# Urban Hybrid House

*and its application in a block context*

Beatriz Machado

THE PROJECT H



## Project Description

The aim of this project is to develop a cluster of hybrid houses in Evanston designed to produce energy and reduce resources consumption in comparison to the houses surrounding it. The project goals are to demonstrate performance improvement. Maximize sun exposure and the interaction between the houses and its gardens. To raise awareness that it is possible to live in a more environmentally friendly unit without hardship is another purpose of the project.

The 3.5 acre site where the project is developed is located in Evanston, close to Northwestern University. It is located 0.3 miles of two transportation nodes, it is close to a retail area and it surrounded by single family homes.

The block is organized to integrate the prime areas of the house with the garden and to maximize south exposure. The landscape strategy is to integrate the houses to its gardens, to emphasize pedestrian circulation and to blur the living machine within the gardens and the common areas. In addition to that the proposed block has 23 houses while the neighboring one has 19 in the same area.

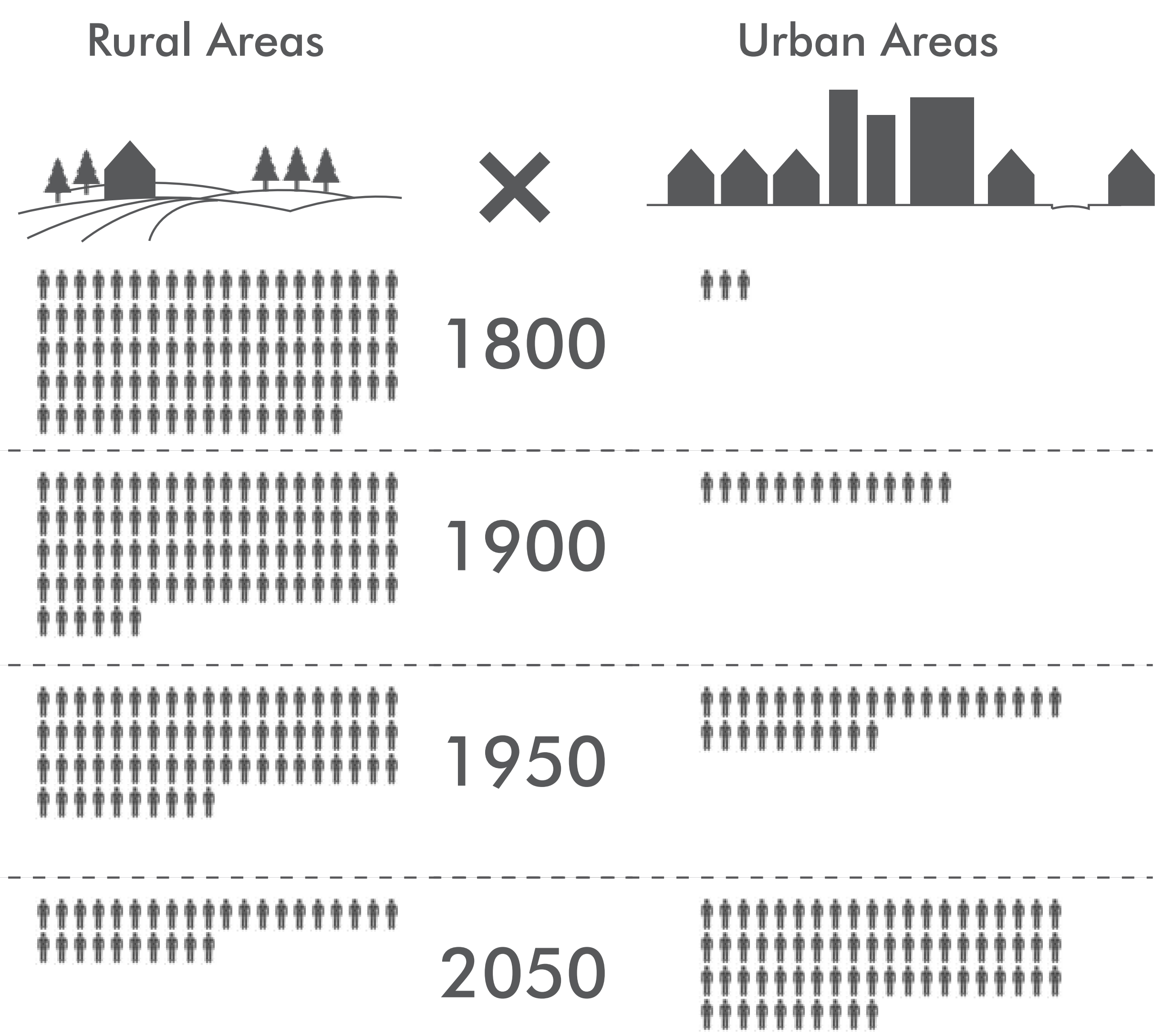
Built with Bio-SIP panels, the houses are highly insulated, the wall assembly achieved the same R-Value as the "Passivhaus" Standard with a 17" thickness reduction. The houses will be equipped with photovoltaic panels that will produce more energy than needed in the summer, delivering the surplus energy to the grid. In winter this energy will be recovered yielding in net zero units.

The houses will also reduce waste generation, be built with materials with low embodied energy, will be designed for deconstruction.

To analyze the house performance, another house with the same area and typical building material was modeled to enable results comparison. In terms of energy consumption the reduction is 40% and in terms of water conservation the reduction is 35%. Each house is collecting 65,000 gallons of water per year and it is producing 29,000 kwh per year.

# Background

Through most of history, the human population has lived in rural areas. This trend is being constantly shifted. In 1800 3% of world population lived in urban areas, while in 1900 this number increased to 14% and 30% in 1950. The world is experiencing this unprecedented growth. The expectation is that by 2050 70% of world population will be living in urban environments.



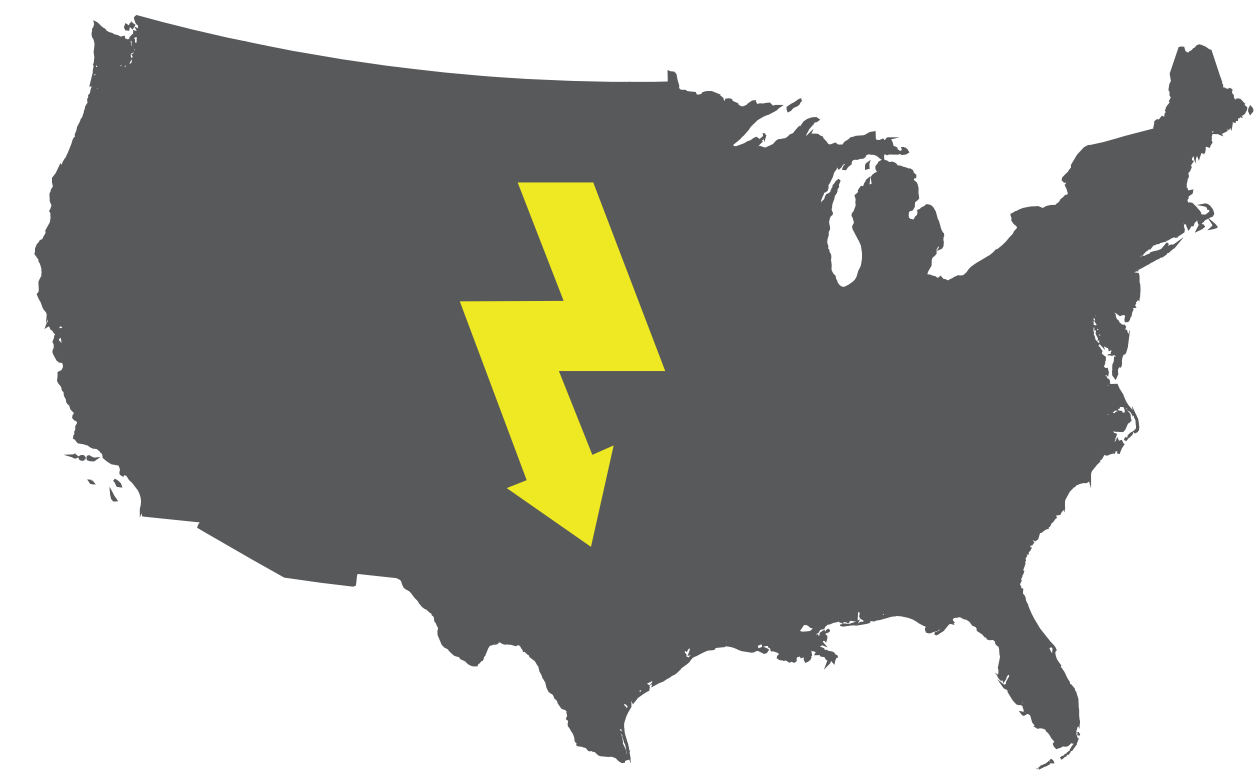

Source: world population reference bureau

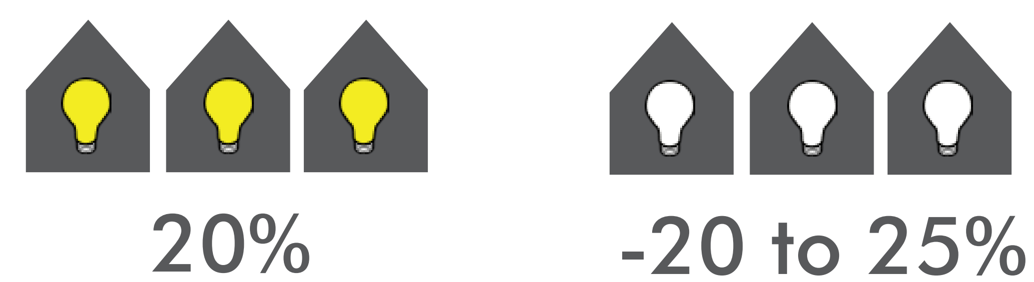
Considering the previous statement and adding to it the fact that buildings in the United States account for a high portion of resources used and waste generation (residential buildings constitute 20% of US total energy consumption [2]). The need for housing will be extremely large and it is paramount to take into account building efficiency in the design process. Changing behavior can reduce energy consumption by 20-25% without reducing the quality of lifestyle[2]. Adding behavioral changes to high performance architecture yields in direct costs savings for the dweller as well as to natural resources preservation.

The general trend of today's urban development is to build high rise buildings, increasing urban density. Single family units represent a significant portion of residential dwellings and energy efficiency must be considered in this regard. With that being said, the first step of this project will be the development of a hybrid single family home with the final goal of creating a healthy building environment that minimizes use of natural resources and reduces operational costs. The idea is to investigate alternatives to increase building's performance in terms of energy consumption, greenhouse gases emissions, water consumption and waste generation.

The second step will be to analyze different configurations of house distribution in a typical Chicago block. Adapt the modules to the new variables brought by the block configuration. Investigate the interaction between units by making a cooperative of houses within whole the block adding communal amenities to the new set and analyzing the aggregate efficiency improvement brought by modular repetition.








Source: US Department of Energy

# Main Goals:

Demonstrate performance improvement.

Develop an example of block configuration that maximizes sun exposure in living areas and enhance interaction between them and the landscape

Awareness that it is possible to live in a more environmental friendly unit without hardship and comfort compromising.

# Special Features:

## Water Conservation

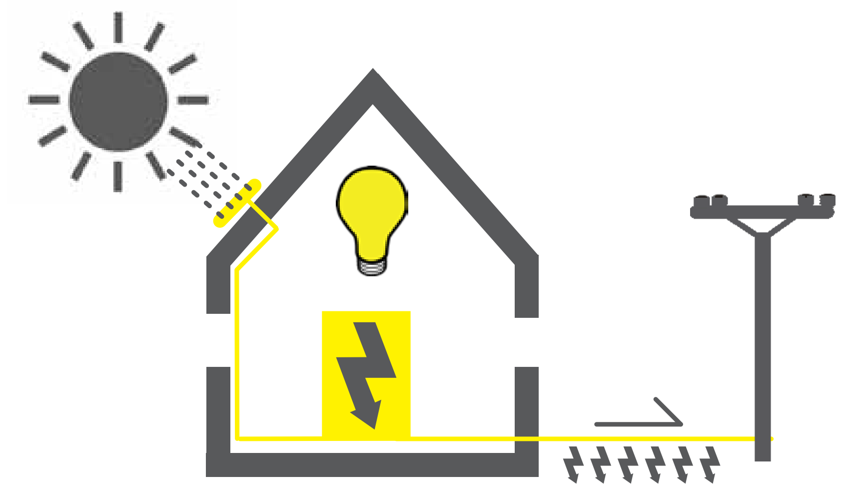
Rain water
collection

Low flow
plumbing fixtures

Water
Recycling

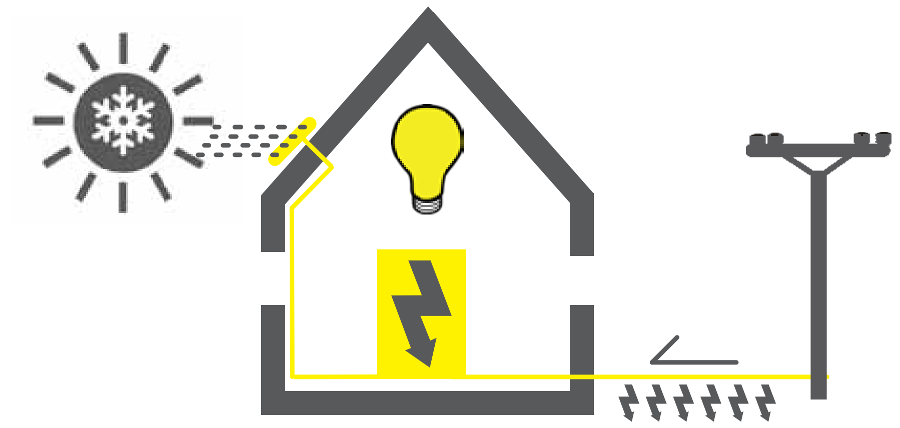
## Energy Production

Summer



Surplus energy
delivered to grid

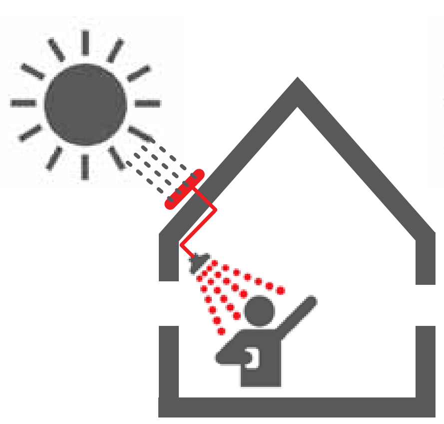
Winter



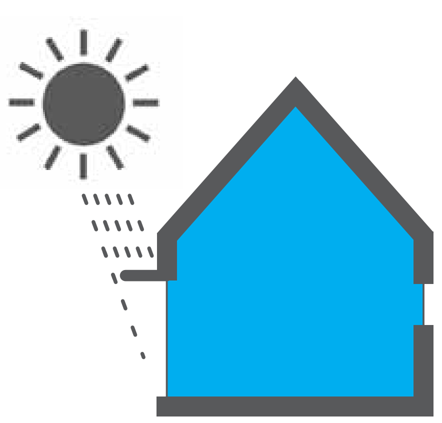
Recover the energy
delivered in summer

NET ZERO

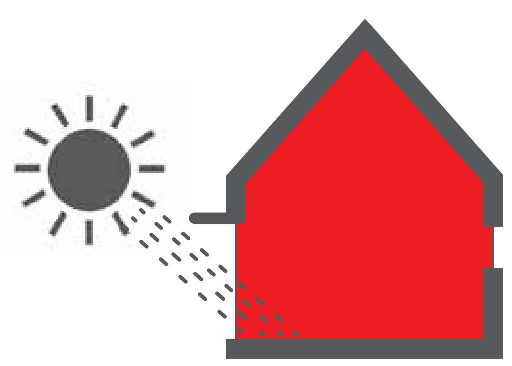
## Energy Conservation



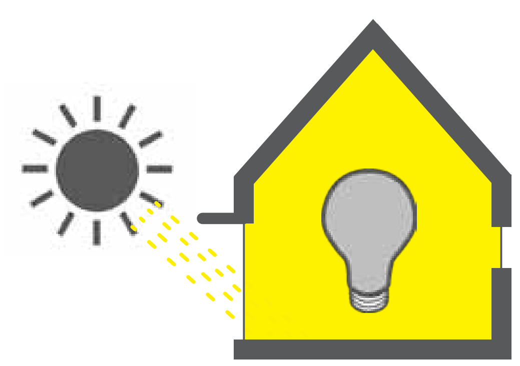
Solar
panels



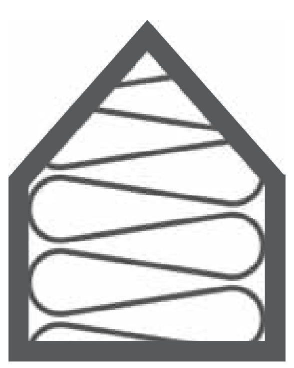
Shading
devices



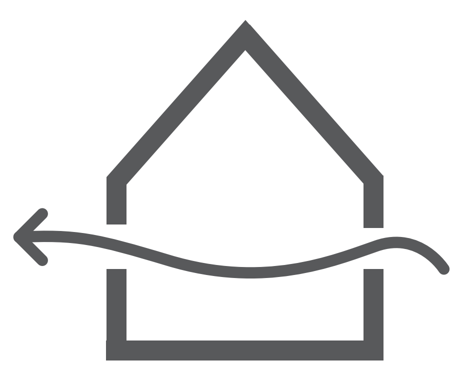
Maximize heat gain in win-
ter



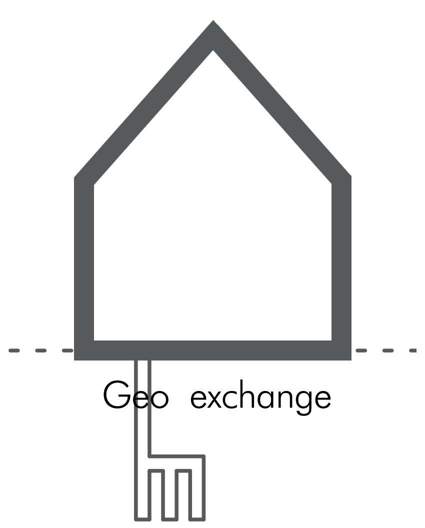
Daylight
Maximization



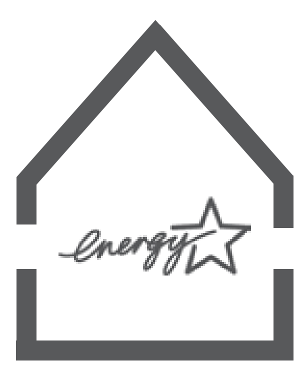
Super insulation
Tight building



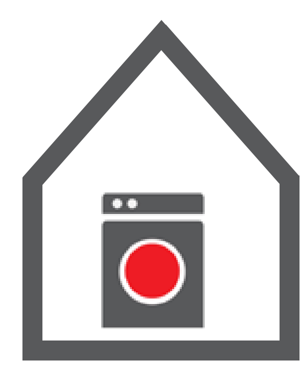
Cross
Ventilation



Geo exchange

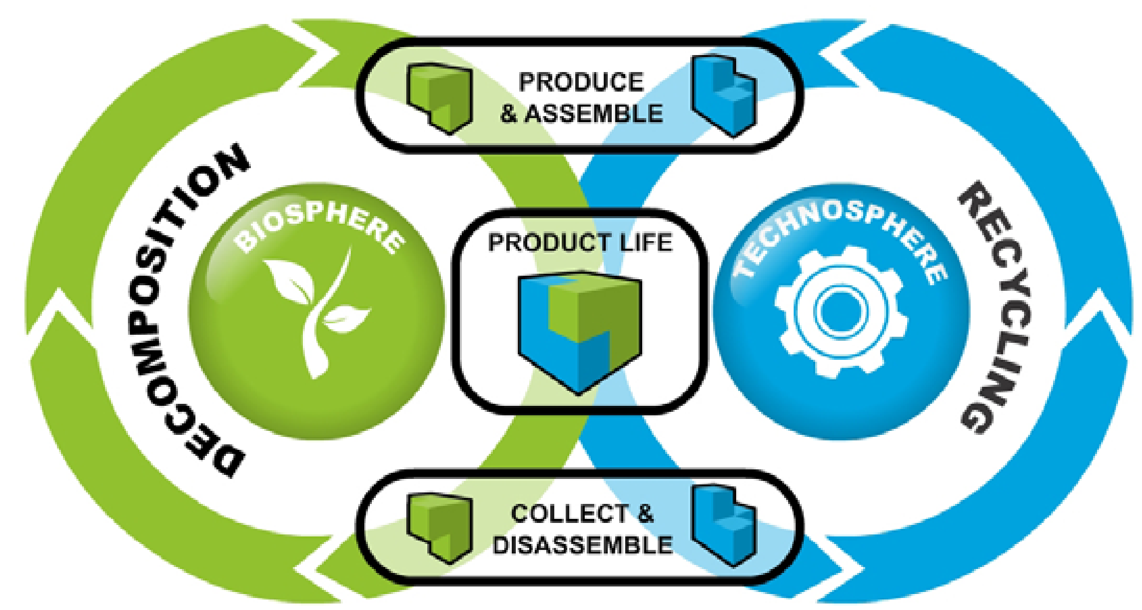



Energy
efficient
appliances



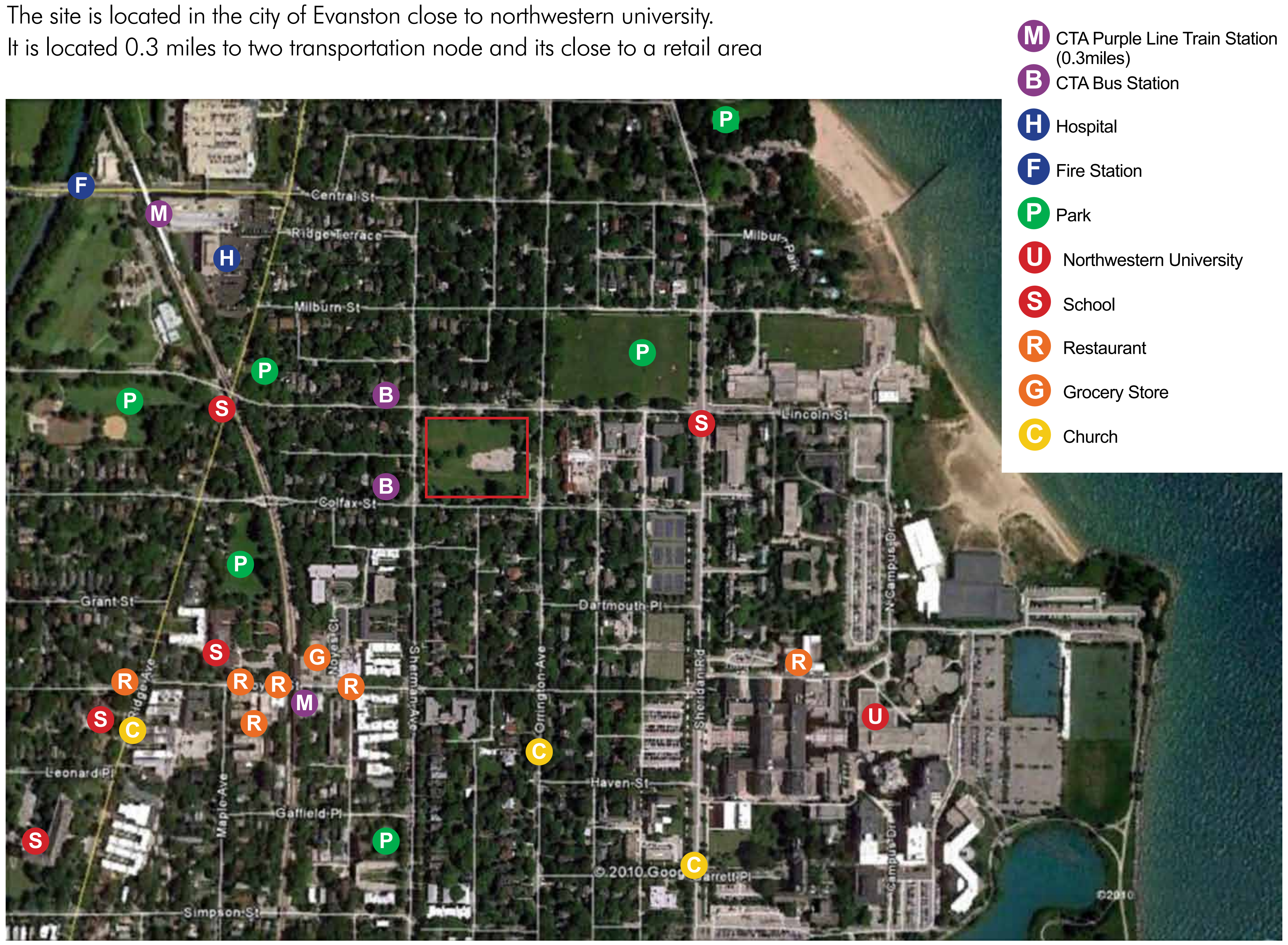
Heat
recovery

## Waste Management
## Material Selection - Low embodied energy
## Design for Deconstruction
## Budget Allocation



## SITE:

The site is located in the city of Evanston close to northwestern university.
It is located 0.3 miles to two transportation node and its close to a retail area



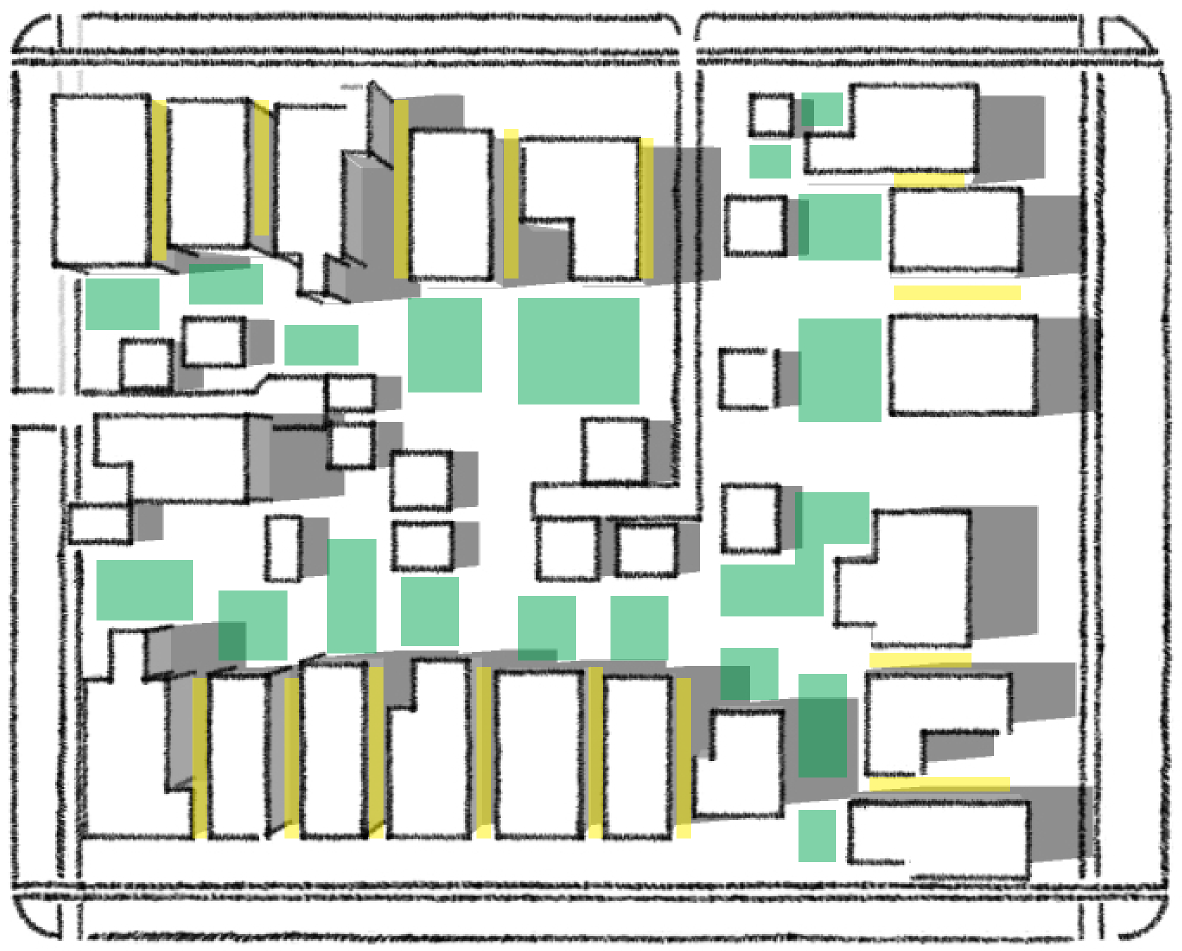

## SITE SELECTION:

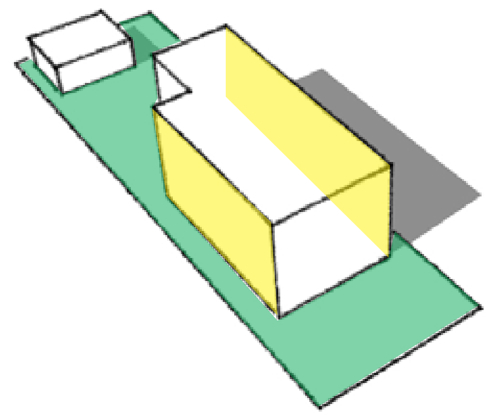
- Appropriate size, 3.5 acres,
- Prime location in the city Northwestern + Lake.
- Surrounded by single family houses
- Easy access to public transportation nodes and commercial areas.


## Neighbor Block vs Block Proposal

The idea is to reorganize the block configuration to integrate the prime areas of the house with the garden and to maximize south exposure. Furthermore the proposed block has 23 houses instead of 19 as the neighboring one

### Typical Block





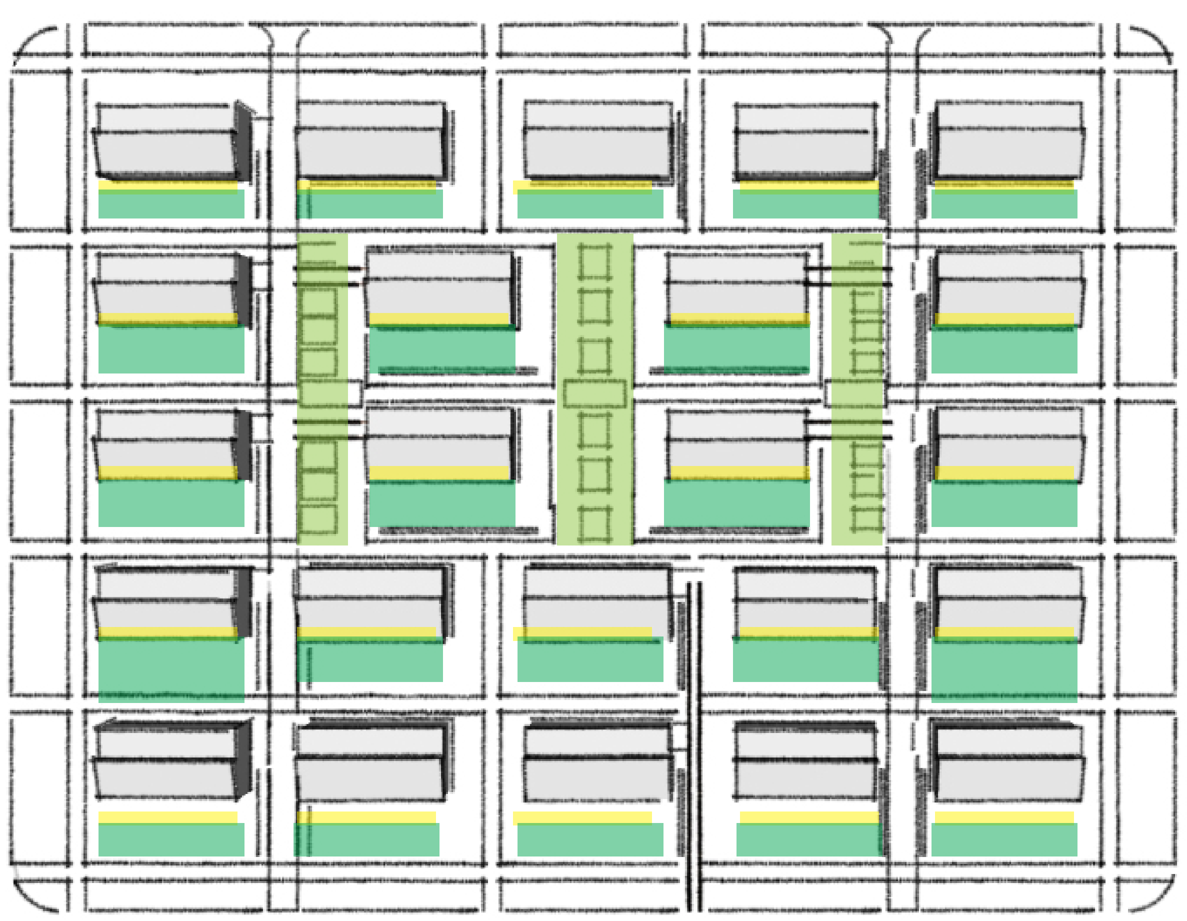
19 houses

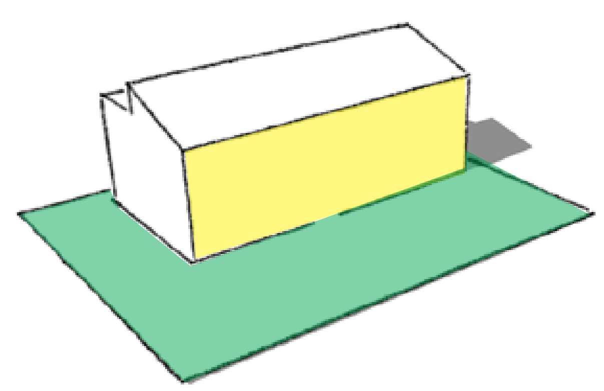
Prime areas facing the neighbor

Excess of residual spaces in the garden

16% South facing

### Proposed Block





23 houses

Prime areas facing the garden

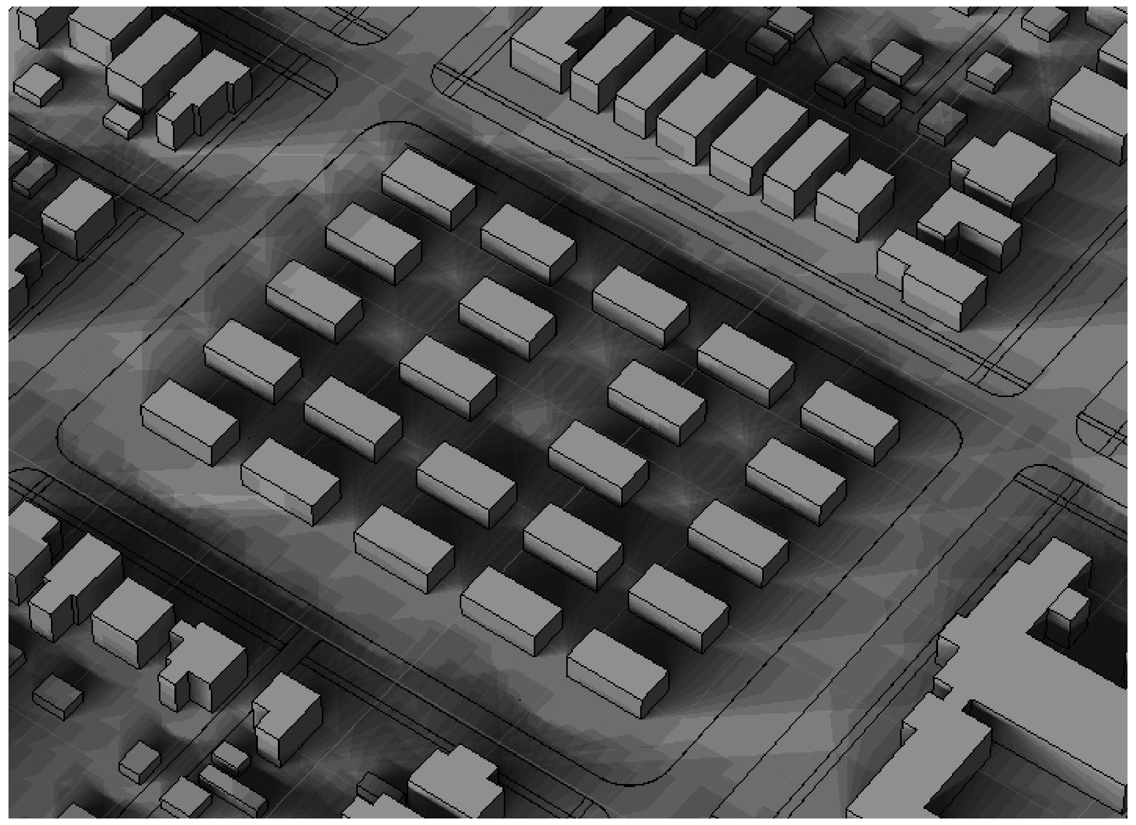
Garden integrated to to the body of the house

33% South facing

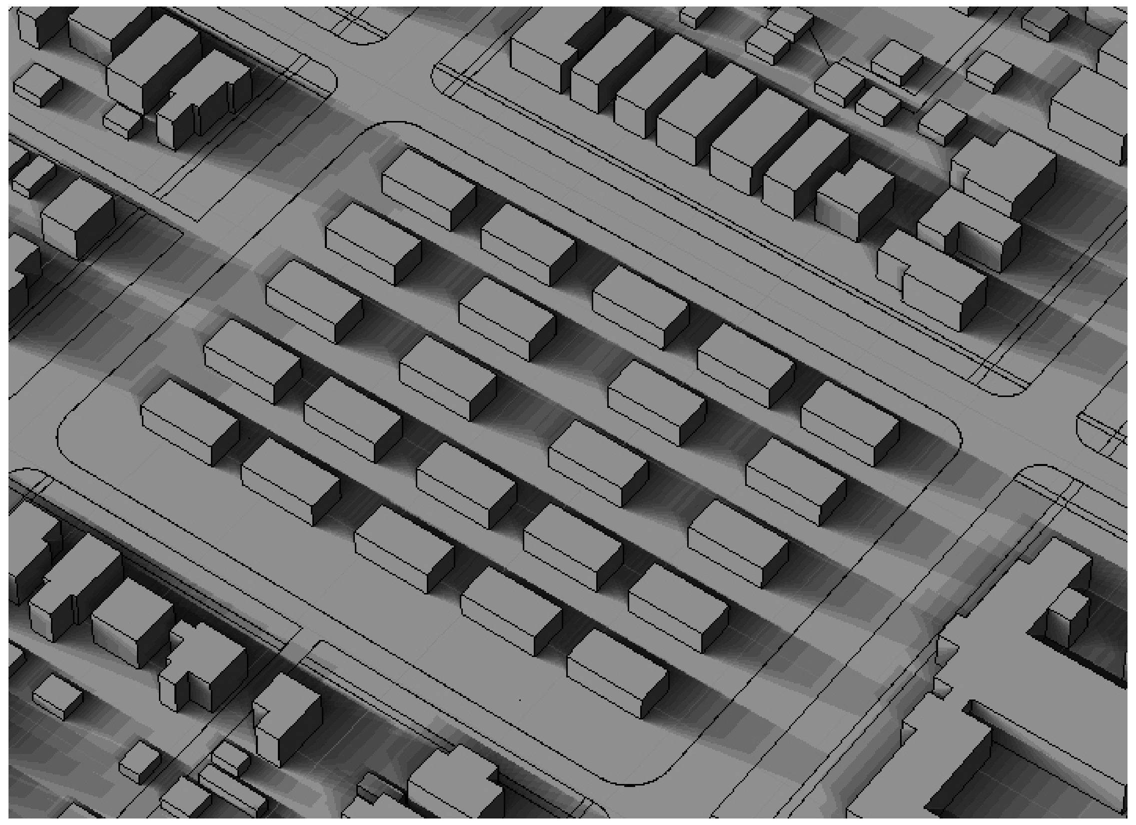
Common green area

## Buildings Distribution/ Shadow Range

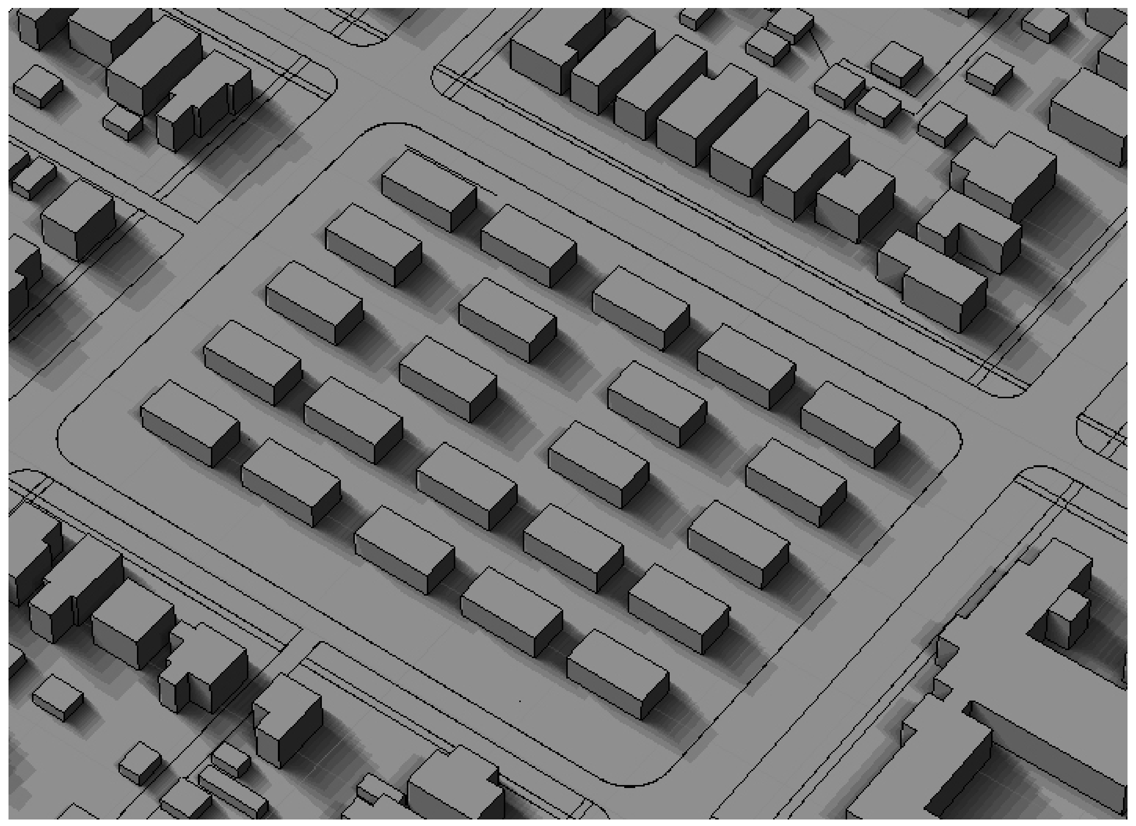
Shadow range studies were paramount for the definition of the buildings distribution. It enables the visualization of the sun interaction with the units during summer solstice, spring and fall equinox and winter solstice. So the body of the house is exposed to the sun all over the year



Winter Solstice

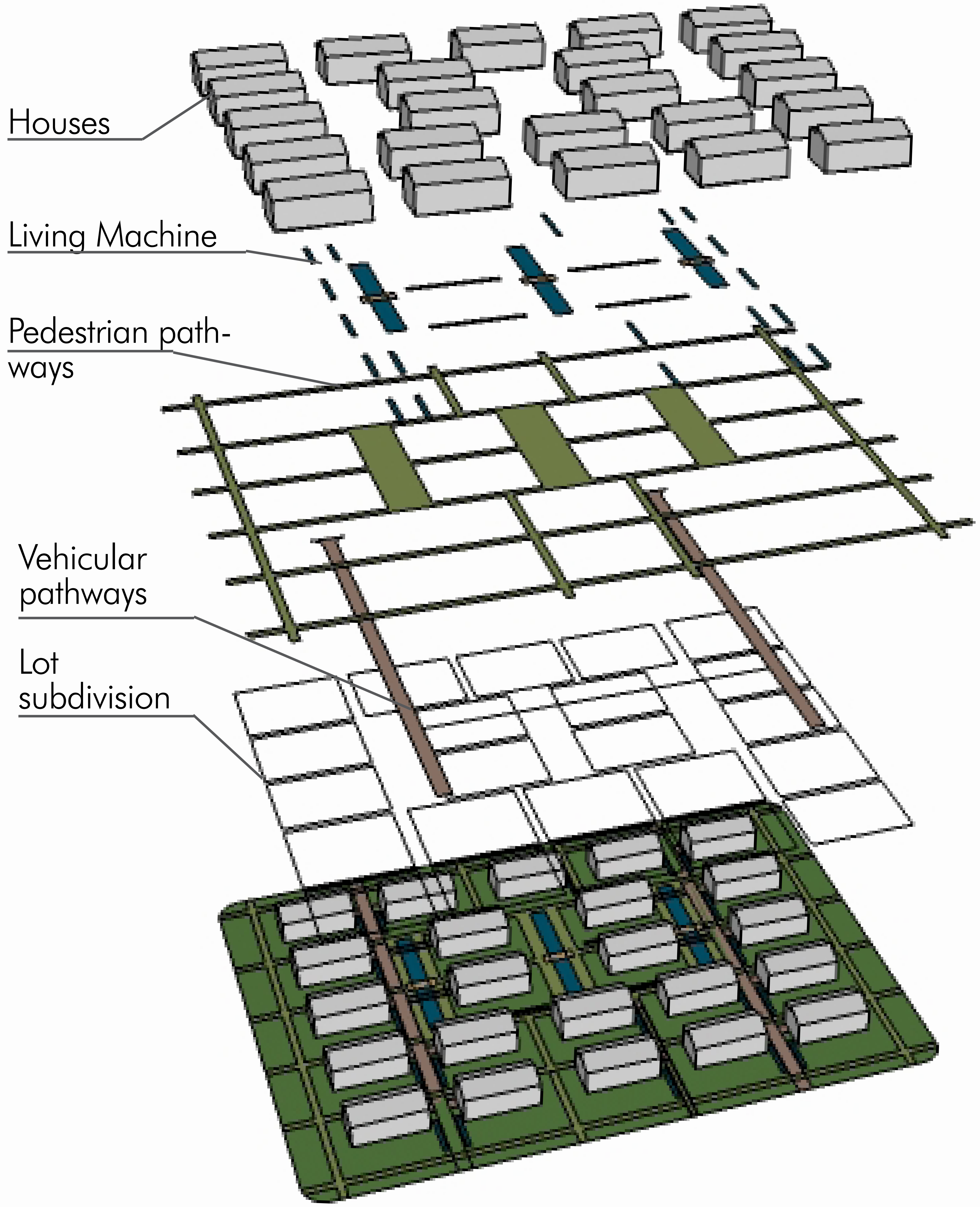


Spring/ Fall Equinox



Summer Solstice

## Site Organization

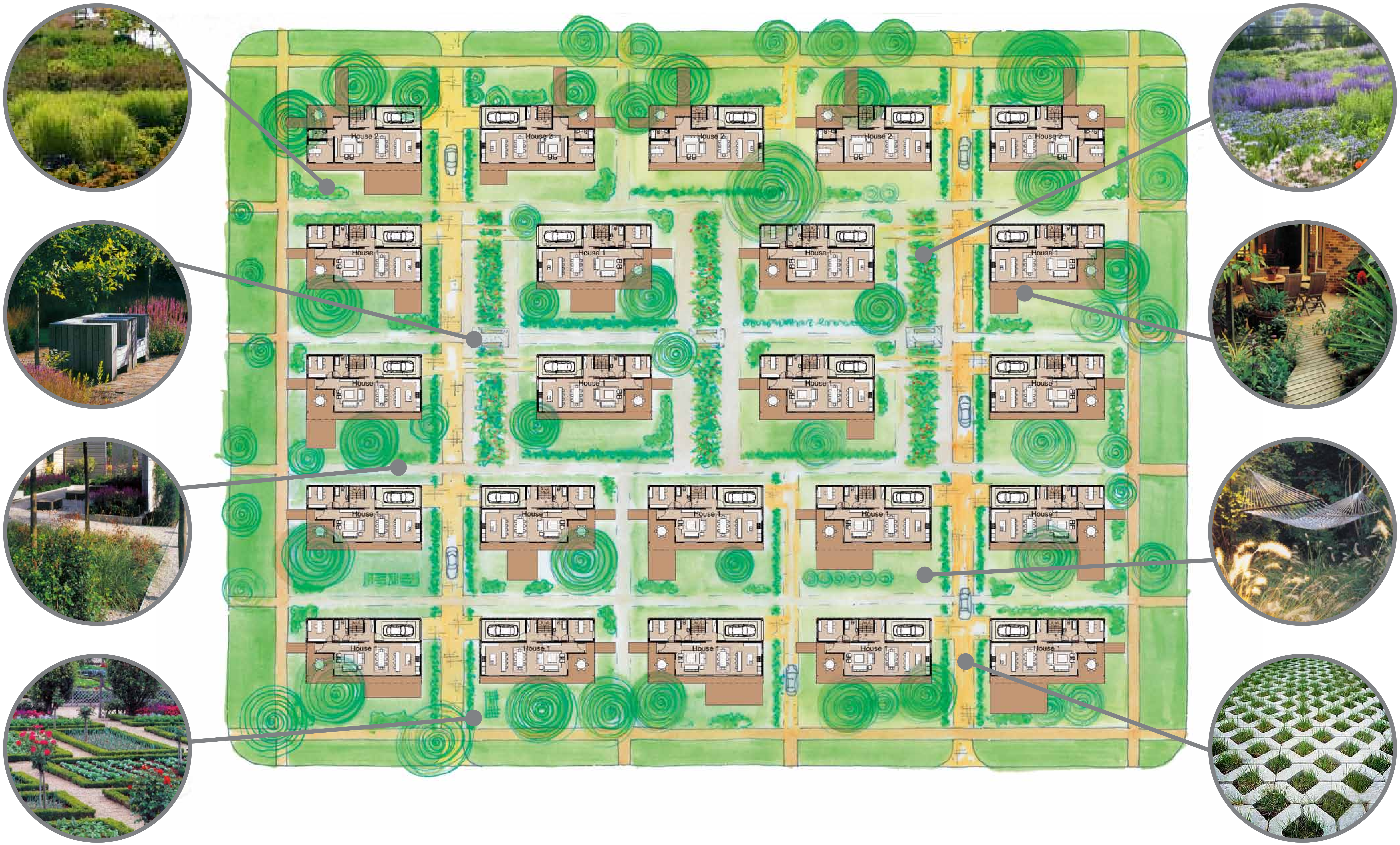


# Site Plan

Lincoln Street
Sherman Avenue
Orrington Avenue
Colfax Street

## Landscape Strategy

The landscape strategy is to integrate the houses to its gardens, to emphasize pedestrian circulation and to blur the living machine within the garden and the common areas

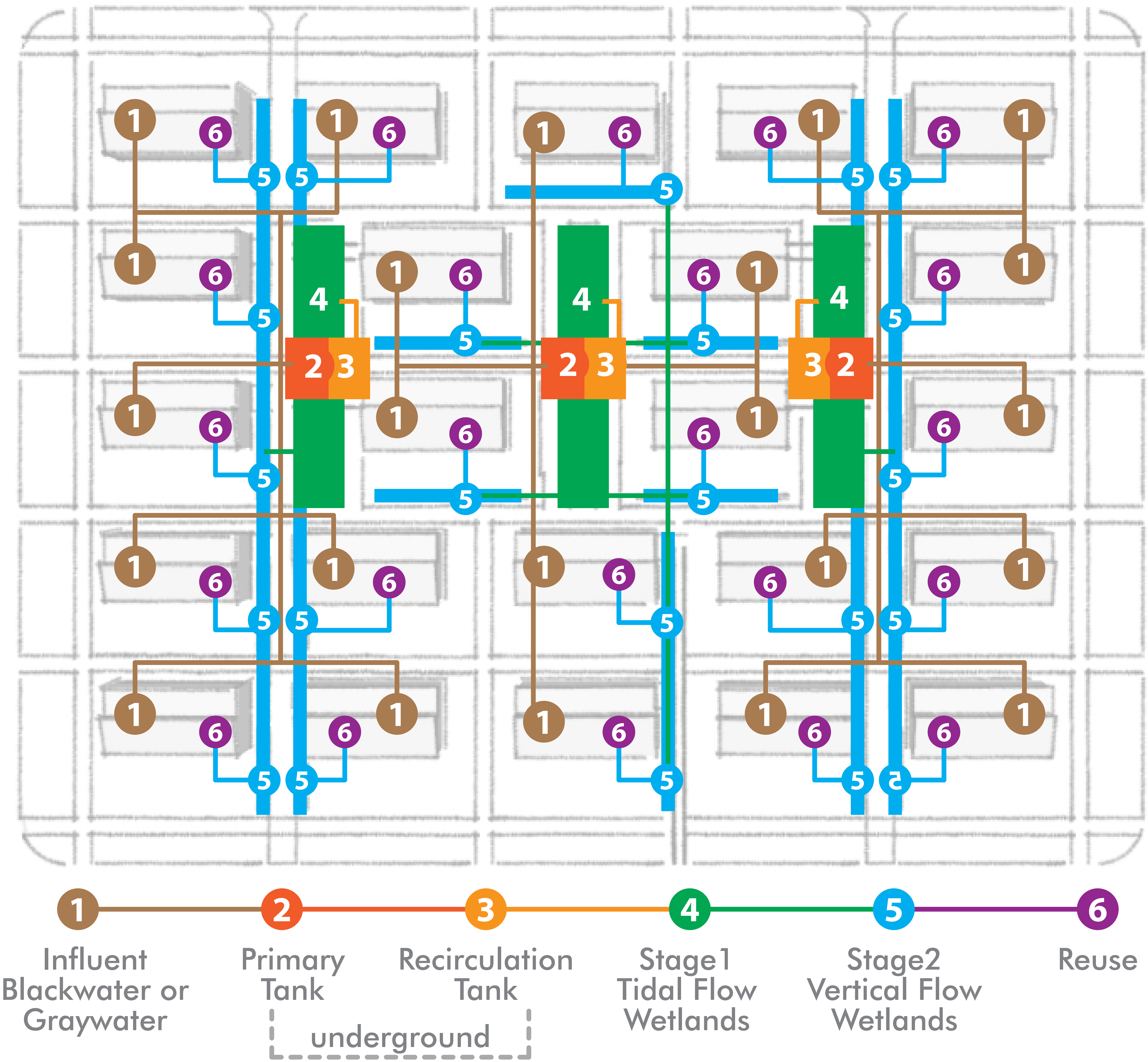


## LIVING MACHINE

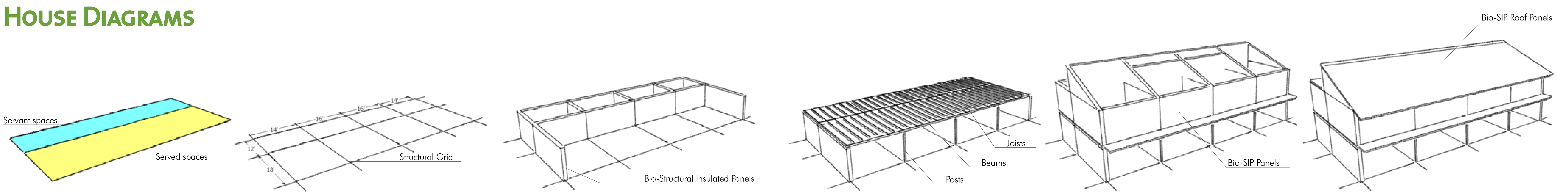
The Living Machine system uses living plants and beneficial microorganisms to turn wastewater into clean water.

This is how the living machine will be implemented in this site.

The waste water goes to a buried primary tank and to the recirculation tank, than it goes to the tidal wetlands, to the vertical flow wetlands and then back to the house to be reused.

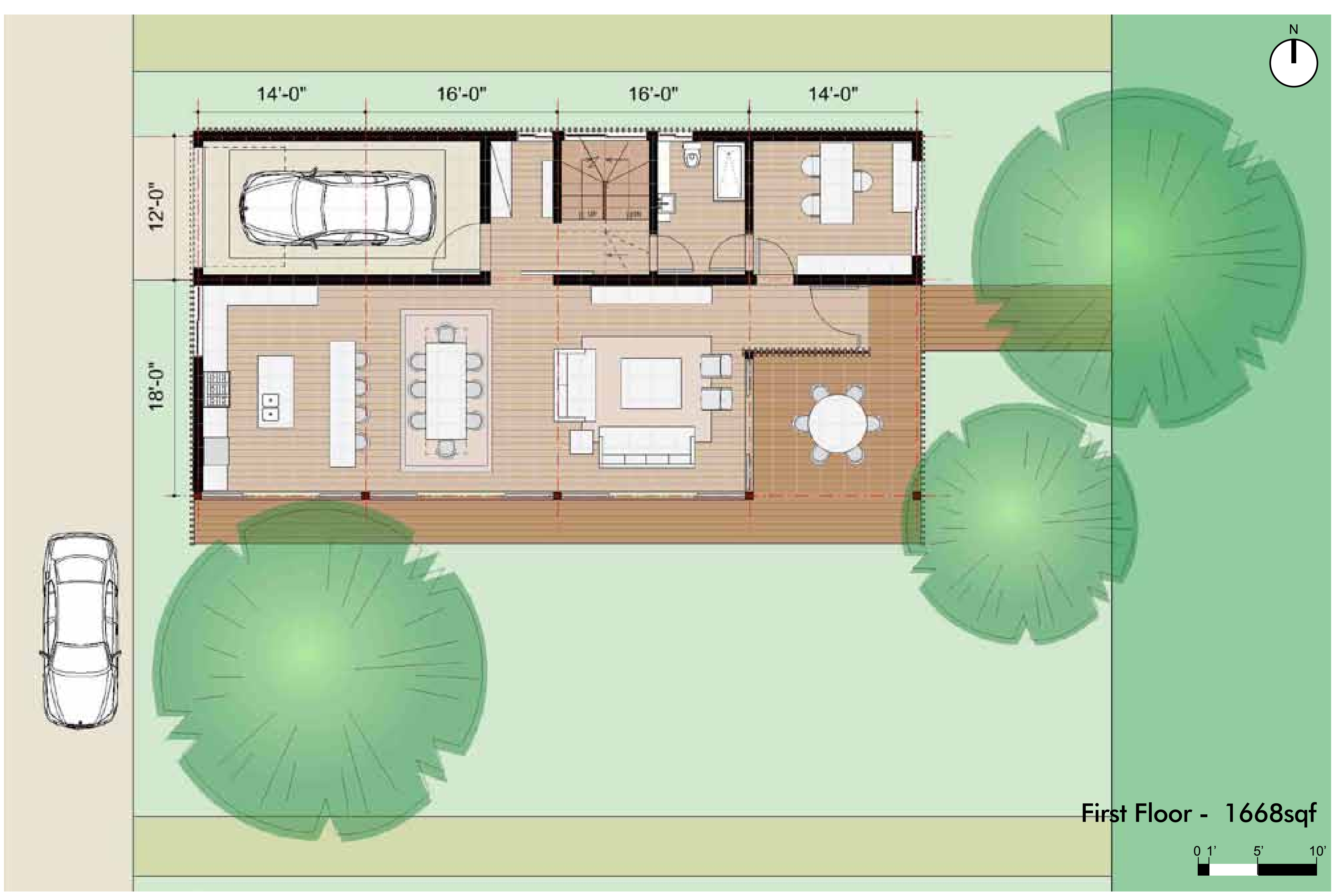


## House Diagrams

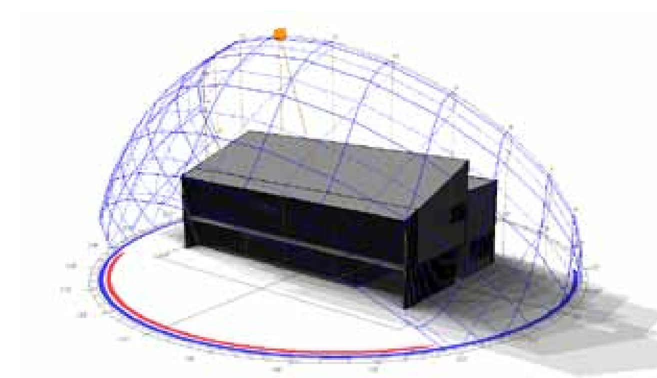


## Prototype House

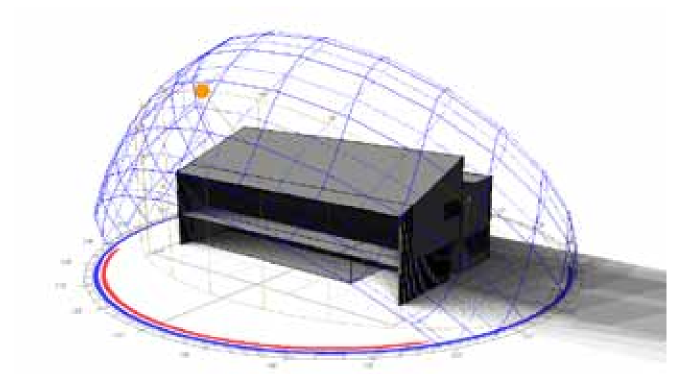
### Floor Plans

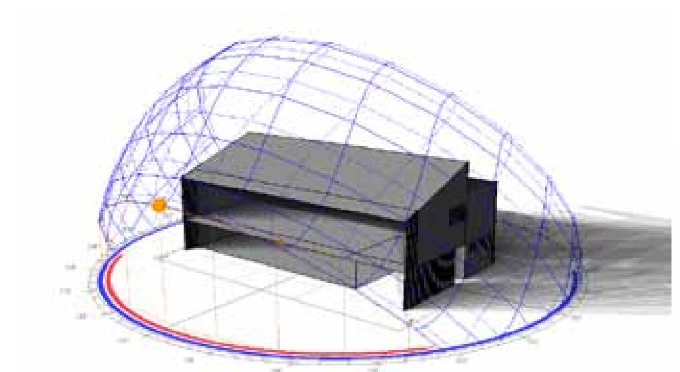

### Shadow Range



Summer



Spring/ Fall

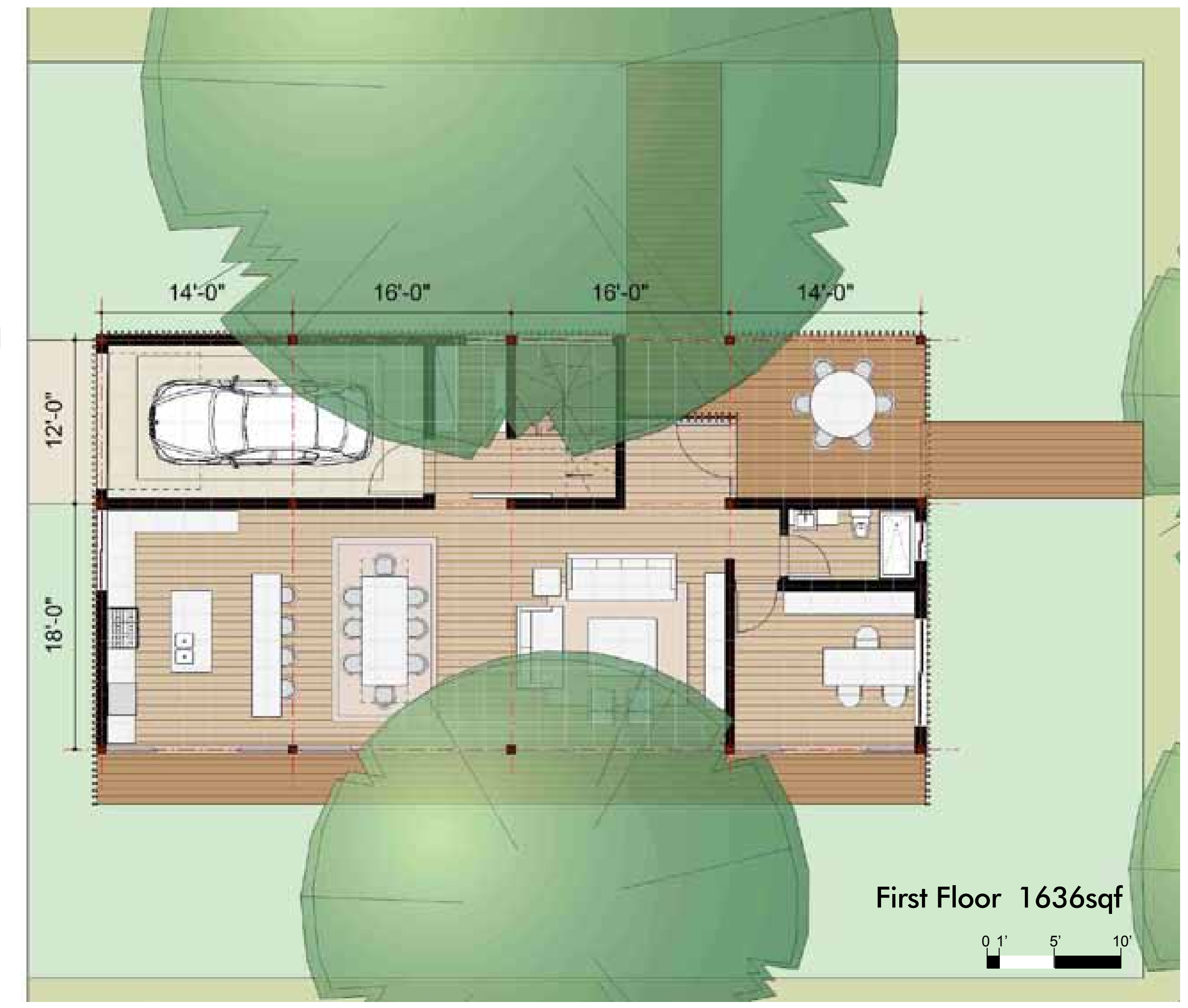


Winter

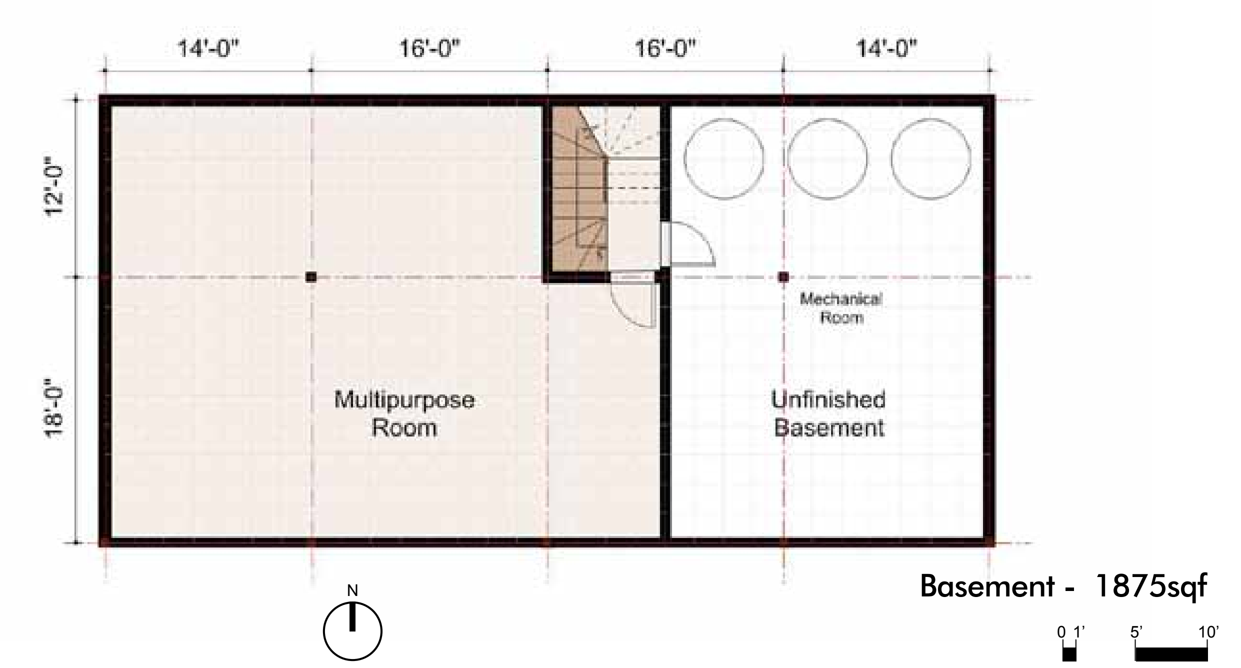
## Variation

### Floor Plans

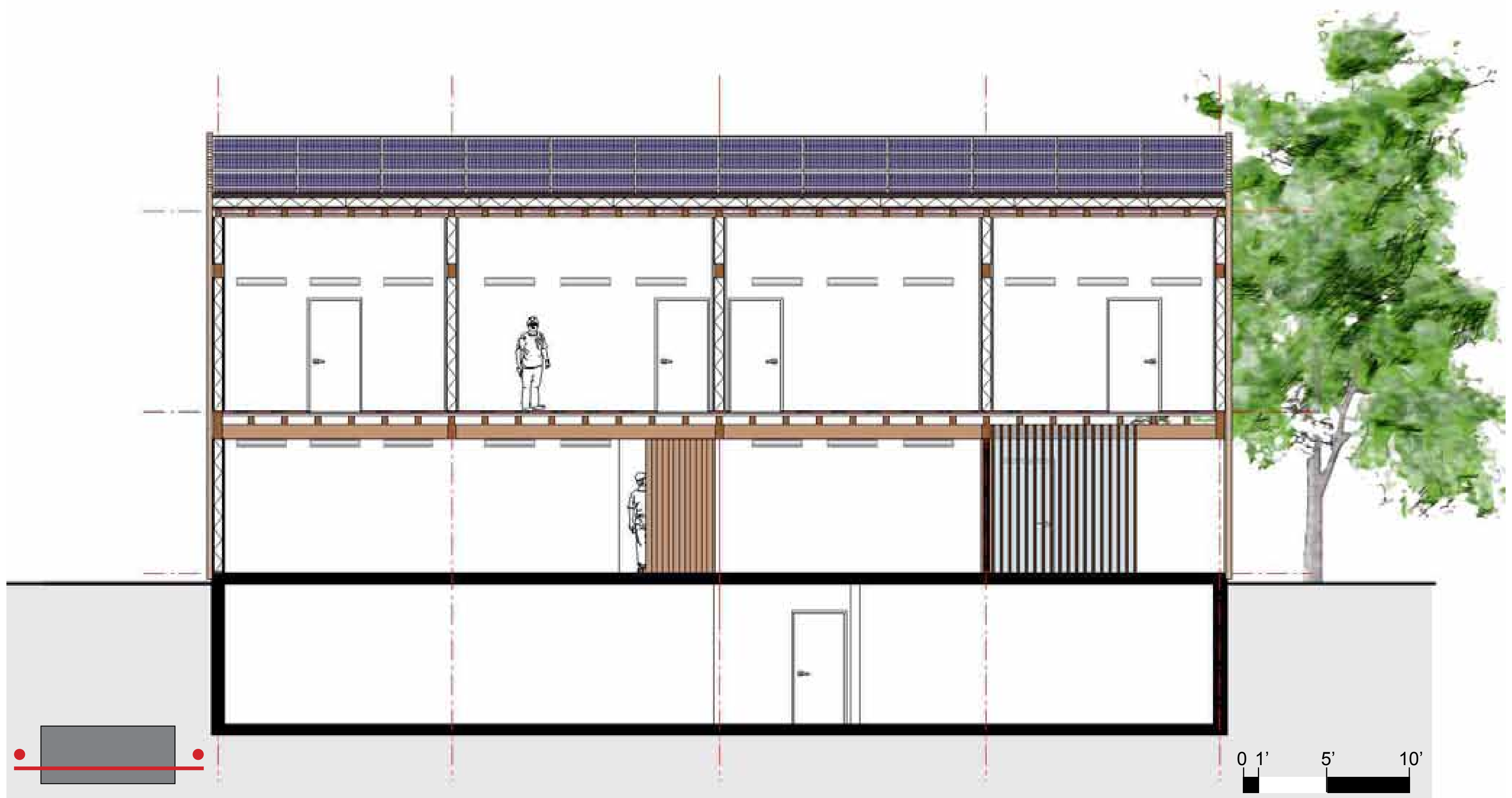
Basement and second floor are the same in both houses





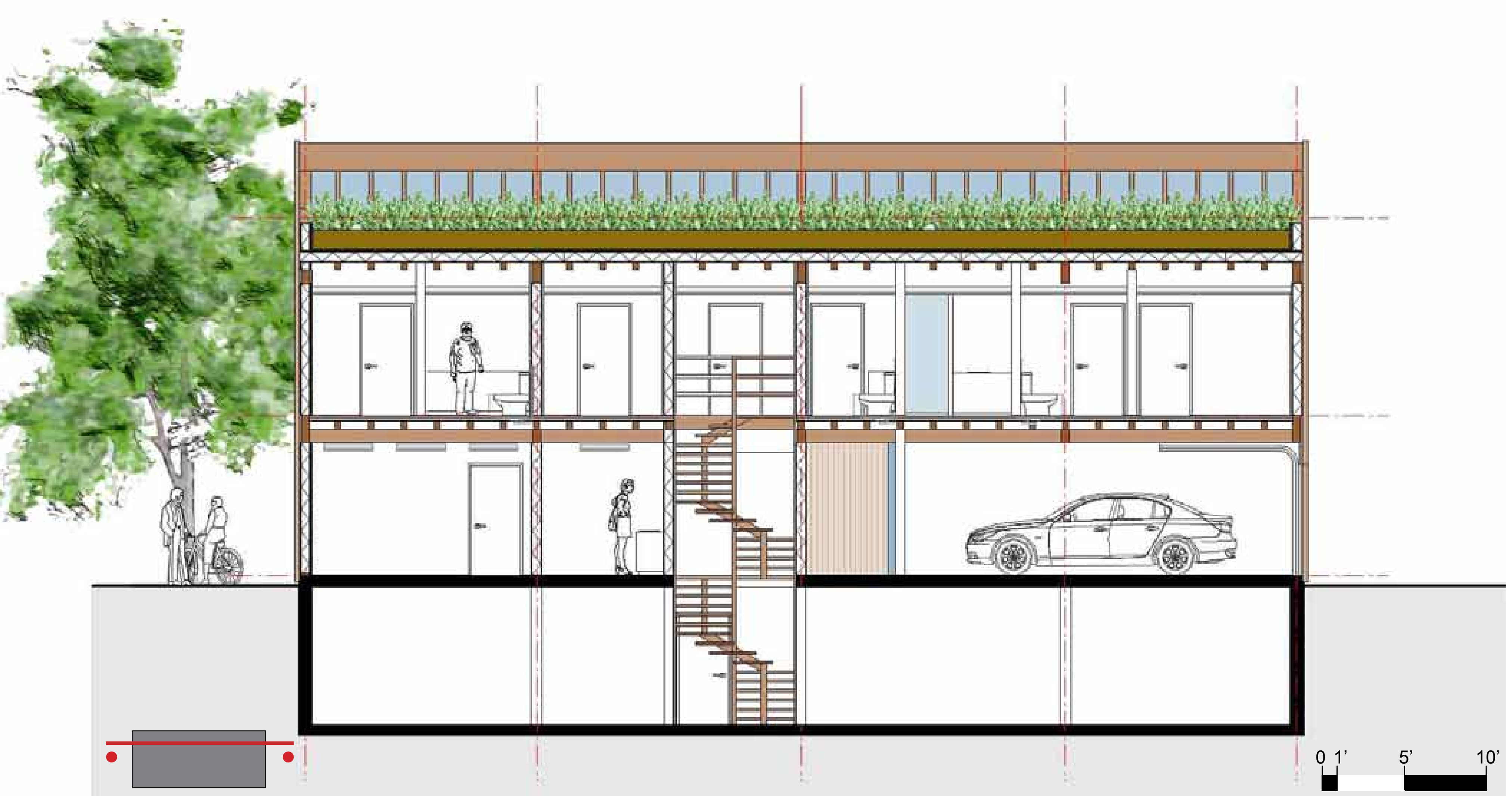


# Sections




Section A-A′


Section C-C′




Section B-B′


Section D-D′

## Facade


South Façade

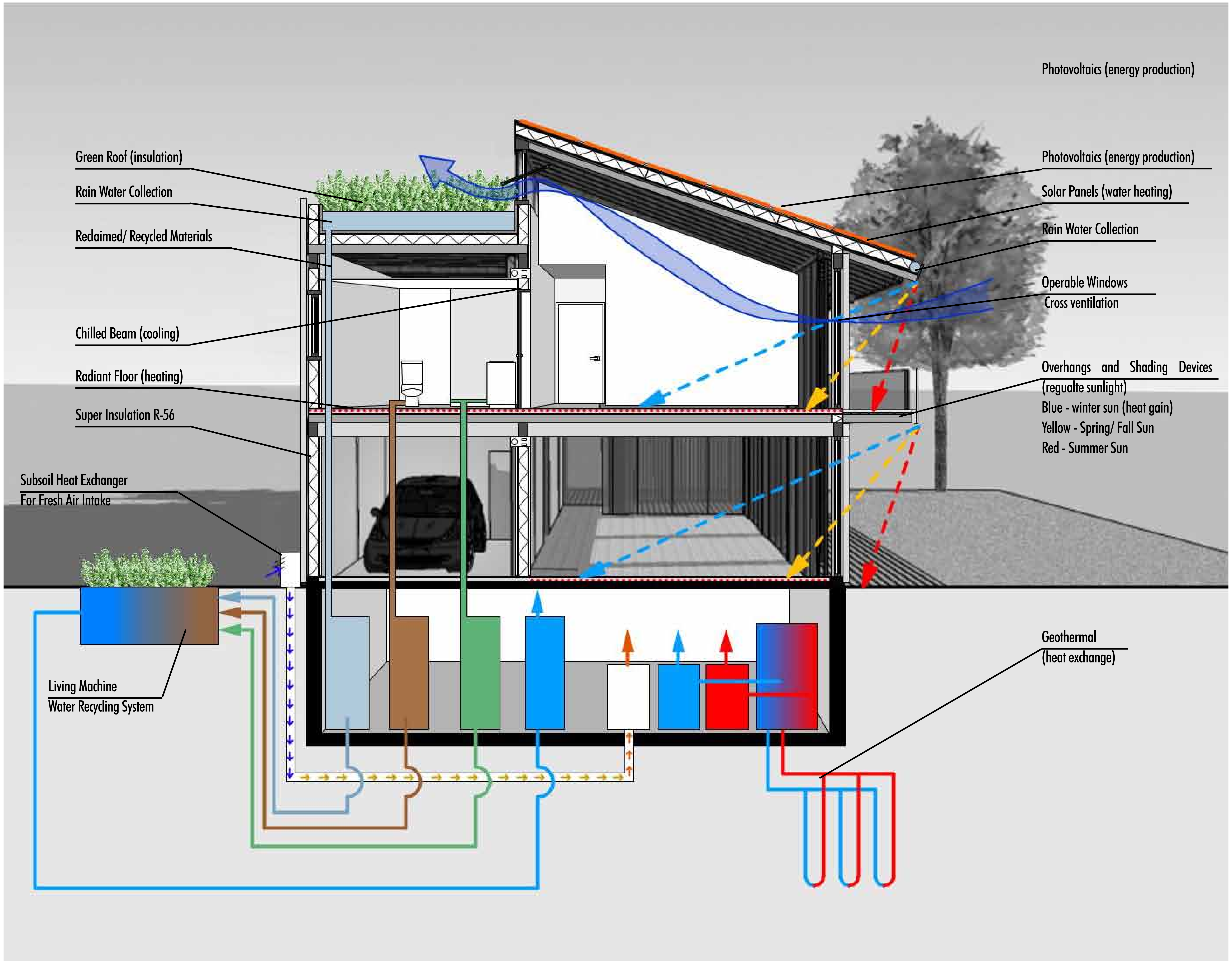

East Façade

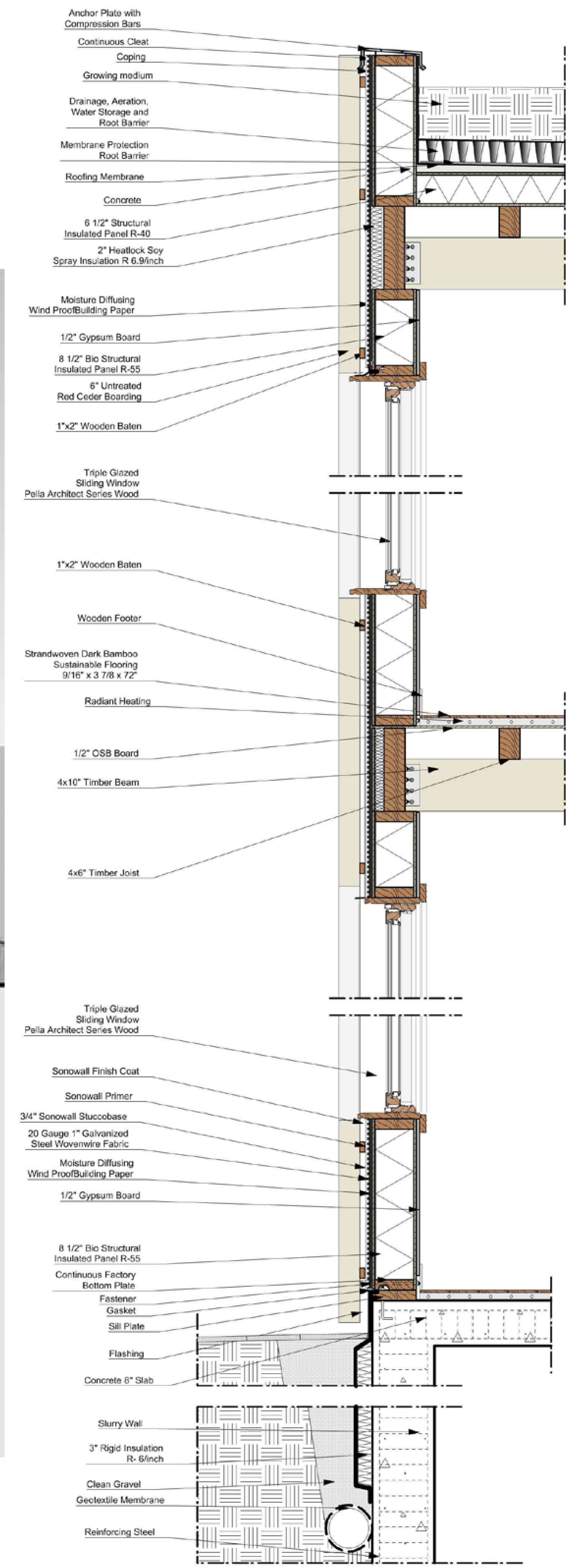

North Façade


West Façade

## Systems and Details

The german passive haus standards for insulation were used as a benchmark. It uses an average 27 inches thick wall with R 56. With the bio-SIP panels I have achieved the same R value with a 10 inch thick wall.



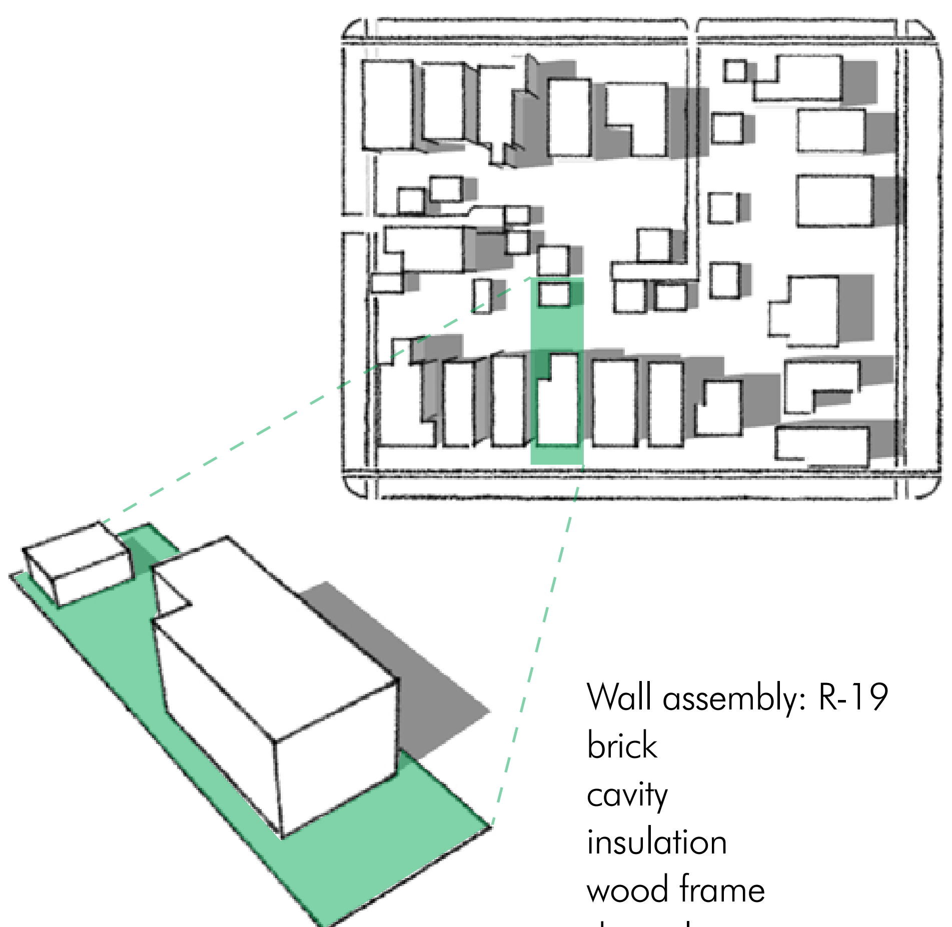



## Criteria

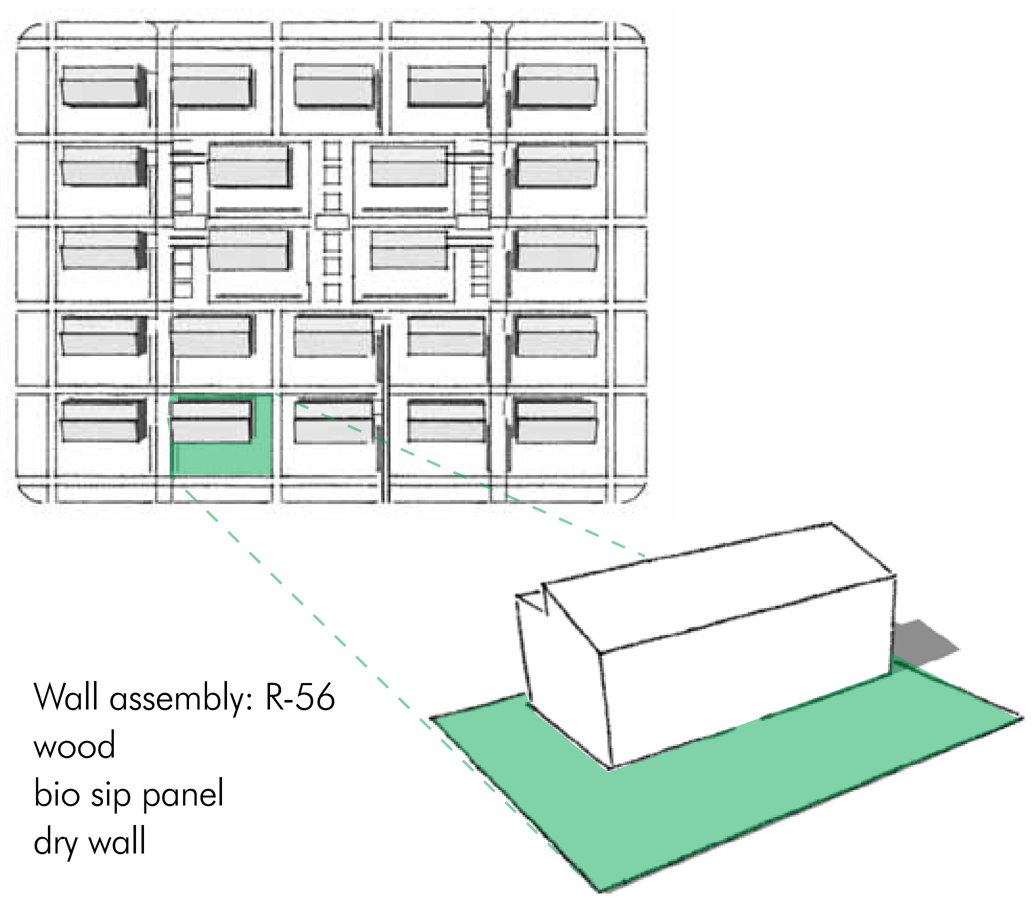
To enable the comparative analysis another house with the same area have been modeled

Typical House vs Prototype House

- Same square footage
- Analized in the same softwares (ecotect, equest and Integrated Environment Solution)
- Same climate conditions
- Similar position in the block



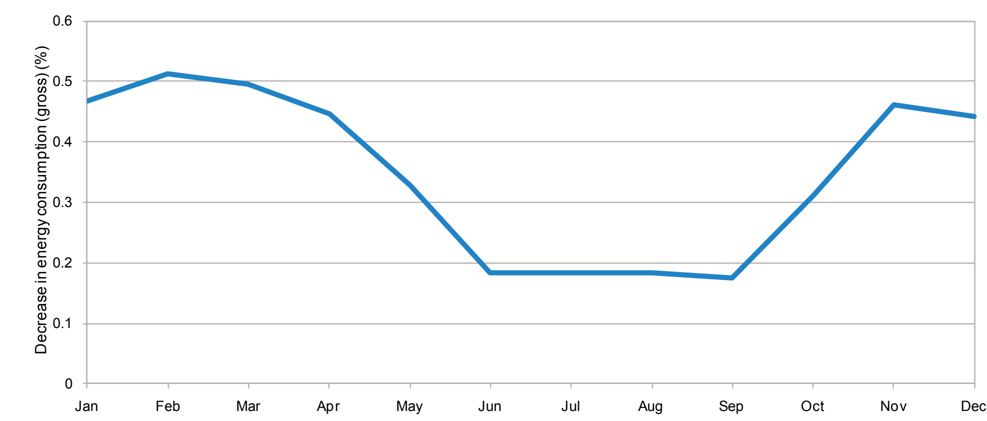
Wall assembly: R-19
brick
cavity
insulation
wood frame
dry wal



Wall assembly: R-56
wood
bio sip panel
dry wall

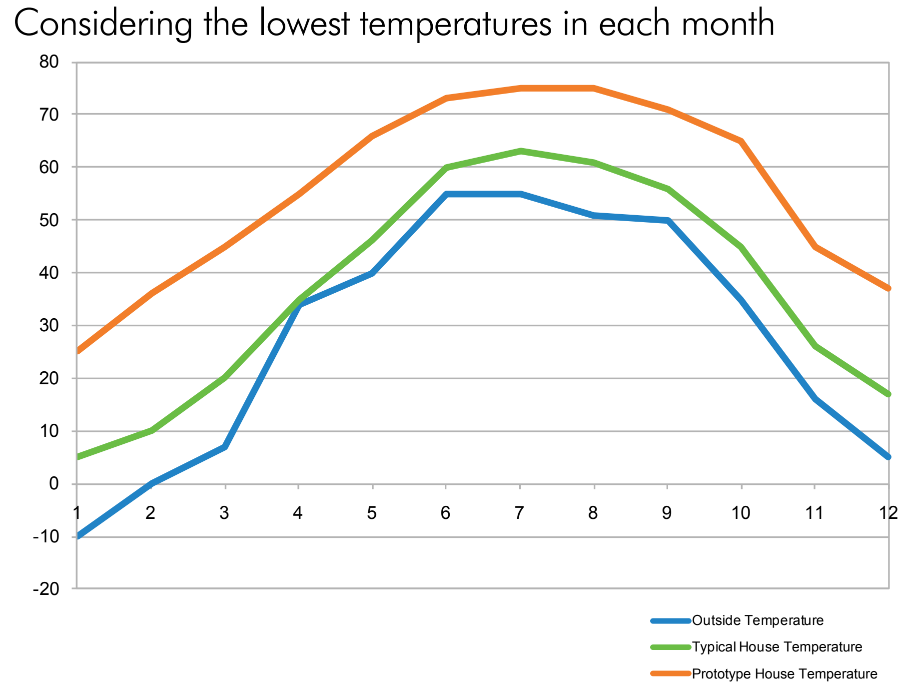
## Efficiency Gains Through The Year

In Comparison to a Typical House with the same square footage



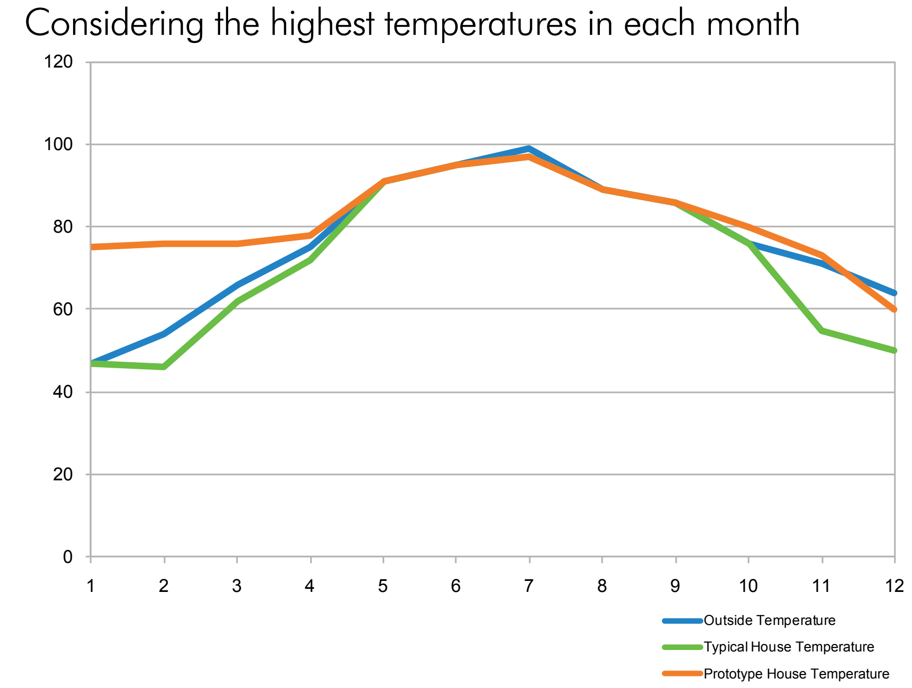

## Temperature Variation Through The Year

Considering the lowest temperatures in each month




## Temperature Variation Through The Year

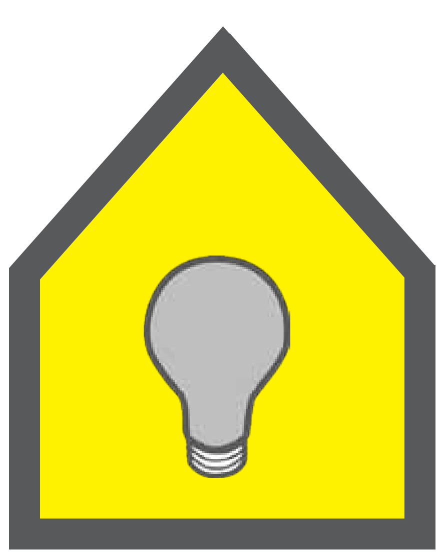
Considering the highest temperatures in each month




## Results:

### Energy and Water Consumption Reduction

In Comparison to a Typical House with the same square footage

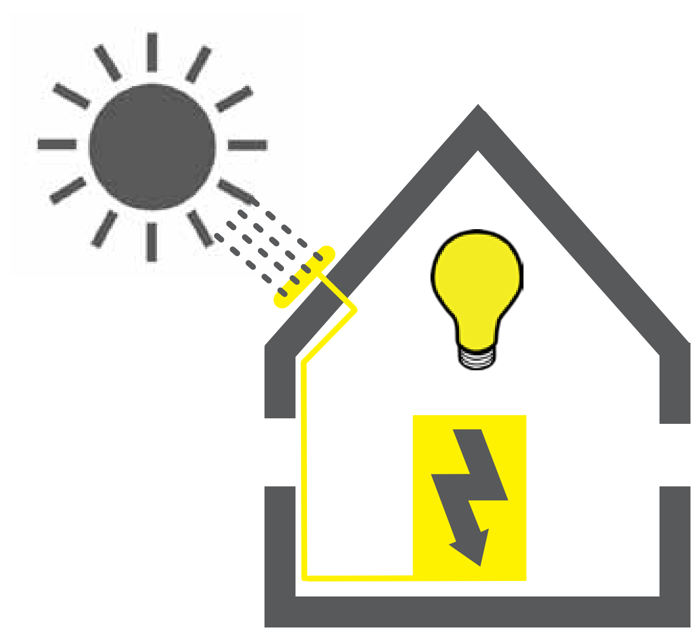


40%

35%

### Energy Production and Water Collection

65,700gal/year



28,807kwh/year

10% surplus energy
80% water used is collected
10% density increase

# The Research

# Project Description and Case Statement

## Elevator Statement:

Development of an urban hybrid house, by incorporating new elements in the dwelling to increase its performance. The goal is to design a single family home able to produce energy, reduce energy consumption, water consumption, waste generation and greenhouse gases emissions in comparison to a typical Chicagoan single family house. After designing the first unit, study its repetition and variations creating a composition of houses within a whole block and analyze the aggregate performance improvement of all houses working together.

## Case Statement:

Through most of history, the human population has lived in rural areas. This trend is being constantly shifted. In 1800 3% of world population lived in urban areas, while in 1900 this number increased to 14% and 30% in 1950. The world is experiencing this unprecedented growth. The expectation is that by 2050 70% of world population will be living in urban environments. [1]

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The second step will be to analyze different configurations of house distribution in a typical Chicago block. Adapt the modules to the new variables brought by the block configuration. Investigate the interaction between units by making a cooperative of houses within whole the block adding communal amenities to the new set and analyzing the aggregate efficiency improvement brought by modular repetition.

1 - source: world population reference bureau
2 - source: speech of Dr. Kristina M. Johnson, under secretary of US Department of Energy
http://www.youtube.com/watch?v=XNsxdIGLUiA&feature=player_embedded#!



| Goals | Guiding Principles |
| --- | --- |
| 1- Demonstrate the performance improvement of a hybrid house compared to a typical housing unit and a group of hybrid houses working in collaboration in a block compared to a typical city block. | 1- Make use of passive strategies and vernacular solutions combined with high technology to provide energy conservation and production, water collection and conservation, waste management and reduction. Analyze the results in terms of maintenance cost reduction and its effects in terms of encouraging people to a more healthy and environmental conscious lifestyle. |
| 2- Design an urban single family unit that maximizes the potential for being independent of the utility grid terms of water, energy and waste. | 2- Produce a dwelling that minimizes its reliance on the utility grid by means of producing the energy it consumes, returning the surplus produced locally to the city grid, collecting, reusing and recycling water, recycling waste and managing it as a source of energy. |
| 3- Awareness, that it is possible to live in a more environmental friendly unit without hardship and without compromising comfort. | 3- Develop a design solution dedicated to reduce its operational costs and environmental impact without behavioral changes and as a consequence of that awareness that with a slight change in behavior the savings could be even bigger. |
| 4- Create a building that changes over seasons | 4- Develop an adaptable building envelope able to change its features based on seasonality. During winter it converts in a completely tight building and enables sunlight in to heat the ambient. During summer blocks the sunlight and provides openings to cool the unit. |
| 5- Generate a prototypical design solution and locate the module in a specific site to make the project more tangible | 5- Develop a design solution that consist of 75% of generic solutions that could be applied to any site/city and 25% of its features uniquely connected to the site conditions in order to leverage all the potential variables that provide performance enhancement. |
| 6- Design for deconstruction and make a stringent material selection. | 6- Specify recycled, reclaimed and green materials, analyzing materials life cycle and embodied energy as well as developing a design solution that takes into account the deconstruction of the house. |
| 7- Dedicate at least 5% of the site for drainage | 7- The landscape in this project will be developed to absorb noise, collect rain water, raise humidity, reduce temperature fluctuation and wind speed and produce a calmer environment for urban life. |

## Timeline

| October | November | December | January | February | March | April | May |
|---|---|---|---|---|---|---|---|
| Week 1<br>• Elevator Statement<br>• Case Statement<br>• Case Studies<br>• Bibliography | Week 1<br>• Site requirement/ Analysis<br>• Organizational Diagrams<br>• "Sustainable features" research - low/ high tech strategies | Week 1<br>• Finals Week | Week 1<br>• Winter Break | Week 1<br>• Design Development (house module)<br>• House Repetition Scheme (block study) | Week 1<br>• Design Development (block) | Week 1<br>• Final Presentation Preparation | Week 1<br>• Final Presentation |
| Week 2<br>• Goals<br>• Guiding Principles<br>• Case Studies<br>• Bibliography | Week 2<br>• Conceptual Design | Week 2<br>• Schematic Design (house module)<br>• Concept Development | Week 2<br>• Concept Refinement<br>• Design Development (house module) | Week 2<br>• Details (house module)<br>• House Repetition Scheme (block study) | Week 2<br>• Design Development (block)<br>• Energy Model | Week 2<br>• Final Presentation Review | Week 2<br>• Final Presentation |
| Week 3<br>• Program<br>• Space Requirements<br>• Stakeholders ????<br>• Case Studies | Week 3<br>• Conceptual Design<br>• Document Review | Week 3<br>• Schematic Design (house module)<br>• Concept Development | Week 3<br>• Design Development (house module) | Week 3<br>• Repetition Studies | Week 3<br>• Design Development (block)<br>• Physical Model | Week 3<br>• Final Adjustments | |
| Week 4<br>• Program Refinement<br>• Site Requirements/ Definition<br>• Organizational Diagrams<br>• Housing Typologies | Week 4<br>• Complete Document | Week 4<br>• Schematic Design (house module)<br>• Energy Modeling | Week 4<br>• Design Development (house module)<br>• Physical Model | Week 4<br>• Module Adaptation based on block layout<br>• Analysis of communal/ shared opportunities | Week 4<br>• Details<br>• Digital Model | Week 4<br>• Final Adjustments/ Rehearsal | |
| | | Week 5<br>• Winter Break | | | Week 5<br>• Details<br>• Storyboard of final presentation | | |

# Process

Research:

- Different housing typologies around the world
- Low and high tech design strategies
- Site analysis
- Case studies

Design:

- House Module - Schematic Design/ Energy Modeling analysis + BIM
- House Module - Design Development/ Energy Modeling analysis + BIM
- House Module - Details/ Energy Modeling analysis + BIM
- Evaluate how combinations of this typology can configure a block
- Block - Schematic Design/ Energy Modeling analysis + BIM
- Block - Design Development/ Energy Modeling analysis + BIM
- Block - Details/ Energy Modeling analysis + BIM

Conclusion:

- Comparison between the House Module and a Typical House with the same square footage
- Comparison of the House Module efficiency with the Block of Hybrid Houses efficiency

# Qualitative Parameters/ Users

The main idea of developing this Hybrid House is to create a single family unit dedicated to a family of five individuals (father, mother and three children) and demonstrate that living in a highly efficient house does not require sacrificing "creature comforts" compared to living in a regular house. The home has the same features of traditional house enhanced with solutions that increase its efficiency. The feeling of normalcy for the residents is a paramount aspect that will enable people to realize that a more environmental friendly lifestyle does not represent sacrifice or extra work.

In order to bring variety to the block configuration, two other multifamily typologies were introduced: The first one is a two bedroom unit, which will configure a three dwellings townhouse. The second one is an one bedroom unit which will configure a townhouse with six dwellings.

Considering the house repetition in a block, and also thinking forward to the neighborhood and the whole city, the economy of scale will represent an important cost reduction to the dwellers, to the city in terms of reducing the pressure on the utility grid and also to the environment since those units are less dependent on natural resources.

# Quantitative Parameters

## Space Requirements

### Basic Typology - Single Family
### One four-bedroom unit

| | |
|---|---|
| Hall | 5X5' = 25sqf |
| Vertical Circulation | 10x8' = 80sqf |
| Living Room | 13X14' = 182sqf |
| Dining Room | 18X15' = 270sqf |
| Family Room | 18X15' = 270sqf |
| Powder Room | 5X5' = 25sqf |
| Kitchen | 17X12' = 204sqf |
| Office | 12X12' = 144sqf |
| Workout Room | 15X11' = 165sqf |
| Master Bedroom | 15X20' = 300sqf |
| Master Bathroom | 10X10' = 100sqf |
| 2nd Bedroom | 13X11' = 143sqf |
| 3rd Bedroom | 13X11' = 143sqf |
| Shared Bathroom | 10X8' = 80sqf |
| 4th Bedroom | 15X12' = 180sqf |
| 4th Bathroom | 10X6' = 60sqf |
| Laundry | 10X6' = 60sqf |
| Garage/Storage | 20X18' = 360sqf |
| Mechanical Room | 20X18' = 360sqf |
| TOTAL | 3,450sqf |

### Typology for Repetition - Multi-Family 1
### Three two-bedroom units

| | |
|---|---|
| Common Areas: | |
| Hall | 10X5' = 50sqf |
| Vertical Circulation | 10X8' = 80sqf |
| Workout Room | 16X14 = 224sqf |
| Garage/Storage | 30X18 = 540sqf |
| Mechanical Room | 20X18 = 360sqf |
| | sub total = 1,254sqf |
| Private Areas: | |
| Hall | 4X4' = 16sqf |
| Living Room | 13X14' = 182sqf |
| Dining Room | 18X15' = 270sqf |
| Family Room | 18X15' = 288sqf |
| Powder Room | 5X4' = 20sqf |
| Kitchen | 14X12' = 168sqf |
| Office | 12X12' = 144sqf |
| Master Bedroom | 15X17' = 255sqf |
| Master Bathroom | 10X8' = 80sqf |
| 2nd Bedroom | 13X11' = 134sqf |
| 2nd Bathroom | 10X6' = 60sqf |
| Laundry | 8X6' = 48sqf |
| | sub total = 1,656sqf (x3) |
| TOTAL | 6,222sqf |

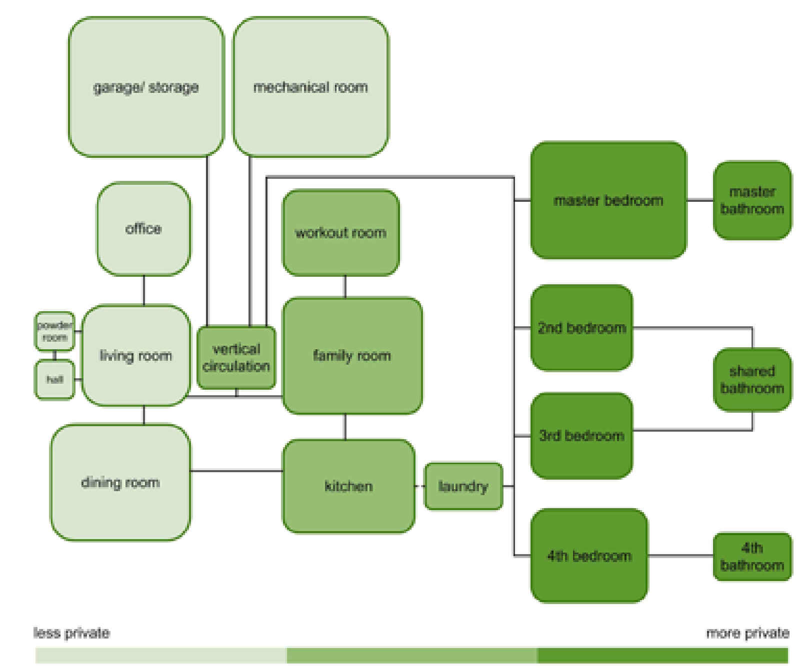
### Typology for Repetition - Multi-Family 2
### Six one-bedroom units

| | |
|---|---|
| Common Areas: | |
| Hall | 10X5' = 50sqf |
| Vertical Circulation | 10X8' = 80sqf |
| Workout Room | 16X14 = 224sqf |
| Garage/Storage | 60X28 = 1,680sqf |
| Mechanical Room | 20X20 = 400sqf |
| | sub total = 2,434sqf |
| Private Areas: | |
| Hall | 4X4' = 16sqf |
| Living Room | 18X15' = 270sqf |
| Dining Room/ Kitchen | 14X15' = 210sqf |
| Office | 10X10' = 100sqf |
| Master Bedroom | 14X14' = 196sqf |
| Bathroom/ Powder room | 8X8' = 64sqf |
| Laundry | 6X4' = 24sqf |
| | sub total = 880sqf (x6) |
| TOTAL | 7,714sqf |

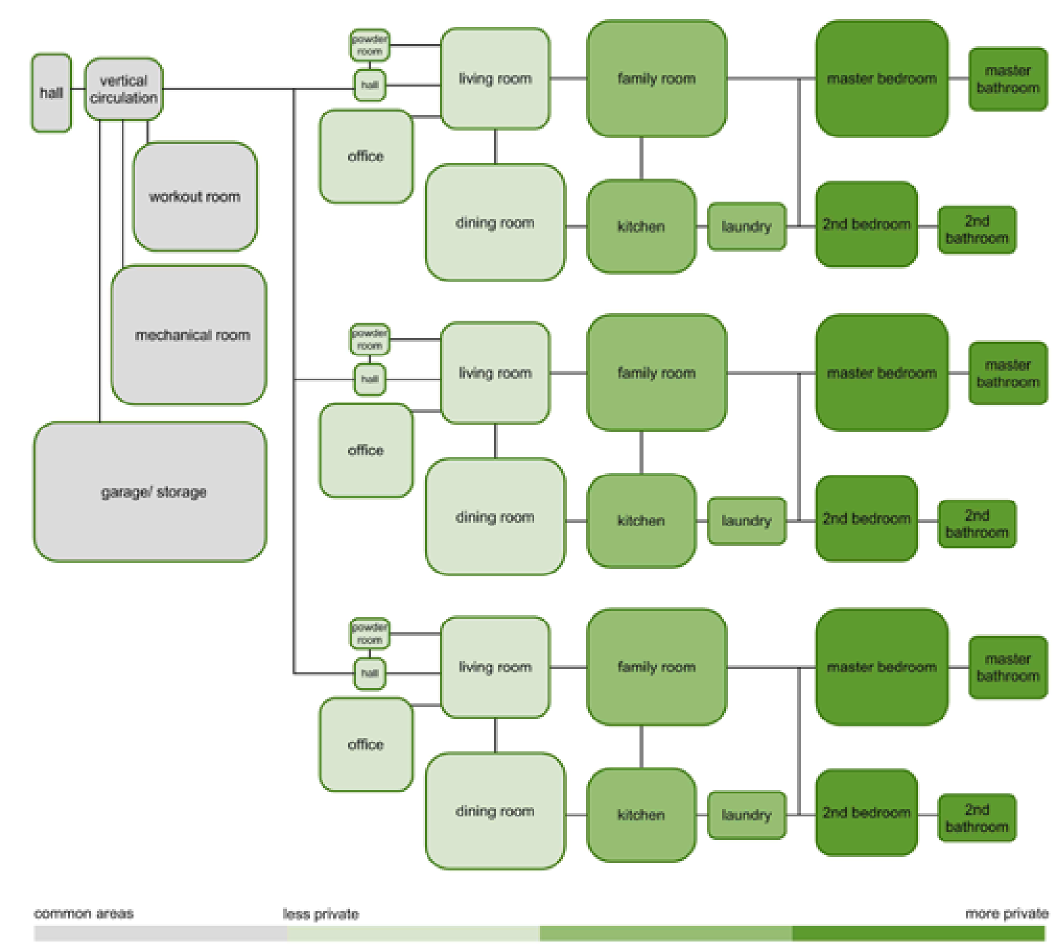


# Organizational Parameters

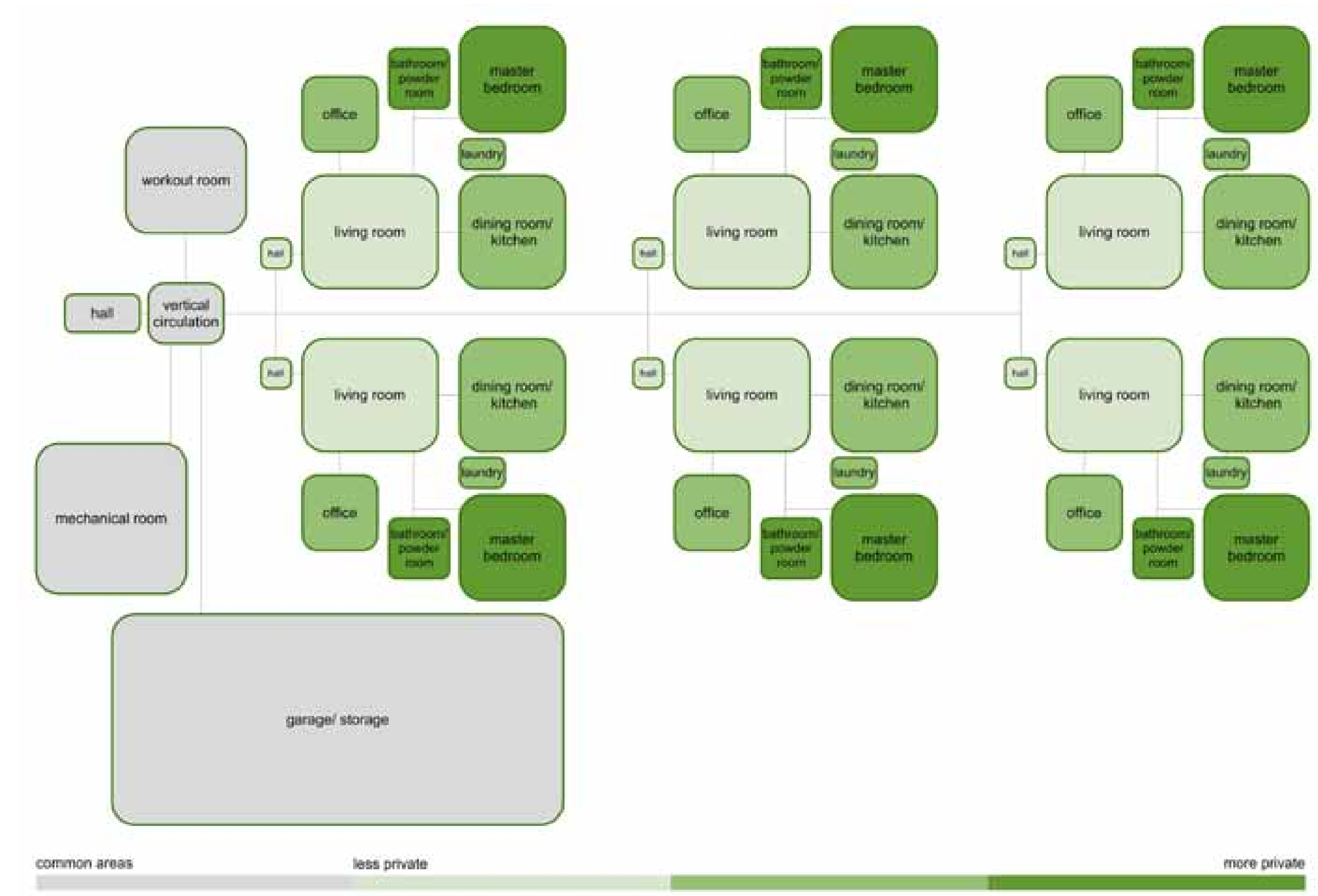
Single Family - One four-bedroom unit




Multi-Family 1-Three two-bedroom units




Multi-Family 2 - Six one-bedroom units



# Yannell House

*Chicago, IL*
*By Farr & Associates + dbHMS*

The home aims to be the first fully-functional zero-net energy home in the Midwest and hopes to achieve LEED for Homes Platinum Certification. The Zero Energy Home is participating in the USGBC's LEED for Homes pilot program and the City of Chicago Department of Environment's Cool Roofs grant program.

## Water Conservation

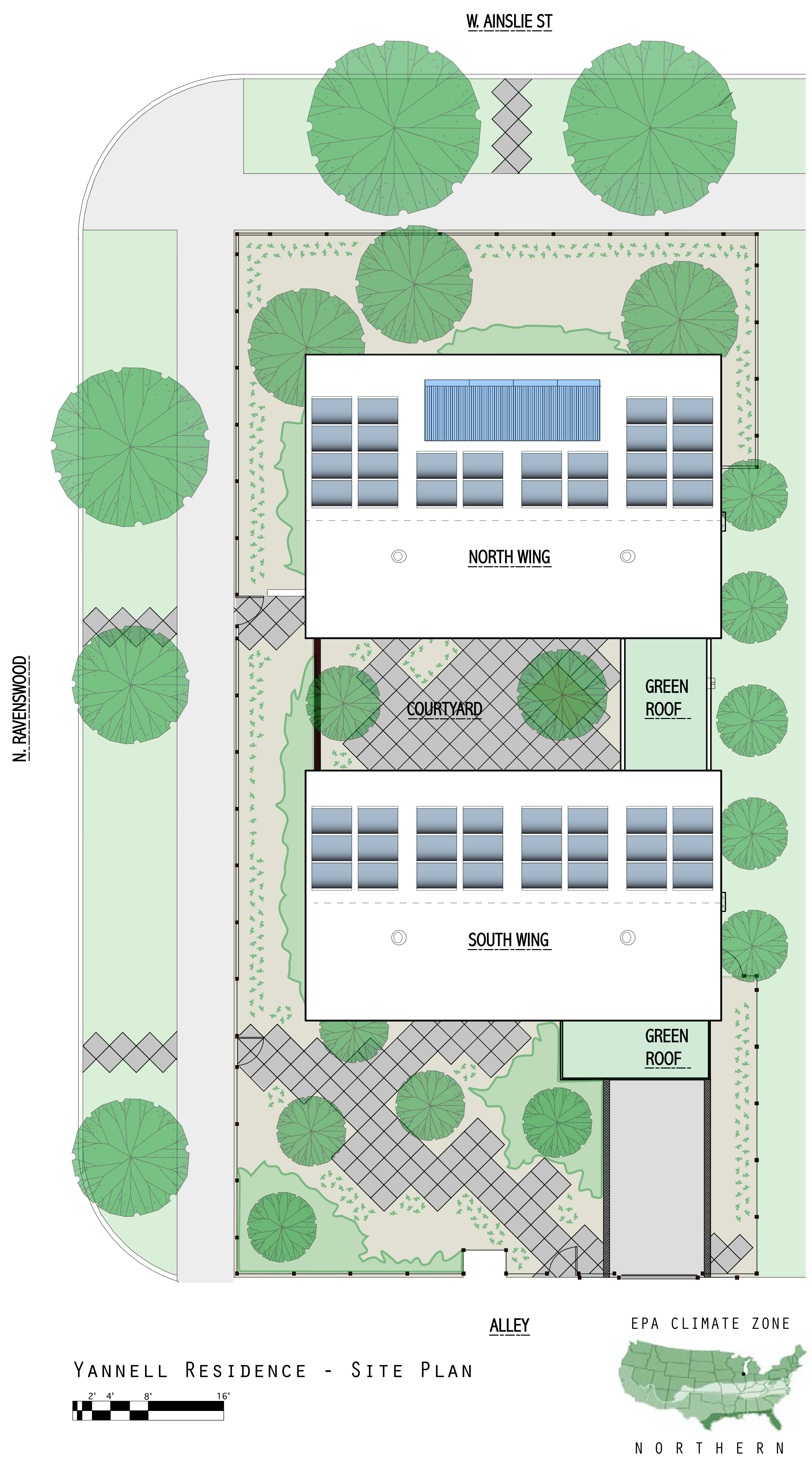
The home's state-of-the-art water conservation and recycling program includes a rainwater collection and irrigation system along with a gray water collection and reuse system that employs low-flow plumbing fixtures.

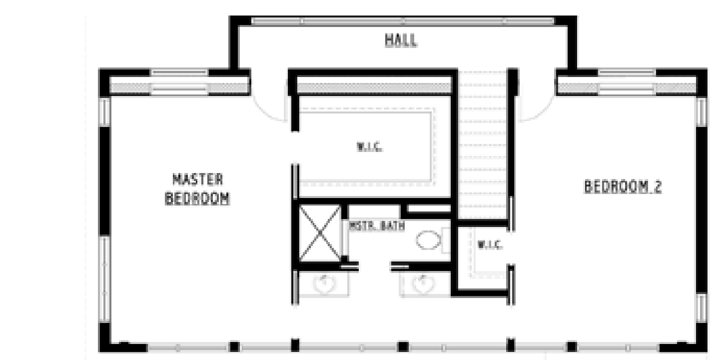
A damper diverts the rainwater to a 550 gallon cistern that is located in the basement of the home. The water collected in this cistern will be constantly agitated and circulated up to a water feature fountain in the courtyard. Collected water will be used to irrigate the landscaping around the house. Should the cistern become full, the system will detect this and overflow will divert to the city sewer.

Waste water from the washing machine will be collected in a smaller, 35 gallon cistern, also in the basement, and eventually be reused to flush the two toilets in the home. Before this occurs, the water will be treated with chlorine, pass through two micro-filtration devices, and then be exposed to ultraviolet filtration.

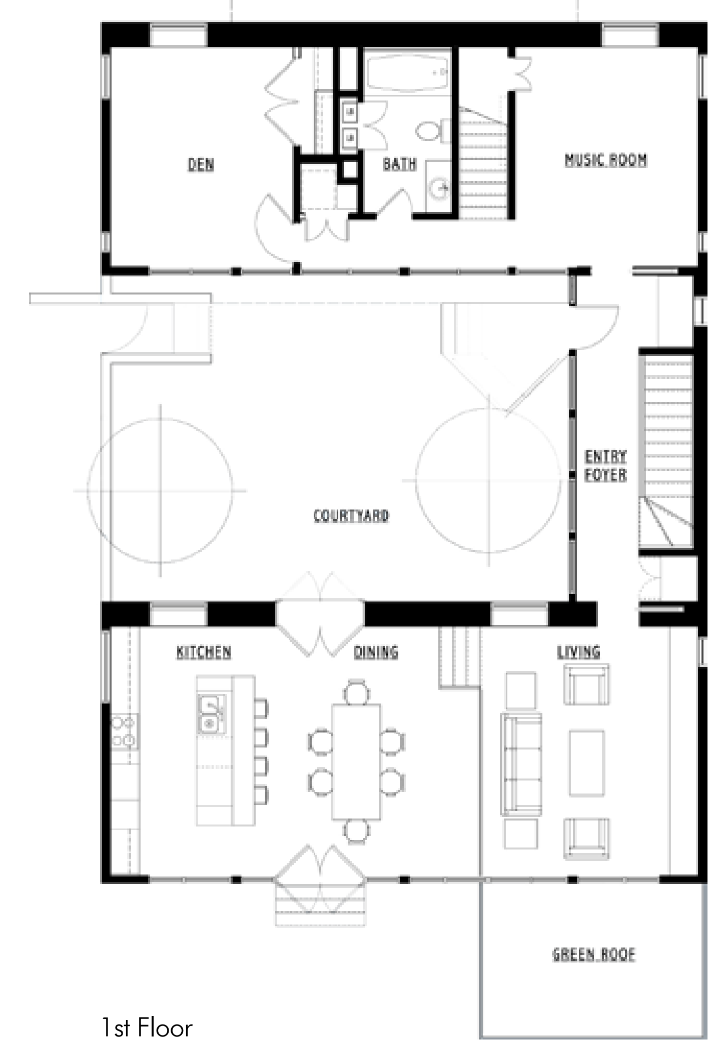
## Energy Conservation

The heating and cooling energy system, comprised of geothermal technology, solar-thermal water heating and passive solar and photovoltaic solar panels, is designed to dramatically reduce dependence upon fossil fuels. Engineers predict that every year, this energy system will generate at least as much electricity as it consumes, with an excess being fed back into Chicago's energy pool.

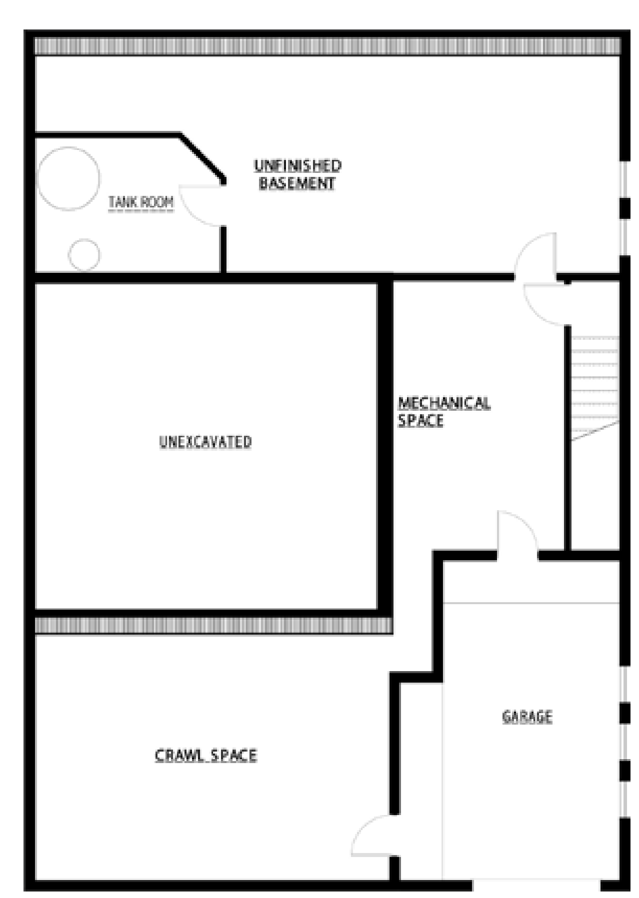



2nd Floor




1st Floor




Basement

## Photovoltaic Solar Panels

The Home will feature a 10kW Solar Photovoltaic System which will consist of 48 solar electric panels. There will also be four evacuated tube Solar Thermal Water Heating panels.

When the panels are producing electricity, any excess electricity not immediately used by the home will flow into the city electrical grid. With "net metering" this means that the meter will turn backward when this is occurring. This is central to the zero-net energy theme. During the warm months of the year, the panels will produce a significant amount of excess electricity, much of which will go directly into the city's electrical grid. During the colder months, the panels will have a shortfall of electricity, and the electricity sent into the grid in the summer will be bought back in the winter. If the home produces more electrical energy than it uses over the year, the electric utility effectively purchases the excess (at a reduced rate, of course). This is the most efficient use of the electricity generated by the panels, and by foregoing on-site battery storage, energy losses caused by conversion and the relatively short life span of these toxic environmentally unfriendly batteries is avoided.

## Solar Thermal System

The Solar Thermal Water Heating Panels are "evacuated tube collectors" covered with tempered glass. A water/food grade glycol mix is circulated up to the panels and absorbs the solar heat that has collected in the panels' tubes. It then travels down to a heat exchanger where the heat is transferred to potable water stored in the solar storage tank. This hot water is then fed into the electric hot water heater. The electric hot water heater will only turn on when the water fed to it from the solar side drops below a minimum temperature. Amazingly, solar thermal panels are able to heat water efficiently even on cloudy days and through the winter.

The hot water generated by the system will be used for domestic hot water uses and the radiant heating system.



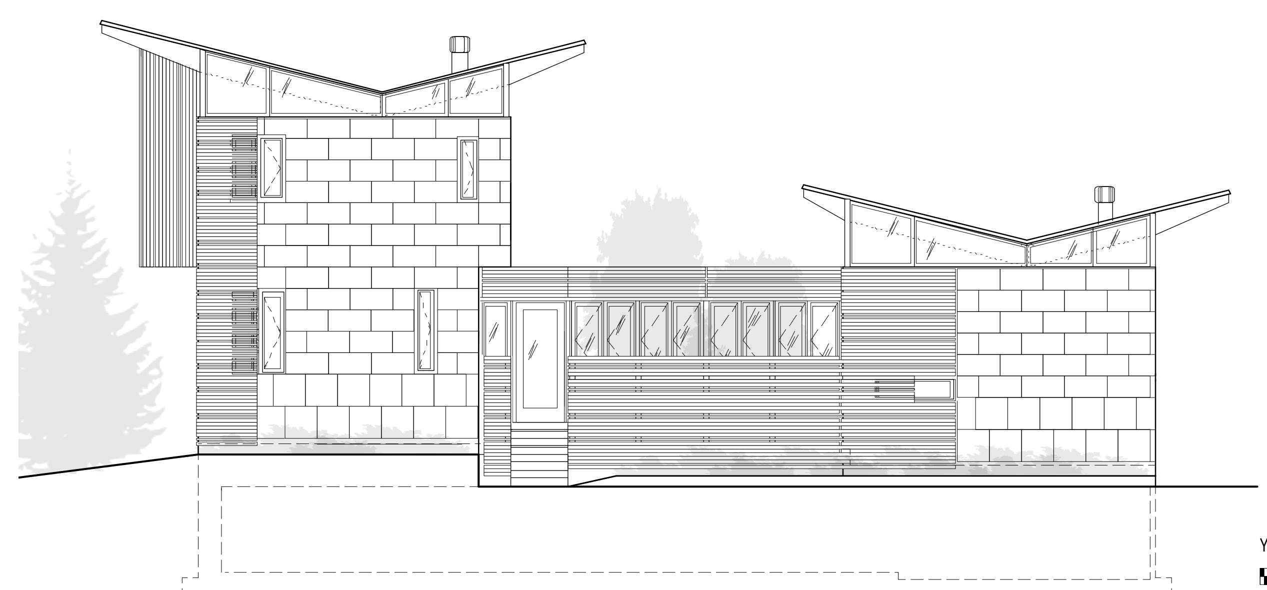
## Geothermal System

The Geothermal system consists of an electrically driven water-source heat pump and 3 "wells" that go to a depth of 250 feet. The system is connected to a radiant floor heating/cooling array that runs through the concrete floors of the entire house (including the basement). The system does the work that is ordinarily done by a furnace and an air conditioner, is quite compact and very quiet.

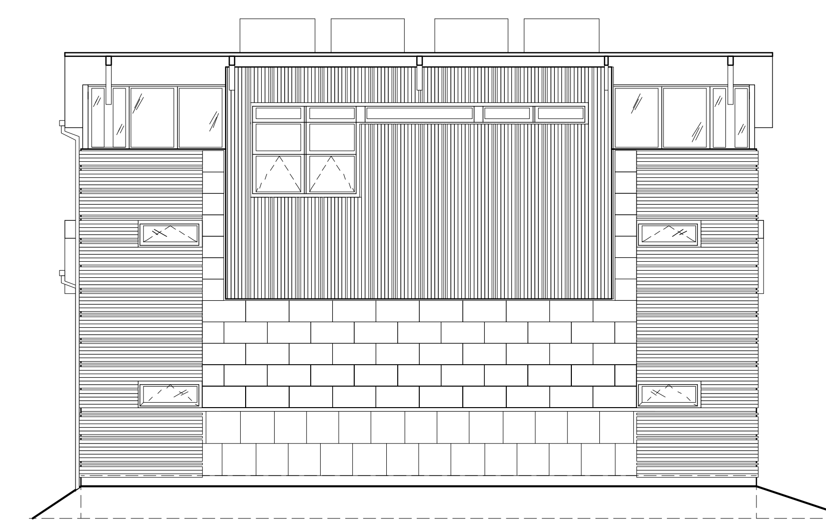
Instead of burning non-renewable fossil fuels to produce heat, geothermal systems rely on the relatively constant temperature of the Earth below the frost line (about 50 degrees F). The 3 wells allow the circulating fluid to "pick up" the heat of the earth and bring it up to the heat pump where, much like a refrigeration unit, a compressor and heat exchanger in a vapor compression cycle are used to magnify this heat gain and distribute it to the radiant system.

For cooling, the process is reversed. As the fluid circulating through the radiant system draws heat from the home, that heat is transferred to the fluid circulating through the wells. The earth then acts as a heat "sink", absorbing this heat and cooling the fluid as it runs through the loop.

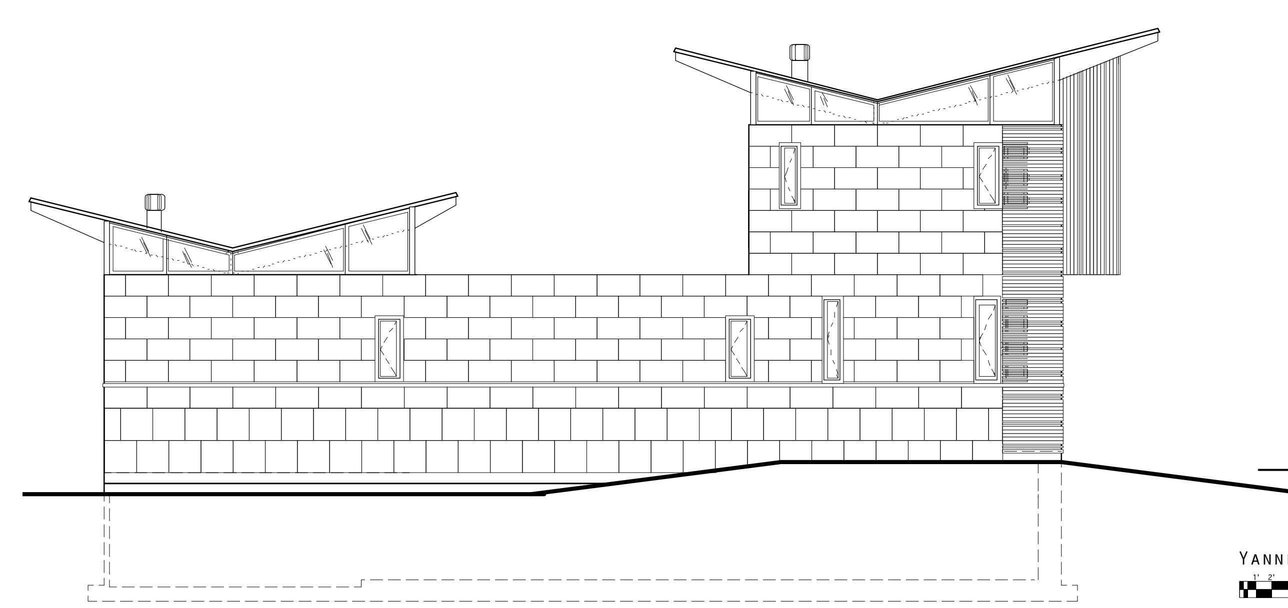
Geothermal systems use less energy because they don't have to work as hard as traditional heating and cooling appliances. It is much easier to capture heat from 50 degree soil than from the atmosphere where the air temperature may be below zero. During cooling, the relatively cool earth absorbs the home's waste heat more easily than hot outdoor air.



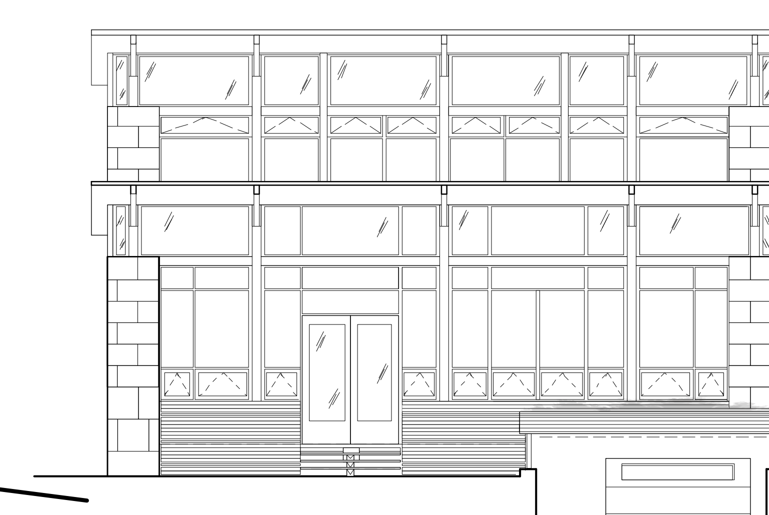
Yannell Residence - West Elevation



Yannell Residence - West Elevation

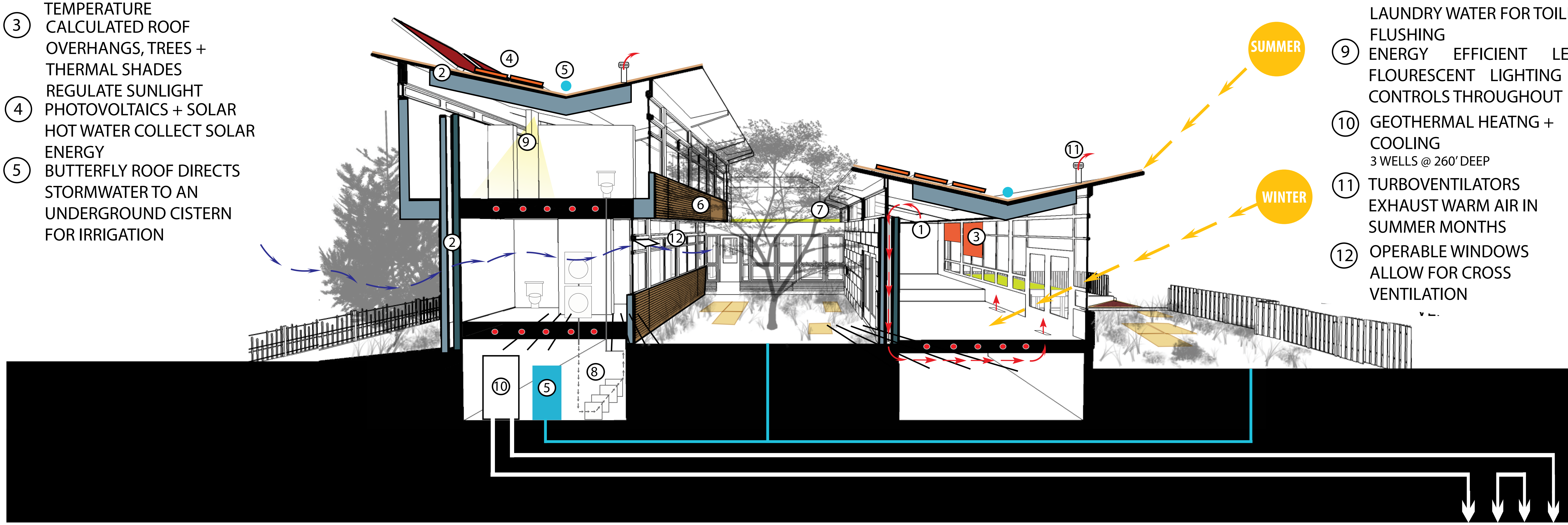


Yannell Residence - East Elevation



Yannell Residence - South Elevation

1. RETURN AIR PLENUM WALL + FLOOR DISTRIBUTES WARM AIR + RADIANT FLOORING HEATS THE SPACE
2. INTERNAL MASONRY MASS WALLS R-33 WALLS + R-57 ROOF REGULATE INTERNAL TEMPERATURE
3. CALCULATED ROOF OVERHANGS, TREES + THERMAL SHADES REGULATE SUNLIGHT
4. PHOTOVOLTAICS + SOLAR HOT WATER COLLECT SOLAR ENERGY
5. BUTTERFLY ROOF DIRECTS STORMWATER TO AN UNDERGROUND CISTERN FOR IRRIGATION
6. EXTERIOR RAINSCREEN CLADDING SYSTEM
7. GREEN ROOFS FILTER STORMWATER + PROVIDE ADDITIONAL INSULATION
8. GREYWATER SYSTEM RECYCLES + TREATS LAUNDRY WATER FOR TOILET FLUSHING
9. ENERGY EFFICIENT LED, FLOURESCENT LIGHTING + CONTROLS THROUGHOUT
10. GEOTHERMAL HEATNG + COOLING
    3 WELLS @ 260' DEEP
11. TURBOVENTILATORS EXHAUST WARM AIR IN SUMMER MONTHS
12. OPERABLE WINDOWS ALLOW FOR CROSS VENTILATION



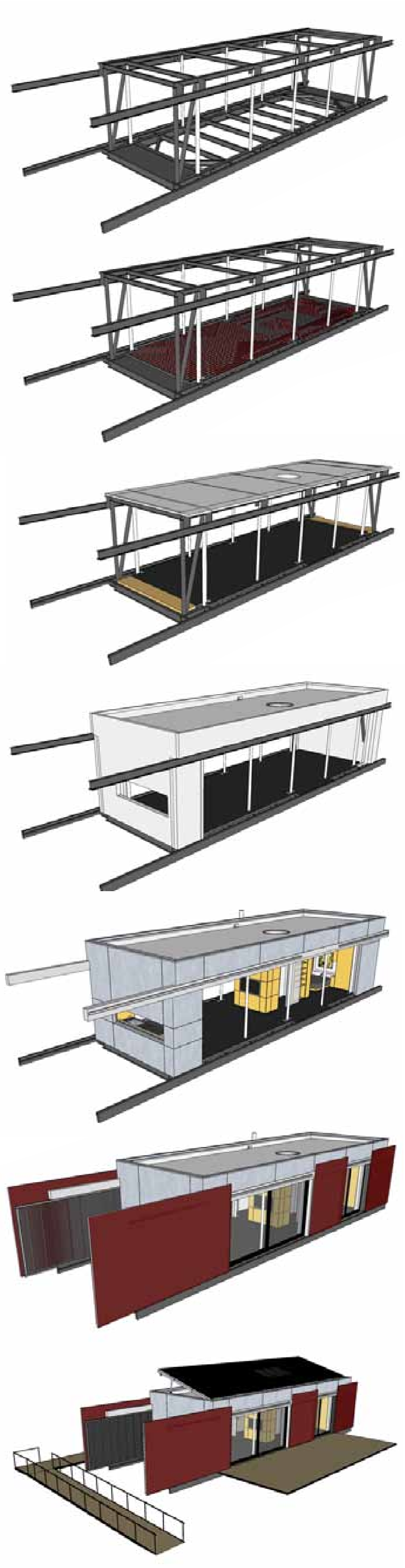
# LUMENHAUS

*Virginia Tech*
*2010 European Solar Decathlon Winner*

LUMENHAUS™ emphasizes integrity and endurance. Choices of materials and components are based on the basic requirements of environmental conservation and energy use, as well as the longevity of each product. General concepts for sustainable architecture – compact volume, little air infiltration, strategic insulation, natural/cross ventilation, passive heating, and integrated geothermal energy sink – are articulated with appropriate technologies. Design decisions and material selection aim to reduce indoor pollutants, minimize global warming, reduce waste, include recycled content, represent low embodied energy in manufacture and harvest, limit destruction to habitat, and rapidly renew resources.

The best way to address issues of energy in buildings is to use as little as possible. The pavilion architecture allows low-energy patterns of use through passive heating, solar shading, and cross ventilation. Responsive Architecture optimizes energy use by adapting to changing environmental conditions while increasing the quality of space. Utilizing smart home technology and environmental controls the house produces more energy than it consumes while providing for increased livability. Through the concept of Responsive Architecture, the house employs sliding fenestrations (Eclipsys System) to optimize energy use while providing for different architectural spatial qualities. Computer automated controls allow the house to automatically adapt to changing environmental conditions. Living in smaller and adaptable houses uses fewer resources, and the prefabricated construction process reduces waste and increases efficiency. We can downsize our dwellings while improving the quality of life.

As a modern pavilion, LUMENHAUS is an architectural space of distinction. Where most energy-conscious houses are closed with strategic openings to resist heat transfer, LUMENHAUS has open, flowing spaces linking occupants to each other within the house and to nature outside. Inspired by the Farnsworth House by Mies Van Der Rohe, the north and south walls are all glass, maximizing the owner's exposure to bright, natural daylight. The fully automated Eclipsis System, comprising independent sliding layers, permits a revolutionary design in a solar-powered house, while filtering light in beautiful, flowing patterns throughout the day.



LUMENHAUS does more than literally deliver a brighter day, however. LUMENHAUS epitomizes a "whole building design" construction approach, in which all the home's components and systems have been designed to work together to maximize user comfort with environmental protection. LUMENHAUS uses technology optimally to make the owner's life simpler, more energy efficient and less expensive. On the cutting edge of responsive architecture, LUMENHAUS can operate completely self sufficiently, responding to environmental changes automatically to balance energy efficiency with user comfort. LUMENHAUS is a zero-energy home that is completely powered by the sun. Other sustainable features include the use of passive energy systems, radiant heating and building materials that are from renewable and/or recyclable sources.

LUMEN means "the power of light." During the day, the house maximizes occupants' exposure to natural daylight, which research shows improves mood and well-being. Energy collected during the day is symbolically radiated back out at night through a low-energy lighting system within the insulating panels. The color temperature of the white lights can be controlled by the occupant to again optimize mood and wellbeing.

HAUS is a reference to the BauHaus movement, and architect Mies Van Der Rohe, whose Farnsworth House inspired LUMENHAUS. The Virginia Tech College of Architecture and Urban Studies also has roots in the Bauhaus movement. The word Haus in German means both house and home, reflecting the multi-audience appeal of LUMENHAUS.

### Solar Energy

Solar energy means using light from the sun to make electricity – what could be more powerful than that? A vast array of solar (or photovoltaic or PV) panels covers the roof of LUMENAHUS, allowing it to be completely powered by the sun. There will be a meter that records the influx and usage of energy throughout the day. If the house produces more energy through the photovoltaic panels than it uses, there will be a net energy gain. This will give the homeowner an opportunity to earn a net income from energy sold back to the power company. Excess energy could also be used to power an electric car. This system is known as net metering. The panels automatically adjust to best capture the sun's energy in all seasons and all weathers. In the cold months, the Eclipsis System will open up to allow sunlight to passively heat the concrete slab floor, decreasing the amount of energy needed to heat the house.

### Natural Daylight

There will be no need for electric light from sunrise to sunset because the pavilion design and north and south sliding glass walls allow vast amounts of natural daylight to penetrate the home. LUMENHAUS breathes with variations in natural light that no electric light can mimic. Filtered through different combinations of the Eclipsis System, at different times of day and during different weather conditions, the light varies from subtle dancing shadows created by the circular tabs in the Shading Shutter to full sun exposure when the screens and glass doors are completely open.

By maximizing exposure to natural daylight, LUMENHAUS helps improve the homeowners' health and well-being. Research demonstrates that daylight is one of the greatest natural healing remedies. For example, sunlight can stimulate your appetite and improve your digestion and metabolism. Sunlight increases the production of endorphins and serotonin, which boost your mood, leaving you with a renewed sense of well-being. Exposure

to natural light during the day can even increase your melatonin output at night, helping you sleep better. Sunlight improves the function of your liver and helps it to break down toxins and wastes that could lead to cancer and other diseases.

**Indoor Lighting System**

The energy collected during the day will be symbolically radiated back out at night through a low-energy, long-lasting Light Emitting Diode (LED) lighting system. Built right into the insulating panels of the Eclipsis System and throughout the house in strategic spots, the interior and exterior spaces will be amply lit. LED lights are extremely energy efficient light fixtures that emit a very high quality white light. They produce more lumens per watt than traditional incandescent bulbs. They also have extremely long lives and are very durable, being resistant to heat, cold and shock.

The color temperature of the white lights inside can be controlled by the homeowner to optimize mood. For example, a warmer (lower color temperature) could be used to promote relaxation while a cooler (higher color temperature) could be used to increase concentration.

**Appliances and Fixtures:**

- Fisher & Paykel DD24SI6 drawer-style dishwasher equipped with an eco-setting for less energy use (Energy Star)
- Diva 24" three burner electromagnetic induction cooktop with a 90% efficiency of heat transferred to cooking utensils compared to 50% for gas and 60% for other cooking technologies (Energy Star)
- Summit FFBF245 compact refrigerator/freezer that is more energy efficient than most on the market for its size (Energy Star)
- Kohler water-conserving kitchen faucet
- Kohler toilet with Dual Flush technology that meets the EPA's strict WaterSense flushing performance guidelines (uses at least 20% less water than standard 1.6-gallon toilets)
- Energy Star rated SMEG SC712U convection oven that operates at a lower temperature yet cooks food faster than a conventional oven, also equipped with an eco-mode that brings the device up to temperature in the most efficient way
- LG combination front-loading ventless clothes washer and dryer cleans and dries clothes in a single appliance, halving embodied energy, maintenance, and floor space
- Laundry Alternative Spin Dryer uses a 3200-rpm spin cycle to remove most water from clothing using very little energy, which cuts heated drying time by 30 minutes or more
- Touch screen ASUS computer uses energy management software that throttles system resources based on process requirements
- Samsung LED series Eight TV uses 20-30% less energy than a comparable size television, while producing better color and contrast

**Materials:**

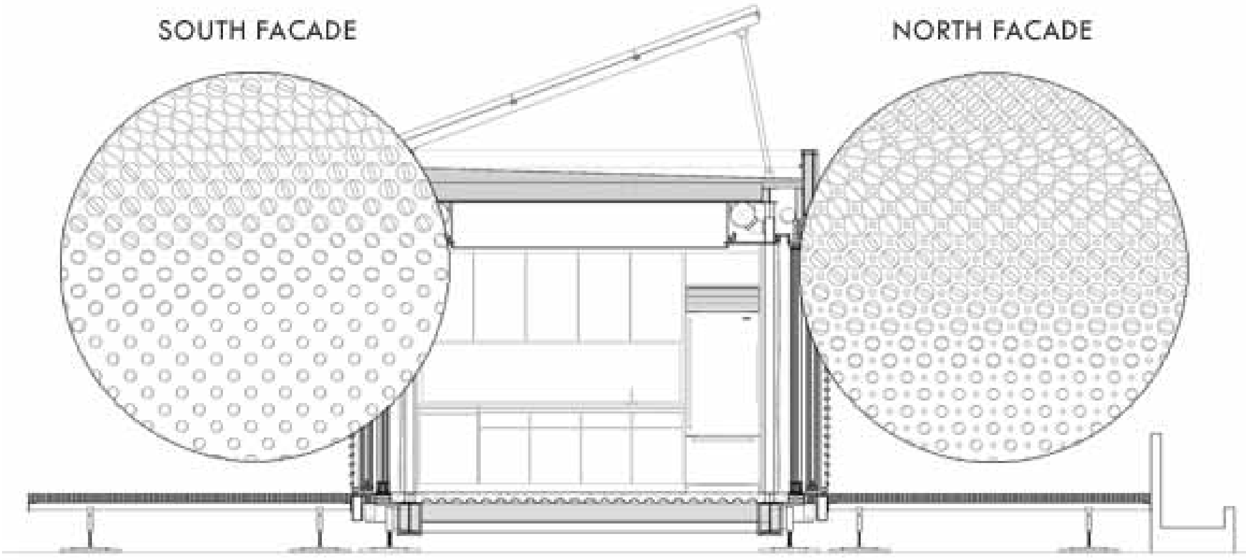
- Minimized painted surfaces using green line paint with low VOC content from Sherwin-Williams, minimizes the impact on air quality while still delivering maximum performance
- Long lasting polished HTC Superfloor concrete floor is durable, easily cleaned and doubles as a thermal mass for passive solar strategies
- Structural Insulated Panels (SIPs) provide superior insulation as well as structural strength, while reducing infiltration and optimizing the use of framing materials
- Closed-cell spray foam insulation containing no CFCs, HCFCs, or measurable levels of formaldehyde promotes tight enclosure and increases R-values
- Wall surfaces of durable and easy to clean maple-veneered plywood from Columbia Forest pure bond line non-toxic technology with soy-based adhesives
- Long lasting aluminum framed Fleetwood sliding glass doors obtained from vendors who practice waste reduction by recycling remnants and glass scrap for future use
- Lightweight Barrisol stretched fabric ceiling made from recycled, lead-free co-polymer fabric ceiling
- Environmentally preferable electrochromic glass, SageGlass, helps to reduce heating and cooling loads while automatically improving light quality by tinting the glass if the intensity of the sunlight is too strong
- Daltile bathroom tile made from recycled materials
- Durable and easy to maintain rubber tile produced by Johnsonite, is recyclable
- Space utilization products from Hafele which allow for a smaller house footprint, requiring fewer materials and using less energy
- Aerogel filled polycarbonate panels give a high insulation value while transmitting a beautiful translucent light
- Stainless steel shutters provide sun protection, security, privacy, cross ventilation, strategic views and a dynamic diffused natural light
- Zinc façade panels can be completely recycled
- Roofing system utilizes a white, lightweight, weatherproof, Acrylife PVC membrane that protects the roof from harsh weather conditions while also reflecting light, therefore decreasing the amount of heat from sunlight that is absorbed through the building envelope
- All energy provided by 45 grid-tied solar panels – the Sanyo 190 HIT Double Bifacial Photovoltaic Module, which simultaneously absorb sunlight from the back face of the panel; a portion of the sunlight passes through the panels, combining with sunlight reflected off the surface below, thus transferring the highest power per square footage to the bifacial solar cells and producing up to 30% more electricity than a one sided panel
- Maintenance free, long lasting, durable, and rot and termite resistant decking – wood (ipe) harvested under the guidelines of the Forest Stewardship Council (FSC), ensuring minimal impact to the environment
- Aluminum walk off mat – recyclable and lightweight - helps prevent tracking of debris into the house

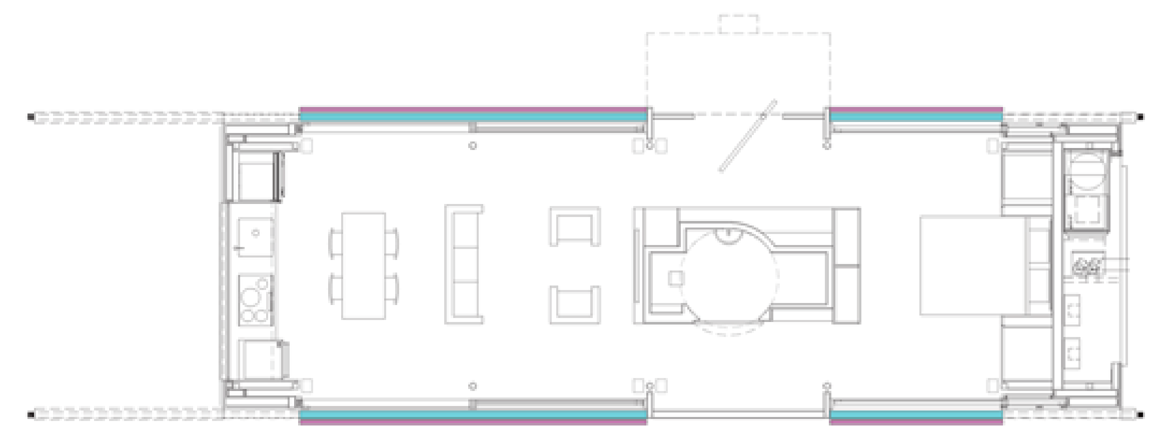
**Geothermal Heating and Cooling**

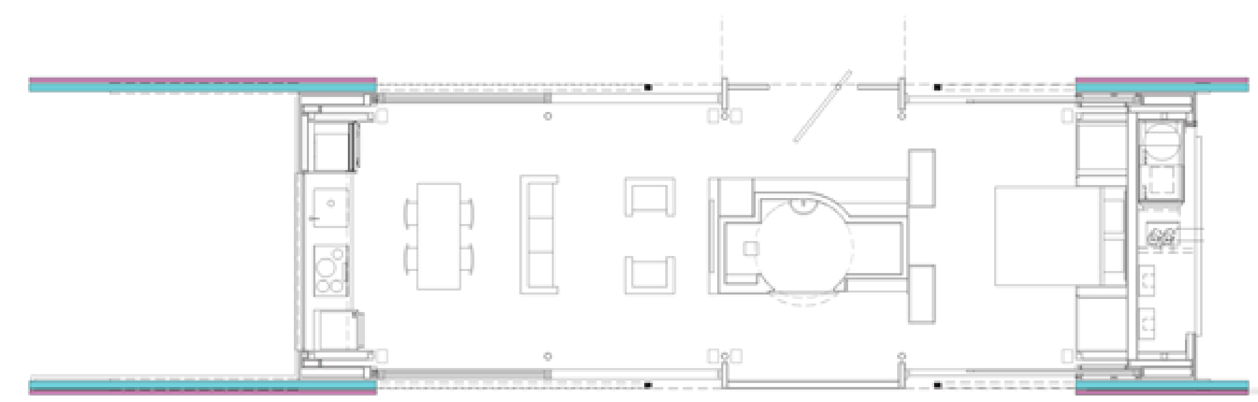
- Fully automated, high efficiency geothermal-tied heat pump system increases efficiency for heating and cooling
- Radiant floor heating system by REHAU generates heat evenly and consistently throughout the room. No blowing air, quiet operation
- Siemans APOGEE Building Control System (BCS) software and web applications allow users to manage all facility systems and equipment from one workstation, compiling all information to work smarter and more efficiently
- Titus Dynafuser linear slot diffuser with actuators redirect the air to optimize for thermal comfort as it relates to the season.
- Automated Eclipsis System (stainless steel sunscreen and aerogel filled translucent insulated polycarbonate panel) maximizes conservation of energy and brings the outside to the inside

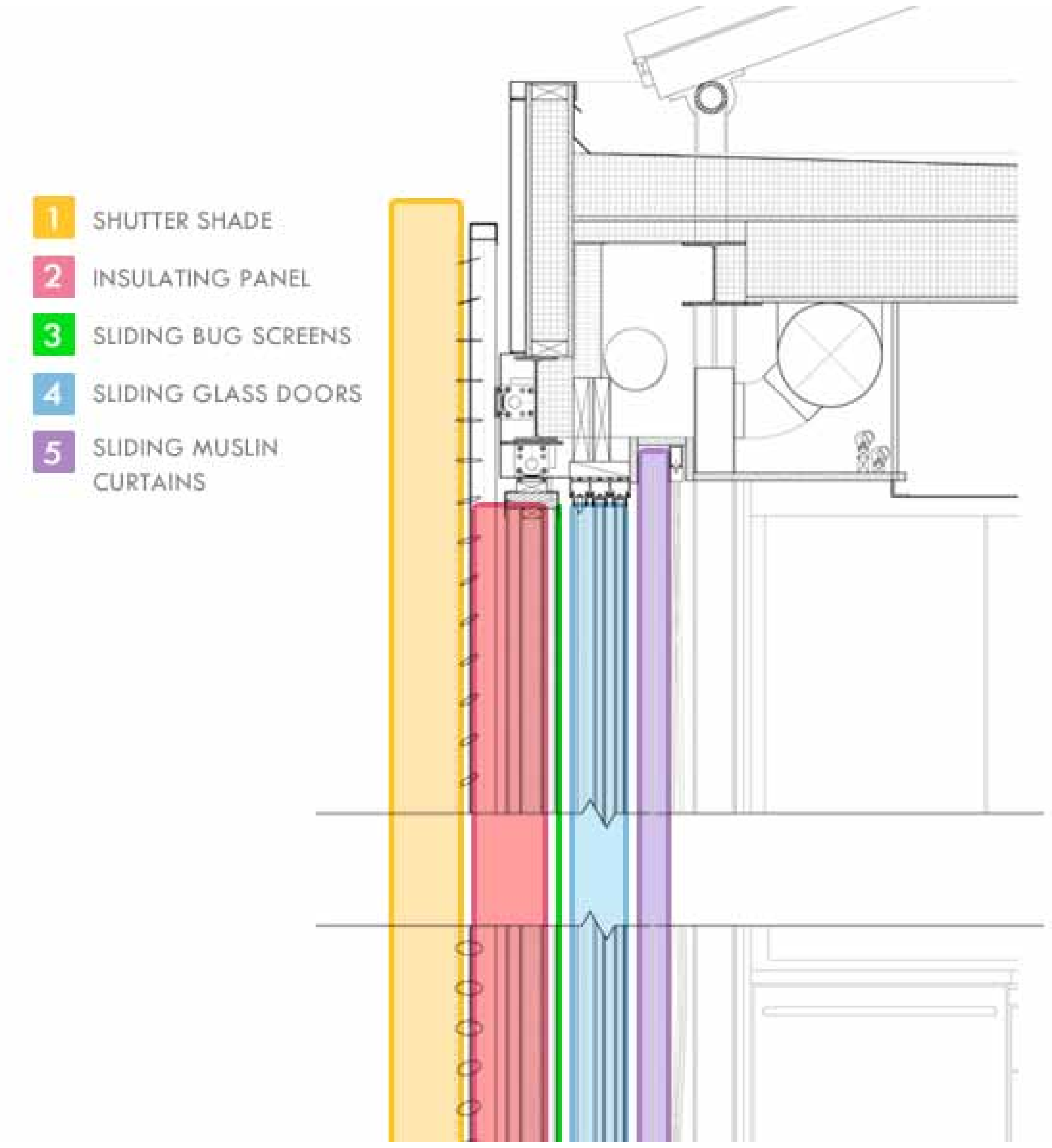
**Landscape**

- Three-stage gray water treatment system for water purification and subsequent reuse
- Landscape ponds including hydroponic plants that treat wastewater, prevent the growth of algae, and repel insects to prevent infestation
- Varieties of sedum used as a surface landscape ground cover that absorb carbon dioxide emissions from the surrounding environment and serve as a runoff system for impervious surfaces surrounding the house







# surPLUShome

*Technische Universität Darmstadt*
*2009 Solar Decathlon Winner*

The surPLUShome introduces the concept of energy efficiency and sustainability as surplus in everyday life. The building features many elements allowing the user to break common stereotypes of living concepts and to generate a new lifestyle. As a pun, sur+ allows to integrate all these different building elements or building aspects and to make them an integral part of surPLUS. We will use this as communication concept especially in the sur+round on the National Mall.

## About surPLUShome

The surPLUShome of Technische Universität Darmstadt is aimed to demonstrate innovative sustainable design and to make it an object of discussion. Our vision introduces the concept of energy efficiency and sustainability as surplus in everyday life. The building features many elements, which allow the user to break common stereotypes of living concepts and to generate a new efficient lifestyle. It is a surPLUS

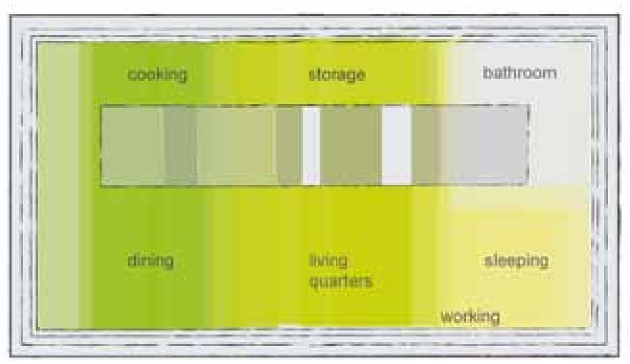
## Design concept

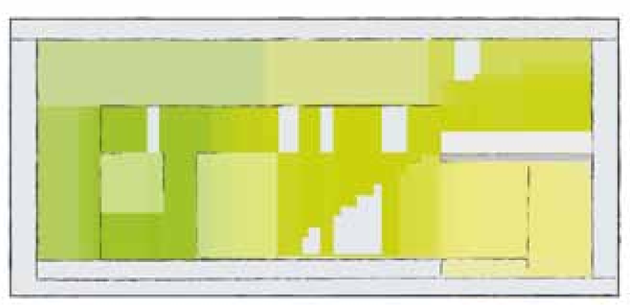
The design of our house aims to create a maximum amount of living space, a maximum energy income and the best possible adaptation to the environment.
To achieve these goals, we have placed a multifunctional body within the dimensions of the maximum cubature.

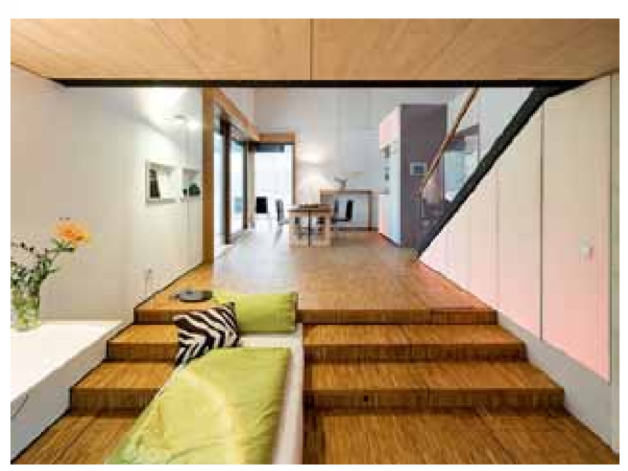
The multifunctional body is the heart piece of our design, it accommodates all primary functions, building services and furnishings. According to the user's needs these functions are exposed and utilized. Due to this feature, we have generated a highly functional and multifaceted one room living space, which is defined into a public and a private area through a topographical design on the ground floor and a gallery on the upper floor.

The façade of the building is also multifunctional and solves all technical requirements. Besides the energy-gaining aspect and architectural claims, it also features constructive moisture protection and technical exhaust ventilation. Furthermore the façade offers a highly effective shading and lightning control system all in one.

The construction is based on the traditional principle of shingles. We picked up this technique and transferred the principle onto a new appearance of modern materials like glass-glass PV-modules and acrylic glass pieces.



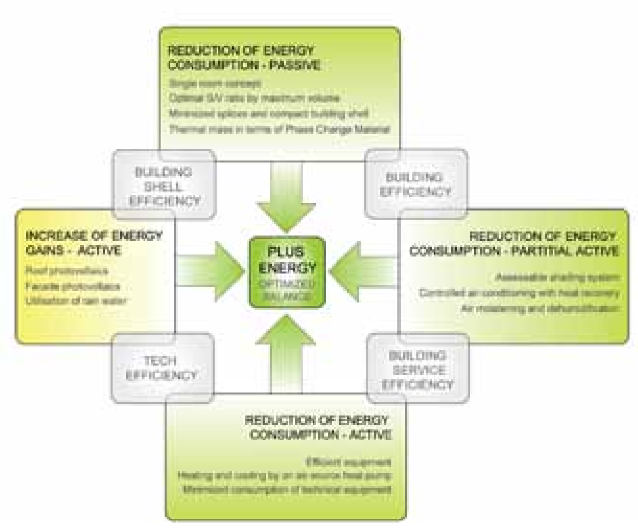





## Strategies of Energy Use

A popular theory in high energy efficient buildings design is to integrate as much passive systems as possible before running active ones.

A conceptual building analysis of the shown Solar Decathlon buildings and especially of the German contribution in SD 2007 shows that a design cascade from passive to active systems does not necessarily lead to a plus-energy building. Active and passive technologies have to interdigitate. The German contribution for the Solar Decathlon in 2009 tries to do so. Regarding the whole system we searched for ideal combinations of both active and passive systems. We found partial active systems as well which allows us to compose an optimized solution.







## Sustainable design

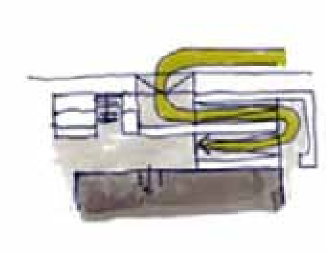
Sustainable architecture does not intend mean to save or to produce as much energy as possible. Ecological, economical and social aspects have to integrated in design with convenience of the inhabitant in its center. Therefore the aims and ideas in the planning process have to be challenged and verified again and again.

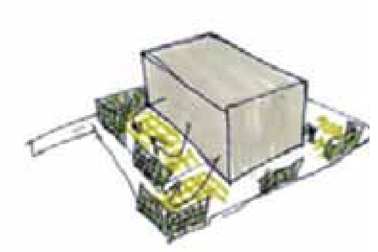
On the one hand, the Solar Decathlon competition offers us specific possibilities not common in usual planning processes. With a prototype home we will be able to contribute to sustainable development by generating new ideas in building related people or showing the livability and beauty of a sustainable house. We believe that sustainable houses are a lifestyle element in the future. On the other hand , the rules and rags of the Solar Decathlon are quite intense and leave only a little space for creative interpretation. Many of the given rules and rags could collide E.g. Concerning our roof we would produce more energy if we would have installed the mono-crystalline photovoltaics in an angle of 60°. But our intention was to allow the inhabitant to experience the room from different perspectives and offer different atmospheres inside the house. This is the reason why we decided to build the second floor and using the max. envelope, instead of energy surplus.

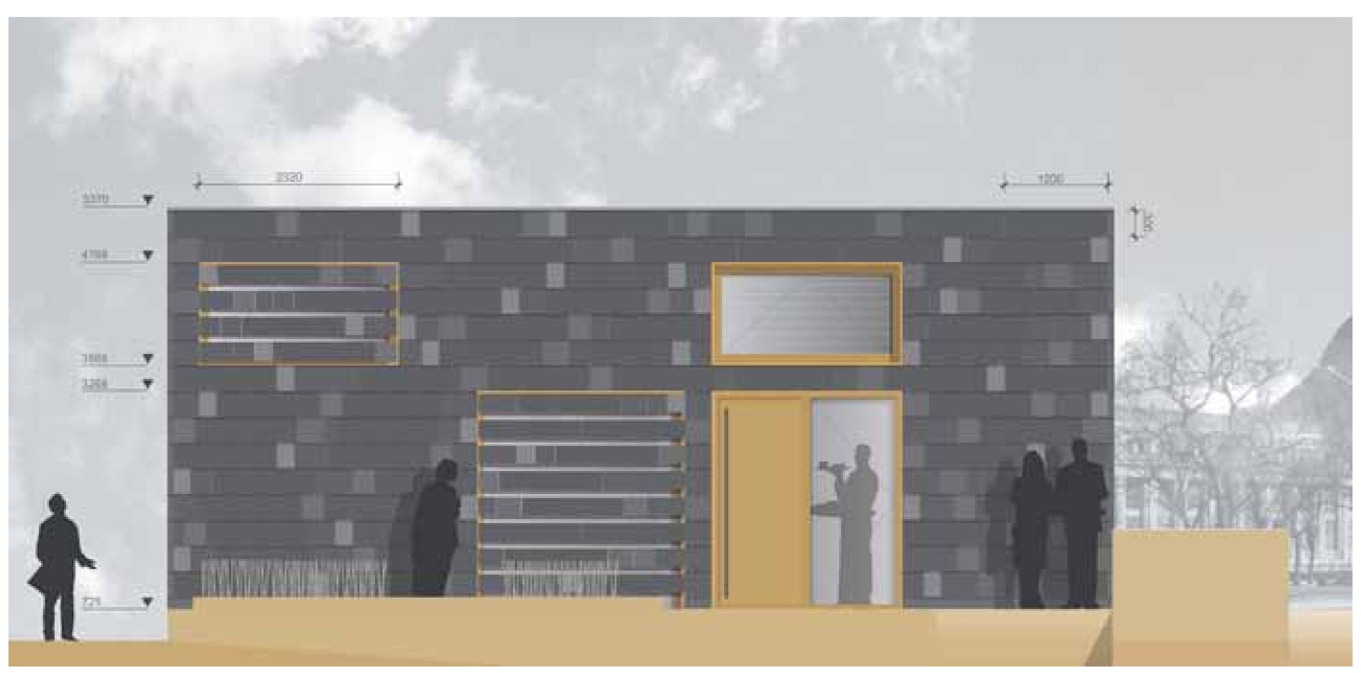
To show the worthiness of sustainable design, we would like to certify our building in sustainability reasons. In cooperation with the DGNB - Deutsche Gesellschaft für Nachhaltiges Bauen (german association of sustainable building) we will certify our building and present a pre-certification on the washington mall in october.

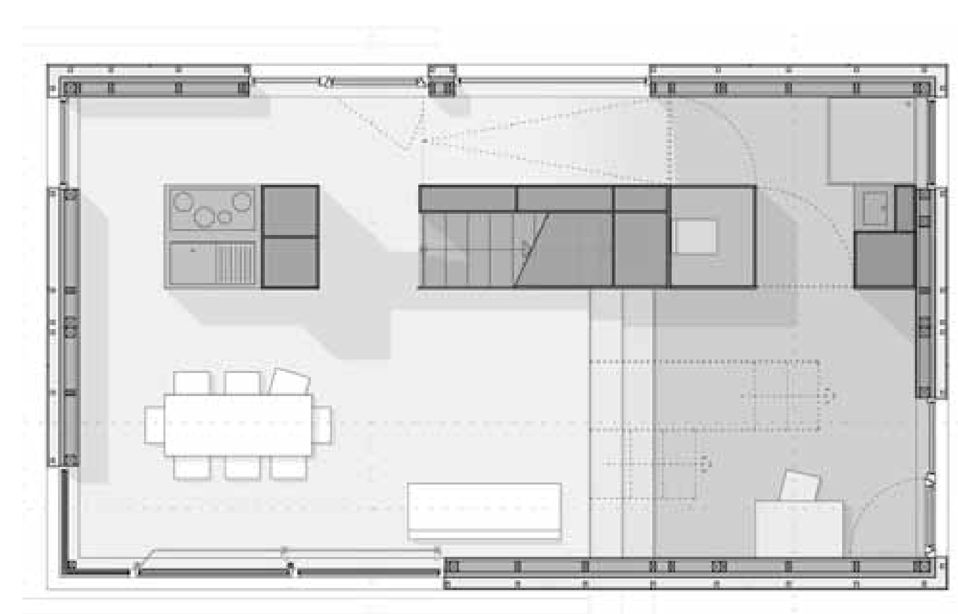
## Exterior Design

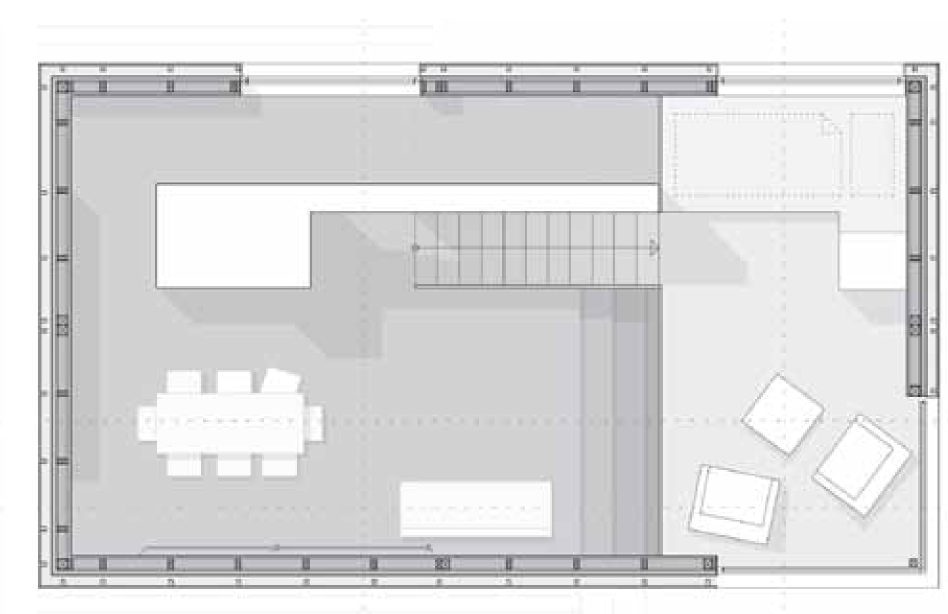
The exterior deck design is characterised by it's elevation changes, which coincides with the interior design. In respect to accessability and design aspects we have designed the deck to be on even level with all window and door openings. The elevation changes are connected by both stairways and ramps which comply with the Americans with Disabilities (ADA) accessibility guidelines. Other aspects such as the public tour played an important role in the design process. The deck is meant to be an inviting and interesting place. Along the path to our house we will display building material samples and informatio boards.Benches are also provided where visitors can rest and enjoy the view of our and the other houses.
.
The primary structure of the deck consists of conventional scaffolding elelments, on which the secondary structure will be placed, consisting of wooden beams. The planking consists of oak beams, which are suitable for outdoor use.

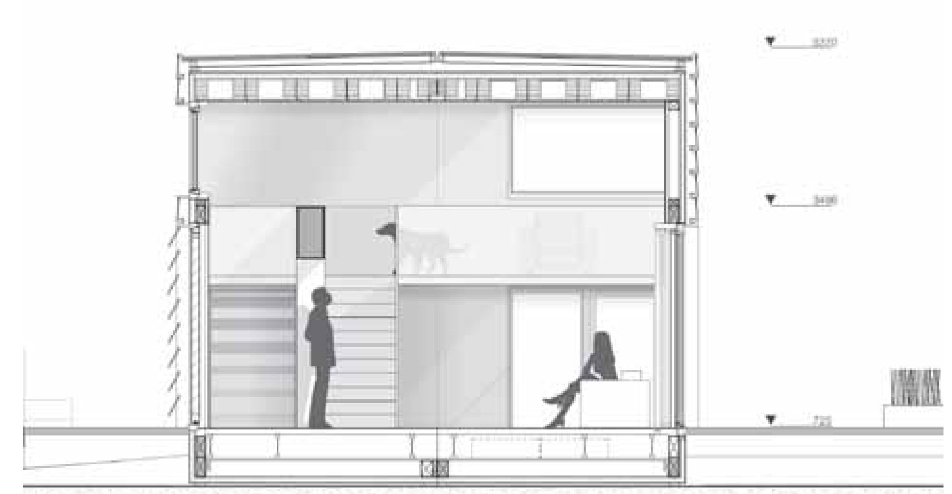


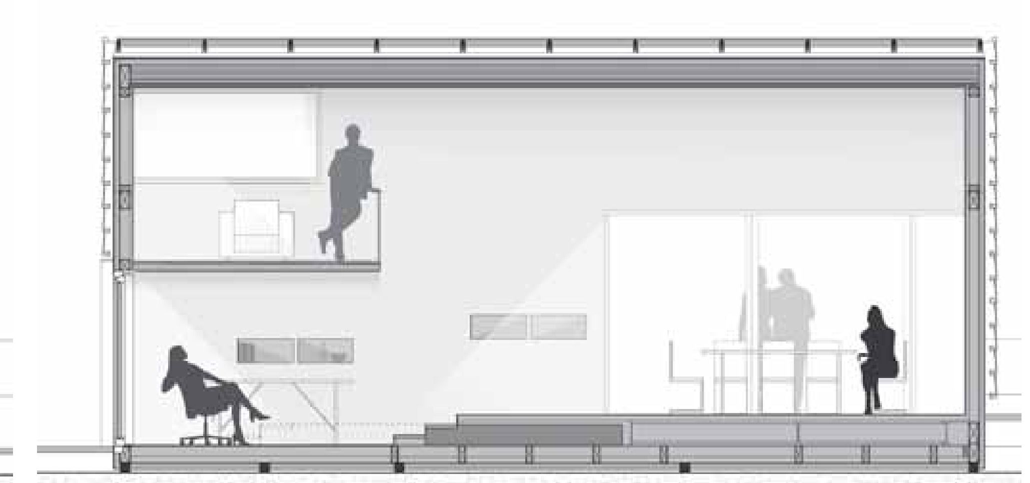










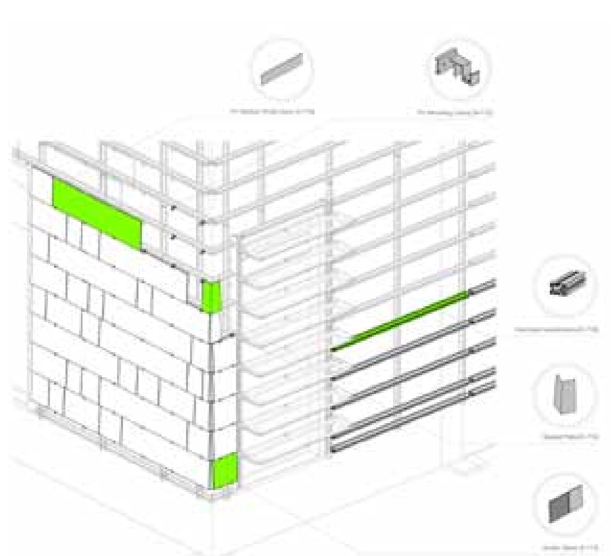


**Description of the Façade**

During the intensive design and optimization process we achieved a façade-system which is in accordance to all different requirements of building façades. Besides the energy-gaining aspect and architectural claims, it also features constructive moisture protection and technical exhaust ventilation. Furthermore the façade offers a highly effective shading and lightning control system all in one.

The construction of the façade is based on the traditional principle of shingles. We picked up this technique and transferred the principle onto a new appearance of modern materials like glass-glass PV-modules and acrylic glass pieces. This application of high-tech elements like PV-modules in the façade has some special technical terms, we have to solve. In order to generate a façade, which functions working in all orientations we are forced to use amorph cells with good responding behavior to indirect solar radiation.

The angle of the cells towards the sun is optimized by this construction. For the single cell inside of the photovoltaic modules the best direction is the vertical, due to reasons of self-shading of the modules. The company Würth Solar supports us in the technical development and production and offers us innovative thin-film photovoltaic modules optimized for this façade-system.



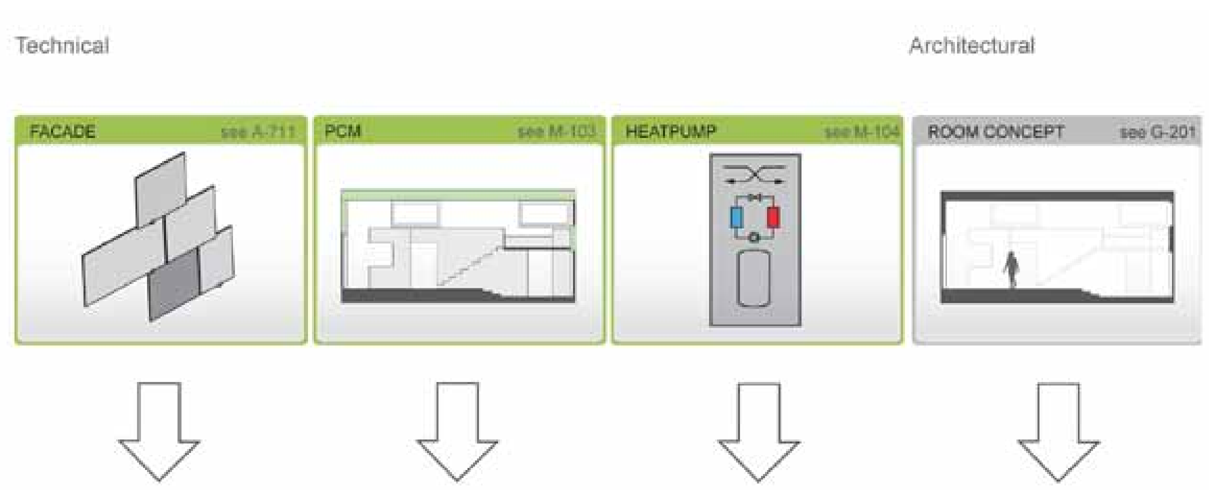
**Systems**

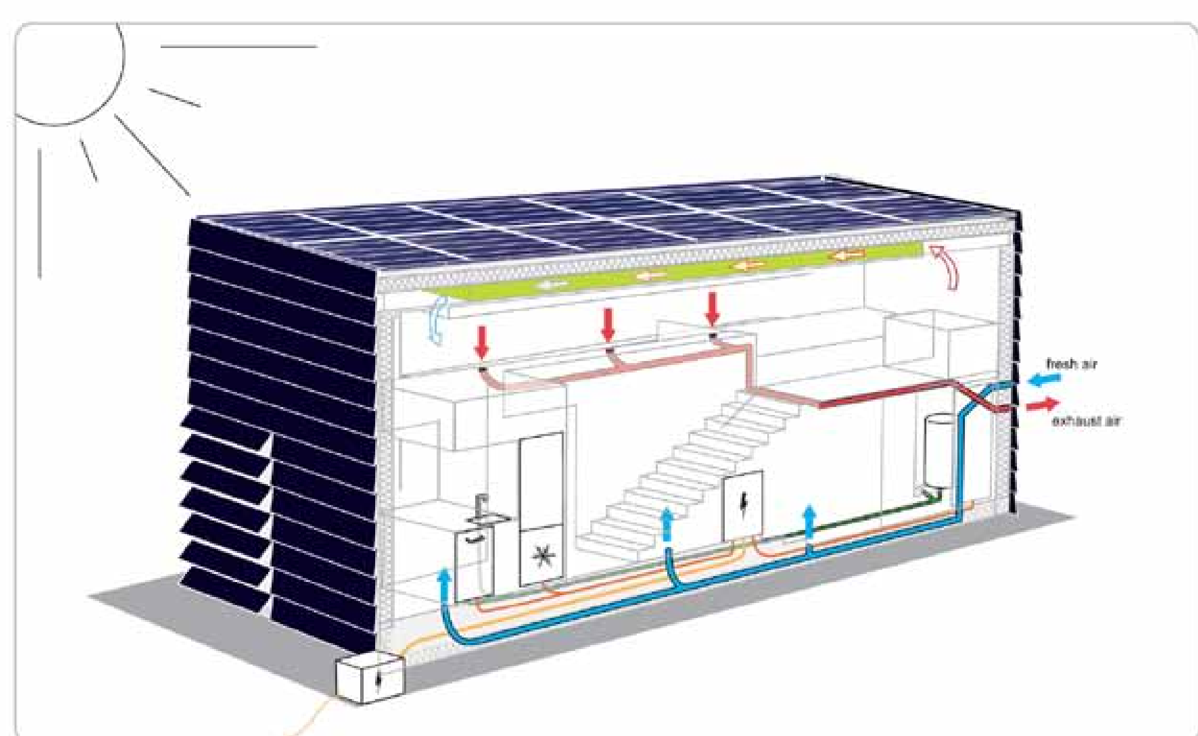
The energetic concept of our house combines a high level of comfort with intuitive building control, energy saving and energy producing systems and above all, aesthetic pleasure. The technical systems applied are integrated in a coherent design to reach a complete integration of all functions. Each system could work on its own and can be adapted for other buildings.

Due to the special conditions of this competition the concept has to face both, the climatic conditions of Washington, D.C. and of Darmstadt.

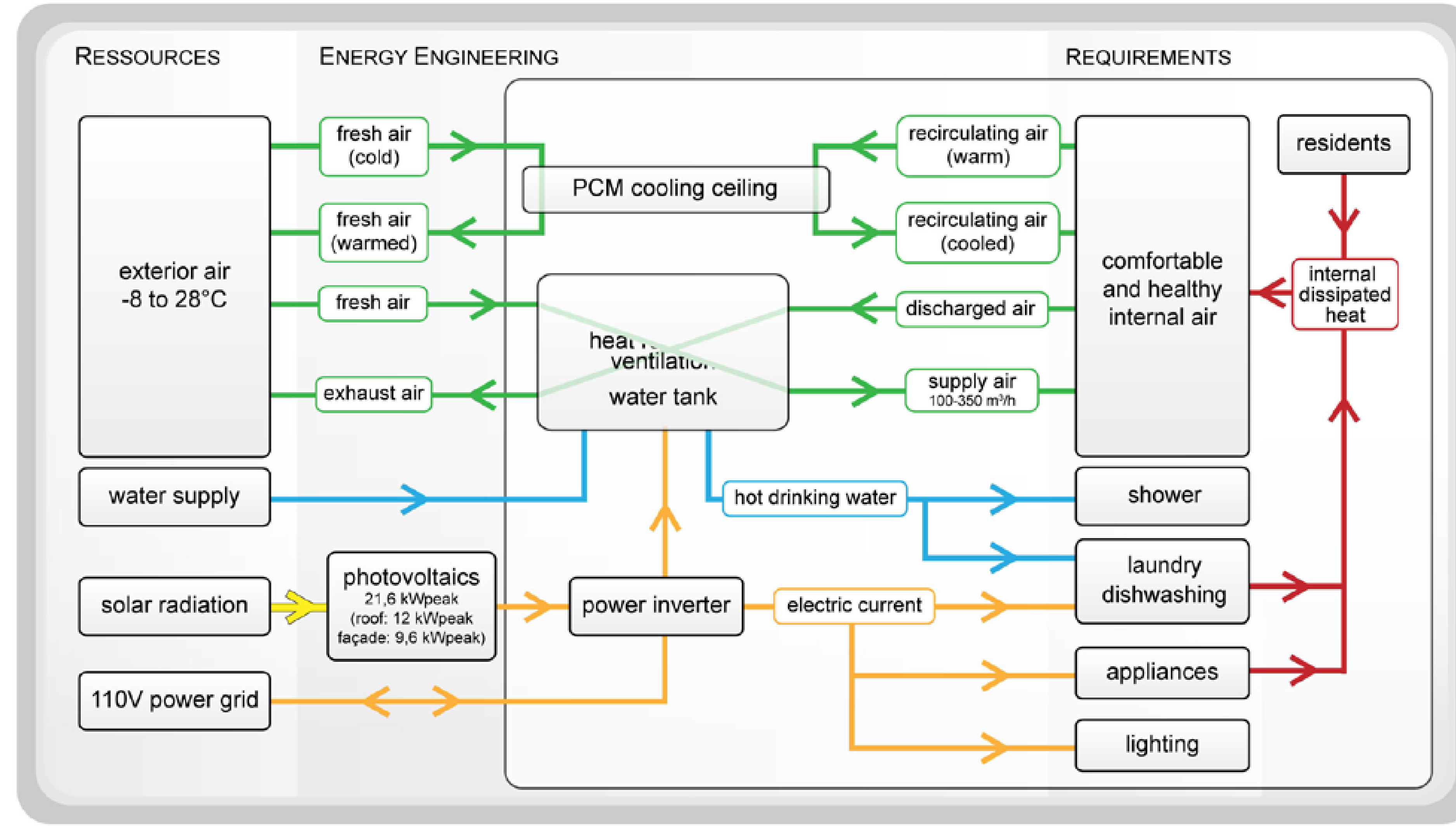
For the reduction of energy demand, the building envelope consists of highly insulated and airtight components; additionally it is, of course, equipped with controlled ventilation and heat recovery. Optimal climate control is achieved by a heat pump, which takes energy from the surrounding air. Controlled air ventilation is necessary, so technical components like radiators are superseded by air conditioning.

By this the heat transfer is easily possible. The building envelope is optimized for energy production, using different kinds of photovoltaic technologies: on the roof high efficient monocrystalline PV is installed, while CIS PV is applied on the facade. These cells provide extraordinary possibilities of architectural integration, which is one important aim of the energy concept. The facade regulates daylight, solar gains (heating) and cooling demands. It also includes blinds and visors.





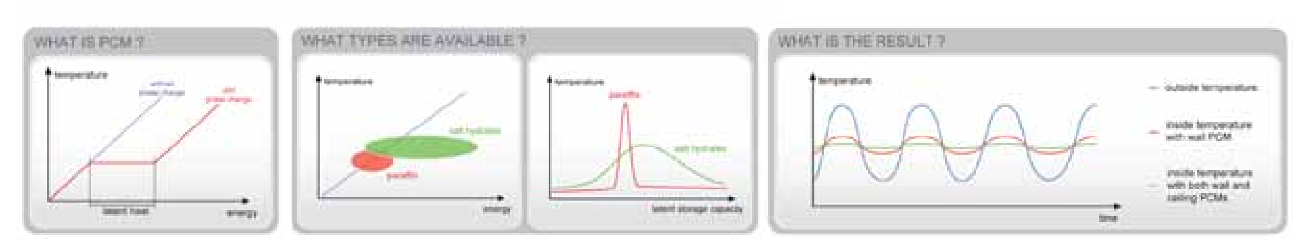



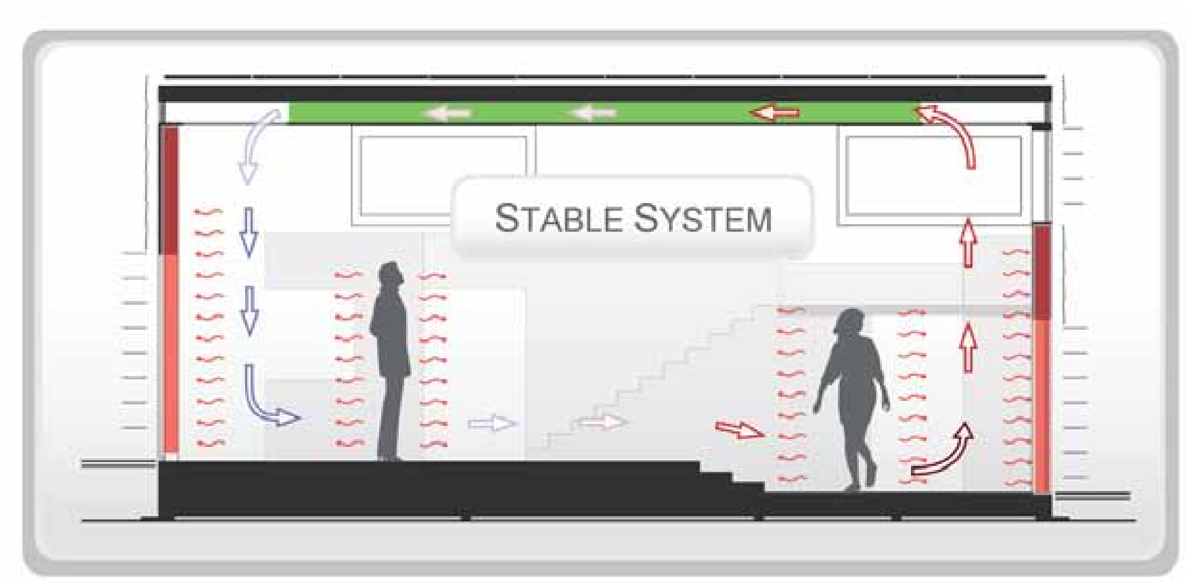

PCM-System

Every material is capable to accumulate thermal energy and to deliver it again.
A phase change material (PCM) is a substance with a high heat of fusion. Thermal energy is absorbed or released when the material changes from solid to liquid and vice versa; thus, PCMs are classified as latent heat storage units.

Water for example is solid below 0°C (Ice), fluid between 0°C and 100°C and gaseous above 100°C. At the point of phase transition extra energy is needed. Water requires the same amount of energy to transform from a solid state to liquid, as to heat it up from 0°C to 80°C.
We are using phase change materials in our interior walls (paraffins) and in the cooling ceiling (salt-hydrate). They have their fusing point at a temperature of 23°C, therefore we can store much heat during daytime in little mass. The thermal mass will be discharged at night. The capacity is equivalent to the energy needed for one day of cooling.

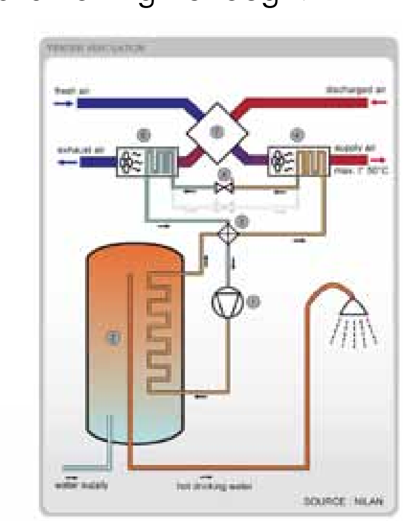
The PCM in the internal wall is not controllable because it is the surface of the interior room with it´s thermal sources. It is a passive system.
The PCM in the ceiling is a partial active system, as a result of being separated from the interior room and controllable by the built in fans with the ability to regulate the air speed in the ceiling, we can increase cooling load whenever needed.
We calculated the coefficient of performance between 9 to 15 regarding the ambient temperature.

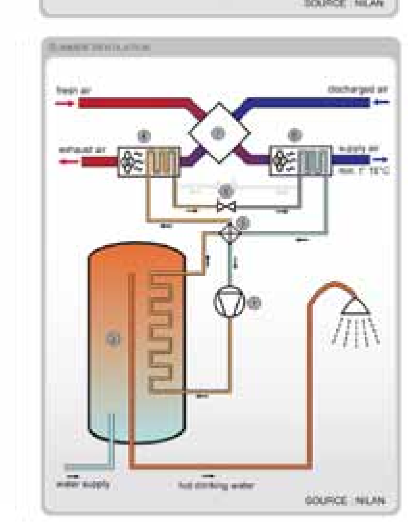



**Heatpump with Heat Recovery and Watertank**

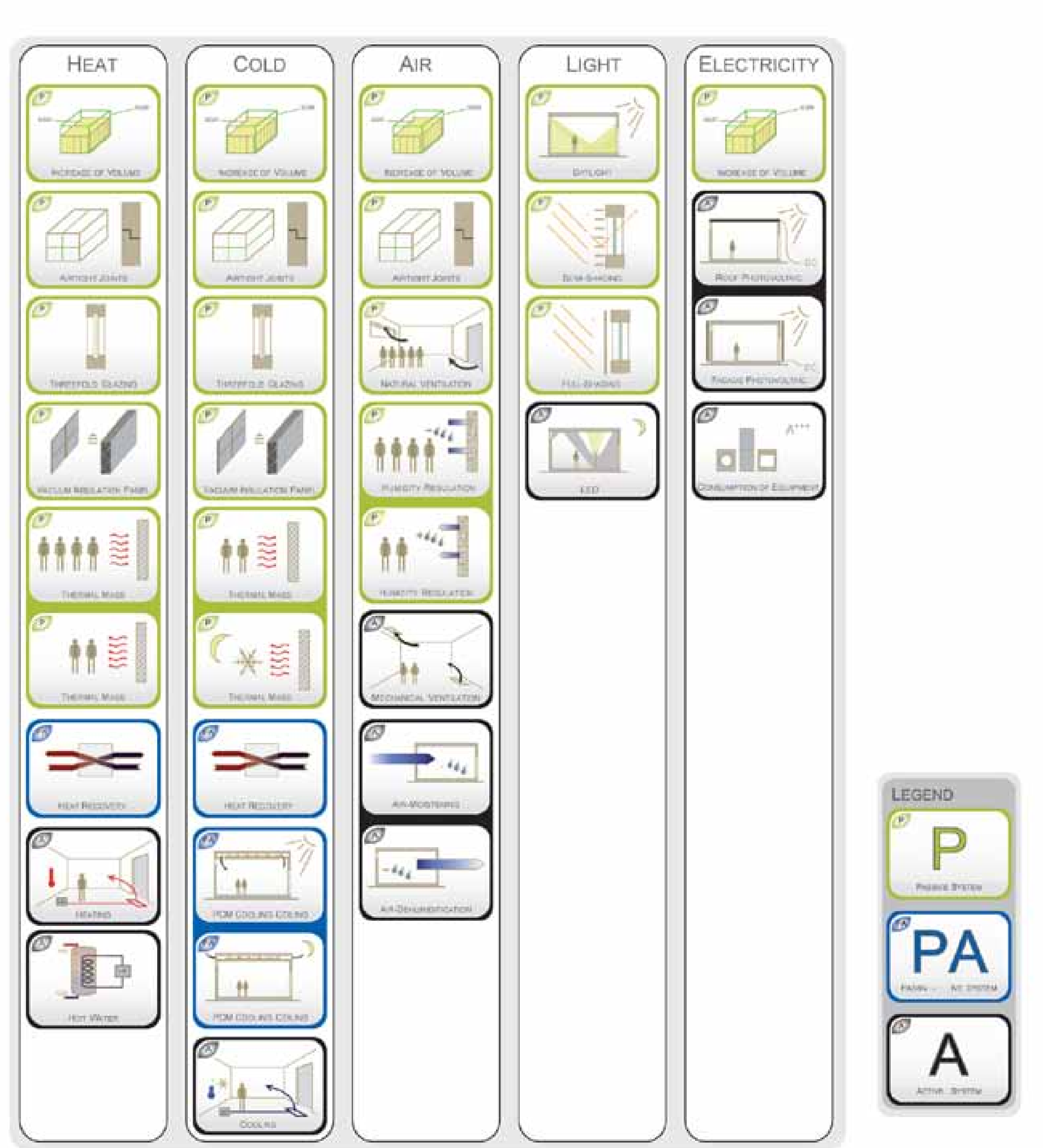
Due to the german "Passivhaus" -standard and the resulting small loads, we decided to condition our house by air only. The centre of our active system is an air source heat pump. It also integrates a ventilation compliance, a heat recovery with a coefficient of 80% and a two layer hot water tank with 180l. In case of air cooling the emerging heat goes into the hot water tank if needed. Otherwise it´s going to be blown of. The tank also has an electrical immersion fresh air discharged air fresh air discharged air heater, whether the capacity of the heat pump is not high enough.





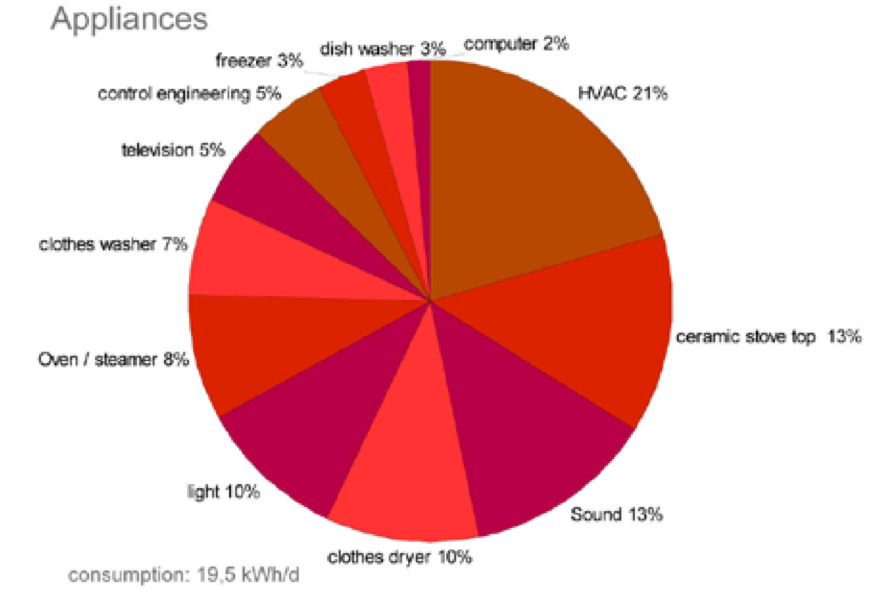
Energy Themes
The use of efficient and innovative technologies is an essential base of our work. Thus we have combined five energy themes in our house: heating, cooling, air-condition, lighting and electricity. In order to get an energy gaining building, we have applied passive, active and a cobination of both strategies.

As example for passive technologies and in order to reduce the energy consumption, we have tried to create an airtight building shell, which also complies with the German "Passivhaus"-standard. Other elements are thermal mass in form of Phase Change Materials, natural ventilation during the night, to cool down the PCM, and sensible openings for daylight. Examples for partitial active systems are our cooling ceiling and the shading system that allows a semi- or full-shading. The centre of our active system is an air-source heat-pump with a hot water tank. It is used for conditioning the air in the house. To gain as much energy as possible, we have monocristallin photovoltaic cells on the roof, and amorphous cells on the facade.





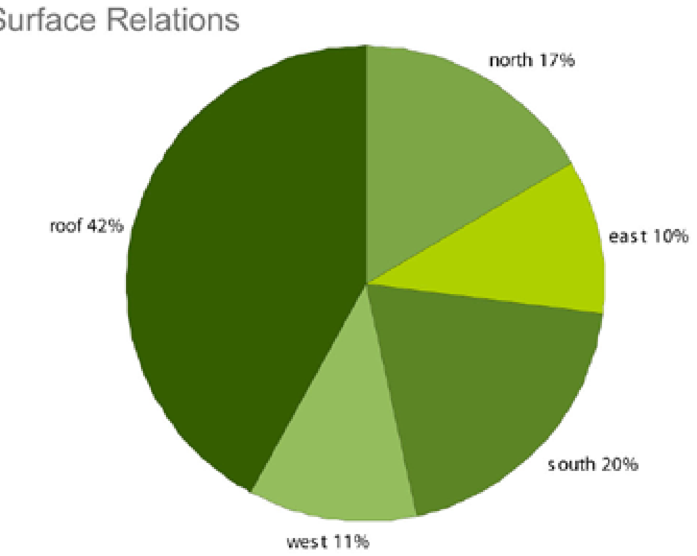
Energy Balance Washington (day in contestweek)

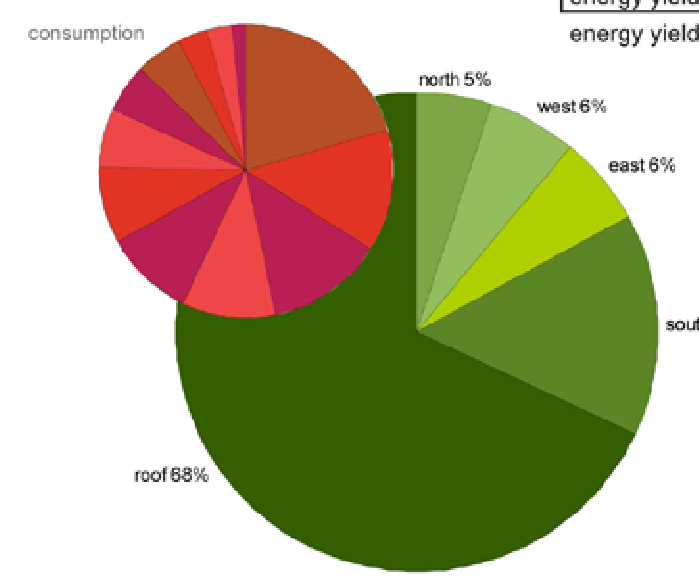



Calculation (relating to available space)

| orientation | irridation (Wash. October) | irridation/d | allocated area | energy cycle efficiency | gain per area |
|---|---|---|---|---|---|
| roof | 107 kWh | 3,5 kWh/m²d | 63,72 m² | 0,183 | 40,81 kWh/d |
| south | 120 kWh | 3,9 kWh/m²d | 30,24 m² | 0,11 | 12,97 kWh/d |
| west | 65 kWh | 2,2 kWh/m²d | 17,64 m² | 0,11 | 4,27 kWh/d |
| north | 27 kWh | 0,9 kWh/m²d | 25,56 m² | 0,11 | 2,53 kWh/d |
| east | 67 kWh | 2,1 kWh/m²d | 16,2 m² | 0,11 | 3,75 kWh/d |
| | | | aggregate power level | | 64,33 kWh/d |
| | | | contamination (-10%) | | 57,90 kWh/d |
| | | | losses of system (-5%) | | 55,01 kWh/d |
| | | | losses of inverter (-10%) | | 49,51 kWh/d |

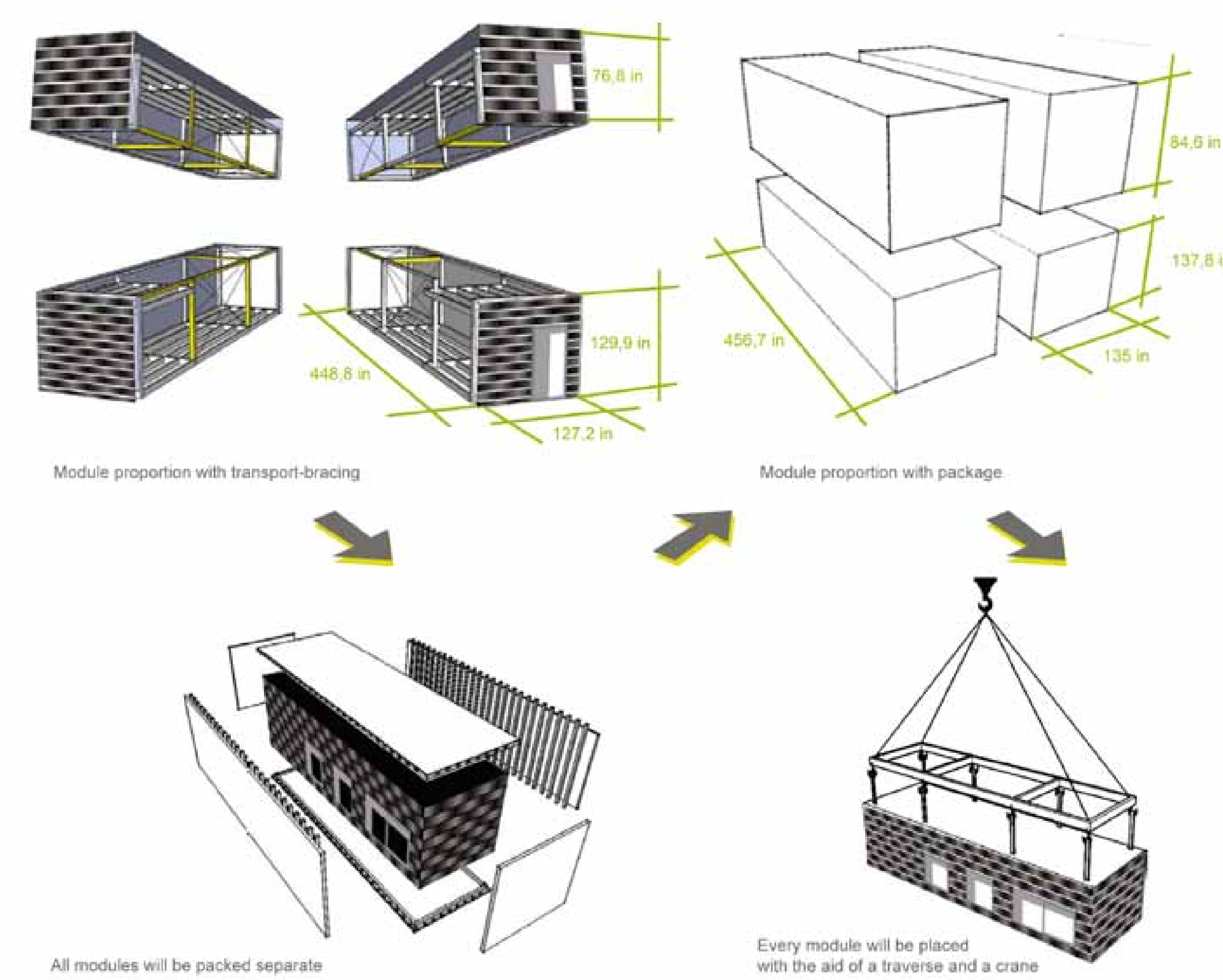
energy yield per day: 49,51 kWh/d
energy yield in contest week: 396,04 kWh




Balance (day): 49,51 - 19,5 kWh = 30,01 kWh
Balance (week): 396,04 - 156 kWh = 240,04 kWh

**Primary Construction/ Modularity**
The structure of the surPLUShome is made of a timber frame construction. The reinforcement of the wood frame is guaranteed by OSB-plates (oriented strand board). To reach a minimal structure of basement and ceiling we also used elements of block construction. The floor consists of main beams that stretch in longitudinal direction. The box-section ceiling stretches over 10 meters without any necessity of additional columns in the interior space. Extensive prefabrication by large panels allows a fast assembly of the construction. Because of the necessity of transport, the surPLUShome is divided into four modules. The longitudinal module cut in the basement is manufactured as half dovetail. This special wooden joint helps to position the lower modules and to ensure an airtight building shell. In vertical direction wooden thole pins (conical oak pegs) help to position the upper modules onto the lower modules and to get a first connection in case of assembly. The mechanical connection of the modules is realized by U-shaped steel clips to prevent the roof from taking-off in case of storm. Steel swords tighten the main columns across the horizontal module cut to prohibit crippling.



# Passive Haus

*Darmstadt, Kranichstein Germany + Urbana, Illinois, USA*

**What is a Passive House?**
The Passive House concept represents today's highest energy standard with the promise of slashing the heating energy consumption of buildings by an amazing 90%. Widespread application of the Passive House design would have a dramatic impact on energy conservation. Data from the U.S. Energy Information Administration shows that buildings are responsible for 48% of greenhouse gas emissions annually and 76% of all electricity generated by U.S. power plants goes to supply the Building Sector. It has been abundantly clear for some time that the Building Sector is a primary contributor of climate-changing pollutants, and the question is asked: How do we best square our building energy needs with those of our environment and of our pocketbook? In the realm of super energy efficiency, the Passive House presents an intriguing option for new and retrofit construction; in residential, commercial, and institutional projects.

A Passive House is a very well-insulated, virtually air-tight building that is primarily heated by passive solar gain and by internal gains from people, electrical equipment, etc. Energy losses are minimized. Any remaining heat demand is provided by an extremely small source. Avoidance of heat gain through shading and window orientation also helps to limit any cooling load, which is similarly minimized. An energy recovery ventilator provides a constant, balanced fresh air supply. The result is an impressive system that not only saves up to 90% of space heating costs, but also provides a uniquely terrific indoor air quality.

A Passive House is a comprehensive system. "Passive" describes well this system's underlying receptivity and retention capacity. Working with natural resources, free solar energy is captured and applied efficiently, instead of relying predominantly on 'active' systems to bring a building to 'zero' energy. High performance triple-glazed windows, super-insulation, an airtight building shell, limitation of thermal bridging and balanced energy recovery ventilation make possible extraordinary reductions in energy use and carbon emission.

Today, many in the building sector have applied this concept to design, and build towards a carbon-neutral future. Over the last 10 years more than 15,000 buildings in Europe - from single and multifamily residences, to schools, factories and office buildings - have been designed and built or remodeled to the passive house standard. A great many of these have been extensively monitored by the Passiv Haus Institut in Darmstadt, analyzing and verifying their performance. Even governmental agencies have adopted passive house standards in their policy-making

**Darmstadt Haus** The Passive House in Darmstadt Kranichstein has been constructed in 1990/91 on design plans by architects Prof. Bott/Ridder/Westermeyer for four private clients.

Spring: In 2006 it took a long time. But: In this Passive House we did not have to use the heating system since March 15th (to have something to compare, in the German Climate heating is needed normally until the mid of May). And the windows may be opened in our Passive House whenever we want. This building keeps warm by itself during March. On the other hand, we can leave the windows closed, too, if we want: A sufficient amount of fresh air always is guaranteed by the ventilation system. There can not be bad air quality in this house, even if you keep the windows closed for several days long. In the photography you can see the exhaust air outlet of the Eastern dwelling (at mid bottom of the gable wall). The two outlets of the mid dwellings can be seen just glimpsing through the fine new green of the shrub mid of the Southern facade.

During Summer the wild wine spends shadow - and the Venetian blinds, which will be closed quite often. The dwelling to the left does not have Venetian blinds, but insulated gliding shutters. Early in the morning it is still cool outside and we can ventilate the dwellings by opening the windows. Even during the extremely hot European Summer in 2003 we were able to keep our Passive House cool without a cooling system (without active air conditioning) - the same was true during the hottest month ever measured so far in Germany, July 2006. The long time constant of the Passive House allow for keeping the cool indoor conditions for a quite long time.

This is an image taken by the professional photographer H. G. Esch from early times (1992) showing the Southern facade of the Passive House in Darmstadt Kranichstein later in the Summer. At this early times the gliding insulating shutters of the western dwelling (left) had not been installed and the wine had not yet grown. Measurements dating from 1991/92 even show, that in spite of the insufficient shading comfortable conditions had been kept for indoor climate. There are four reasons for that: The very good conditions for night ventilation by opening the windows in different floors of the dwelling, the orientation of the facade exactly to the South (there is not a lot of solar radiation available during Summer on vertical South orientated surfaces in this geographic latitude), the small, but during Summer efficient shading by the lintels of the windows and the small balconies and the long time constant of the building.

This is a snapshot of the Northern facade of the Passive Houses (June 2006). The big glazed space at the Northern part is not important for the energy balances - its an architectural feature. From the glazed space there is access to each individual rooms in the basement. All four fresh air inlets can be seen in this image in height of the ground floor ceilings. Behind the inlet grid there is back-to-back the highly efficient air filter (F8). The air ducts have proven to be absolutely clean even after a time of 15 years - of course these ducts were carefully sealed to be airtight from the beginning.

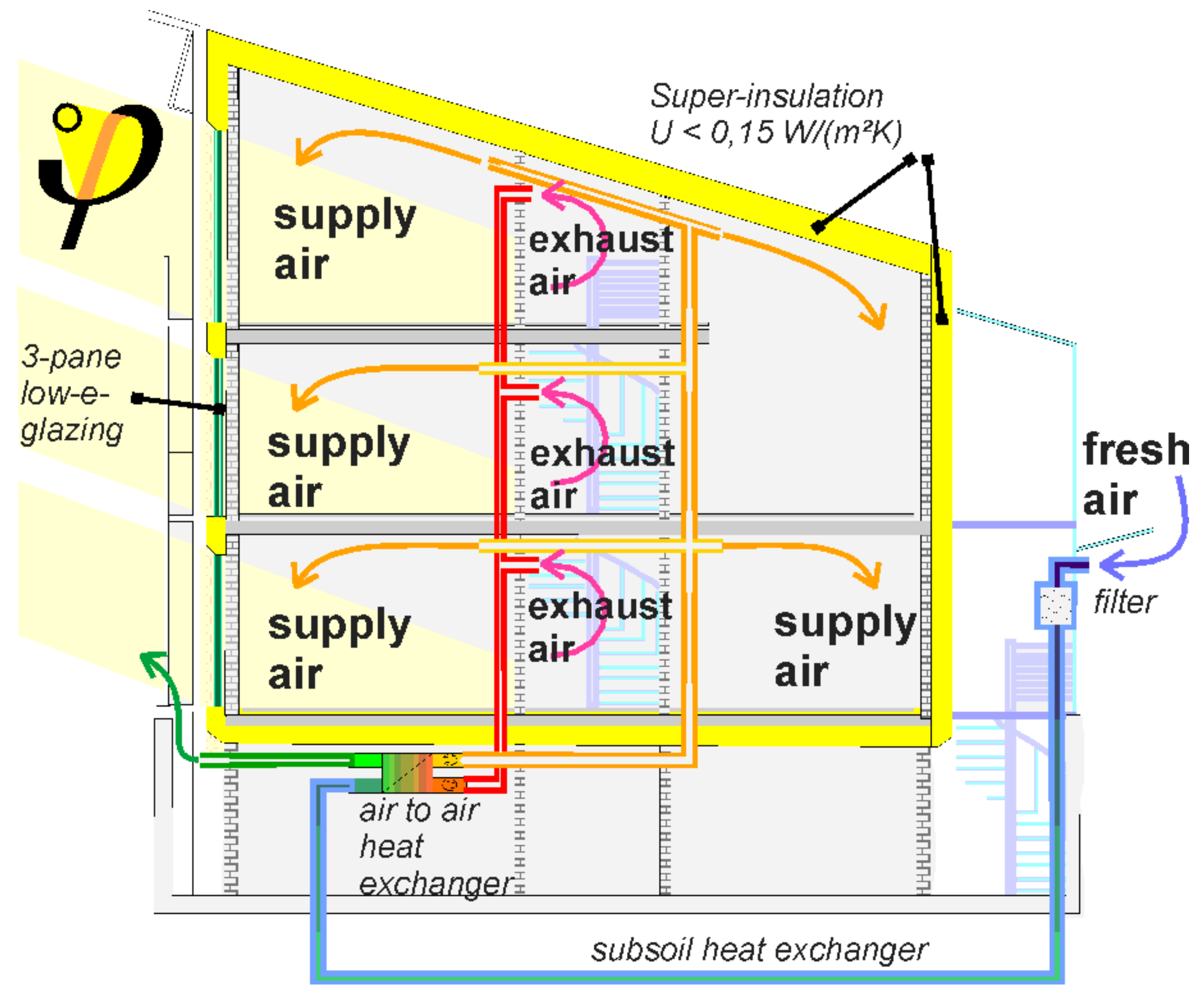
The blaze of color during autumn. This image was taken 8th of November - it still will be a long time, before the heating will have to be activated in the dwellings. But it is comfortable warm in the house (between 21 and 23°C) and from time to time windows will still be opened. In the image you can see, that even some Venetian blinds are still closed: Not any quanta of solar energy is absolutely needed at this time, the home keeps warm, anyhow. As a rule some when in December the central gas fired heating system is switched to "Winter-mode", depending on weather-conditions. There were years with no need to start heating earlier than Christmas day. At any sunny day the radiation shines deep inside the rooms. During the day the house may warm up to 23 °C; during a sunny day late in autumn the average temperature may rise by 1 degree (Celsius). But, in this climate, unfortunately beginning mid of December cloudy conditions prevail. Without direct sun the house "loses" in a 24 hour period some 0,1 up to 0,2 °C, depending on outside temperature. Therefore it takes some time until the losses consumed the stored internal energy - and the heating has to be activated.

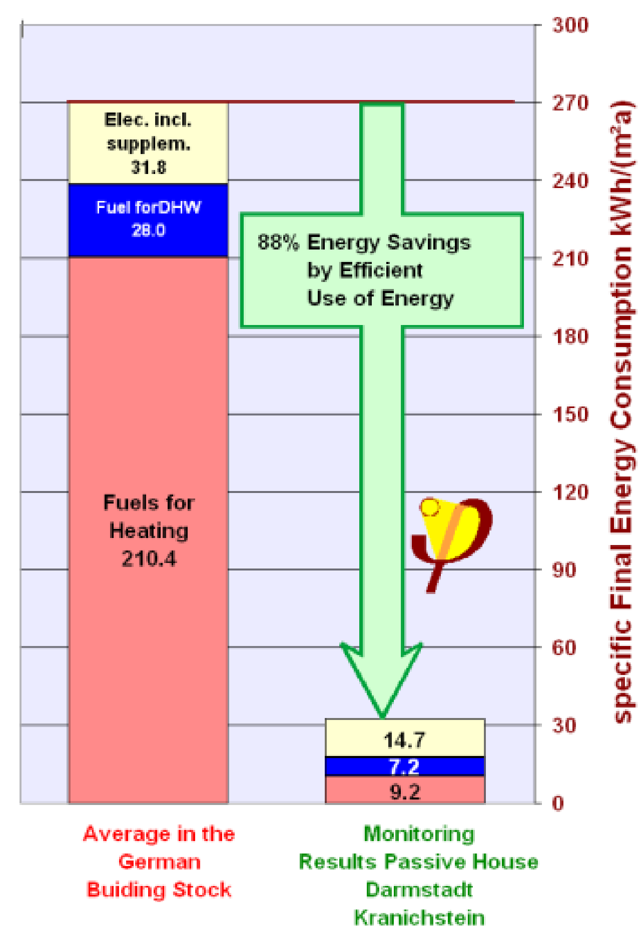
Not very often there was such a big amount of snow in Darmstadt, like we had in Winter 2005/2006. But in January 2005 there was snow, too (Image: W. Ebel). During such cold weather we are very happy to have a ventilation system delivering fresh air and keeping a good indoor air quality without a need to open the windows. The earth buried tubes and the heat recovery of the ventilation system keep the temperature of the fresh air entering the room to be higher than 18 °C. The air inlets are positioned near to the ceiling of the rooms. The air has already mixed up with room air before it enters the living space. To deliver space heating, in this building small radiators placed at internal walls are used. That can be done in a Passive House, because all indoor surfaces, especially those of the windows, are comfortable warm. The surfaces do not lose a lot of heat, and the envelope is really airtight, all this together guarantees that there are no cold drafts in this building.

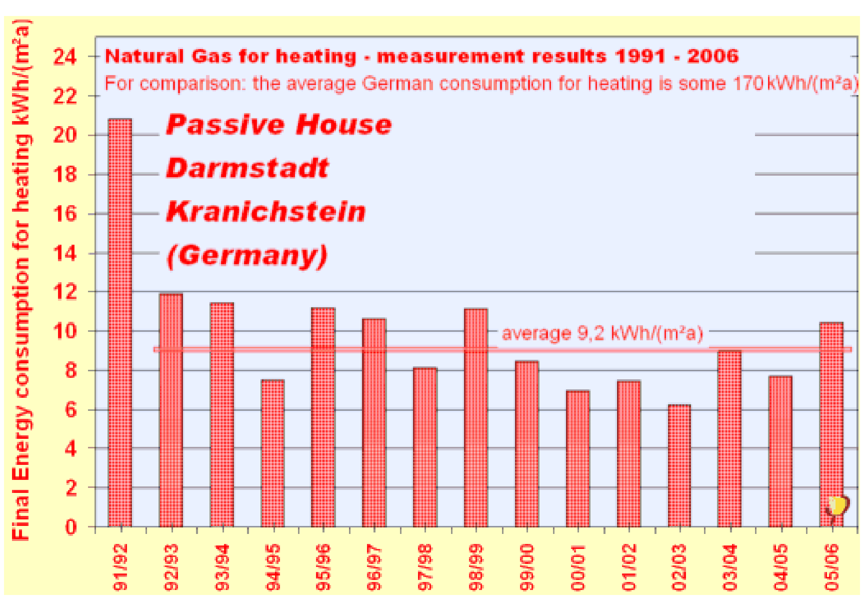
The Northern part of the Passive House in Darmstadt Kranichstein has a spacious glazed space, which is not heated. There are only single pane windows used - during frost there will be frost patterns on the panes. A splendid example is shown in the next image. In the image above the fresh air inlets in a height of 2.80 m can be seen.

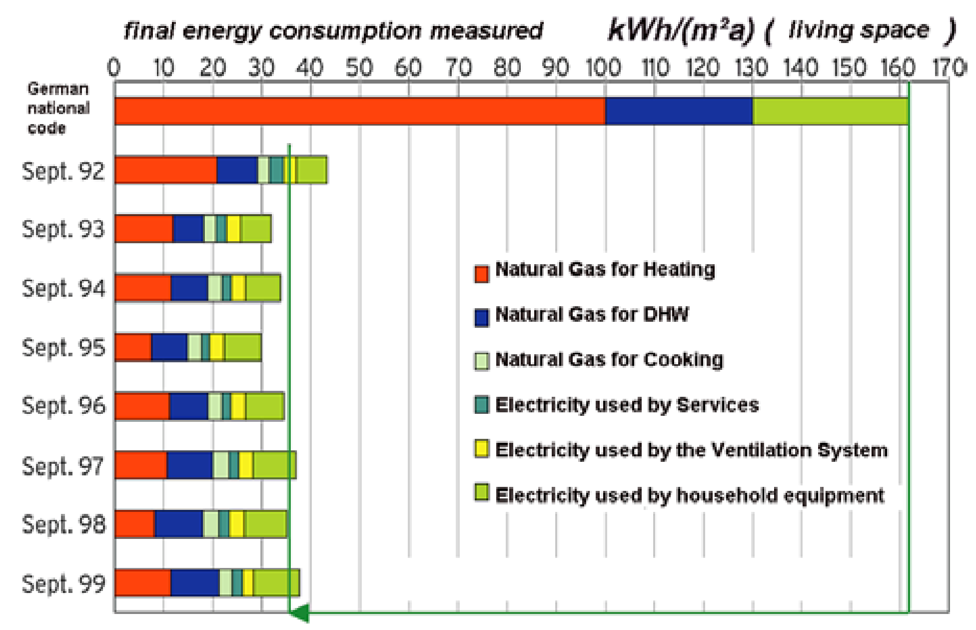
Frost patterns at the interior surface of the single pane glazings in the Northern glazed space of the passive house. Children still can experience this phenomenon of nature - without uncomfortable cold conditions in the living space. The thermal envelope of the house is the northern separation wall to the glazed space (see the section shown below). There are big triple glazed windows in that wall and the wall is insulated almost at the same level (namely 27.5 cm) as all the other external walls. Therefore it is cold during winter in the glazed space.

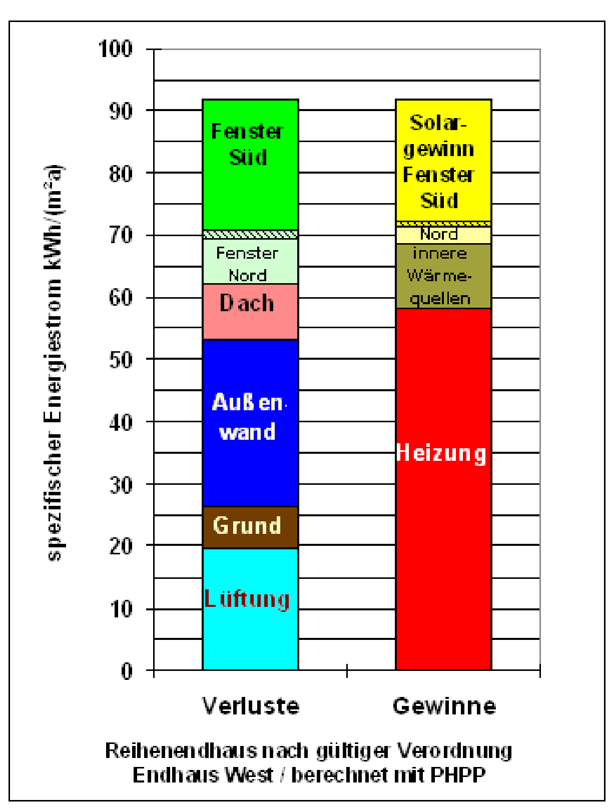
An interior view of a spacious living area in the ground floor of the Passive House at Darmstadt Kranichstein



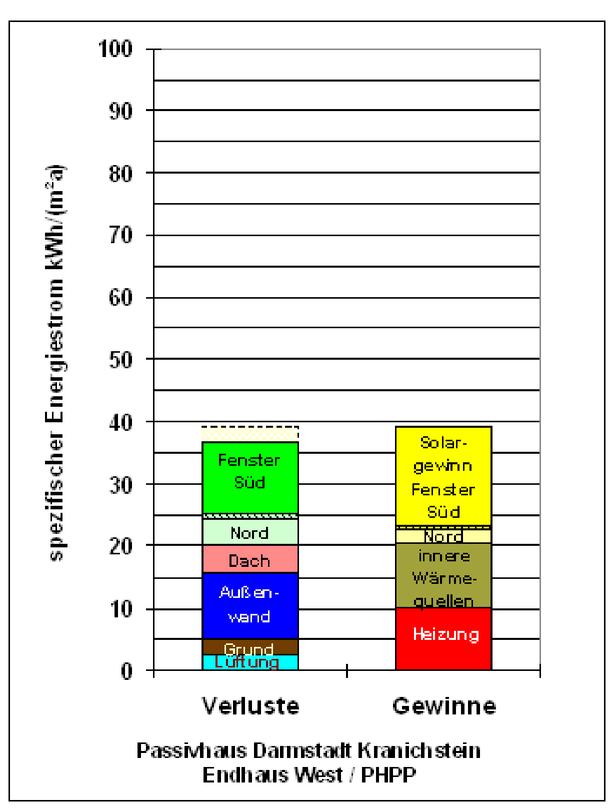



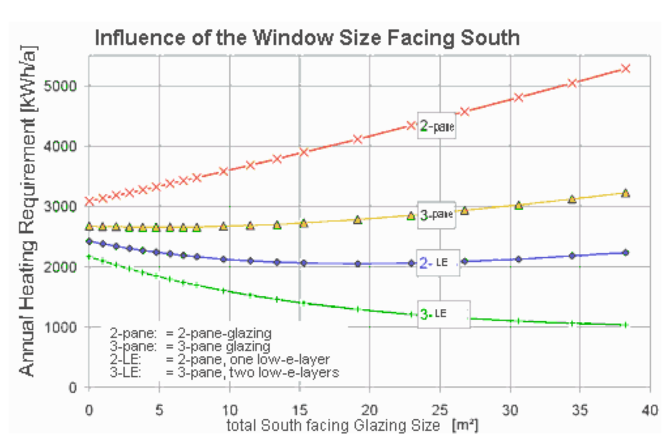



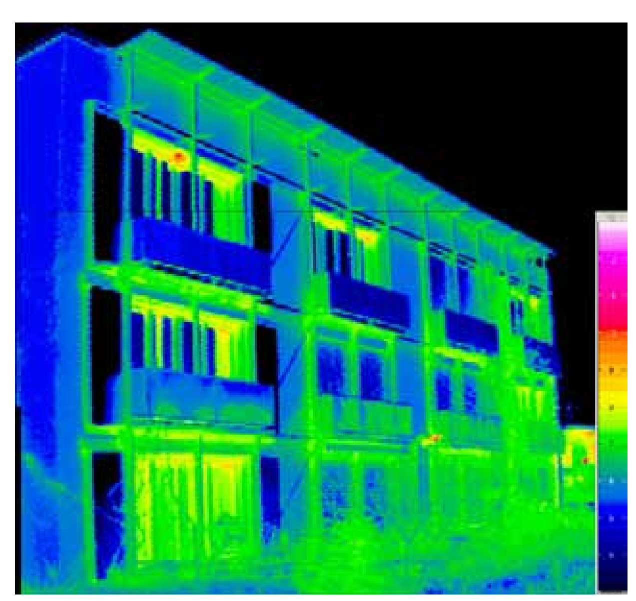




Performance of an row-end house meeting the current national energy standard in Germany (EnEV). A heating energy requirement of 58 kWh/(m²a) was computed using PHPP




This calculation for and end-row unit from the Passive House at Darmstadt Kranichstein was calculated with PHPP. Heating energy was determined to be 10.5 kWh/(m²a) what is very close to the actual measured values.



**Smith Haus:** In 2003, German-born Katrin Klingenberg, founder of e-co lab, completed a 1,200 square foot home in Urbana, Illinois. Her goal was to demonstrate that stringent Passive House energy standards could be met in the severe climate of Central Illinois. The project has succeeded, inspiring the ongoing construction and research efforts of e-co lab.

Applying computer modeling, Klingenberg implemented several, but not all, of the many techniques, systems and materials that can be used to reduce energy load the required 90 percent. Among them:

1. Super insulation (total R value of 56) and super tight thermal envelope— thermal bridges are minimized.
2. Orientation that maximizes passive solar heating in winter, cooling in summer.
3. Triple-glazed windows
4. 100-foot long earth-tube air intake for pre-heating and -cooling.
5. Heat Recovery Ventilation (HRV) that recovers heat from exhaust air, and ensures constant outdoor air ventilation for excellent indoor air quality.
6. Instantaneous electric water heater.

| | |
|---|---|
| *Location* | Urbana, IL |
| *Region and Climate* | Cold Climate |
| *Heating degree-days* | 6,359 |
| *Cooling degree-days* | 888 |
| *Year of Construction* | 2002-2003 |
| *Typology* | Single-family residence |
| *Finished Floor area* | 1,200 sf, including double story space |
| *Owner / Designer* | Katrin Klingenberg / Nicolas Smith |
| *Builder* | Edward Sindelar, Chicago |
| *Energy Consultant* | Conservation Technologies, Duluth, MN |
| *Foundation Type* | Concrete block frost wall |
| *Foundation Perimeter Insulation* | 6 in (152mm) EPS |
| *Under-Slab Insulation* | 14 in (356mm) EPS |
| *Wall Framing* | Vertical 12 in (305mm) TJIs |
| *Wall Insulation* | 12in (305mm) blown-in fiberglass<br>4in exterior rigid polystyrene |
| *Roof Framing* | 16in (406mm) TJIs with vent channels above the sheathing |
| *Roof Insulation* | 16in (406mm) blown-in Fiberglass |
| *Window Type* | Fiberglass frames with EPS insulation, triple-pane glazing, argon-filled, low-e glazing; 0.61 SHGC south facing, 0.37 all other orientations, avg overall U-value of frame and glazing : 1.09 W/(m2K) |
| *Ventilation* | 90% Sensible Efficiency HRV |
| *Heating and Cooling* | 1000W (3,400 Btu/h) electric resistance element in the HRV<br>100ft earth tube, 40sf in-floor electrical radiant heating |
| *DHW System* | Tankless electric water heater, with spare conduit for later solar thermal addition |
| *Power Generation* | Pre-Wired Photovoltaics (not installed) |
| *Specific Heating Energy Required* | 2.5 kBtu/ft2/yr (8 kWh/m2a) |
| *Whole-house Specific Primary Energy Required* | 35.2 kBtu/ft2/yr (111 kWh/m2a) |
| *Peak Heating Load* | 4.2 Btu/sf-hr (13.1 W/m2) |
| *System Requirement for Net Zero Site Energy* | 2 kW Photovoltaic System (not installed, but wired in) |
| *System Requirement for Net Zero Source Energy* | 4.5 kW Photovoltaic System (no installed, but wired in) |
| *System Requirement for Carbon Neutrality (Positive Energy)* | 5 kW Photovoltaic System (not installed, but wired in) |
| *Airtightness* | 0.6 ACH50 |
| *Surface Area to Volume Ratio (A/V)* | 0.72 |

## Passivehouse Construction Check List

1 Site planning
- How suitable is the site for a passivehouse
- Does the site have access and utilities connections?
- Is planning permission for a passivehouse likely?
- Is a compact building shape possible? Terraced houses or larger blocks are an advantage.
- Is a southerly orientation (±30°) and large south-facing window areas possible?
- Consider shading factors preventing the use of solar gains - any trees with conservation orders?

2 Pre-planning
- Compact buildings - possible to extend existing buildings to get fewer external walls?
- Dimension south-facing glazing for solar gains. Dimen sion east/north/west facing glazing for sufficient light, not larger than necessary.
- Minimize winter shading:
  - garden walls
  - vegetation
  - balconies
  - roof overhangs
  - outbuildings.
- Simple envelope shape, if possible avoid steps in walls, dormer windows, etc. Clearly define the thermal (heat ed) envelope and the airtight layer.
- Floor plans:
  - make installation zone(s) compact and concentrated, e.g. by placing bathrooms above or next to kitchens, etc.
  - consider routing of, and space for, ventilation ducts.
- Separate cold basement if present:
  - airtight
  - no cold bridges.
- Acquire local climate data in a form suitable for use with PHPP. Verify if calculated by Meteonorm or similar inter polation software.
- Carry out the first iterations of PHPP to see if the ideas add up in passivehouse terms.
- Contact local Planning Office to discuss initial ideas and site plan. Explain passivehouse ventilation principles since these may not follow local regulations

3 Planning towards passivehouse realization
- Plan wall/foundation/roof construction and insulation thickness.
- Avoid cold bridges in the design - modify as required. Mitigate by minimizing or optimizing cold bridging if avoidance is impossible.
- Plan in enough space for building technology. Make sure there is space and access for regular maintenance.
- Floor plans:
- short pipe lengths for cold, hot and waste water
- short ventilation ducts - cold air ducts outside the heated envelope, warm ducts inside

4 Planning: building elements
- Ultra-insulated construction elements according to pas sivehouse rules, for external elements the rule is U ≤ 0.15 W/(m²K) - strive for 0.1 W/(m²K). Use "Details for Passive Houses"
- Design connection details to eliminate cold bridging - if in doubt calculate and verify.
- Design connection details to assure airtightness.
- Optimise glazing:
  - type of glazing
  - frames/casings
  - glass area
  - sun shading, etc.
- Calculate the specific space heating demand using PHPP.

5 Planning: ventilation
- Routing of ventilation ducts:
  - keep cold ducts outside the heated envelope. If they need to be inside then only for very short lengths and highly insulated
  - keep warm ducts inside the heated envelope. If they need to be outside then only for very short lengths and highly insulated
  - use short ducts with smooth walls
  - keep flow velocities below 3 m/s throughout
  - design measurement and flow balancing facilities into the system
  - consider fire protection
  - consider noise factors, including noise reduction.
- Air inlets:
  - avoid short-circuiting air flows
  - consider throw widths
  - incorporate flow regulation/balancing possibilities.
- Air exhausts:
  - do not place above heating elements (if present).
- Dimension overflow openings for a pressure drop Δp ≤ 1 Pa.
- Central ventilation/heat recovery unit:
  - position heat exchangers close to or inside the thermal envelope. Good positions are inside the heated enve lope or in a basement
  - position air heating units inside the thermal envelope
  - add additional insulation as required in each case
  - the unit should meet or (preferably) exceed these data:
    - -overall efficiency ≥ 75%
    - -leakage to surrounding air < 3% of the rated flow volume
    - -internal leakage (between intake and exhaust air flows) < 3% of the rated flow volume high electri cal efficiency, power consumption < 0.45 Wh/m³ air
  - have suitable regulation/control facilities
  - low noise rating
  - excellent heat insulation.
- Ventilation user controls:
  - settings: high, normal, low
  - possibly time-limited booster functions in kitchens, toi lets and bathrooms.
- Kitchen extractors connected to the ventilation system should have good extraction capabilities at a very low flow rate and be fitted with grease filters. However, it is preferable to use circulation only extractors with active coal and grease filters.
- Optionally, consider installing a ground heat exchanger to keep intake air frost free. This can either be a ground-to-air exchanger or a ground-to-liquid exchanger with a liquid-to-air exchanger close to the ventilation unit. In some climates this will probably not be required. If re quired, consider:
  - airtightness
  - distance between cold channels and the building
  - summer bypass/cooling facilities
  - extraction of condensate
  - cleaning

6 Designing additional building technology
- Sanitation, hot water:
  - short pipes, very well insulated
  - routed inside the thermal envelope.
- Sanitation, cold water:
  - short pipes, normal insulation.
- Insulate warm water and heating fittings.
- Use water-saving taps, etc.
- Connect washing machines and dish washers to the hot water supply.
- Waste water:
  - short branch pipes, preferably a single (internal) dis charge stack
  - preferably, the stack should be ventilated into a roof void, otherwise through an insulated external pipe.
  - Sanitation and electrical/communications installations should preferably not penetrate the airtight layer but be cast into the foundation and sealed. In case the airtight layer has to be breached an efficient seal must be en sured (sleeves, tape, sealant).
  - Use energy efficient appliances, the most modern mod els. The inventory should be sensible vis-a-vis PHPP

7 Construction phase - envelope
- Site management: Check that all materials supplied actu ally correspond to the materials specifications. Run a clean site with minimal waste.
- Freedom from cold bridges. On-site quality control.
- Integrity of the insulation. Unbroken insulation layers - no gaps in insulation materials.
- Airtightness: Check transitions, e.g. between walls and floors, seals where pipes, cables or flues are carried through the airtight layer and seams that form part of the airtight layer while still accessible.
- Airtightness: Carry out a pressure test as early in the con struction phase as possible!
  - When? As soon as the airtight envelope is finished and while it is still accessible, i.e. before fixes (coordinate with relevant trades).
  - -How? n50-test using a blower door or the ventilation system. All leaks must be located while the building is pressurised (smoke, handheld anemometer, if necessary, thermography).

8 Construction phase - ventilation
- Airtightness. Check that piping and duct-work conserve the integrity of the airtight envelope.
  - ducts: make sure they are clean and leak free
  - central ventilation unit: check accessibility for filter change and noise reduction measures
  - check duct insulation - is it present where required and correctly installed?
- Flow settings in normal operation:
  - measure intake and exhaust air flows - compare them to ensure they are balanced
  - compare fresh and stale air distribution
  - measure electrical power consumption

9 Construction phase, after fixes - additional building technology
- Airtightness: ensure that airtightness is preserved when in stallations are carried through the airtight layer. Consider wall constructions incorporating an internal installation void.
- Heat insulation of pipes and fixtures: check correctness and integrity.

# BedZed

*Beddington Zero-Fossil Energy Development*

Site area: 1.65ha
Dwellings per hectare: 50
Habitable rooms per hectare: 164

Built in 2002, Beszed is a community of 82 homes, 18 work/live units and 1,560m2 of workspace and communal facilities. The goal was reconcile a higher quality, affordable lifestyle and workstyle in an outer london dormitory suburb, with a step change in carbon footprint.

BedZed generates enough renewable energy over the course of the year to meet total heat and power demands. This means exporting electricity to the grid in summer, when demand is lower, and importing from the grid in winter, when demand is higher.

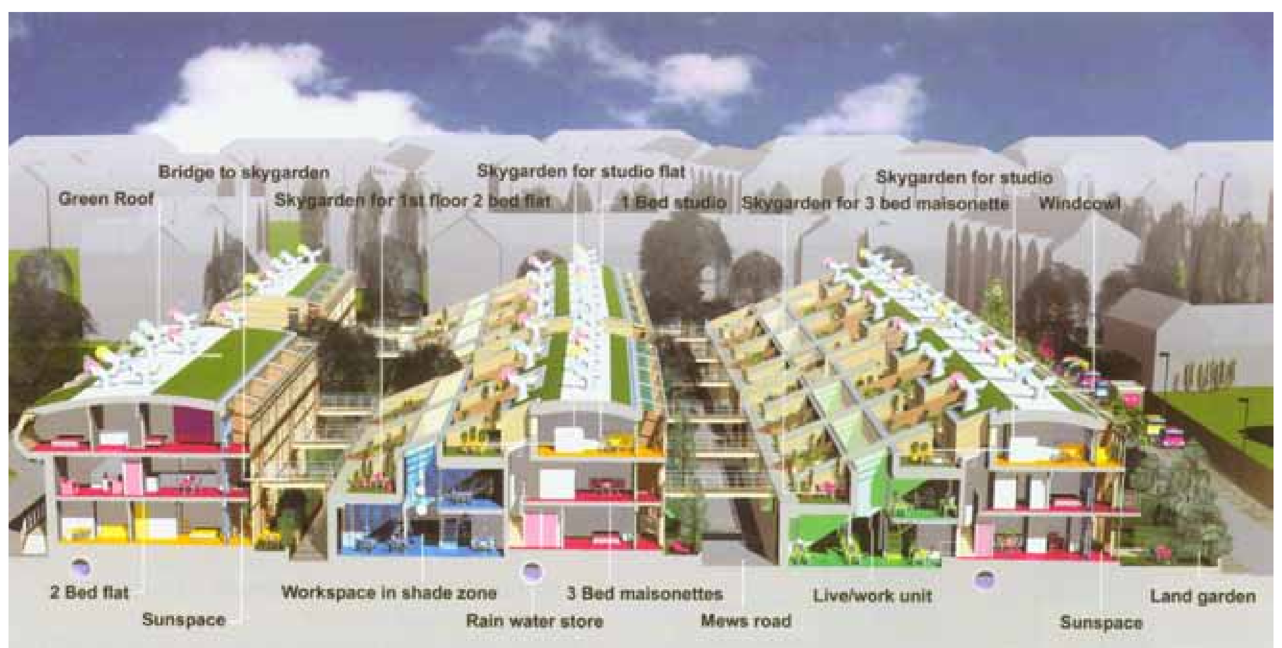
The challenge at BedZed was to show that it is possible to provide a holistic living/ working community enjoying a high overall quality of life, while limiting its consumption of scarce natural resources.

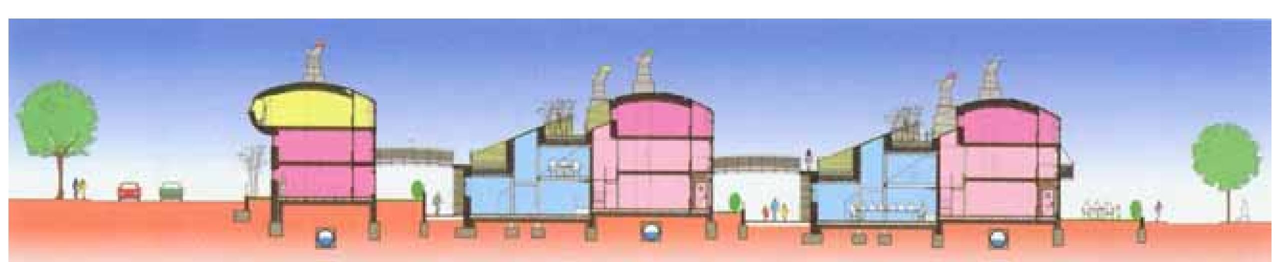
A study by Brenda and Robert Vale showed that the average uk family's annual carbon emissions were spent in the following way:

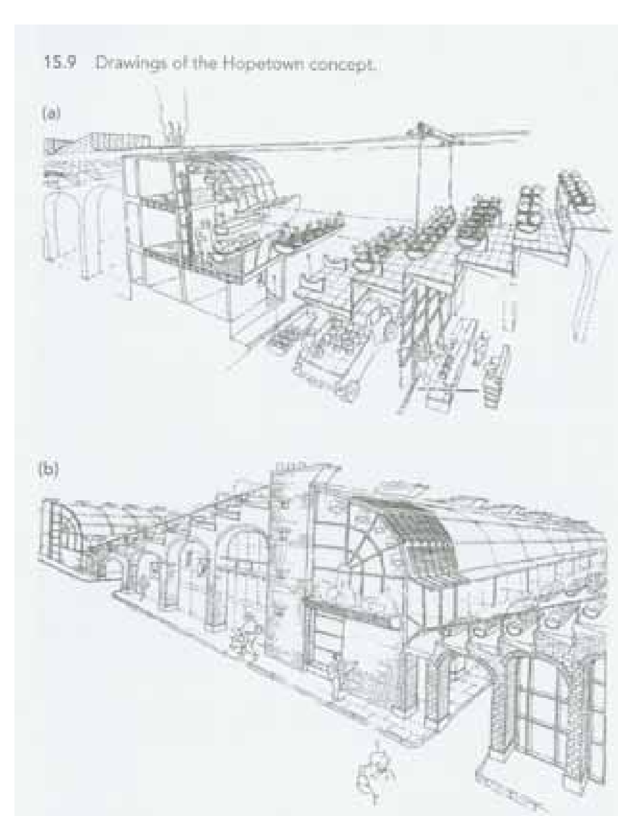
- 1/3 for heating and powering home
- 1/3 for private car use
- 1/3 for foodmiles (2000 miles from farm to dinner plate on average)

Energy Strategy:
BedZed incorporates a minimum 300mm insulation, triple glazing, south facing glazed sunspaces, thermally massed floors and walls, good daylight, and passive stack ventilation with heat recovery, and energy-efficient lighting at the latest A-rated appliances.

Importantly, by combining workspace with housing, the community's energy demand matches the heat and electricity output of the CHP (combined heat and power plant room) which is often not achieved with single-use residential schemes. If to generate sufficient electrical energy over the year to meet the annual demand, the CHP provides more heat than is needed for summer domestic hot water, the heat produced form renewabel energy will be








dumped and wasted. Beddington Zero Energy Development is the UK's largest mixed use sustainable community. It was designed to create a thriving community in which ordinary people could enjoy a high quality of life, while living within their fair share of the Earth's resources.

BedZED was initiated by BioRegional and BDa ZEDfactory, and developed by the Peabody Trust. It was completed and occupied in 2002. The community comprises 50% housing for sale, 25% key worker shared ownership and 25% social housing for rent.

People move to BedZED with typical lifestyles, and over the years change their behaviour significantly. The holistic design works on three levels:

1.the design solves problems such as heating and water usage;

2. the design and services offered help people make sustainable choices such as walking rather than driving; and

3. the community have created their own facilities and groups to improve quality of life and reduce their environmental impact.

**Green Lifestyles - completing the stainability picture**
People are attracted to living and working at BedZED for many reasons. But whether you like the architecture, the location or are a committed environmentalist, green living comes as standard.

Energy and water efficiency have been 'designed in' at BedZED. Households and businesses achieve significant reductions in environmental impact just by living or working at the development. However, sustainability cannot be achieved through bricks and mortar alone. In the UK, carbon emissions from our day-to-day lives are split roughly three ways between our homes, transport, and growing and transporting our food. Therefore, a development cannot be truly sustainable unless travel, food buying and waste are also addressed.

These 'lifestyle' aspects of sustainability cannot simply be integrated into the BedZED building fabric. How you travel, deal with your waste and buy your food are individual choices.

To help achieve One Planet Living at BedZED, BioRegional have worked with residents to extend their eco-living beyond bricks and mortar with fresh ideas for greening food, travel and waste.

For the first year of residency, BioRegional employed a Green Lifestyles Officer, to help residents maximise the green living potential of the development. A key part of the role was to offer training and support to residents to run these schemes in the long term.

**Local and Sustainable Food**
Approximately one third of the average UK resident's eco-footprint comes from the production and transportation of their food. The current trend in the UK is for shoppers to expect to be able buy any food no matter what the time of year. Understanding the environmental and social impacts of food is very difficult, there are so many factors to consider from growing the food to transporting it, cooking it and dealing with the waste.

Reducing food miles is an argument that makes a lot of sense. But just "buying local" could actually drive up your ecological footprint if you buy out-of-season produce that was intensively grown in heated greenhouses, whilst harming countries in the global South that rely on exports for development. There are some simple steps that you can take to reduce the impact of the food you eat:

1. Only buy the food that you need, and use leftovers. In the UK we throw away more than 30% of our food!
2. East less meat and dairy, which accounts for over half the average UK resident's food footprint. Livestock are responsible for 18% of global greenhouse gas emissions, more than all transport!
3. Buy vegetables that are local (reducing transport needs), seasonal (rather than


grown in heated greenhouses) and organic/non-intensive (reducing the use of oil-intensive chemicals).

To reduce these environmental impacts, the following initiatives were introduced at BedZED:

- Local organic box schemes provide local, seasonal, organic produce that supports the local farming industry. Hankham Nursery in East Sussex supplies fruit and vegetable boxes, and a range of organic wines and beers to stock 'ZEDbar'.
- Buying locally Residents' welcome packs included details of local farmers markets – and residents have organised a series of on-site local produce markets.
- Internet shopping with delivery via a Homeport system which allows secure delivery to your home even when you are out.
- Growing your own food Training and equipment was offered to residents to help them grow their own fruit and vegetables, in their gardens and on-site mini allotments.

The complementary Community Composting scheme turns kitchen and garden organic waste into nutrient-rich compost, for use in gardens and allotments. The scheme creates a closed loop system where organic waste is recycled into fruit, vegetables and flowers. Funding to establish the Community Composting scheme came from the Onyx Environmental Trust.

### Sustainable Transport

If no action is taken, road traffic is set to increase by up to 50% by 2026 from the current level of 21 million cars. This is obviously something that needs to be urgently addressed when we consider the already congested state of our roads and the impact that cars have on the environment.

BedZED took the following measures to decrease car dependency for residents: BedZED's green transport plan was written into the land purchase contract. Private car ownership at BedZED was therefore limited, with the target for fossil fuel car miles to be 50% of the average. To formalise this agreement The Peabody Trust entered into a legally binding agreement – the first of its kind for a housing developer in the UK to sign up to. Residents and businesses pay an annual fee to park on-site and parking spaces are prioritized for disabled drivers, electric / LPG vehicles and cars with smaller engines.

The Green Transport Plan reduces car ownership and use in three ways:
1. Offering alternatives to private car travel
2. Promoting public transport
3. Reducing the need to travel

Alternatives to private car travel
On site Car Club: BedZED was the first low car development in the UK to incorporate a car club. The club was established in partnership with City Car Club (formerly Smart Moves) – the UK's largest car club operator. City Car Club provided vehicles, an internet-based booking system and in-car technology whilst BioRegional employed a development officer.

The car club service was introduced to potential BedZED residents at pre-sales open days and at monthly residents welcome evenings as people began to move in.

The first car club booking was made in March 2002. A year later, membership had risen steadily to 35 people, sharing the use of three vehicles. Roughly half of the club's members work for BedZED-based businesses, and half are BedZED residents. The club has also attracted members from the wider community. As a result of the car club service, nine members had sold cars or deferred car purchases by March 2003.

Electric vehicles: BedZED is equipped to make running an electric car a practical option. Public transport or car club vehicles can be used for journeys beyond the range of an electric vehicle.

Cycling facilities: Cycling offers a practical and fun way of travelling for all ages. There are no vehicle emissions and cycling helps you to keep fit.

BioRegional and local cycling group Cyclism formed a partnership to run free Dr Bike Sessions. The sessions provided a 10-minute bike check and basic repairs for BedZED residents and the local community.

Free cycling packs were compiled for residents. The packs contain everything you need to know about cycling including a booklet, 'On your bike', produced by BioRegional with a grant from the London Cycling Campaign, information on local cycling groups, money off vouchers for local cycling shops, local and regional cycle maps and information about cycle club membership and insurance.

There is good cycle storage provision around the site in the form of Sheffield stands and wall mounted locking points, and there are changing facilities in the club house.

Promoting public transport
The BedZED development site was chosen for its excellent public transport links. Hackbridge station (5 minutes walk away) offers regular trains to Victoria (20 minutes) and Kings Cross (40 minutes) and Mitcham Junction station (15 minutes walk away) is linked to Wimbledon and Croydon via tram system. Three local bus routes serve the development.
When residents first moved in, BioRegional delivered public transport information such as new timetables direct to the households and businesses.



Reducing the need to travel
BedZED's mix of homes and workspace offers the option of working at home and cutting commuting. On-site facilities enable businesses and residents to meet more of their everyday needs without getting in the car. These include a 5-a-side football pitch with club house, a dance studio, nursery, multi-use centre which can be used for film nights and book clubs etc., village square, recycling bins, home food delivery and allotments.

### Reducing Waste

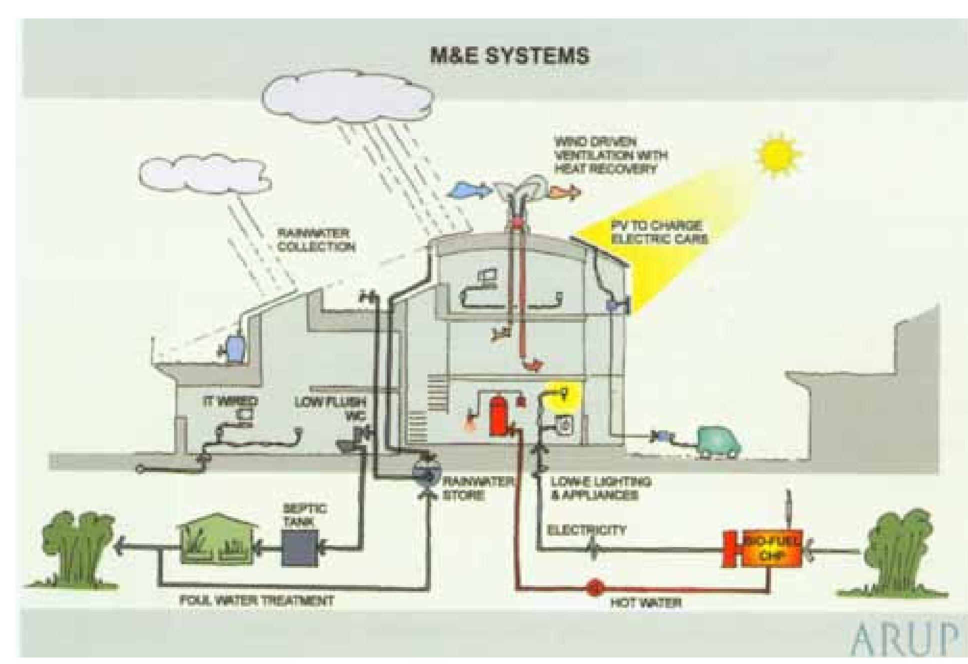
BedZED has been designed to make it easy to recycle, with the aim of reducing household waste output and to attain a recycling rate of 60%.

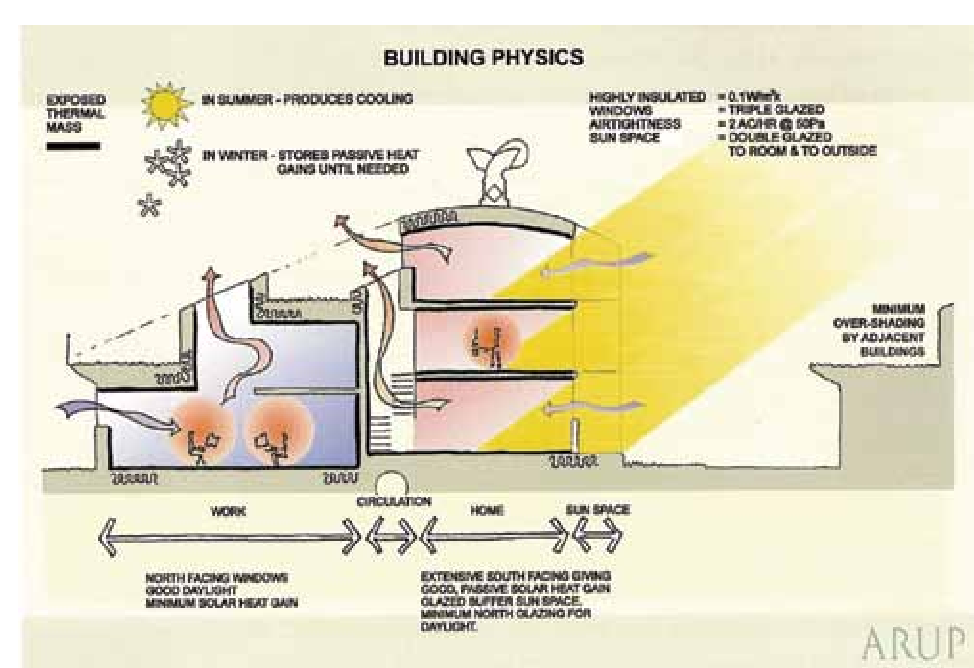
Composting: The BedZED Community Composting scheme turns kitchen and garden waste into a resource for growing food.

Segregated under-sink bins: Every BedZED home incorporates a colour coded, segregated under-sink bin. The colours relate to the type of waste – green for compostable vegan waste, two grey sections - for glass, plastics, paper and tins and brown for non-recyclables. This makes separating and transporting the materials to the corresponding outside bins easy.

Local Paper for London (BioRegional's office paper recycling scheme): is available to BedZED residents and businesses. White office paper is collected, cleaned at the local mill in Kent and bought back by the same offices as 100% recycled white paper. A Westminster Council Study showed that paper accounts for 40% of commercial waste from offices.

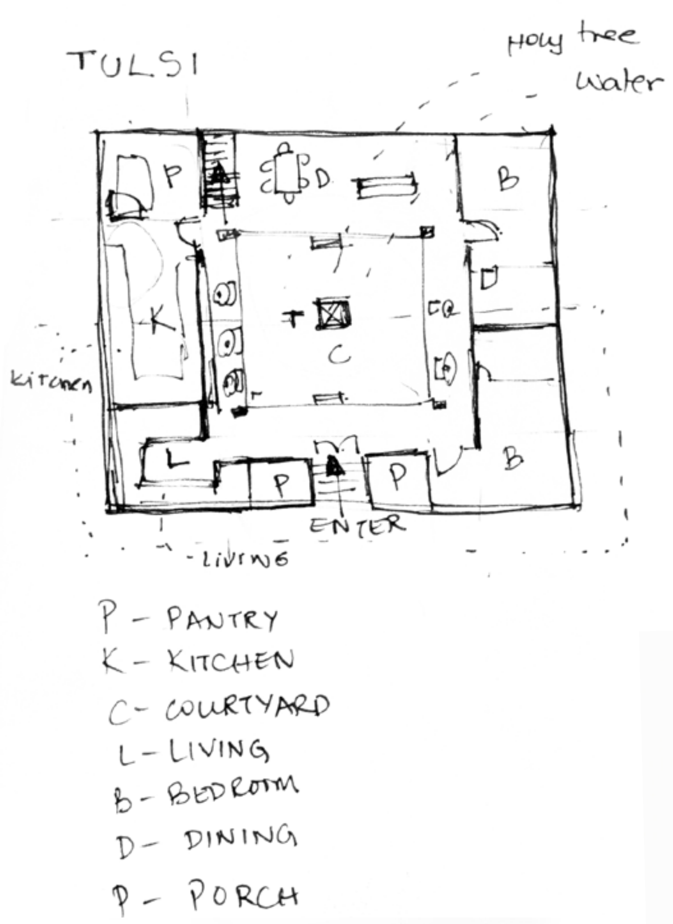
Clothes and furniture swaps: When residents first moved to BedZED a swap shop was set up. Residents took items that they no longer wanted and swapped them with other residents for items that they did. This continues in the BedZED Residents' Newsletter.

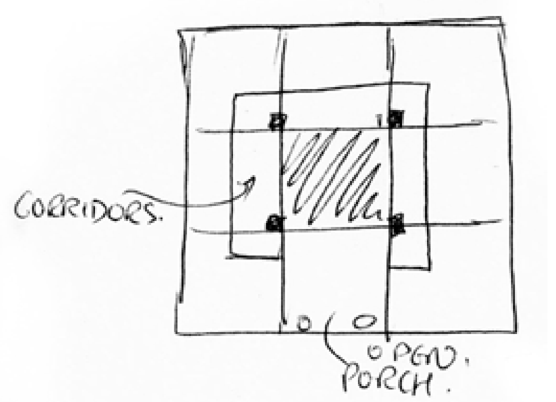


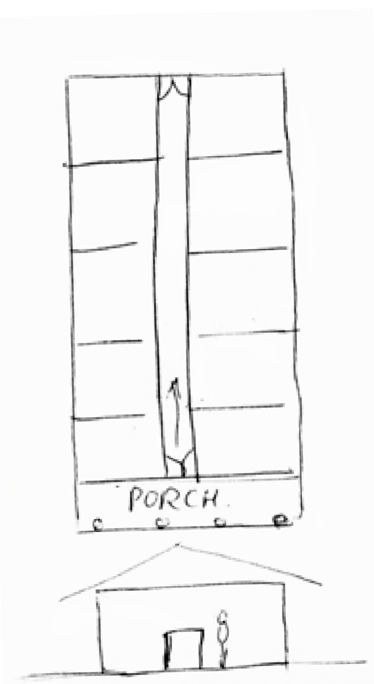



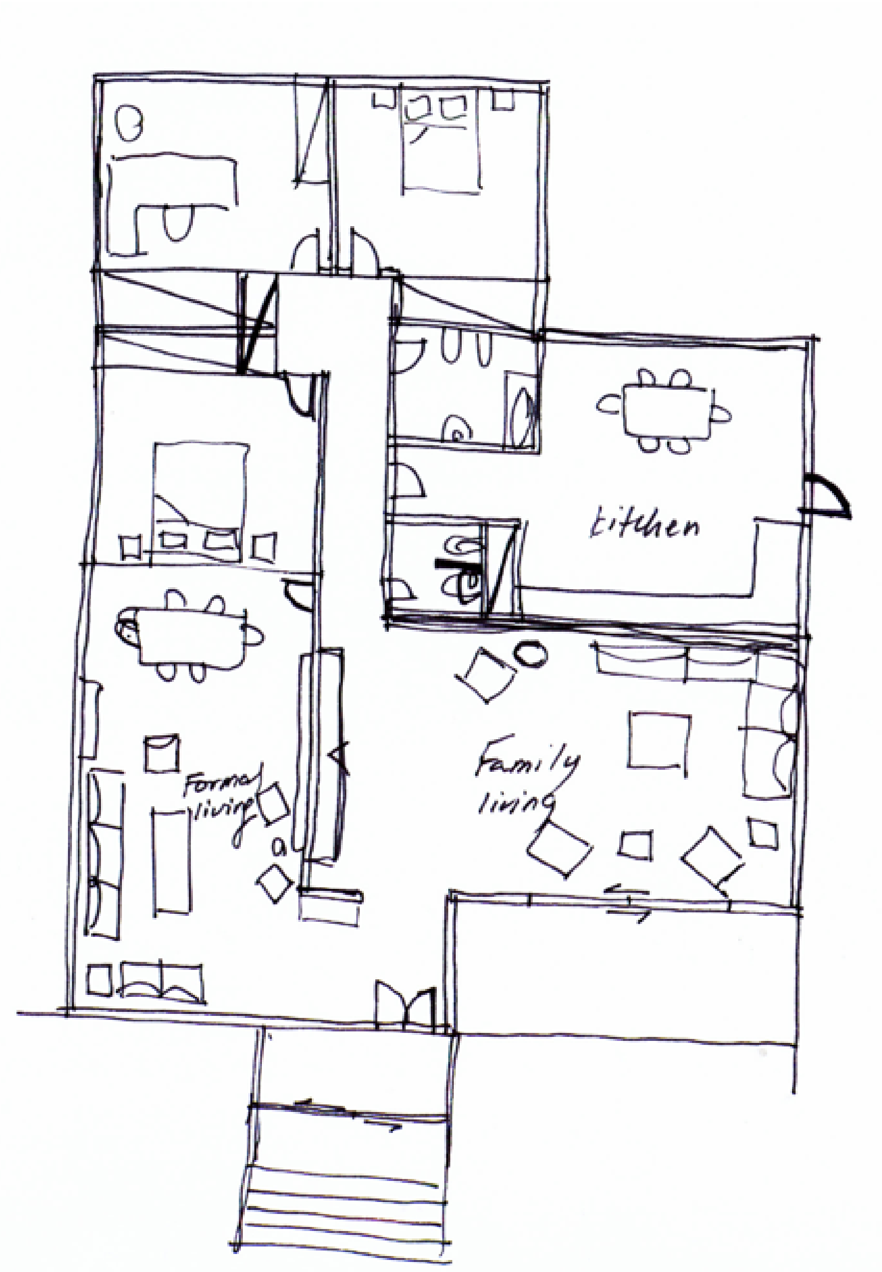

# Housing Typologies Around The World

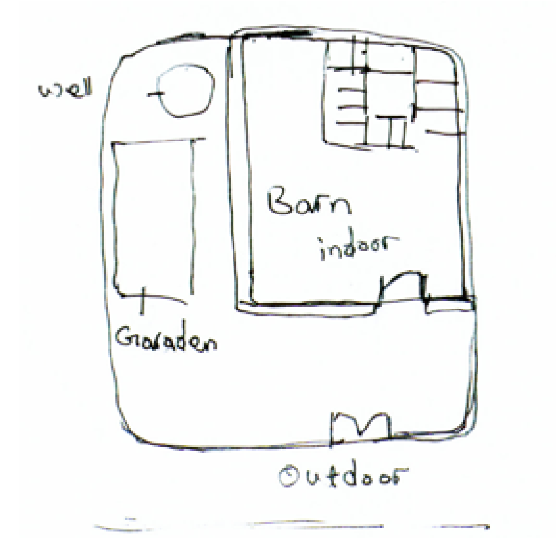
*Analysis of different housing typologies and organization based in cultural aspects*

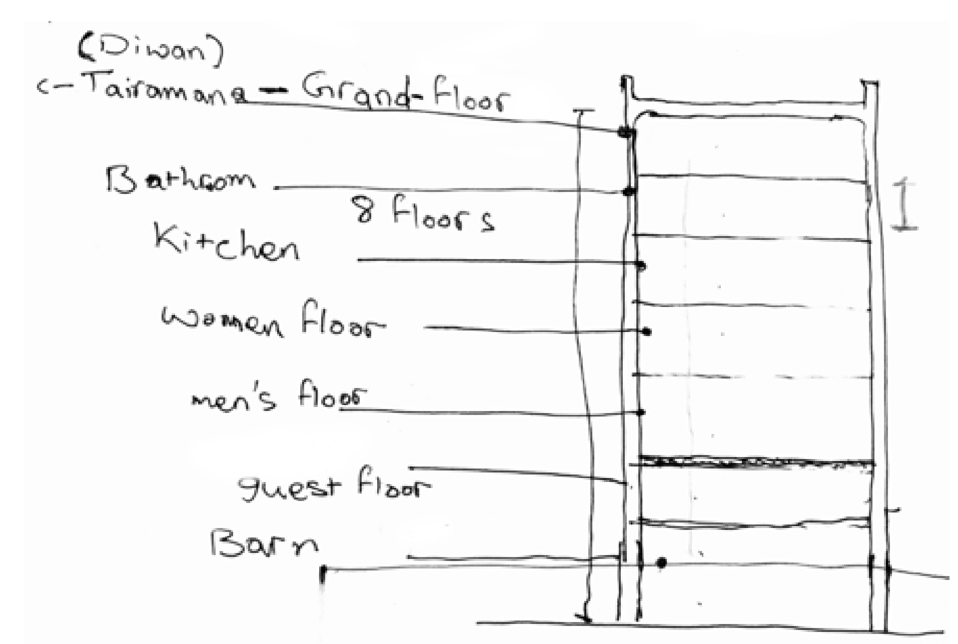


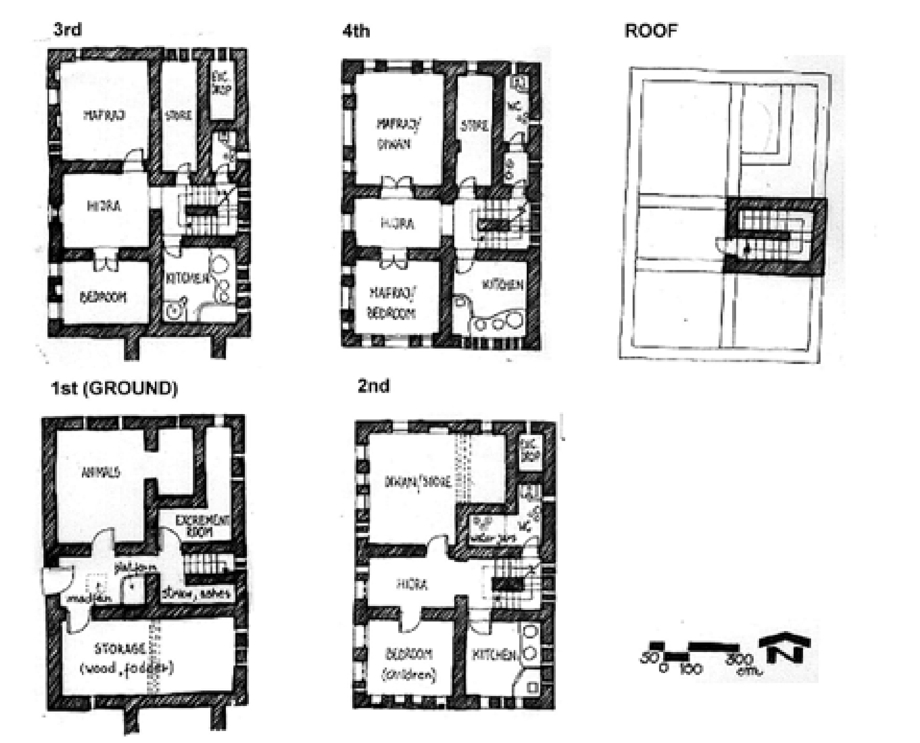



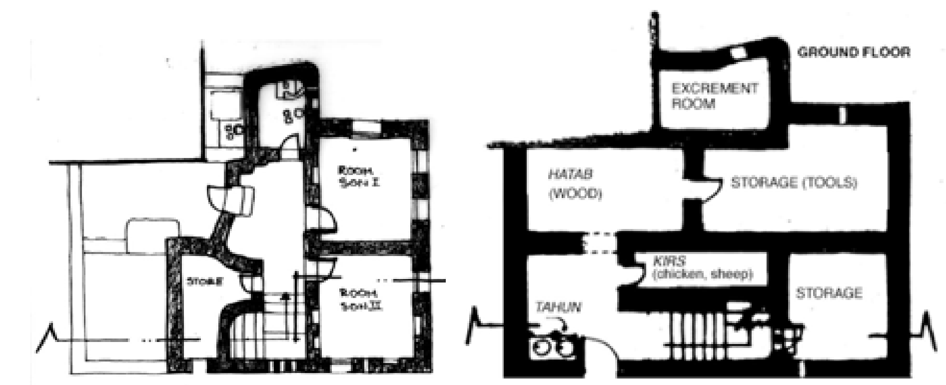




**South India**
City - Kottayam, Kerala
Climate - Tropical - hot and humid
Material - Masonry and wood with clay tile roofs
Population - Varies, sometimes 3 or more generations

The house organization is made around a courtyard where there is a holly tree located. The meals are done outside siting around this courtyard. The upper floor is dedicated for bedrooms.

The use of spaces vary based on the occupation of the owner of the house. The front of the house could be a shop, a school, space to dry grains, raise cattle and so on. The interior spaces end in a storage for grains/ wood/ cattle and so on.
Toilets are separate units detached from the house.

The doors have low height, so the person bows as they enter the house. The typology with the corridor provide a single point of view from the entry to the rear and also lead the "bad energies" straight out of the house.

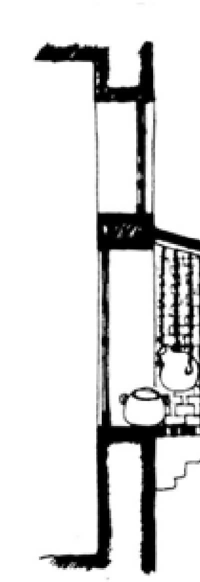
**Jordan**
City - Amman
Climate - Hot and dry - moderately cold winters - variations night and day (10-15° C)
Material - Stone and concrete
Population - 3 people

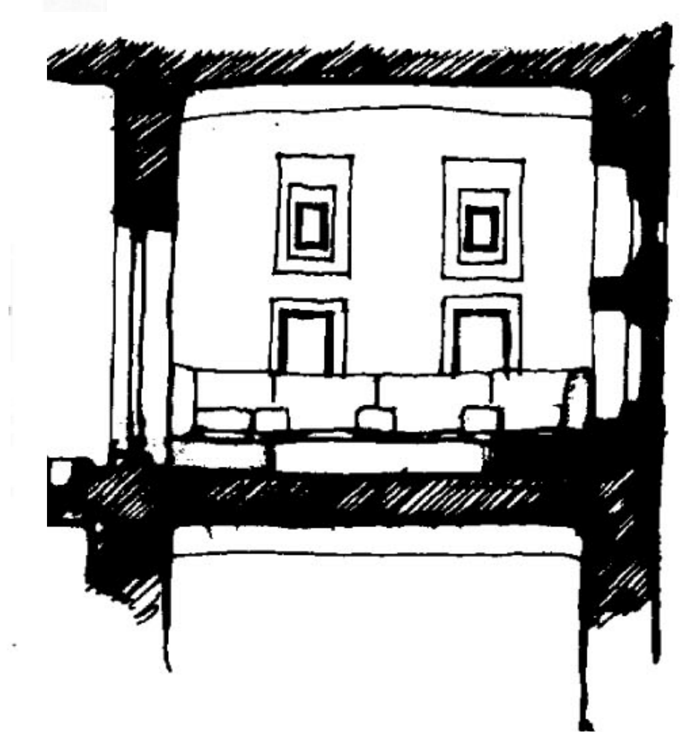
Formal living room is separated from the family living room.
Guests have access only to the formal living room

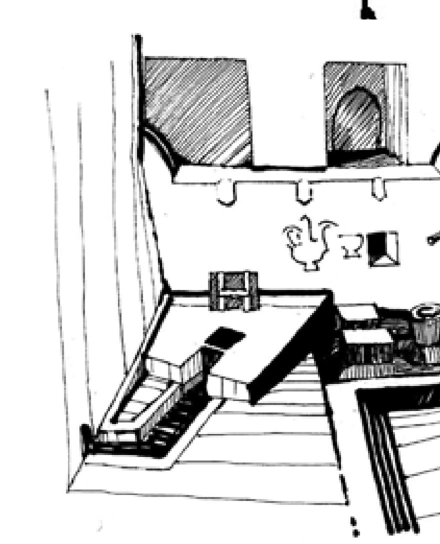
**Yemen**
City - San'aa
Climate - Hot and dry - moderately cold winters - variations night and day
Winter - day 18 to 23° C - night -1 to 10° C
Summer - day 28 to 29° C - night 15 to 20° C
Material - Stone, mud, concrete and lumber
Population - 3 people

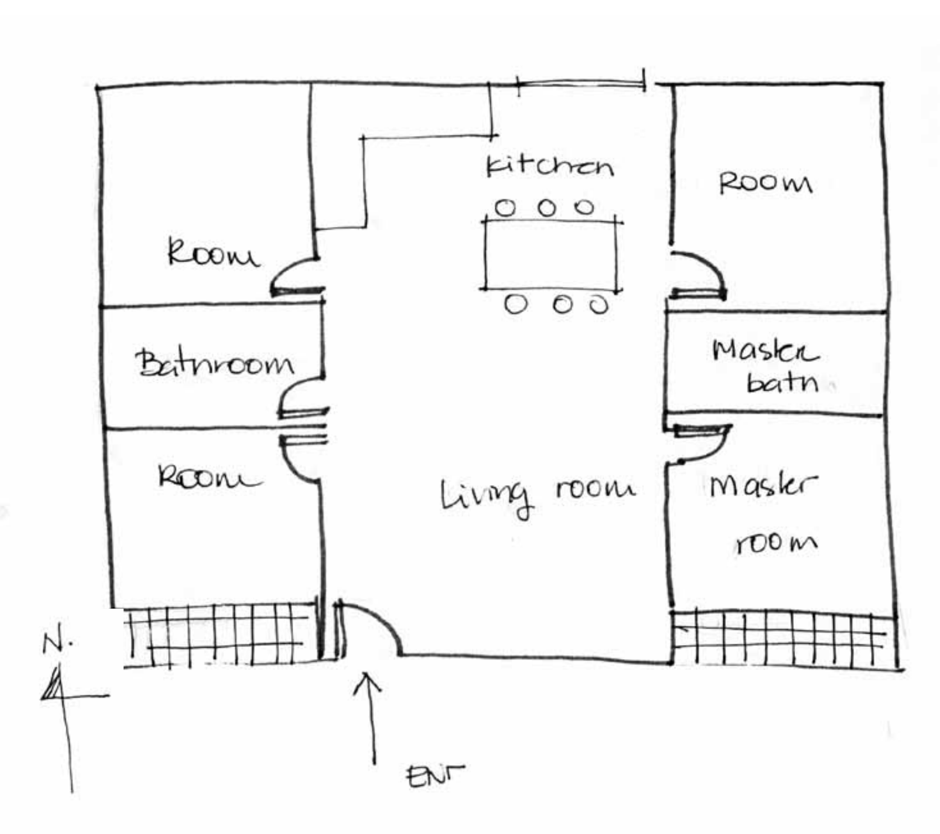
Yemeni house is a complete unit that could survive without the need of going out to buy needs everyday. The house components are: animals barn/ a well/ a little garden for farming

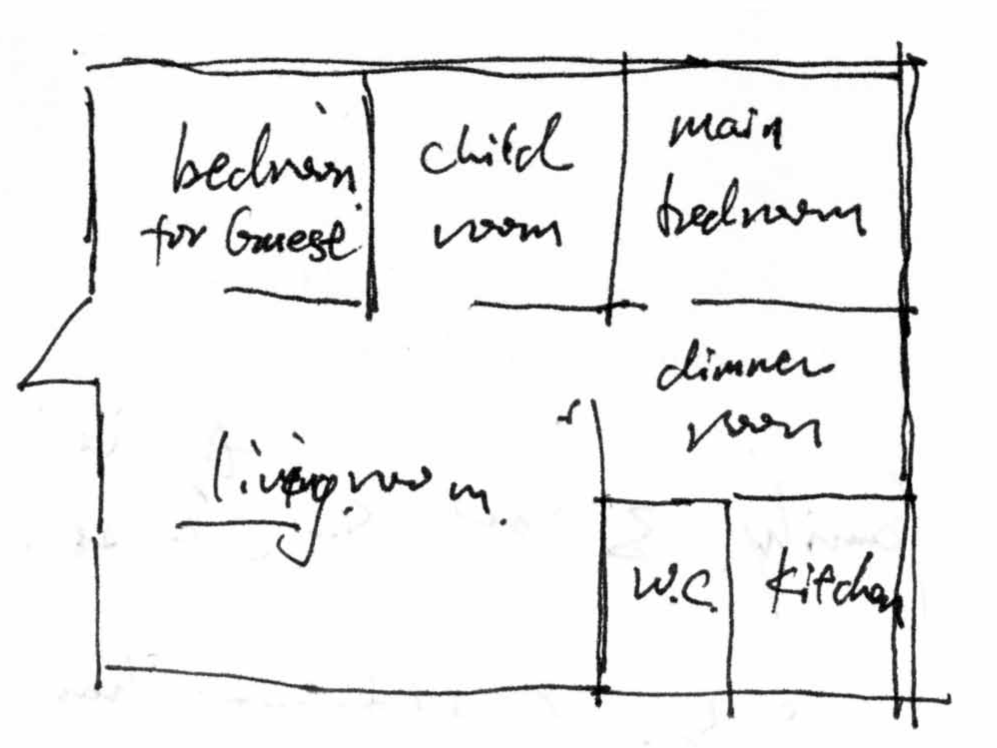
A Yemeni house usually is occupied by extended families, from uncles to grand children and there is a separation between the females and males in the house so the males will be in lower floors and females with children in the upper floors for defensive means. Upper floors are usually connected to a neighbor house for easy escape for woman and children.
Staircases are always directed from left to right since back in the days there were tribal attacks and it was easier to hold your sword or dagger with the right hand as you defend your house and this made it more difficult for the attacker.

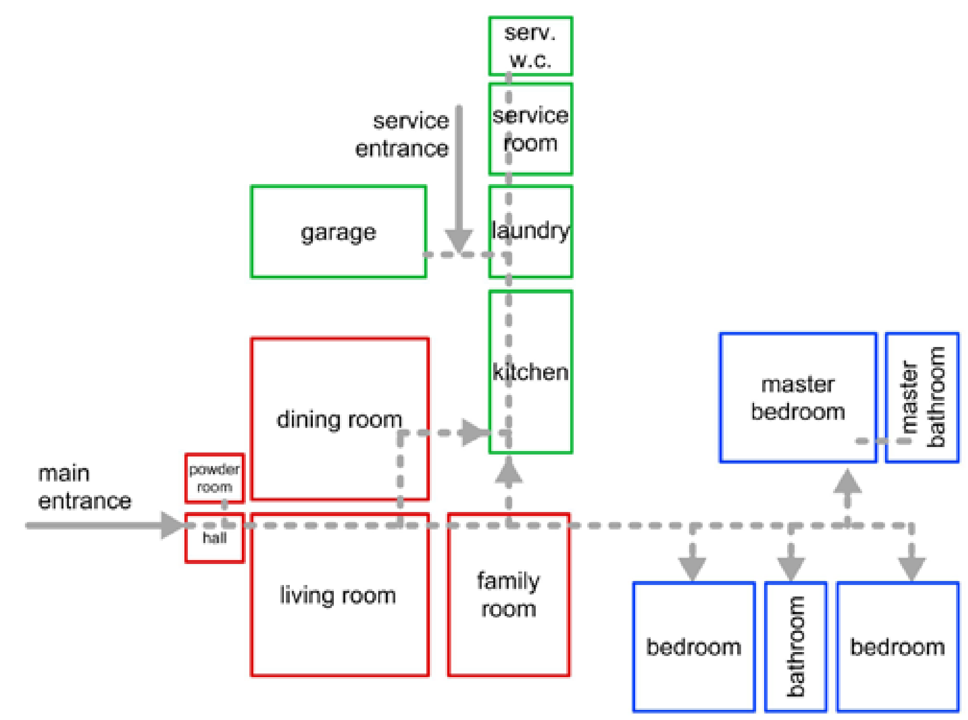










**Korea**
City - Kimpo
Climate - 4 seasons 30° F to 90° F
Material - Concrete, Brick and Glass
Population - 4 people

The Traditional Korean House: *Hanok*
Korean architecture lends consideration to the positioning of the house in relation to its surroundings, with thought given to the land and seasons. The interior structure of the house is also planned accordingly. This principle is called *Baesanimsu*. Houses differ according to region. In the cold northern regions of Korea, houses are built in a closed square form to retain heat better. In the central regions, houses are 'L' shaped. Houses in the southernmost regions of Korea are built in an open 'I' form. Houses can also be classified according to class and social status.

The environment-friendly aspects of traditional Korean houses range from the structure's inner layout to the building materials which were used. Another unique feature is their special design for cooling the interior in summer and heating the interior in winter. Since Korea has hot summers and cold winters, the '*Ondol*' a floor-based heating system, and '*Daecheong*,' a cool wooden-floor style hall were devised long ago to help Koreans survive the frigid winters and to block sunlight during summer. These primitive types of heating and air-conditioning were so effective that they are still in use in many homes today. The posts, or '*Daedulbo*' are not inserted into the ground, but are fitted into the corner stones to keep Hanok safe from earthquakes.

**China**
City - Tianjin
Climate - -3° C in winter, could be more than 36° C in summer
Similar to NYC but does not snow a lot.
Material - Concrete, steel
Population - 3 people (single child family - typical Chinese family)
Area - Around 100m$^2$ or 1076sqf

The living room which is the most important area for the family opens to south. Chinese cooking makes lot's of smoke and also for cultural reasons, the kitchen and the rest rooms must have windows directly to the outside. The main bedroom is the most private room, always located in the deep corner. Bedrooms must have window, north is the best orientation for bedrooms and reading rooms.

In a Chinese city there are not many single family houses. High rise apartments are common for single family. In villages, single family houses are usually built with brick and wood, some new village houses are made of concrete.

The Chinese population make it impossible to build single family home in city areas. For national policy, most Chinese family has one Child. Migration from rural to urban areas broke the traditional big Chinese family. Married people don't live with their parents anymore.

**Brazil**
City - Porto Alegre, Rio Grande do Sul
Climate - humid subtropical - Summer rise above 32 °C (90 °F) winter temperatures range from 8 °C (46 °F) to 20 °C (68 °F).
Summer higher: 41 °C (106 °F) - Winter lover: -4 °C (25 °F)
Material - Masonry concrete and wood with clay tile roofs
Population - 4 people (parents + 2 kids)
Area - 150 - 200m$^2$ / 1076 - 1614sqf

The house organization in Brazil is mainly divided in 3 zones, Living/dining zone, Private zone - bedrooms and Service zones. Even though the kitchen is an important component of Brazilian houses it usually is not integrated to the family room as in American houses for privacy reasons, usually the families have employees that cook and clean the house so those areas are more service dedicated. This trend is slowly changing, the new dwellings are presenting layouts in which the kitchen is more integrated into the living areas.

Natural light and ventilation is also an important aspect in Brazilian lifestyle. All the houses and apartments have operable windows.

The use of air conditioning and heating systems is limited. Not all the houses have heating and cooling system. The concern about insulation and building tightness is not central to building design. The potential for efficiency improvement in Brazilian houses is high.

**Italy**
City - Chiusi, in the province of Siena – Tuscany
Climate - mediterranean: mild winter (5°C average) and hot summer (28°C average)
Material - Structure: concrete frame Walls: hollow bricks, thermal insulation, plaster
Population - 4 to 5 (parents + 2 kids + 1 grandparent/guest)

A small private garden is always appreciated. In traditional houses the service room at the basement is a cellar or a workshop. The kitchen is the heart of the house; the living room is used for receiving guests and it features the best furniture and ornaments.

# Sustainable Design Features

*Sustainable Design: Creating buildings which are energy efficient, healthy, comfortable, flexible in use and designed for long life (Foster and Partners, 1999)*

## Water Conservation

- Rain water collection
- Grey water collection
- Re-use of recycled water to flush the toilets, landscape irrigation and for the washing machine
- Low flow plumbing fixtures

## Energy Conservation

- The house orientation will be chosen to maximize the solar heat gain during winter.
- Shading devices and triple low-e glazing will prevent heat gain during summer.
- A geothermal system will be used as heat exchanger to reduce the temperature difference of water for the heating and cooling systems.
- Solar panels also will be used to heat/ preheat the water
- Natural daylight maximization allied to energy efficient lighting fixtures will reduce power needs for lighting the house.
- High insulation and building tightness will avoid heat loss and gain during winter and summer respectively.
- Operable windows will help to regulate the temperature and reduce the use of air conditioning.
- Green roof, vertical garden and the landscape in general will be an important component for comfort achievement.
- Building automation and energy star appliances will increase energy efficiency.
- The heat produced by the appliances will be recovered and diverted to pre-heat air or water used in the heating system.

## Energy Production

- Photovoltaic panels will be used for energy production as well as wind turbines. The surplus energy will be diverted into the city electrical grid.

## Waste Management

- The house will be designed to make it easy to recycle.
- Composting will allow the kitchen and garden to work together to grow food.



## Materials

- The materials selection will be done taking into consideration the rating system of the Green Guide to Specifications, targeting the use of the best rated materials, site resources and local products.
- Life-cycle assessment and embodied energy of the materials will be highly considered. The use of recycled and reclaimed materials will be prioritized.
- Building Integrated Modeling will be used to increase the level of certainty during design and construction, reduce construction wastes as well as schedule and on-site work.

## Modularity

- The house will be designed in modules that will allow different configurations for repetition, extensive prefabrication and fast assembly.
- The modules will be designed taking into consideration the dimensional of construction and transportation for each module.
- The maximum dimensions are: lenght 60', width 16' and height 13'6".

## Design for Deconstruction

- The building is designed to facilitate disassembly and material reuse to minimize waste, energy consumption, and associated greenhouse gas emissions.
- Development of strategies that maximize materials recovery, reducing the overall embodied energy and greenhouse gas emissions of building materials through reuse. Decreasing environmental and economic costs
- The ultimate goal of the Design for Deconstruction is to responsibly manage end-of-life building materials to minimize consumption of raw materials.

## Budget

- The budget will be allocated in order to increase efficiency and reduce operational costs. For instance: More insulation and better windows will yield in a less expensive mechanical system and reduction in energy consumption.

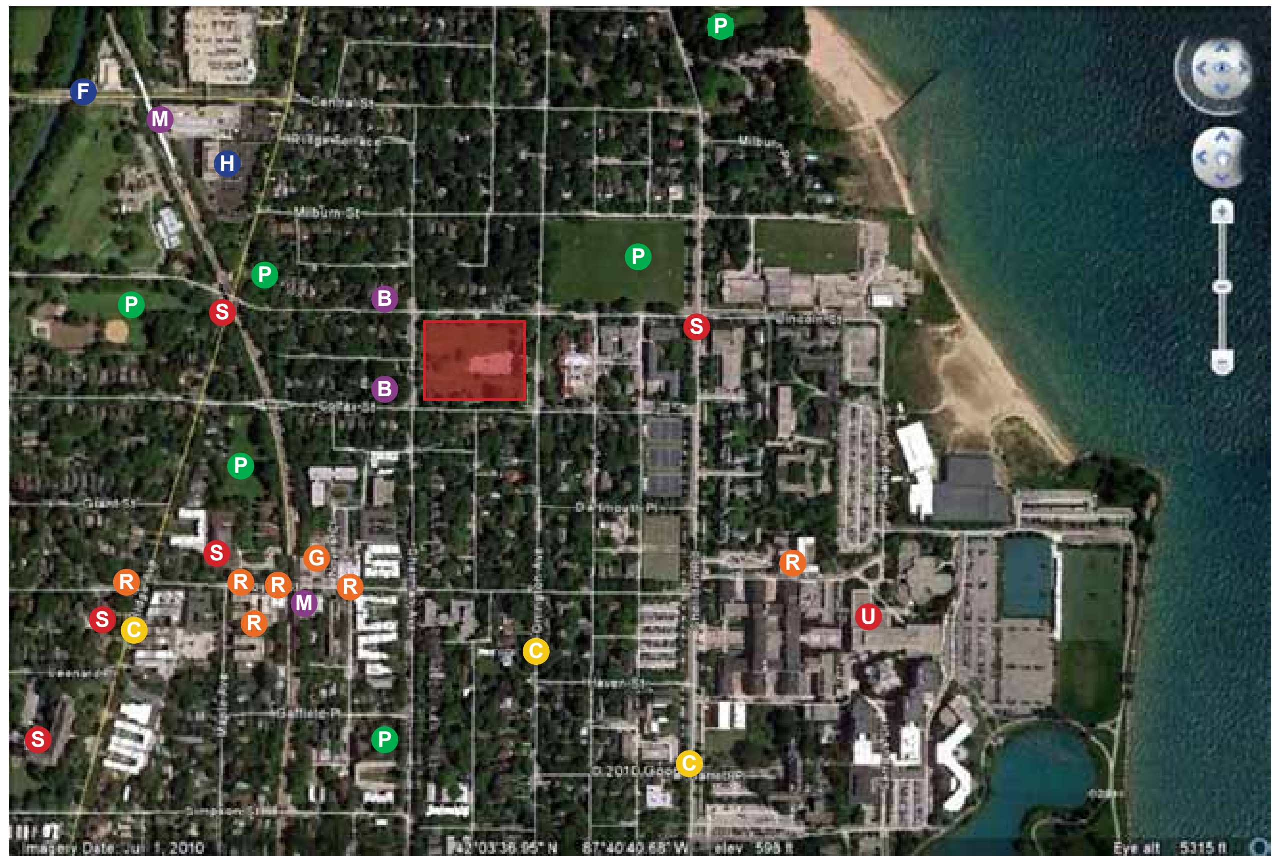
## Site

*Requirements and Analysis*

The site chosen for the development of this study is located in the city of Evanston, IL.
Since 2006, Evanston has been committed to sustainability. In October of 2006 it had engaged in the U.S. Mayor's Climate Protection Agreement. In November of 2008, the City Council adopted the Evanston Climate Action Plan (ECAP).

The Green Building ordinance component of ECAP requires all new commercial, multi-family and municipal constructions over 10,000 square feet achieve "LEED" Silver certification through the U.S. Green Building Council.

This site was selected due to its appropriate size, 3.5 acres, and its prime location in the city, neighboring Northwestern University Campus, and the lake. The site is surrounded by single family houses and permits easy access to public transportation nodes and commercial areas.



- M CTA Purple Line Train Station (0.3miles)
- B CTA Bus Station
- H Hospital
- F Fire Station
- P Park
- U Northwestern University Campus
- S School
- R Restaurant
- G Grocery Store
- C Church

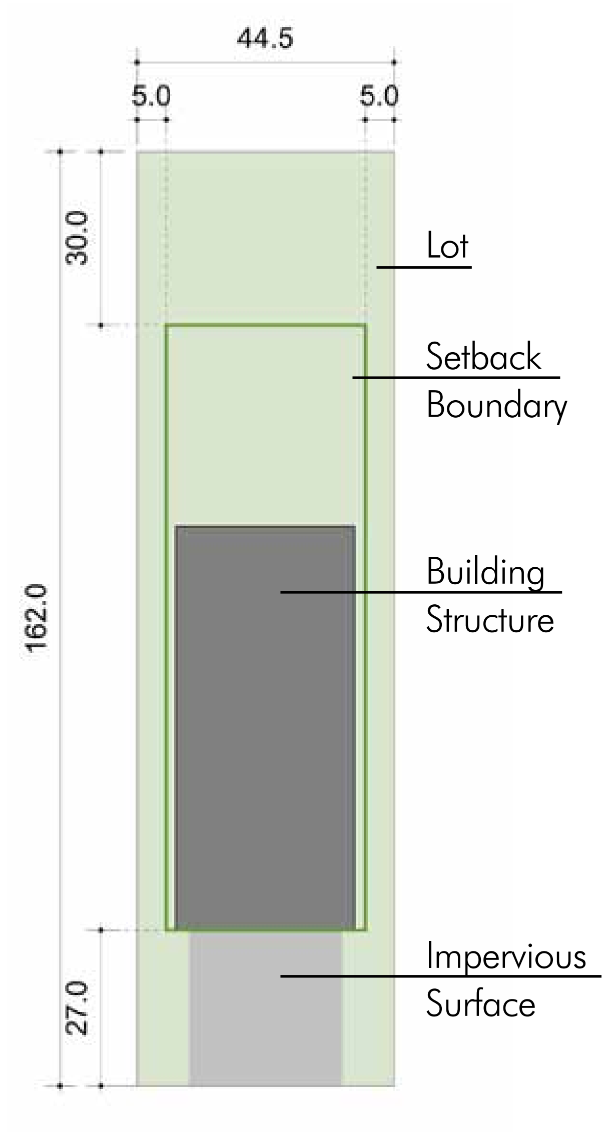


# SITE

*Requirements and Analysis*

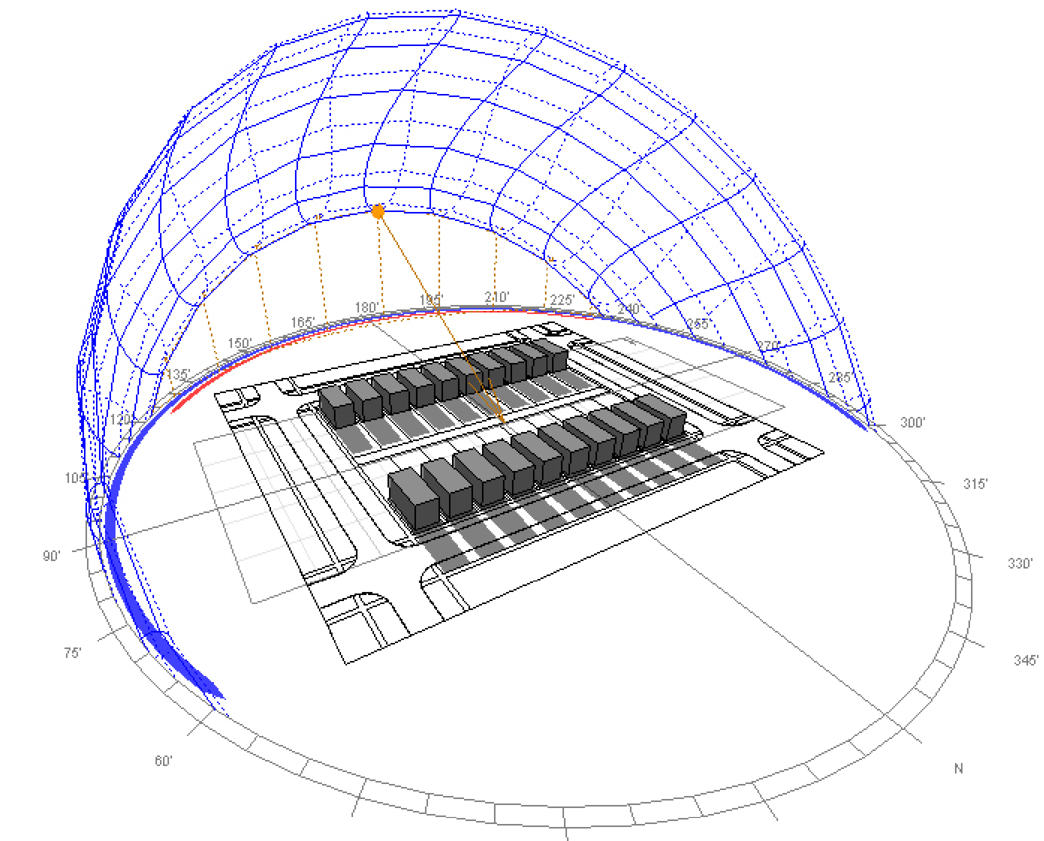
A zoning exception request will have to be issued for the completion of this project since the proposal is to develop a whole block composed by single and multifamily units.

**Code Requirements:**
Zoning: R1 - Single Family only
Minimum lot size: 7,200sqf
Minimum lot front: 35'
Building Structure: 30% lot
Maximum Impervious Surface: 45% lot
Building Height: 35' (2.5 stories)
Setbacks:
- Front: 27'
- Side: 5'
- Rear: 30'

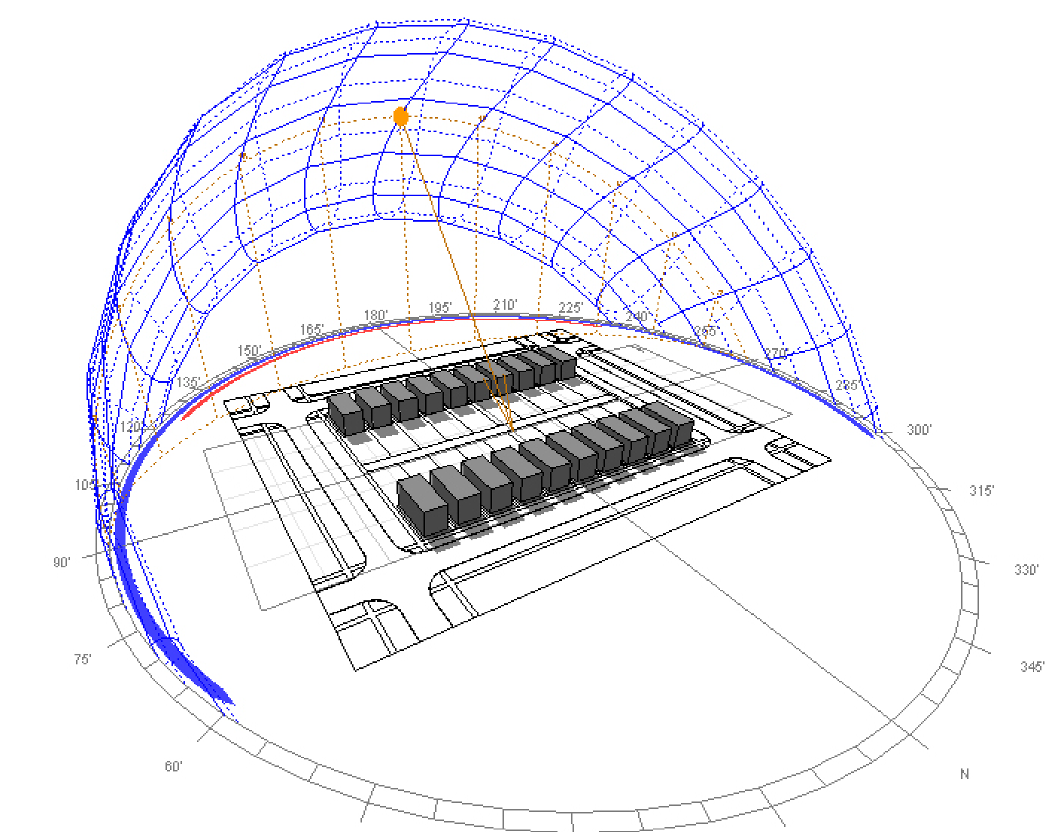



Site size: 153,092 sqf
Basic lot size: 44.5'x 162'
Basic lot area: 7,209 sqf
Building structure area: 2,170 sqf
Impervious surface: 2,888 sqf

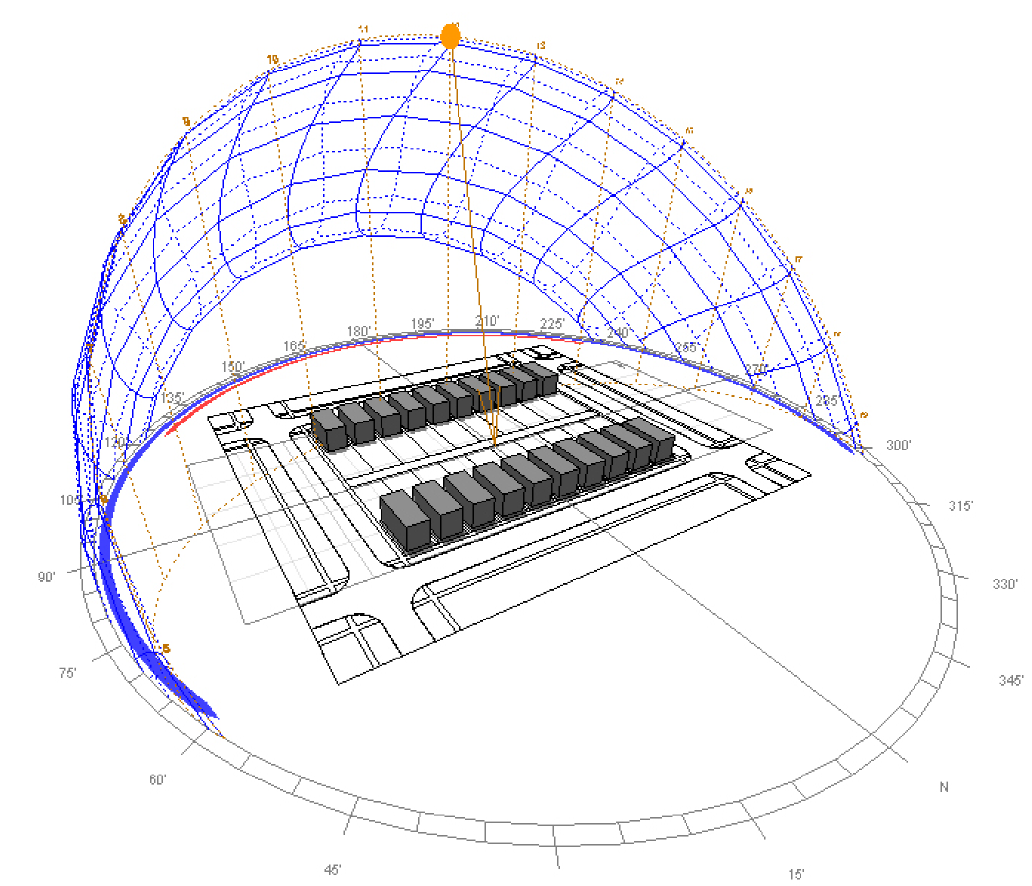
Given the site size and the minimum lot size restrictions, it will be possible to build 20 5,425sqf houses.

Winter Solstice

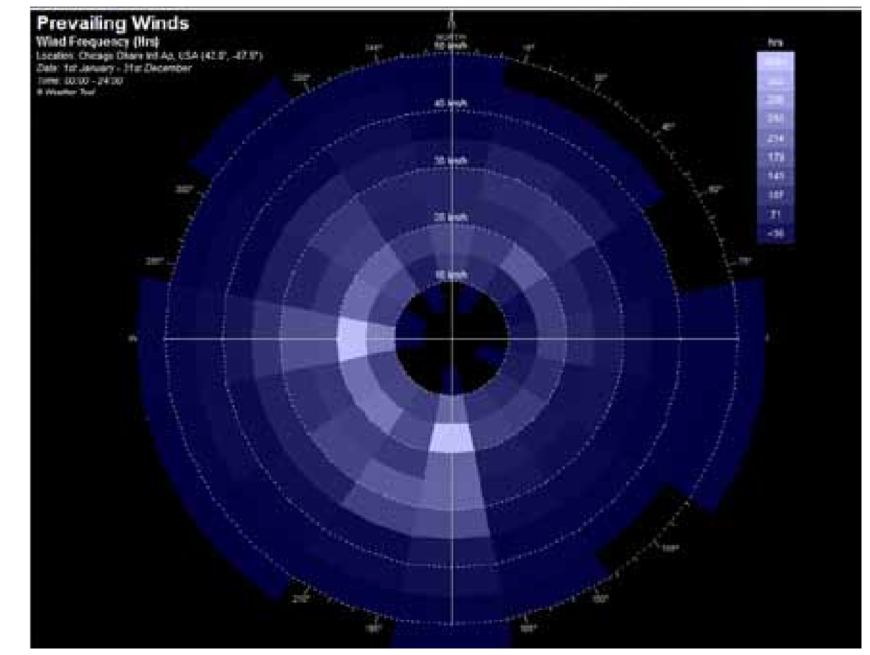


Spring/ Fall Equinox



Summer Solstice

Prevailing Winds

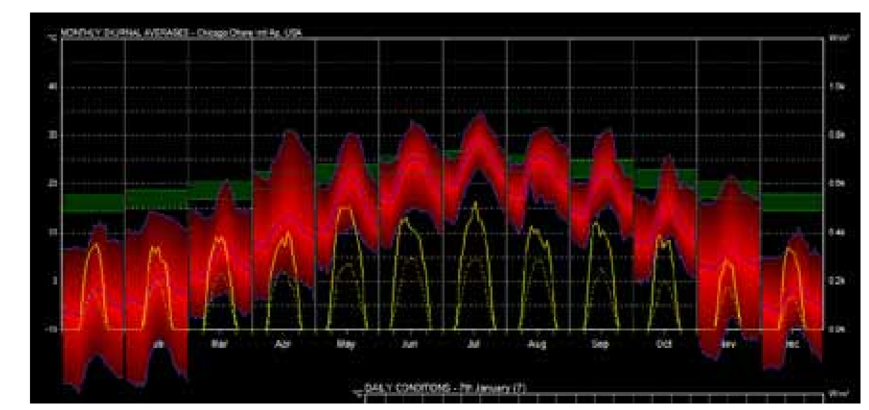



| Wind Speed - S - km/h | | |
|---|---|---|
| Month | 9 a.m. | 3 p.m |
| Jan | 12 | 19 |
| Feb | 25 | 17 |
| Mar | 19 | 12 |
| Apr | 26 | 30 |
| May | 12 | 6 |
| Jun | 30 | 16 |
| Jul | 25 | 25 |
| Aug | 12 | 25 |
| Sep | 20 | 13 |
| Oct | 38 | 35 |
| Nov | 36 | 26 |
| Dev | 19 | 19 |

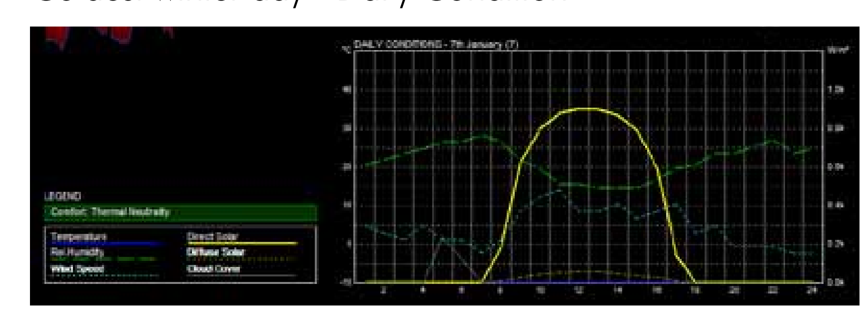
| Wind Speed - SW - km/h | | |
|---|---|---|
| Month | 9 a.m. | 3 p.m |
| Jan | 25 | 29 |
| Feb | 17 | 17 |
| Mar | 16 | 12 |
| Apr | 6 | 0 |
| May | 3 | 9 |
| Jun | 13 | 6 |
| Jul | 12 | 12 |
| Aug | 19 | 16 |
| Sep | 16 | 13 |
| Oct | 19 | 25 |
| Nov | 0 | 16 |
| Dev | 22 | 9 |

| Wind Speed - W - km/h | | |
|---|---|---|
| Month | 9 a.m. | 3 p.m |
| Jan | 9 | 22 |
| Feb | 21 | 35 |
| Mar | 22 | 22 |
| Apr | 20 | 13 |
| May | 12 | 3 |
| Jun | 16 | 10 |
| Jul | 12 | 9 |
| Aug | 22 | 12 |
| Sep | 26 | 20 |
| Oct | 12 | 6 |
| Nov | 26 | 20 |
| Dev | 29 | 32 |

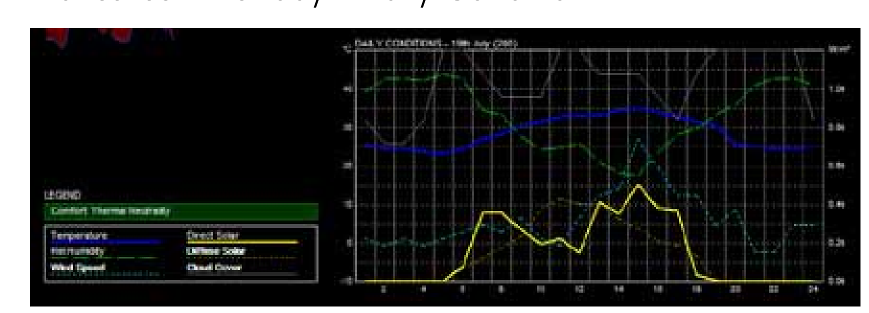
Annual Temperature Fluctuation



Coldest winter day - Daily Condition



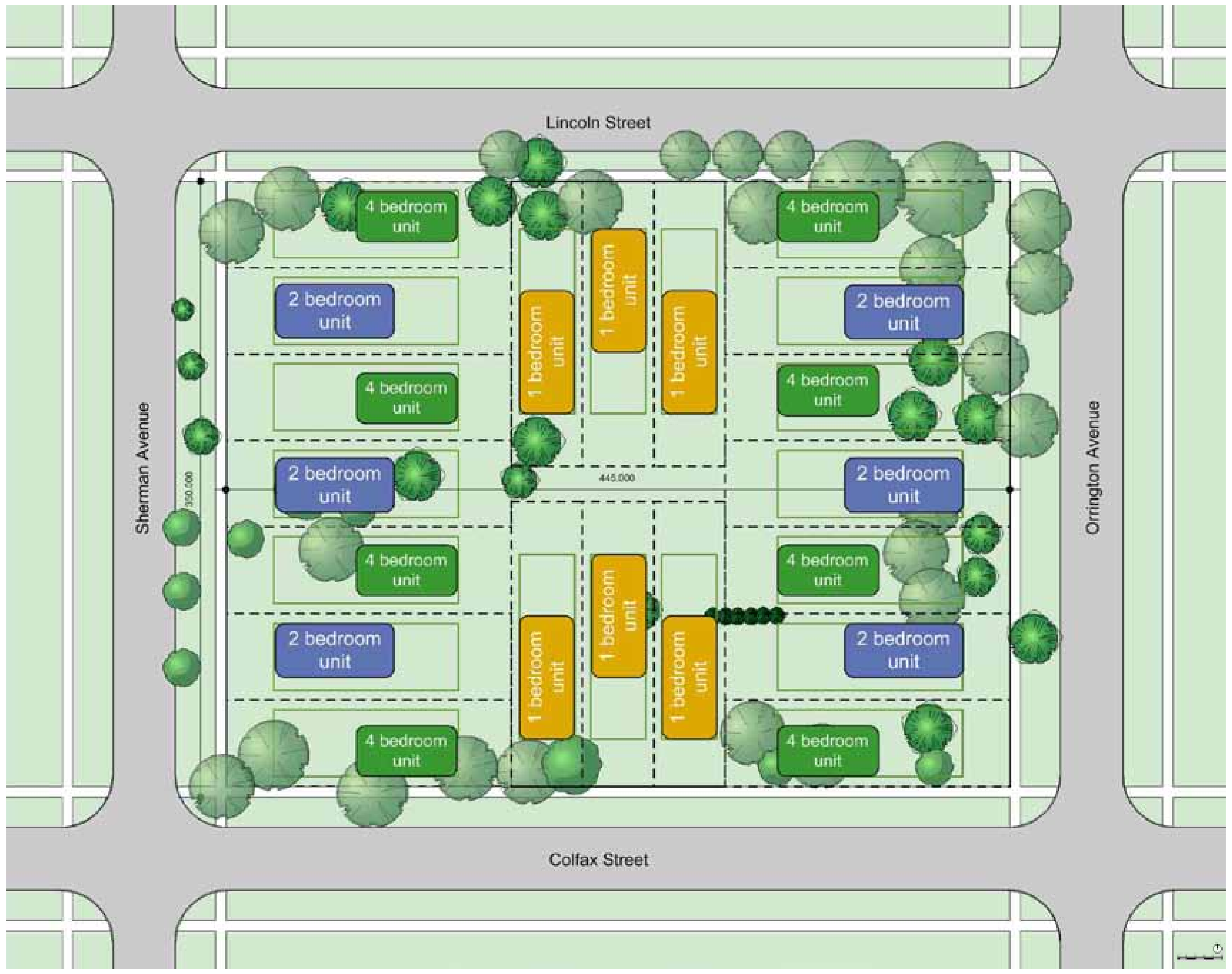
Hottest summer day - Daily Condition



| Rainfall | |
|---|---|
| Month | (inches) |
| Jan | 2,037 |
| Feb | 1,928 |
| Mar | 2,987 |
| Apr | 4,638 |
| May | 4,984 |
| Jun | 6,771 |
| Jul | 9,557 |
| Aug | 8,512 |
| Sep | 6,625 |
| Oct | 4,286 |
| Nov | 3,580 |
| Dev | 2,109 |

Latitude: 42° N
Longitude: 87.9° W
Summer Sun Angle: 72°
Spring/ Fall Sun Angle: 49°
Winter Sun Angle: 24°
Water Table: 3 - 6'

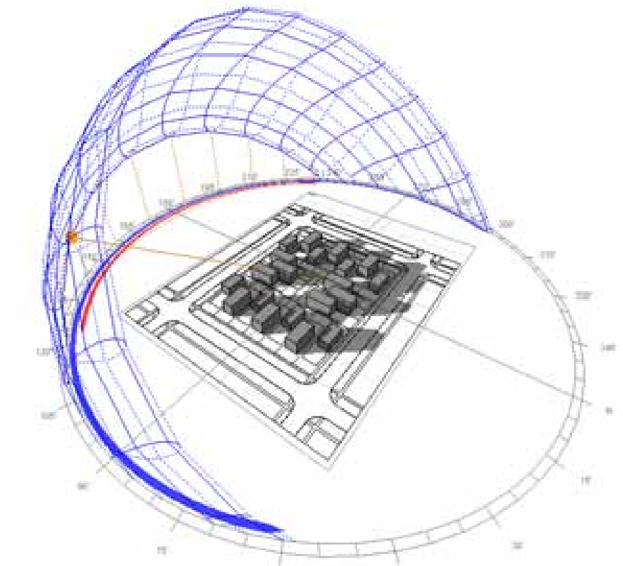
# Conceptual Design




| Square Footage | | | |
|---|---|---|---|
| Typology | units/ building | quantity | sqf |
| 4 bedroom | 1 | 8 | 25,112 |
| 2 bedroom | 3 | 6 | 37,332 |
| 1 bedroom | 6 | 6 | 46,284 |
| | | Total | 108,728 |

| Population | | | | |
|---|---|---|---|---|
| Typology | units/ building | quantity | inhab/ unit | population |
| 4 bedroom | 1 | 8 | 5 | 40 |
| 2 bedroom | 3 | 6 | 3 | 54 |
| 1 bedroom | 6 | 6 | 2 | 72 |
| | | | Total | 166 |

| | | |
|---|---|---|
| Density | 47.4285714 | inhab/acre |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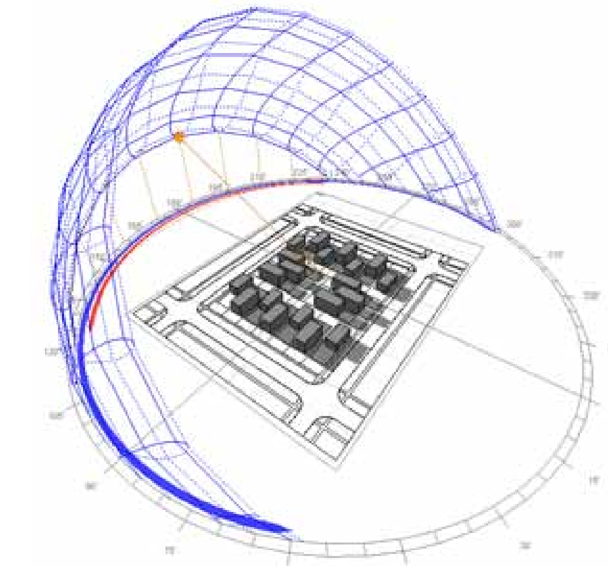
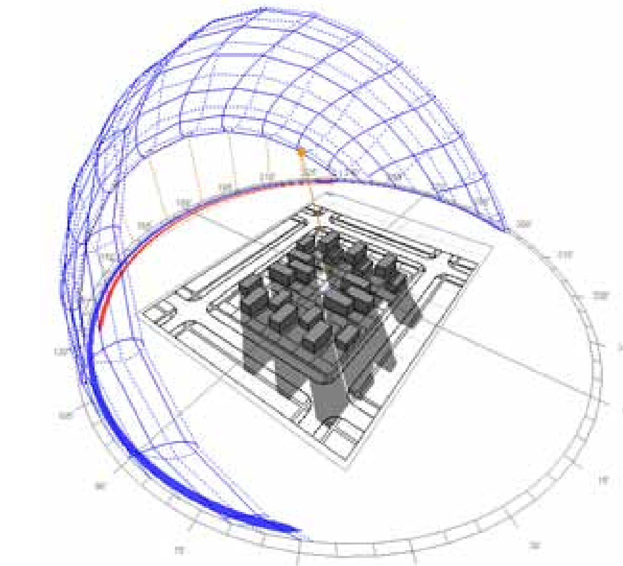
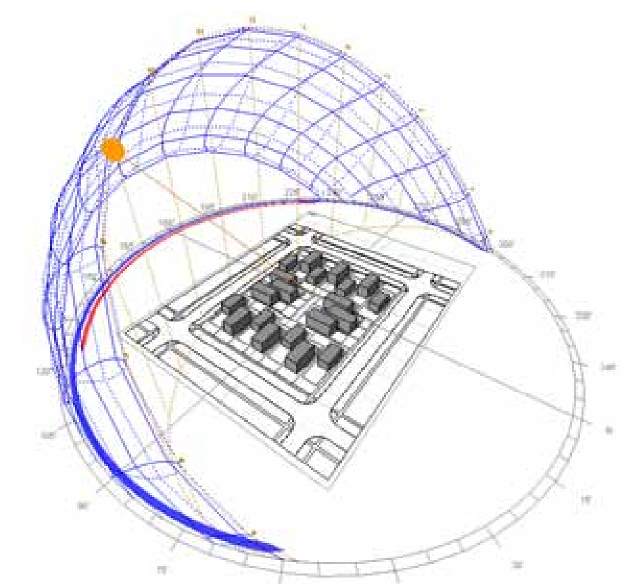

21 Dec. Noon


21 Dec. 3P.M.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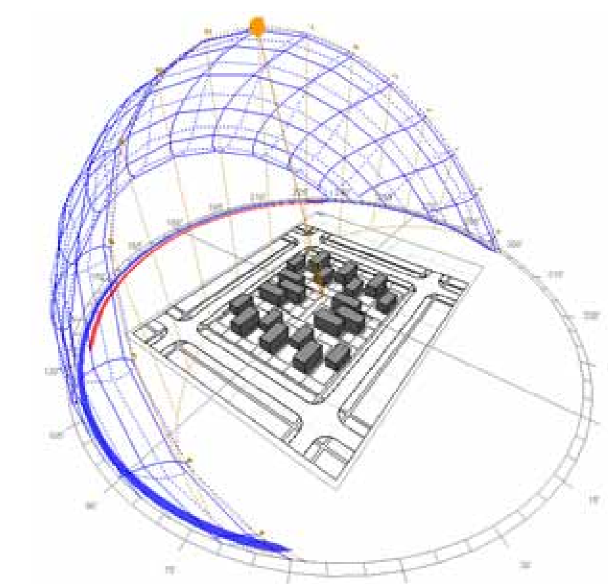
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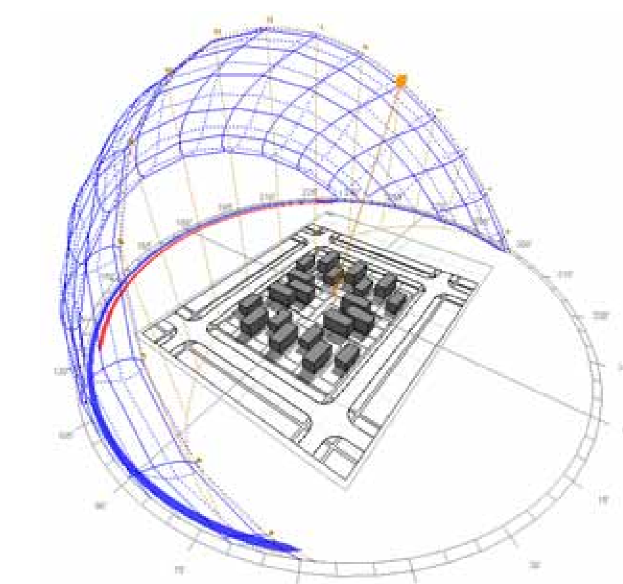
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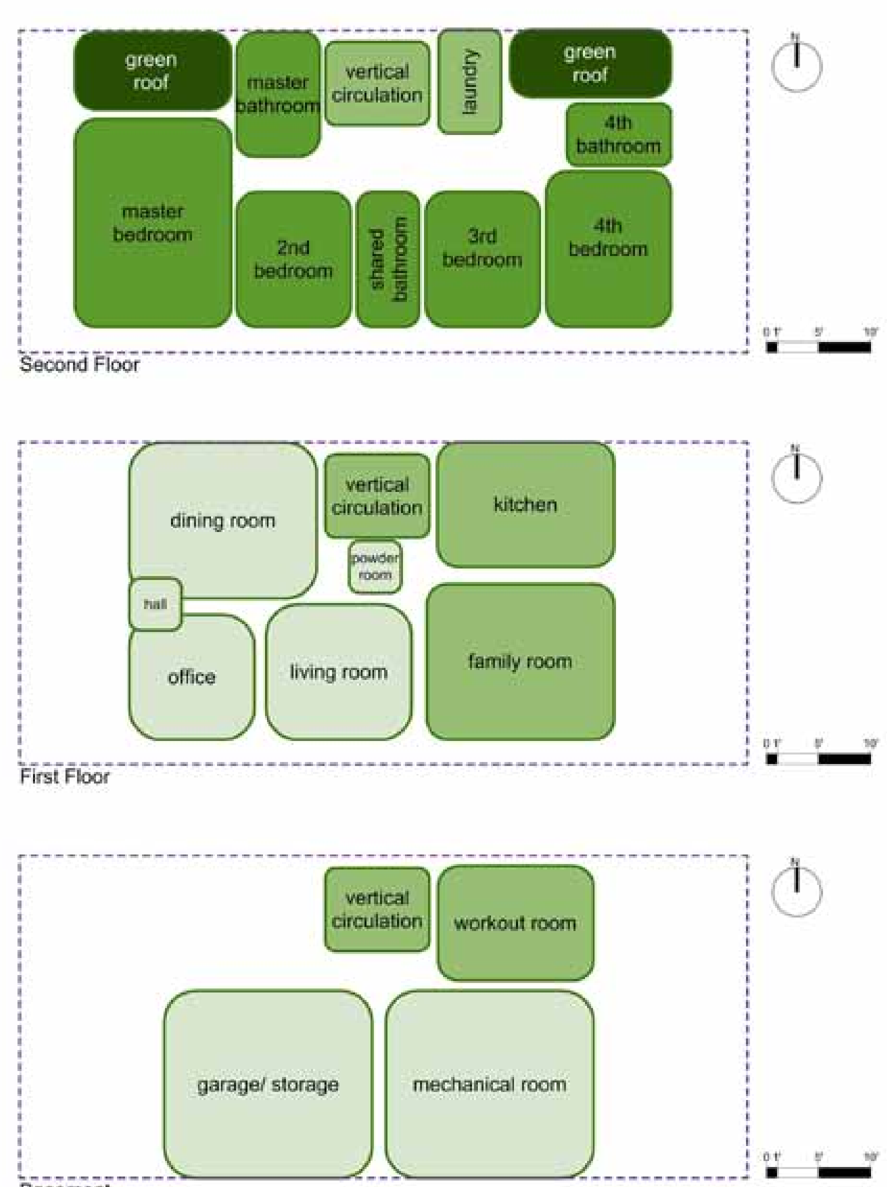
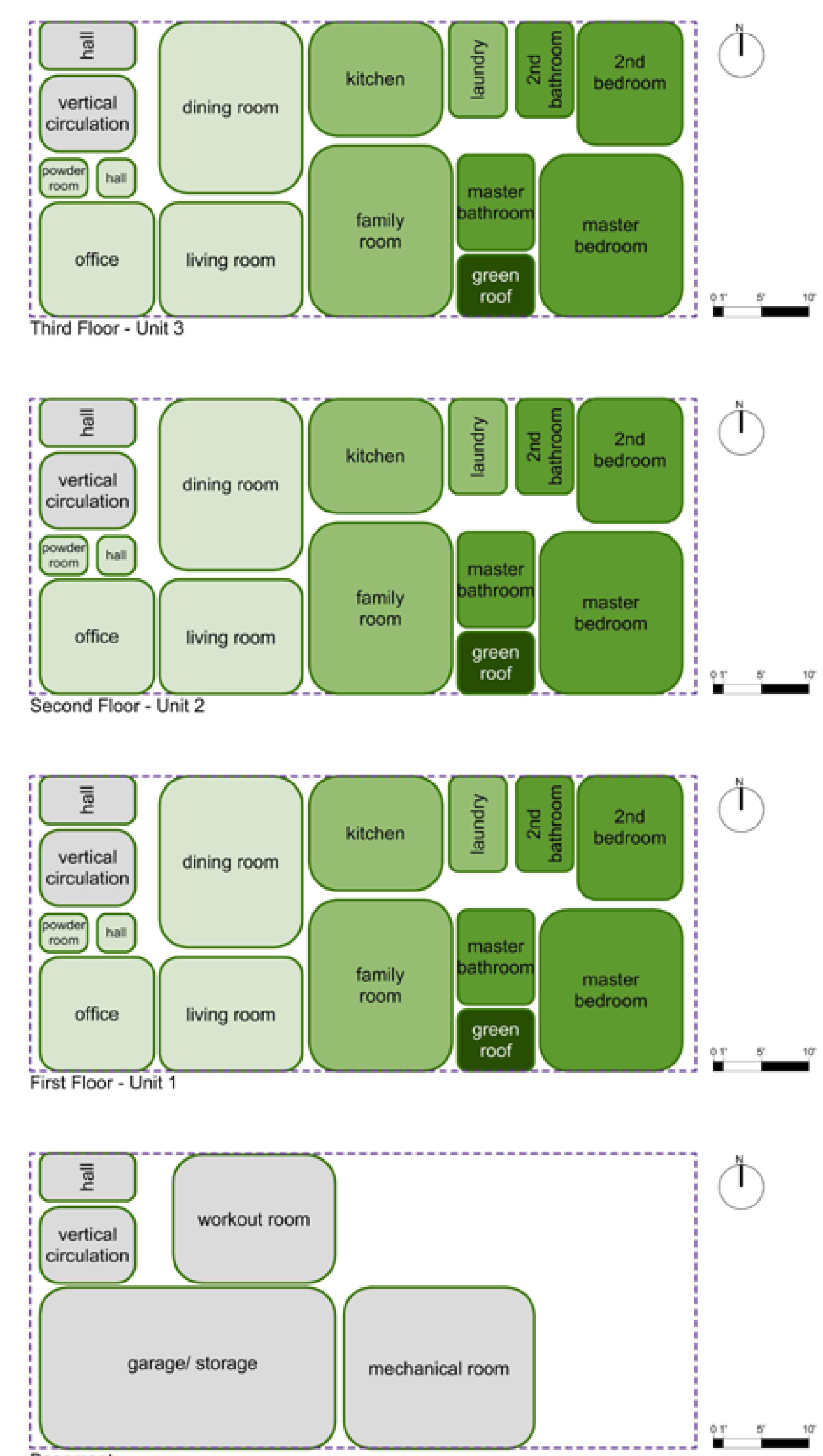
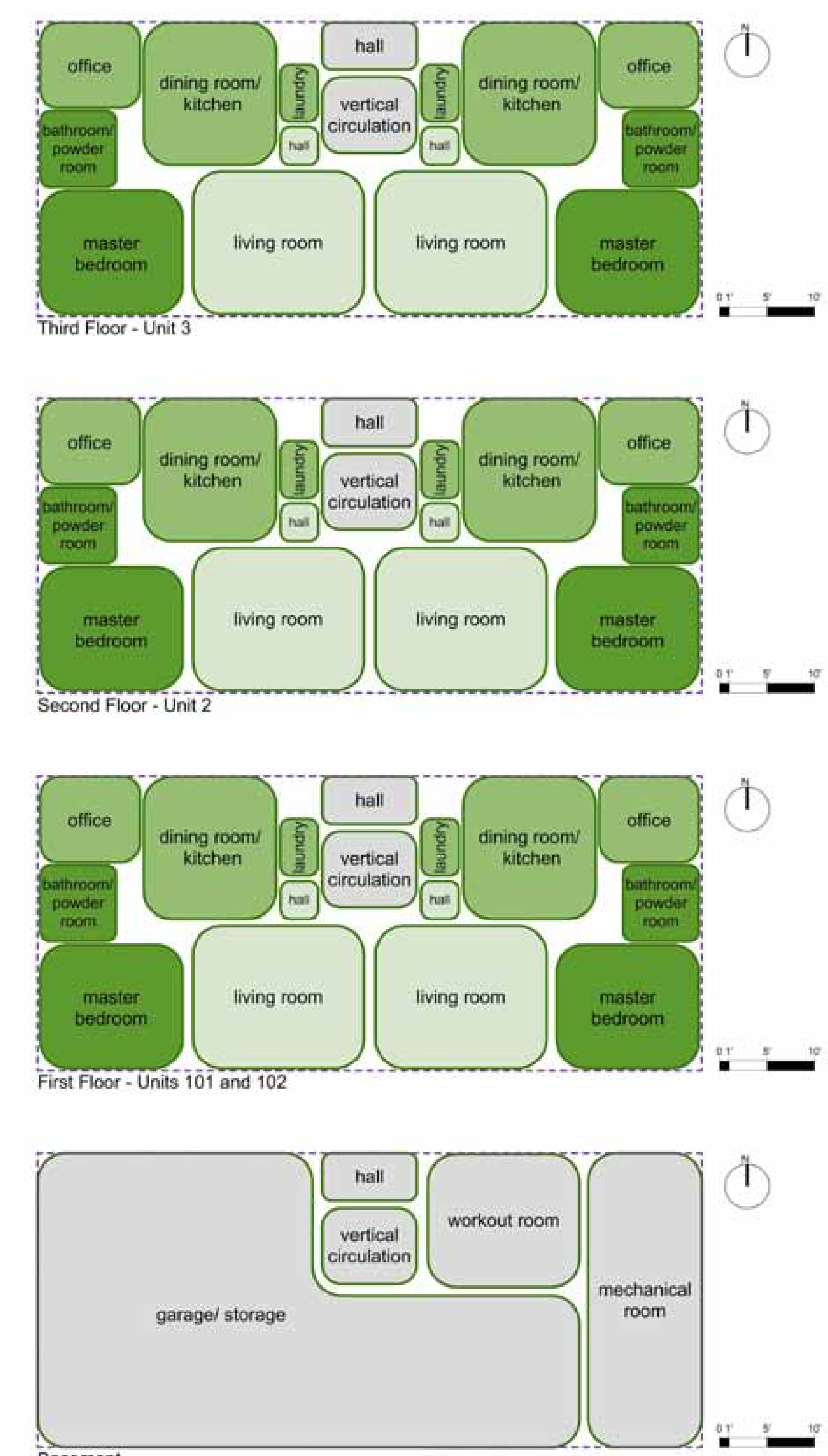


Single Family - One four-bedroom unit



Multi-Family 1- Three two-bedroom units



Multi-Family 2 - Six one-bedroom units

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