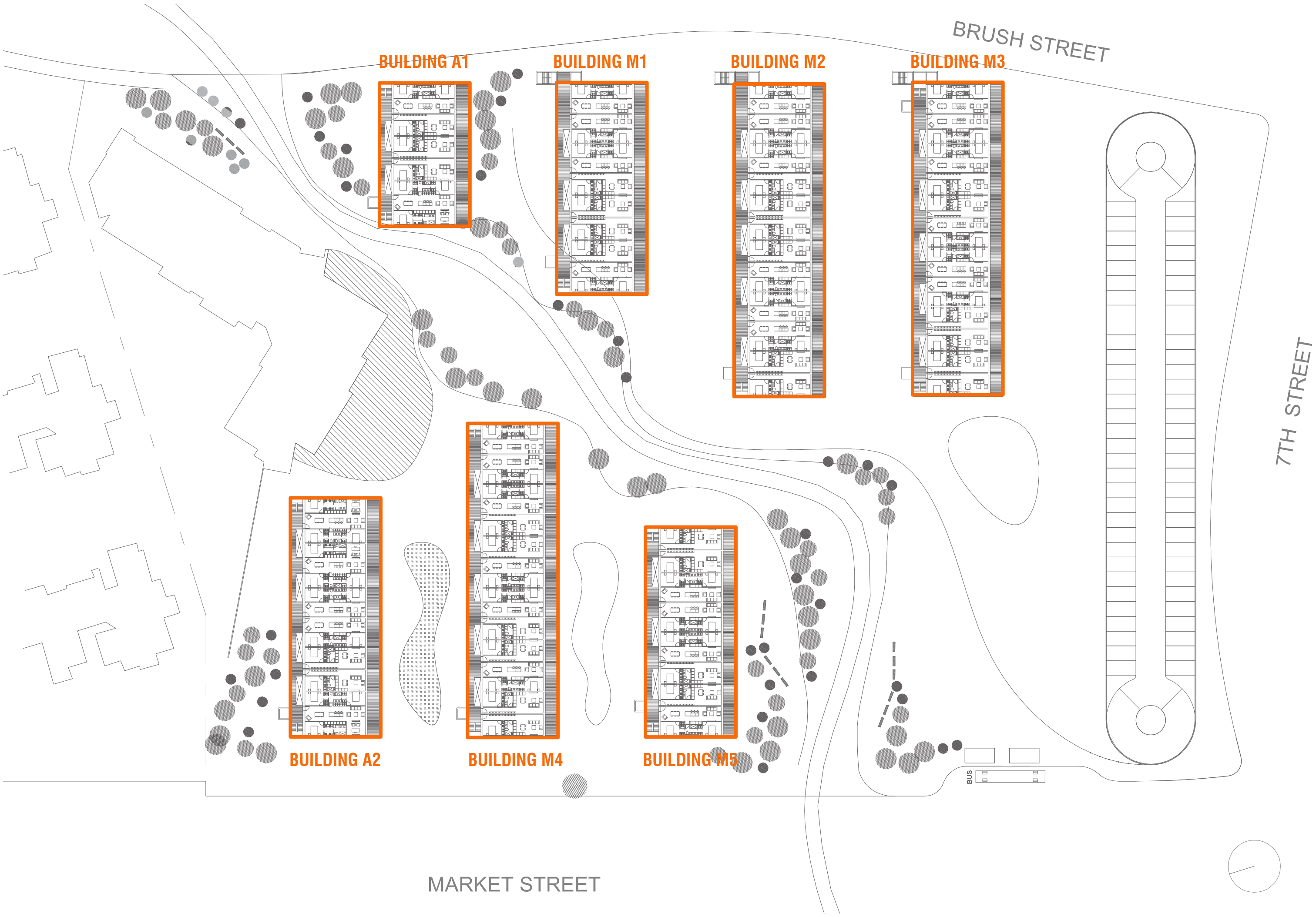
SYMBIOSIS

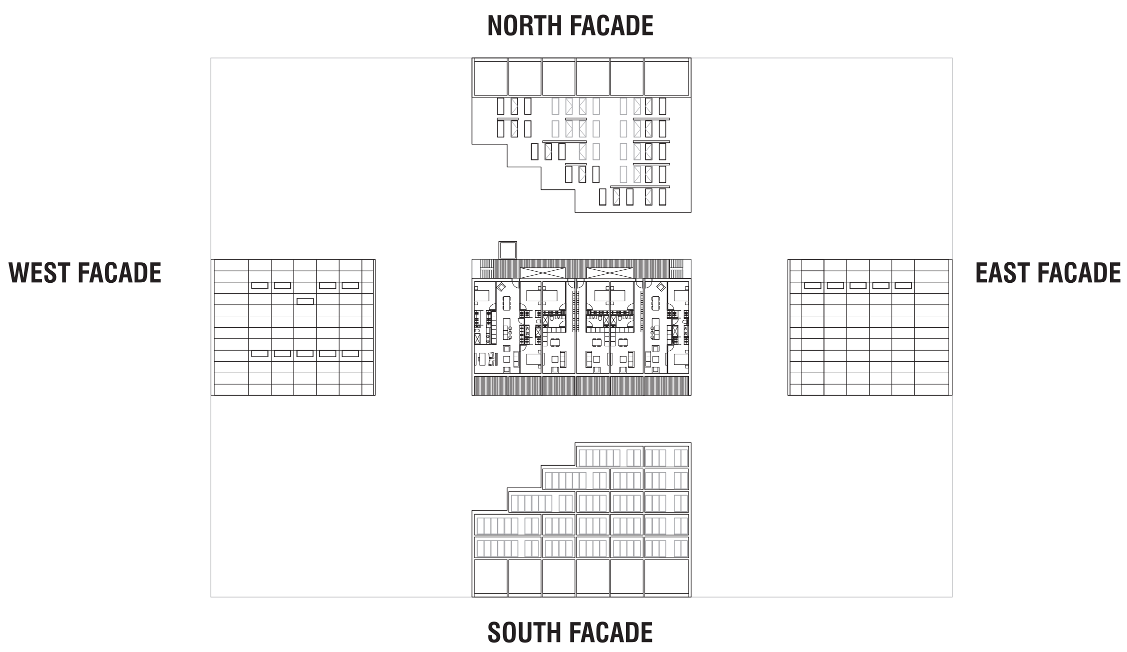
TASK 2: ENERGY PERFORMANCE DOCUMENTATION

Based on principles of modularity and flexibility, the seven residential buildings are based on the same scheme. As a consequence, all calculations can be easily extrapolated to each of them, just changing the length of the building. For that reason, unless otherwise indicated, the following sections will be calculated based on results obtained from the analysis of building M2.



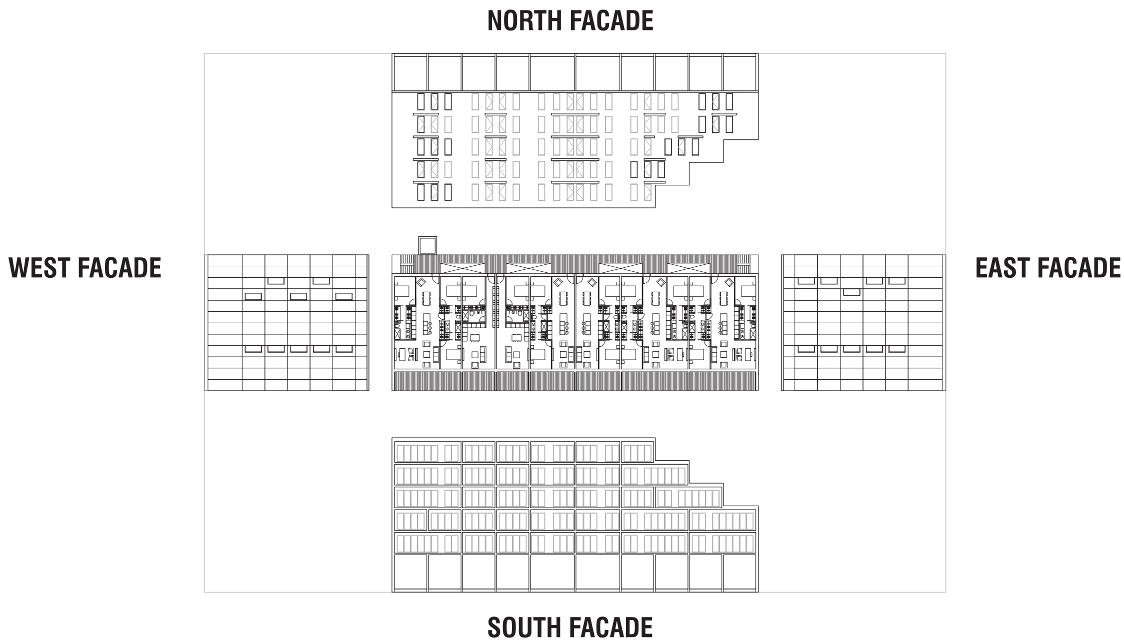
2A. WINDOW-TO-WALL RATIO

BUILDING A1
North
Step 1: Total area of light transmitting glazing surfaces on north facade: 48 m^2
Step 2: Total area of north façade: 367 m^2
Window-to-Wall Ratio of north facade = number from step 1/ number from step 2 = 0.13
East
Step 1: Total area of light transmitting glazing surfaces on east facade: 10m^2
Step 2: Total area of east façade: 279 m^2
Window-to-Wall Ratio of east facade = number from step 1/ number from step 2 = 0.036
South
Step 1: Total area of light transmitting glazing surfaces on south facade: 202 m^2
Step 2: Total area of south façade: 367m^2
Window-to-Wall Ratio of south facade = number from step 1/ number from step 2 = 0.55
West
Step 1: Total area of light transmitting glazing surfaces on west facade: 20 m^2
Step 2: Total area of west facade: 279 m^2
Window-to-Wall Ratio of west façade = number from step 1/ number from step 2 = 0.072
Total Building Window-to-Wall Ratio
Step 1: Light transmitting glazing total = step 1 north + step 1 east + step 1 south + step 1 west = 280 m^2
Step 2: Façade area total = step 2 north + step 2 east + step 2 south + step 2 west = 1292 m^2
Total Window-to-Wall Ratio = number from step 1/ number from step 2 = 0.216



2A. WINDOW-TO-WALL RATIO

BUILDING A2
North
Step 1: Total area of light transmitting glazing surfaces on north facade: 108 m^2
Step 2: Total area of north façade: 669 m^2
Window-to-Wall Ratio of north facade = number from step 1/ number from step 2 = 0.161
East
Step 1: Total area of light transmitting glazing surfaces on east facade: 20m^2
Step 2: Total area of east façade: 279 m^2
Window-to-Wall Ratio of east façade = number from step 1/ number from step 2 = 0.072
South
Step 1: Total area of light transmitting glazing surfaces on south facade: 372 m^2
Step 2: Total area of south facade: 669 m^2
Window-to-Wall Ratio of south facade = number from step 1/ number from step 2 = 0.556
West
Step 1: Total area of light transmitting glazing surfaces on west facade: 20 m^2
Step 2: Total area of west façade: 279 m^2
Window-to-Wall Ratio of west façade = number from step 1/ number from step 2 = 0.072
Total Building Window-to-Wall Ratio
Step 1: Light transmitting glazing total = step 1 north + step 1 east + step 1 south + step 1 west = 520 m^2
Step 2: Facade area total = step 2 north + step 2 east + step 2 south + step 2 west = 1896 m^2
Total Window-to-Wall Ratio = number from step 1/ number from step 2 = 0.274



2A. WINDOW-TO-WALL RATIO

BUILDING M1

North

Step 1: Total area of light transmitting glazing surfaces on north facade: 66 m^2
Step 2: Total area of north facade: 442 m^2
Window-to-Wall Ratio of north facade = number from step 1/ number from step 2 = 0.149

East

Step 1: Total area of light transmitting glazing surfaces on east facade: 8 m^2
Step 2: Total area of east facade: 225 m^2
Window-to-Wall Ratio of east facade = number from step 1/ number from step 2 = 0.036

South

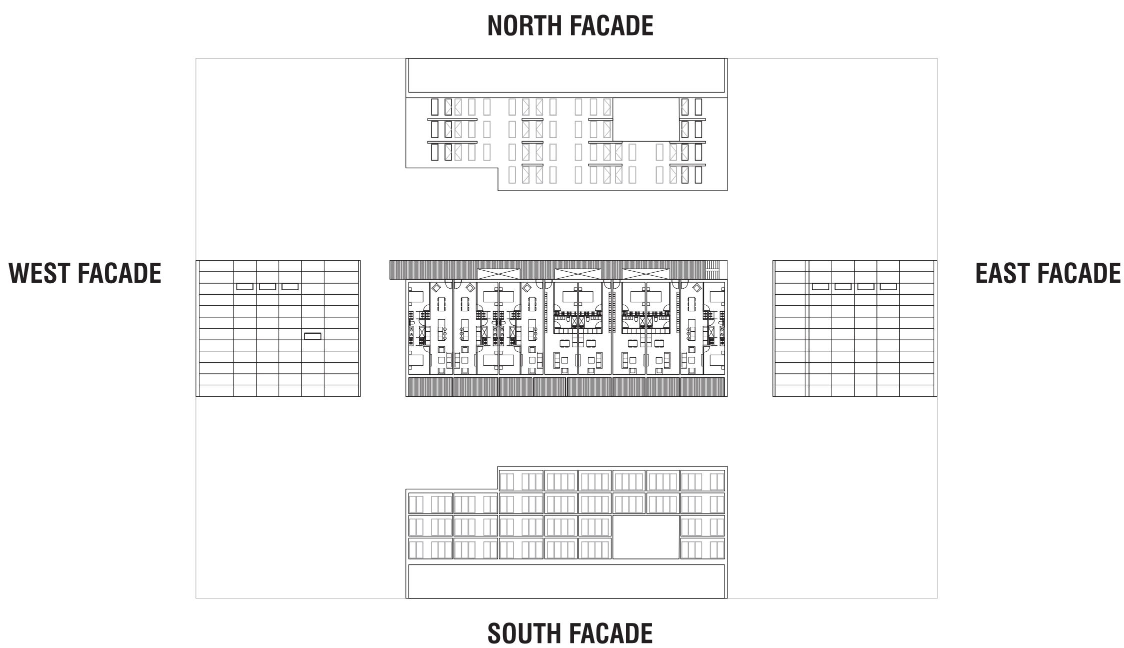
Step 1: Total area of light transmitting glazing surfaces on south facade: 236 m^2
Step 2: Total area of south facade: 442 m^2
Window-to-Wall Ratio of south facade = number from step 1/ number from step 2 = 0.534

West

Step 1: Total area of light transmitting glazing surfaces on west facade: 8 m^2
Step 2: Total area of west facade: 225 m^2
Window-to-Wall Ratio of west facade = number from step 1/ number from step 2 = 0.036

Total Building Window-to-Wall Ratio

Step 1: Light transmitting glazing total = step 1 north + step 1 east + step 1 south + step 1 west = 318 m^2
Step 2: Facade area total = step 2 north + step 2 east + step 2 south + step 2 west = 1334 m^2
Total Window-to-Wall Ratio = number from step 1/ number from step 2 = 0.238



2A. WINDOW-TO-WALL RATIO

BUILDING M2

North

Step 1: Total area of light transmitting glazing surfaces on north facade: 106 m^2

Step 2: Total area of north facade: 669 m^2

Window-to-Wall Ratio of north facade = number from step 1/ number from step 2 = 0.158

East

Step 1: Total area of light transmitting glazing surfaces on east facade: 8 m^2

Step 2: Total area of east facade: 225 m^2

Window-to-Wall Ratio of east facade = number from step 1/ number from step 2 = 0.036

South

Step 1: Total area of light transmitting glazing surfaces on south facade: 360 m^2

Step 2: Total area of south facade: 669 m^2

Window-to-Wall Ratio of south facade = number from step 1/ number from step 2 = 0.538

West

Step 1: Total area of light transmitting glazing surfaces on west facade: 16 m^2

Step 2: Total area of west facade: 225 m^2

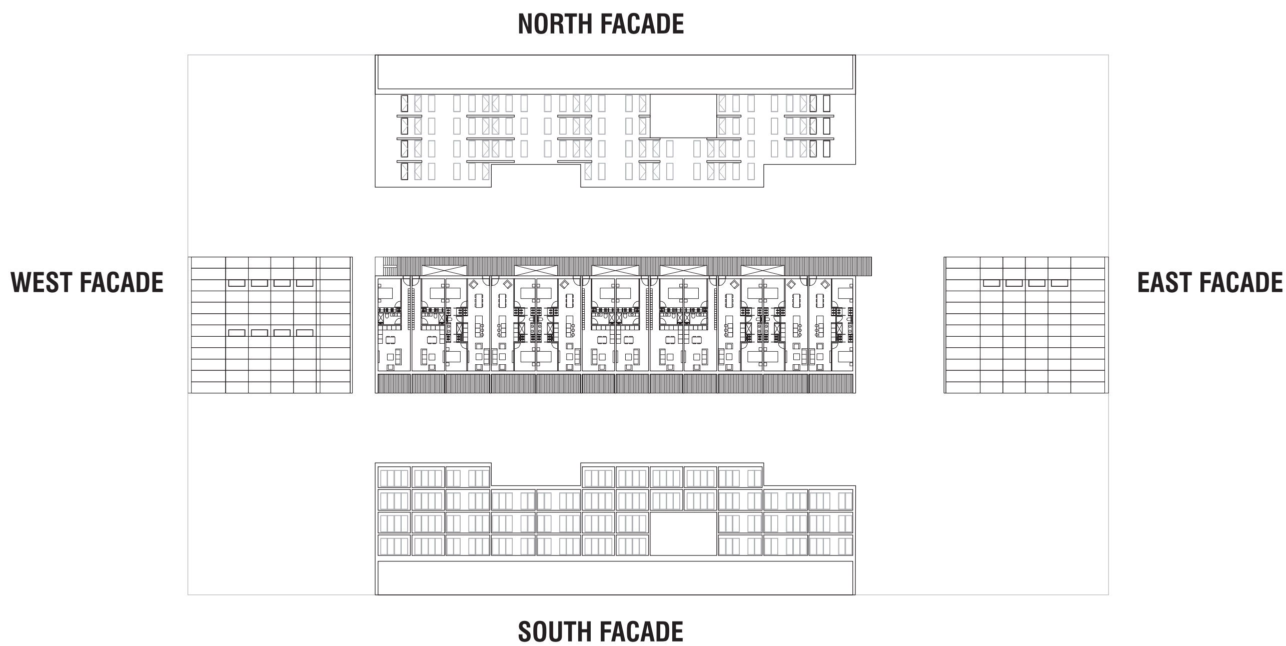
Window-to-Wall Ratio of west facade = number from step 1/ number from step 2 = 0.071

Total Building Window-to-Wall Ratio

Step 1: Light transmitting glazing total = step 1 north + step 1 east + step 1 south + step 1 west = 490 m^2

Step 2: Facade area total = step 2 north + step 2 east + step 2 south + step 2 west = 1788 m^2

Total Window-to-Wall Ratio = number from step 1/ number from step 2 = 0.274



2A. WINDOW-TO-WALL RATIO

BUILDING M3

North

Step 1: Total area of light transmitting glazing surfaces on north facade: 106 m^2

Step 2: Total area of north facade: 669 m^2

Window-to-Wall Ratio of north facade = number from step 1/ number from step 2 = 0.158

East

Step 1: Total area of light transmitting glazing surfaces on east facade: 8 m^2

Step 2: Total area of east facade: 225 m^2

Window-to-Wall Ratio of east facade = number from step 1/ number from step 2 = 0.036

South

Step 1: Total area of light transmitting glazing surfaces on south facade: 360 m^2

Step 2: Total area of south facade: 669 m^2

Window-to-Wall Ratio of south facade = number from step 1/ number from step 2 = 0.538

West

Step 1: Total area of light transmitting glazing surfaces on west facade: 16 m^2

Step 2: Total area of west facade: 225 m^2

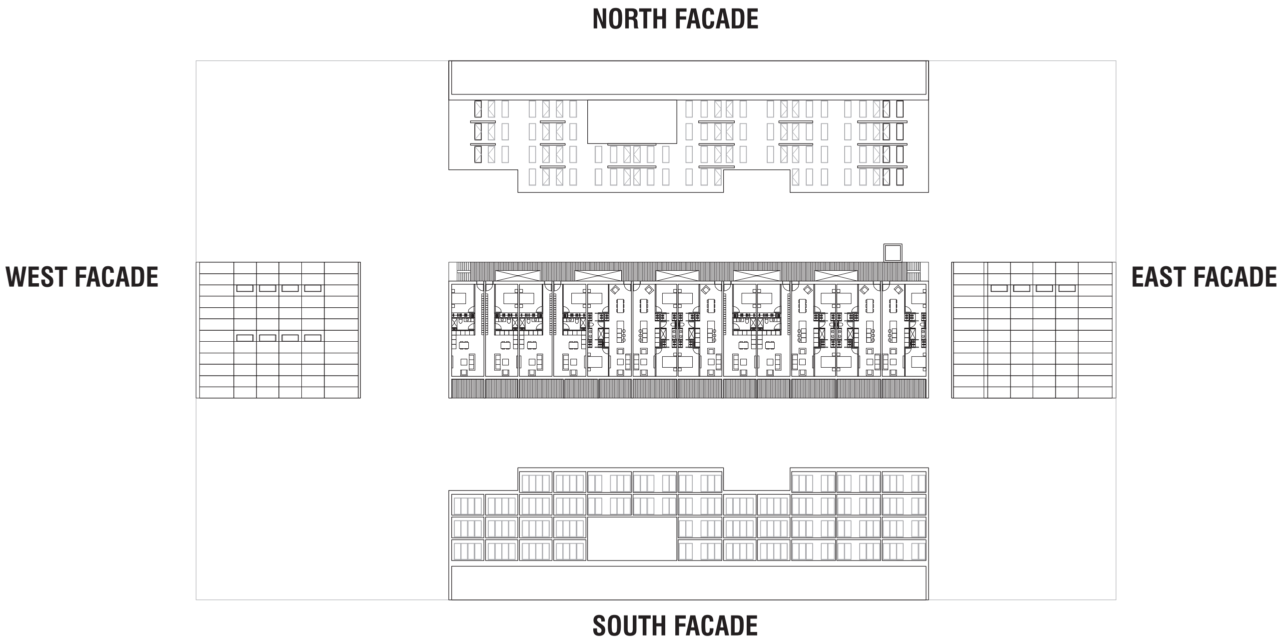
Window-to-Wall Ratio of west facade = number from step 1/ number from step 2 = 0.071

Total Building Window-to-Wall Ratio

Step 1: Light transmitting glazing total = step 1 north + step 1 east + step 1 south + step 1 west = 490 m^2

Step 2: Facade area total = step 2 north + step 2 east + step 2 south + step 2 west = 1788 m^2

Total Window-to-Wall Ratio = number from step 1/ number from step 2 = 0.274



2A. WINDOW-TO-WALL RATIO

BUILDING M4

North

Step 1: Total area of light transmitting glazing surfaces on north facade: 106 m^2

Step 2: Total area of north facade: 659 m^2

Window-to-Wall Ratio of north facade = number from step 1/ number from step 2 = 0.16

East

Step 1: Total area of light transmitting glazing surfaces on east facade: 8 m^2

Step 2: Total area of east facade: 225 m^2

Window-to-Wall Ratio of east facade = number from step 1/ number from step 2 = 0.036

South

Step 1: Total area of light transmitting glazing surfaces on south facade: 354 m^2

Step 2: Total area of south facade: 659 m^2

Window-to-Wall Ratio of south facade = number from step 1/ number from step 2 = 0.537

West

Step 1: Total area of light transmitting glazing surfaces on west facade: 16 m^2

Step 2: Total area of west facade: 225 m^2

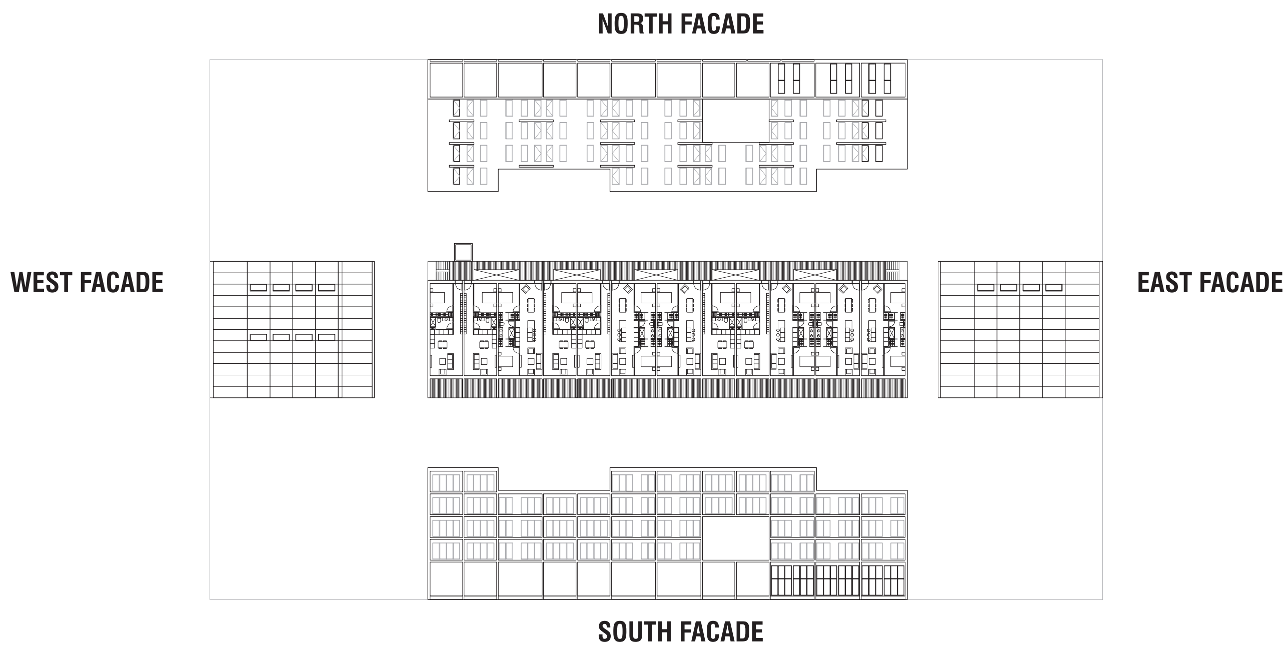
Window-to-Wall Ratio of west facade = number from step 1/ number from step 2 = 0.071

Total Building Window-to-Wall Ratio

Step 1: Light transmitting glazing total = step 1 north + step 1 east + step 1 south + step 1 west = 484 m^2

Step 2: Facade area total = step 2 north + step 2 east + step 2 south + step 2 west = 1768 m^2

Total Window-to-Wall Ratio = number from step 1/ number from step 2 = 0.273



2A. WINDOW-TO-WALL RATIO

BUILDING M5

North

Step 1: Total area of light transmitting glazing surfaces on north facade: 64 m^2
Step 2: Total area of north facade: 440 m^2
Window-to-Wall Ratio of north facade = number from step 1/ number from step 2 = 0.145

East

Step 1: Total area of light transmitting glazing surfaces on east facade: 16 m^2
Step 2: Total area of east facade: 225 m^2
Window-to-Wall Ratio of east facade = number from step 1/ number from step 2 = 0.071

South

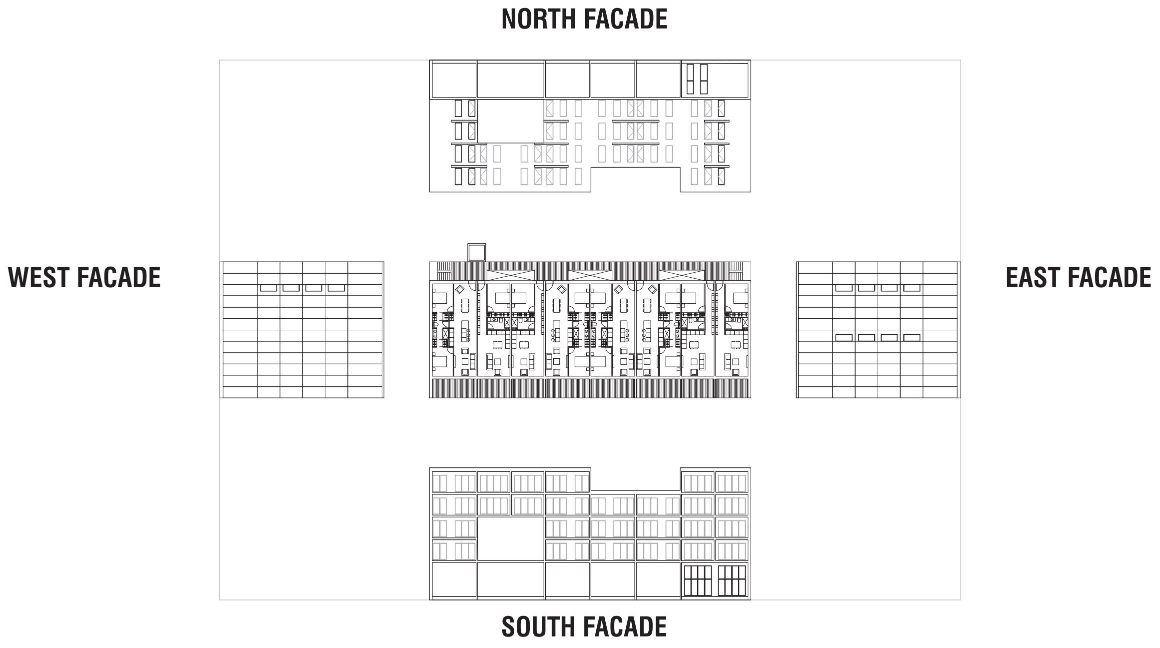
Step 1: Total area of light transmitting glazing surfaces on south facade: 236 m^2
Step 2: Total area of south facade: 440 m^2
Window-to-Wall Ratio of south facade = number from step 1/ number from step 2 = 0.536

West

Step 1: Total area of light transmitting glazing surfaces on west facade: 8 m^2
Step 2: Total area of west facade: 225 m^2
Window-to-Wall Ratio of west facade = number from step 1/ number from step 2 = 0.036

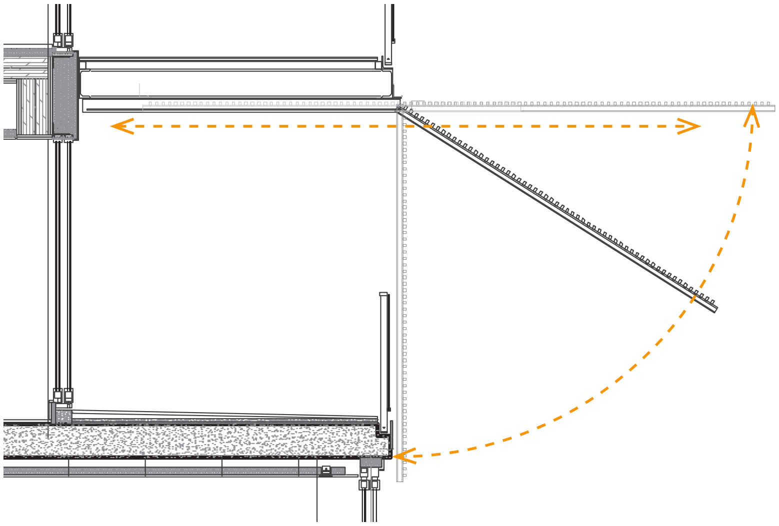
Total Building Window-to-Wall Ratio

Step 1: Light transmitting glazing total = step 1 north + step 1 east + step 1 south + step 1 west = 324 m^2
Step 2: Facade area total = step 2 north + step 2 east + step 2 south + step 2 west = 1330 m^2
Total Window-to-Wall Ratio = number from step 1/ number from step 2 = 0.243

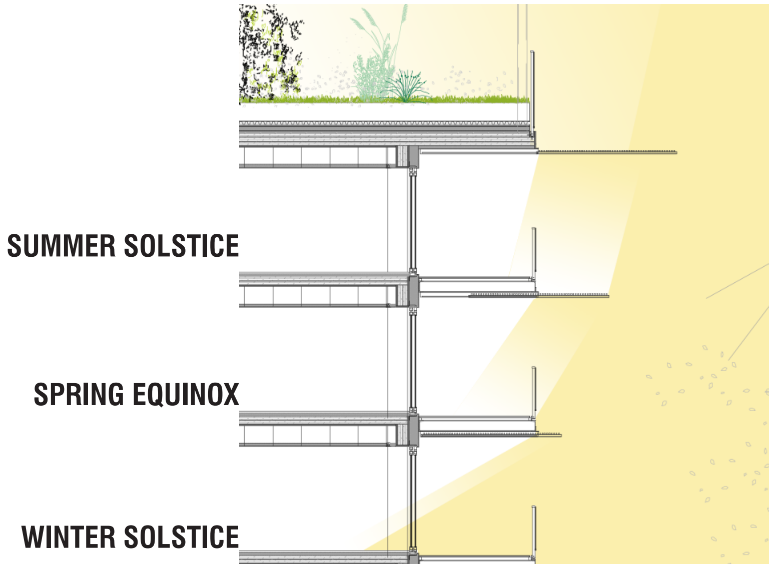


2B. WINDOW OPENINGS AND WINDOW SHADING

The design approach taken to regulate incoming light and heat from the sun is based on a Passive Solar Design approach.
Buildings have been located along an east-west axe, thus allowing a maximum exposure towards the south orientation.
In order to optimize heat gains, large openings occupy 53 % of the south façade and only 5 % of east and west façade and 14 % of the north façade. Besides, the south façade is protected from the sun by 2.5 m wide balconies and sunshades. Sunshades can be regulated in order to take advantage of sun angle variation along the year.



Sunshades can be regulated in order to take advantage of the sun angle variation along the year. Solar gains are almost zero during Summer. However, south facing windows are heated during winter, reducing the energy demand for heating and maintaining the units warm during the day.



TYPE OF WINDOWS AND GLASSES

In addition to these passive measures, Passive House standards are included in the design. The type of windows and glasses used in each of the residential buildings is the same, as well as the performance numbers targeted for U-factor, solar heat gain coefficient (SHGC) and visible transmittance, and are:

A. EAST FACING (ORIENTATION: 106.8° - NO OVERHANG – EXTERIOR SHADING)
i. Typical Floor (residential)
Window Type: Double-low-e Argon
Frame Type: standard PU on wood
U-factor: 0.24 W/ (m2K); SHGC: 0.27 Visible Transmittance: 0.64
ii. Ground Floor (commercial)
Window Type: Double-low-e Argon
Frame Type: wide PU on wood
U-factor: 0.24 W/ (m2K); SHGC: 0.27 Visible Transmittance: 0.64

B. SOUTH FACING (BOTH RESIDENTIAL AND COMMERCIAL) (ORIENTATION: 163.2° - 8.2 FT. DEPTH OVERHANG)
Window Type: Triple-low-e Kr08
Frame Type: wide PU on wood
U-factor: 0.13 W/ (m2K); SHGC: 0.32; Visible Transmittance: 0.6

C. WEST FACING (ORIENTATION: 186.8° - NO OVERHANG – EXTERIOR SHADING)
i. Typical Floor (residential)
Window Type: Triple-low-e Kr08
Frame Type: standard PU on wood
U-factor: 0.13 W/ (m2K); SHGC: 0.32; Visible Transmittance: 0.6
ii. Ground Floor (commercial)
Window Type: Triple-low-e Kr08
Frame Type: wide PU on wood
U-factor: 0.13 W/ (m2K); SHGC: 0.32; Visible Transmittance: 0.6

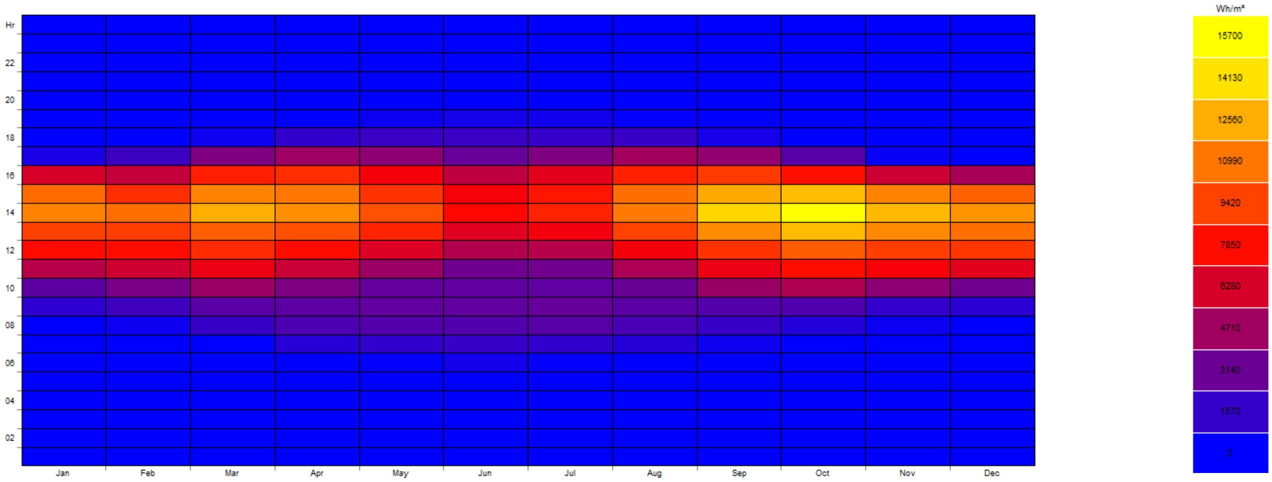
D. North facing (both residential and commercial) (orientation: 343.2° - 8.2 ft. depth overhang)
Window Type: Triple-low-e Kr08
Frame Type: standard PU on wood
i. Typical Floor (residential)
U-factor: 0.13 W/ (m2K); SHGC: 0.32; Visible Transmittance: 0.6
ii. Ground Floor (commercial)
U-factor: 0.13 W/ (m2K); SHGC: 0.32; Visible Transmittance: 0.6

2B. WINDOW OPENINGS AND WINDOW SHADING

DIAGRAMS OF WINDOW SHADING

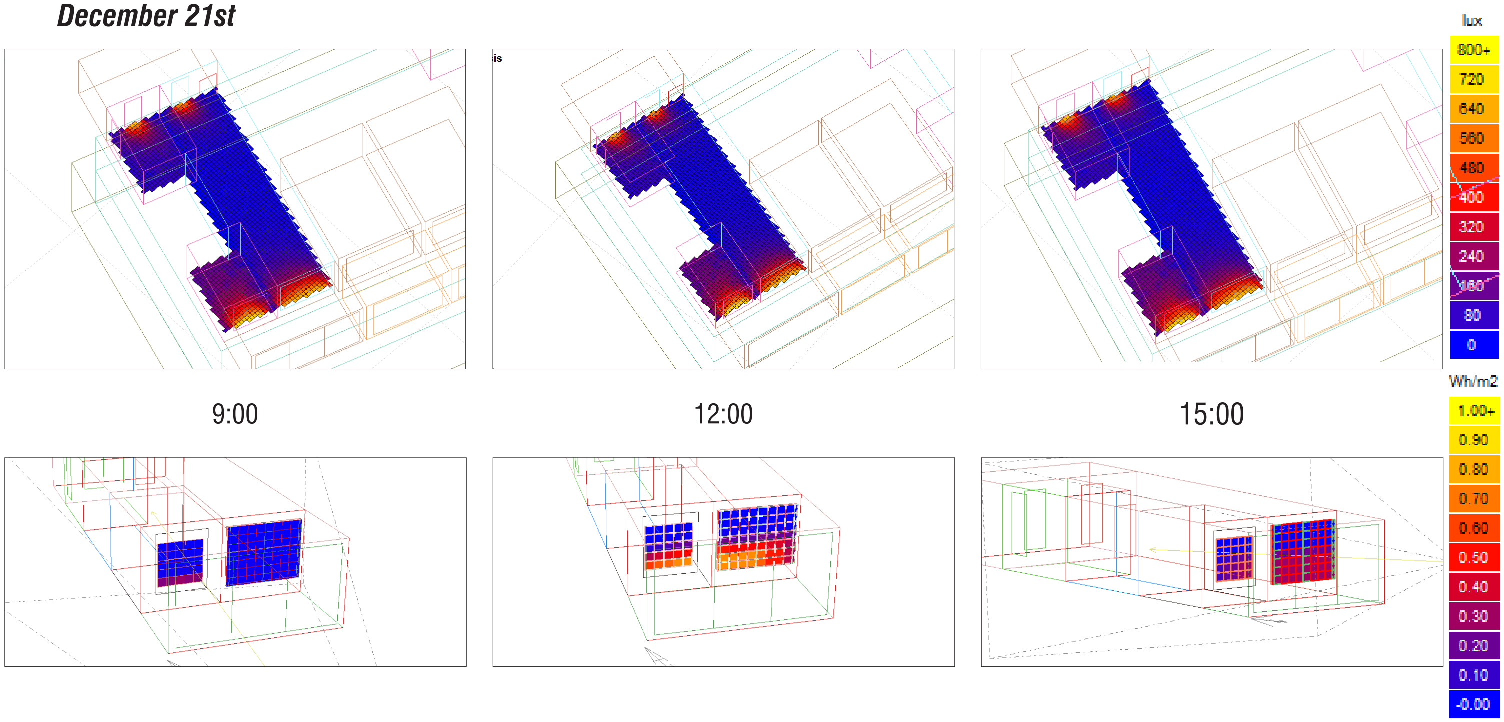
A. SOUTH ELEVATION

i. Annual Incident Solar Radiation



ii. Daylight analysis and Solar Radiation

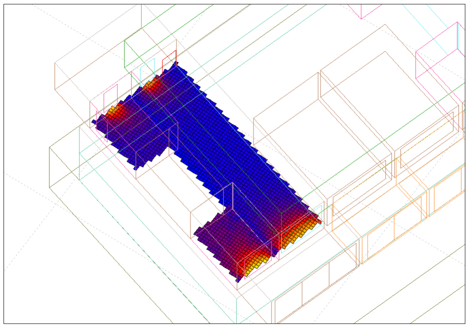
December 21st



2B. WINDOW OPENINGS AND WINDOW SHADING

DIAGRAMS OF WINDOW SHADING

March 21st



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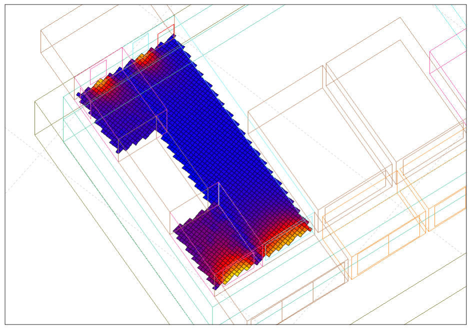

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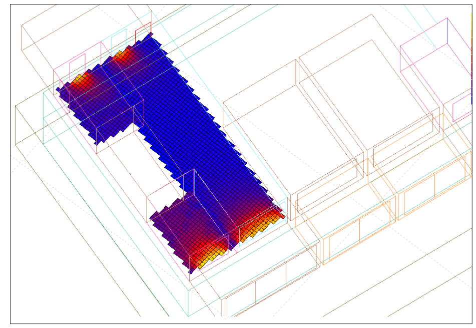

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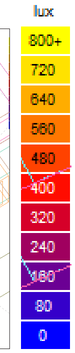

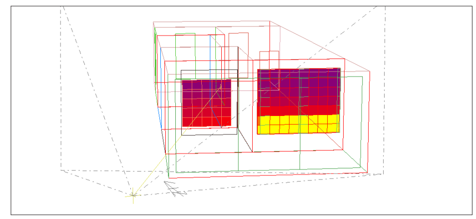

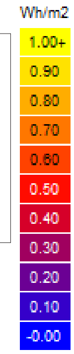

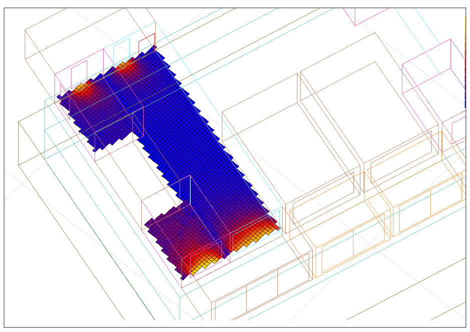

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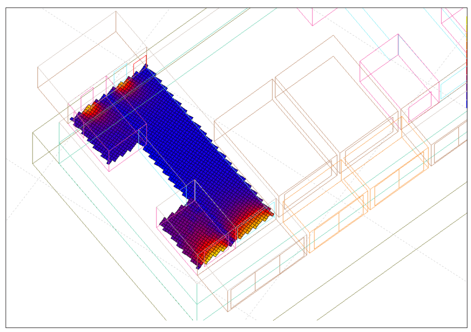

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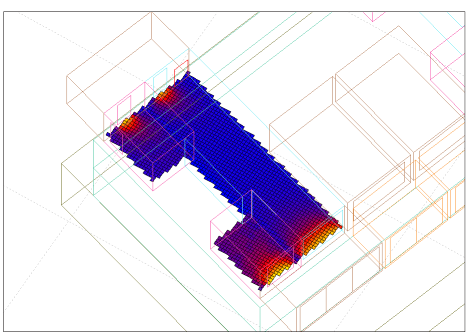
June 21st



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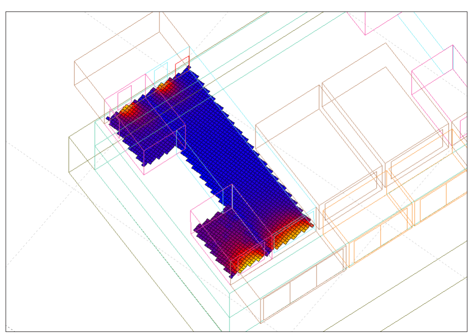

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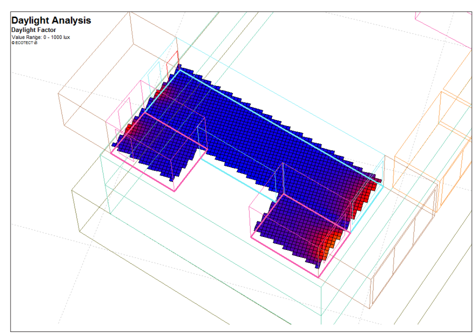

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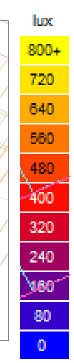
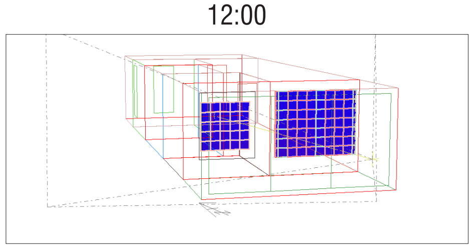
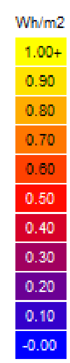




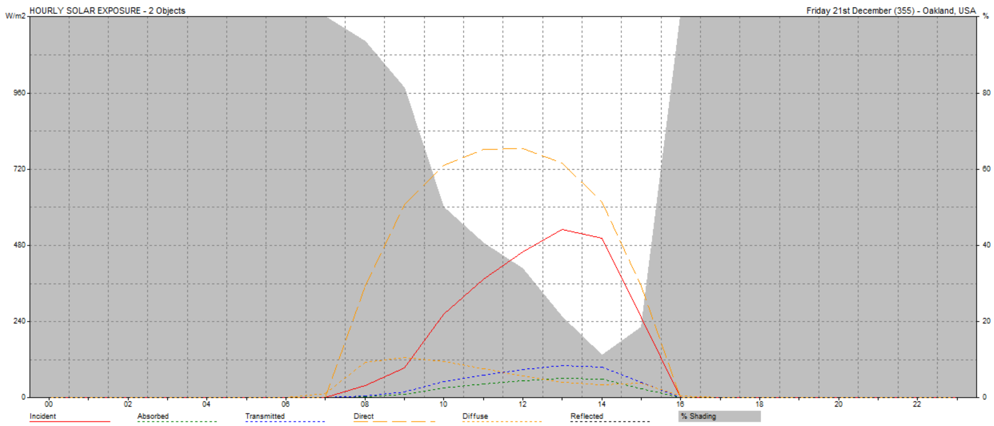


2B. WINDOW OPENINGS AND WINDOW SHADING

DIAGRAMS OF WINDOW SHADING

iii. Hourly Solar Exposure

December 21st



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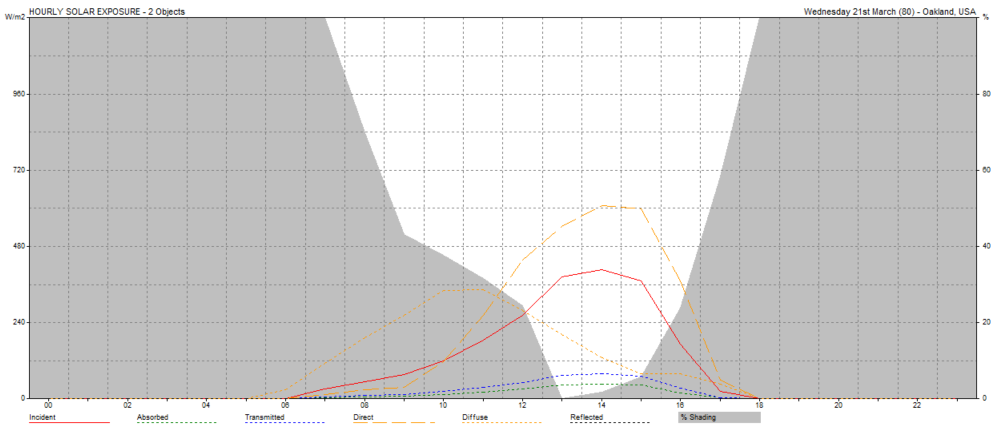

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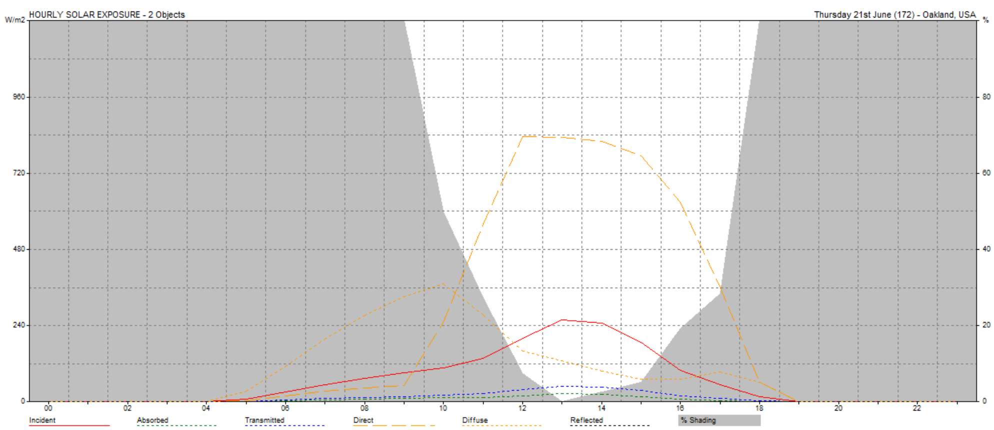
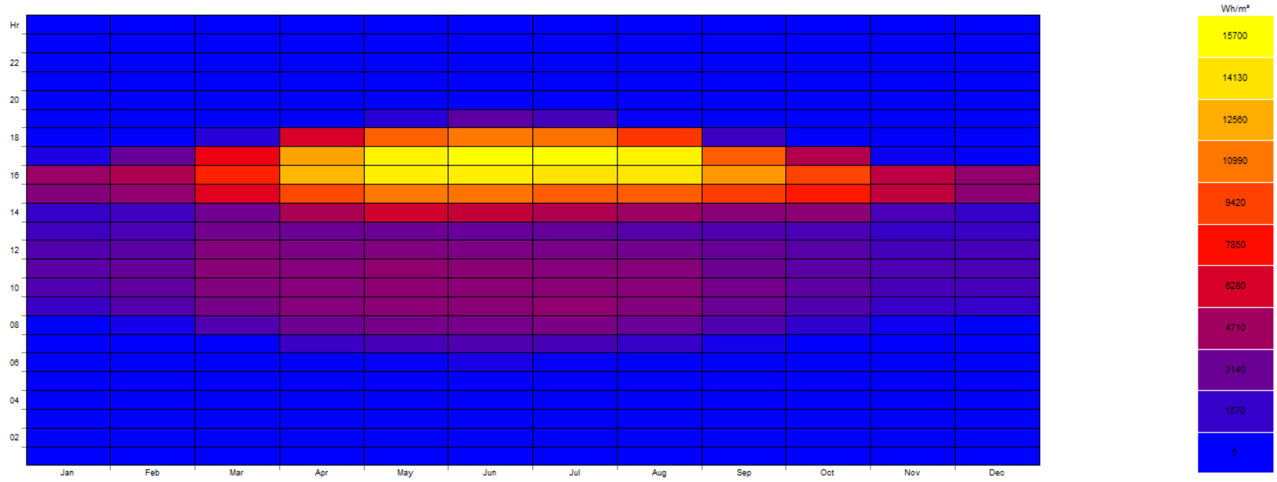


2B. WINDOW OPENINGS AND WINDOW SHADING

DIAGRAMS OF WINDOW SHADING

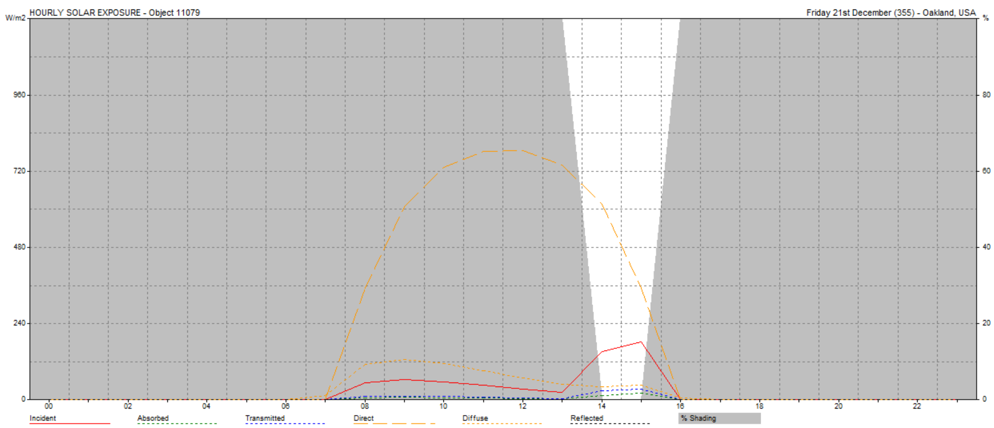
B. WEST ELEVATION

i. Annual Incident Solar Radiation



ii. Hourly Solar Exposure

December 21st



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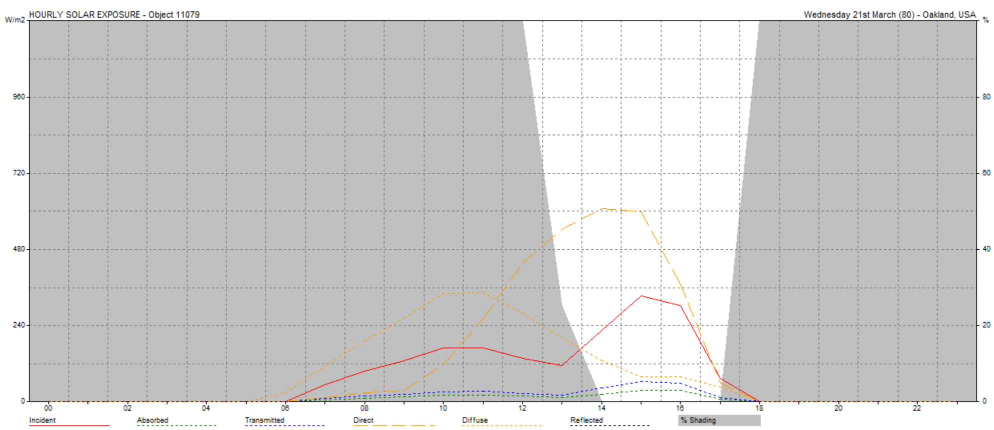
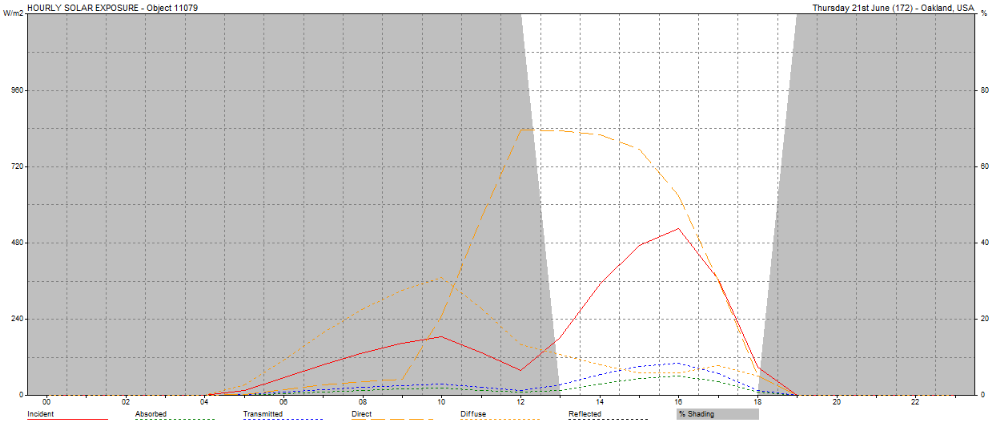


2B. WINDOW OPENINGS AND WINDOW SHADING

DIAGRAMS OF WINDOW SHADING

June 21st

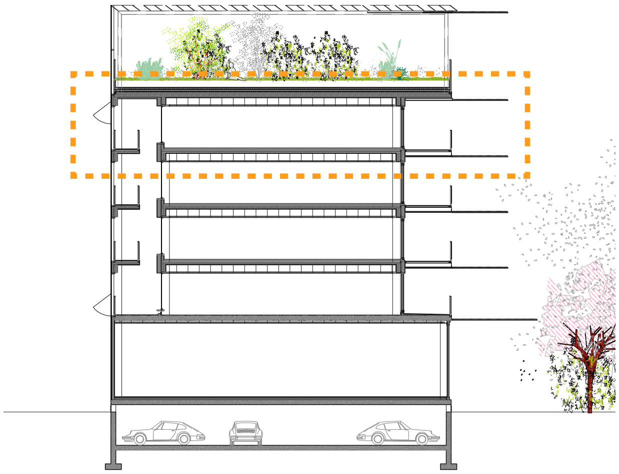


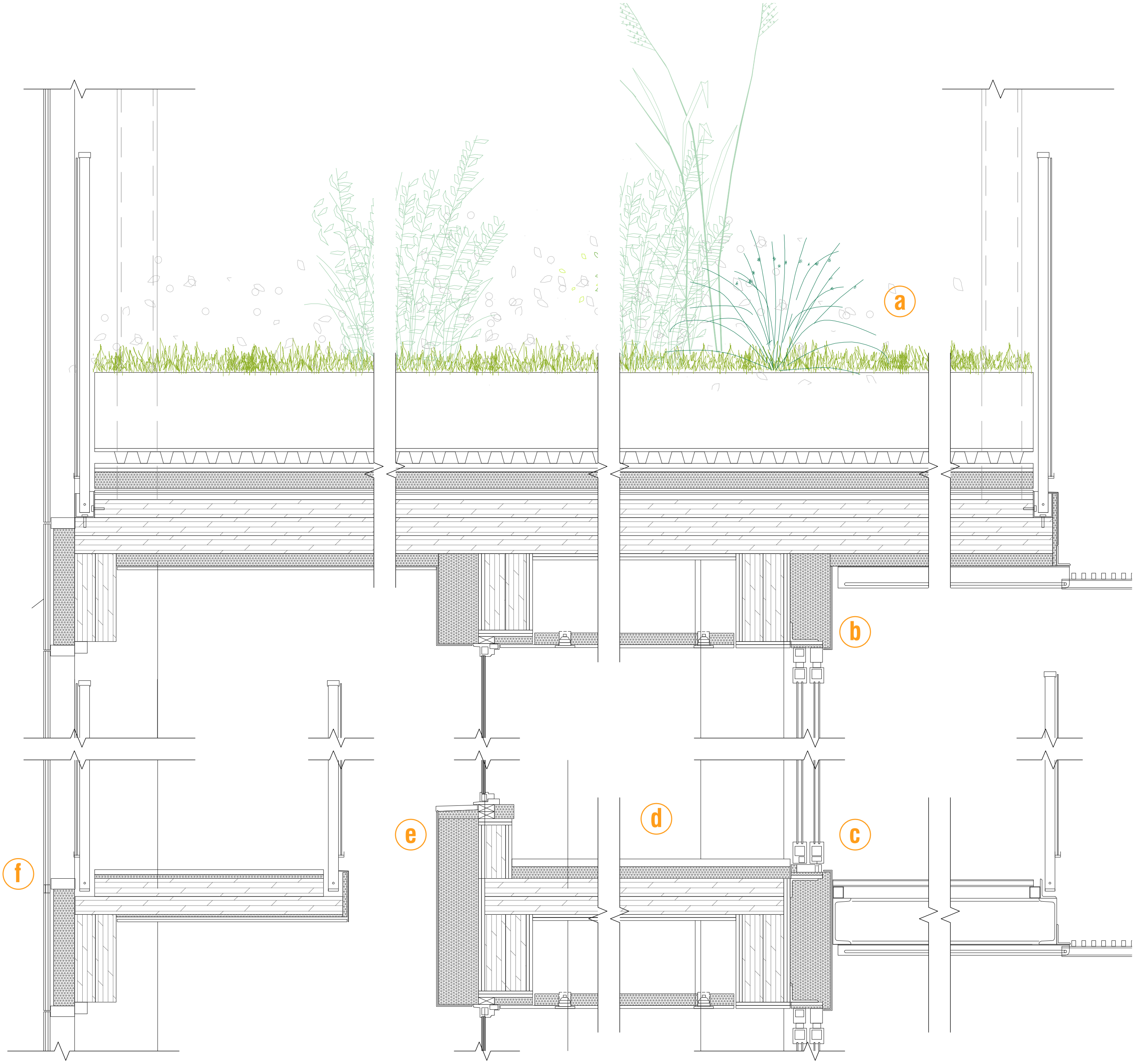
2C. BUILDING ENCLOSURE DETAILS

THERMAL BRIDGES: DETAILS

Following the Passivhaus standards, careful construction detailing is required to ensure the junctions to not create unecessary heat loss paths.
The use of external insulation provides a major advantage in reducing thermal bridges at geometric junctions. Strategic placement of insulation in and around junction details helps to reduce connection heat loss paths.

According to the standard requirements, the following details have been designed to have thermal bridges whose psi value is ≤ 0.01 W/mK.





2C. BUILDING ENCLOSURE DETAILS

THERMAL BRIDGES: DETAILS

a. Extensive green roof (U=0.10 W/m2K)
5/8” gypse suspended ceiling; mineral wool acoustic insulation, 30 mm; ceiling void, 40 mm; 2 layer 5/8” type X gypsum board; structural deck (engineered timber panels); waterproofing membrane; protection course; root barrier; drainage layer; EPS thermal insulation, 300-400 mm; aeration layer; moisture-retention layer; reservoir layer with optional aggregate; filter fabric; engineered soil with planting;
b. Window Head
c. Window Sill
d. Floor slab
Concrete floor, 50 mm, with integrated under-floor heating; separating layer; EPS thermal insulation 20 mm; mass timber structural panels; 2 layer 5/8” type X gypsum board; ceiling void, 40 mm; mineral wool acoustic insulation, 30 mm; 5/8” gypse suspended ceiling
e. Vertical external wall at corridor (U=0.14 W/m2K)
Metal panel; EPS thermal insulation, 300 mm; adhesive compound, 10 mm; mass timber vertical panels; 2 layer 5/8” type X gypsum board
f. Vertical external wall at North facade (U=0.15 W/m2K)
Curtain wall facade system of polycarbonate triple walled pannel; EPS thermal insulation, 300 mm; mass timber structure

2D. DESCRIPTION AND DIAGRAM OF WHOLE BUILDING HEATING AND COOLING SYSTEM

Several passive and active measures are used to reduce the annual needs for heating and cooling of each building. Solar gains in Winter at the South façade thanks to the optimization of glazing on the south façade (see section 2A-Window-to-Wall ratio) with reduced glazing on the North facade, usage of thermal inertia through the use of engineered timber construction, high-wall insulation of the envelope and heat recovery ventilation.

All buildings have been designed using the same energy concept. As shown on the diagram, the components of each building HVAC systems are:

A. RESIDENTIAL UNITS AND NURSERY

i. HYBRID VENTILATION SYSTEM

During hot or cold periods, a Heat Recovery system with enthalpy wheel operates (efficiency of heat recovery: 85%; electric efficiency: 0.40 W h/m^3; Average Air Flow Rate: 117 m^3/h; Average Air Change Rate: 0.30/h). Nonetheless, windows can be opened at any time. The layout of units allow a natural cross-ventilation to happen when the windows of both side of each unit (North and South) are opened, helping to reduce overheating and, consequently, the cooling energy demand.

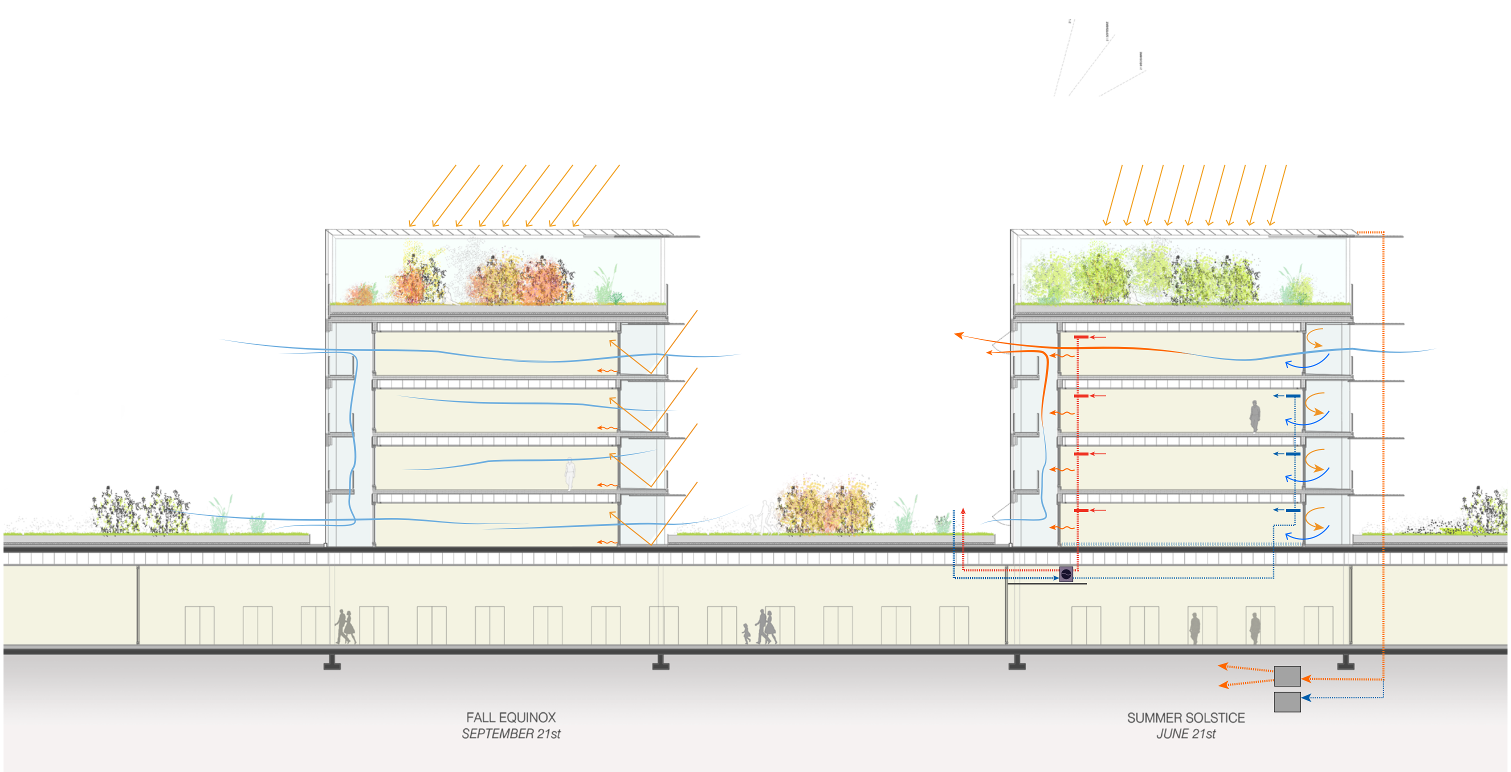
ii. HEATING/COOLING SYSTEMS

As explained before, in all but the coldest and the warmest temperatures, each building is capable of maintaining an internal temperature of 20°C solely by relying on the heat given off by appliances, occupants and solar gains. However, residential units are cooled/ heated via underfloor coils, whose demand is covered by an air-to-water heat pump. A small amount of supplementary heating and cooling will be provided also in the form of post-air heating/cooling unit in the MVHR ventilation system.

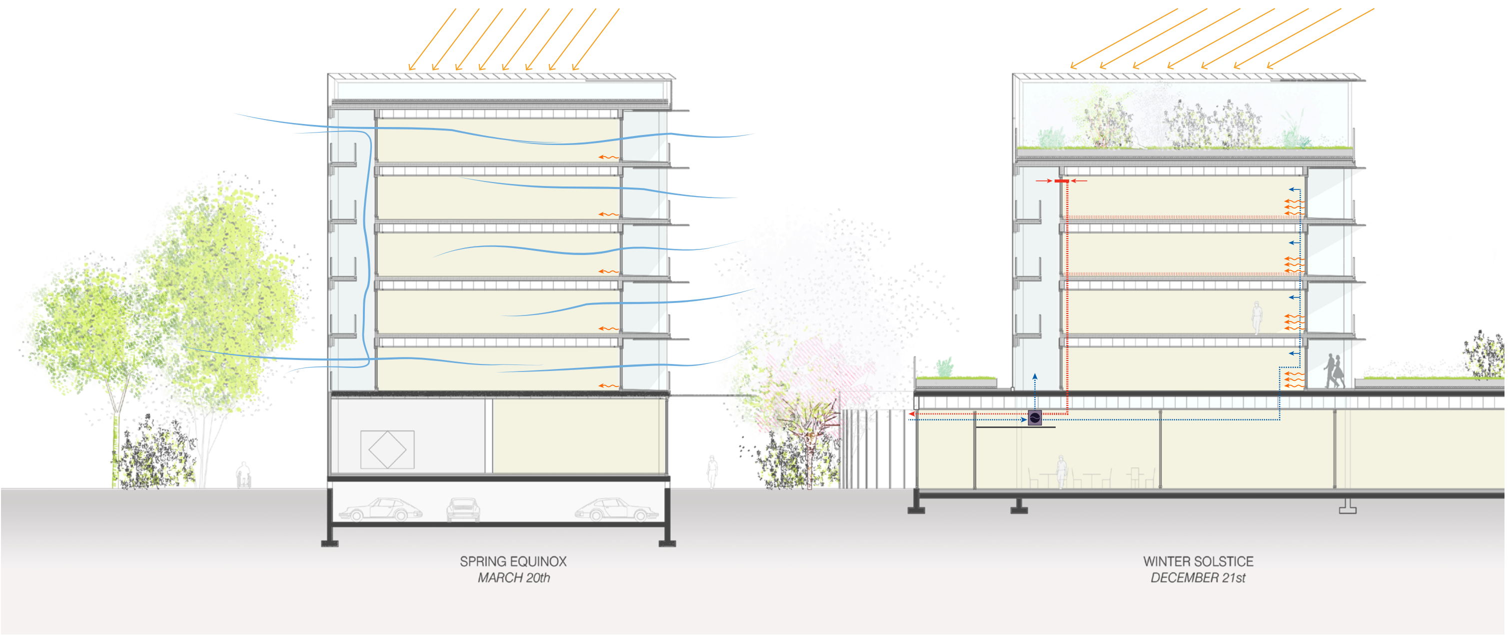
B. COMMON SPACES

Apart from the entrance at the ground floor (equipped with a ventilation system –both inlet and outlet), all common spaces (corridors, staircases, mechanical rooms, etc.) are unheated and uncooled. All corridors and staircases are located at the north side of each building and act as a double-skin (a thermal buffer) of the north façade. During summer, operable windows remain open at the bottom and at the top of the quadruple-height space. As a consequence, a chimney effect takes place allowing natural ventilation to happen. The rest of the year, when outdoor temperatures are below 15°C, fresh air is introduced through the ventilation system at the lowest floor and exhaust air is extracted at the highest point. This approach increases the R-value of the North façade and reduces the heat and the cold losses of the residential units.

For buildings M1, M2 and M3, waste heat from the refrigeration system in the ground floor grocery store is used to pre-heat fresh air used to ventilate the buildings by the heat recovery units, thus reducing the overall energy use of these three buildings.



2D. DESCRIPTION AND DIAGRAM OF WHOLE BUILDING HEATING AND COOLING SYSTEM



2E. DESCRIPTION AND DIAGRAMMATIC SKETCH OF RESIDENTIAL UNIT SYSTEMS

All residential units are equipped with the following systems:

A. HEATING/COOLING

Heat is circulated through an underfloor heating system. The same system can be used in summer for actively cooling the living spaces.

B. VENTILATION

As explained previously, residential units are ventilated by a ventilation system with heat recovery. The ventilation units are located in the mechanicals rooms at the ground level. Fresh air circulates through vertical ducts and is introduced through supply air ceiling outlets at each room. Exhaust air is extracted at the toilet. Also, units can be ventilated naturally thanks to its operable windows located at the north and the south façade. The presence of predominant winds along the southwest-northeast axis permits active cross ventilation.

C. HOT WATER

Domestic Hot Water (DHW) is provided through two different systems depending on the building the residential unit is located in:

- RESIDENTIAL UNITS IN BUILDINGS A1, A2, M4 and M5

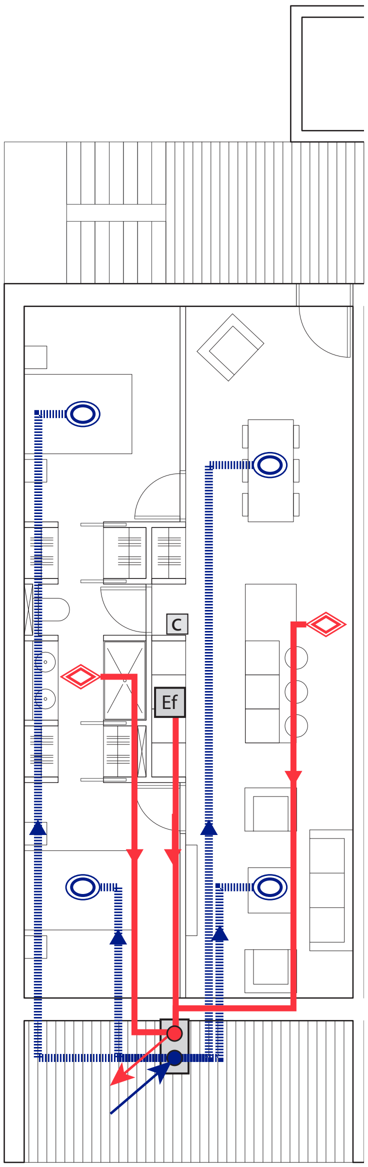
DHW is provided by the heat pump, which uses the extract air as a heat source. Hot water is kept at a hot water storage cylinder at each unit, thus reducing the amount of heat losses when circulating hot water.

- RESIDENTIAL UNITS IN BUILDINGS M1, M2 and M3

A solar hot water system installed at the roof of the parking building provides domestic hot water for these three buildings. Hot water is kept in a tank and delivered to each unit by an insulated circuit.

2E. DESCRIPTION AND DIAGRAMMATIC SKETCH OF RESIDENTIAL UNIT SYSTEMS

VENTILATION SYSTEM



C ventilation control

direction of air flow

Ef intermittent exhaust fan

balance energy-recovery ventilator ERV system

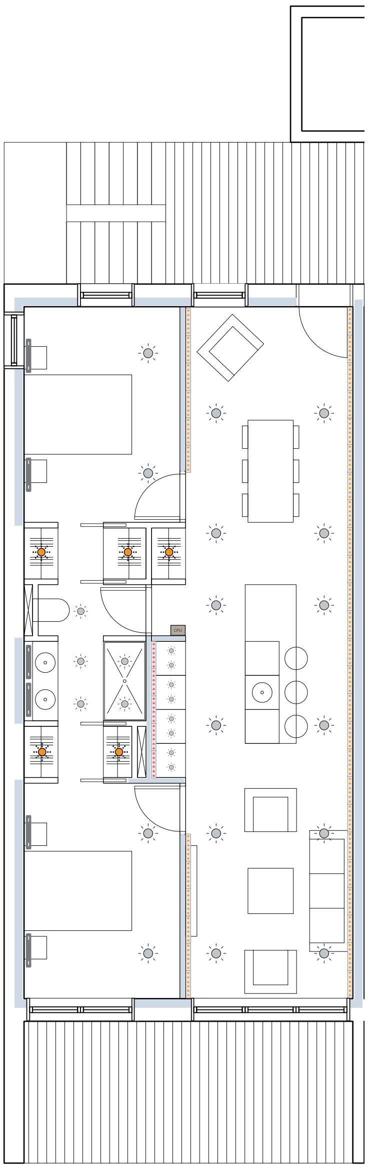
ceiling exhaust griles

ceiling supply griles

ventilation supply ducts

ventilation exhaust ducts

LIGHTING SYSTEM



LED bars recessed into floor
combination of natural white 4000°K, cool white 6000°K, and amber

LED bars recessed into ceiling
combination of natural white 4000°K, cool white 6000°K, and amber

Wall finish to reflect light

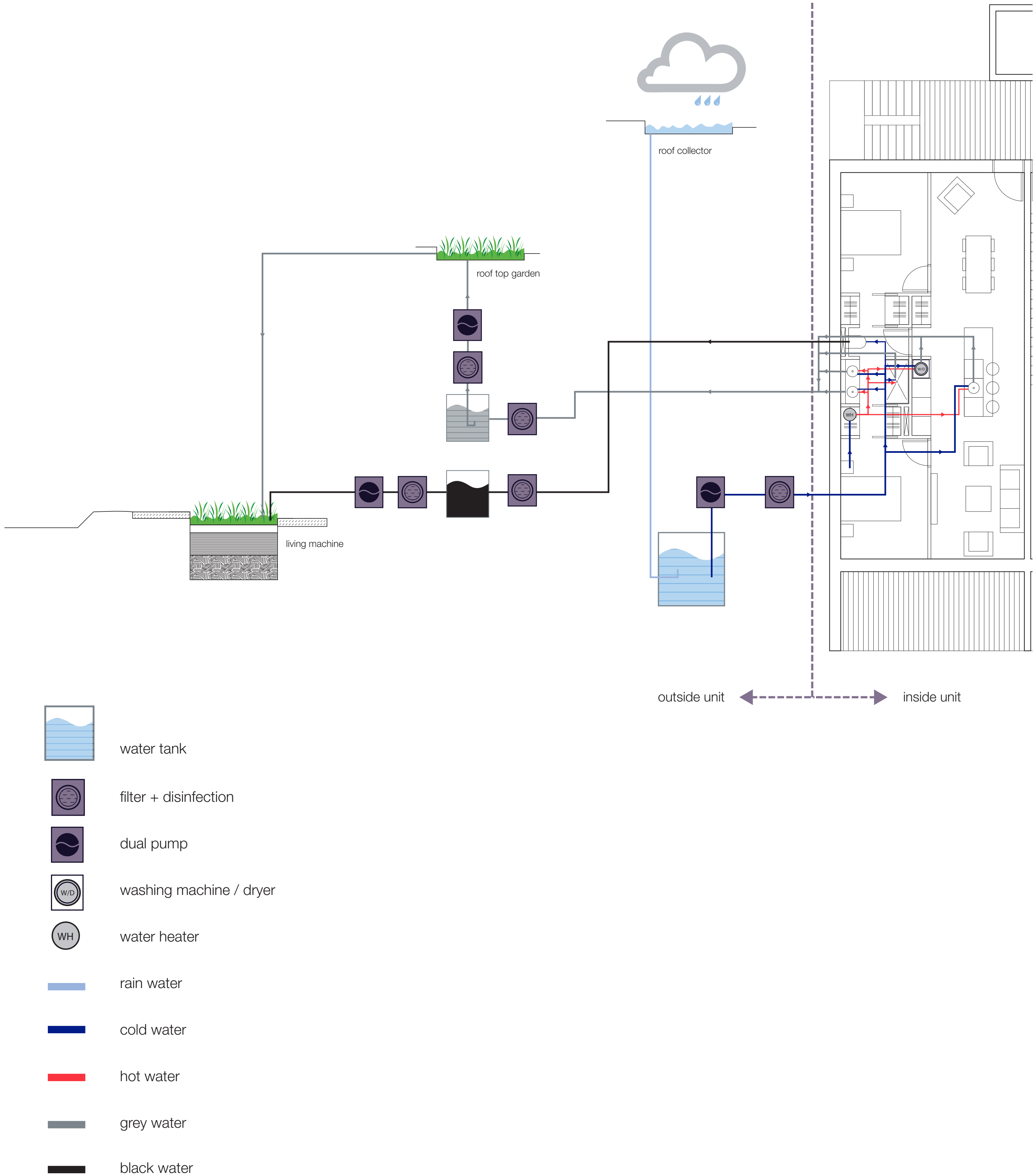
Wall mounted lighting

Recessed / indirect lighting LED

General lighting 32-watt Compact Fluorescent Light Bulb (CFL)

CPU Lighting controller according to daylight and shading devices

WATER USE SYSTEM



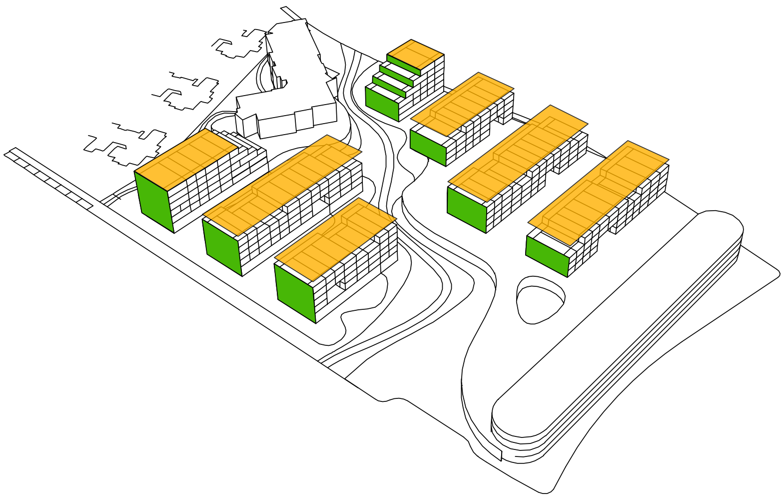
2F. RENEWABLE ENERGY

Although the requirements of PassivHaus have been taken into account all along the process, the energy demand considered for the Net Zero performance calculations follows the conclusions of the study conducted by ARUP , The Technical Feasibility of Zero Net Energy Buildings in California, which are:

High-rise Multifamily -	19.6 kBtu/sq.ft/year
Grocery -	73 kBtu/sq.ft/year
Childcare -	22 kBtu/sq.ft/year
Strip Mall -	25.6 kBtu/sq.ft/year
Grocery -	73.3 kBtu/sq.ft/year

In order to achieve the Net Zero target, two main energy production strategies have been developped:

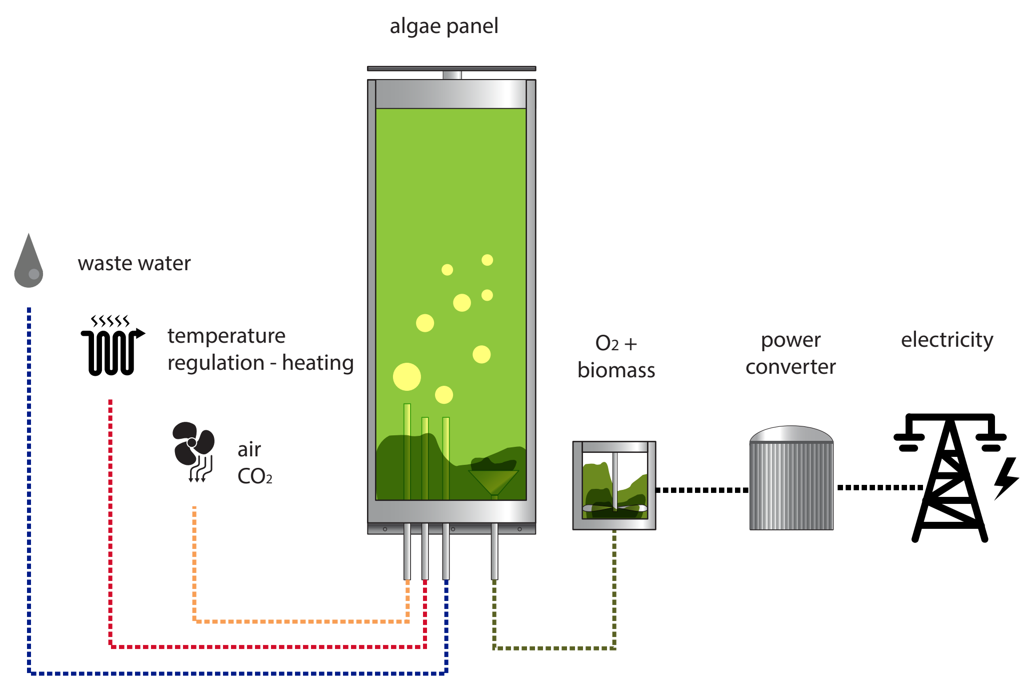
- **Microalgae System** at the east and west facades.
- **Photovoltaic System** at the roof of the buildings



MICROALGAE SYSTEM

Energy production with microalgae is dependent on the amount of sunlight, the chosen microalgae strain, the type of cultivation and type of energy. Energy production per m2 is around 49.92 kWh/m2/year (15.82 kBtu/sq.ft/year).

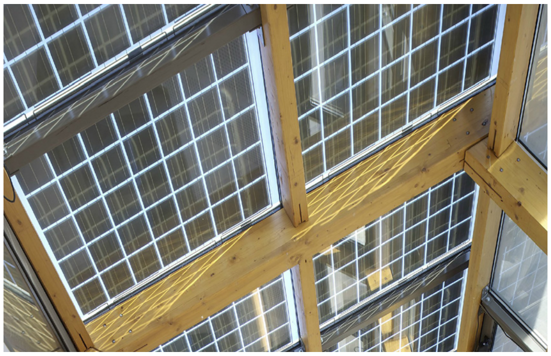
For a facade area of +/- 34,055 sq.ft, the total energy production would be 538,750.1 kBtu/year



PHOTOVOLTAIC SYSTEM

A photovoltaic laminated glass system is installed at the roof of the buildings. According to the PVWatts Calculator (National Renewable Energy Laboratory), the system performance is 4,082,900 kWh/year [13,930,854.8 kBtu/year] *

* PV System Specifications (Residential): DC System Size 2241.76 kW; module Type Premium; Array Type 1-Axis Tracking ; Array Tilt 37.8°; Array Azimuth 180°; System Losses 14%; Inverter Efficiency 96%; DC to AC Size Ratio 1.1; Ground Coverage Ratio 0.4



Source: SUNEWAT XL

ZNE PERFORMANCE ANALYSIS

		AREA [sq.ft.]	**ENERGY DEMAND** [kBtu/year]
PARCEL 1 - AFFORDABLE HOUSING	Building A1	16,162	316,775.2
	Building A2	29,805	584,178
	Childcare	13,584	298,848
	TOTAL	59,551	**1,199,801.2**
PARCEL 2 - MARKET-RATED HOUSING	Building M1	19,310	378,476
	Building M2	29,385	575,946
	Building M3	28,966	567,733.6
	Building M4	28,966	567,733.6
	Building M5	19,310	378,476
	Commercial Areas	5,318	1,806,284.8
	Grocery Store	65,240	4,782,092
	TOTAL	196,495	**9,056,742**

ENERGY PRODUCTION [kBtu/year]	
PV panels	**13,930,854.8 kBtu/year**
Microalgae	**538,750.1 kBtu/year**

CONCLUSION

Thanks to all the efficient technologies installed, the energy demand for heating, cooling and ventilation has been significantly reduced.

As a consequence, the new buildings will produce more energy than it consumes, offering the possibility to feed the surrounding buildings during peak hours. Also, electrical storage systems will be installed. giving the residents the chance to manage their energy consumption.

2G. OCCUPANT BEHAVIOR

An interface will be installed in every residential unit, which will show the residents their current energy use, the power level of the battery installation mentioned above and the current level of electricity generated by the photovoltaic installation. This device will make recommendations, so residents will know when to turn on their washing machine or dryer.

Incentives will be created as well in order to encourage occupants to reduce their energy demand. A flat rate calculated based on an average energy consumption will be established. Whenever the energy bill will stay below this threshold, the resident will receive bonus from the administration company. Going beyond this limit will have as a consequence a penalty fee. Since occupants will have access to their current energy use, possible adjustments to their demand routine will provoke an improvement in people's responsibility towards the environment.

REFERENCES

PASSIVHAUS
PHPP 2007 Demo Package

MICROALGAE SYSTEM
AETRANGERE. (2012b). Algae green loop Marina City Chicago.
Retrieved 09 october, 2014, from http://www.architizer.com/en_us/projects/view/algae_green-loop-marina-citychicago/32664/#.UdwV7Pnjd8F

Fong, Q. (2013). Algae Architecture.
Retrieved 29 july, 2014, from http://www.repository.tudelft.nl/

Growenergy. (2013). One Techonology, Unlimited Possibilities.
Retrieved 06 october, 2014, from https://www.growenergy.org/research/

Sciencedaily. (2013b). Engineering Algae to Make the 'Wonder Material' Nanocellulose for Biofuels and More.
Retrieved 8 apirl, 2013, from http://www.sciencedaily.com/releases/2013/04/130407132938.htm

Wallis, D. (2013). When algae on the exterior is a good thing.
Retrieved 12 may, 2013, from http://www.nytimes.com/2013/04/25/business/energy-environment/german-building-uses-algae-forheating-and-cooling.html?pagewanted=all&_r=0

Wurm, J. (2012). Photobioreactors as adaptive shading devices.
Retrieved 02 october, 2014, from:
http://smartgeometry.org/index.php?option=com_content&view=article&id=154:photobioreactors-asadaptive- shading-devices&catid=45:sgarticles&Itemid=160
http://www.iba-hamburg.de/en/themes-projects/the-building-exhibition-within-the-buildingexhibition/smart-material-houses/biq/projekt/biq.html