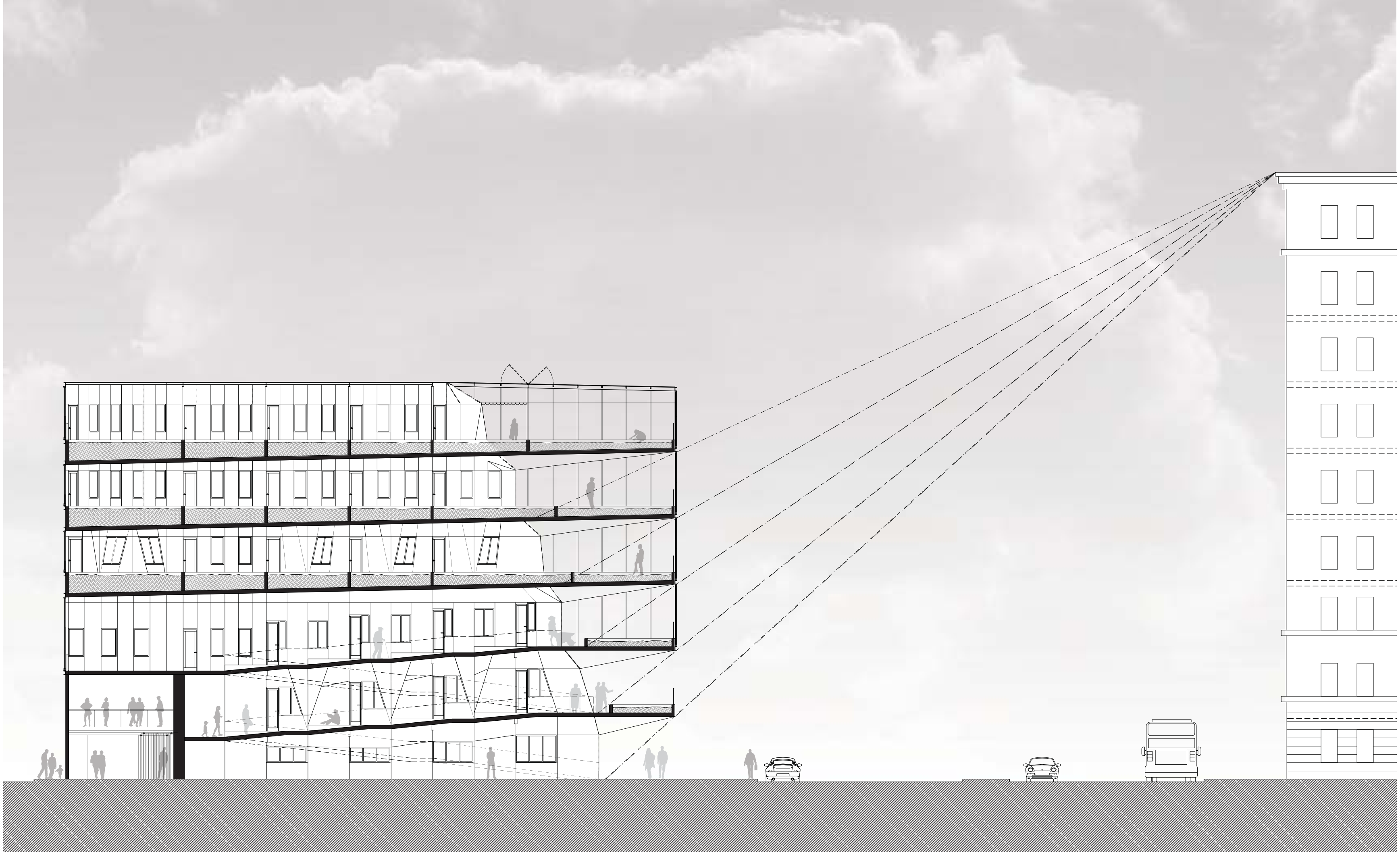
THERMAL MASS

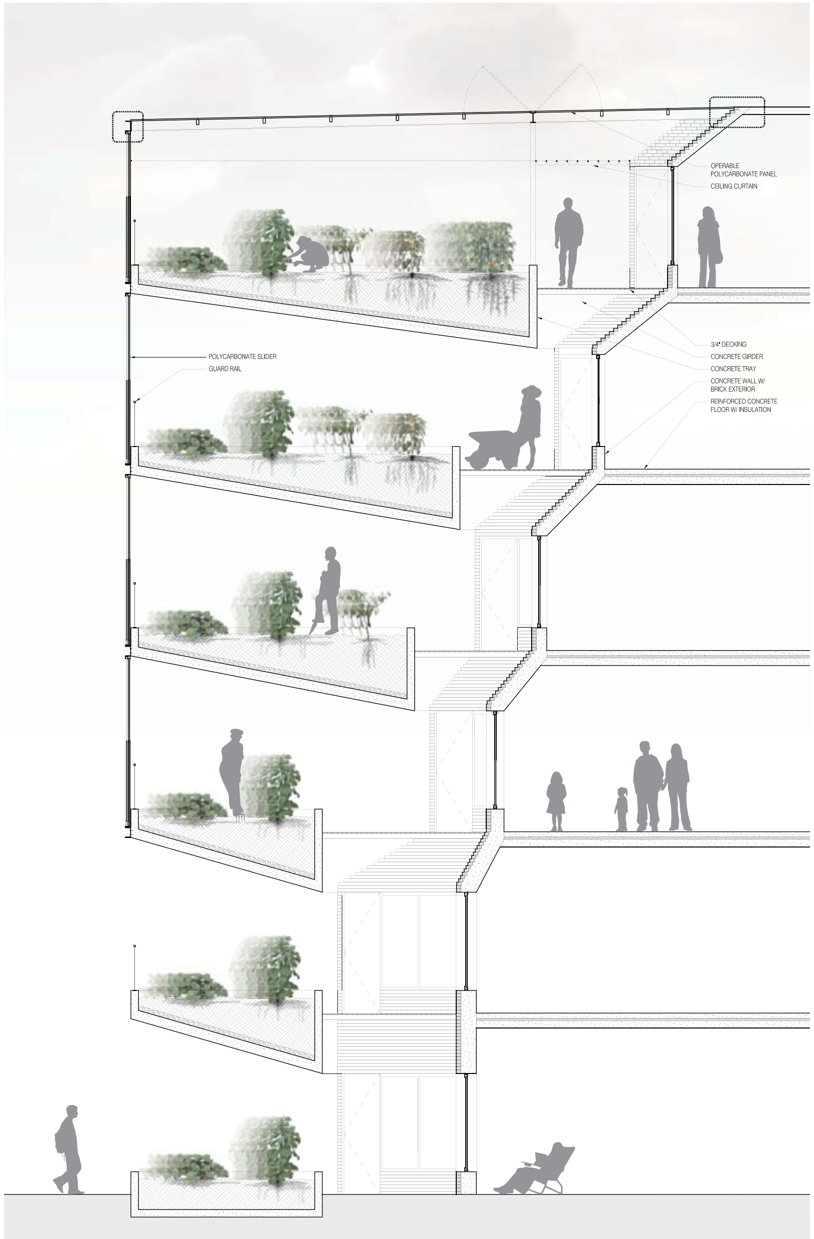
URBAN GARDEN

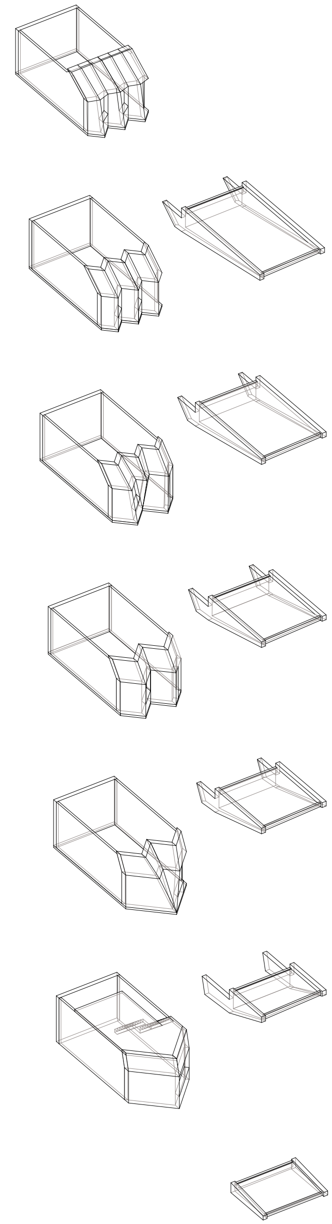


>Building Section

(BELOW) Building section is taken through the solar room's planting trays along the southwest circulation. The tray depth tapers from 5' to 1' deep at the corner due to the massive cantilever of the solar room. The section also reveals the produce and gardening market at the ground level and level 2.



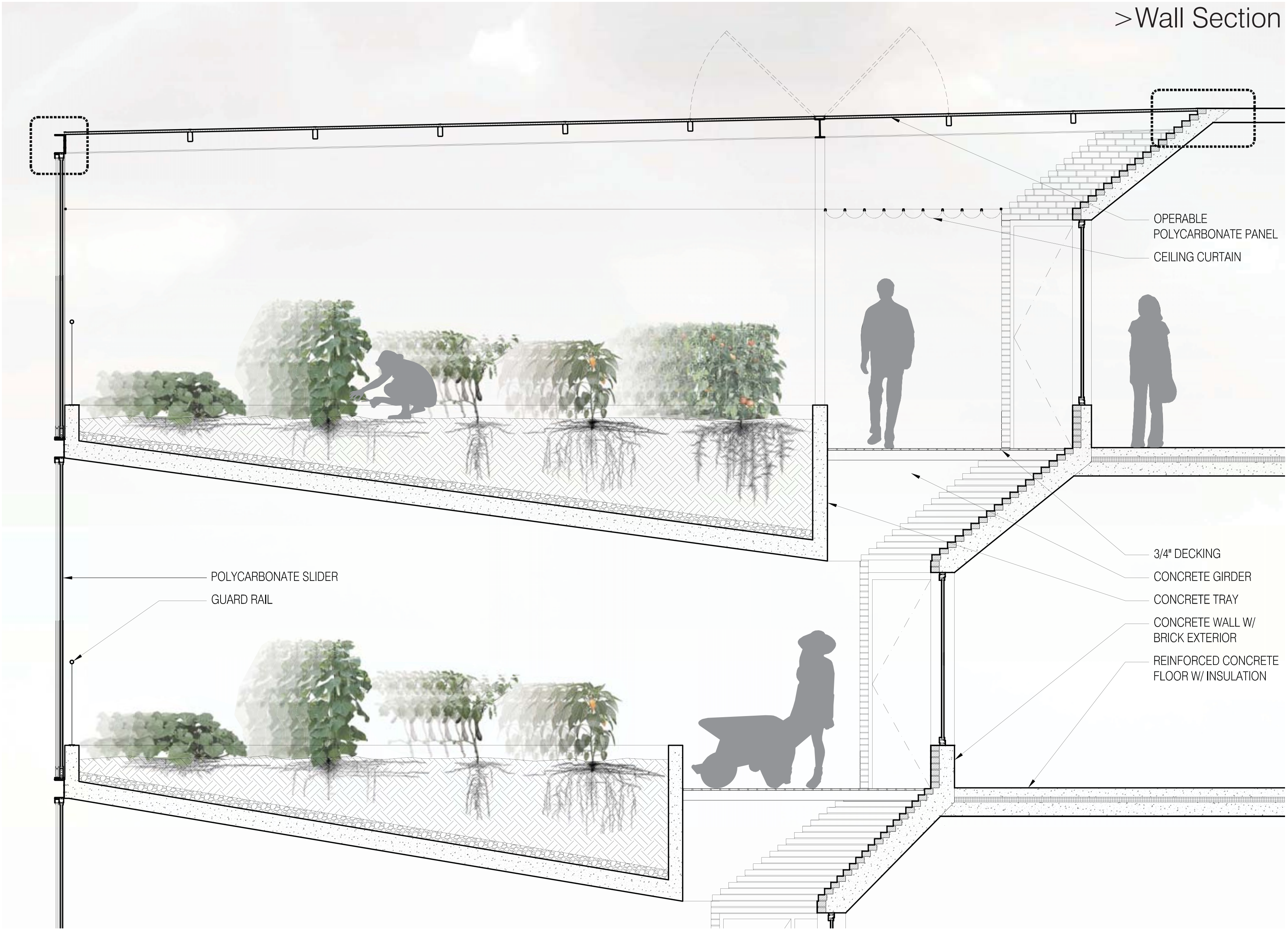




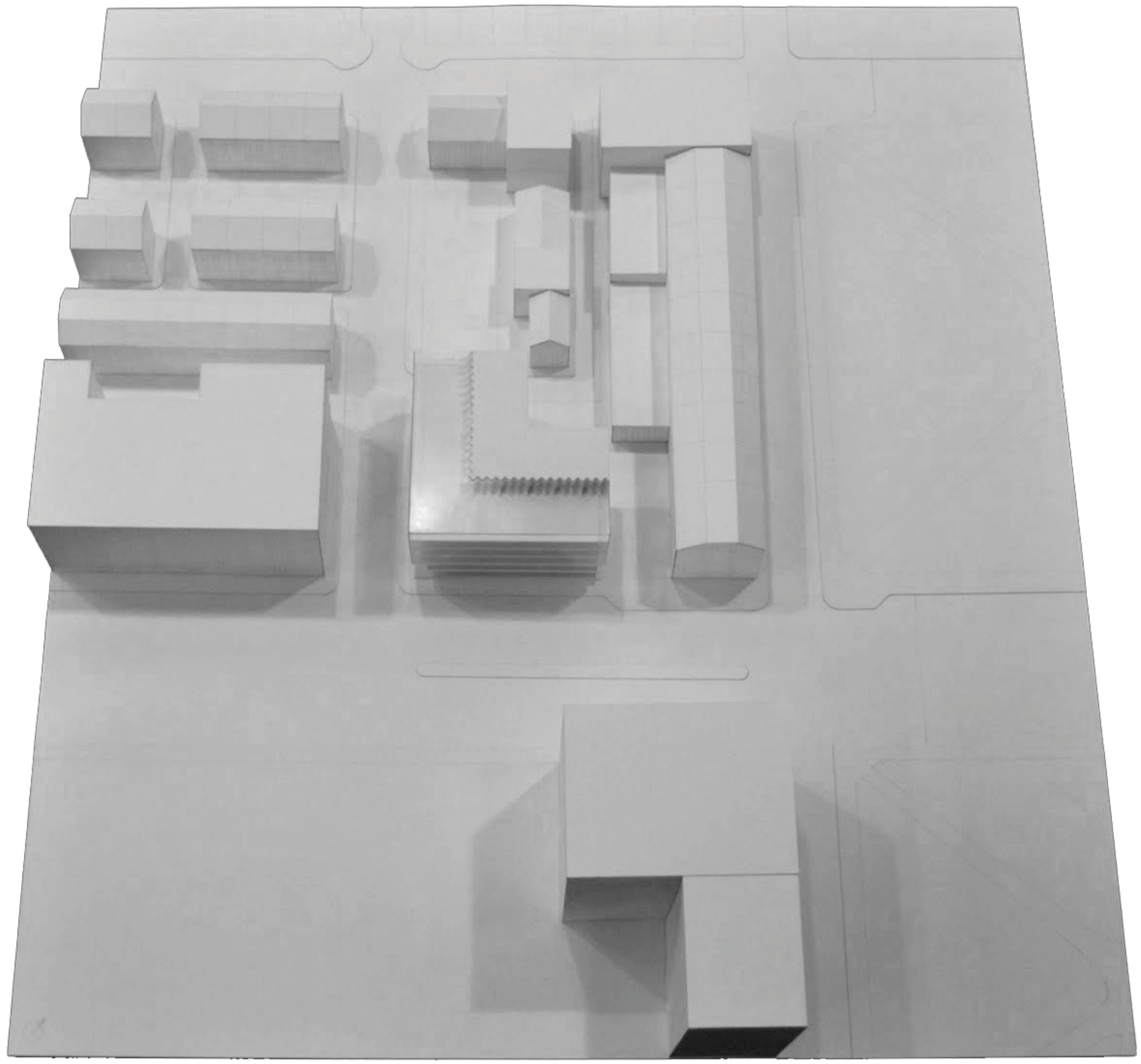
(LEFT) Wall section of solar rooms showing the different size planting trays and thermal mass wall geometry. The different depths in the planting trays allow vegetation with varying root depth to flourish. The public garden is located on the ground level and level 2, while private urban garden contained within the depth of the solar room exists from level 3 through level 6.

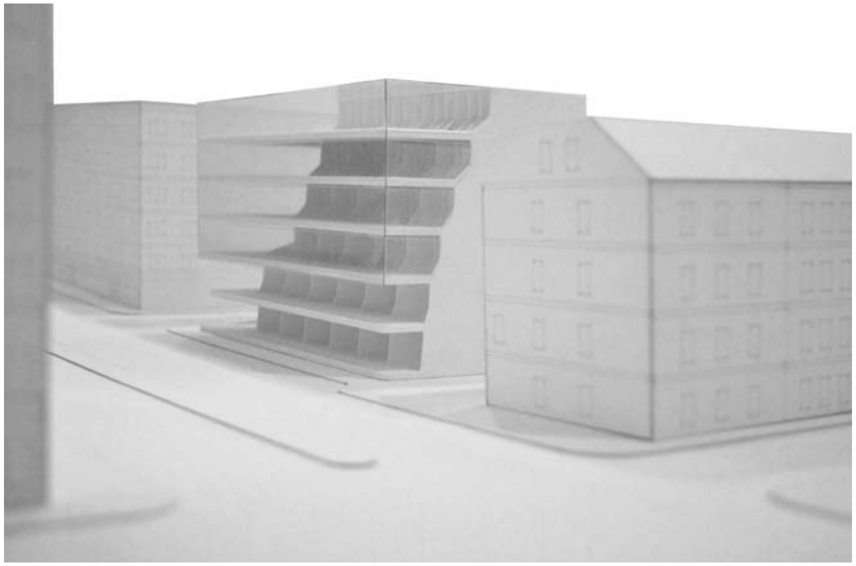
(RIGHT) Diagram of residential unit transforming from a single V-shape thermal mass wall to triple pleated wall, and its relationship to planting trays of varying depths.

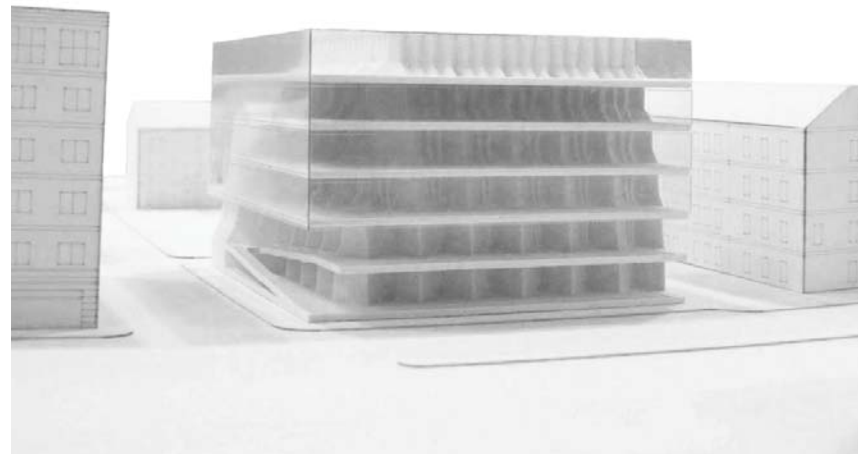
(PAGE RIGHT) Enlarged wall section through solar room and thermal mass wall.

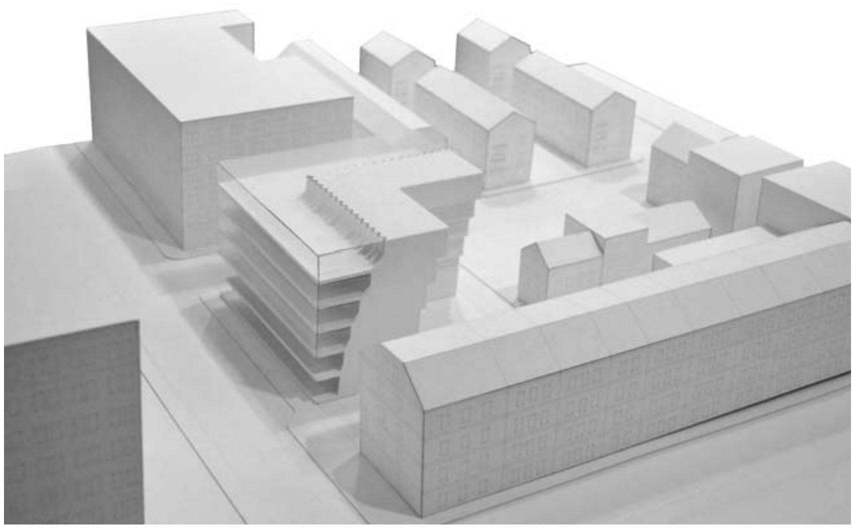

>Wall Section
OPERABLE POLYCARBONATE PANEL
CEILING CURTAIN
3/4" DECKING
CONCRETE GIRDER
CONCRETE TRAY
CONCRETE WALL W/ BRICK EXTERIOR
REINFORCED CONCRETE FLOOR W/ INSULATION
POLYCARBONATE SLIDER
GUARD RAIL

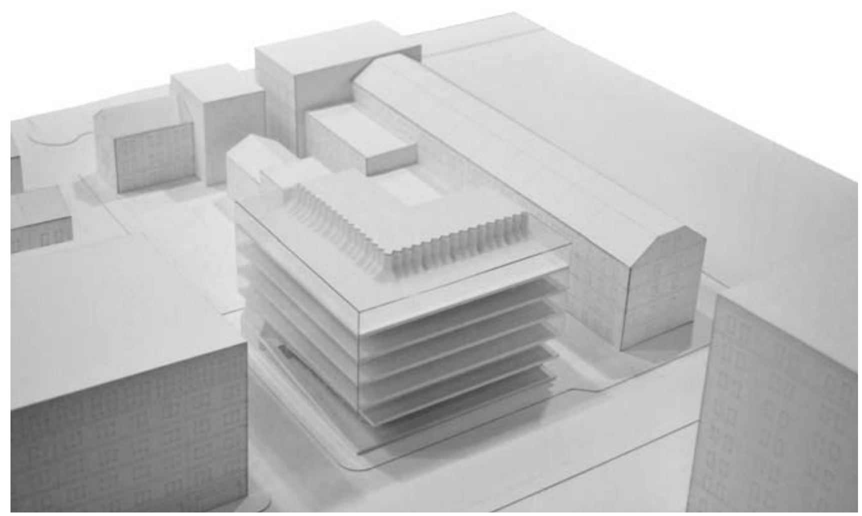
>Model Photographs





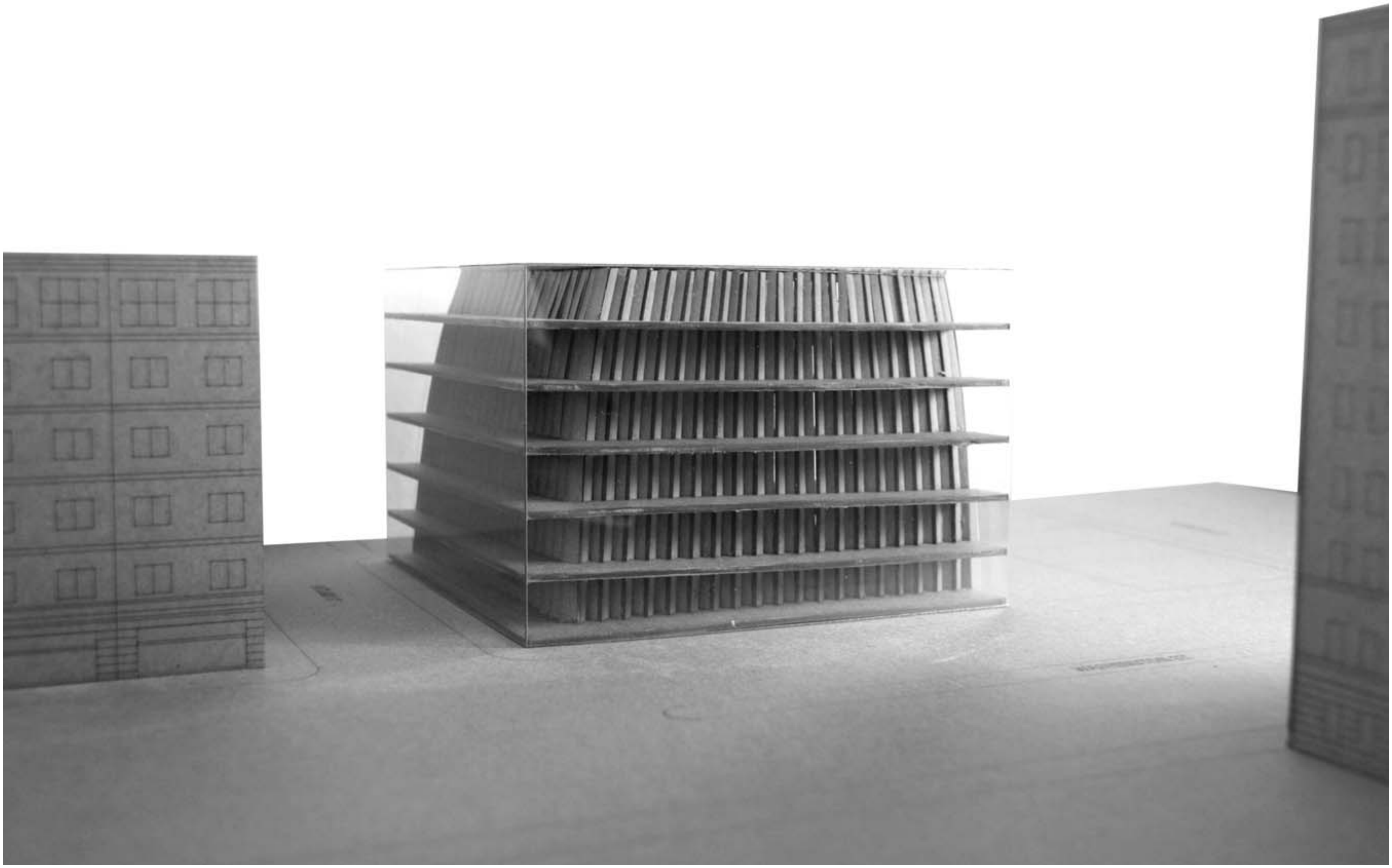






>Model Photographs

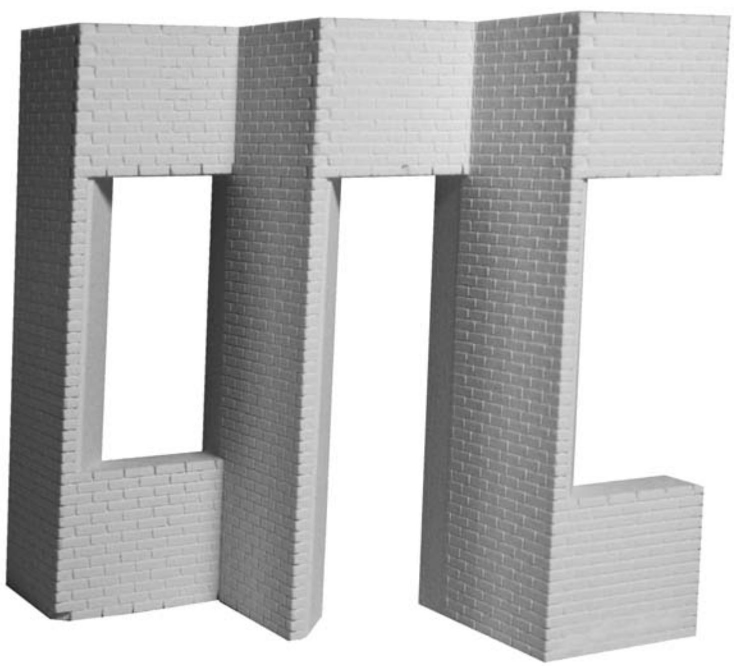
Study model with glazed solar rooms, floor cantilever, thermal mass wall, and residential units behind.

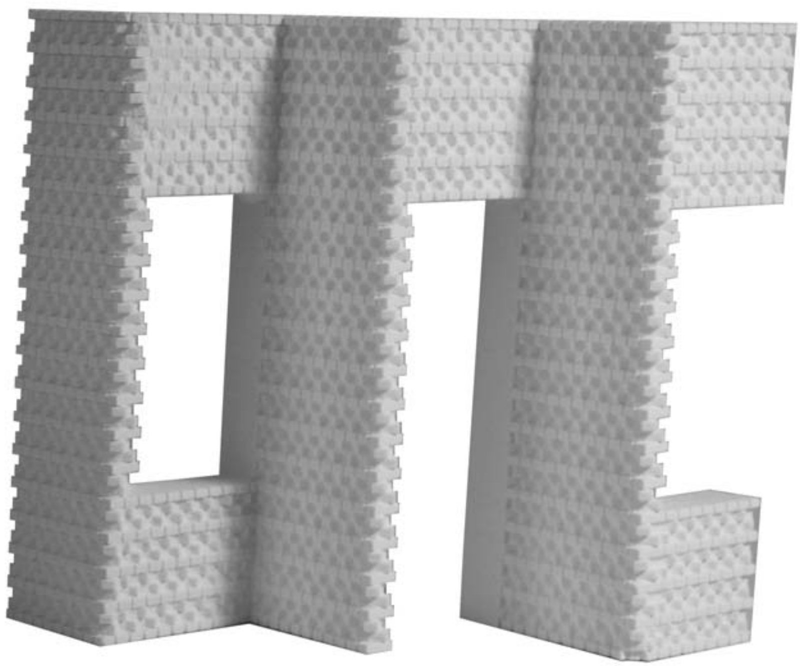


>Model Photographs

(LEFT) Printed 3D model of running bond brick construction detail, showing a section of triple pleated wall with door and window openings.

(RIGHT) Printed 3D model of hounds tooth bond brick construction detail, showing a section of triple pleated wall with door and window openings.





photograph by andy hsu

12.19.2011 thesis presentation to guest critics: marc pasnik, michelle fornabai, tim love; and thesis committee: joel lamere, yung ho chang, and john fernandez. photograph by ann woods.

Bibliography

Banham, Reyner. “A Home Is Not a House.” *Architectural Design* (1969): Page 45-48.

Brown, Coco, Richard Meier, and Alastair Gordon. *American Dream: the Houses at Sagaponac : Modern Living in the Hamptons*. New York: Rizzoli, 2003.

Curtis, William J.R. “Enigmas of Surface and Depth.” *Herzog & De Meuron 1993 - 1997*. Vol. 84. Madrid: El Croquis Ed., 1997. Page 32-49.

Evans, Robin. “Translation from Drawing to Building.” *Translation From Drawing to Building and Other Essays*. London: Architectural Association, 1997. Page 152-93.

Gissen, David. *Subnature: Architecture’s Other Environments*. New York: Princeton Architectural, 2009.

Hays, K. Michael. “Critical Architecture: Between Culture and Form.” *Perspecta 21: the Yale Architectural Journal*. By Carol J. Burns and Robert Taylor. Cambridge, MA: MIT, 1984. Page 389-397.

Hays, K. Michael. “The Envelope as Mediator.” *The State of Architecture at the Beginning of the 21st Century*. Ed. Bernard Tschumi and Irene Cheng. New York: Monacelli, 2003. Page 66-67.

Iwamoto, Lisa. Introduction. *Digital Fabrications: Architectural and Material Techniques*. New York: Princeton Architectural, 2009.

Kennedy, Sheila. “Future Forecast: Scattered Fabrications with a Chance of Agency.” Introduction. *Uncertain Futures: Two Years of Student Research at the MIT Department of Architecture*. Cambridge, MA: SA+P, 2009.

Kennedy, Sheila. “Responsive Architecture.” *Material Design Materialitat in Der Architektur*. Basel: Birkhauser, 2011.

Keyser, Barbara Whitney. “Ornament as Idea: Indirect Imitation of Nature in the Design Reform Movement.” *Journal of Design History.* Vol. 11, No. 2, 1998. Page 127-44.

Kipnis, Jeffrey. “Ordos: Nine Houses by GSD Faculty.” *Harvard Design Magazine*, Spring - Summer 2009, Issue 30. Page 105-25.

Kirsch, Karin. *The Weissenhofsiedlung: Experimental Housing Built for the Deutscher Werkbund, Stuttgart 1927*. New York: Rizzoli, 1989.

Lally, Sean. *Energies: New Material Boundaries*. London: J. Wiley, 2009.

Loos, Adolf. “Adolf Loos: Ornament and Crime.” *Programs and Manifestoes on 20th-Century Architecture*. Ed. Ulrich Conrads. Cambridge, MA: MIT, 1970. Page 19-24.

Moussavi, Farshid, and Michael Kubo. *The Function of Ornament*. Barcelona: Actar, 2006.

Semper, Gottfried. *The Four Elements of Architecture: and Other Writings*. Cambridge: Cambridge Univ., 1989.

Smith, Elizabeth A.T. *Case Study Houses*. Köln: Taschen, 2002.

Venturi, Robert. “The Inside and the Outside.” *Complexity and Contradiction in Architecture*. New York: Museum of Modern Art, 1977. 70-87.

Urban Solarium

Thermal Performance in Boston

by

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