Low Carbon Architecture

New Approach Toward Sustainability in Relation to Existing Buildings

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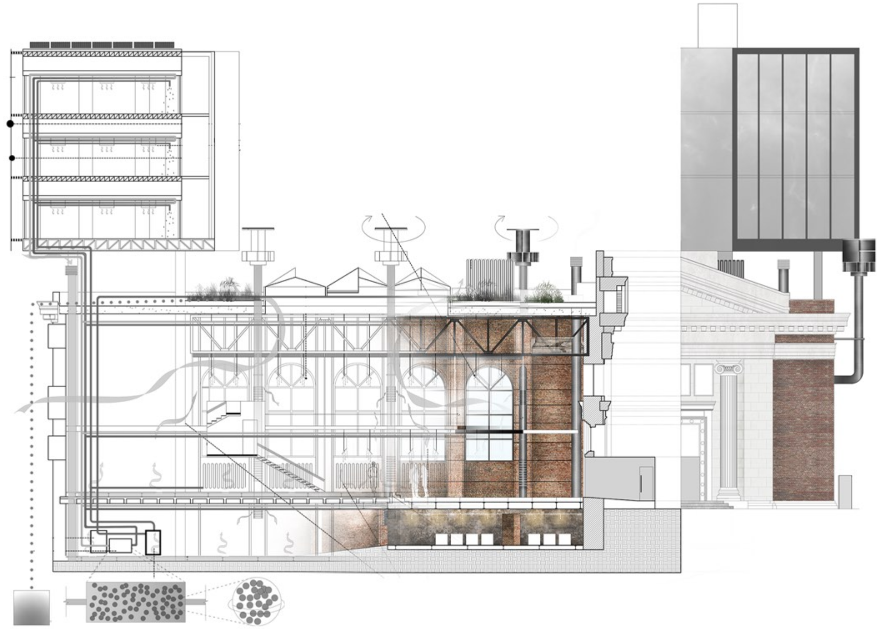

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Abstract

The built environment puts the greatest pressure on the natural environment out of all human activities, so it has a fundamental obligation to be environmentally sustainable. Carbon dioxide (CO2) or carbon emissions is a significant greenhouse gas that is inevitably associated with energy use when energy is produced via the combustion of fuels.

Total life cycle energy, embodied and operational energy over a building's lifetime, creates significant environmental impacts through the production of CO2. By keeping and reusing existing and historic buildings rather than discarding them and building new, the embodied energy, or the energy that is locked up, can help to mitigate future damage. These buildings already exist, which indicates that the energy consumed to build them has been applied and the carbon associated with their construction has been released.

The greenest buildings are ones that are already built. They are inherently more sustainable than any new buildings even with green and zero net energy systems and can be retrofitted to become more energy efficient. To demonstrate this thesis specifically, a design project engages with an abandoned late nineteenth-century bank building in Philadelphia and transforms it into a high-performance building that is prepared for long-term use. For the immediate next use, the project creates a work environment and a new vertical expansion of residential units.

The preservation field always confronts the challenge of bridging the gap between embodied energy and operational energy. In the abandoned bank, there are some aspects of this building that are near permanent and define its character, such as brick walls with masonry ornament, two bank vaults, Wissahickon Schist foundation wall, and ceiling trusses. This thesis explores new approaches to leverage the embodied energy of the permanent parts of the abandoned bank and transform it into a high-performance building. A lot of energy of the abandoned bank, the building's material, and thermal mass is still actively performing. The building's envelope, the thick masonry wall, provides a moderately good insulating effect that will temper the indoor air that also preserves its historical character both inside and outside. The embodied energy of the building's envelope is leveraged by pairing it with localized heating and cooling using a radiation and conduction system. Other approaches that increase energy performance in the existing building, include the use of phase-change material for cooling the process water, solar hot water, creating drinking water via a solar still in the skylight, and distilled water from radiant cooling surfaces. In the new construction, a thermal switch facade and double-skin facade for the residential units are proposed, along with providing flexible space with thick mobile interior wall units.

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General Audience Abstract

Global warming as a problem of the twenty-first-century increase concentrations of greenhouse gases in the atmosphere due to human actions like burning fossil fuels. The built environment puts the greatest pressure on the natural environment of all industrial parts, and it has a fundamental role to manage the environment sustainably. Total life cycle energy, embodied and operational energy over the lifetime of the buildings, creates significant environmental impacts through the production of CO2. Embodied energy is the whole amount of energy applied to extract the raw materials, manufacture, transport, install, and use the product across its life cycle. Assessments of the embodied energy of historic and existing buildings are helping to mitigate future damage to resources. These buildings already exist, which indicates that the energy consumed to build them has been applied and the carbon associated with their construction has been released.

The greenest buildings are ones that are already built. They are inherently sustainable and can be retrofitted to become more energy efficient. Specifically, this design engages with an abandoned late nineteenth-century bank building in Philadelphia and transforms it into a high-performance building that is prepared for long-term use. For the immediate next use, the project creates a work environment and in a new vertical expansion, residential units.

In the abandoned bank, there are some aspects of this building that are near-permanent and define its characters, such as brick walls with masonry ornament, two bank vaults, Wissahickon Schist wall, and ceiling trusses. This thesis explores the new approaches to leverage the embodied energy of the permanent parts of the abandoned bank and transform it into a high-performance building. This is achieved through various means such as providing localized heating and cooling by using a radiation and conduction system, the use of phase-change material for cooling the process water, solar hot water, creating drinking water via a solar still in the skylight and distilled water from radiant cooling surfaces. In the new construction, a thermal switch facade and double-skin facade for the residential units are proposed, along with providing flexible space with thick mobile interior wall units.

Acknowledgments

I would like to thank my committee members Paul Emmons, Meredith Sattler, and Susan Piedmont-Palladino for their passion for my project and process, for encouraging my curiosity, and for always challenging me to dig a little deeper.

I also would like to express my gratitude to my parents and my sister for their endless support, I would never be here without you.

I would like to thank Jodi la Coe for introducing this wonderful building and for her kindness and assistance during my education.

Finally, I would like to thank the owner of the bank, Timothy McDonald, for kindly showing me the building and without his initial support, the project would have been very difficult.

TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION

Energy and Carbon
Operational Energy
Embodied Energy
Energy Value Within Existing Buildings
Bridging the Time Gap
Abandoned Bank
Program

Energy and Carbon

In recent years, the global knowledge of environmental impacts of climate change and ozone layer depletion significantly increased. The built environment puts the greatest pressure on the natural environment of all industrial parts. The role of the built environment is very fundamental to manage the environment sustainably. Carbon dioxide (CO2) or carbon emissions is a significant greenhouse gas that is inevitably associated with energy use when energy is produced via the combustion of fuels. A large amount of energy is required for the building's operation. Approximately six tons of material per person per year are used in the construction industry which is the highest user of materials in the world(1). Annually approximately 40% of global energy is dedicated to building's production, operation, maintenance, replacement, and demolition phases(2).

Total life cycle energy, embodied and operational energy over the lifetime of the buildings, creates significant environmental impacts through the production of CO2. Reducing energy consumption in buildings provides a reduction in environmental degradation generated by CO2.

Although much research has been done on the possibility of reducing operational energy consumption, limited research has been done on diminishing the energy needed for the construction of buildings period. Of those studies on the assessment of energy and carbon in the construction industry, there has been much focus on the construction of new buildings. Energy and carbon evaluation of the existing buildings were usually restricted to only operating energy.

One reason is that it is commonly accepted that a building's operating energy over its normal forty-year lifespan is several times higher than the energy needed for a building's construction. Therefore, it has received more attention to areas that are considered to be the largest energy savings benefits. However, with the appearance of a greater amount of buildings with low operation energy, the importance of embodied energy is expected to grow. Various recent studies propose that the primary construction's energy is much greater than formerly believed. Thus, this significant energy demand of construction must be reduced. One approach to diminish the cons-

-truction embodied energy is to increase the current rates of reusing the existing buildings.

Operational Energy

Operational energy is defined as the energy utilized for maintaining the interior environment of the building which includes total energy which is brought within the system to run ventilation, lights, elevator, heating, cooling, heating water, and appliances. Energy can be generated from fossil fuel which creates high carbon emissions, renewable energy from on-site, or a mix of both which produces low carbon emissions.

Embodied energy

Crowther defines embodied energy as "The embodied energy of a building can be described as the total energy required in the creation of a building, including the direct energy used in the construction and assembly process, and the indirect energy that is required to manufacture the materials and components of the building"(3). Direct energy includes energy used in the project site or offsite operations, like transportation, construction, assembly, prefabrication, and administration. The total amount of energy needed from the extraction of raw material, through processing and production, and total energy consumed for transportation through this process is considered as Indirect energy. Measuring embodied energy is not yet an exact science. Few recent studies however indicate that the embodied energy has a much greater value than previously estimated.

It is worthwhile to break down the embodied energy value into the direct construction's energy, and indirect energy of materials and components. In 1993 some studies of the industrialized building done by Cole, Oka, and Treloar show that nearly 5% to 13% of the whole value of the embodied energy is the direct energy applied on-site to assemble the building. The rest of the embodied energy is in the components and materials, about 20% to 50% is in the building's structure, approximately 50% to 70% of the remaining being in the building envelope, finishes, and the services. However, with these primary values, the embodied energy does not come to an end.

Again, the same researchers have noted that the embodied energy in the restoration of a building over its lifetime is likely from 20% to 100% of the primary embodied energy(4-6).

Energy Value Within Existing Buildings

Global warming as a problem of the twenty-first century increases concentrations of greenhouse gases due to human activities like burning fossil fuels. Assessments of embodied energy and carbon of historic and existing buildings are helping to mitigate future damage to resources. These buildings already exist, which indicates that the energy consumed to build them has been applied and the carbon associated with their construction has been released. Embodied energy has to be the focal point for the preservation field by focusing on all of the energy that was locked up in a historic building from its original construction. Preservation has numerous sustainable attributes that make it a cohesive partner to sustainability and is considerably more carbon and energy-efficient than demolishing historic buildings and replacement with new more energy-efficient ones. Naming the new building “green” is absurd when it takes so much energy to replaces an existing building with new.

The Greenest Building is examined the climate change reductions that can occur from reusing existing buildings over demolition and replacing them with new buildings:

“This groundbreaking study concludes that building reuse almost always offers environmental savings over demolition and new construction. Moreover, it can take between 10 and 80 years for a new, energy-efficient building to overcome, through more efficient operations, the negative climate change impacts that were created during the construction process”(7).

Historic preservation has the potential for displacing a large fraction of the energy used directly at the job site and embodied in construction materials. If all of the inputs of operational and embodied energy of a normal lifespan of forty years are combined altogether, it is noticeable that most part of the total energy consumption is from the embodied energy of the building’s materials.

Many historical and old buildings have been built from durable, long-lasting materials such as masonry wall, high-quality timberwork, or slate roofing. Thus, it is predictable that these buildings can be pretty cost-effective and enduring in terms of energy and carbon. Every brick in building needs fossil fuels to be burned to be manufactured, and energy must be used to cut and transfer each piece of timber. Since the building stands, that energy is there, serving effective intention. Ruin a building and you destroyed the energy embodied in that building too.

The greenest buildings are ones that are already built and to bring the new life to it we have to reuse it. They are inherently sustainable and can be retrofitted to become more energy efficient. From an energy perspective that is infinity more sustainable than any new signature of zero net energy buildings or any new, green, energy-efficient systems.

Bridging the Time Gap

The preservation field always confronted with the challenge of bridging the gap between embodied energy and operational energy when comparing the energy efficiency of historic and existing buildings versus new constructions. This thesis explores the new approaches to leverage the embodied energy of an abandoned late-nineteenth-century bank building in Philadelphia and by creating the bridge between the embodied and operational energy, transforms it into a high-performance building that is prepared for long-term use. For the immediate next use, the project creates a work environment and in a new vertical expansion, residential units.

In the abandoned bank, there are some aspects of this building that are near-permanent and define its characters, such as brick walls with masonry ornament, two bank vaults, Wissahickon Schist wall, and ceiling trusses. This thesis explores the new approaches to leverage the embodied energy of the permanent parts of the abandoned bank and transform it to a high-performance building. A lot of energy of the abandoned bank, the building’s material and thermal mass is still actively performing. The building's envelope, the thick masonry wall provides a moderately good insulating effect that will temper the indoor air that also preserves its historical character both inside and outside. The embodied energy of the building's envelope is leveraged by pairing localized heating and cooling by using a radiation and conduction system. Other approaches that increase energy performance in the existing building, include the use of phase-change material for cooling the process water, solar hot water, creating drinking water via a solar still in the skylight and distilled water from radiant cooling surfaces. In the new construction, a thermal switch facade and double-skin facade for the residential units are proposed, along with providing flexible space with thick mobile interior wall units.

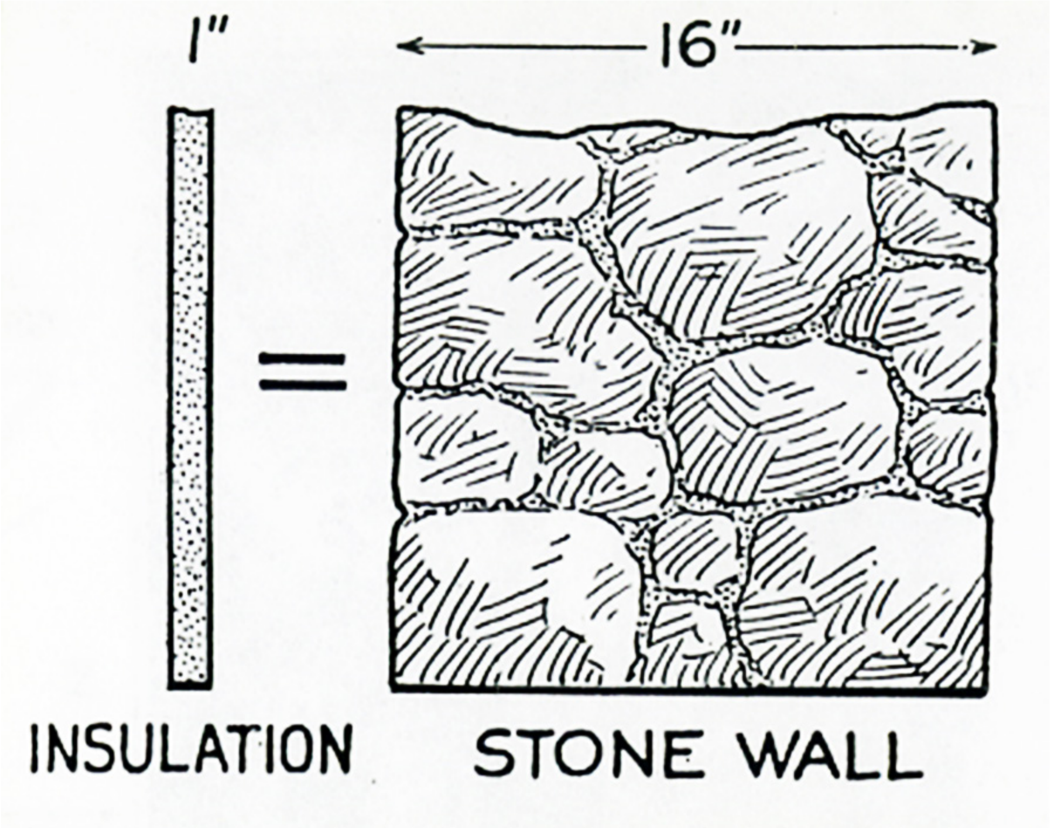


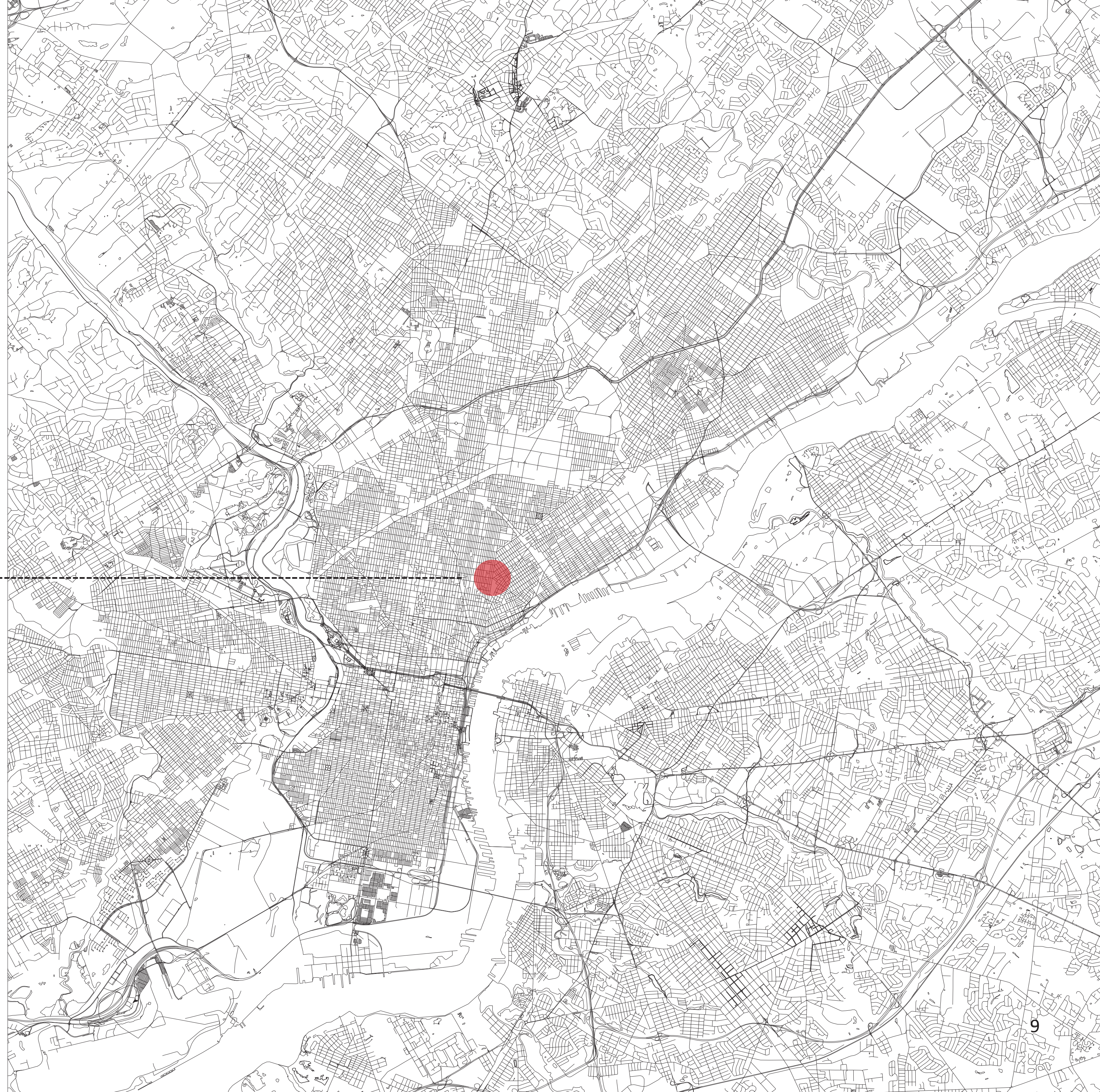
Figure 1: Paul Close, Building Insulation: *Principles and Application of Heat and Sound Insulation for Buildings* (Chicago: American Technical Society, 1941)

1958 N Front St

Philadelphia

PENNSYLVANIA

Abandoned bank

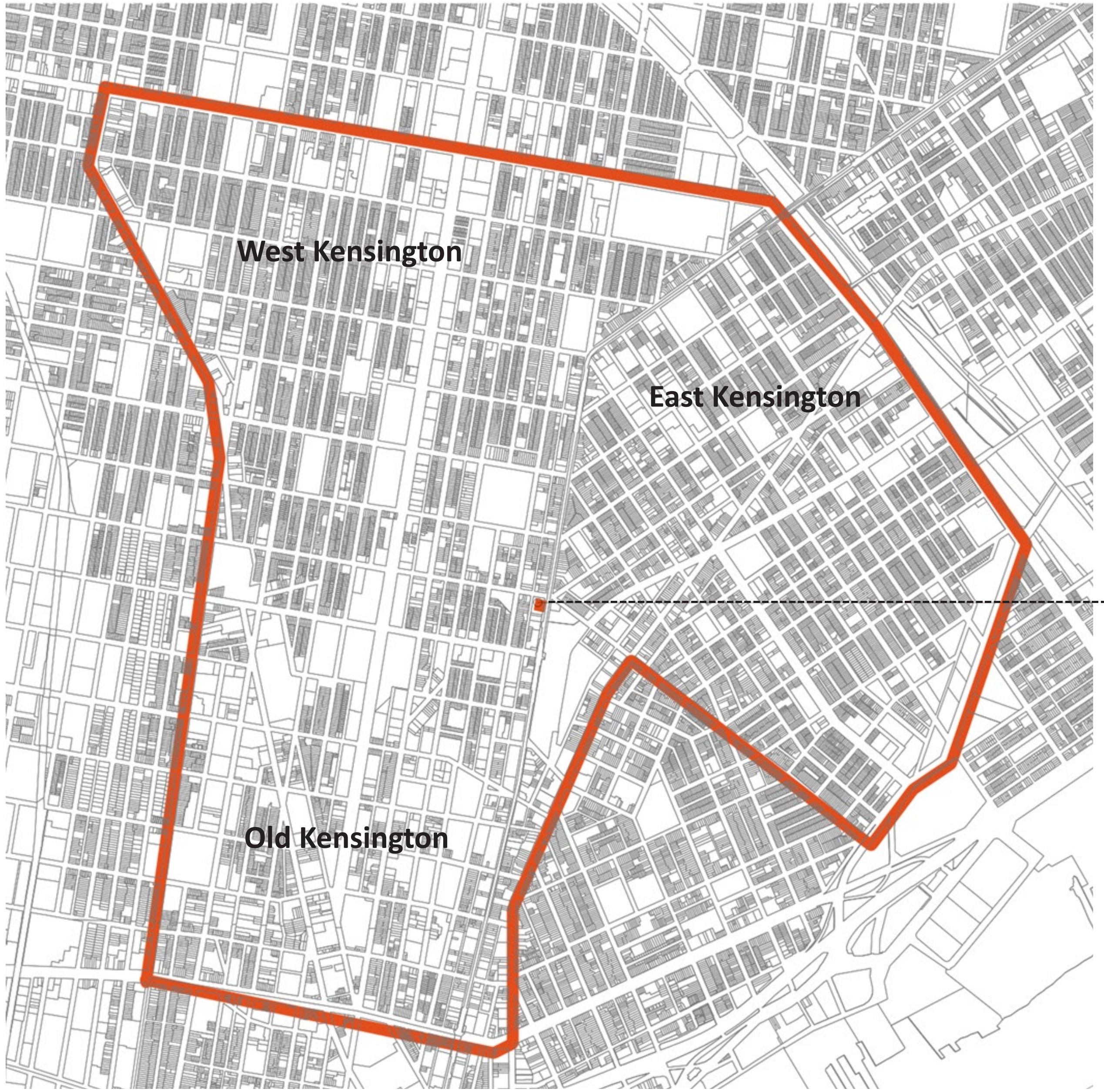


Beginning in the early 19th century, the Kensington neighborhood of Philadelphia was dominated by the textile and textile-related industries(8).

For over one hundred years, it was known as “one of the greatest industrial centers in the world, and through its influence Philadelphia [became] the leading manufacturing city in the United States”(9).

By 1810, Kensington was already “becoming a manufacturing settlement” and had 869 buildings of varying types(10).

Figure 2. Advertisement, Public Ledger, 1916. http://www.preservationalliance.com



Boundary of buildings related to Textile industry in Kensington

Project Site, Abandoned Bank

Figure 3. Progress of steel construction, looking north from bent 189, showing crosswires, Sept. 11, 1916. [including Ninth National Bank, Front St. bel. Norris Street.] . The Library Company of Philadelphia . https://digital.librarycompany.org

“The two structures on the southwest corner of Front and Norris are the remnants of Ninth National Bank (on the corner) and the Industrial Trust, Title and savings Company (the building south of the bank). The Ninth Bank was founded by a group of Kensington Textile manufacturers. It’s started its operation on August 1, 1885 after failed Shackamaxon Bank on the corner of Frankford and Palmer. The Industrial Trust, Title and Savings Company had a very similar board with many overlapping members of Ninth National Bank. It was founded very soon after Ninth Bank”(11). The two institutions officially merged together in 1923.

Figure 4. Progress of steel construction in Kensington Avenue at bent 265, looking south, October 16, 1916.

Figure 5. Progress of steel construction, looking south on Front St. from Bent 155, August 14, 1916.

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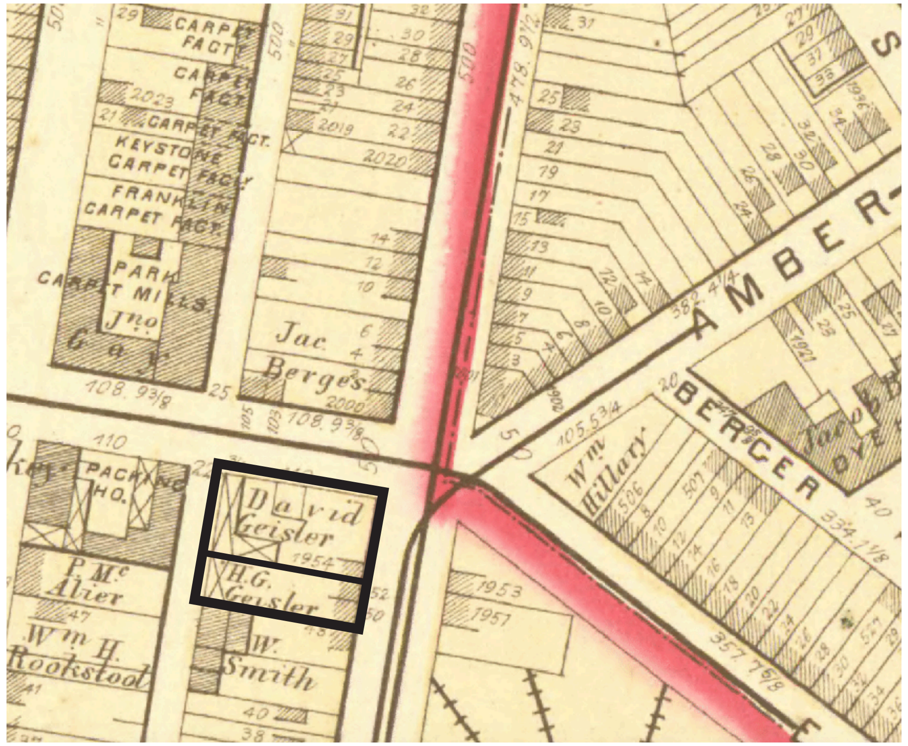
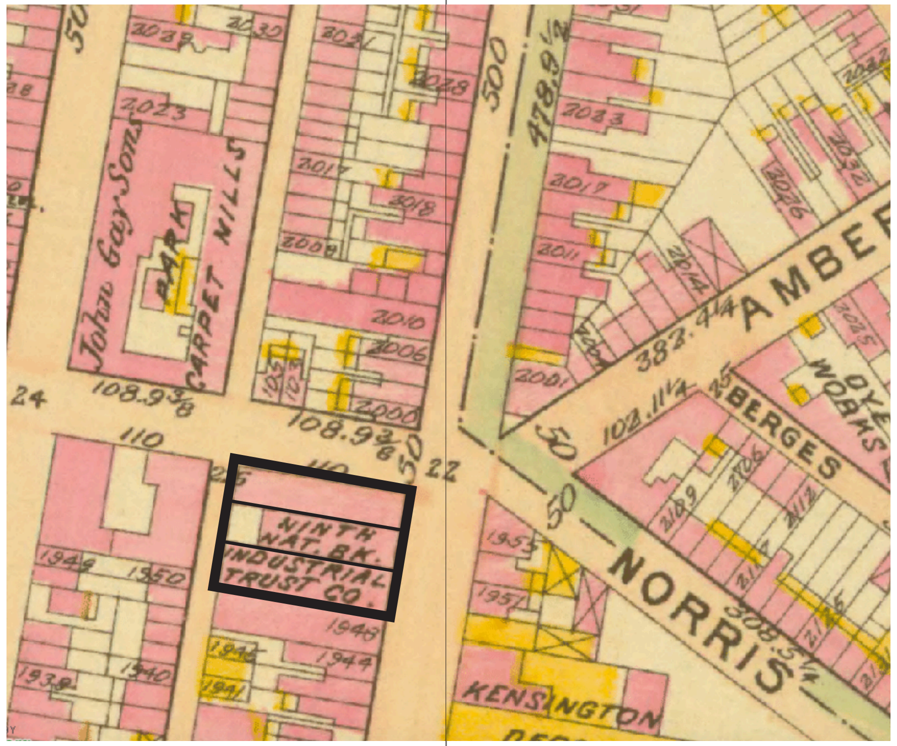


Philadelphia, Kensington neighborhood, 1875.

Beginning in the early 19th century, the Kensington neighborhood of Philadelphia was dominated by the textile and textile-related industries.

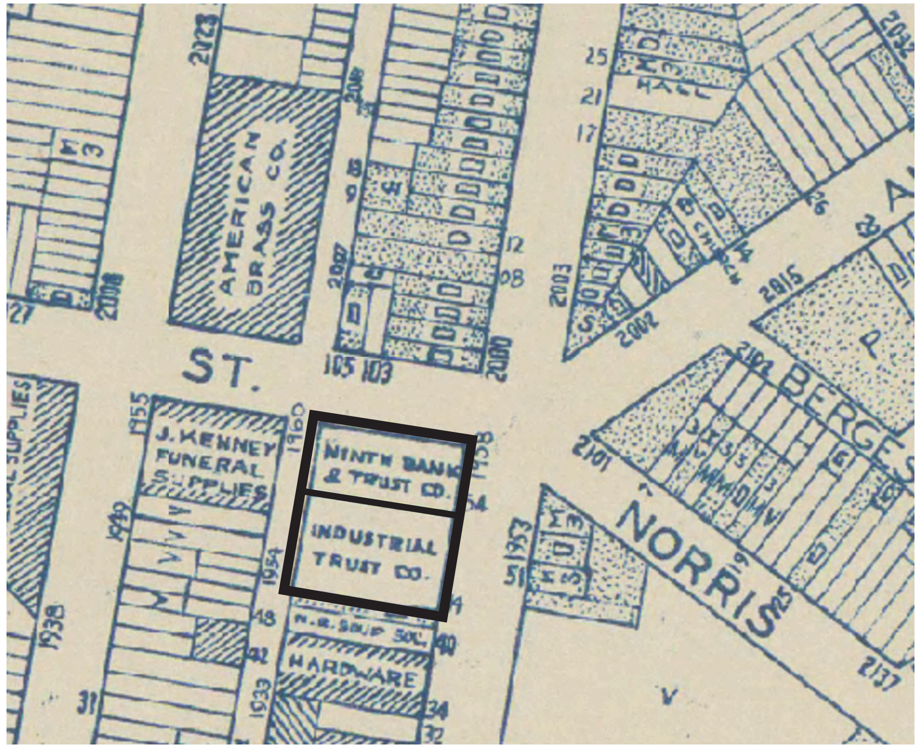
Figure 6. https://www.philageohistory.org



Philadelphia map, Kensington neighborhood, 1910.

Ninth National Bank, started its operation on August 1, 1885. Very soon after, the Industrial Trust Company was founded.

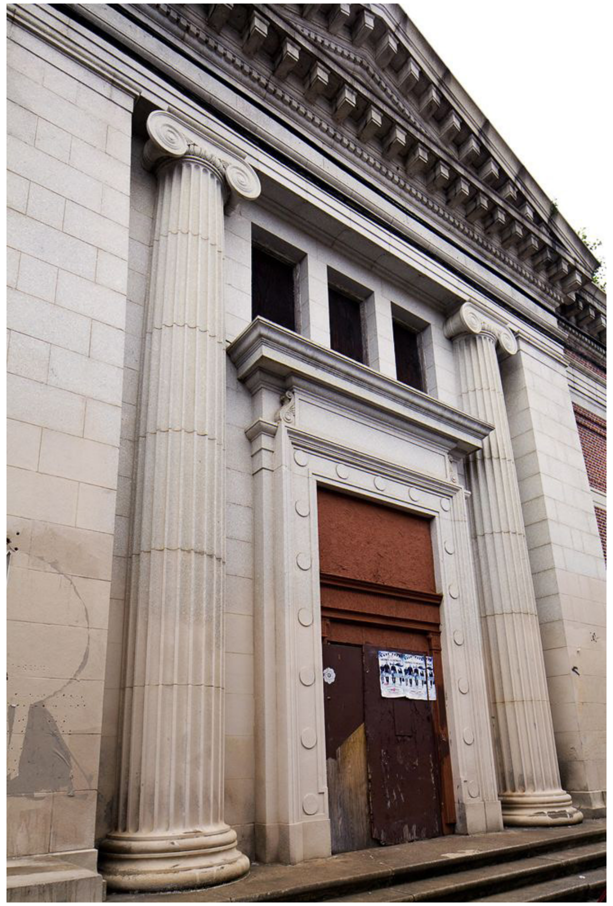
Figure 7. https://www.philageohistory.org



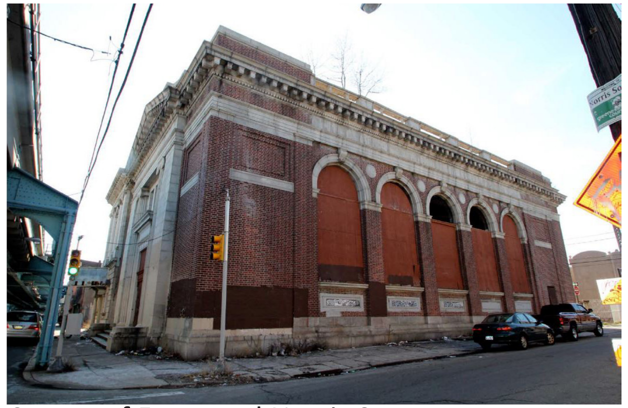
Philadelphia map, Kensington neighborhood, 1942.

Ninth National Bank and Industrial Trust andsavings company formally merged operations in 1923.

Figure 8. https://www.philageohistory.org



East Elevation Front Street



Corner of Front and Norris Street

Corner of Norris and Hope Street

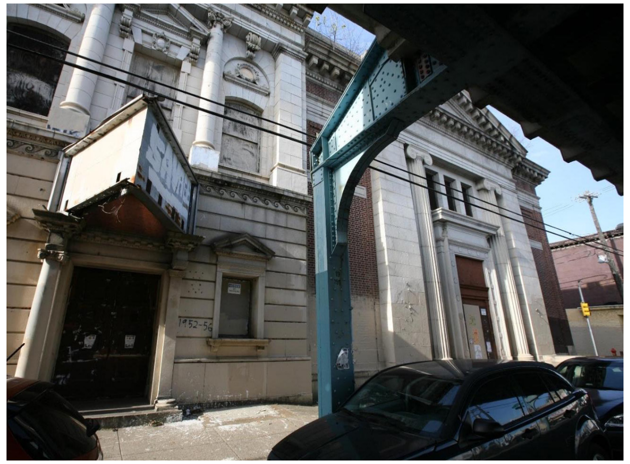
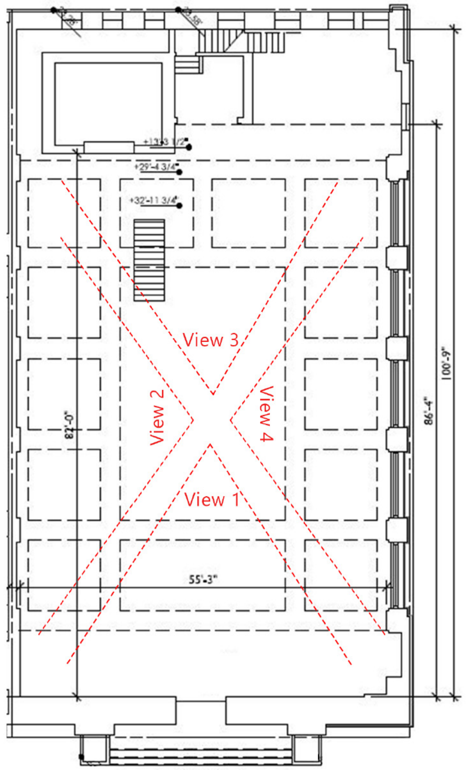


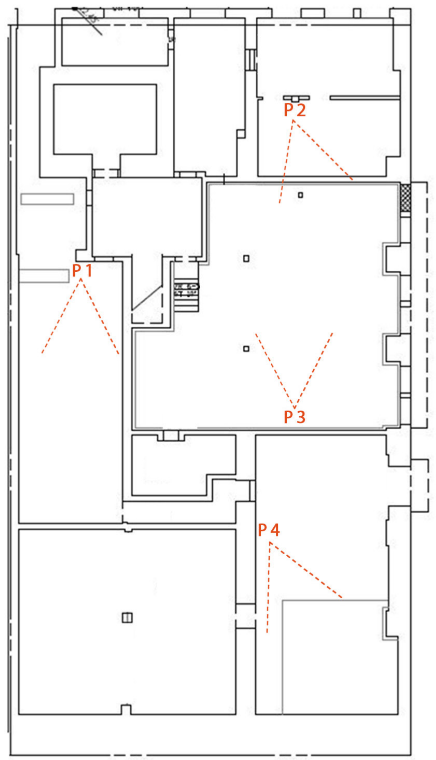
Photo above: Railroad Bridge crosses through Front Street, adjacent to the east facade
Photo Below: View to the abandoned bank from railroad bridge in Front Street

Interior Perspectives of Abandoned Bank

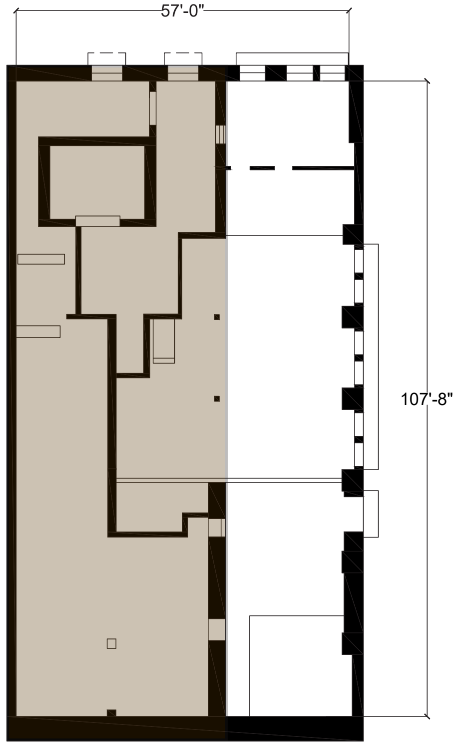


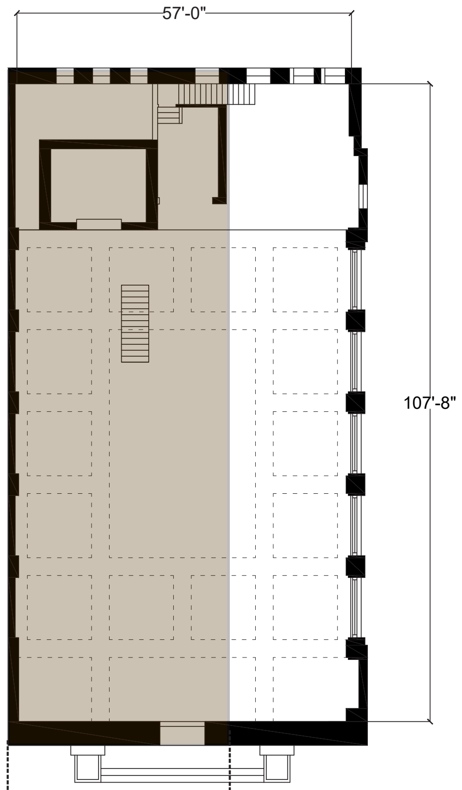
Ground Floor

Interior Perspectives of Abandoned Bank



Basement Floor Plan





The entire building was built in two different eras. The operation of the first part began in 1885, and the second part was added 50 years later. So, the building has two different (ground floor/ basement ceiling) structure system. The older structure system is brick arches at the ceiling with load-bearing walls (Wissahickon schist wall), and the newer one is the concrete beam and block roof with the masonry load-bearing wall.

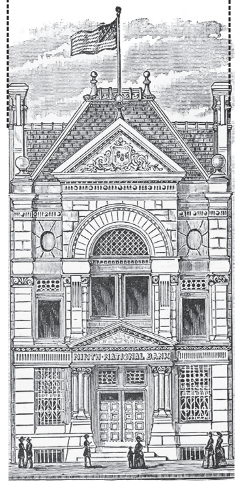
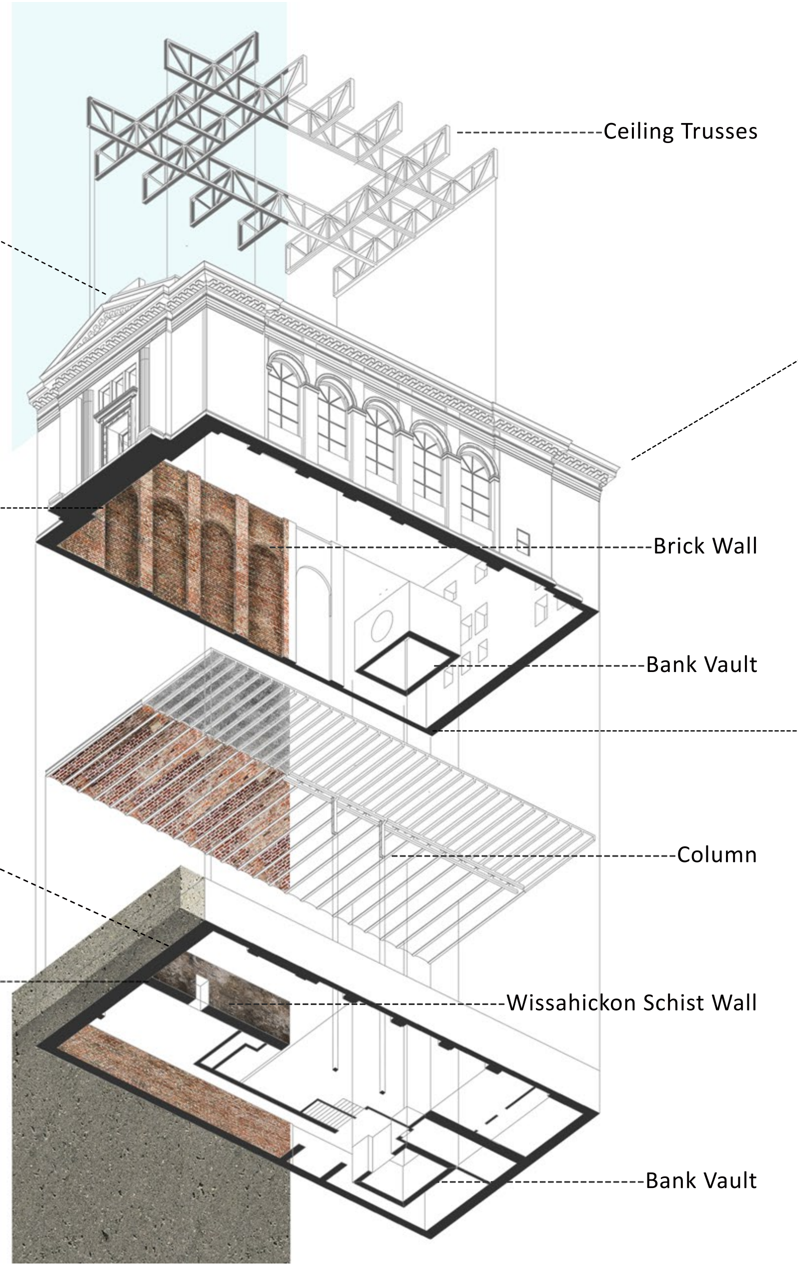


Figure 9. Ninth National Bank First Elevation. https://libwww.freelibrary.org

Brick Arch Ceiling, Basement

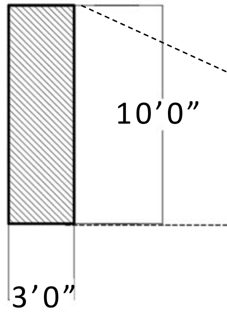
Brick Arch Ceiling, Basement

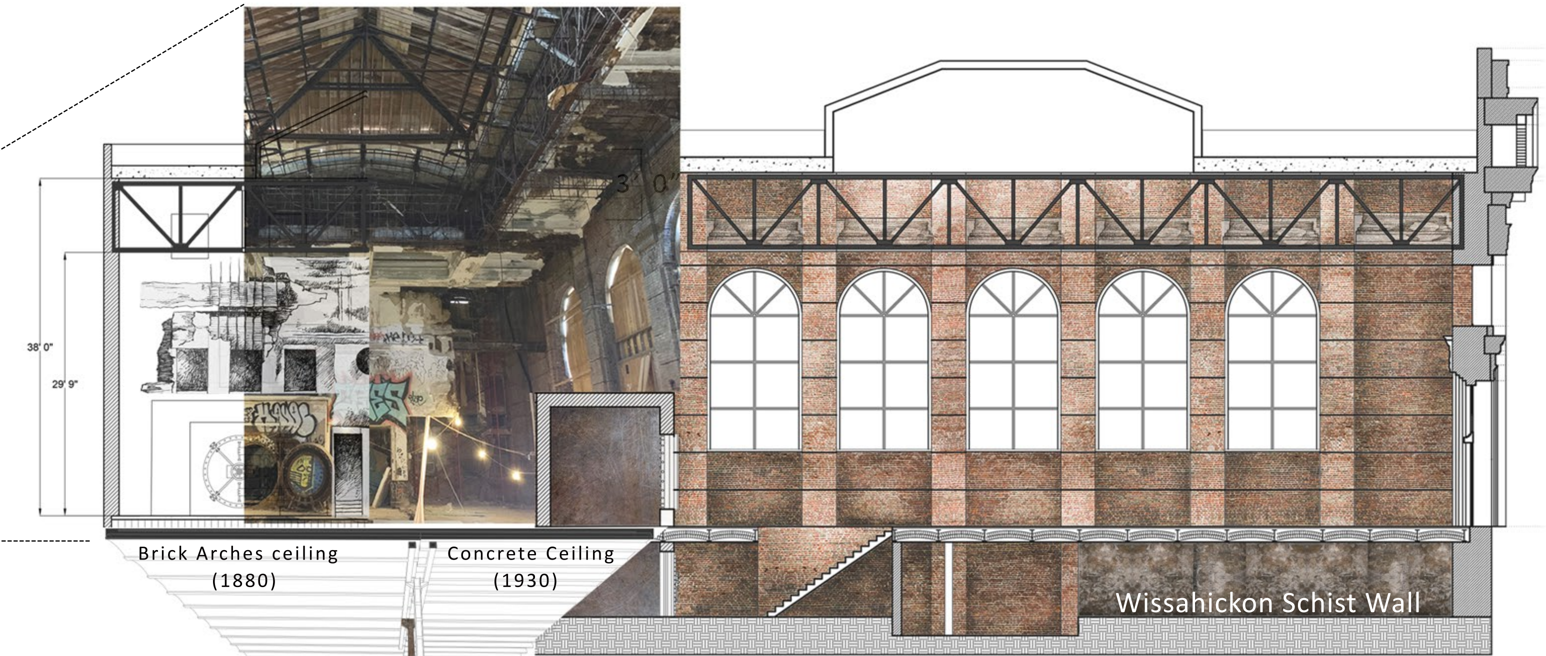
Conceret Ceiling, Basement



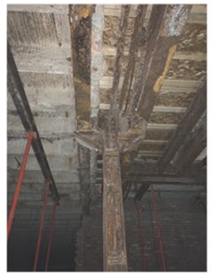
The **embodied energy** of the abandoned bank’s material and thermal mass is still **actively performing**.

The building’s **envelop, the thick masonry wall** provides a moderately good insulating effect that will temper the indoor air that also preserves its historical character both inside and outside.

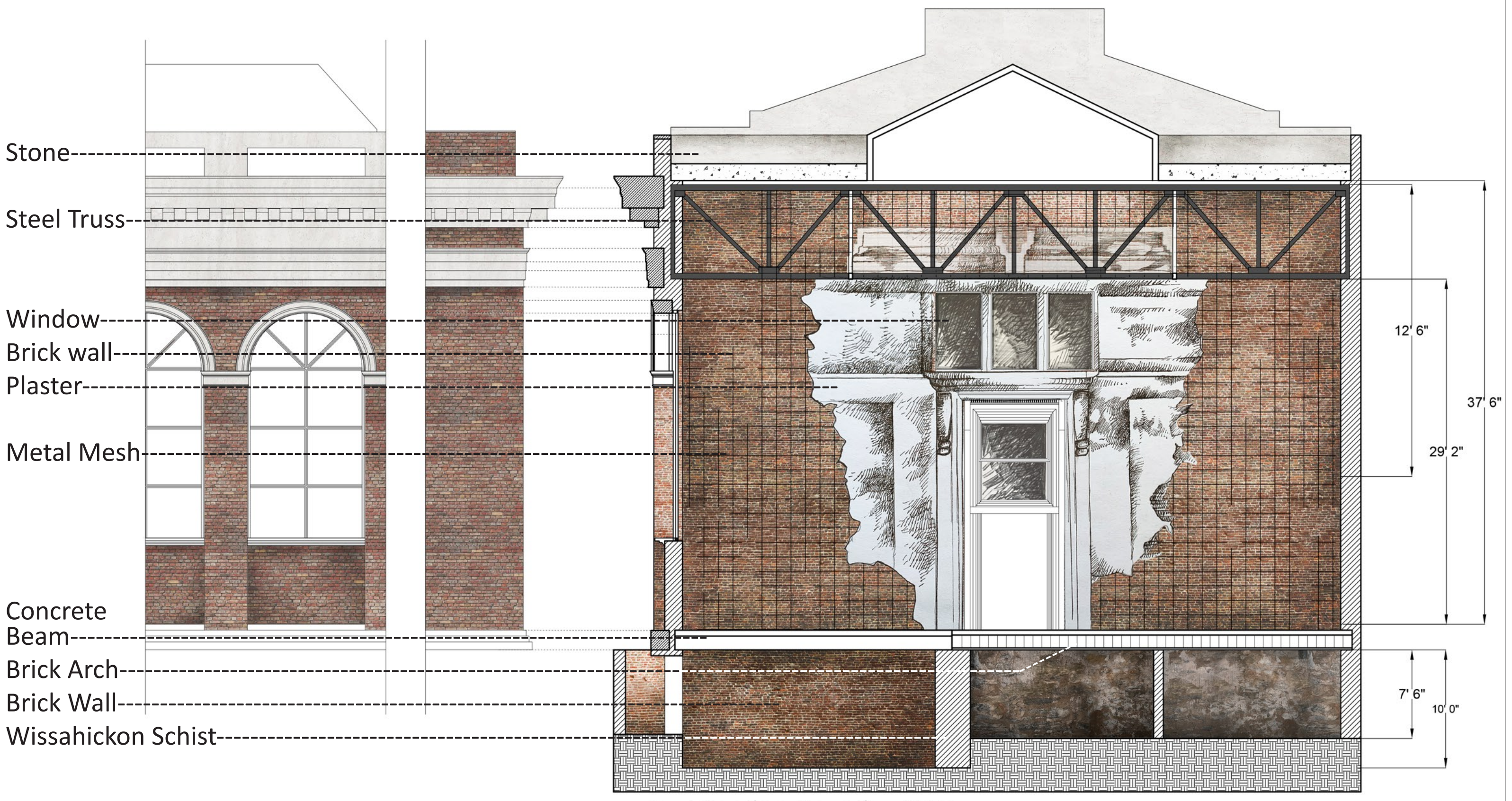




North Elevation . OLD



In the abandoned bank, there are some aspects of this building that are **near-permanent and define the characters** of the building. The project wants to concurrently **preserve and enhance the embodied energy of permanent parts** which include brick walls with masonry ornament, two bank vaults, Wissahickon Schist wall, ground floor's structure, and ceiling trusses **while keeping it’s aesthetic and historical values.**

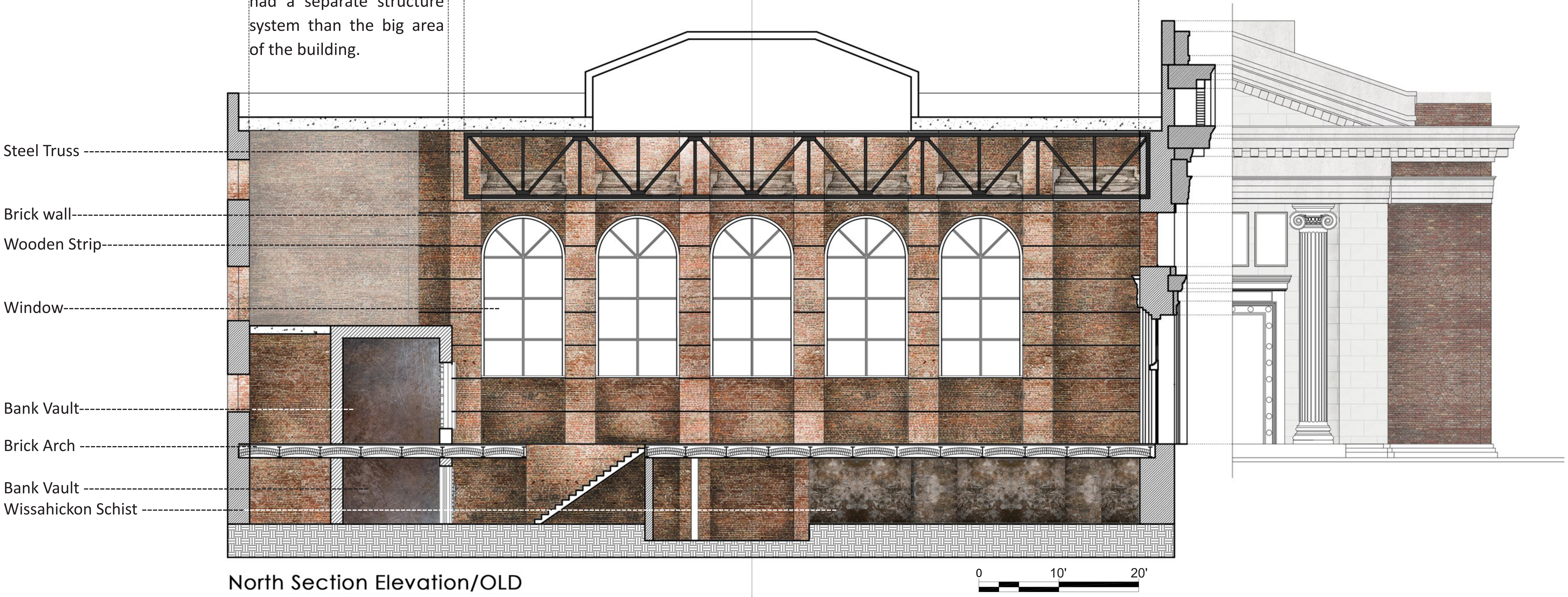


East Section Elevation/OLD

West Section Elevation/OLD

This part of the building was three stories which most of it is ruined and had a separate structure system than the big area of the building.

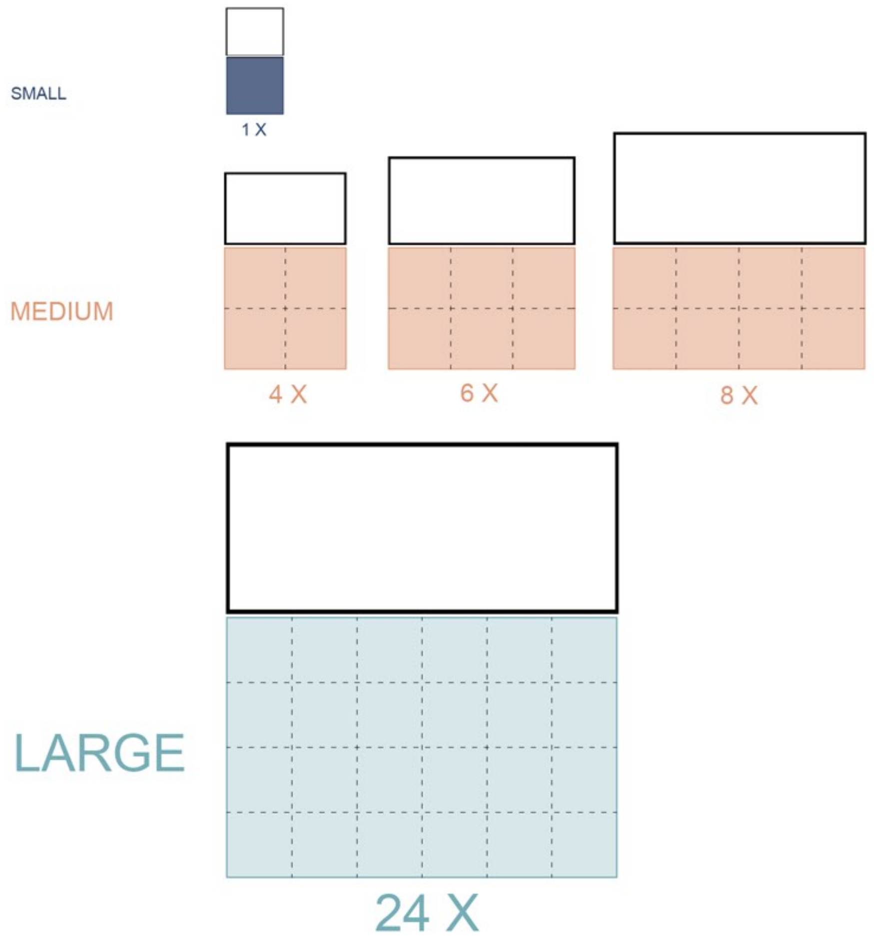
Main large space of the building which was one story with ceiling trusses and a big skylight.



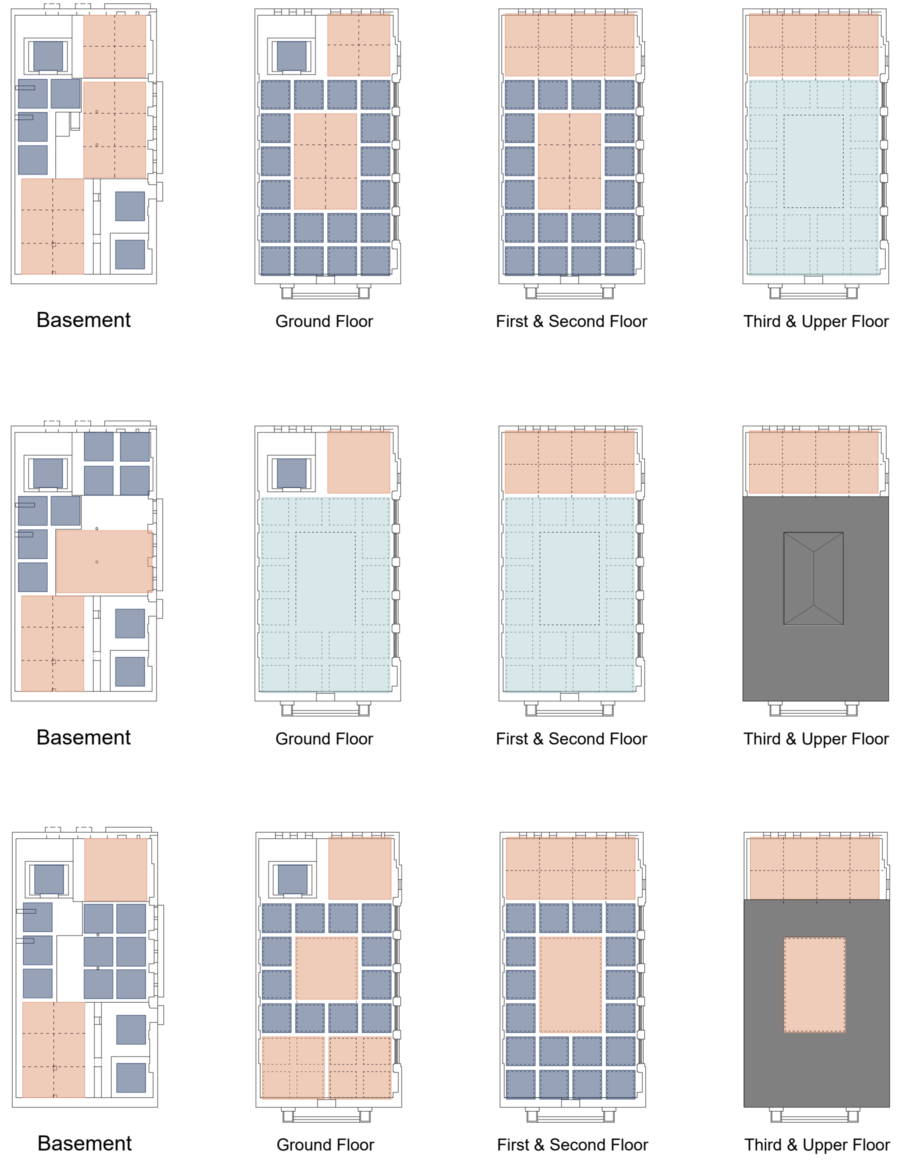
North Section Elevation/OLD

PROGRAM:

For long-term use design, it is more valuable and flexible to **define program based on size and dimension**. Thus, the project defines space based on three sizes, small, medium, and large and various programs can be fit to these spaces according to the needs of the community. But for the immediate next use, the project creates a work environment and a new vertical expansion of residential units.



Different Alternatives



Program		Small		Medium		Large	
		1-4 Person Per Room Seating	**12 Person per Room Standing**	**30 Person per Room Seating**	**30 Person per Room Standing**	**200 People per Room Seating**	**100 People per Room Standing**
Cultural Architecture	Performing Art Center Theater Dance Hall	Projection Room Single dressing Room Office Room	Clock Room Locker Shower Changing Room	Dressing Room Cafe/ Bar/ Restaurant Green Room	Workshop Locker Storage Rehearsal Room Stage	Auditorium (Seating Area)	Ball Room
	Cinema	Projection Rom Office Room	Clock Room Reception and Waiting Area	Cafe/ Bar/ Restaurant		Seating Area	
	Exhibition Gallery	Lounge Office Room	Reception and Lobby Exhibition Space Storage Kitchen	Cafe/ Bar / Restaurant Media Room	Exhibition Space Shop		Exhibition Space
Education	School of Music, Drama & Light Craft	Staff Rooms Solo Practice Room	Kitchen Lounge	Study Area Orchestra Rehearsal Area Social Room Dining Hall Class Room	Storage	Art and Craft and Needle Work	Drama Studio Performing Area
	Art School	Office Room	Exhibition Space	Glass Cold Shop Dining Hall Media Room Class Room	Wood Shop Print Making Storage Gallery Metal Studio	Painting and Drawing Shop	Glass Blowing Shop
	Library	Writing Studio Sound and Vision Studio Record-ing Study Room	Photocopies Search Area Reception and Lobby	Study Area Administration Building Support Cafe / Restaurant / Bar Conference Room Research Area		Open Collaborative Study Area	Library Stack
	Culinary School Cooking Library	Waiting Area Lounge	Reception and Lobby Small Cooking Class	Bakery and Cafe Lounge and Cafe Open Plan Area: Deli	Shop Showcase Kitchen	Dining Space + Library Stack + Shops	Library Stack + Exhibition

Program		Small		Medium		Large	
		1-4 Person Per Room Seating	12 Person per Room Standing	30 Person per Room Seating	30 Person per Room Standing	200 People per Room Seating	100 People per Room Standing
Hospitality	Hostel Dorm Airbnb	Administration, Massage Room Bed Room/ Study Room	Storage Kitchen	Rooms Housekeeping Rest Room Spa Area	Kitchen Storage	Bar / Restaurant / Self Service	
	Restaurant Bar Cafe	Waiting Area / Lounge Seating Area (Dining) Administration Room	Reception and Lobby	Seating Area / Dining : Sushi Bar Coffee Bar	Kitchen Standing bar tables	Seating Area (Dining)	
	Read Cafe	Space for Reading	Reception and Lobby	Space for Reading Book Bar Cafe	Kitchen	Open Collaboration Study Area (Education and Drinking)	Book Stack
Commercial	Department Store Store / Retail / Show Room	Lounge Office Room	Display Area Waiting Room Fitting Room	Staff Room Lounge Cafe	Display Area Showcase Area Storage Shop Area		Shop Area Exhibition Space
Sport	Fitness Club	Lounge Administration Office Room Massage Room	Reception and Lobby Shower Locker	Cafe / Restaurant Lounge Rest Room Studios: Yoga, Pilates, ...	Warm up Area Changing Room		Weight Lifting and General Exercise Area
Religious Architecture	Church	Small Group Room Office Room	Lounge	Education Room Lounge, Cafe Conference Room Practice Room (Orchestra)	Storage Exhibition	Chapel	
Office Building	Work Environment	Small Meeting Room Study / Work Room Administration	Kitchen Storage Reception and Lobby	Dining Area Lounge Space Break Room/ Food and Service Area Conference Room Cafe Library		Shared Office Area (Convergence of hospitality and work space)	

CHAPTER 2

BRIDGING THE ENERGY EFFICIENCY GAP

Embodied Energy within the Building's Envelop
Heat Transfer Disciplines
The Old Method of Heating
Local Insulation
Portable Heating System
Conductive Heating System
Radiant and Conductive Heating System
Infrared panels: Vertical or Horizontal?
Local Heating and cooling as an Alternative to Insulation
Thermal Comfort Improvement
Cooling System
Radiant Cooling
Heating and Cooling Design Strategies: Heating people, NOT places
Personal Distilled Water

Embodied Energy within the Building's Envelop

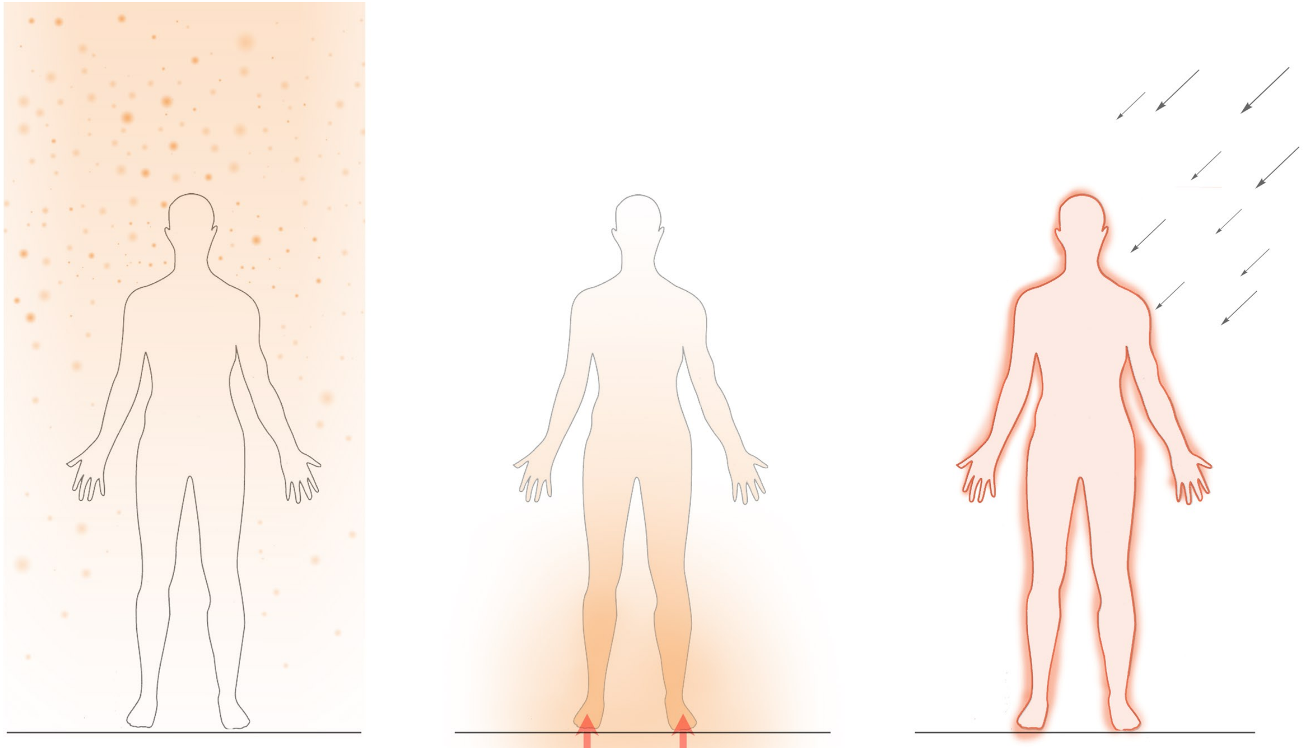
The preservation field always confronted with the challenge of bridging the gap between embodied energy and operational energy. The energy that was spent 150 years ago for creating this abandoned bank and a little more energy is needed to retrofit and build new in. But a lot of that energy, the thermal mass is still performing. The building's envelop, the thick masonry wall provides a moderately good insulating effect that will temper the indoor air that also preserves its historical character both inside and outside. Thus, instead of using an air system that would obscure the visual and the fabric of the building by huge ducts and vents and then it requires putting the insulation on that fabric, the building's envelope considers as a mass which is still actively performing. By pairing localized heating and cooling by using a radiation and conduction system, we can leverage the performance of that building.

Heat Transfer Disciplines

Most modern heating systems are based on convection, heating the entire amount of air in a space to keep people comfortable. The old method of heating was primarily based on radiation and conduction, which transmits heat directly to people, causes energy consumption to be independent of the size of the room or building, and was much more energy-efficient than convection.

Heat transfer with the human body and its environment happens through radiation, convection, conduction, and evaporation. By convection, heat will transfer from fluids (gases or liquid) and skin. Conduction relates to the heat transfer between the human body and another object that is in contact with each other at different temperatures. Radiation is a method of heat transfer that happens by electromagnetic waves between the skin and the surrounding objects that do not upon any physical connection between the heated object and the heat origin. By evaporation, heat is exchanged as water changes state from a liquid to gas from the skin.

People can be thermally comforted at lower air temperatures by the radiant and conductive heating system. Direct sunlight is a simple example. In spring or autumn with relatively low air temperature with direct sunlight, we can sit conveniently outdoor and wearing only a T-shirt. But at the same point in the shade, although the air temperature is almost the same, you might need a coat.



Convection: Through a Liquid: Heat can be considered to be transported or carried by fluid's motion.

Conduction: Direct Solid to Solid: Thermal energy transfer by conduction always occurs in the direction of decreasing temprature.

Radiation: Through a Vacuum: Heat is transfered by electromagnetic waves, therby not requring a medium for transport.

The air doesn’t warm directly by the sun’s radiant energy. However, because air small mass, it does indirectly. The earth’s surface has absorbed the radiant energy of the sun and then convert it to heat. The warmer earth’s surface then slowly releases this heat to the air conduction occurs between solid to solid objects, solid and gases, like air, and also between gases as well. In other words, the Earth’s surface warms the air, not the sun.

Radiant heating systems and sun work in a similar way. They heat the objects directly, including human skin, and can provide thermal comfort at colder air temperature.

The Old Method of Heating

Buildings were mostly heated by a central radiant heat source before the advent of central air heating systems in the twentieth century. In the old way of heating such as Kang, dikang, Ondol, and Hypocaust or later coal, wood, gas stove or fireplace, the location in the room creates a substantial difference in thermal comfort of the people. In an air-heated system, the exact location of people in the room does not matter much. People can benefit just a very little portion of the energy applied by an air heating system. In a space warmed by a central radiant and conductive heating source, location is very critical.

As air heating distributes heat relatively uniformly all over a space, a radiant heating source produces a local microclimate that can be entirely distinct from other parts of the place since the kinetic energy of a radiant heating source decreases with distance. Infrared waves do not get weaker, they become more dispersed as they are scattered apart from a particular source.

> In the old days, only the occupied parts of a building were heated instead of heating the entire space. Almost all the energy used by a radiant heating system is effectively heating humans. The concept of heating was more localized.

In “Radiant Heating and Cooling Handbook” Richard Watson illustrates the difference between air heating and radiant heating system. The left picture illustrates the radiant heat distribution in a room, from the top, which is warmed by a forced-air heating system. The average radiant temperature in the room is 68º Fahrenheit and it is almost uniform all over the space.

The drawing on the right illustrates the same place with a radiant heat source at the center and an average temperature of 68º Fahrenheit. It can be new technology, an electric longwave infrared panel, or a fireplace in the heart of the place which gives the same result. The highest radiant temperature is in the center of the room and it decreases quickly in concentric spheres towards the sides of the room. The difference between the lowest and the highest radiant temperature is much greater than an air heating system.

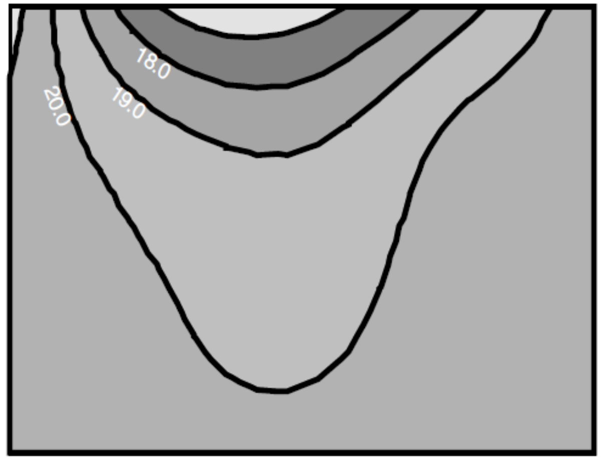


Figure 10. “Contour plot of MRT gradients for **forced air heating system** with average room MRT of 20°C”. Watson, Richard, and Kirby Chapman. Radiant heating and cooling handbook. McGraw Hill Professional, 2002.

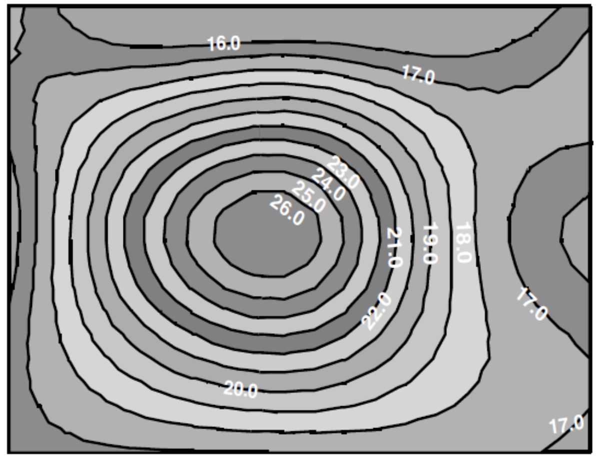


Figure 11. “Contour plot of MRT gradients for **radiative heating system** with average room MRT of 20°C”. Watson, Richard, and Kirby Chapman. Radiant heating and cooling handbook. McGraw Hill Professional, 2002.

Local Insulation

The drawback of the radiant system in old time was asymmetry - each part of the body feels different radiant temperature. Our ancestors improved local heating with **local insulation** to create a comfortable micro-climate without radiant asymmetry or draft.

12

13

14

Figure 12. Hooded chair. https://www.bidsquare.com
Figure 13. Bed with canopy and curtain. https://en.wikipedia.org/wiki/Four-poster_bed
Figure 14. Folding Screen. https://madparis.fr

Portable Heating System

The downside of local heating is that you have to be in a particular place to be comfortable. Other areas of the room that were farther away from the heating source were better for activities with higher metabolism. People were “migrating” throughout the place to find a place appropriate for their needs. However, a portable heating system was added to the radiant heating system and local insulation to improve thermal comfort.

Figure 15. Mid-17th century paintings with women using foot warmers of the fire pot in wooden box kind. https://www.wga.hu/html/m/man/chess_pl.html

Figure 16. Portable heating source, https://en.wikipedia.org/wiki/Foot_stove

A **Persian korsi** is a type of movable low table, with a heater, traditionally heated with a brazier containing hot coals, underneath it, and a thick blanket or quilt was placed above the table to trap the heat. The entire family or other gathering sat on the floor and slid their legs under the table. Figure 17. *https://en.wikipedia.org/wiki/Korsi*

Conductive Heating System

The heat was transferred through conduction with some historical radiant heating system. The word "Kang" traced back to 10000 BC as a heating system and It was mostly used in ancient China(13). It was a raised heated platform which was used for sleeping and during the day as a heated living and working surface. It was found in either U shape, such as bench, and or traditional bed. The heat was transferred through conduction by trapping smoke gases in a thermal mass (brick, adobe, or stone.) Then the heat radiates to the inhabitants and space(14).

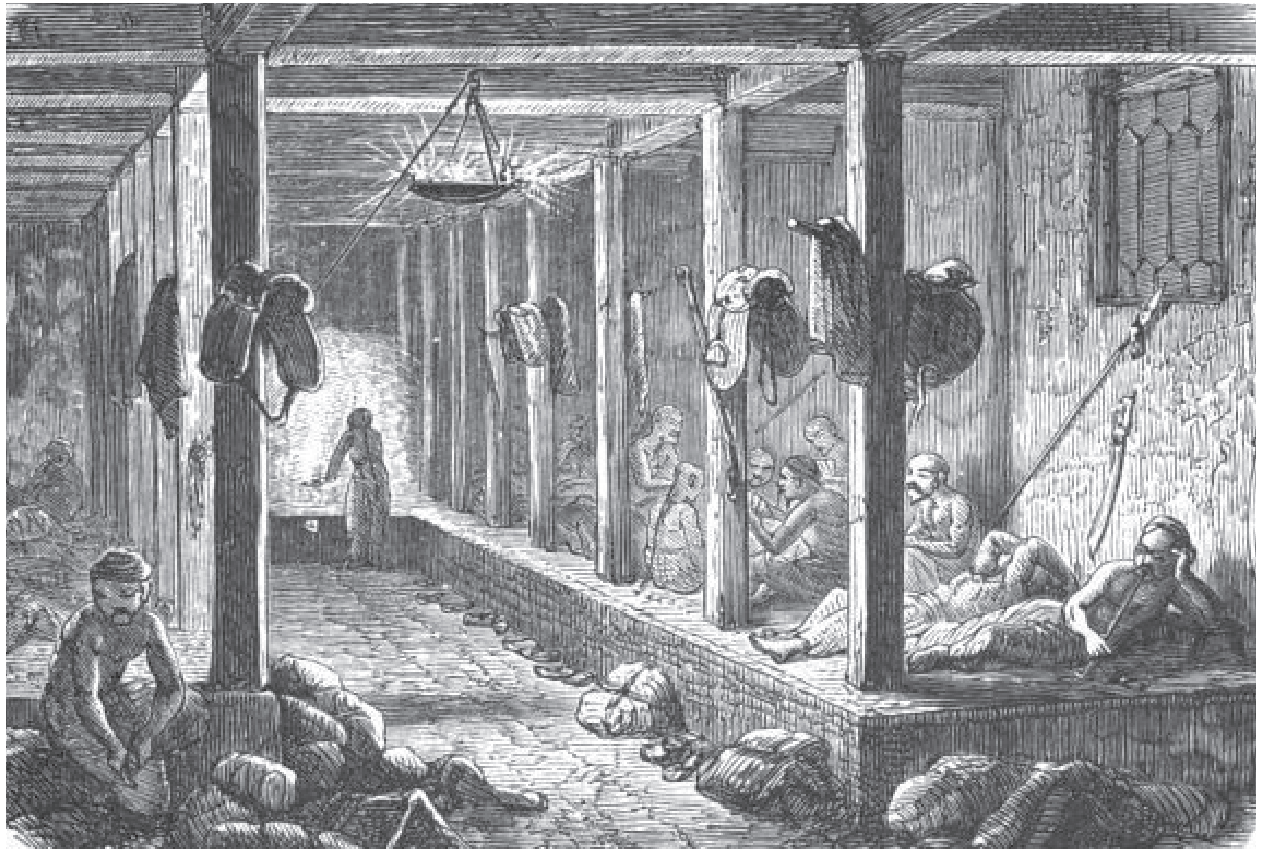


Figure 18. "A large kang shared by the guests of a one-room inn in a then-wild area east of Tonghua, Jilin, as seen by Henry E.M. James in 1887". https://www.wikiwand.com/en/Kang_bed-stove

The Koreans developed the heated surface and it is known as Ondol, which means "warm surface". From Knapp:

> "...in a traditional Korean house, rooms typically have two kinds of floors: gudeul and maru. Underfloor heating systems, called gudeul (also ondol), are installed within closed rooms that are used for sleeping. Gudeul differ in important ways from the heated brick beds or kang, which are found in northen China, although they share certain common elements. Consisting of two principal components, a fire source and a series of flues, gudeul draws heat from a fire hole in the kitchen stove along an outside wall, then leads it through flues before being exhausted through a chimney. As the warm air passes through the flues, it warms flat stones that are placed above the flues, which then radiate heat into the room above... The warmth of gudeul-heated rooms has given rise to the lifestyle in which Korans remove their shoes before entering, and then use the comfortable floor for sitting or sleeping"(15).

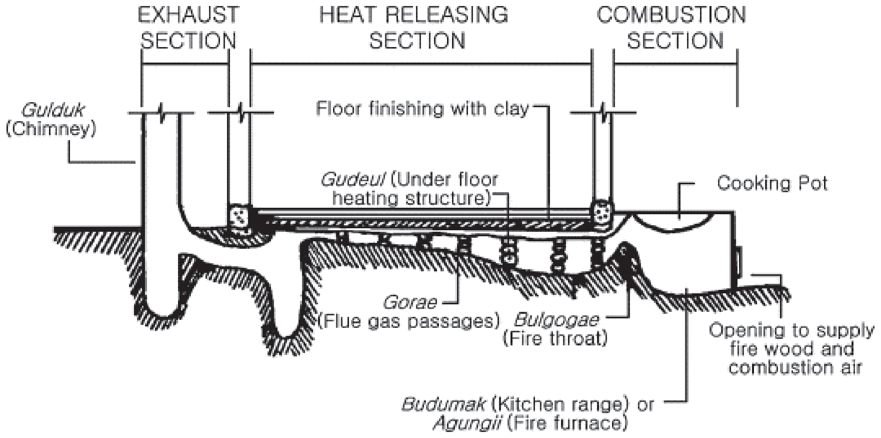


Figure 19. The structure of traditional Ondol(before the 1950s), Yeo, Myoung-Souk, In-Ho Yang, and Kwang-Woo Kim. "*Historical changes and recent energy saving potential of residential heating in Korea.*" Energy and Buildings 35, no. 7 (2003): 715-727.

Around 500, the use of heated floors and walls was expanded by Greeks and later Romans with the Hypocaust which is a central heating system in a building that includes an open area under a raised floor that allows the passage of hot air to heat the floor space. In this system, the walls may be heated by passing hot air through a series of pipes in the wall(16).

Figure 20. Roman Hypocaust, Beirut., https://cushareejournal.wordpress.com/2019/04/06/the-hypocaust-an-assessment-of-non-ancient-varieties/

Figure 21. Sunday Afternoon 1861, Albert Anker, https://commons.wikimedia.org/wiki/Category:Tiled_stoves_in_art

Figure 22. Old Feissli with child by the stove, Albert Anker, https://commons.wikimedia.org/wiki/File:Albert_Anker_Sonntag_Nachmittag_1861.jpg

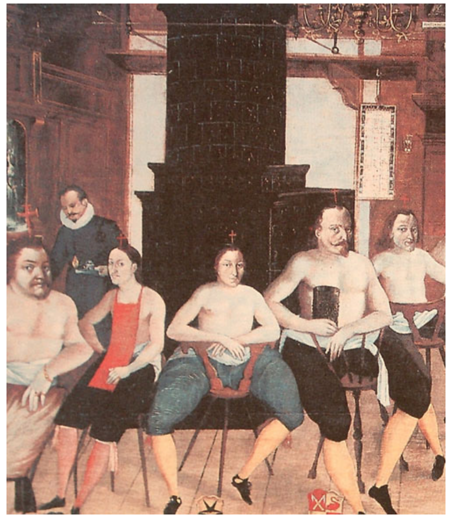


Figure 23. Tile Stove 1604, De Decker, Kris, and V. Grosjean. "*Low-Tech Magazine.*" (2007).

The tile stove or masonry heater which usually combined with a bench seat or sleeping platform transfer heat by radiation and conduction and provides local heating (central place) of comfort and coziness that no longer happen in the modern air heating system.

Oven stoves appeared on drawings and paintings in the 1300s. Although the Greeks and Romans invented the hypocaust, that knowledge was largely lost when their civilization collapsed, but the oven stove is the first heating device in history.

The labyrinth of smoke channels and smoke rooms are kept the hot gasses inside the oven as much as possible. So that heat can be absorbed by stone the stone before it channels out of the chimney(17).

Most contemporary heating systems are based on convection: they warm the air. An oven stove heat people by radiation, like infrared radiation, which is similar to the heat of the sun. The impact is similar to that person who enjoys sunbathing while skiing, despite the cold temperatures. The body of skier heats up directly by the radiant energy of the sun.

Convection produces constant airflow in the building since warm air is going upwards and cold air moves downward. Hot air rises to the ceiling, while the occupied part of the building is on the floor. This is not efficient at all. Moreover, it is always too hot near the stove or fireplace and too cold on the other side of the room.

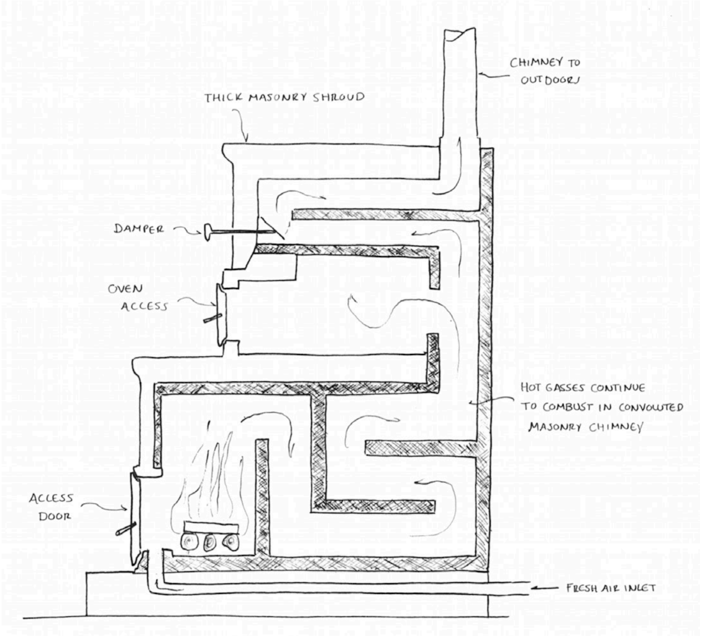


Figure 24. Interior diagrams of Russian stoves, https://endeavourcentre.org/2017/02/residential-heating-system-basics/50-masonry-heater/

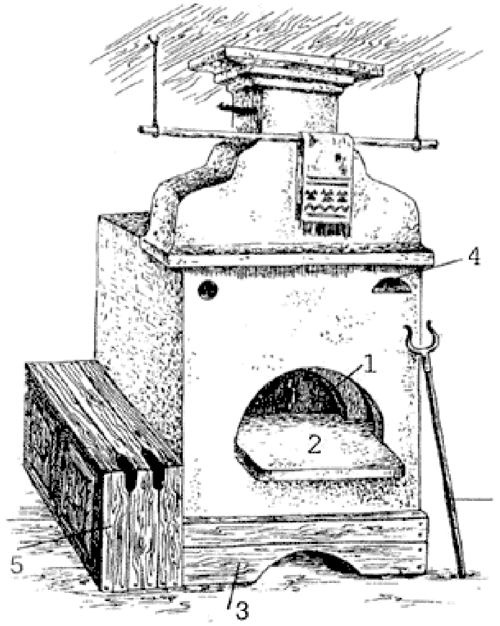


Figure 25. Russian stove, http://www.litsovet.ru/index.php/gallery.view?gallery_id=850

Restoring the old concept of heating “**Heating People, NOT Places**” without new technology does not make sense. Most traditional heating systems were inefficient, dangerous, polluting, and impractical. Nowadays, with the new technology, we have better possibilities available, which can be combined in interesting ways with the old ideas.

As explained before, heat can be transferred through convection, conduction, and radiation. Most modern heating systems are based on convection, but conductive and especially radiant heat sources also indirectly heat the air. Even the sun which produces 100% radiation in space (vacuum), on earth, because of the air’s very small mass, does not only heat the earth and objects but also warm the air a little bit.

Radiant and Conductive Heating System

A modern radiant heating/cooling system emerged with the advent of the general water accessibility in the 19th century. “**Thermally active surfaces**” are the building’s surface which would be warm or cold by running hot or cold water through the metal pipes within the thermal mass.

Thermally active surfaces cannot release heat quickly since they have a high thermal mass. They produce heat evenly throughout the space, so they are not appropriate for localized heating. In the building with the thermally active surface, the whole space above the surface would be evenly warm or cold regardless of how many people are there.

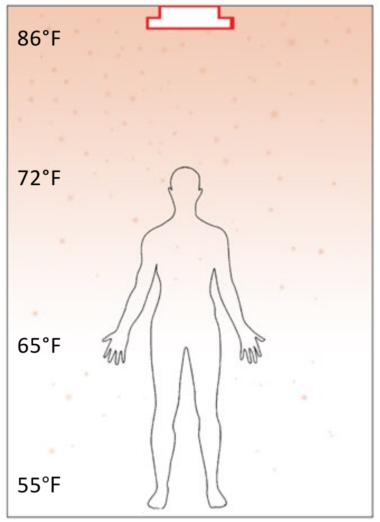
This system is almost a reasonable option for new buildings. However, for reducing the energy use in the existing buildings and to save energy, other options should be considered.

Infrared panels are the new radiant heating systems which perform by electricity or hot water. Radiant panels like tile stoves, heat locally, and can create a warmer micro-climate within the cooler space. Since the infrared heating panels are covered with the thin metal heating surfaces which have little thermal mass, they can create heat very fast. Therefore, the room only needs to

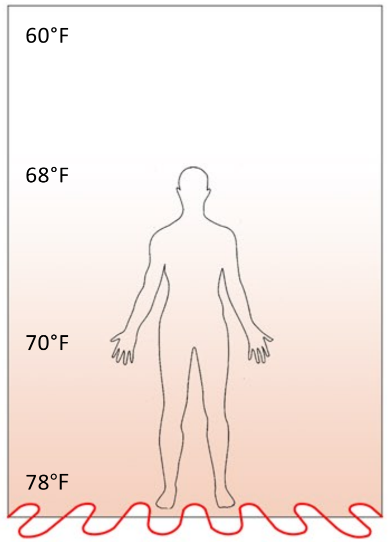
be heated when someone enters it.
The advantage of Infrared panels is that they are light and compact, and easy to locate in an existing building and the tenants can take their panels with themselves when they move to another place. In electric panels, the heat is produced by electric resistance. In comparison with hydronic panels, they are easier to install and even more responsive -- electric panel radiates heat at full power in less than 5 minutes.

Infrared heating panels and high mass radiant heating systems can complement each other. For instance, while radiant heating with high mass comes to speed, an infrared heating panel can warm part of a space immediately and it would provide thermal comfort for people who have irregular schedules.

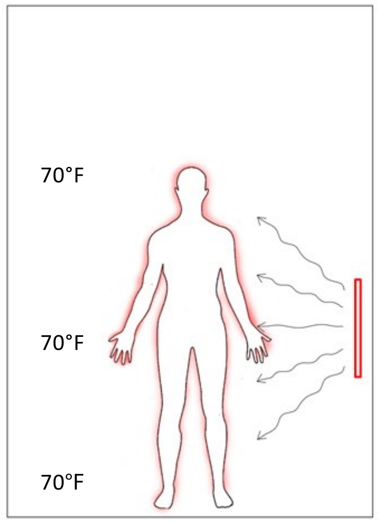
The “fast” and a “slow” radiant heating source can complete each other in separate spaces of a building.



Forced Air Convection. Winter



Thermally Active Surface.Winter Hydronic Radiant Floor. Slow Radiant Heating Source.



Infrared Heating Panel. Winter Fast Radiant Heating Source.

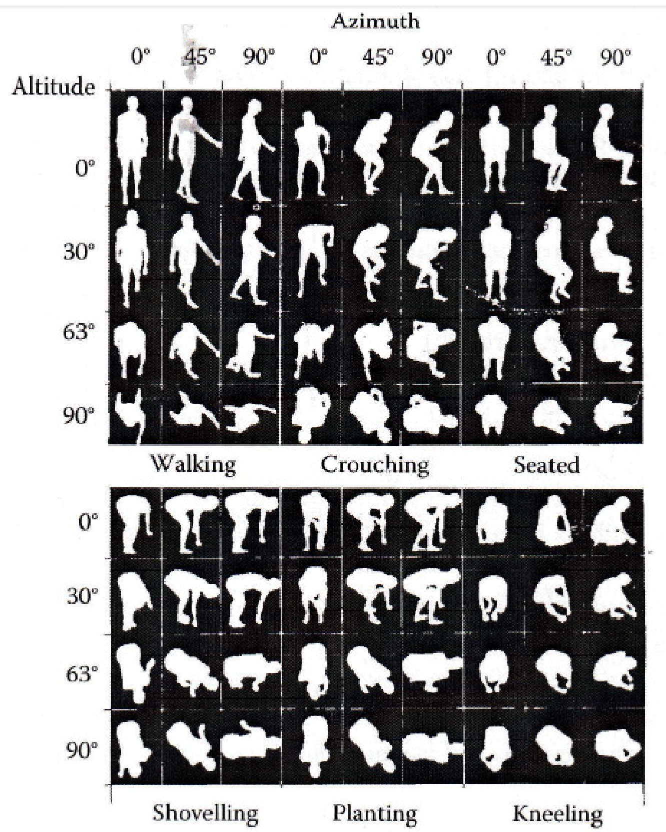


Figure 26. Parsons, Ken. "*Human thermal environments: the effects of hot, moderate, and cold environments on human health, comfort, and performance".* CRC press, 2014.

Infrared panels: Vertical or Horizontal?

The orientation of the surface is strongly related to the natural, upward motion of hot air. Although a panel in the ceiling with horizontal orientation maximizes radiant heat production, a panel in vertical position maximizes radiant heat reception. During waking hours, humans are mostly in a vertical position, either standing up or sitting down. Therefore, when the heating surface is vertical a greater part of the body will be exposed to radiation directly.

Local Heating and cooling as an Alternative to Insulation

Unlike air heating, which spreads warmth evenly throughout a room, radiant and conductive heating systems operate much more locally; The thermal comfort of the occupants can be provided by them at lower air temperature without heating the whole space.

> The thermal comfort and energy efficiency of **older, uninsulated buildings** can be enhanced with **local heating and cooling systems**. They reduce the heat loss from the building since they create comfort at colder air temperatures, and hence making thermal insulation less important.
>
> Local heating can create a healthier indoor climate compared to air heating systems. It can be combined with natural ventilation much better than the air system.

When we heat a space through the air, a heat storage device is also a ventilation device. Measures such as building airtightness for improving the efficiency and comfort of air heating, have an adverse effect on the health of the indoor environment, while measures that support a healthier indoor climate, like regularly opening the window, are harmful to the efficiency and comfort of the heating system.

Air is not the medium for heat storage in local heating. Heat is directly transferred to people. Because local heating creates thermal comfort at cooler air temperatures, it expends less energy to draw in more fresh air.

Thermal Comfort Improvement

People are different in their activities, personalities, metabolism, and what they wearing, while modern heating systems provide a thermal environment that's the same for everyone.
The study with International Comfort Standards shows that even at an "ideal" temperature an

80% of users will be comfortable. In other words, in the best-case scenario, one in five would be too warm or too cold by using modern heating systems. A constant temperature all over space is an inherent characteristic of modern air heating and cooling systems, not a state for feeling comfortable. Although the traditional forced-air systems are hoped to provide total even heating throughout a building, most often fail and there are places that are too cold and too warm that make conditioning more expensive and reduce the productivity of people working in those spaces. 100% of occupants would be able to find their perfect thermal comfort in a space that's warmed by local heating sources.

Reviving the traditional idea of
"Heating People, NOT Places"
provides a new definition of thermal comfort.

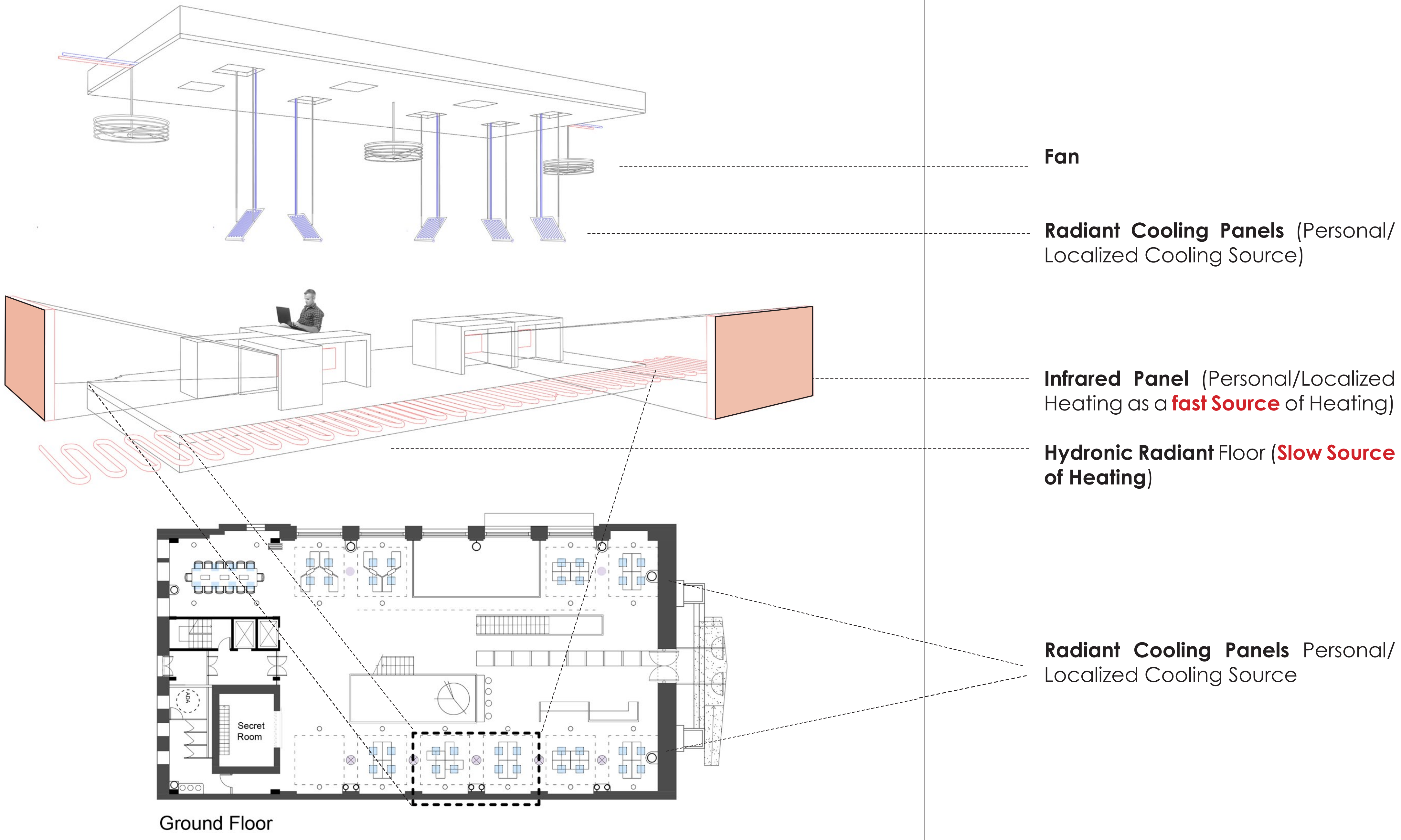
Cooling System

The most modern way of cooling people is air-conditioning which is not energy-efficient at all because it means that all the air in an enclosed area requires to be refrigerated to cool the occupants. It provides the same thermal comfort for all. The air system also needs hug ducts and vent which takes up a lot of space. Especially in the adaptive reuse of historical buildings it also obscures the aesthetic and historical character of the existing buildings.

Moving air around by fans needs much less energy than refrigerating it and the cooling effect of it can be applied locally and has an immediate effect, and it provides personal microclimates. Radiant cooling similar to circulating fans is considerably efficient than air-conditioning since there is no need to chill the air. Another downside of air-conditioning is that space has to be an airtight and enclosed to keep the chill air inside. Circulating fans and radiant cooling systems, however, work the same inside and outside. Natural ventilation can be combined with fan and radiant cooling surface to the benefit of an extra free cooling effect when it is available.

Radiant Cooling

In contrast to conventionally air-conditioned buildings which cool the entire volume of space to provide thermal comfort for people, radiant cooling directly cold individuals. The radiant cooling principle is that people are largely cooled by body heat being radiated to cooler surfaces. The cooling or heating effects of radiant surfaces on human skin are much more responsive than direct contact with the air all around the body.



Heating and Cooling Design Strategies: Heating people, NOT places

In this design, the infrared panel as a fast source of heating is placed in each desk which creates a warmer microclimate within cooler space. The hydronic radiant floor is considered as a slow source of heating. There is also the hydronic radiant surface around the parameter of building under windows. The infrared panels create local heating and directly transfer heat to people and allow 100% of occupants can find their ideal thermal comfort.

For cooling, there are also personal radiant cooling surfaces which they are embedded in the ceiling. When someone needs to use them it can be drop down and be at the occupied level and when someone doesn't need it, they can go up. The ceiling fans also combined with radiant cooling surfaces. Circulating fans provide cooling locally and have an immediate effect, and it enables the creation of personal microclimates. Both cooling and heating systems provide a new definition of thermal comfort.

Radiant cooling panels on the ceiling are installed in such a way that they can be used

Personal Distilled Water

When warm air touches radiant cooling surfaces, condensation will occur. The purified water produced by condensing will be collected to create distilled water. Each personal cooling surface provides personal drinking water too. The amount of water obtained is small, but at the end of the day, each person can drink a glass of water.

CHAPTER 3

DESIGN OVERVIEW

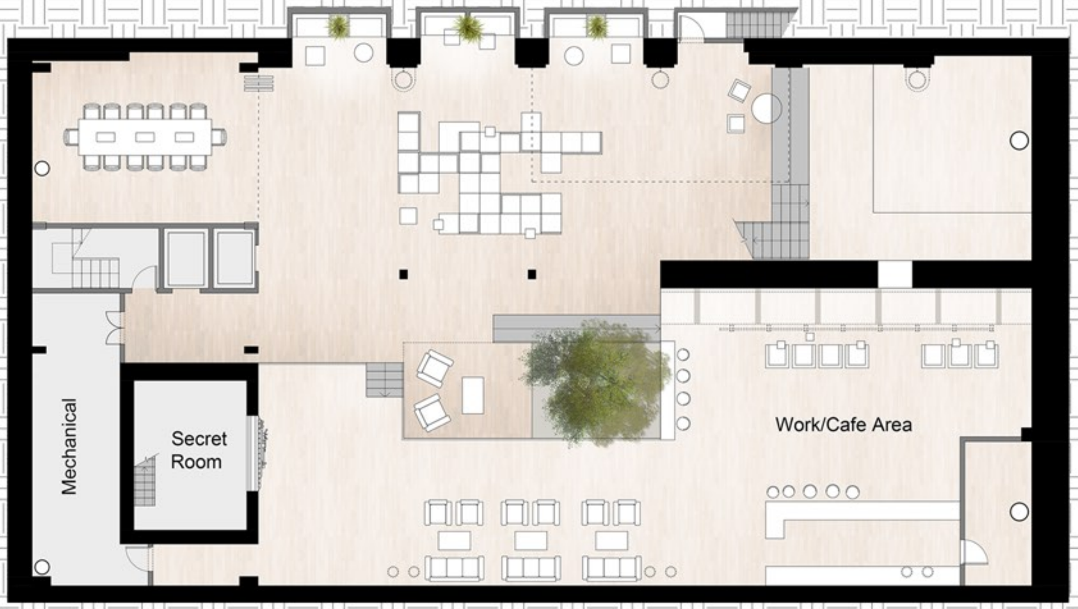
Site Plan
Plans
Perspectives
Sections
Green Rooftop
Residential
Localized Heating and Cooling in Residential Units

Site Plan

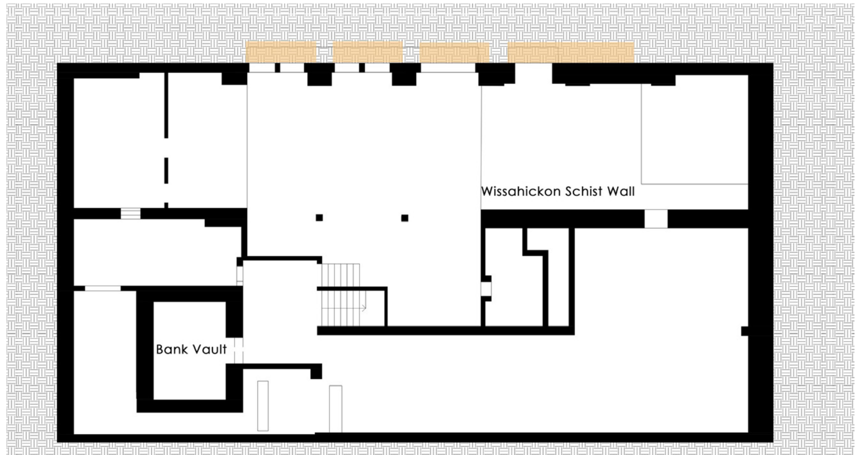
The selected building is in the corner of Front and Norris Street and a railroad bridge passes adjacent to this building.

NEW EXPANSION
RESIDENTIAL

WORK ENVIRONMENT
OLD BUILDING



Basement Floor Plan

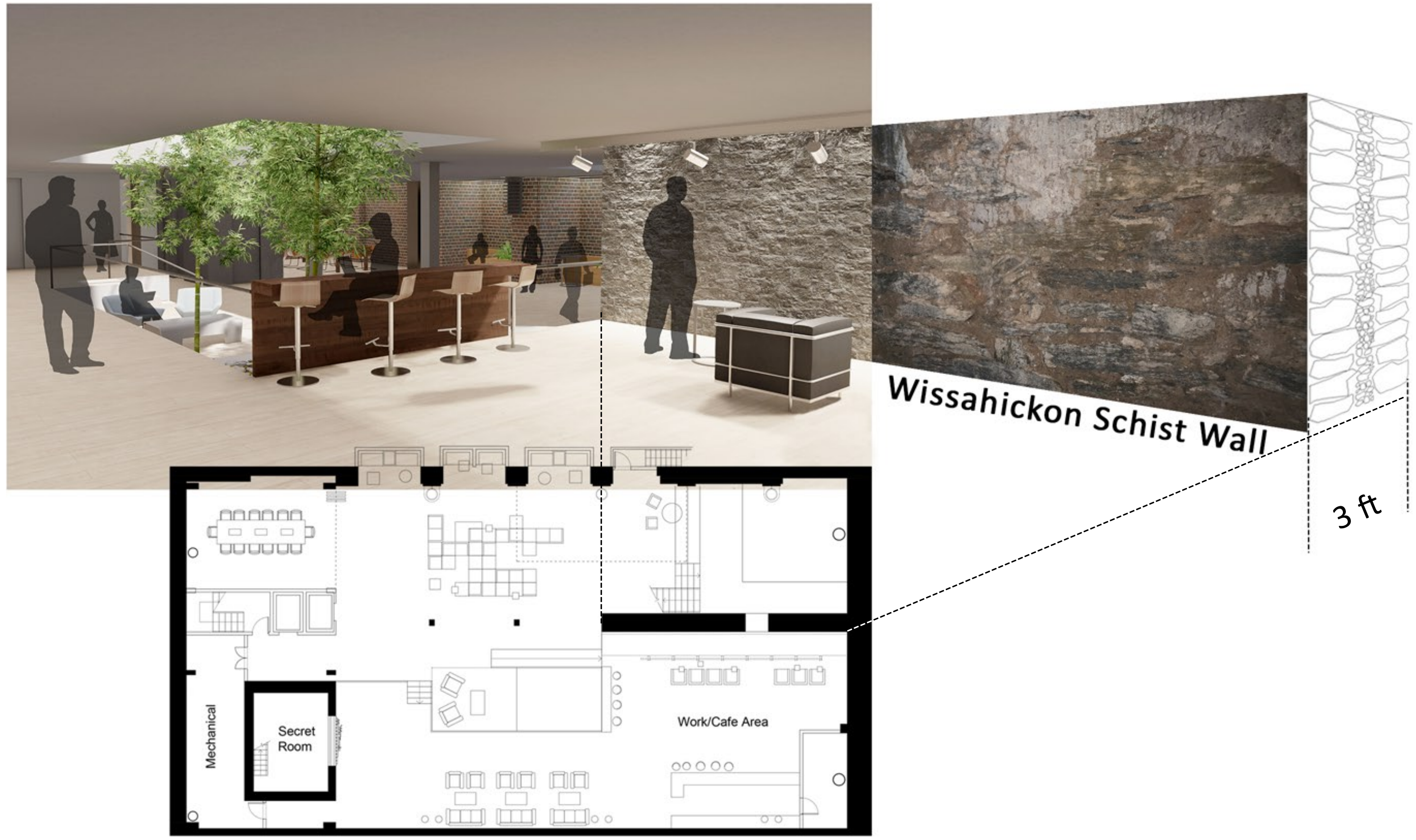


Basement Floor Plan/Old

Sc:1/8"=1'-0"

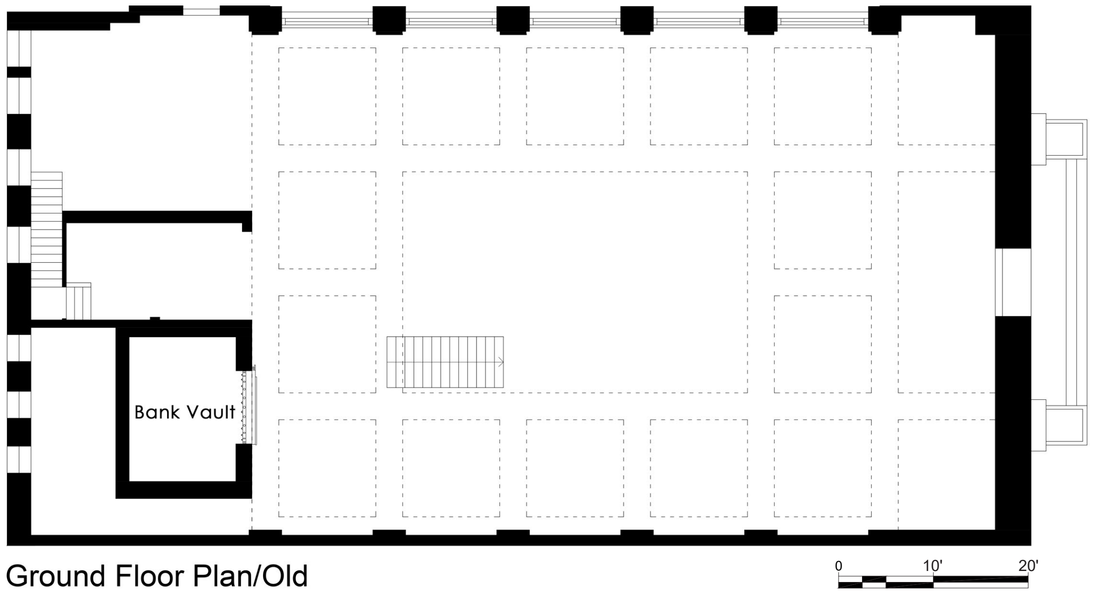
In the basement of original design, there were some horizontal opening (window) at the top, on the ground level at the sidewalk. In the new design, the **plan was expanded to underneath of these opening** to use the advantage of more light for the basement.

The Wissahickon Schist Wall, with three feet thickness, was originally the foundation for the exterior wall. Fifty years later after the second part was added, this unique element of the existing building which works as a load-bearing wall, connects the two different ceiling structures, the brick arch, and the concrete structure.



Basement New Floor Plan

The basement was originally built at two heights. in the new design, the same characteristic was kept in most parts.

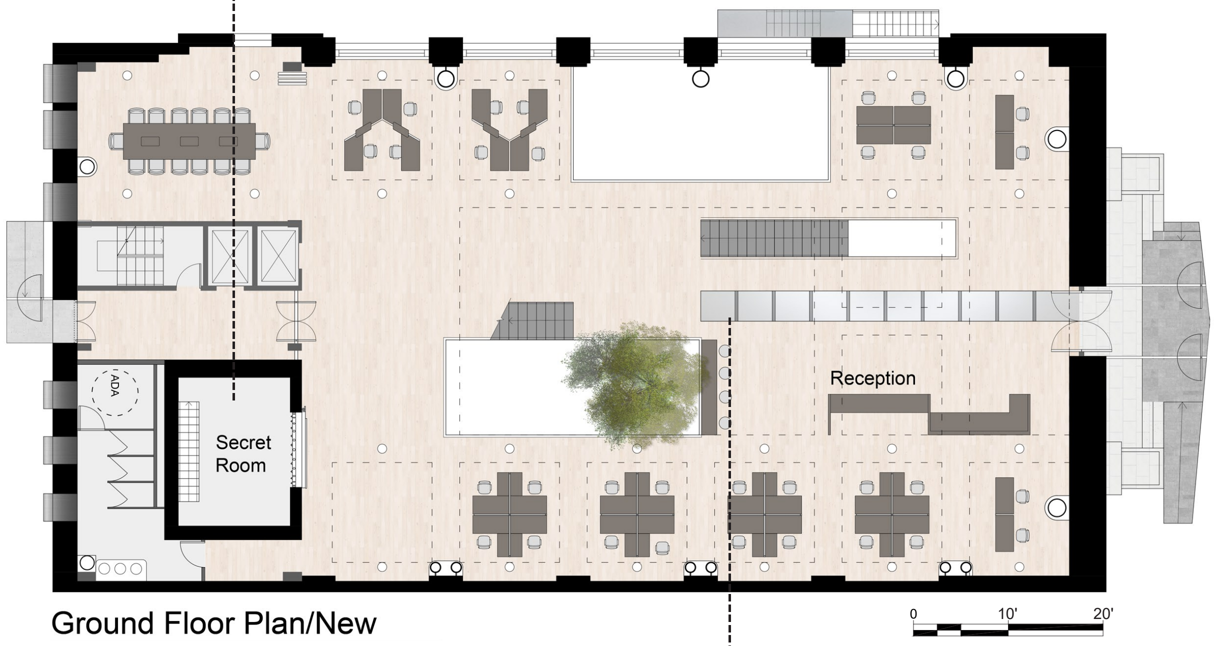


Ground Floor Plan/Old

Ground Floor Plan/Old

The Bank Vault called the **SECRET ROOM**, which it is a mysterious part of the building. The various things can happen there based on the immediate needs of the people who work there.

The main entrance for the work environment is on the east side of the building and the residential entrance is on the west side.



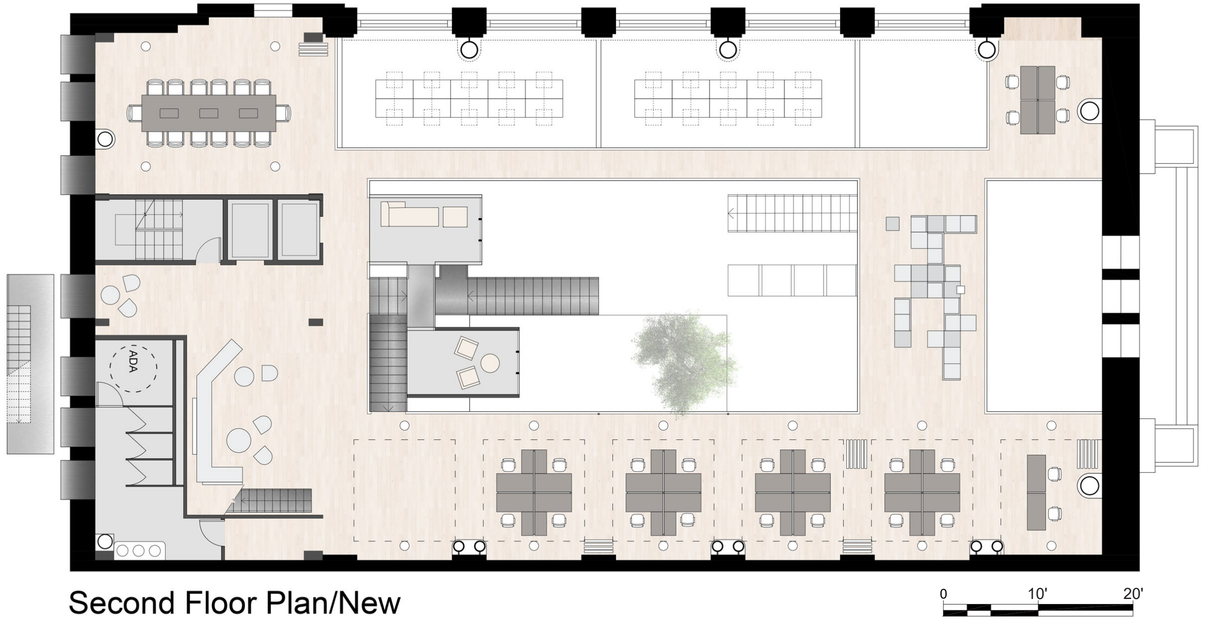
Ground Floor Plan/New

In the new design, some area of the existing floor structure was cut to bring natural light for the basement area and create a visual connection between the basement and other floor levels.

There is a glass floor at the top of the Wissahickon Schist Wall for a couple of reasons: first, to get people's attention to this wall as an important historical character of the building, and second to bring more light on this wall.

The main entrance for the work environment

The floor next to the window is not fixed. If necessary, it goes down and goes up when it is no longer needed. The space on this floor is dedicated to a function that is not always occupied, such as a larger meeting space, which may only be used for two or three hours a day.

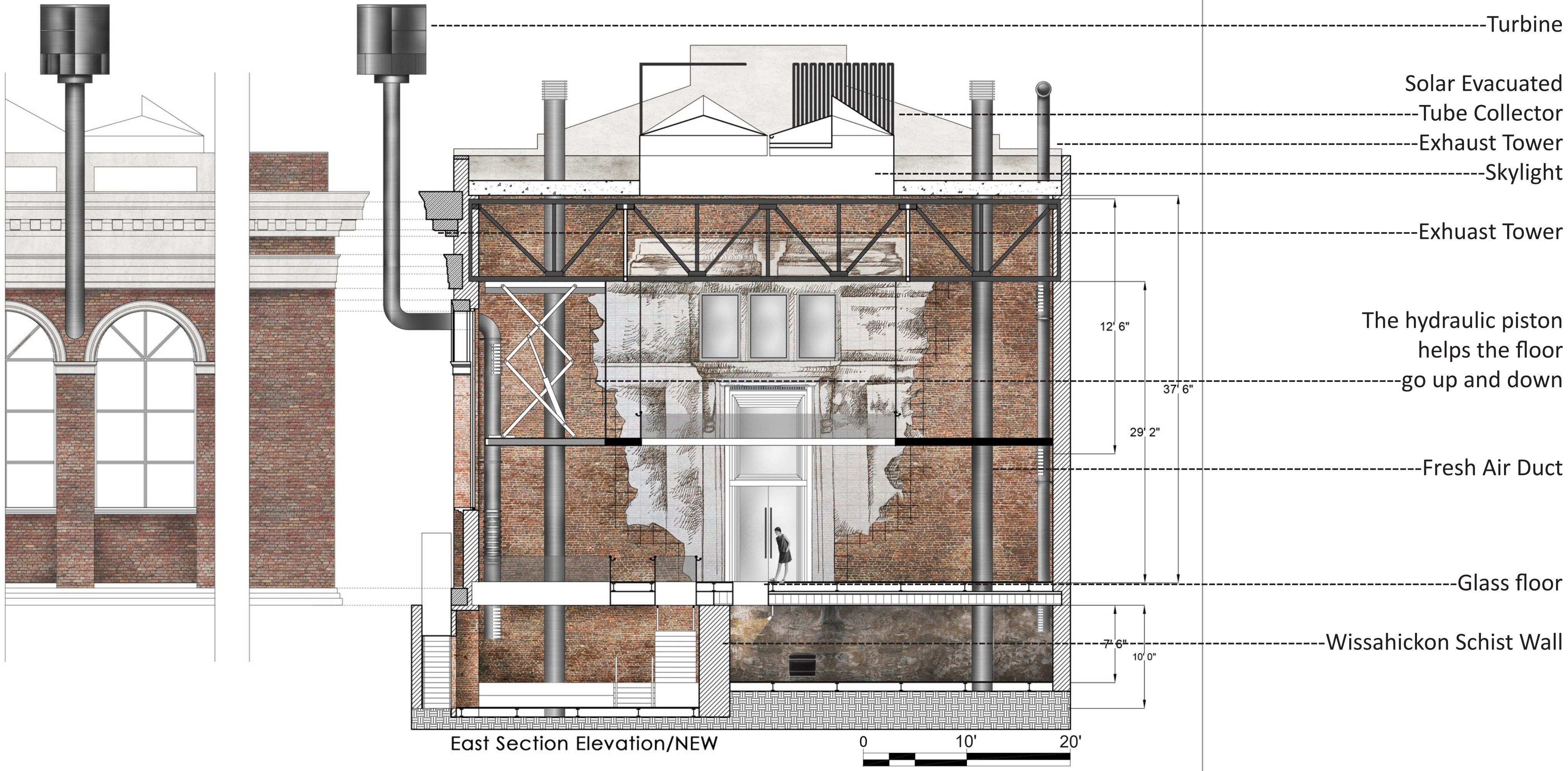


Second Floor Plan/New

The open floor plan is considered for the work environment to provide maximum flexibility. The dividers (partitions) help to provide a smaller space when it is necessary.

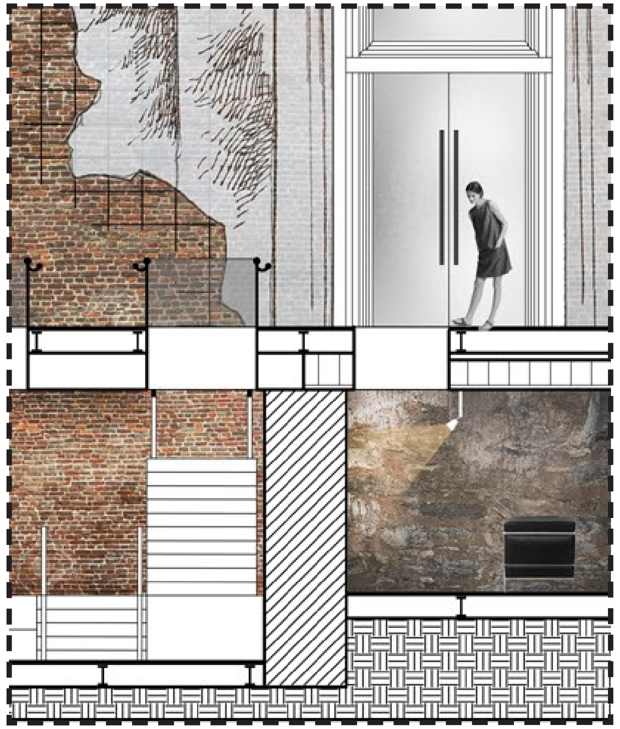
INTERIOR WORK ENVIRONMEN

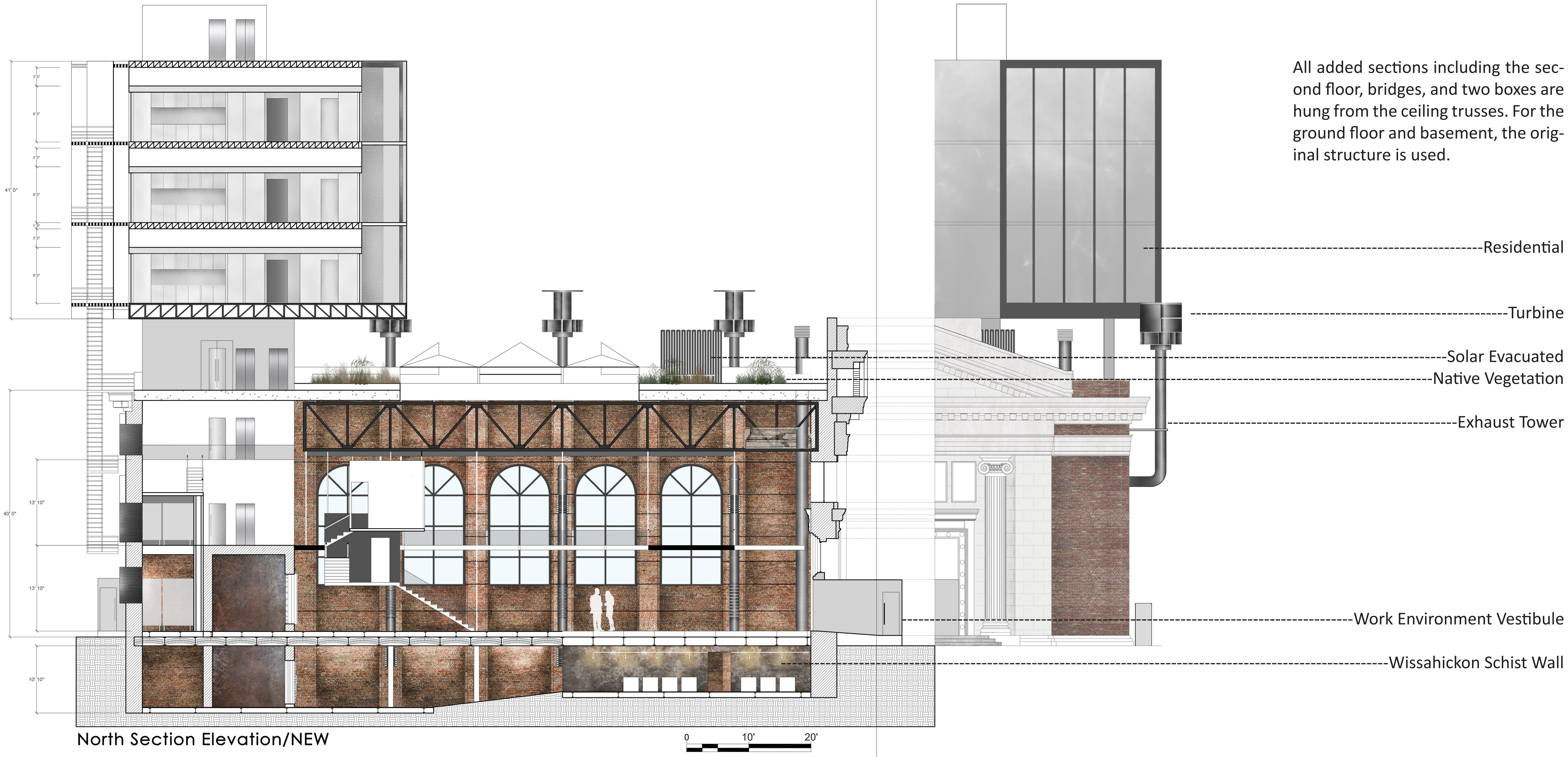
INTERIOR WORK ENVIRONMEN



East Section Elevation/NEW

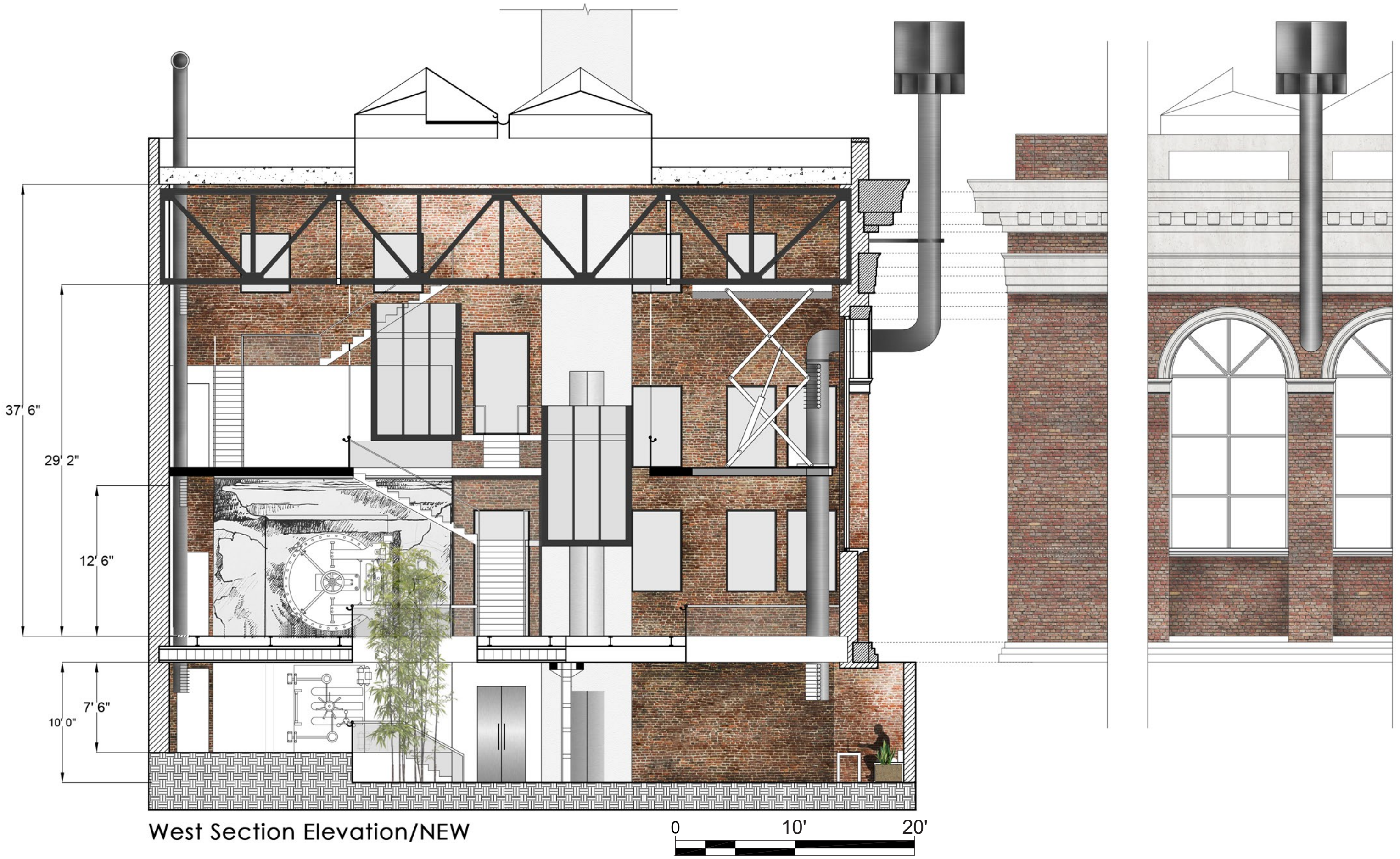
Glass Floor. Transparent floor at the top of Wissahickon Schist Wall is place to bring more light on this historical foundation andcalso get people's attention to this wall as well.



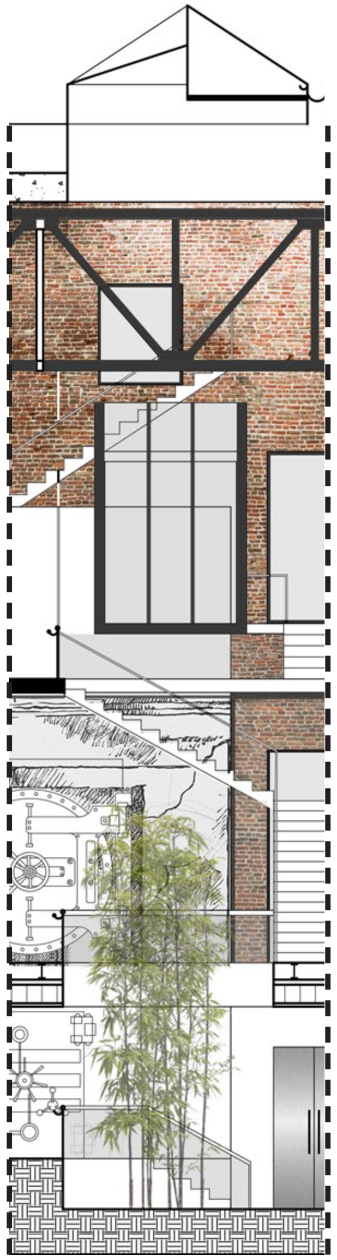


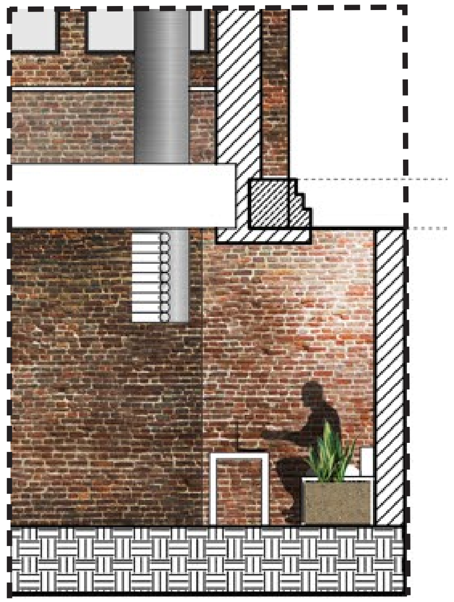
North Section Elevation/NEW

All added sections including the second floor, bridges, and two boxes are hung from the ceiling trusses. For the ground floor and basement, the original structure is used.



West Section Elevation/NEW

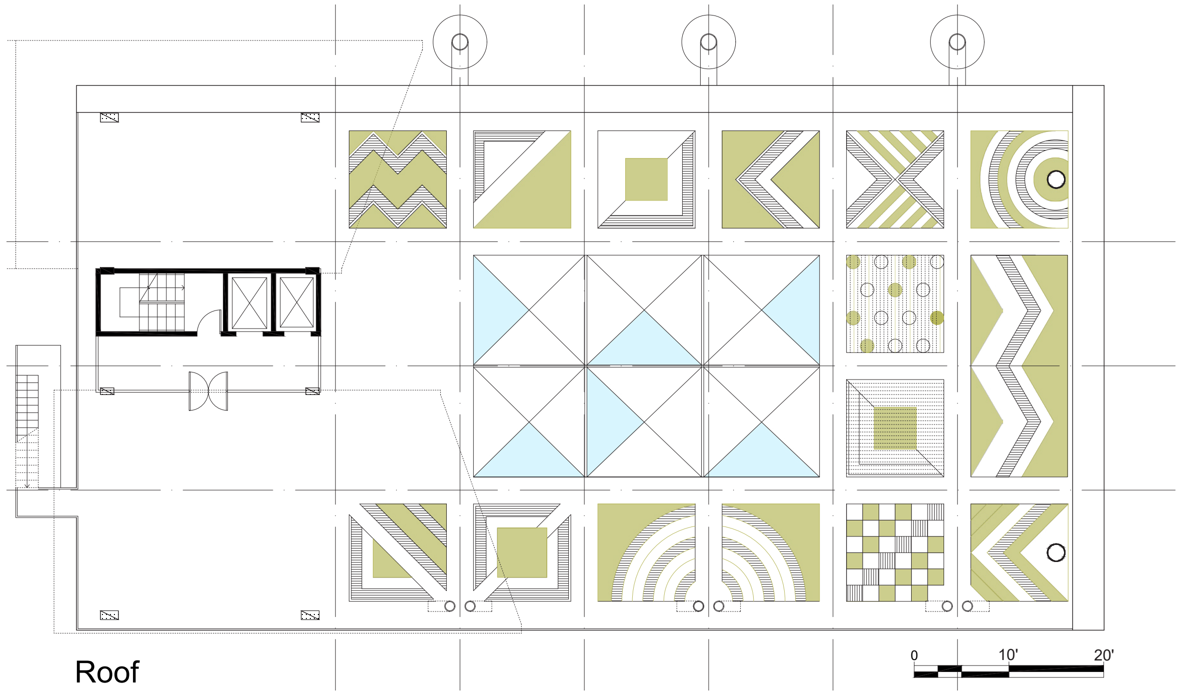




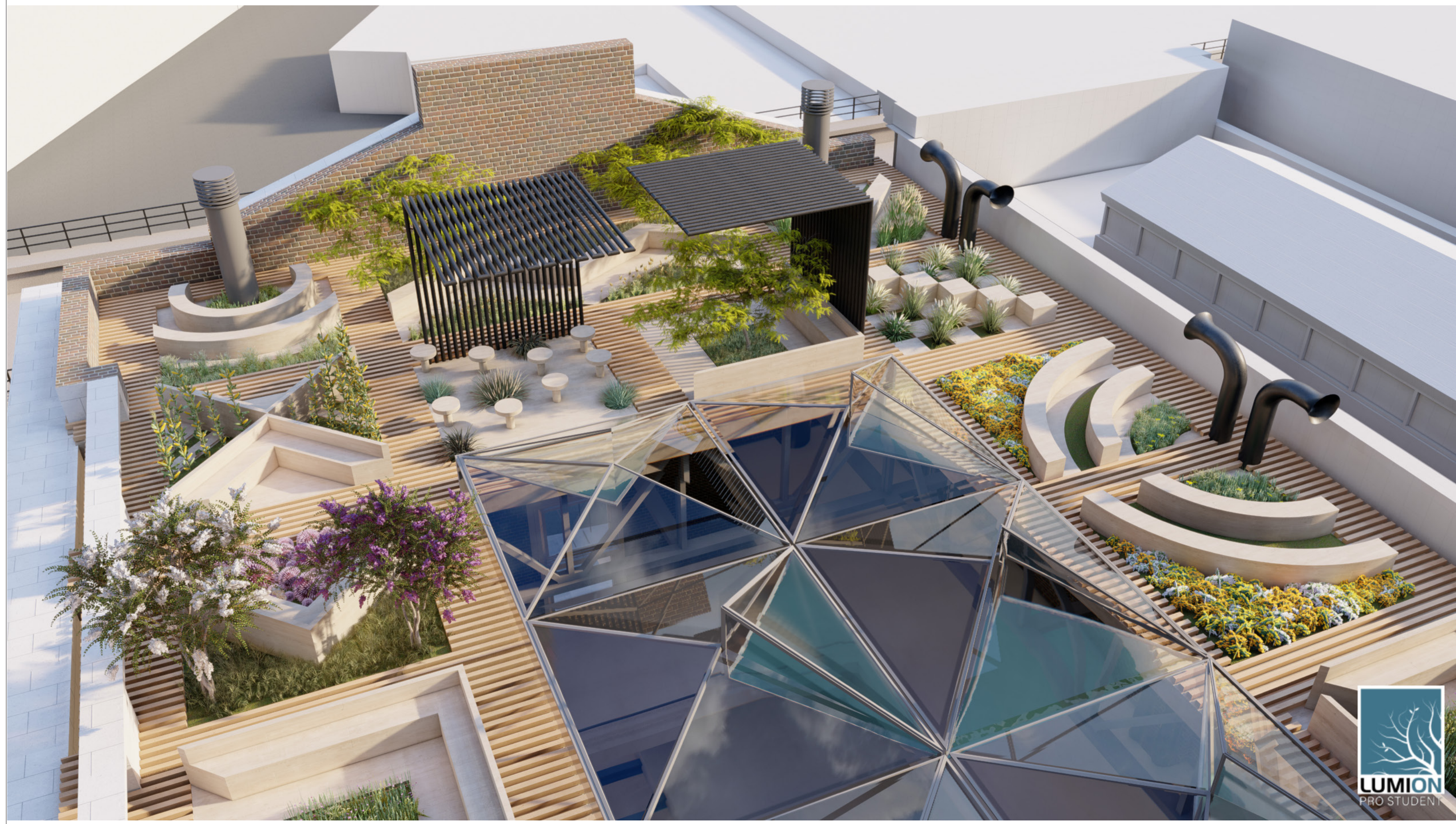
The **plan was expanded to underneath of the original opening** at sidewalk to use the advantage of more light for the basement.

There are bamboo trees in the basement and the space above it is open all the way under the skylight.

Green Rooftop



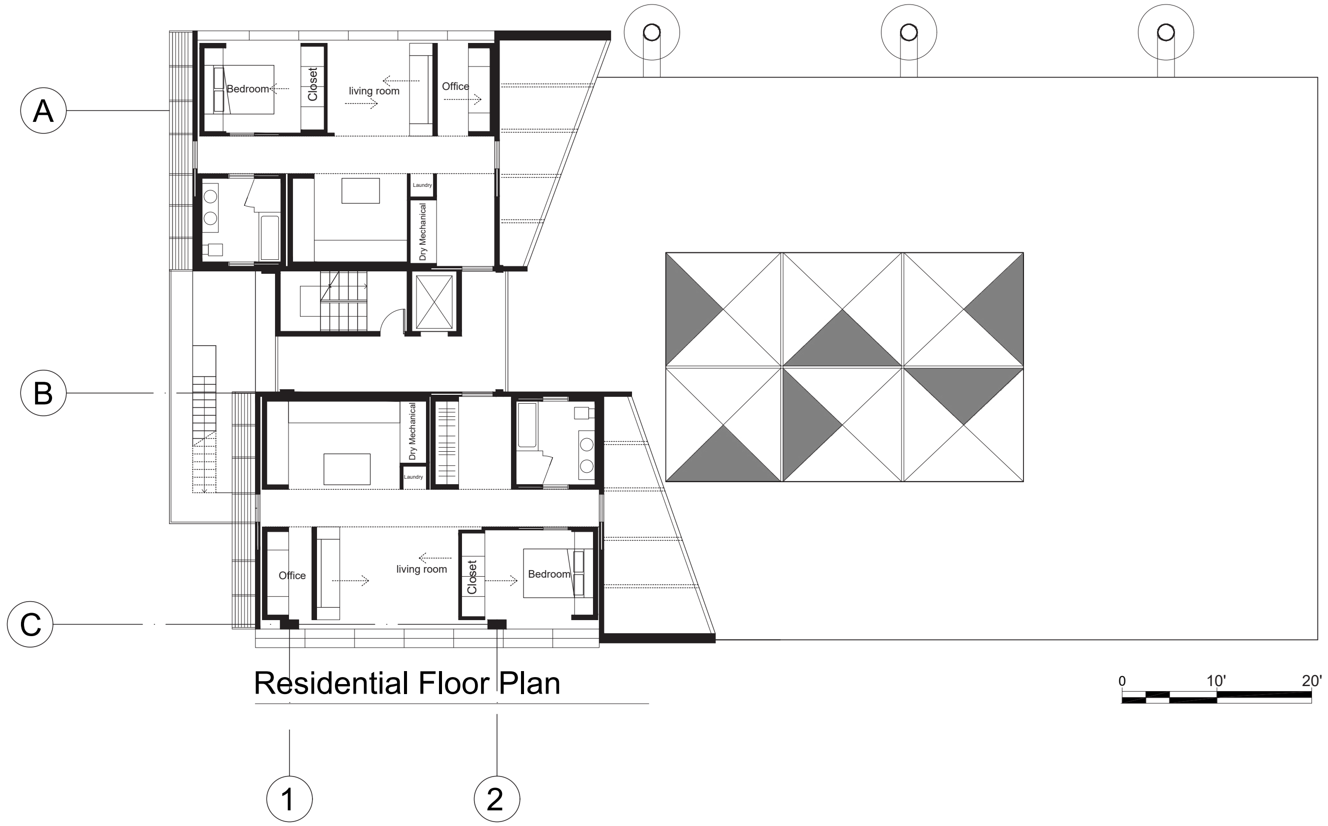
The design proposed the green roof with native and adapted plant species on a rooftop with the permeable surface to trap rainwater and prevents it from running off the roof. The roof design pattern is a reflection of the ceiling trusses geometry.



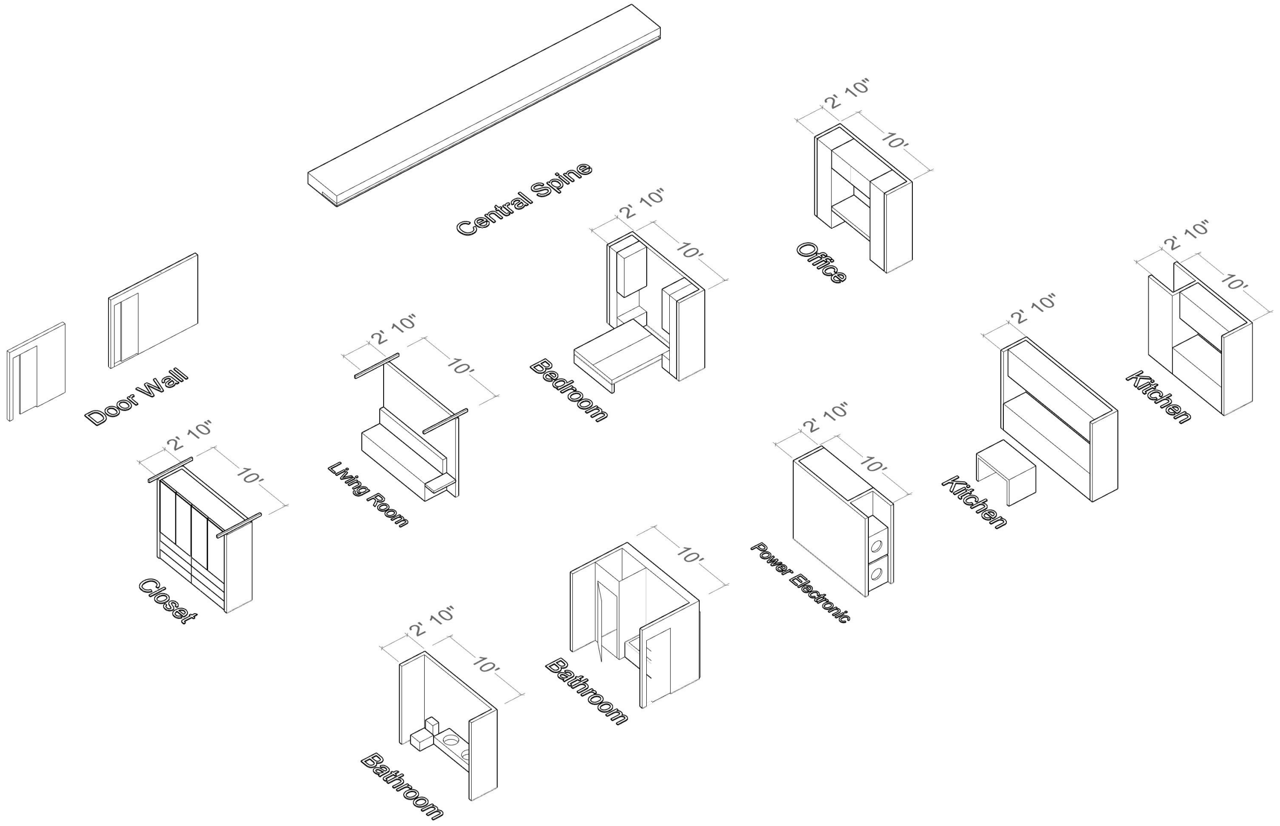
RESIDENTIAL

For the immediate next use, the project creates a new vertical expansion, residential units. The main concept for designing the residential is to create micro-home or micro narrow home and adaptable or transformable rooms. All the building's components and systems designed to work together to maximize the comfort of occupants with environmental protection.

The apartment is intended to be very flexible, to adapt to the changing needs of occupants, daily. Each space can have particular activities but the user can have the possibility to adjust the areas for their own needs.

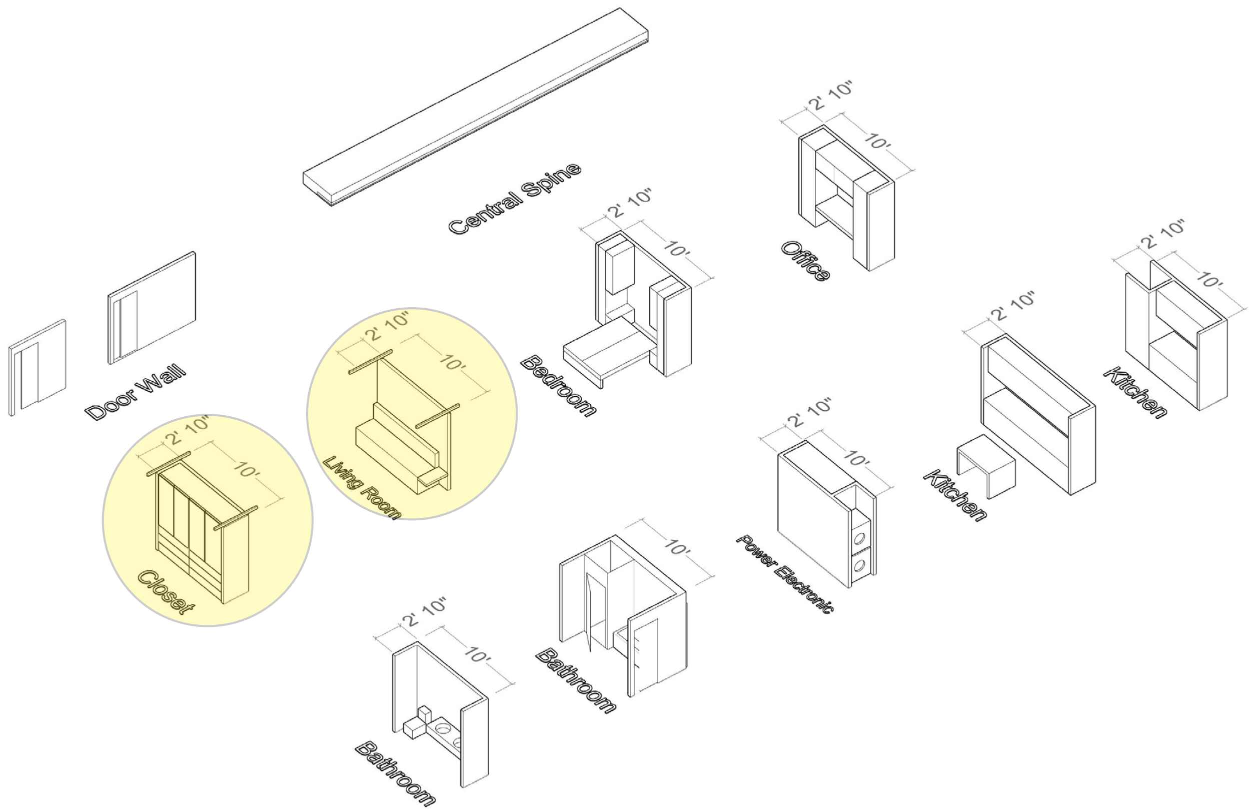


Residential Floor Plan



Prefabricated components:

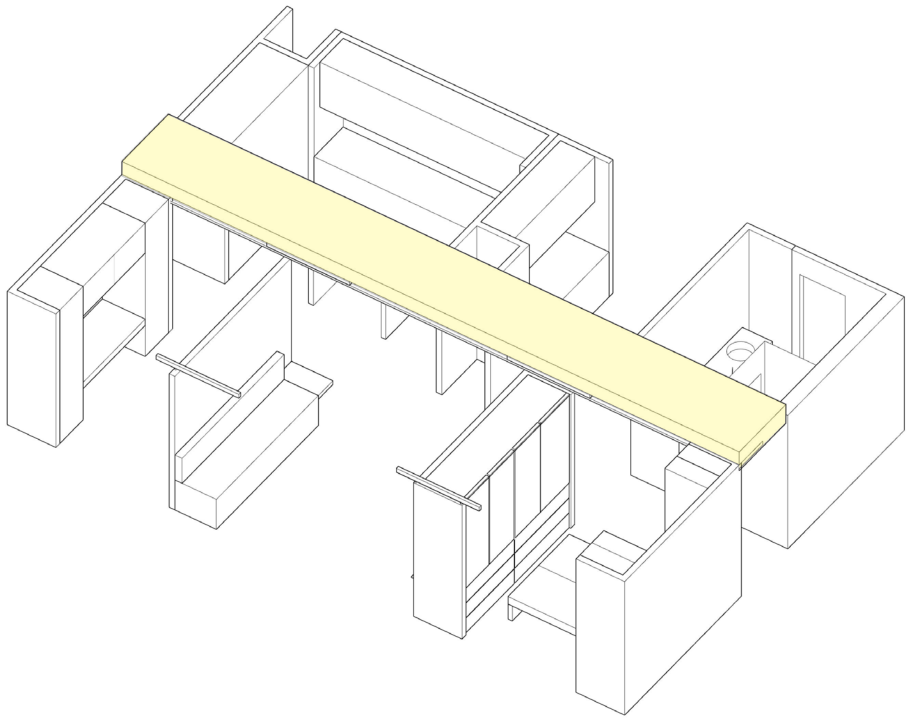
Space is defined by prefabricated walls. They are separate pieces similar to Lego, plug, and play components such as bedroom, home office, kitchen, bathroom, closet, laundry room, etc. Most of them are 10’ by 2’ 10” and they are pre-plumbed, pre-installed, prewired, and they have been finished in the factory. The moving walls provide **flexible space** which allows for the best use of a smaller footprint home - cause lower energy usage and expenses.



Living Area:

With a flexible concept, the room can be adjusted in size according to real-time conditions with the movement of two automated walls to adjust to the three program spaces during the day. By day the home can be transformed into an office, in the evening an enlarged living room, and a full bedroom by night.

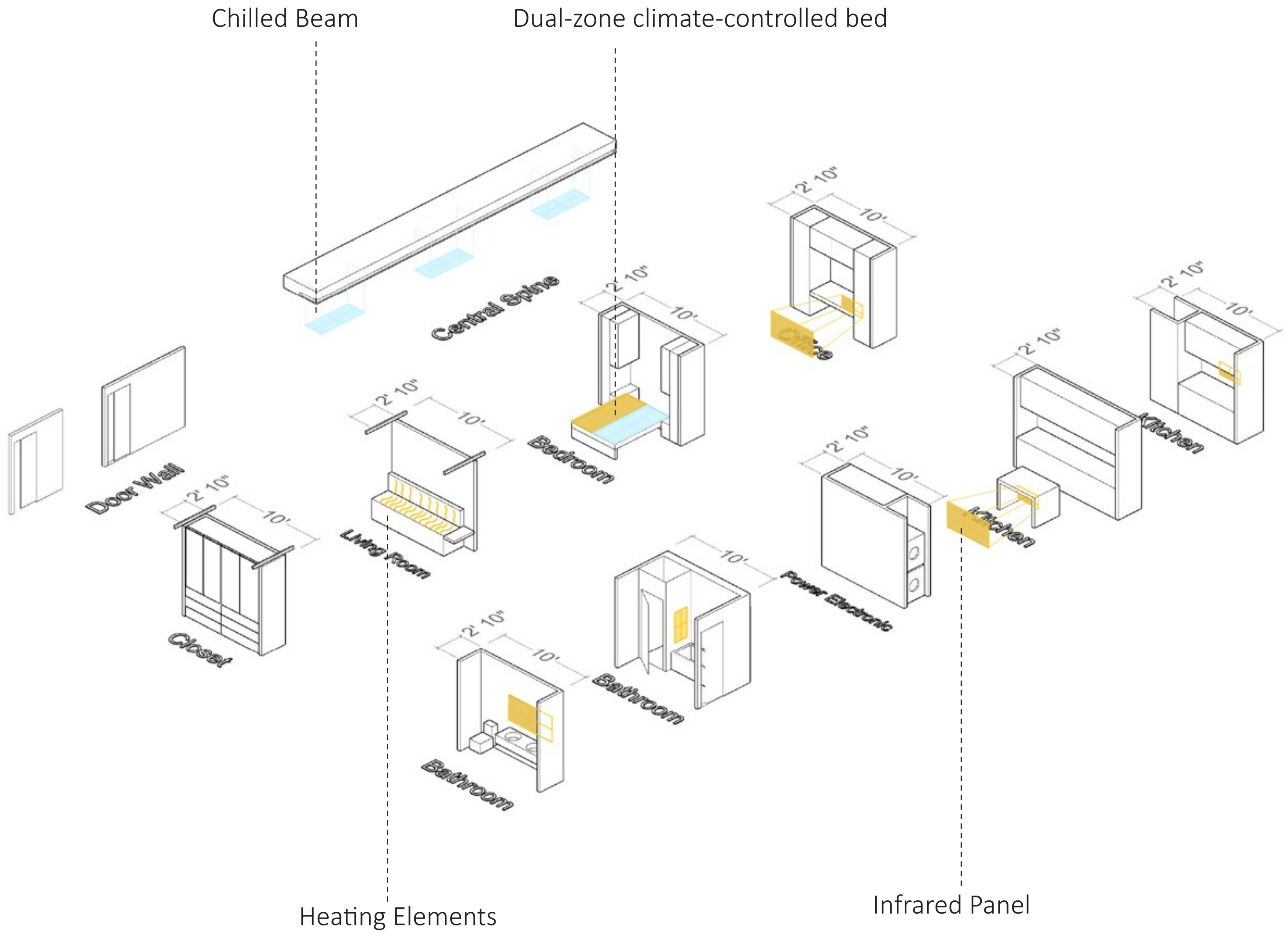
Direct Current (DC) is distributed to these walls. The powered rail allows flexible energy distribution for the moving walls and more energy efficiency. The wall between the home office and the living room can be a sofa wall, library wall, or TV screen wall. This wall can also rotate to share the television, sofa, or library between the living room or home office, thereby emphasizing the flexible space.



The Home Office: Depending on the positioning of the moving wall, several office sizes can be created from closed offices to one desk, to the 2 desks, and the conference room.

Bedroom: The bedroom includes a mechanically Murphy style bed that lifts to reveal a dressing room with a mirror at the back of the bed. The wall can move to create various size for bedroom or living room.

The Spine: is located over the central hallway contains all home run electrical and communication lines in addition to the HVAC system. The spine also connects the power electronic component to the other prefabricated walls and it is the essential component that makes the home installation easy, organized, and fast.



Localized Heating and Cooling in Residential Units

A similar approach as the work environment is used for heating and cooling in residential units. Heating and cooling are based on conduction and radiation and they directly transfer heat or cold to individuals.

Bedroom:

Dual-zone climate-controlled bed allows users to control and set a different temperature for each side of the bed. Blanket, comforter or top mattress could significantly lower energy costs by allowing users to heat or cool their bodies directly rather than managing the temperature of their whole home. The water-based system controls the bed temperature from 55 to 100-degree Faranhight.

Living room:

Heated seats are powered by a **heating element,** a long strip of material that functions as a resistor. A resistor resists the flow of electricity. When an electric current flows through it, the energy is turned into heat, which flows through the seat, **warming the people through conduction.**

Infrared panels are placed in the home office wall, bathroom wall, and kitchen in the table which create local heating and transfer heat directly to people.

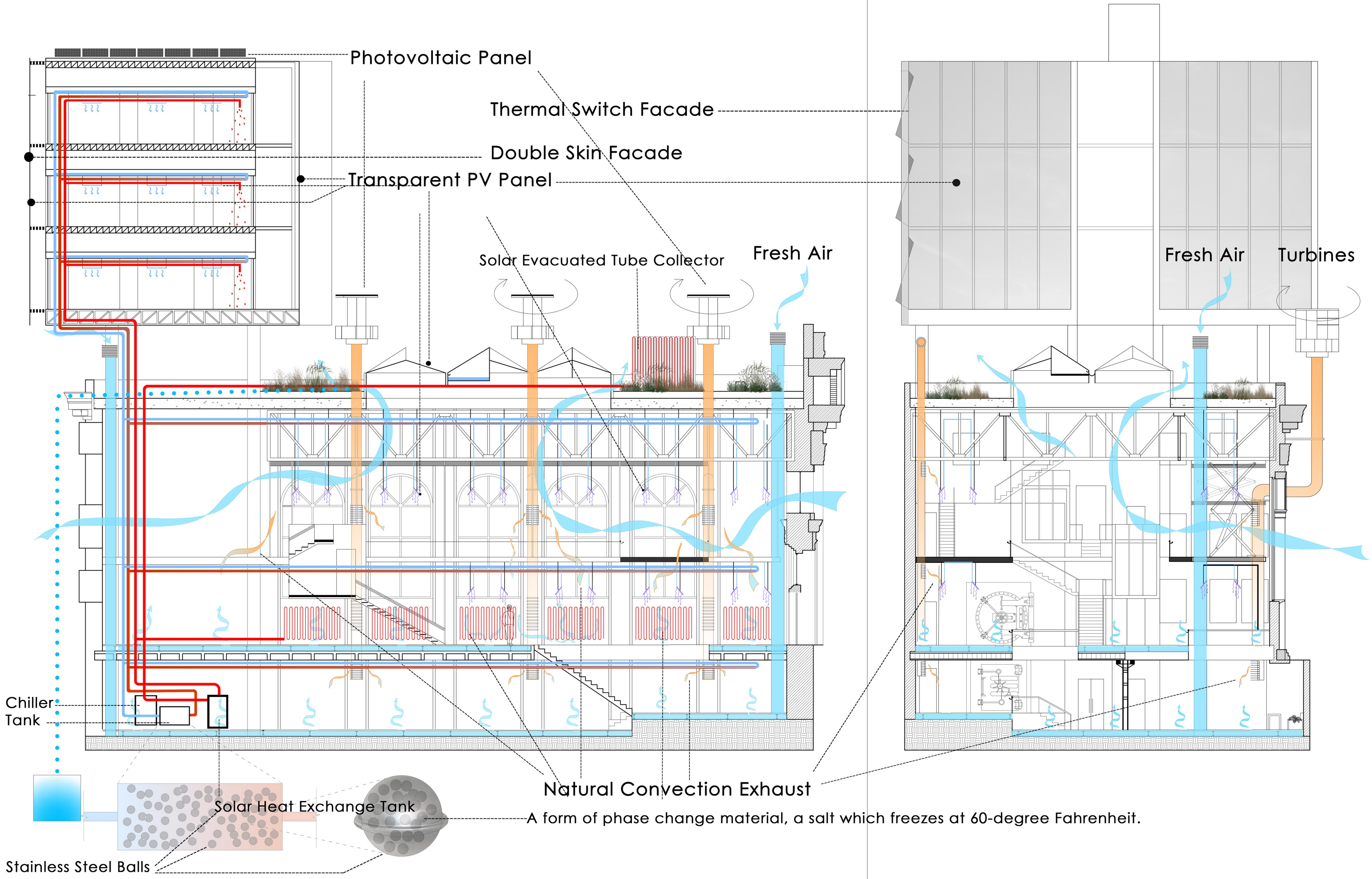
Central Spine:

In addition to Infrared panels and the smart duvet, **active chilled beams** are used in Central Spine. A chilled beam acts as a radiator chilled by recirculated water. Warm air rises and is cooled by the chilled beam; once it's cooled, the air falls back to the floor, where the cycle starts over. In an active beam, the ventilation air is delivered to the beam. They are work for both cooling and heating.

CHAPTER 4

OPERATIONAL ENERGY

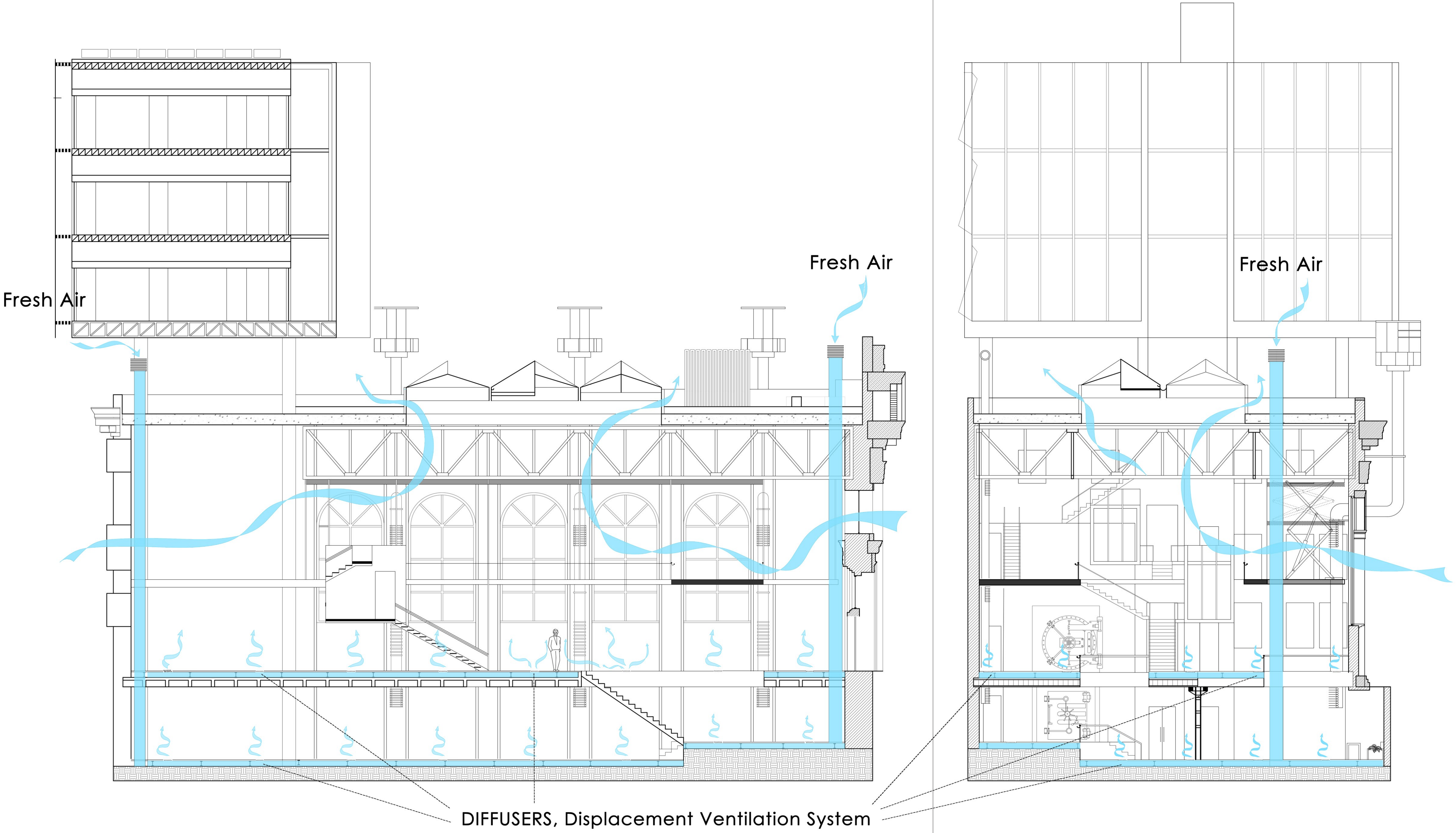
Building’s Operation
Ventilation. Fresh Air
Ventilation. Exhaust air
Photo-voltaic Panels
Cooling process water with Phase changed Material
Solar Hot Water
Skylight and distilled water
Thermally Adjustable Facade
Double Skin Facade
Rainwater Management Strategies
Water Efficiency Strategies



Building's Operation

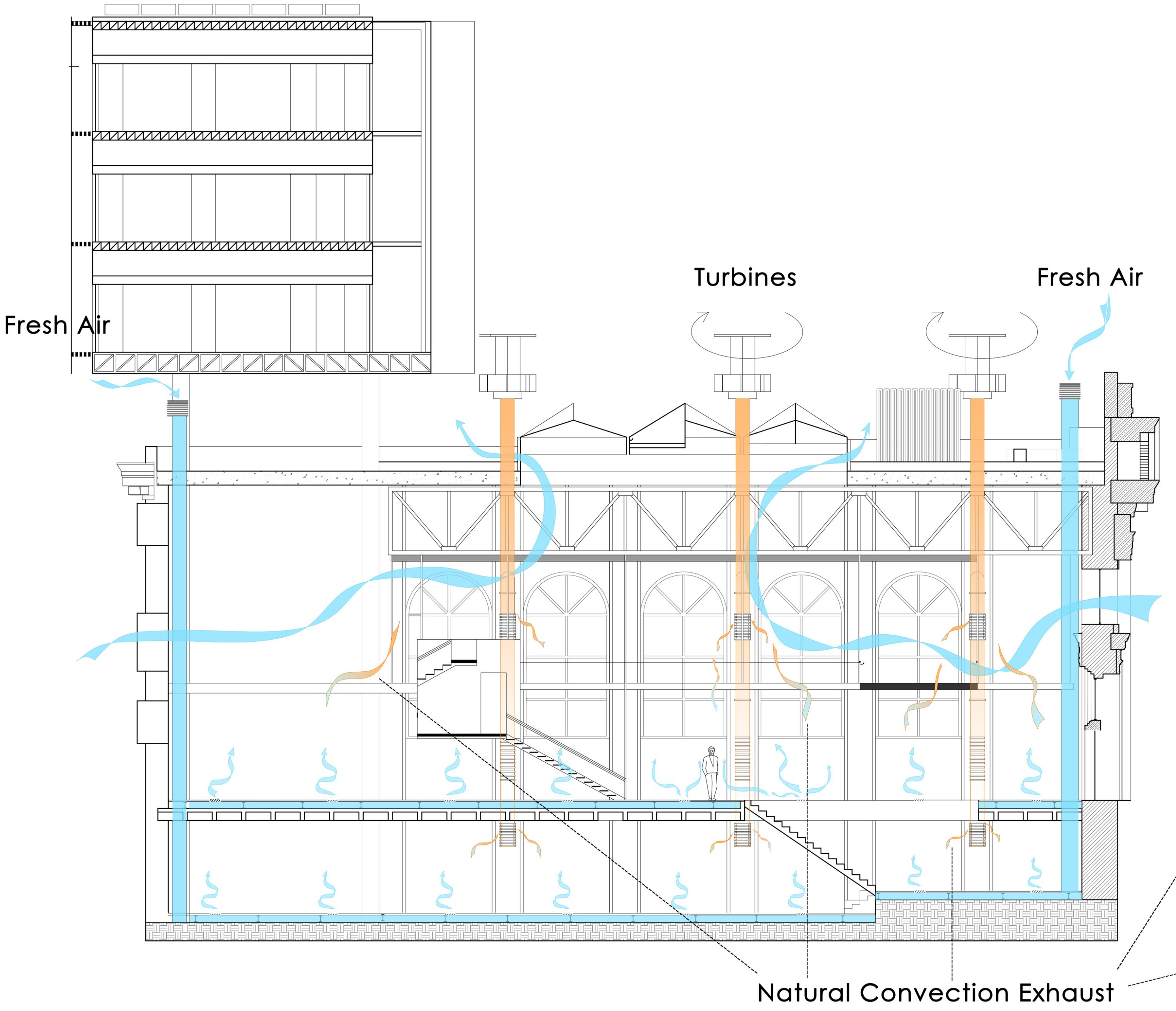
Generally, most of the existing buildings in their primary states are not energy efficient in their operation as the buildings that currently built to be high performance and energy-efficient. The preservation field always confronted with the challenge of bridging the gap between embodied energy and operational energy when comparing the energy efficiency of historic and existing buildings versus new constructions. Clearly, The more energy-efficient a building is the less energy it uses in its operation and, therefore, the less carbon will emission.

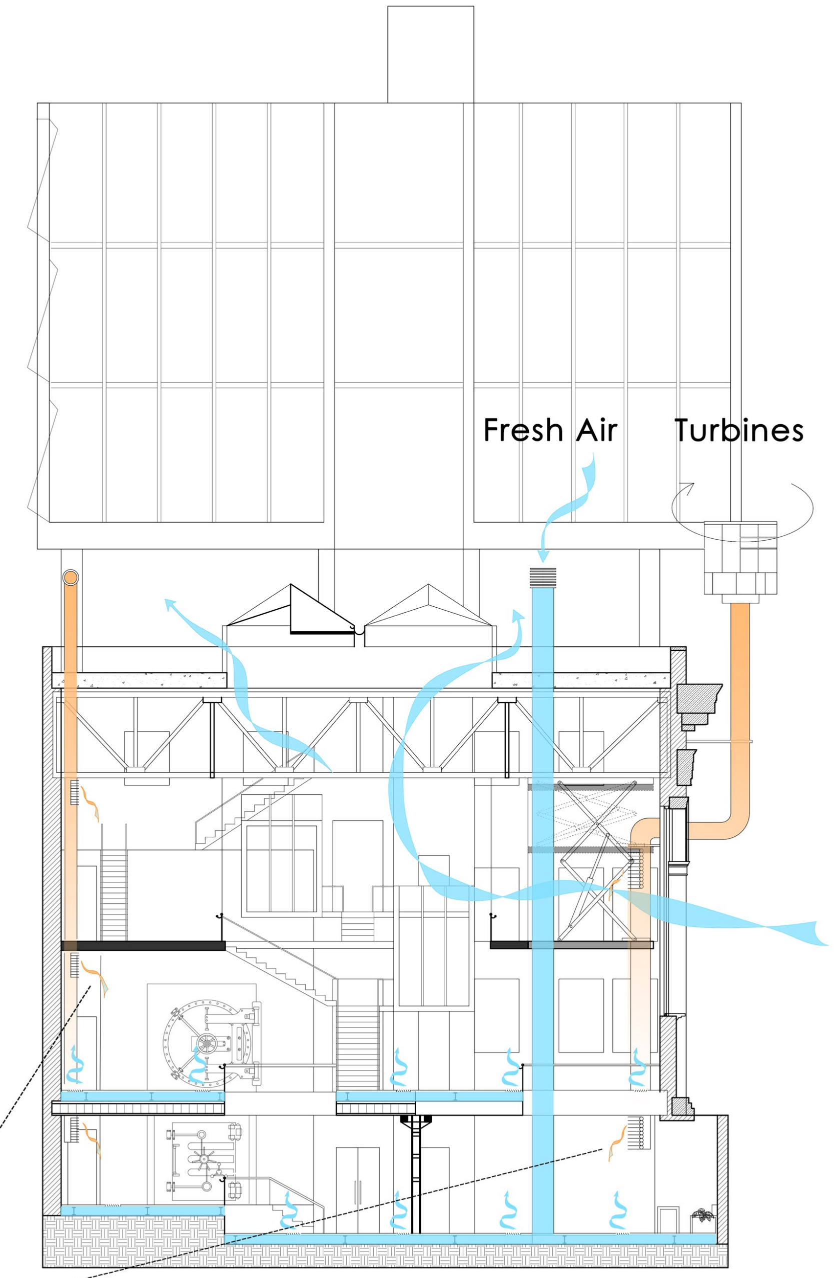
Operational energy is defined as the energy is utilized for maintaining the interior environment of the building which includes total energy that is brought into the system to run lights, elevator, heating, cooling, and ventilation systems, water heating, and building's appliance. In this project, the electricity generation is mainly based on on-site renewable sources.



Ventilation: Fresh Air

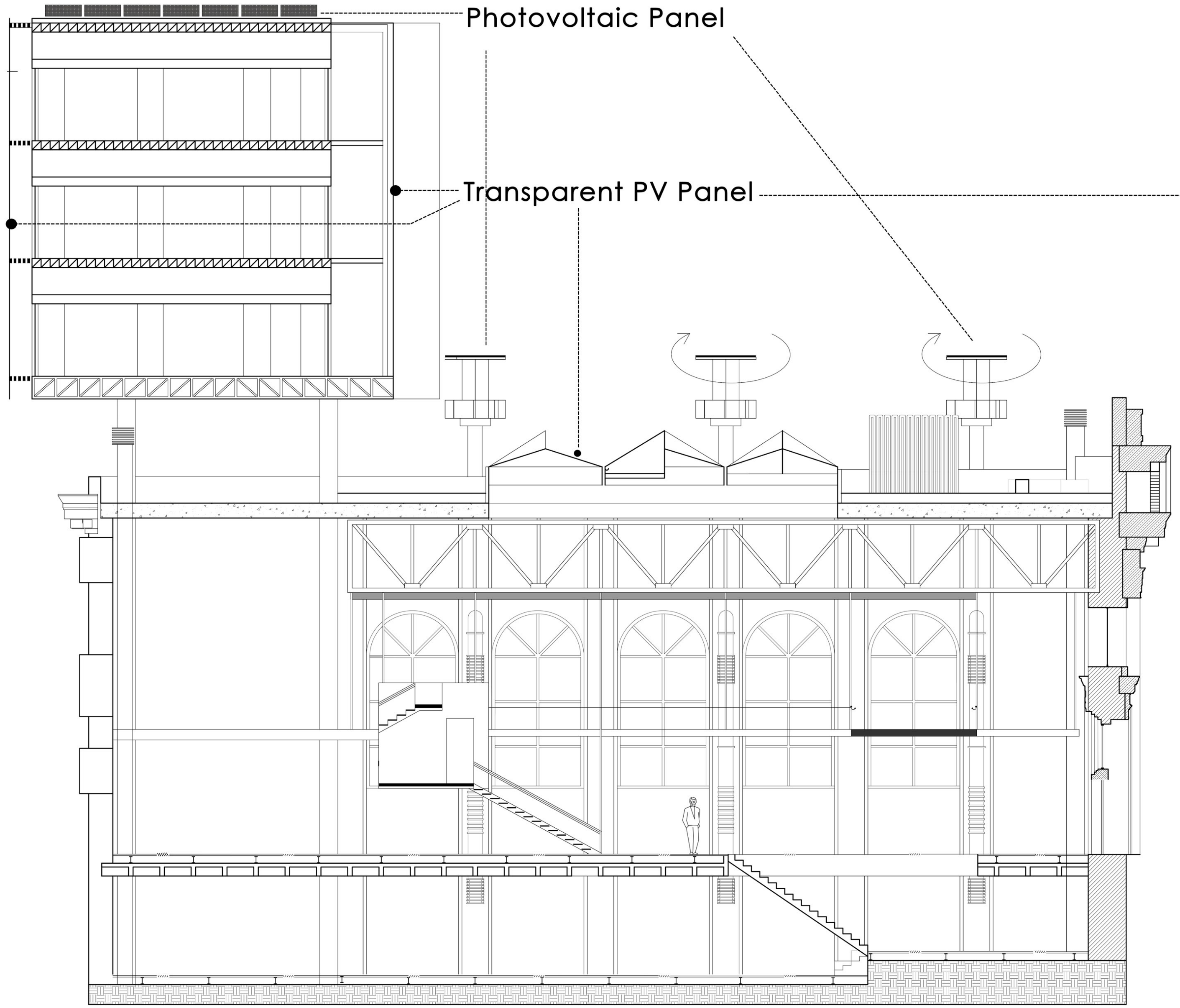
Besides the natural stack ventilation that happens through operable windows at the east, west, and north side of the building and opening at the skylight, the Displacement Ventilation System is used to enhance the indoor air quality of the building. In Displacement Ventilation System **conditioned outside air is supplied through vertical ducts release air to the underfloor plenum and fresh air continually fed at low velocity through diffusers**. Displacement Ventilation System is coupled with radiant cooling and heating surfaces in the building to **provide indoor air quality and thermal comfort** with the least energy use. The air supplied temperature that releases from floor vent in the building is approximately 68° Faranhight and it is only used once and is exhausted by natural convection to the atmosphere. To provide a flexible work environment, swirl diffusers located on movable floor tiles.





Ventilation: Exhaust air

As the fresh air warms, it gently rises through the natural convention and enters the gaps in the exhaust towers and is channeled out of the building and the turbines are used to help draw air out of the building.



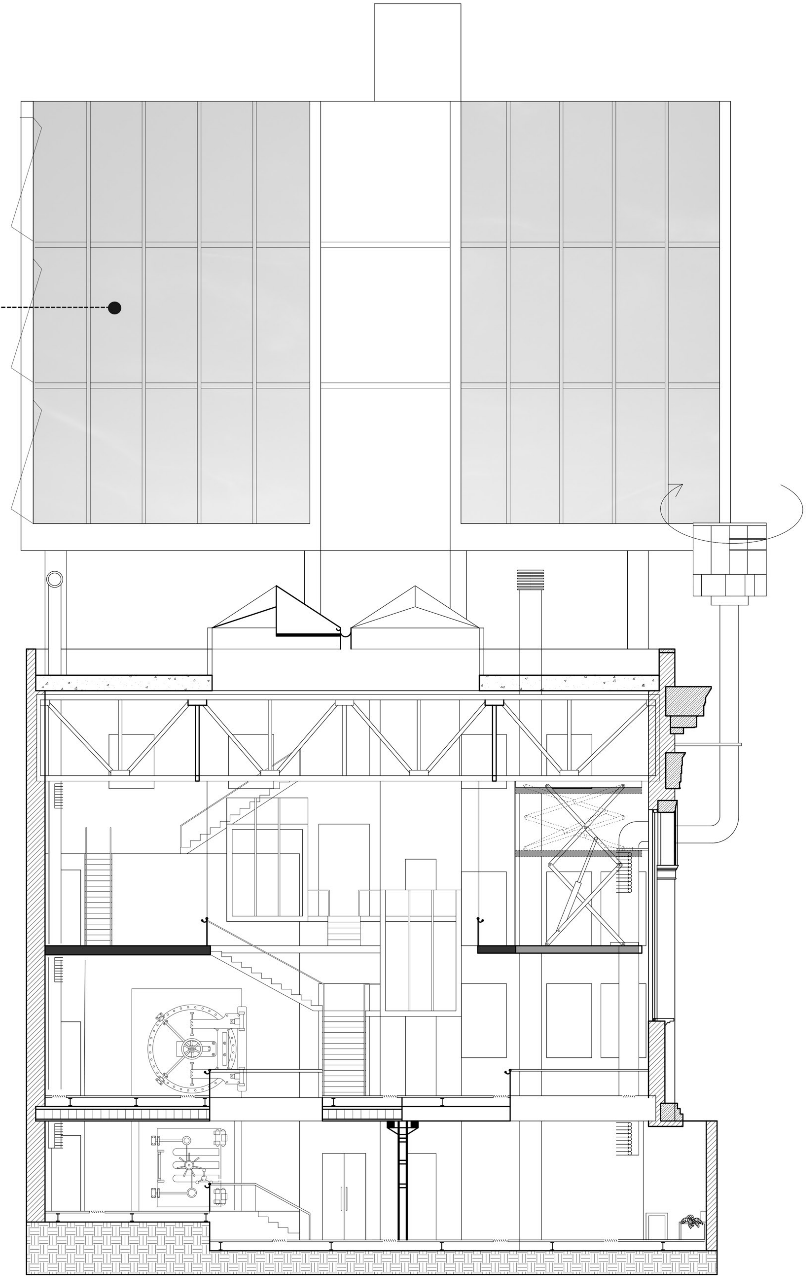


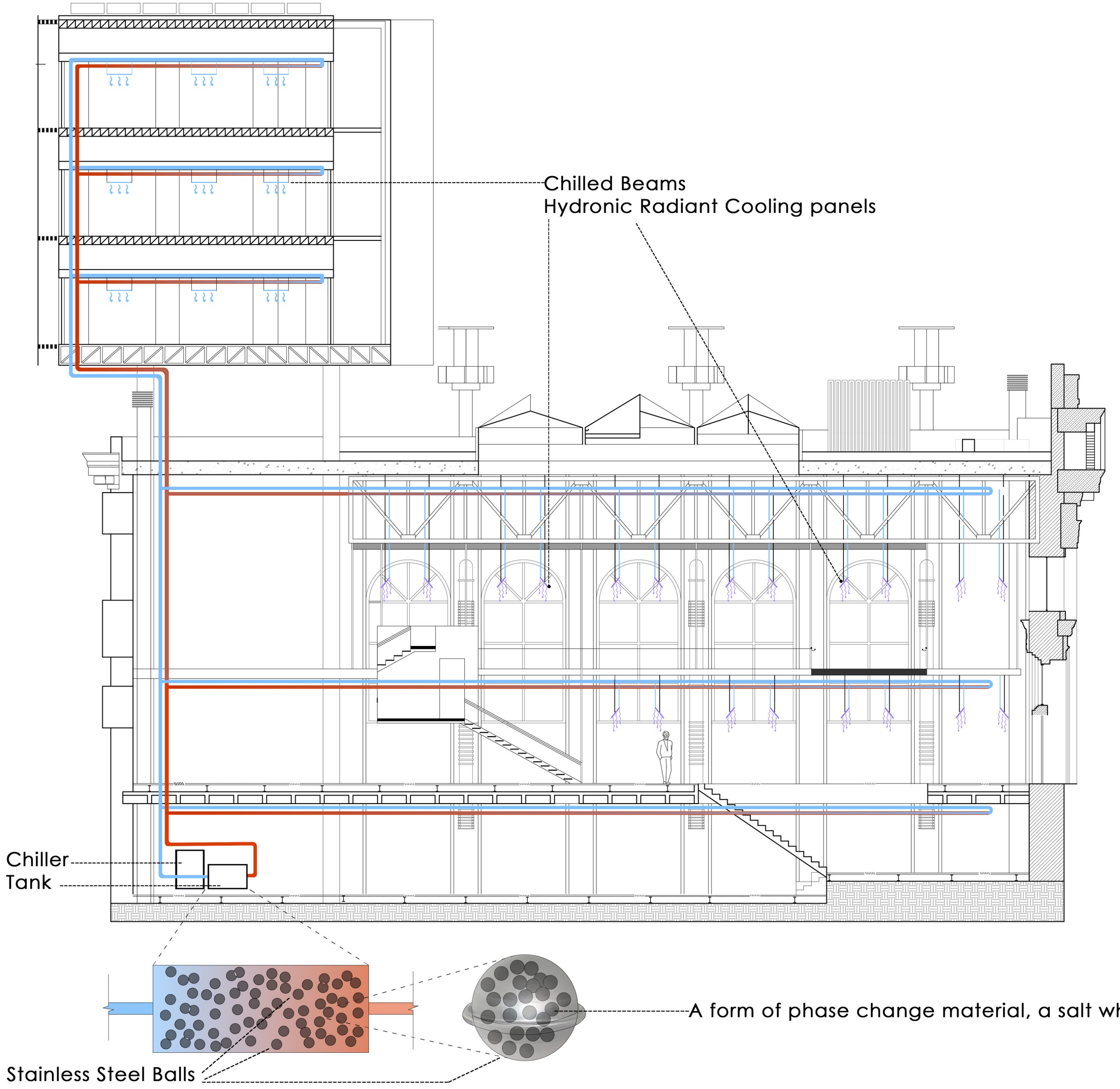
Photo-Voltaic Panels

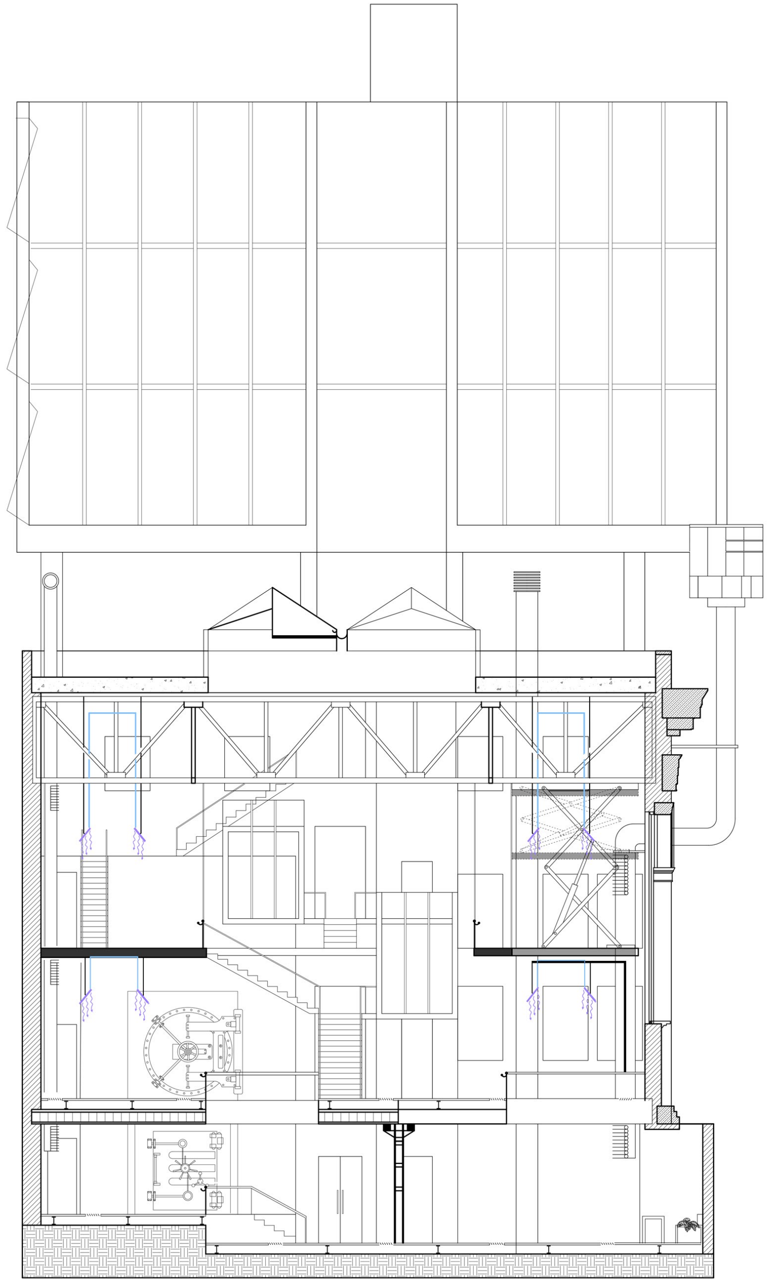
At the top of the turbines there ate photo-voltaic panels. When the wind blows, and/or the sun shines, electricity is generated and is supplied to electrical equipment.

More photo-voltaic panels are located at the top of the residential roof. Solar panels generate the maximum energy when that sunlight is perpendicular to the panel surface. Therefore, the most beneficial angle for the solar panels is the one that provides the most perpendicular, direct light to the panels.

Since the sun's position is higher in the sky during the summer and lowers during the winter, it has an average position right in between the two seasons. To get the maximum average output of the solar panels during the year, they are tilted at the same angle as the latitude of Philadelphia which is 39 degrees.

Transparent photo-voltaic panels are used on east and west facades of the residential building as well.

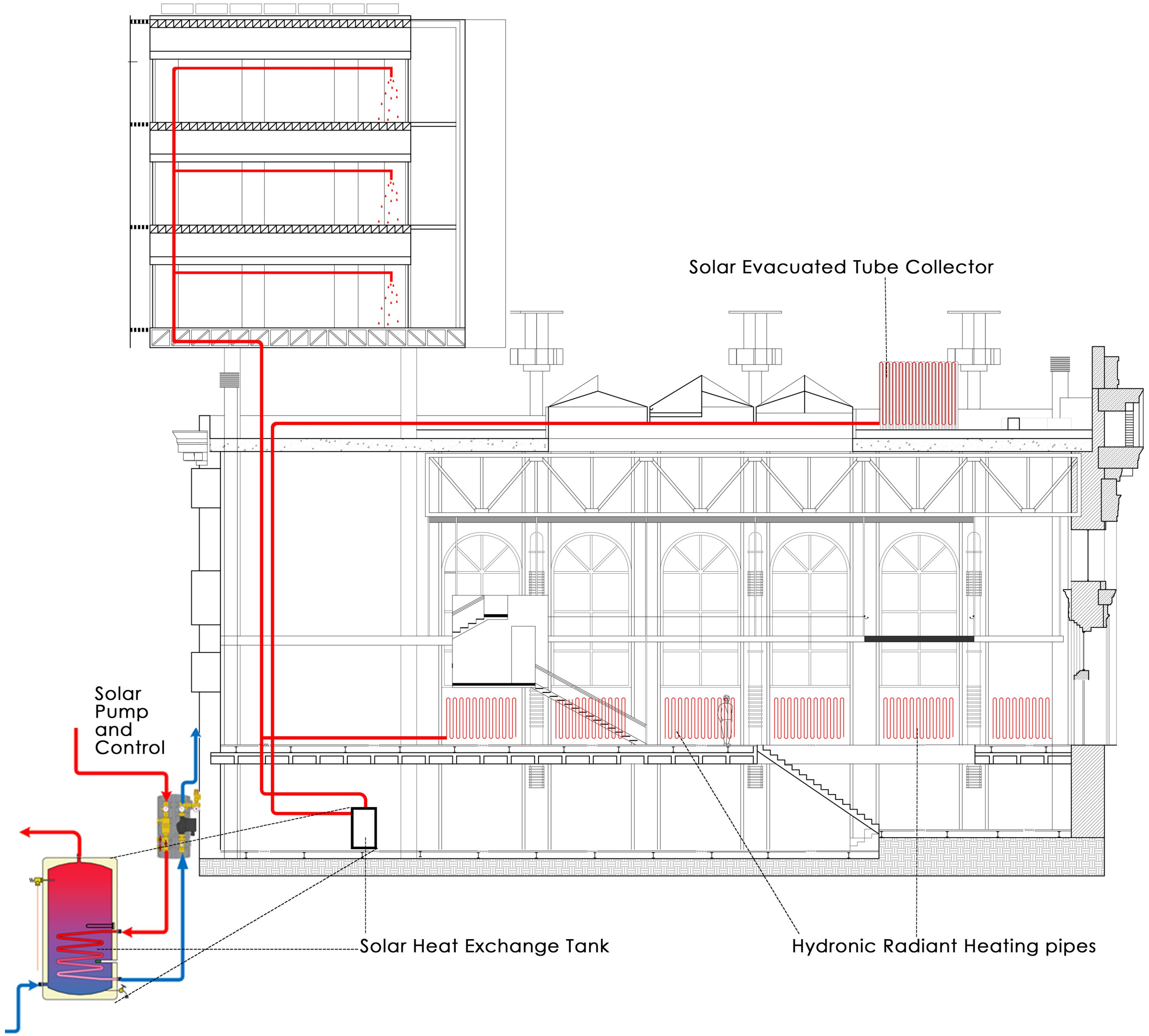


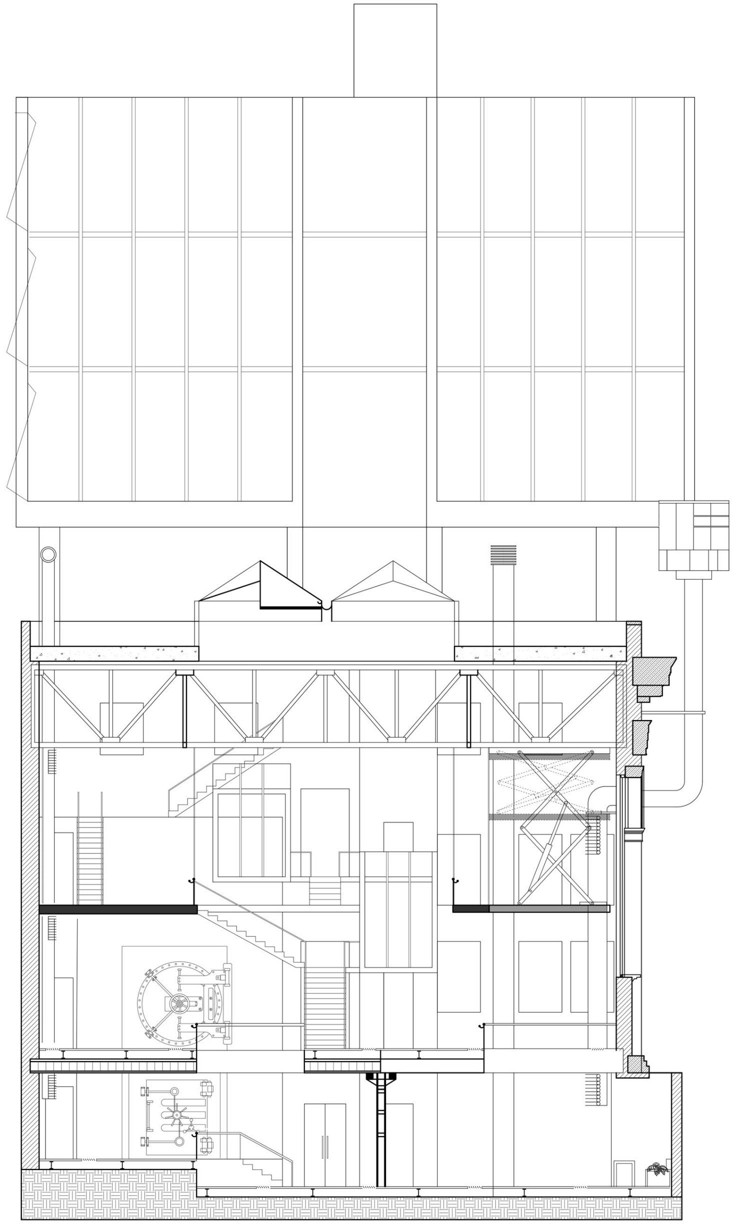


Cooling Process Water with Phase Changed Material

For cooling the process water in a passive mode, the cold water is supplied by a large tank at the basement to the ceiling panels. A tank includes small stainless-steel balls, which filled with the form of **phase change material (PMC)**, salt which freezes at 60-degree Fahrenheit.

Frozen phase change material chills the water in the tanks and then when cooling is required, pumped around the building to the radiant cooling panels. The water will be two to three degrees warmer when it is coming back from this circulation. The phase change material balls continue to absorb heat until they melt. They operate as a thermal storage battery. When the heat does not be able to absorb by the phase change material, the PCM system is turning off, and for cooling water needed for the radiant surfaces, the chiller in the basement is utilized.





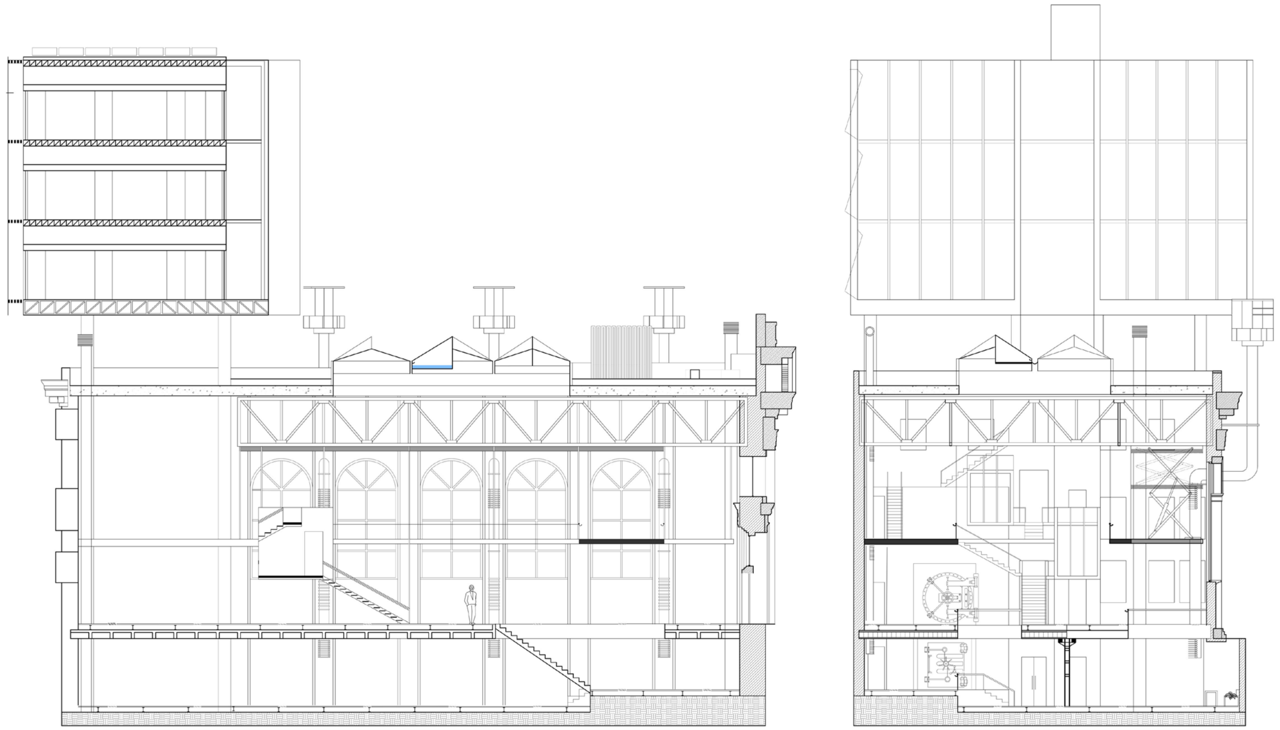
Solar Hot Water

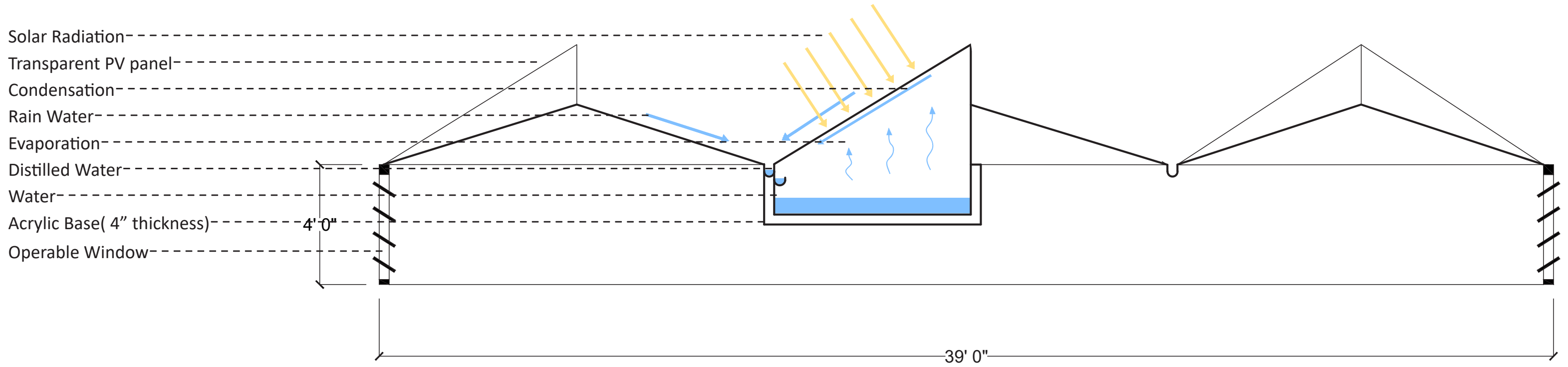
Solar hot water takes the sun's heat and turns it into usable thermal energy. When the solar evacuated tube collector on the roof is warmer than the water tank, the pump will be activated by a differential temperature controller. This pumps then circulates a fluid (water and glycol mixture as antifreeze) to the solar collector on the roof and the solar-heated fluid is then pumped to a high-insulated storage tank where it emits its heat as it moves via a heat exchanger. As long as the sun is shining it is pumped back to the collector to continue the cycle. For most of the year, all the hot water for use in the building is provided by the sun, even on cloudy days. The sun will still help in the darker days of winter but a boiler as a backup unit will run to ensure constant hot water for the building.

Skylight and distilled water

The skylight brings daylight but also designed to capture stormwater and collect distilled water and the surface operate as transparent photovoltaic panels.

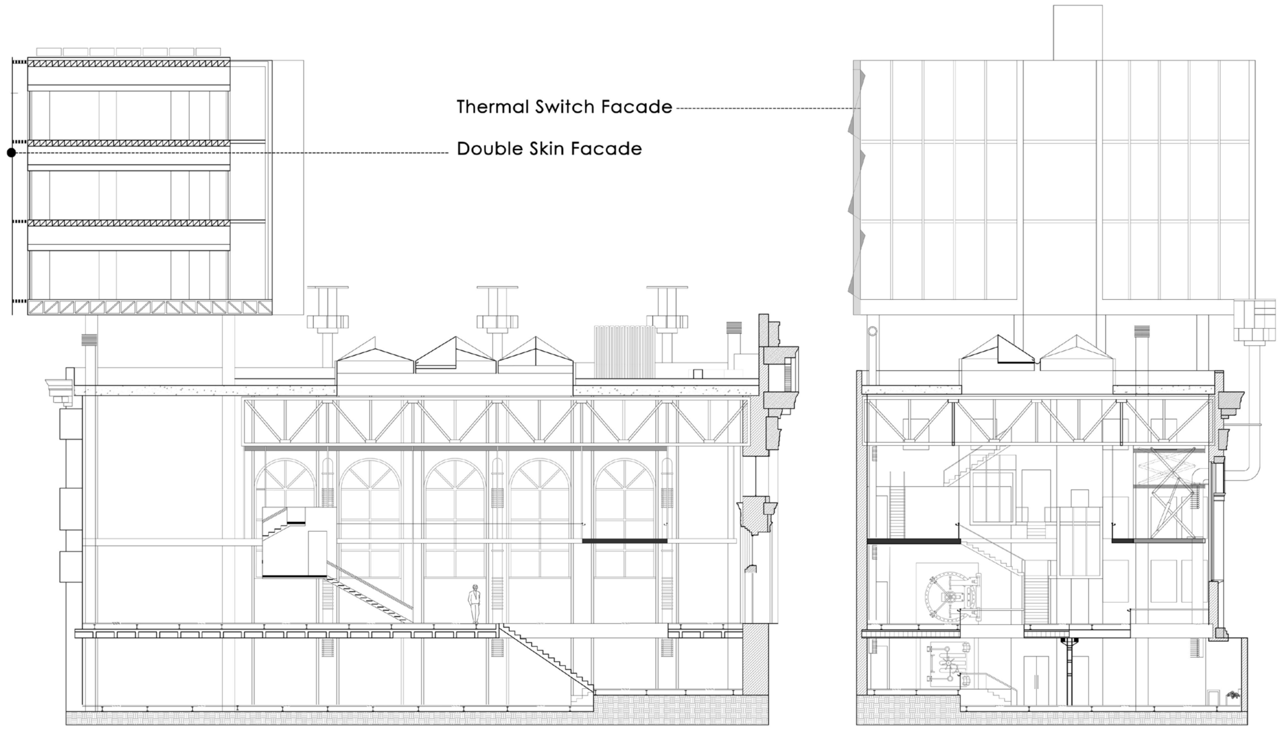
The water will be heated by the energy of the sun to the point of evaporation. When water evaporates, water vapor rises, and as it touches the interior surface of the glass and cools, condensing into the water again and the droplets can then be collected. This process leaves behind some impurities such as salts and heavy metals that will leave behind as a result of this process. The result is pure distilled drinking water.



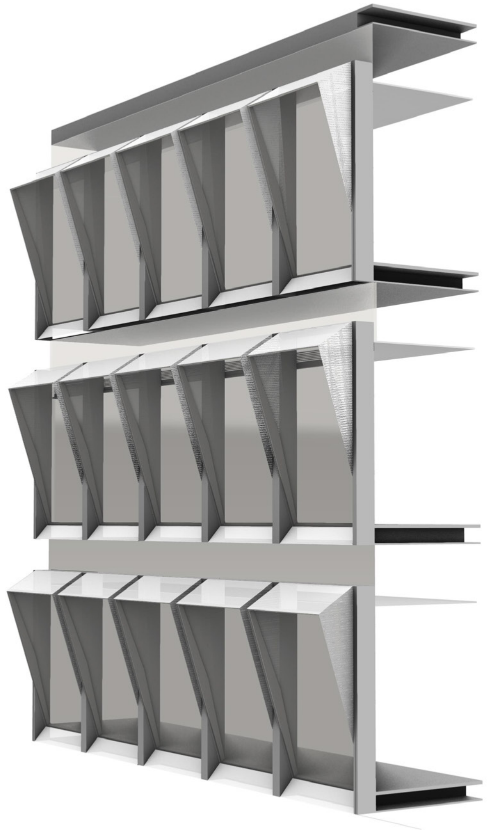


Thermally Adjustable Facade

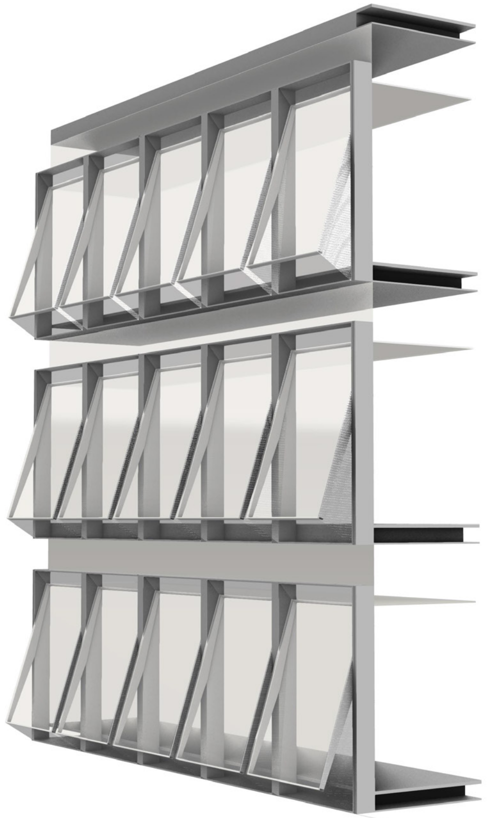
The concept behind the Thermally Adjustable Facade unit is to create a double skin and allow the envelope to breathe and control the interior conditions by changing with temperature. The vented space within the skin causes the facade tilt either toward or away from the sun by utilizing the Nickel Titanium or nitrile wire depending on temperature. The ambient temperature will active the Nickel-Titanium within the cavity. For enhancing the airflow into the building, the facade needs to move with the dynamic temperatures. Therefore, the **facade would be changed with the seasons. Thus, for maximizing the sunshade in summer and obtain solar in winter, the facade has to be tilted**.

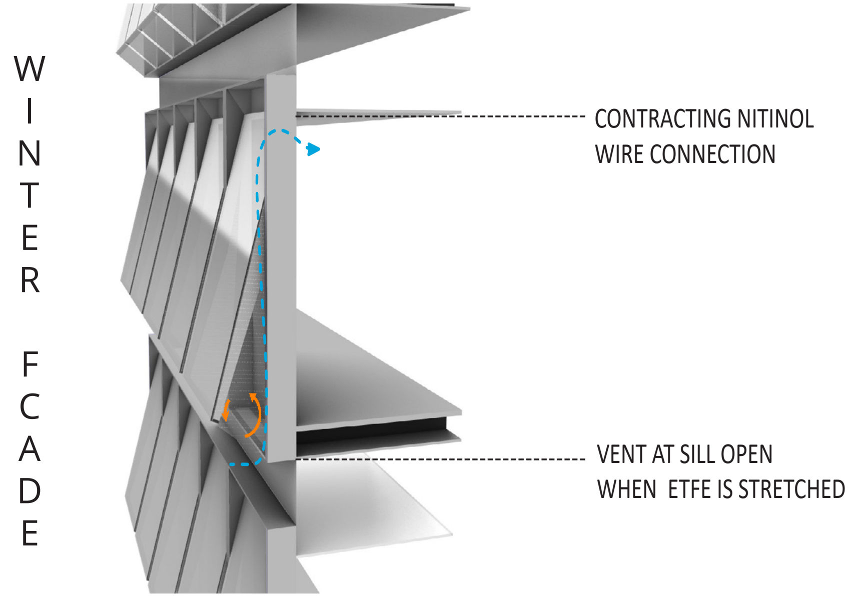


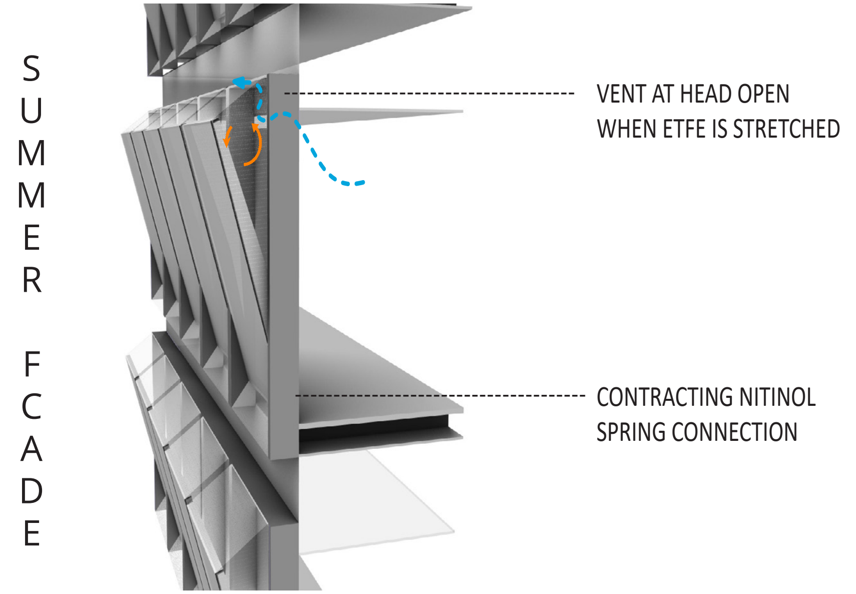
SUMMER FACADE



WINTER FACADE

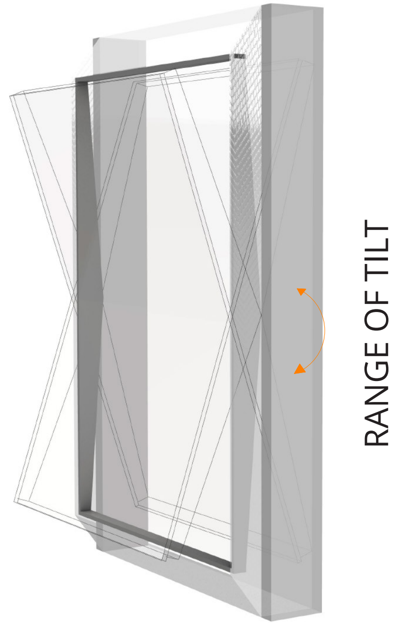


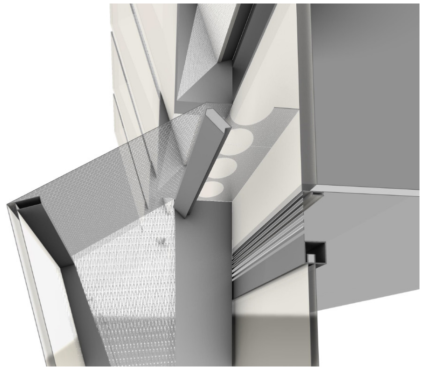




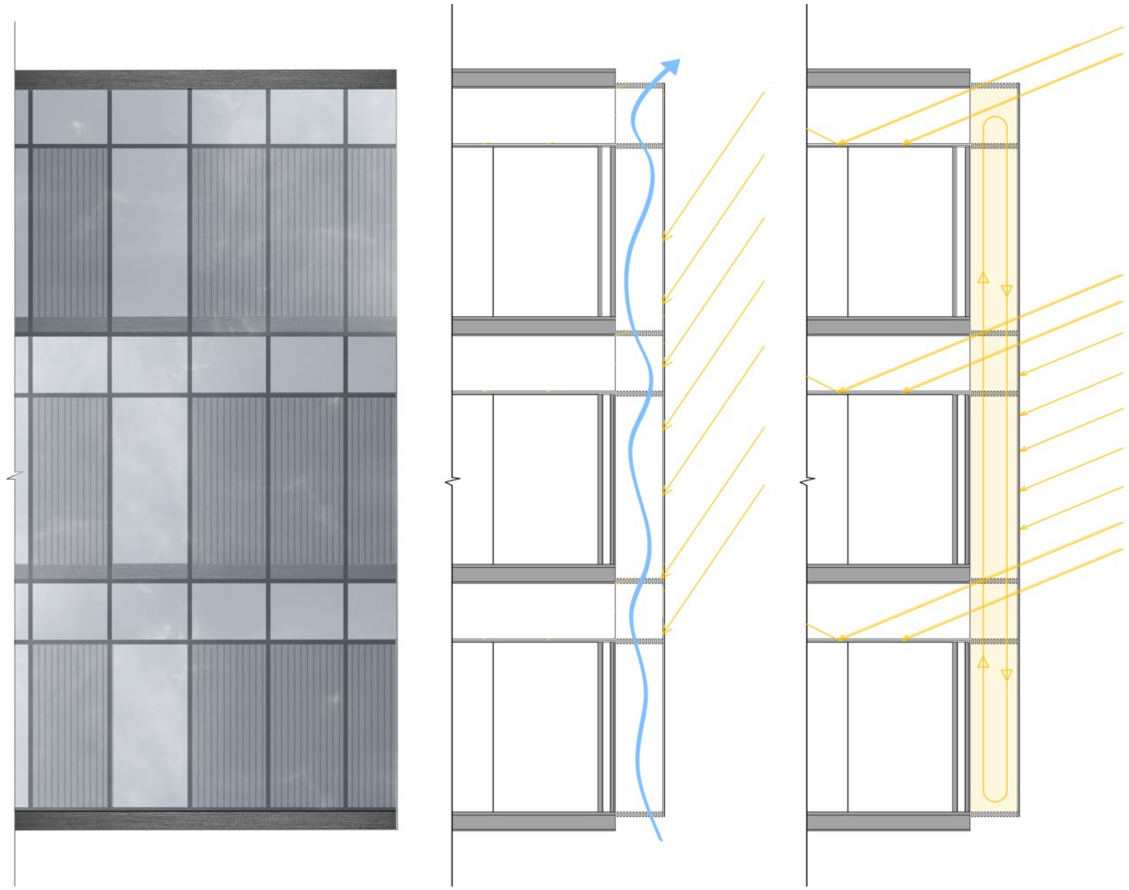
A convection current happens by this tilting process which draws fresh air from the outside into the space between the skins and heats it as it enters into the room or vents out warm air from the building. The envelope has the potential to draw air passively via the facade, without dependency on mechanical appliances, and create air circulation for residents.

> "Nitinol alloys show two closely similar and unique characteristics: superelasticity and the shape memory effect. With the shape memory effect, the original shape can be recovered after deformation by heating; with superelasticity, any apparent plastic deformation can be returned to the original shape by releasing the load. Because of these unique properties, the Ti–Ni alloy is used for guide wires, stents, orthodontic archwires, endodontic reamers, and files(18)".





Ethylene Tetrafluoroethylene (ETFE), a fluorine-based polymer, as the cladding material is chosen. A single-ply membrane provides freedom for moving the system.



Double Skin Facade

The double skin enclosure of the east and west facade is a passive method of climate control. The double skin acts as a thermal blanket trapping air to keep the building warm during the cooler seasons and also allowing for the passage of air through it to cools the building in the warmer periods of the year.

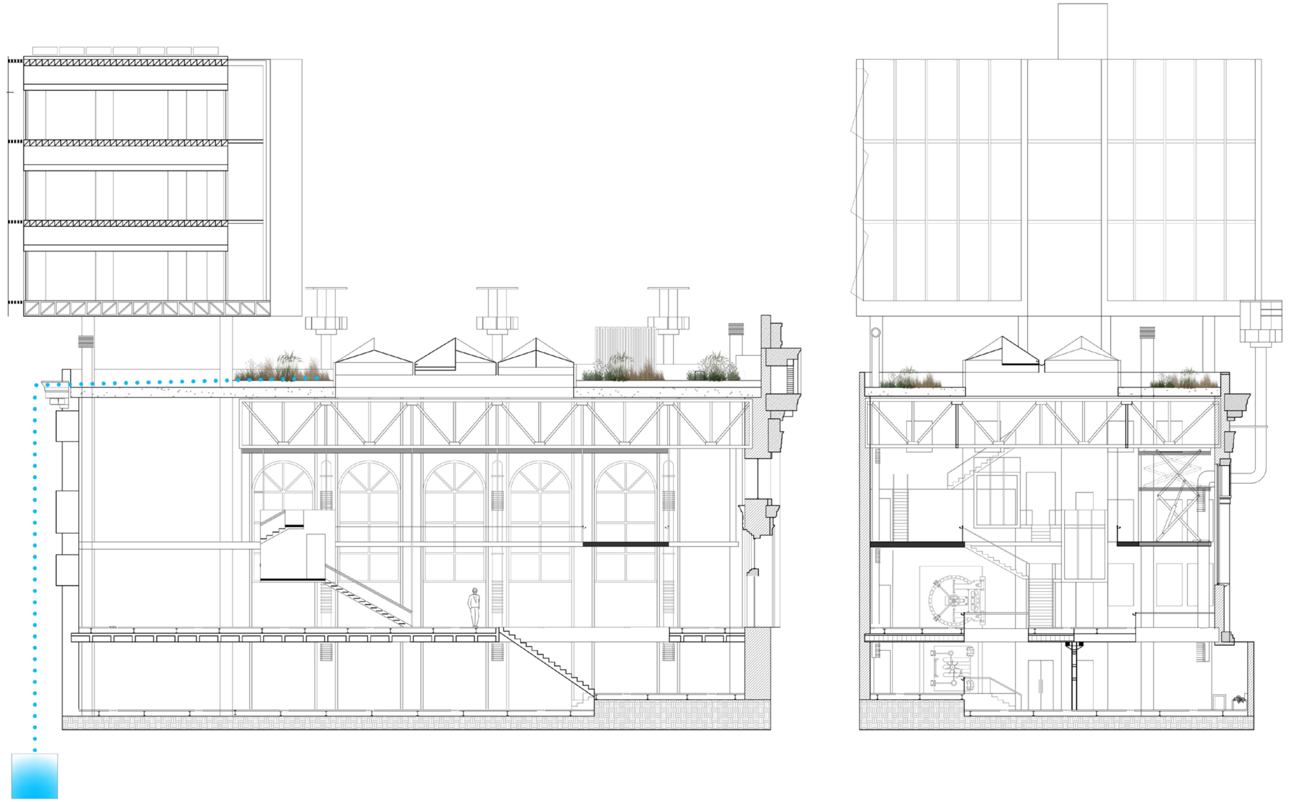
Light first passes through the outer glass skin and then through rows of windows at the top along the interior skin and then through the light ceiling. The building illuminated differently depending on the time of day. Thus, an environment of natural light is created.

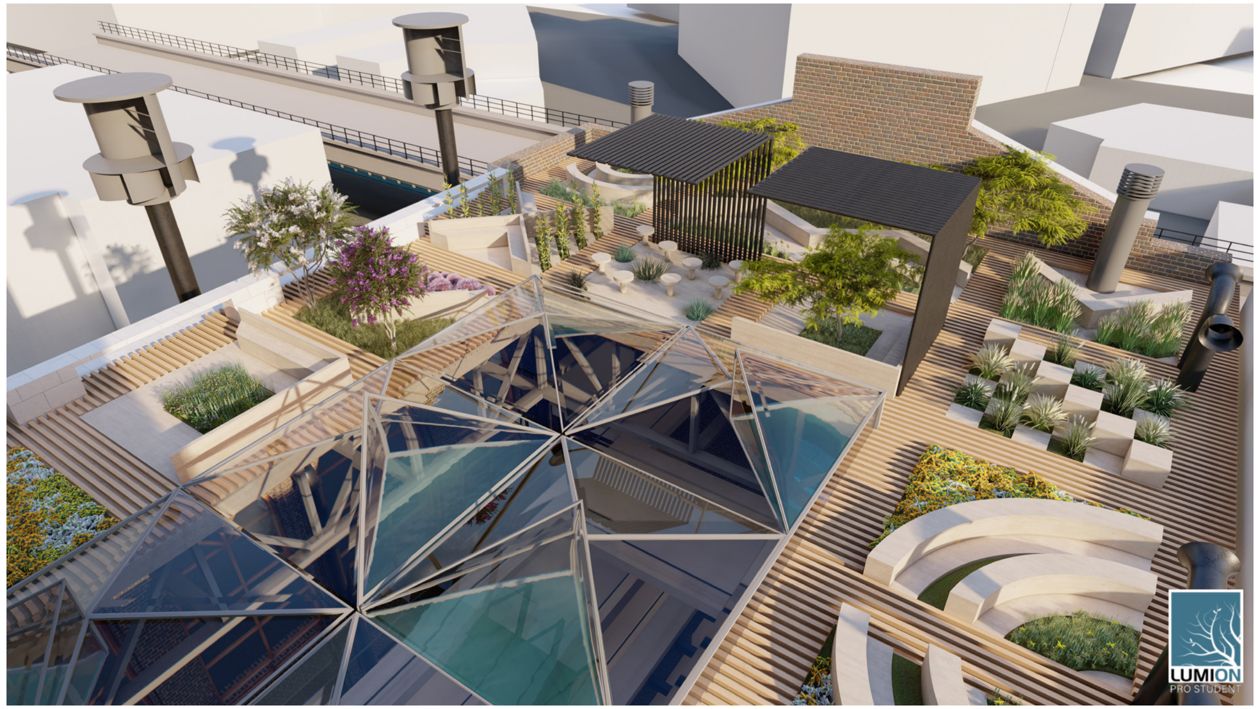
Rainwater Management Strategies:

For the rainwater management, the project proposed a green roof with native and adapted plant species on a rooftop to trap rainwater and prevents it from running off the roof, using pervious surface, collecting Rainwater.

Water Efficiency Strategies:

The goal of water efficiency is to decrease the amount of potable water used for a purpose other than drinking and to treat and reclaim all the greywater. Water performance strategies that proposed include using high-efficiency or no flush fixtures, implementing a greywater and rainwater water reclamation system, and installing submeters that measure and report water flow.





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(9) George Morgan, The City of Firsts (Philadelphia: Historical Publication Society, 1926), 248.

(10) Ellis Paxson Oberholtzer, Philadelphia: *A History of the City and Its People* (Philadelphia: S.J. Clarke Publishing Company, 1912), 1:424. Old City, in contrast, had 13,241 buildings.

(11) Milano, Kenneth W. *Hidden History of Kensington and Fishtown.* Arcadia Publishing, 2010.

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(14) Bean, Robert, and Kwang Woo Kim ArchD. "*Part 1: History of radiant heating & cooling systems.*" Ashrae Journal 52, no. 1 (2010): 40.

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(17) De Decker, Kris, and V. Grosjean. "*Low-Tech Magazine*." (2007).

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Figure 1: Paul Close, Building Insulation: *Principles and Application of Heat and Sound Insulation for Buildings* (Chicago: American Technical Society, 1941)

Figure 2. Advertisement, Public Ledger, 1916. http://www.preservationalliance.com

Figure 3. Progress of steel construction, looking north from bent 189, showing crosswires, Sept. 11, 1916. [including Ninth National Bank, Front St. bel. Norris Street.]. The Library Company of Philadelphia . https://digital.librarycompany.org

Figure 4. Progress of steel construction in Kensington Avenue at bent 265, looking south, October 16, 1916.

Figure 5. Progress of steel construction, looking south on Front St. from Bent 155, August 14, 1916.

Figure 6-8. https://www.philageohistory.org

Figure 9. Ninth National Bank First Elevation. https://libwww.freelibrary.org

Figure 10,11. Watson, Richard, and Kirby Chapman. "*Radiant heating and cooling handbook*". McGraw Hill Professional, 2002.

Figure 12. Hooded chair. https://www.bidsquare.com

Figure 13. Bed with canopy and curtain. https://en.wikipedia.org/wiki/Four-poster_bed

Figure 14. Folding Screen. https://madparis.fr

Figure 15. https://www.wga.hu/html/m/man/chess_pl.html

Figure 16. *https://en.wikipedia.org/wiki/Korsi*.

Figure 17. https://www.wikiwand.com/en/Kang_bed-stove

Figure 18. Yeo, Myoung-Souk, In-Ho Yang, and Kwang-Woo Kim. "Historical changes and recent energy saving potential of residential heating in Korea." Energy and Buildings 35, no. 7 (2003): 715-727.

Figure 19. The structure of traditional Ondol(before the 1950s), Yeo, Myoung-Souk, In-Ho Yang, and Kwang-Woo Kim. "*Historical changes and recent energy saving potential of residential heating in Korea.*" Energy and Buildings 35, no. 7 (2003): 715-727.

Figure 20. Roman Hypocaust, Beirut., https://cushareejournal.wordpress.com/2019/04/06/the-hypocaust-an-assessment-of-non-ancient-varieties/

Figure 21. https://commons.wikimedia.org/wiki/Category:Tiled_stoves_in_art

Figure 22. https://commons.wikimedia.org/wiki/File:Albert_Anker_Sonntag_Nachmittag_1861.jpg

Figure 23. De Decker, Kris, and V. Grosjean. "Low-Tech Magazine." (2007).

Figure 24. Interior diagrams of Russian stoves, https://endeavourcentre.org/2017/02/residential-heating-system-basics/50-masonry-heater/

Figure 25. Russian stove, http://www.litsovet.ru/index.php/gallery.view?gallery_id=850

Figure 26. Parsons, Ken. "*Human thermal environments: the effects of hot, moderate, and cold environments on human health, comfort, and performance*". CRC press, 2014.

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