NEIGHBORHOOD DESIGN GOAL

harmony with immediate context

connectivity with the surrounding neighborhood

accommodating social and economic interaction
PERFORMANCE DESIGN GOAL

Buildings live in average 50 – 100 years

Natural ventilation in current time and 2080

Solar electricity production
PROTOBLOCK EVOLUTION

REFERENCE BLOCK
Courtyard typology
3-4 Stories.
Mainly residential.
FAR: 2

FIRST PROTOBLOCK
Courtyard typology
Mixed buildings.
FAR: 4.5

FINAL PROPOSAL
Courtyard typology
5-12 Stories.
Mixed buildings.
FAR: 3
NEIGHBORHOOD DESIGN

- Bus Stations
- Main and Secondary Streets
- Bikes
- Garden Path
- Central Park
- Bazar / Market
- Water Front
- Railway and Highway Facing Blocks
Based on Adaptive Comfort Model
92% of the year Natural Ventilation is Possible
Based on Adaptive Comfort Model
92% of the year Natural Ventilation is Possible
NATURAL VENTILATION

Horizontal section of **North-South** facing building

Horizontal section of **East-West** facing building
NATURAL VENTILATION

Windward

A

Leeward

B

Air flowrate: 0.2 m³/s
Opening to Wall ratio: 1%

Wind Driven

Buoyancy Driven

C

Air flowrate: 0.4 m³/s
Opening to Wall ratio: 7%

Wind + Buoyancy Driven
NATURAL VENTILATION

Wind Driven Natural Ventilation Potential
Pressure Coefficient Distribution Map

Lower CP difference between opposite sides
Lower potential for ventilation
NATURAL VENTILATION

Wind Driven Natural Ventilation Potential
Pressure Coefficient Distribution Map

Higher CP difference between opposite sides
Higher potential for ventilation
Façade PV (electricity production)

Façade PV (air preheating and electricity production)

Causes overheating  Causes overheating

Effective for NV
Minimum air gap between PV and facade-30 cm

Minimum air gap between PV and facade-15 cm

PV
Air Gap
**NATURAL VENTILATION + PV METRIC**

**Façade PV**
(air preheating and electricity production)

South and East Facade

<table>
<thead>
<tr>
<th>Season</th>
<th>Outdoor Air Condition</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warm</td>
<td>Direct outdoor air for NV</td>
<td>21.5, 23.0</td>
</tr>
<tr>
<td>Cold</td>
<td>Preheated outdoor air for NV</td>
<td>14.0, 20.3</td>
</tr>
</tbody>
</table>

**Temperature(°C)**

50 42 34 26 18 10
Roof Top PV (electricity production)

178 kWh/m²/year
75% of horizontal rooftop

Façade PV (air preheating and electricity production)

130 kWh/m²/year
1/3rd of South and East Facades

Façade PV (electricity production)

70 kWh/m²/year
South and East Facades
**NATURAL VENTILATION + PV METRIC**

**SCORE CARD**

PV Score

NV Score

PV+NV Score

PV Score = \( \frac{\text{PV Electricity Production}}{\text{Total EUI}} \)

NV Score = \( \frac{\text{Naturally Ventilated Hours}}{\text{Comfortable Hours}} \)

PV+NV Score = \( \frac{\text{PV Score}}{\text{NV Score}} \)

**%**

PV Production/ EUI

% Naturally Ventilated Hrs/ Comfort Hrs

% Average (NV Score, PV Score)

**Naturally Ventilated Hours are considered for times which are within adaptive comfort model.**

Current: outdoor temperature is between 18 and 26.5°C.

2080: outdoor temperature is between 19 and 27.5°C.
Regulations: Natural Ventilation and PV

Prescriptive

For Naturally Ventilated Buildings

Indoor temperature range 18°C - 27°C.

Minimum opening to wall ratio:
- North and West facade is 1%.
- South and East facade is 5%.

Overheated hours should not exceed 20% of the year or 1750 hrs.

For All Buildings

No PV panels on first and second floors.

Crystalline Silicon PV (c-Si) used for preheating ventilation air
- Maximum coverage 30% of façade
- Minimum air gap 30cm from façade.

Crystalline Silicon PV (c-Si) used only for electricity
- Minimum air gap 15cm from façade.
Amorphous Silicon (a-Si) PV panels can be installed on the first and second floors if annual solar radiation is above 1000 kWh/m²/year.

Minimum opening to wall ratio:

North and West facade can be lower than 1% if:
- Airflow rate is 0.2 m³/s
- Air speed is lower than 0.8 m/s

South and East facade can be lower than 5% if:
- Airflow rate is 0.4 m³/s
- Air speed is lower than 0.8 m/s
92% of the year Natural Ventilation is Possible

84% of the year Natural Ventilation is Possible
New schedule based on design for natural ventilation and solar energy use

Heating load reduced by using pre-heated air with building integrated PV panels

Cooling load reduced by using natural ventilation majority of the time.

Comfortable hours are improved.
ENERGY USE INTENSITY

BASE CASE

<table>
<thead>
<tr>
<th></th>
<th>CURRENT</th>
<th>2080</th>
</tr>
</thead>
<tbody>
<tr>
<td>OVER HEATED HOURS</td>
<td>2,800 hrs</td>
<td></td>
</tr>
<tr>
<td>TOTAL EUI</td>
<td>69 kWh/m²</td>
<td></td>
</tr>
<tr>
<td>COOLING LOAD</td>
<td>0 kWh/m²</td>
<td></td>
</tr>
<tr>
<td>HEATING LOAD</td>
<td>1 kWh/m²</td>
<td></td>
</tr>
</tbody>
</table>

PROPOSED USE PROFILE

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>OVER HEATED HOURS</td>
<td>1,270 hrs</td>
<td></td>
</tr>
<tr>
<td>TOTAL EUI</td>
<td>78 kWh/m²</td>
<td></td>
</tr>
<tr>
<td>COOLING LOAD</td>
<td>10 kWh/m²</td>
<td></td>
</tr>
<tr>
<td>HEATING LOAD</td>
<td>0 kWh/m²</td>
<td></td>
</tr>
</tbody>
</table>
## Energy Use Intensity

### Current

<table>
<thead>
<tr>
<th>Base Case</th>
<th>Over Heated Hours</th>
<th>Total EUI</th>
<th>Cooling Load</th>
<th>Heating Load</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2,800 hrs</td>
<td>69 kWh/m²</td>
<td>0 kWh/m²</td>
<td>1 kWh/m²</td>
</tr>
</tbody>
</table>

### 2080

<table>
<thead>
<tr>
<th>Scenario 1 (no cooling system)</th>
<th>Over Heated Hours</th>
<th>Total EUI</th>
<th>Cooling Load</th>
<th>Heating Load</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4,300 hrs</td>
<td>68 kWh/m²</td>
<td>0 kWh/m²</td>
<td>0 kWh/m²</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scenario 2 (cooling system)</th>
<th>Over Heated Hours</th>
<th>Total EUI</th>
<th>Cooling Load</th>
<th>Heating Load</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 hrs</td>
<td>99 kWh/m²</td>
<td>31 kWh/m²</td>
<td>0 kWh/m²</td>
</tr>
</tbody>
</table>

### Proposed Use Profile

<table>
<thead>
<tr>
<th>Proposed Use Profile</th>
<th>Over Heated Hours</th>
<th>Total EUI</th>
<th>Cooling Load</th>
<th>Heating Load</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1,270 hrs</td>
<td>78 kWh/m²</td>
<td>10 kWh/m²</td>
<td>0 kWh/m²</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scenario 3 (hybrid natural ventilation and cooling system)</th>
<th>Over Heated Hours</th>
<th>Total EUI</th>
<th>Cooling Load</th>
<th>Heating Load</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>650 hrs</td>
<td>90 kWh/m²</td>
<td>21 kWh/m²</td>
<td>0 kWh/m²</td>
</tr>
</tbody>
</table>
sDA - 36%
(200 lux)

**Functional Distribution:**
Upper levels are prioritized for office spaces.
Functional Distribution: Upper levels are prioritized for office spaces.

Building Depth: 12m - 18m
Neighborhood Embodied CO₂
102 kg CO₂/m²

Neighborhood Embodied Energy
1152 kWh/m²
WALKABILITY

Existing Amenities around Project Site
Walkability Score: 8
With Proposed Amenities on Project Site

Overall Walkability Score: 58
Project Site Walkability Score: 85
FINANCIAL PERFORMANCE

PV INVESTMENT COST: $345/M²*

Roof Top PV
Payback time: **11 years**

Façade c-Si PV (air preheating and electricity production)
Payback time: **15 years**

Façade a-Si PV (electricity production)
Payback time: **28 years**

*Verberne et al, 2014

OVER ALL FINANCIAL PERFORMANCE

ROI (Return of Investment)
- Without daylight premium: 10%
- With daylight premium: 14%
OUTDOOR COMFORT

Summer - August
- Outdoor Temp: 31°C
- Global Radiation: 850Wh/sq.m
Result: Strong Heat Stress

Shoulder Season - April
- Outdoor Temp: 20°C
- Global Radiation: 680Wh/sq.m
Result: No thermal Stress

Winter - December
- Outdoor Temp: 14°C
- Global Radiation: 450Wh/sq.m
Result: No thermal Stress

Buildings create shading for comfortable outdoor walkways.

Summer average hottest hour - August
**CURRENT TIME**

<table>
<thead>
<tr>
<th>PV Score</th>
<th>NV Score</th>
<th>PV+NV Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 %</td>
<td>100 %</td>
<td>58 %</td>
</tr>
</tbody>
</table>

**PV PRODUCTION/ EUI**  
15 %  

**NATURALLY VENTILATED HRS/ COMFORT HRS**  
100 %  

**IMPORTANCE WEIGHT**  
Similar importance weight is given for natural ventilation and PV electricity production.
Similar importance weight is given for natural ventilation and PV electricity production.

2080

13% PV production/EUI (importance weight - 1)
86% Naturally ventilated hrs/comfort hrs (importance weight - 2)
62% Average score of natural ventilation and PV production

NV-PV Score:
\[
\frac{(PV \text{ Score} \times PV \text{ Importance weight}) + (NV \text{ Score} \times NV \text{ Importance weight})}{\text{Total weight}}
\]
### PVent Lisbon

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land area (m²)</td>
<td>243,500</td>
</tr>
<tr>
<td>Building area (m²)</td>
<td>390,000</td>
</tr>
<tr>
<td>Residents (pp/m² land)</td>
<td>0.029</td>
</tr>
<tr>
<td>Workers (pp/m² land)</td>
<td>0.055</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>kWh/m²y</td>
<td>82</td>
</tr>
<tr>
<td>kWh/m²</td>
<td>1152</td>
</tr>
<tr>
<td>kgCO₂/m²</td>
<td>795</td>
</tr>
<tr>
<td>% DA</td>
<td>36</td>
</tr>
<tr>
<td>% WS</td>
<td>85</td>
</tr>
<tr>
<td>% ROI</td>
<td>14</td>
</tr>
</tbody>
</table>

**Operation Energy**

**Embodied Energy (50y)**

**Building GHG Emissions (50y)**

**Daylight Area**

**Walkability Score**

**Financial Return (1y)**
Lisbon’s Mediterranean climate has good potential for natural ventilation.

Current Climate: **92%** of the year (overheated hours 690 hrs)

2080: **80%** of the year (overheated hours 1380 hrs)

Current buildings to consider increased cooling loads in changed climate

Current Cooling Load: **10kWh/m²**

2080: **20kWh/m²**

BIPV can be used to preheat air in Winter

Heating Load Reduced to **0kWh/m²** during sunshine hours
OBRIGADO!