

SUSCITY Project

Designing Sustainable Cities

Professor Paulo Ferrão (IST)

Professor John E. Fernández (MIT)

André Pina, PhD

Khadija Benis

Merav Gazit

André Malan

Claudia Sousa Monteiro

Melina Philippou

Irmak Turan

Rui Ximenes



September 29, 2015

OUTLINE

1. OVERVIEW
2. DATA
3. BUILDING ARCHETYPES
4. ENERGY MODEL
5. MODELING URBAN FLOWS
6. U-MIRA TOOL

1. OVERVIEW

GOALS

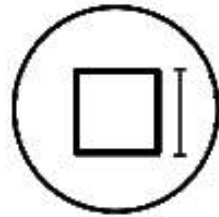
Characterize
residential resource consumption
at the neighborhood scale

+

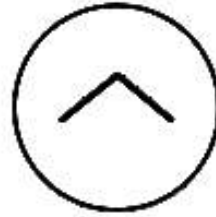
Develop a tool to
visualize and communicate
material & energy stock and flows

2. DATA

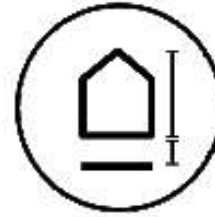
GEOMETRY



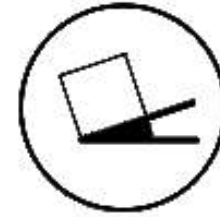
aspect ratio



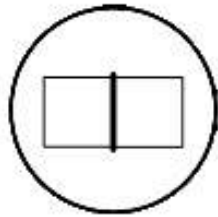
roof types



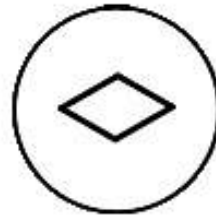
**facade height
total height**



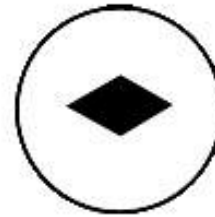
orientation



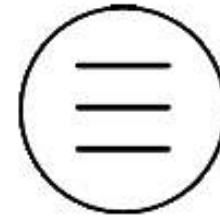
**party wall
length**



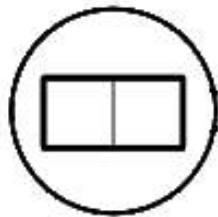
**footprint
perimeter**



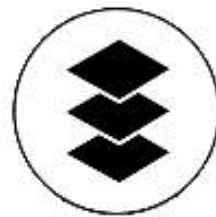
footprint area



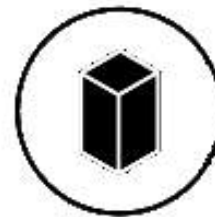
number of floors



**party wall
length**



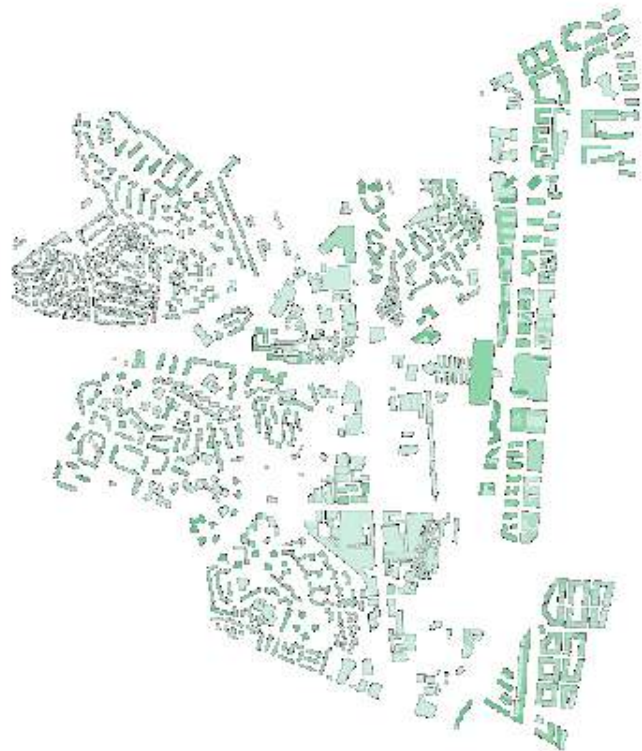
construction area



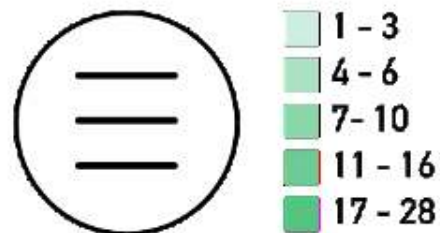
volume



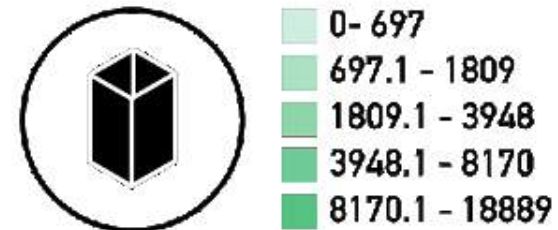
surface area



number of floors



surface area (m2)





street address



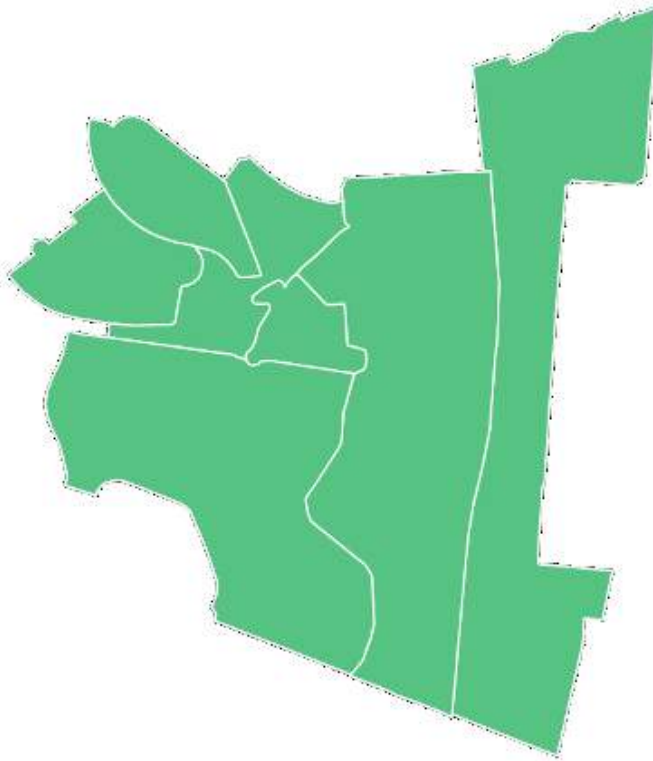
BGR11



sus city neighbourhood



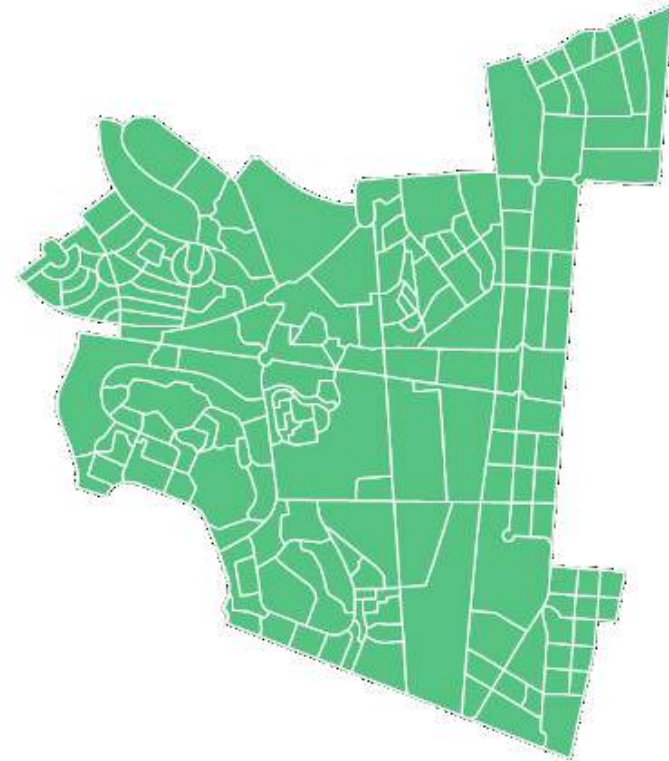
freguesia



SusCity neighborhoods



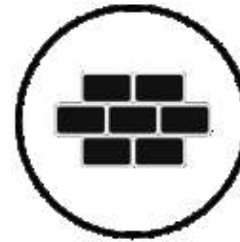
- / Area Subject to Urban Planning
- / Encarnacao
- / Not Planned Area
- / Olivais Sul
- / Olivais Velho
- / Parque das Nações
- / Olivais Norte



CENSUS 2011 subsector



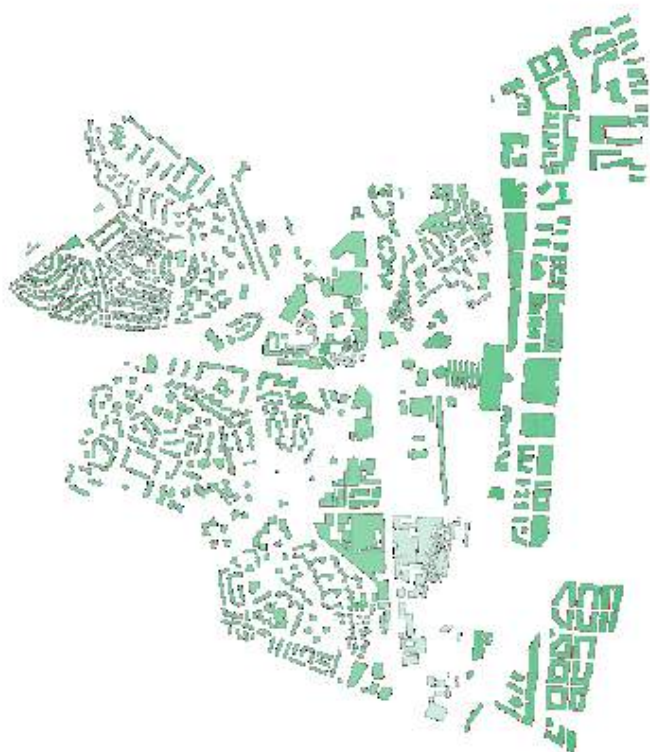
TIME



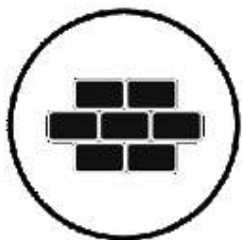
period of construction



year of renovation



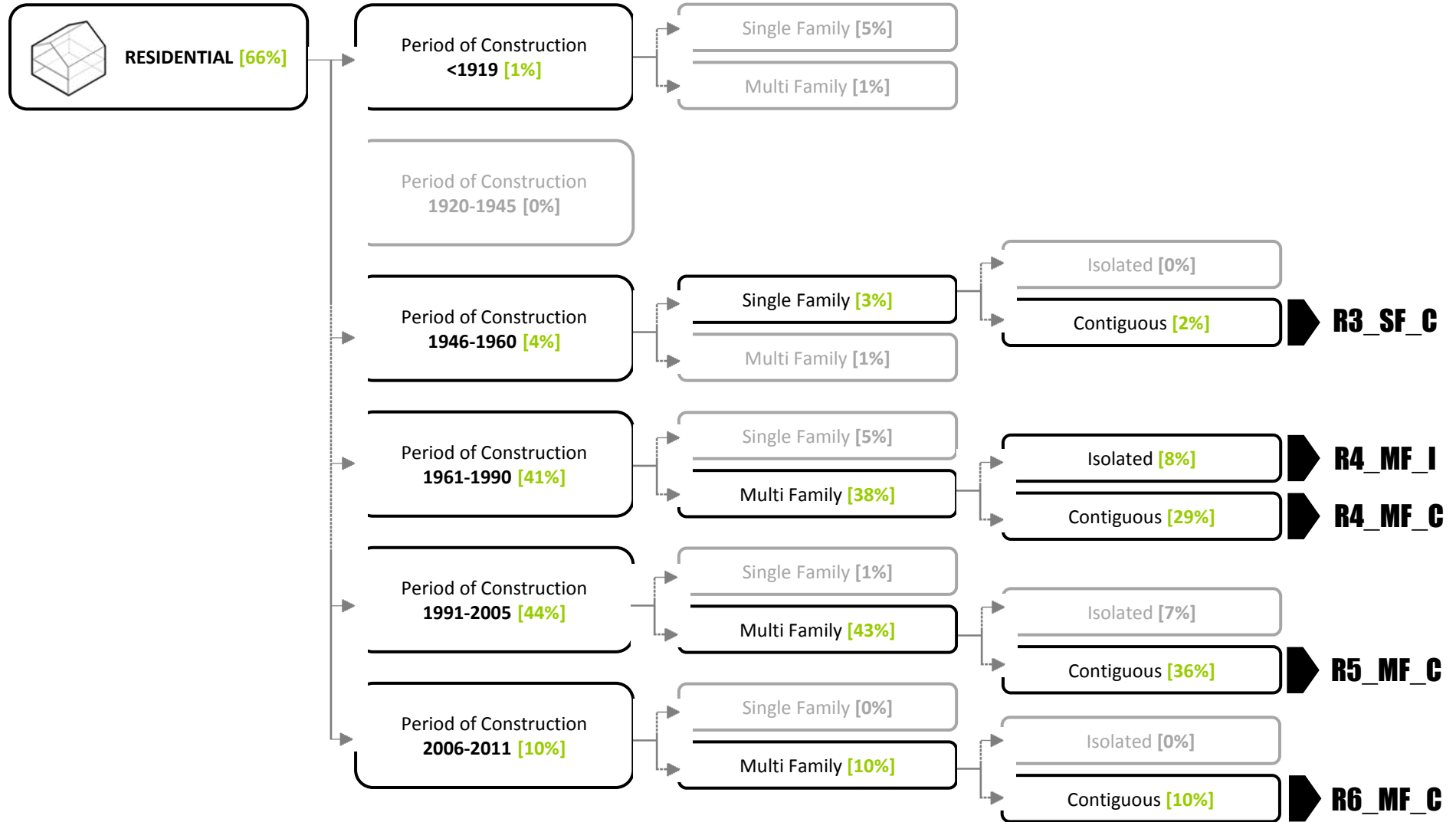
period of construction



- 1919
 - 1946_1960
 - 1961_1990
 - 1991_2005
 - 2006_2011
-

3. BUILDING ARCHETYPES

BUILDING ARCHETYPES



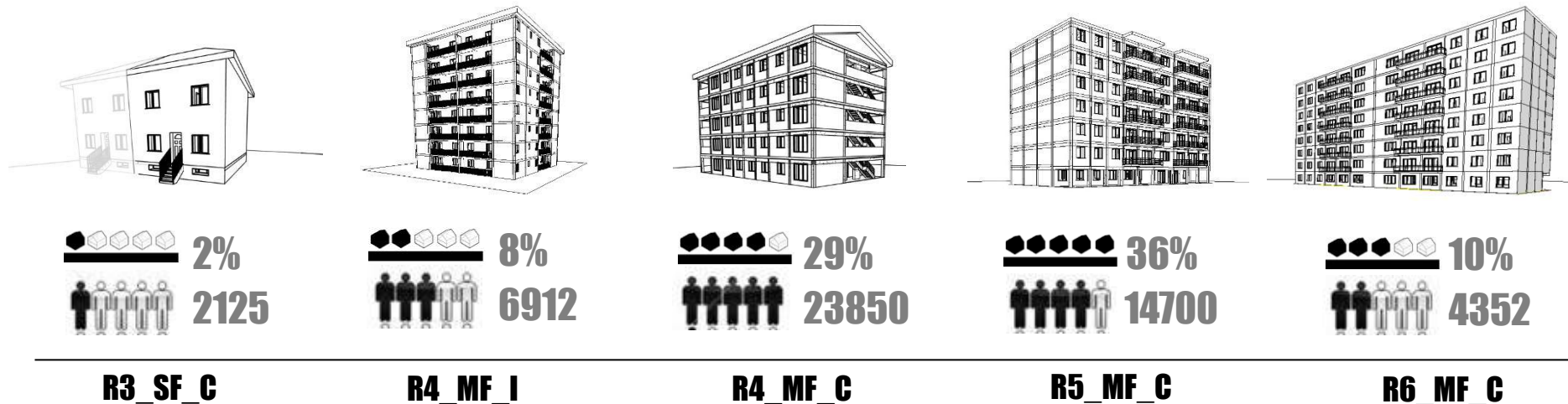
86% Constructed area

BUILDING ARCHETYPES



	Parameters	R3_SF_C	R4_MF_I	R4_MF_C	R5_MF_C	R6_MF_C
GENERAL	Location	I1V2	I1V2	I1V2	I1V2	I1V2
	Main Use	Residential	Residential	Residential	Residential	Residential
	Prd Construction	1946-1960	1961-1990	1961-1990	1991-2005	2006-2011
	Frequency (based on area)	2%	8%	29%	36%	10%
	Nr Buildings	425	72	477	175	34
	Occupants/building	5	96	50	84	128
	Occupants	2125	6912	23850	14700	4352
GEOMETRY	Bld Size-Class	Single-Family	Multi-Family	Multi-Family	Multi-Family	Multi-Family
	Neighboring	Contiguous	Isolated	Contiguous	Contiguous	Contiguous
	Nr. Dwellings	1	32	20	21	32
	Nr. Rooms/dwelling	4	2	2-3	3	3
	Nr. Floor	2	8	5	7	8
	Lenght (Avg)	9,2	21	23	31	43
	Width (Avg)	6,9	18	12,5	17	15
	Footprint Area (Avg)	62,5	332	241	604	809
	Constructed Area (Avg)	133,2	2693	1422	4792	6326
	Floor-to-floor	3	2,7	2,72	3	3
	Floor-to-ceiling	2,8	2,5	2,5	2,8	2,5
	Volume (Avg)	412	8101	4269	14347	19003
	Façade (Surface) Area (Avg)	212	1937	1202	2669	3179
	Shape-Factor (S/V)	0,54	0,25	0,31	0,22	0,22
	WWR	0	0	0	0	0
Angle	68	90	102	54	44	
CONSTRUCTION	Façade (U-value)	2,05	1,1	1,1	0,5	0,46
	Roof (U-value)	3,8	1,5	2,4	0,55	0,55
	Interior Floor (U-value)	1,2	1,3	2,4	0,85	0,85
	Ground Floor	-	-	-	-	-
	Partitions (U-value)	1,7	1,18	1,48	0,62	0,62
	Windows (U-value)	4,3	5,2	5,2	2,9	2,9
	Shading (shading factor)	0,07	0,07	0,07	0,07	0,07

BUILDING ARCHETYPES



BIM

Building Information Modeling



BUILDING ARCHETYPES

MODEL INPUTS



CATEGORY	FAMILY	Material	Thick (m)	R (m2.K/W)	k (W/mK)	c _p (J/kg.K)	ρ (kg/m3)	Therm. ε	Solar α	Visual α
Superstructure	Rectangular Footing	Concrete	0,8	0,028	1	840-2078	2400-2498	0,92-0,97	-	-
	Rectangular Beams	Concrete	0,4	0,028	1	840-2078	2400-2498	0,92-0,97	-	-
	Rectangular Columns	Concrete	0,3	0,028	1	840-2078	2400-2498	0,92-0,97	-	-



CATEGORY	FAMILY	Material	Thick (m)	R (m2.K/W)	k (W/mK)	c _p (J/kg.K)	ρ (kg/m3)	Therm. ε	Solar α	Visual α
Floor	Interior Floor	Ceramic tiles	0,02	0,015	1,5	745	2000	-	-	-
		Reinforced Concrete slab	0,08	0,021	2	840-2078	2400-2498	0,92-0,97	-	-
		Hollow Brick Blocks	0,08	0,248	0,41	745-2078	2000-2498	0,92	-	-
		Finishing - plaster	0,02	0,028	0,5	-	-	0,97	-	-
	Ground Floor	Ceramic tiles	0,02	0,015	1,5	745	2000	-	-	-
		Reinforced Concrete Slab	0,25	0,073	1	840-2078	2400-2498	0,92-0,97	-	-
		Damp-Proofing	0,005	0,007	1,13	580	<2300	-	-	-
		Floor Concrete	0,1	0,021	1,85	840-2078	2400-2498	0,92-0,97	-	-
		Gravel	0,1	0,028	2	-	2700-2800	-	-	-



CATEGORY	FAMILY	Material	Thick (m)	R (m2.K/W)	k (W/mK)	c _p (J/kg.K)	ρ (kg/m3)	Therm. ε	Solar α	Visual α
Walls	Exterior Walls	Finishing - cement coating	0,02	0,028	0,5	1,000	2000	0,97	0,4	-
		Hollow Brick Wall	0,25	0,028	0,41	840-2078	2400-2498	0,92	-	-
		Air Gap - cavity no insulation	0,04	0,25	0,000	1000	1,00	-	-	-
		Hollow Brick Wall	0,11	0,028	0,41	840-2078	2400-2498	0,92	-	-
		Stucco	0,02	0,028	0,5	-	-	0,97	-	-
	Interior Walls	Stucco	0,02	0,028	0,5	-	-	0,97	-	-
		Hollow Brick	0,25	0,028	0,41	840-2078	2400-2498	0,92	-	-
		Stucco	0,02	0,028	0,5	-	-	0,97	-	-



CATEGORY	FAMILY	Material	Thick (m)	R (m2.K/W)	k (W/mK)	c _p (J/kg.K)	ρ (kg/m3)	Therm. ε	Solar α	Visual α
Roof	Sloped Roof	Clay Ceramic Tiles	0,02	0,015	1,5	840-2078	2400-2498	0,92-0,97	-	-
		Damp-Proofing	0,005	0,007	1,13	580	<2300	-	-	-
		Floor Concrete	0,04	0,024	1,85	840-2078	2400-2498	0,92-0,97	-	-
		Reinforced Concrete slab	0,08	0,021	1	840-2078	2400-2498	0,92-0,97	-	-
		Hollow Brick Blocks	0,08	0,248	0,41	840-2078	2400-2498	0,92	-	-
Stucco	0,02	0,028	0,5	-	-	0,97	-	-		

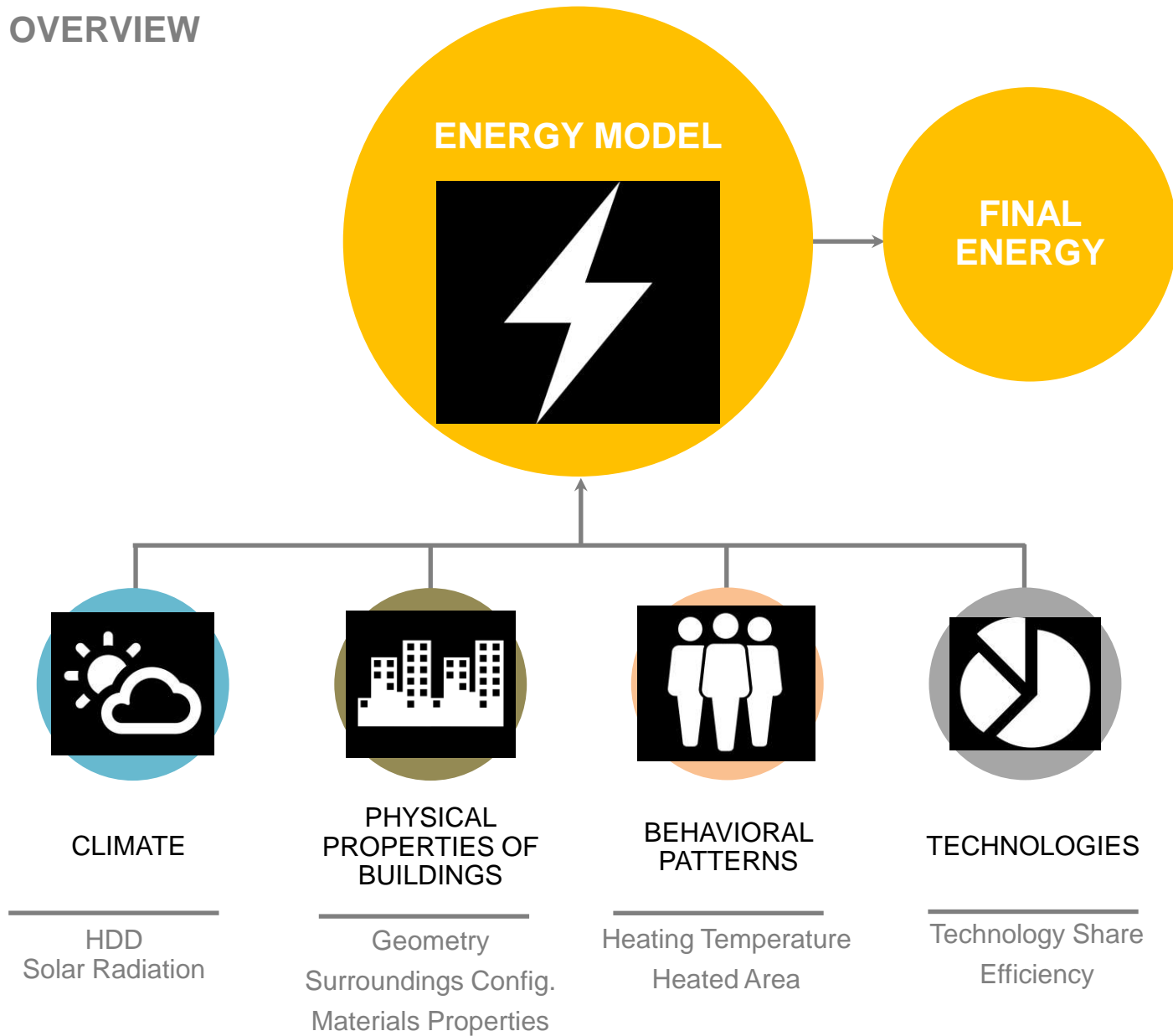


CATEGORY	FAMILY	Material	Frame Type	Solar Factor*	Glass Transmittance*	Color	Break(Y/N)	AreaRatio (%)	Operable (Y/N)
Window	Aluminium Window	Single Glazing (Clear)	Aluminium Frame	0,25	0,8	neutral	N	50	Y

4. ENERGY MODEL

ENERGY MODEL

OVERVIEW

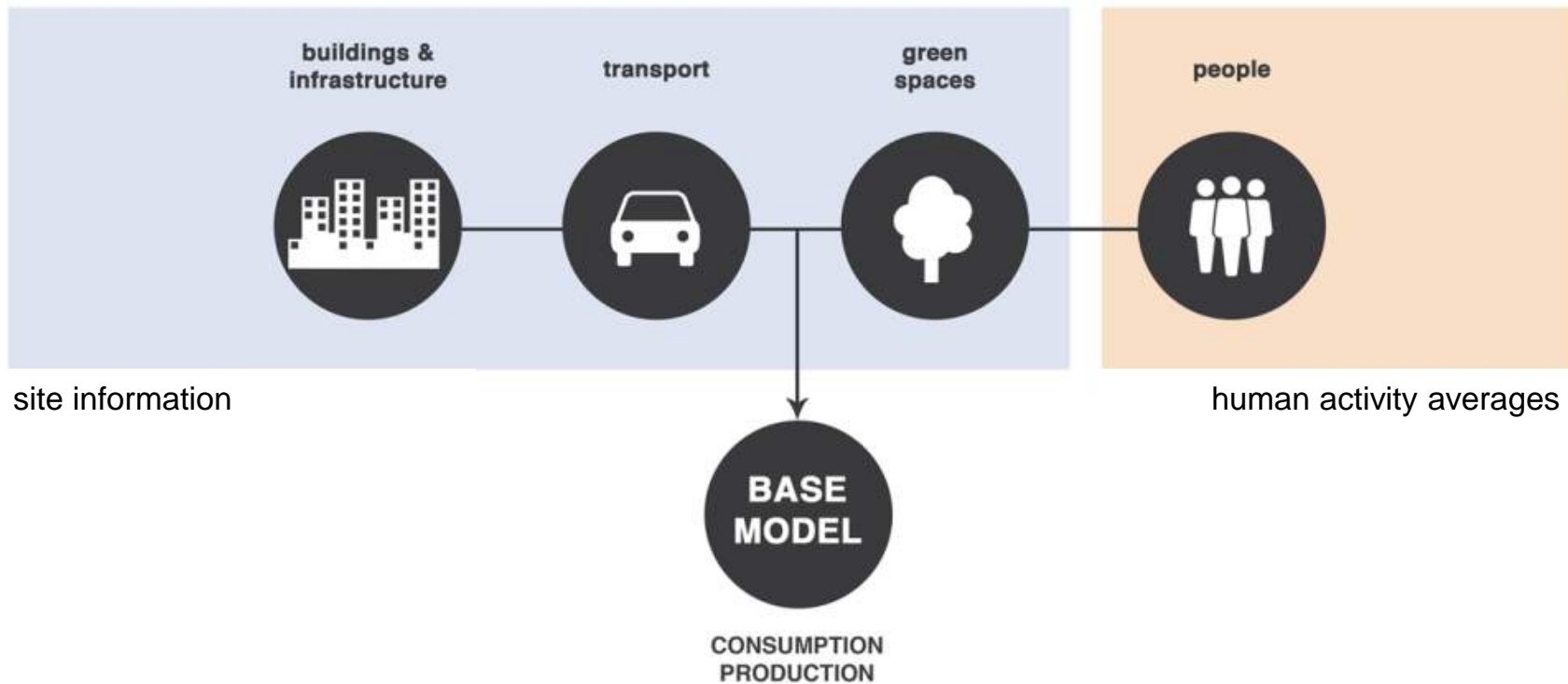


5. MODELING URBAN FLOWS

EXISTING URBAN FLOWS

URBAN SPATIAL CHARACTERISTICS

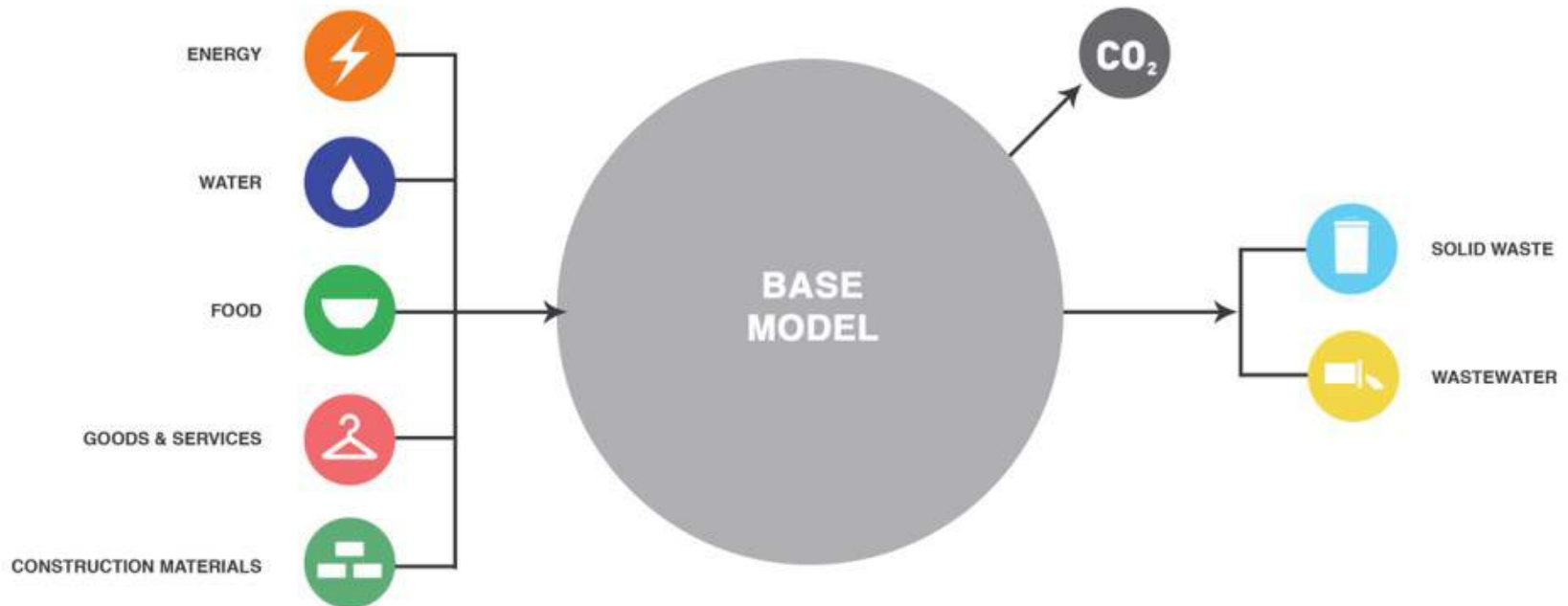
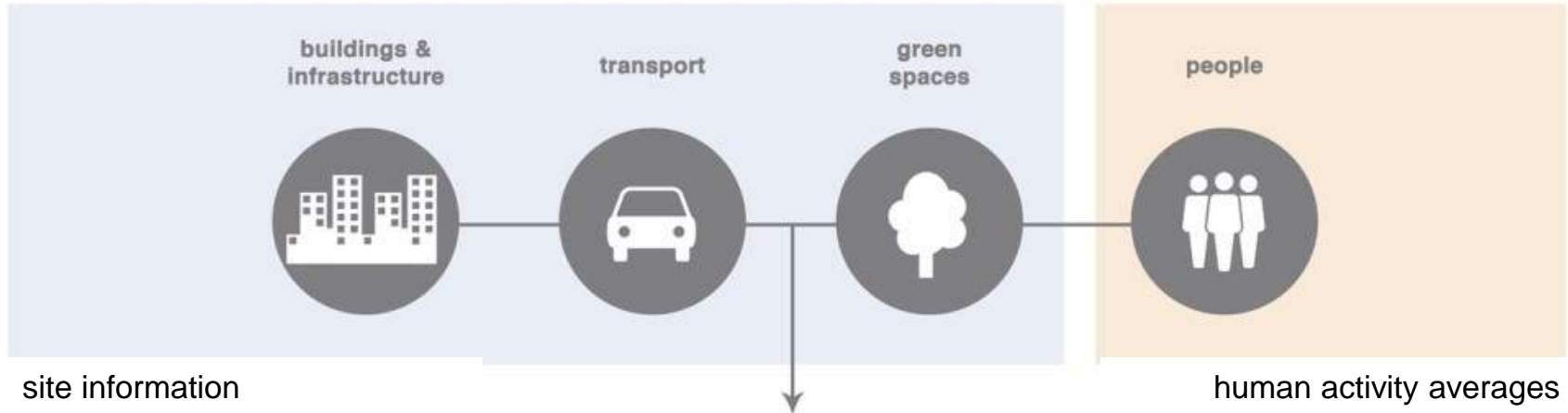
HUMAN CHARACTERISTICS



EXISTING URBAN FLOWS

URBAN SPATIAL CHARACTERISTICS

HUMAN CHARACTERISTICS



EXISTING URBAN FLOWS

BASE MODEL

RESOURCE
FLOWS



ENERGY

kWh



WATER

m³



FOOD

kg



GOODS &
SERVICES

kg



CONSTRUCTION
MATERIALS

kg



SOLID WASTE

kg



WASTEWATER

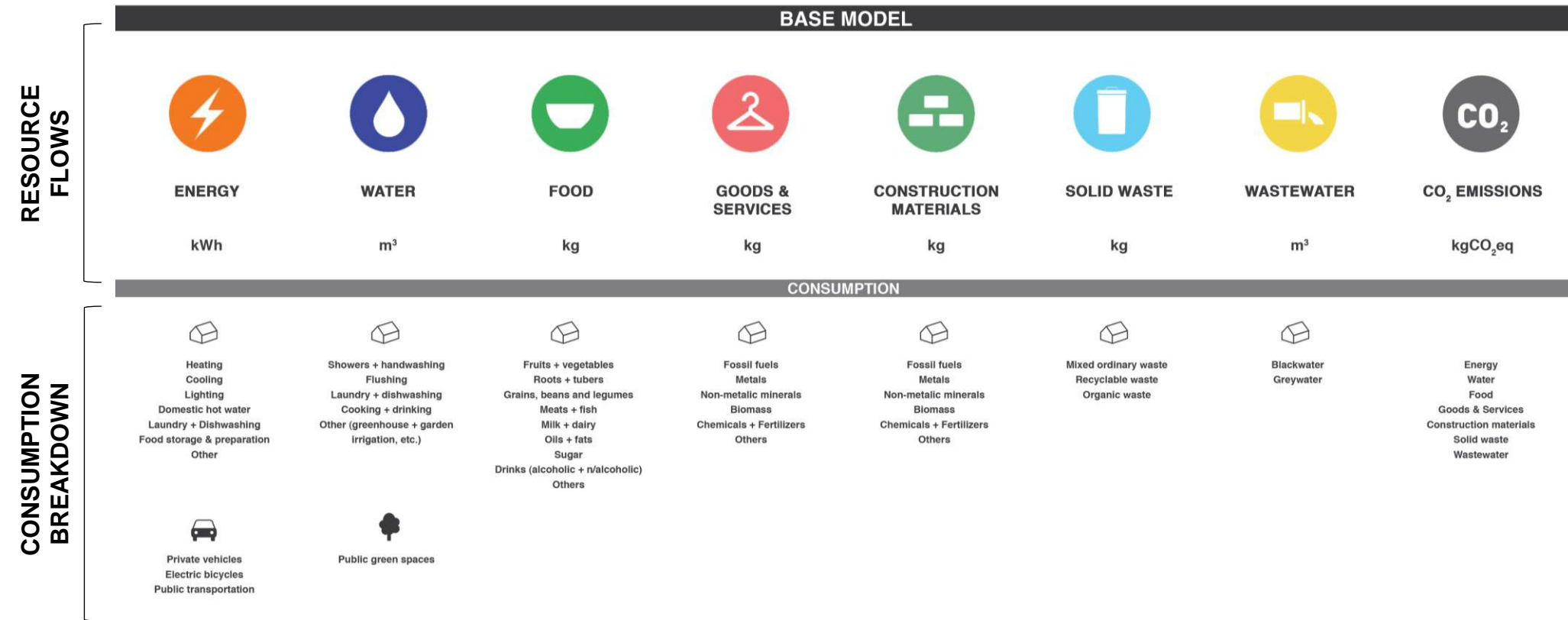
m³



CO₂ EMISSIONS

kgCO₂eq

EXISTING URBAN FLOWS



BASE (i.e. EXISTING) vs STRATEGY

BASE MODEL



ENERGY

kWh



WATER

m³



FOOD

kg



GOODS &
SERVICES

kg



CONSTRUCTION
MATERIALS

kg



SOLID WASTE

kg



WASTEWATER

m³



CO₂ EMISSIONS

kgCO₂eq

↑
VS
↓

DESIGN STRATEGY



ENERGY

kWh



WATER

m³



FOOD

kg



GOODS &
SERVICES

kg



CONSTRUCTION
MATERIALS

kg



SOLID WASTE

kg



WASTEWATER

m³



CO₂ EMISSIONS

kgCO₂eq

SUSTAINABILITY STRATEGIES

What is your vision for the neighborhood?

STRATEGIES												
1	2	3	4	5	6	7	8	9	10	11	12	13
Rooftops	Open Space	Vertical Envelope	Food Production	Energy Production	Energy Efficiency	Water Efficiency	Waste Reduction	Carbon Capture	Outdoor Comfort	Health and Exercise	Pedestrian Safety	Improve Air Quality

DESIGN MEASURES		STRATEGIES												
		1	2	3	4	5	6	7	8	9	10	11	12	13
		Rooftops	Open Space	Vertical Envelope	Food Production	Energy Production	Energy Efficiency	Water Efficiency	Waste Reduction	Carbon Capture	Outdoor Comfort	Health and Exercise	Pedestrian Safety	Improve Air Quality
1	Rooftop Photovoltaic Modules													
2	Façade Integrated Photovoltaics													
3	Solar Thermal System													
4	Piezoelectric Energy Harvesting													
5	Replace Windows													
6	Roof Thermal Insulation													
7	Wall Thermal Insulation													
8	Exterior Shading Devices													
9	Cool Roofs													
10	Green Roofs													
11	Vertical Greenery System													
12	District Heating System													
13	District Co-Generation System													
14	Rooftop Greenhouse													
15	Vertical Greenhouse													
16	Urban Farming													
17	Rainwater Harvesting													
18	Greywater Recycling													
19	Blackwater Recycling													
20	Sustainable Drainage Systems													
21	Composting													
22	Waste-to-Energy System													
23	Anerobic Digestion													
24	Plant Trees													
25	Efficient Outdoor Lighting													
26	Bike Lanes													
27	Outdoor Furniture													

DESIGN MEASURES		STRATEGIES												
		1	2	3	4	5	6	7	8	9	10	11	12	13
		Rooftops	Open Space	Vertical Envelope	Food Production	Energy Production	Energy Efficiency	Water Efficiency	Waste Reduction	Carbon Capture	Outdoor Comfort	Health and Exercise	Pedestrian Safety	Improve Air Quality
1	Rooftop Photovoltaic Modules	x				x								
2	Façade Integrated Photovoltaics			x		x								
3	Solar Thermal System	x				x								
4	Piezoelectric Energy Harvesting		x			x								
5	Replace Windows			x			x							
6	Roof Thermal Insulation	x					x							
7	Wall Thermal Insulation			x			x							
8	Exterior Shading Devices			x			x							
9	Cool Roofs	x					x							
10	Green Roofs	x					x	x		x				x
11	Vertical Greenery System			x				x		x				x
12	District Heating System						x							
13	District Co-Generation System						x							
14	Rooftop Greenhouse	x			x									
15	Vertical Greenhouse			x	x									
16	Urban Farming		x		x					x	x			x
17	Rainwater Harvesting	x	x					x						
18	Greywater Recycling							x						
19	Blackwater Recycling							x						
20	Sustainable Drainage Systems		x					x						
21	Composting		x						x					
22	Waste-to-Energy System						x		x					
23	Anerobic Digestion								x					
24	Plant Trees		x							x	x	x	x	x
25	Efficient Outdoor Lighting		x				x				x	x	x	
26	Bike Lanes		x								x	x	x	
27	Outdoor Furniture		x								x	x	x	

DESIGN MEASURES		STRATEGIES								
		1	2	3	4	5	6	7	8	9
		Rooftops	Open Space	Vertical Envelope	Food Production	Energy Production	Energy Efficiency	Water Efficiency	Waste Reduction	Carbon Capture
1	Rooftop Photovoltaic Modules	x				x				
2	Façade Integrated Photovoltaics			x		x				
3	Solar Thermal System	x				x				
4	Piezoelectric Energy Harvesting		x			x				
5	Replace Windows			x			x			
6	Roof Thermal Insulation	x					x			
7	Wall Thermal Insulation			x			x			
8	Exterior Shading Devices			x			x			
9	Cool Roofs	x					x			
10	Green Roofs	x					x	x		x
11	Vertical Greenery System			x				x		x
12	District Heating System						x			
13	District Co-Generation System						x			
14	Rooftop Greenhouse	x			x					
15	Vertical Greenhouse			x	x					
16	Urban Farming		x		x					x
17	Rainwater Harvesting	x	x					x		
18	Greywater Recycling							x		
19	Blackwater Recycling							x		
20	Sustainable Drainage Systems		x					x		
21	Composting		x						x	
22	Waste-to-Energy System						x		x	
23	Anerobic Digestion								x	
24	Plant Trees		x							x
25	Efficient Outdoor Lighting		x				x			
26	Blke Lanes		x							
27	Outdoor Furniture		x							

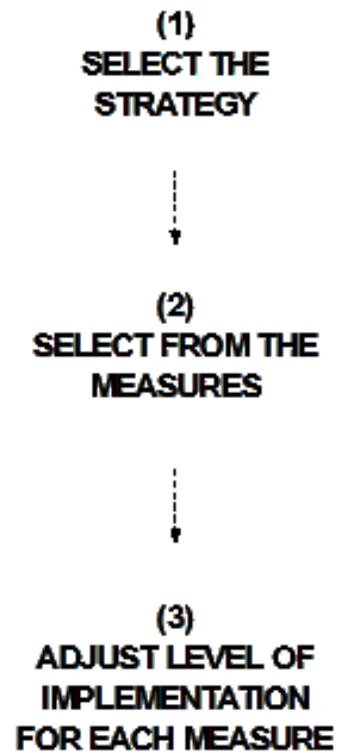
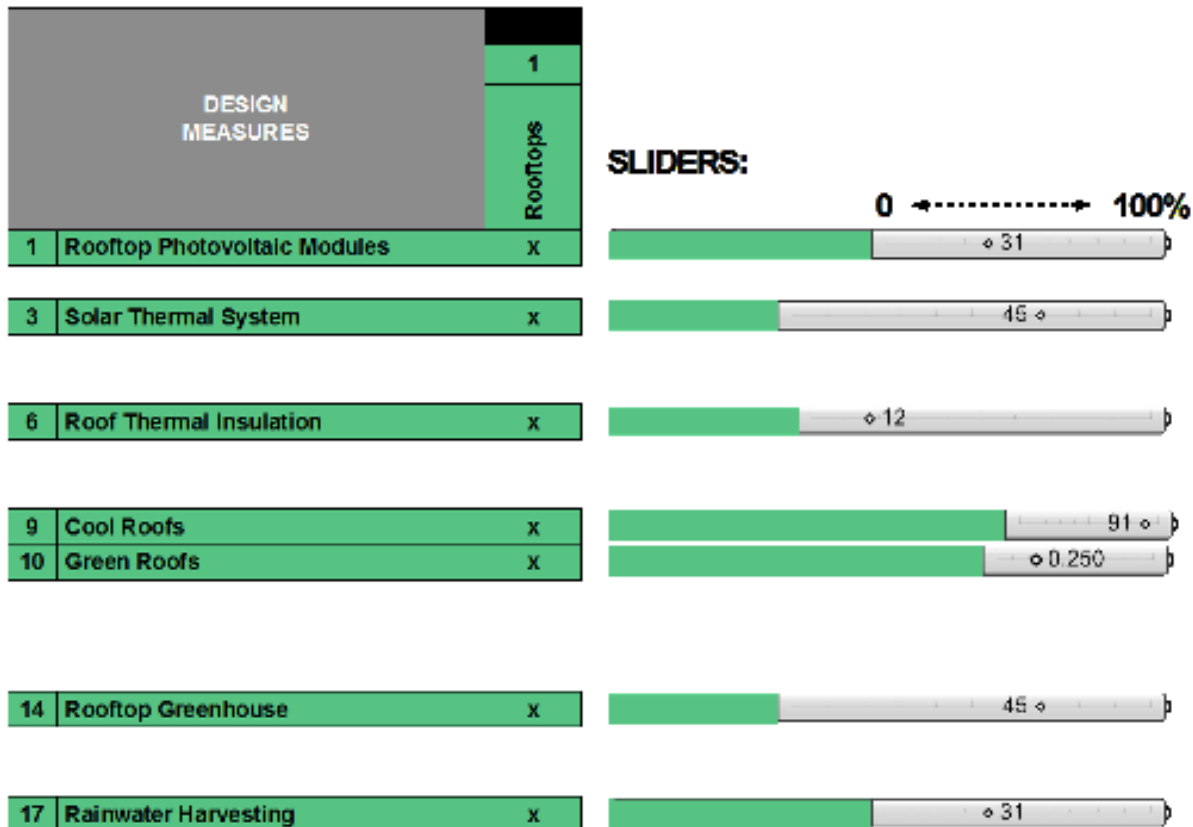
(1)
SELECT THE
STRATEGY

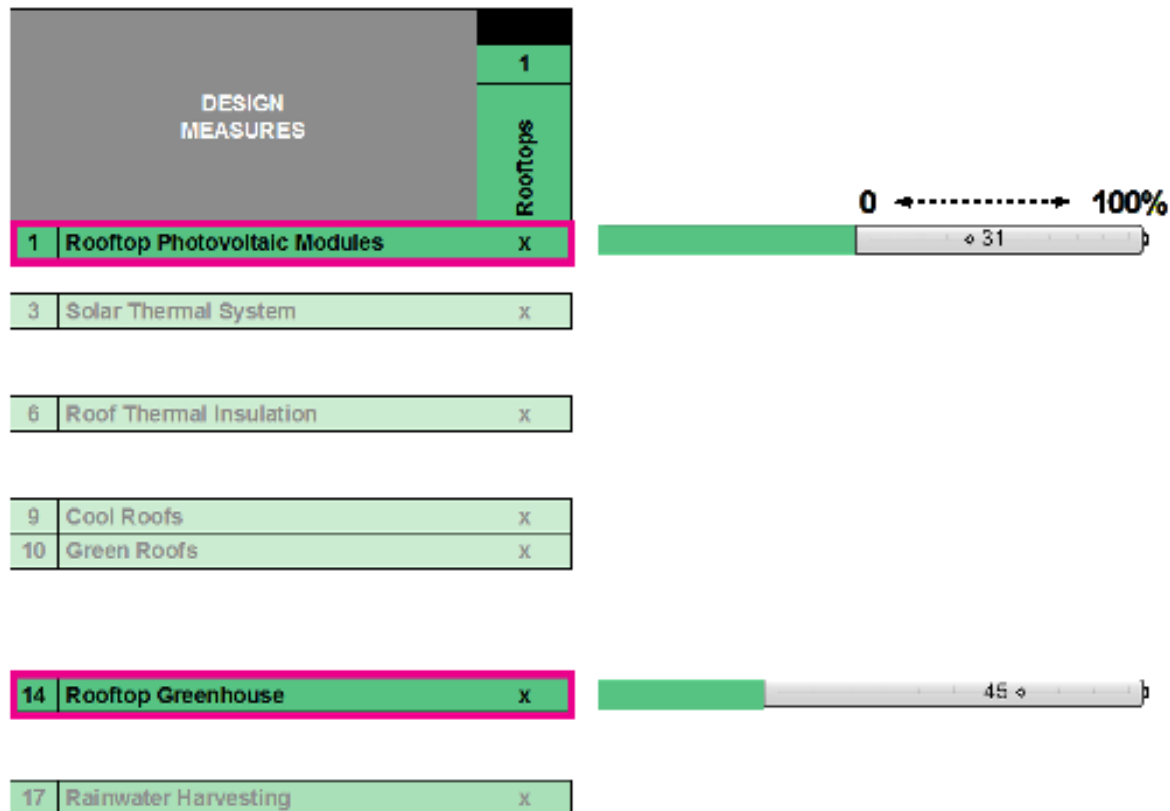
DESIGN MEASURES		STRATEGIES								
		1	2	3	4	5	6	7	8	9
		Rooftops	Open Space	Vertical Envelope	Food Production	Energy Production	Energy Efficiency	Water Efficiency	Waste Reduction	Carbon Capture
1	Rooftop Photovoltaic Modules	x				x				
2	Facade Integrated Photovoltaics			x		x				
3	Solar Thermal System	x				x				
4	Piezoelectric Energy Harvesting		x			x				
5	Replace Windows			x			x			
6	Roof Thermal Insulation	x					x			
7	Wall Thermal Insulation			x			x			
8	Exterior Shading Devices			x			x			
9	Cool Roofs	x					x			
10	Green Roofs	x					x	x		x
11	Vertical Greenery System			x				x		x
12	District Heating System						x			
13	District Co-Generation System						x			
14	Rooftop Greenhouse	x			x					
15	Vertical Greenhouse			x	x					
16	Urban Farming		x		x					x
17	Rainwater Harvesting	x	x					x		
18	Graywater Recycling							x		
19	Blackwater Recycling							x		
20	Sustainable Drainage Systems		x					x		
21	Composting		x						x	
22	Waste-to-Energy System						x		x	
23	Anaerobic Digestion								x	
24	Plant Trees		x							x
25	Efficient Outdoor Lighting		x				x			
26	Bike Lanes		x							
27	Outdoor Furniture		x							

(1)
SELECT THE
STRATEGY



(2)
SELECT FROM THE
MEASURES





**TWO MEASURES TESTED
IN THE MODEL:**

**ROOFTOP PV PANELS
+
ROOFTOP GREENHOUSE**

STRATEGY: ROOFTOP GREENHOUSES



STRATEGY: ROOFTOP GREENHOUSES

MEASURE

ROOFTOP GREENHOUSE

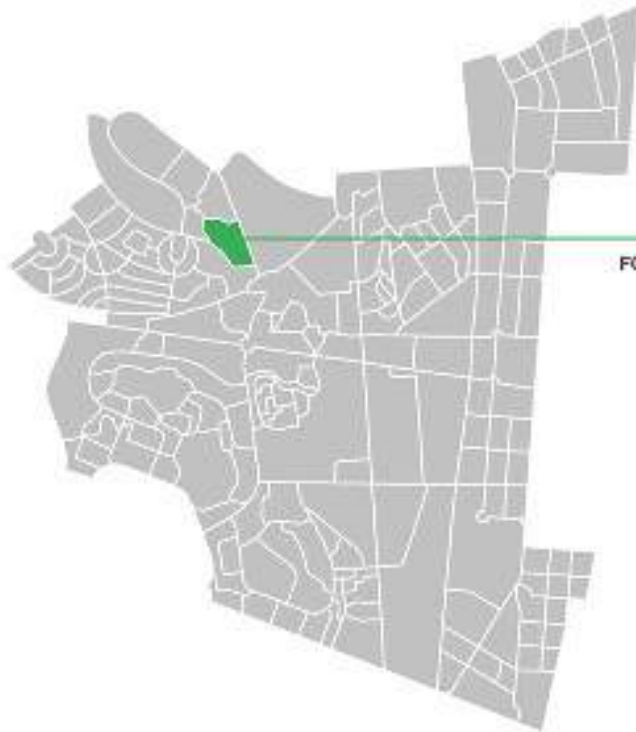
Multifamily buildings



Flat roofs



Hydroponics



OLIVAIS NORTE

FOUR STOREY MULTIFAMILY DWELLING
270 m² FLAT ROOFTOP

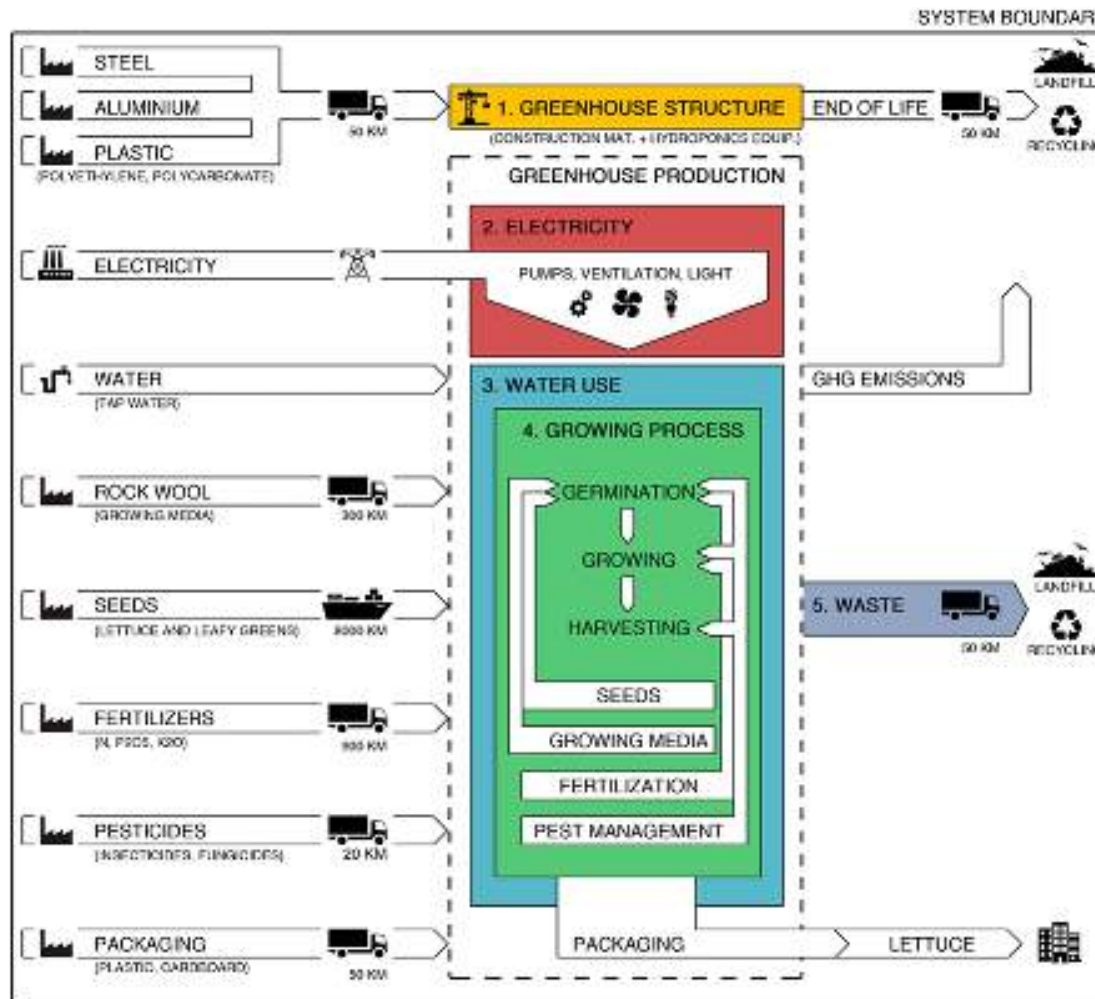
ROOFTOP GREENHOUSE
FOR LETTUCE AND LEAFY GREENS



STRATEGY: ROOFTOP GREENHOUSES

MEASURE

ROOFTOP GREENHOUSE



U-MIRA INTERFACE



Thank you.