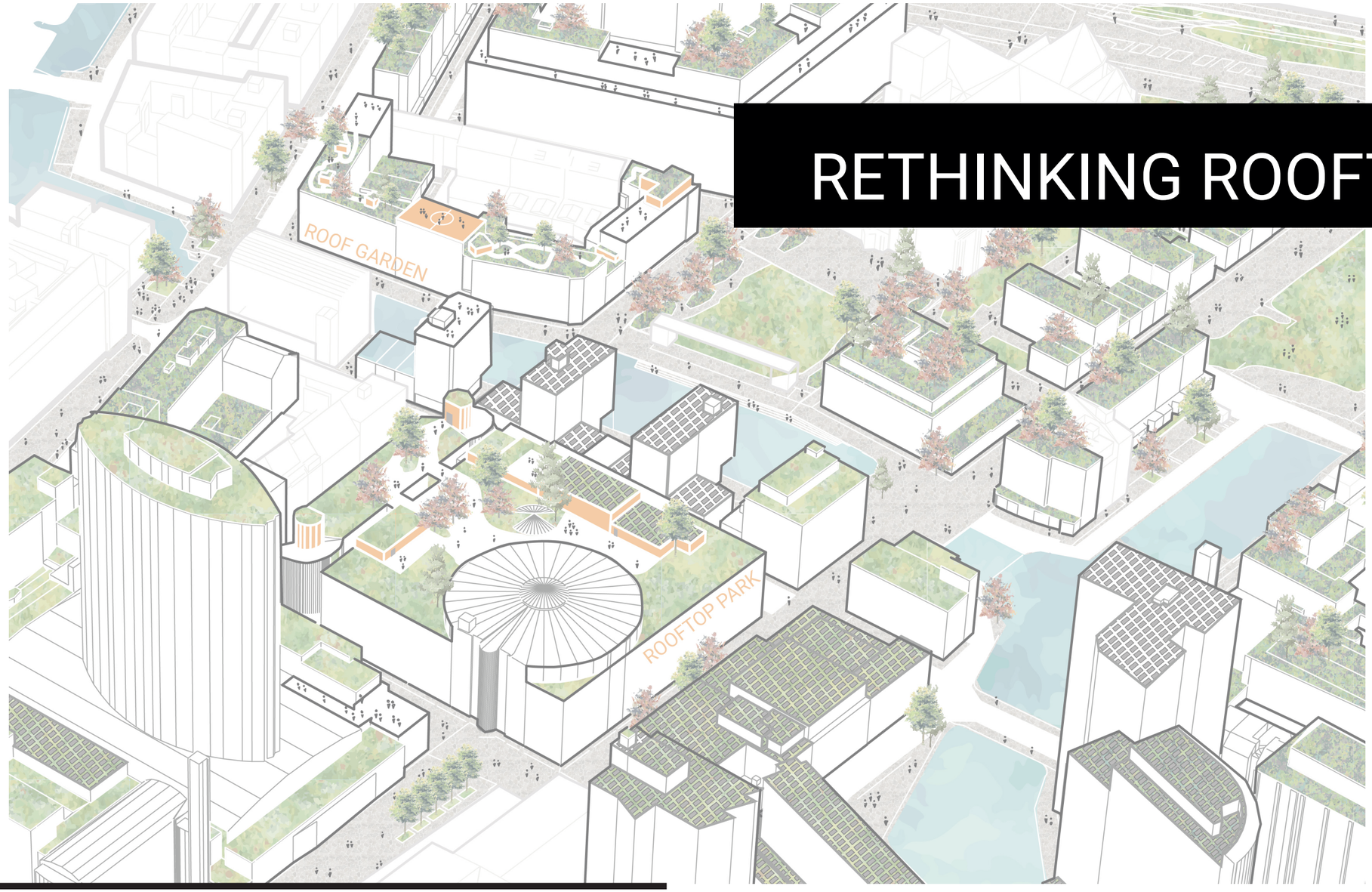


RETHINKING ROOFTOPS

NAME

Joëlle Hermans
4610342

MENTORS

Rients Dijkstra
Arjan van Timmeren

STUDIO

The design of the Urban Fabric

TABLE OF CONTENT

INTRODUCTION

TOP OF OUR CITY

View from Hofpoort (2022)

View from Rotterdam Building (2022)

WHY?

. installations

. invisible

. grey

. bitumen

. roof tiles

YOUR ROOF

. solar panels

. green

. (secret) rooftop terrace

Solarge solar panels at Rotterdam Rooftop Walk (2022)

MANY CHALLENGES

. permits

. roof structure

. high cost

. little subsidy

. neighbours

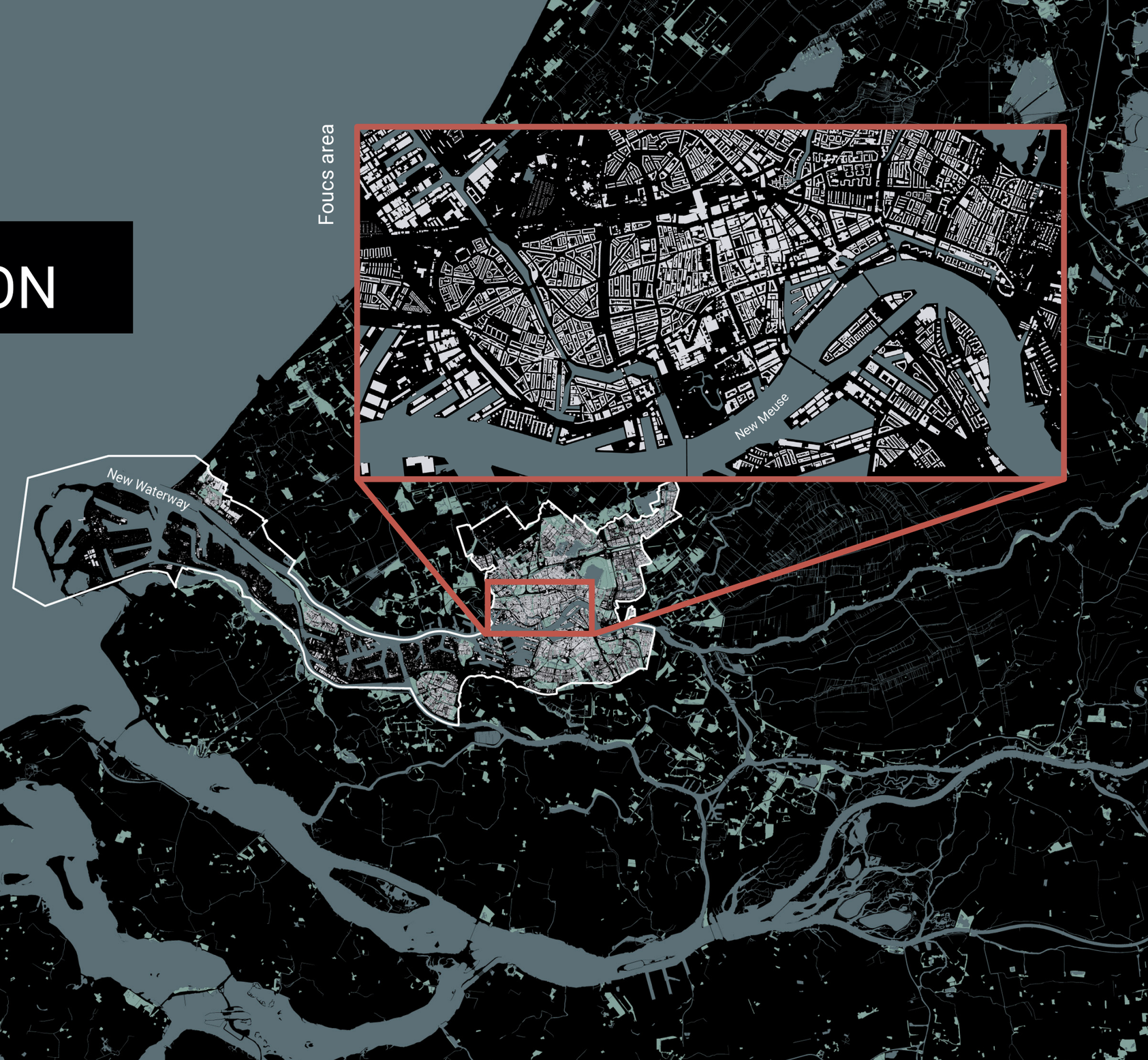
. sound pollution

. no privacy

WE DO TOO LITTLE

WHILE THERE IS SO MUCH POSSIBLE

PROJECT LOCATION



WHY ROTTERDAM?

1940

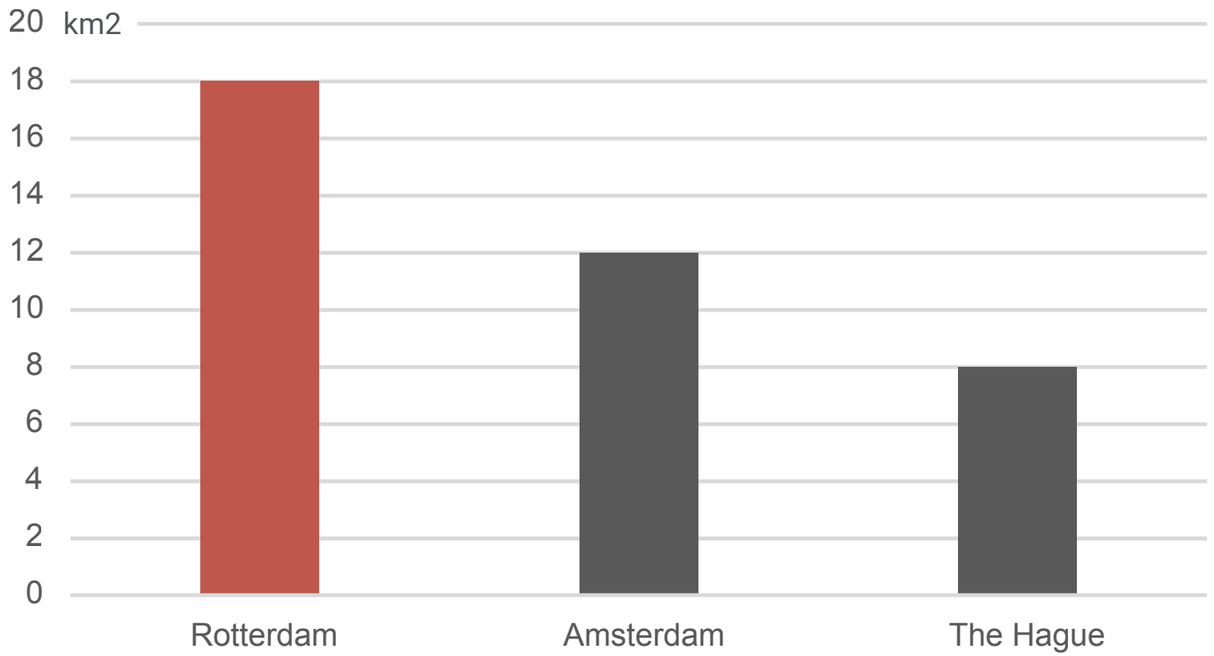
LEGEND

1470-1940
1945-2021
water
fire boundary

0 0,5 km

Source: Stadsarchief Rotterdam (2008)

AMOUNT OF FLAT ROOFS



Source: Municipality of Rotterdam (2021), Rooftop Revolution (2020)

ROTTERDAM’S ROOFS

LEGEND

roofs

water

0 0,5 km

73% IS FLAT

LEGEND

roofs
water
flat roofs

0 0,5 km

18km2

LEGEND

roofs

water

flat roofs

0

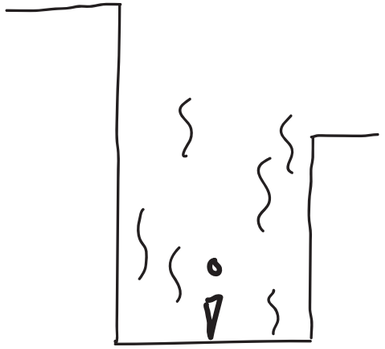
0,5 km

PROBLEM STATEMENT

URBAN CHALLENGES

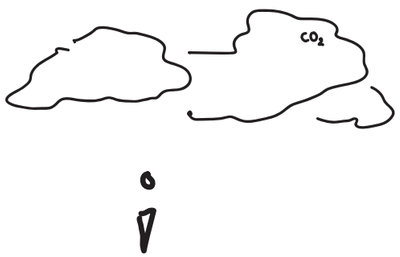
GROWING POPULATION

LACK OF BIODIVERSITY



HEAT STRESS

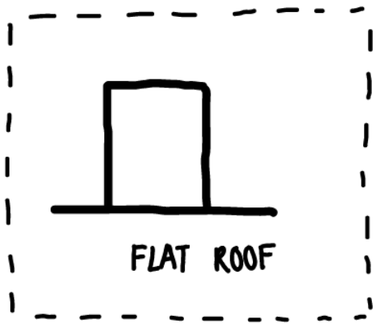
FLOODING RISK



ENERGY TRANSITION

SPACE SCARCITY

TYPE OF PLACE



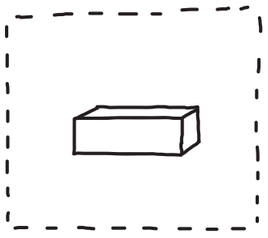
TYPE OF PLACE

TINY

$< 50\ m^2$

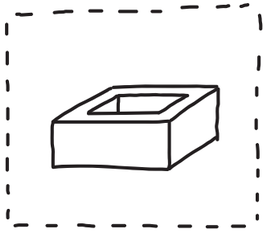
EXTRA SMALL

$\geq 50\ m^2$
$< 500 m^2$



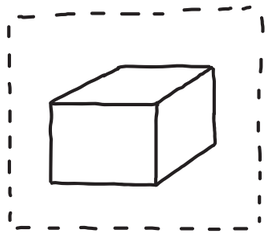
SMALL

$\geq 500 m^2$
$< 2.000 m^2$



MEDIUM

$\geq 2.000\ m^2$
$< 10.000\ m^2$



LARGE

$\geq 10.000\ m^2$

FLAT ROOFS >500m2

4,3 km2 to transform

LEGEND

- pitched roofs, semi-flat roofs, flat roofs <500m2
- small scale flat roofs
- medium scale flat roofs
- large scale flat roofs
- green
- water

0 0,5 km

Source: (Atlas Leefomgeving, n.d.)

LOTS OF INITIATIVES

Roof Groothandelsgebouw (2022)

POTENTIAL OF ROOFS

NEW PUBLIC SPACE

ENRICH BIODIVERSITY

REDUCE HEAT STRESS

STORE WATER

GENERATE ENERGY

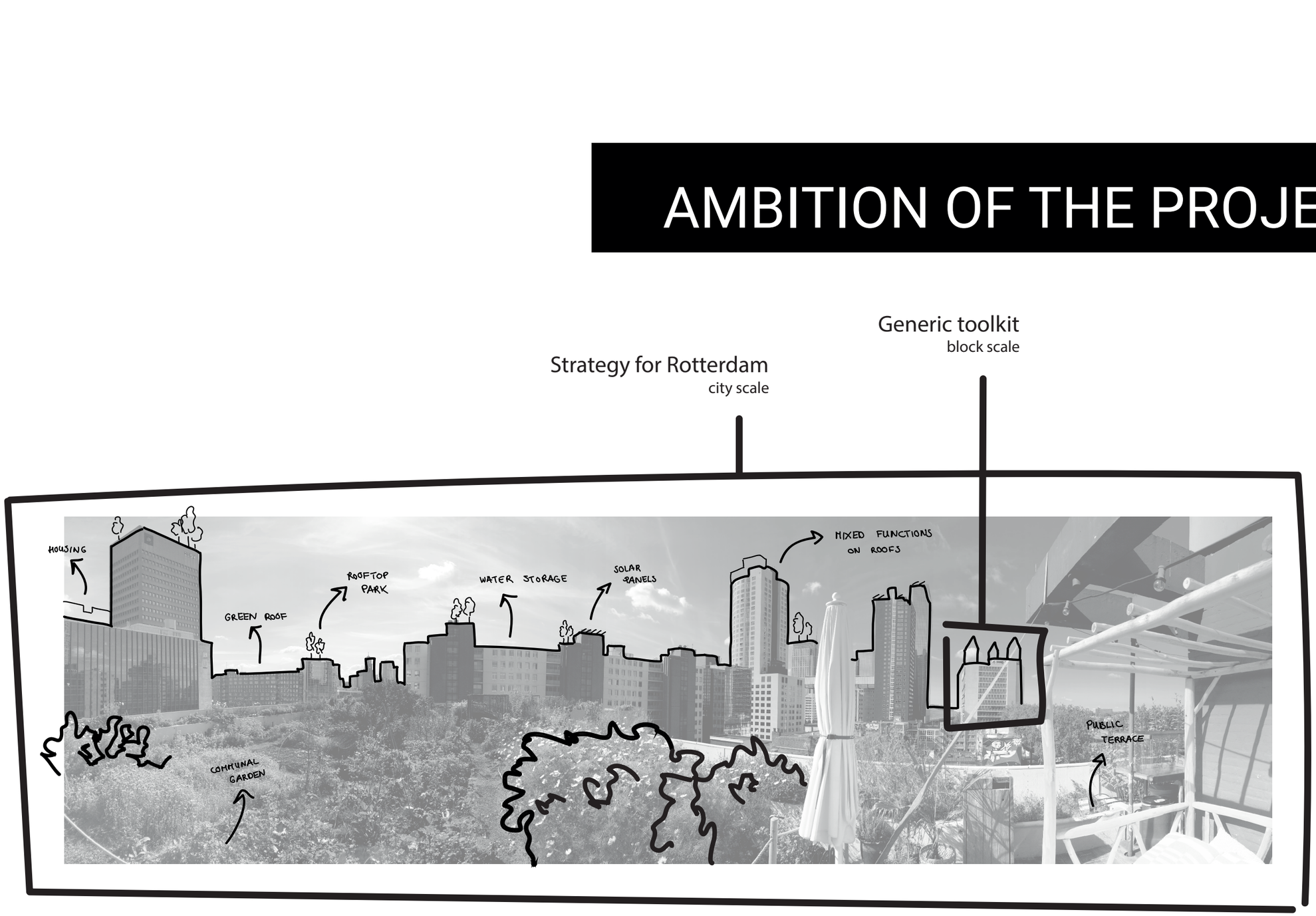
Source: Gemeente Rotterdam (2019), Li&Yeung (2014)

How can the (re)development of Rotterdam’s flat roofs be guided to achieve a significant progress towards a sustainable and resilient Rotterdam in the future?

AMBITION OF THE PROJECT

Strategy for Rotterdam
city scale

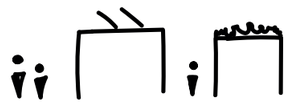
Generic toolkit
block scale



NEW ROOF LAYERS

social layer

CONNECTIONS
growing population



SOCIAL FUNCTIONS
growing population

base layer

SOLAR PANELS
energy transition

EXTENSIVE GREEN
heat stress

INTENSIVE GREEN
heat stress

INTENSIVE GREEN
green corridor

WATER STORAGE
flooding

roof

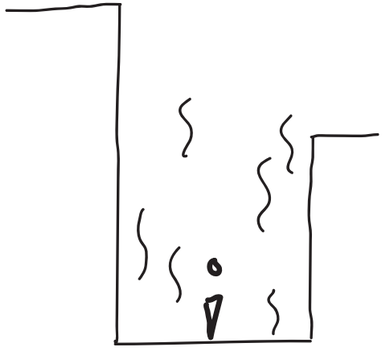
FLAT ROOF>500m2
type of space

DESIGN OF THE BASE LAYER

URBAN CHALLENGES

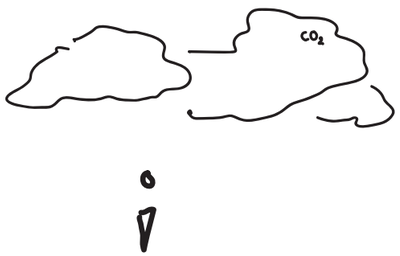
GROWING POPULATION

LACK OF BIODIVERSITY



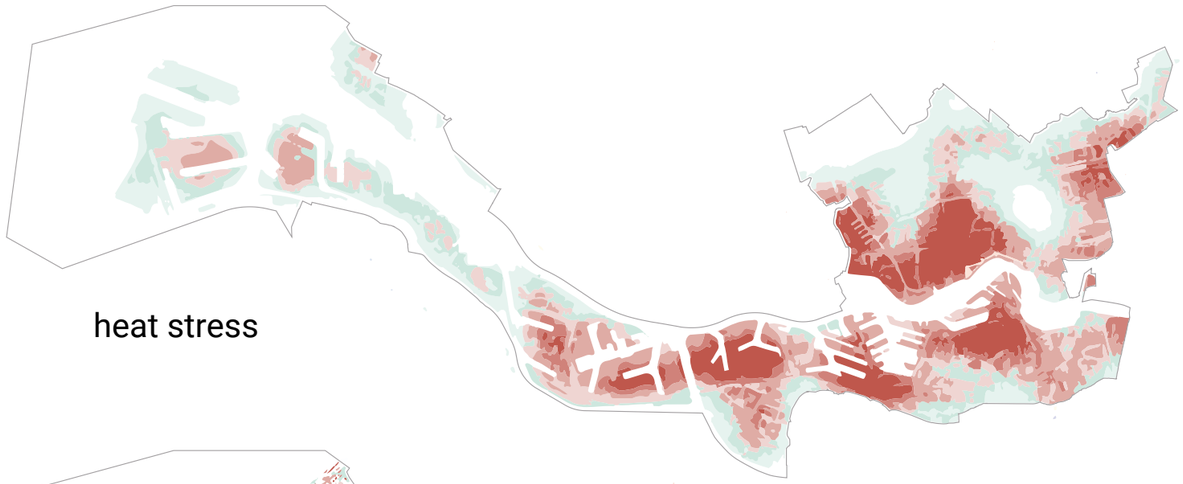
HEAT STRESS

FLOODING RISK



ENERGY TRANSITION

URBAN CHALLENGES



heat stress

flooding risk

lack of biodiversity

LEGEND

Rotterdam

high risk

low risk

0 8 km

Source: Klimaateffectatlas (2021)

HEAT STRESS

LEGEND

flat roofs >500m2

roofs x heat stress

0 0,5 km

Source: Klimaateffectatlas (2015)

FLOODING

LEGEND

flat roofs >500m2

roofs x flooding

0 0,5 km

Source: Klimaateffectatlas (2017)

LACK OF BIODIVERSITY

green corridors

LEGEND

flat roofs >500m2

roofs x green corridor

0 0,5 km

Source: Vereniging Delta Metropool (2018)

ENERGY TRANSITION

100% of all flat roofs >500m2 in harbour area

34% of all flat roofs >500m2 in inner city

URGENCY MAP

LEGEND

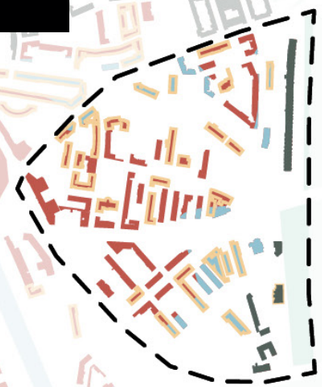
- flat roofs >500m2
- roofs x heat stress
- roofs x biodiversity
- roofs x flooding
- roofs x energy transition
- water
- green
- green corridor

0 0,5 km

FOCUS AREAS

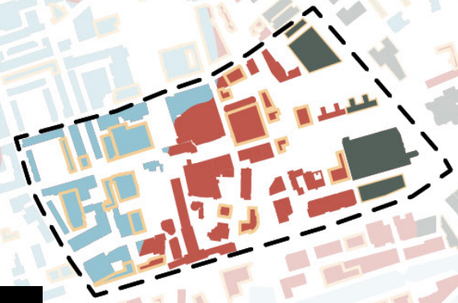
AREA 1

165.590 m2



AREA 2

137.149 m2



LEGEND

- flat roofs >500m2
- roofs x heat stress
- roofs x biodiversity
- roofs x flooding
- roofs x energy transition

0 0,5 km

surrounding buildings

flat roofs>500m2

AREA 1

Nieuwe Westen

Source: Google Maps (2022)

flat roofs>500m2

surrounding buildings

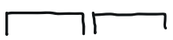
AREA 2

Cool & Stadsdriehoek

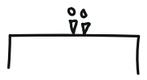
Source: Google Maps (2022)

DIFFERENCES AREAS

AREA 1

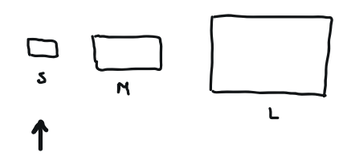


buildings are
4-5 floors high



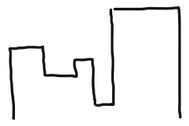
many private
rooftop terraces

apartment buildings have
often solar panels on
their roofs

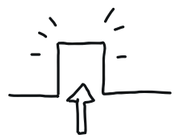


especially small
scale flat roofs

AREA 2



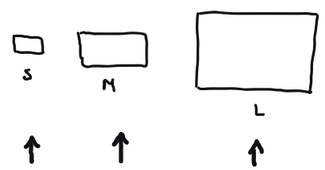
great height
differences



many rooftop
entrances on roofs

(large) air handling
units on roofs

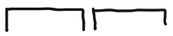
flat roofs accommodate
already many different
functions



all flat rooftop scales
are represented

DIFFERENCES AREAS

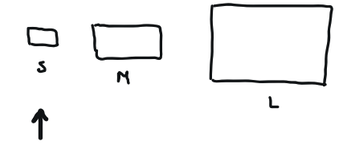
AREA 1



buildings are
4-5 floors high

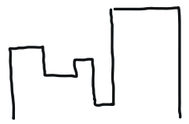
many private
rooftop terraces

apartment buildings have
often solar panels on
their roofs



especially small
scale flat roofs

AREA 2

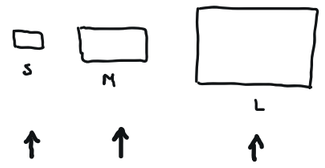


great height
differences

many rooftop
entrances on roofs

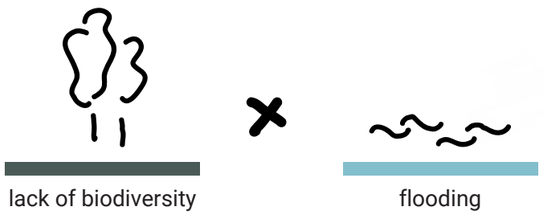
(large) air handling
units on roofs

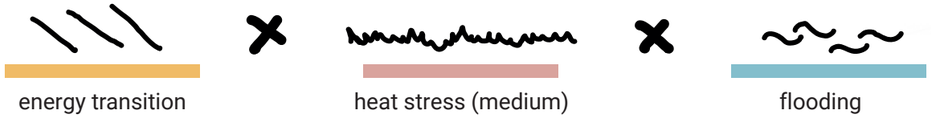
flat roofs accommodate
already many different
functions

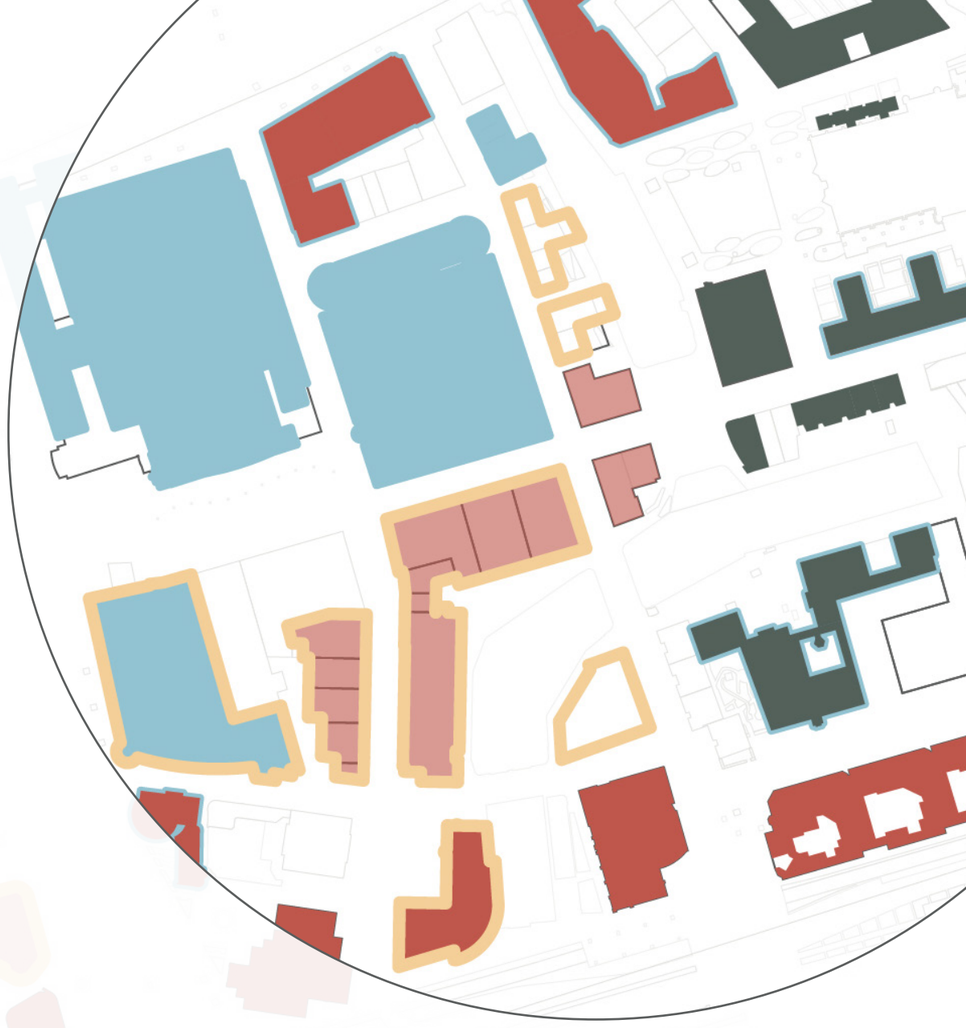


all flat rooftop scales
are represented

COMBINATIONS OF URGENCIES





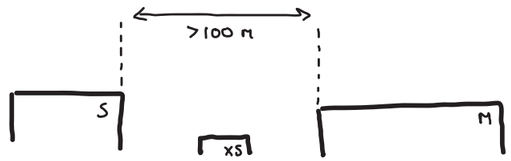


urgency map area 2

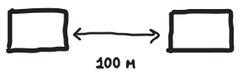
DESIGN RULES

LACK OF BIODIVERSITY

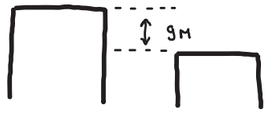
CONFIGURATION OF ROOFS



tiny and extra small flat scale roofs will be used as stepping stones when distance between flat roofs>500m2 is more than 100m (Gout, 2014)



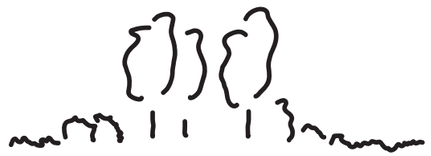
100m maximum distance between roofs (maximum fly distance bees) (Lee & Lin, 2015)



9m is maximum height difference between roofs (maximum distance bees can

REQUIRED ROOF STRUCTURE

minimum thickness of substrate (Wageningen University&Research, 2017)



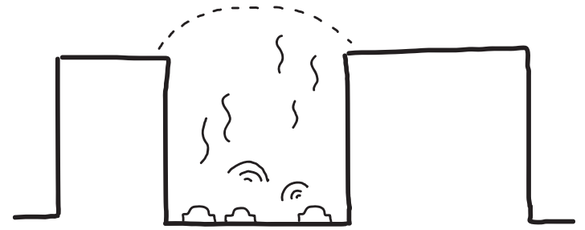
rich and diverse vegetation (MacIvor & Lundholm, 2010)

LOCATION

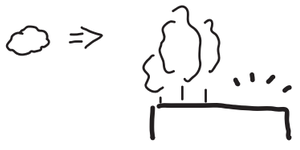
located directly next to desired green corridor in the city

place specific

ORIENTATION



green bridges when corridor is disturbed by traffic zones (sound and air pollution) (Gout, 2014)



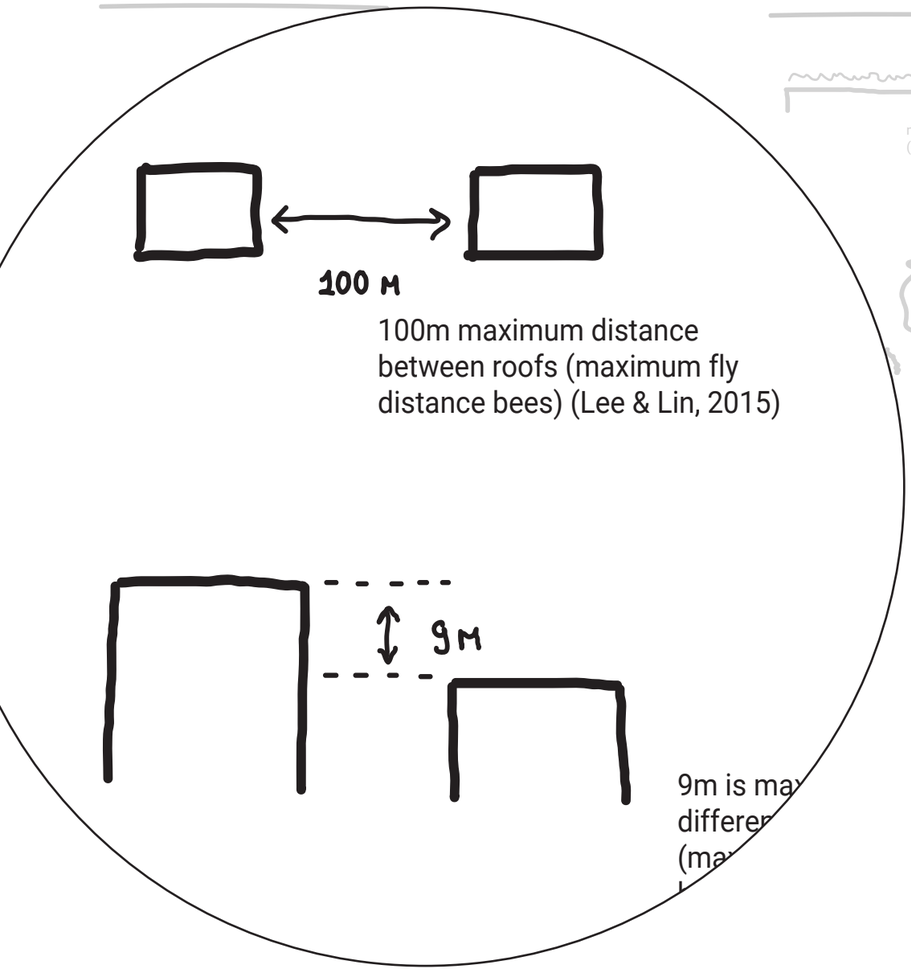
habitats in a wind free zone (Dunnett and Kingsbury 2010).

nesting places in the sun (Dunnett and Kingsbury 2010).

DESIGN RULES

LACK OF BIODIVERSITY

CONFIGURATION OF ROOFS



100m maximum distance between roofs (maximum fly distance bees) (Lee & Lin, 2015)

9m is ma
differe
(ma

REQUIRED ROOF STRUCTURE

minimum thickness of substrate
(Wageningen University&Research, 2017)

rich and diverse vegetation
(MacIvor & Lundholm, 2010)

LOCATION

located directly next to desired
green corridor in the city

place specific

ORIENTATION

green bridges when corridor is disturbed by traffic zones (sound and air pollution) (Gout, 2014)

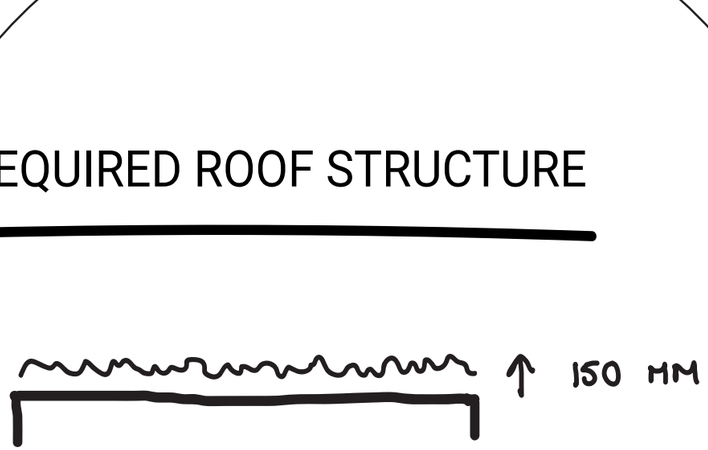
habitats in a wind free zone
(Dunnett and Kingsbury 2010).

nesting places in the sun
(Dunnett and Kingsbury 2010).

DESIGN RULES

LACK OF BIODIVERSITY

REQUIRED ROOF STRUCTURE



minimum thickness of substrate
(Wageningen University&Research, 2017)

CONFIGURATION OF ROOFS

100m maximum distance between roofs (maximum fly distance bees) (Lee & Lin, 2015)

9m is maximum height difference between roofs (maximum distance bees can

LOCATION

located directly next to desired green corridor in the city

place specific

ORIENTATION

green bridges when corridor is disturbed by traffic zones (sound and air pollution) (Gout, 2014)

habitats in a wind free zone (Dunnett and Kingsbury 2010).

nesting places in the sun (Dunnett and Kingsbury 2010).

DESIGN RULES

FLOODING

AMOUNT OF PRECIPITATION

2 L/M² IN 1 DAY

is the average amount of rainfall per day in The Netherlands (Rijksoverheid, n.d.)

50 L/M² IN 1 DAY

is a "wet" day in The Netherlands (Rijksoverheid, n.d.)

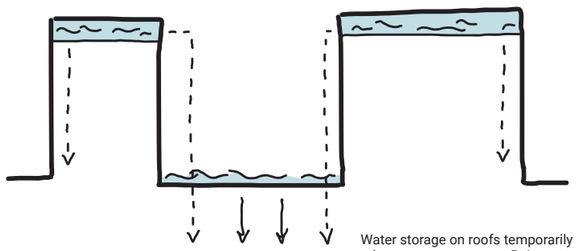
70 L/M² ON A ROOF

is the ambition of Rotterdam for the capacity of water storage on blue roofs (Duurzaam 010, 2021)

100 L/M² MAXIMUM

standard load bearing capacity of a roof construction in The Netherlands (de Vree, n.d.)

WATER STORAGE/RETENTION



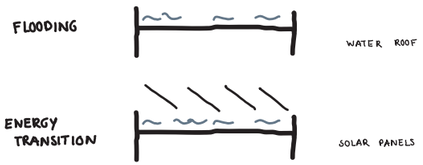
Water storage on roofs temporarily release sewage system. Rain water can also be used for toilet flushing in buildings (Rainproof Amsterdam, 2022).

LOCATION

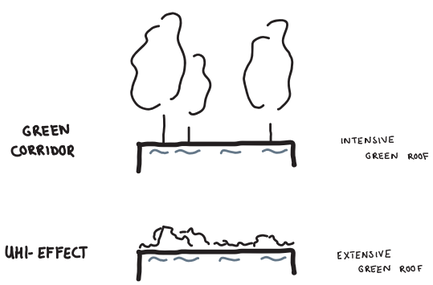
roofs located in or next to areas that flood after heavy precipitation (70mm/2h)

place specific

COMBINATION WITH OTHER ROOFTOP FUNCTIONS



open water storage roofs can be combined with solar panels (Rainproof Amsterdam, 2022)



closed water storage systems can be combined with intensive and extensive green roofs (Rainproof Amsterdam, 2022)

DESIGN RULES

FLOODING

AMOUNT

0 L/M² IN 1 DAY

is a “wet” day in The Netherla
(Rijksoverheid, n.d.)

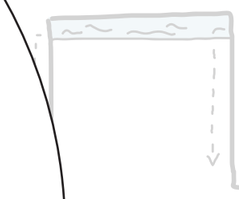
70 L/M² ON A ROOF

is the ambition of Rotterdam for the capacity of water storage on blue roofs (Duurzaam 010, 2021)

00 L/M² MAXIMUM

standard load be
of a roof co
Neth

ETENTION



Water storage on roofs temporarily release sewage system. Rain water can also be used for toilet flushing in buildings (Rainproof Amsterdam, 2022).

LOCATION

roofs located in or next to areas that flood after heavy precipitation (70mm/2h)

place specific

COMBINATION WITH OTHER ROOFTOP FUNCTIONS

open water storage roofs ca
combined with solar panels
(Rainproof Amsterdam, 202

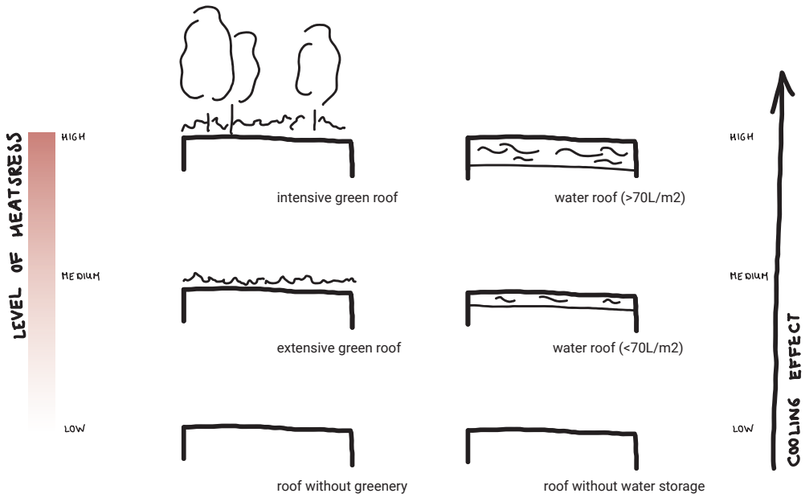
closed water storage syste
can be combined with inter
and extensive green roofs
(Rainproof Amsterdam, 20

DESIGN RULES

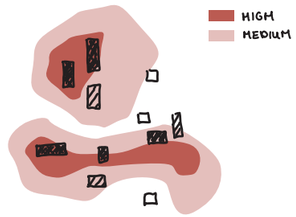
HEAT STRESS

EFFECT OF GREEN & BLUE ROOFS ON HEAT STRESS

(Langelaar, 2019) (Solcerova et al., 2017)



LOCATION

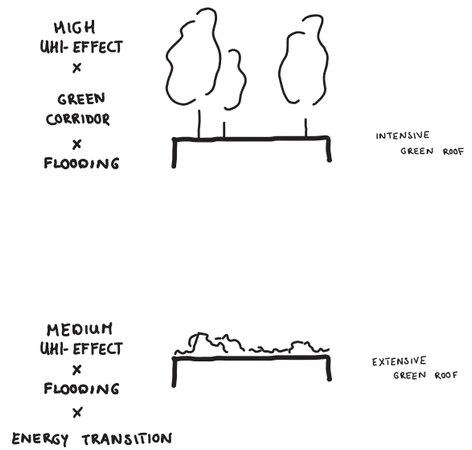


flat roofs>500m2 located in high heat stress zones (high) and next to high heat stress zones (medium)

place specific

COMBINATION WITH OTHER ROOFTOP FUNCTIONS

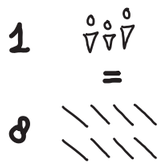
the appropriate urgency determines the thickness of the green layer on the roof



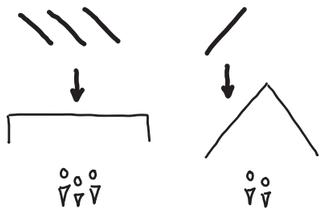
DESIGN RULES

ENERGY TRANSITION

ENERGY DEMAND PER HOUSEHOLD



on average every household needs 8 solar panels to be self sufficient (calculations solar panels)

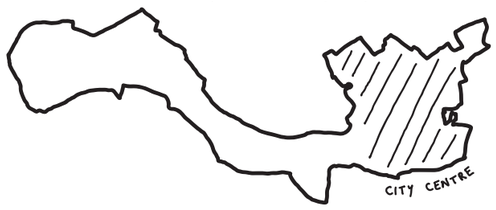


all households in Rotterdam should be provided with renewable energy from solar panels on roofs in 2050

SUITABILITY OF ROOFS

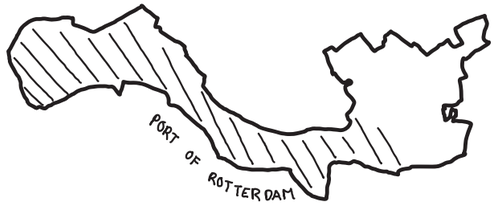
21-34%

of flat roofs>500m2 in the city center must be covered with solar panels (calculations solar panels)



100 %

of flat roofs>500m2 in harbour area must be covered with solar panels (calculations solar panels)



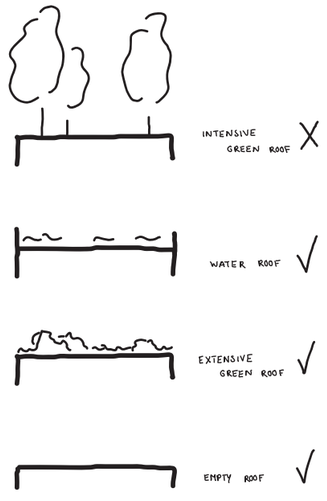
LOCATION

most appropriate to place solar panels on the highest levels (least shadow effect and it does not disturb the views from buildings)

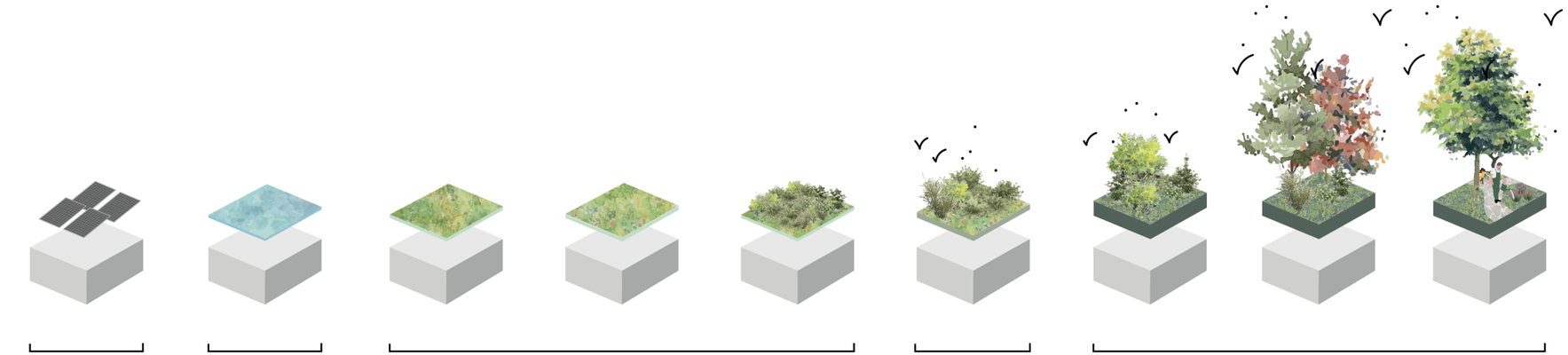
not place specific

COMBINATION WITH OTHER ROOFTOP FUNCTIONS

solar panels can be combined with several other rooftops functions



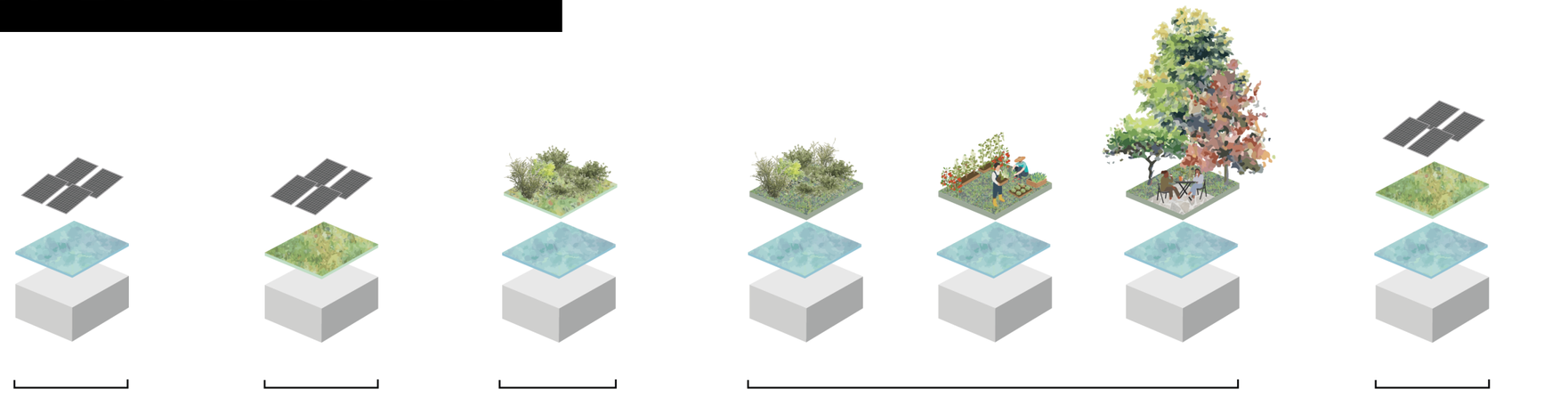
TOOLKIT BASE LAYER



PROPERTIES

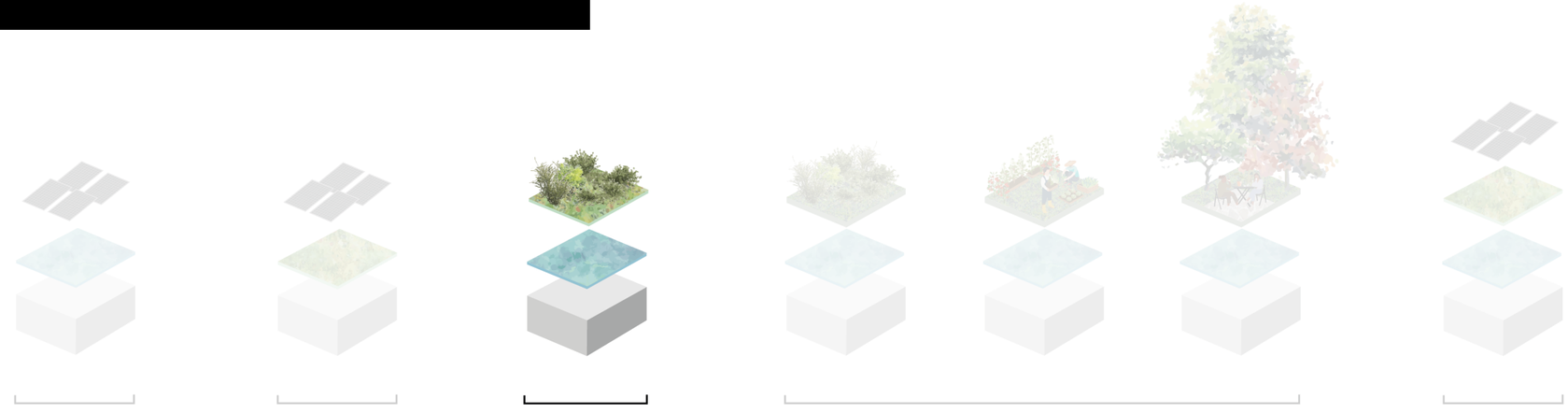
	ENERGY TRANSITION	FLOODING	UHI-EFFECT (medium)		UHI-EFFECT (high)	LACK OF BIODIVERSITY		
water storage	0mm	70-300mm	18mm	25mm	19mm	30-80mm	30-80mm	150-370mm	110-160mm
substrate layer	0mm	0mm	30mm	60mm	60mm	60-150mm	150-210mm	230-400mm	230-400mm
weight	>6kg/m2	70-300kg/m2	55kg/m2	90kg/m2	90kg/m2	<95kg/m2	95kg/m2	310kg/m2	320kg/m2
vegetation	no	no	sedum	sedum (herbs, grasses)	sedum, herbs grasses	herbs, bushes	herbs, bushes	perennials, trees, grass, pavement	perennials, trees, grass, pavement
reference	Solarge DUO	Waterdak (Amsterdam Rainproof)	Dakbegroeiing lichtgewicht (Optigrün)	Dakbegroeiing economisch dak (Optigrün)	Meander FKM 30 (Optigrün)	Natuurdak (Optigrün)	Natuurdak (Optigrün)	Drossel Intensief (Optigrün)	Daktuin (Optigrün)

TOOLKIT BASE LAYER



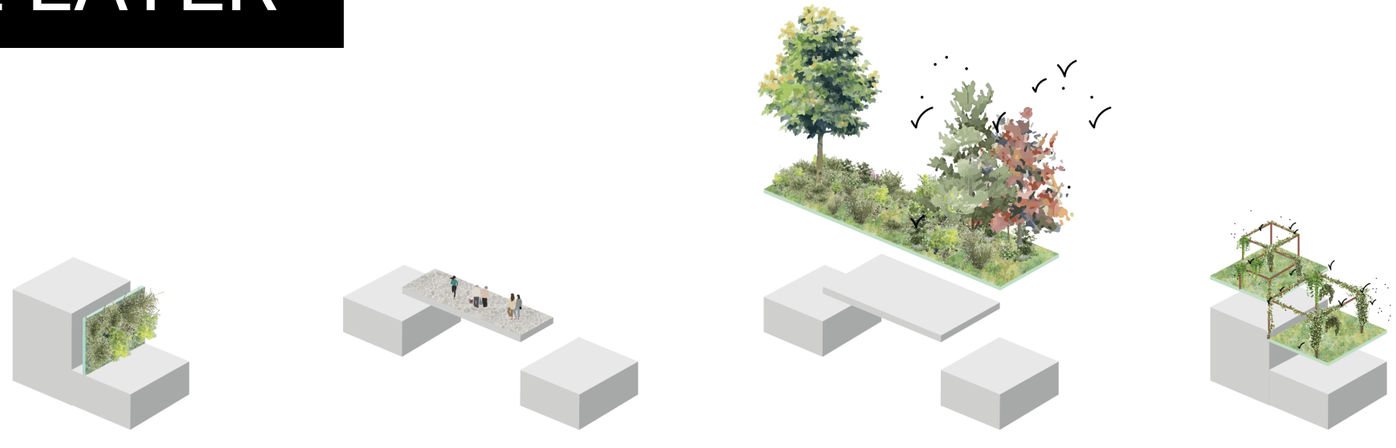
PROPERTIES	FLOODING X ENERGY TRANSITION	UHI-EFFECT (medium) x ENERGY TRANSITION	UHI-EFFECT (medium) X FLOODING	UHI-EFFECT (high) X FLOODING			UHI-EFFECT (medium) X FLOODING X ENERGY TRANSITION
water storage	95-150mm	95-150mm	70-80mm	70-80mm	70-126mm	180-230mm	95-150mm
substrate layer	0mm	80mm	60-80mm	80-210mm	80-400mm	250-400mm	80mm
weight	<120kg/m2	120kg/m2	<95kg/m2	95kg/m2	150kg/m2	600kg/m2	120kg/m2
vegetation	no	sedum	herbs, bushes	herbs, bushes	vegetables, fruits	perennials, trees, grass, pavement	sedum
reference	Solargroendak WRB (Optigrün)	Solargroendak WRB (Optigrün)	Natuurdak (Optigrün)	Natuurdak (Optigrün)	Dakbegroeiing (dakmoestuin) (Optigrün)	Dakpark (verblijfsdak) (Optigrün)	Solargroendak WRB (Optigrün)

TOOLKIT BASE LAYER



PROPERTIES	FLOODING X ENERGY TRANSITION	UHI-EFFECT (medium) x ENERGY TRANSITION	UHI-EFFECT (medium) X FLOODING	UHI-EFFECT (high) X FLOODING			UHI-EFFECT (medium) X FLOODING X ENERGY TRANSITION
water storage	95-150mm	95-150mm	70-80mm	70-80mm	70-126mm	180-230mm	95-150mm
substrate layer	0mm	80mm	60-80mm	80-210mm	80-400mm	250-400mm	80mm
weight	<120kg/m2	120kg/m2	<95kg/m2	95kg/m2	150kg/m2	600kg/m2	120kg/m2
vegetation	no	sedum	herbs, bushes	herbs, bushes	vegetables, fruits	perennials, trees, grass, pavement	sedum
reference	Solargroendak WRB (Optigrün)	Solargroendak WRB (Optigrün)	Natuurdak (Optigrün)	Natuurdak (Optigrün)	Dakbegroeiing (dakmoestuin) (Optigrün)	Dakpark (verblijfsdak) (Optigrün)	Solargroendak WRB (Optigrün)

TOOLKIT BASE LAYER



CONNECTION

PROPERTIES					
function		green facade	elevated walkway	green bridge	green pergolas: enrich, strenghten connetions for flora and fauna
accessibility		public, community, private	public, community	nobody	nobody
maintenance		municipality, community, house owner	municipality	municipality	municipality, community, house owner
reinforce supporting structure		no	yes	yes	no
ownership		housing corporation, municipality,private ownership	housing corporation, municipality	housing corporation, municipality	housing corporation, municipality,private ownership

DESIGN OF THE SOCIAL LAYER

URBAN CHALLENGES

GROWING POPULATION

LACK OF BIODIVERSITY

HEAT STRESS

FLOODING RISK

ENERGY TRANSITION

SOCIAL FUNCTIONS

Pink stage on top of Het Nieuwe Instituut (2022)

OWNERSHIP

area 1

area 2

municipality

housing corporation

private ownership

LEGEND

- owned by municipality
- (partly) owned by housing corporation
- private ownership
- roofs with solar panels, green roofs, or rooftop terraces

0 200 m

Source: Gemeente Rotterdam (2018)

RECREATIONAL AREAS

area 1

area 2

LEGEND

buildings

flat roofs >500m2

0 200 m

CAFES & BARS

area 1

area 2

LEGEND

buildings

flat roofs >500m2

0 200 m

PUBLIC SQUARES

area 1

area 2

LEGEND

buildings

flat roofs >500m2

0 200 m

POTENTIAL SOCIAL ROOFS

area 1

area 2

LEGEND

buildings

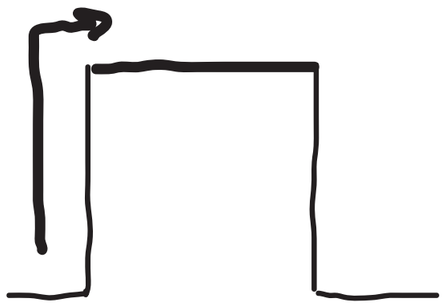
flat roofs >500m2

0 200 m

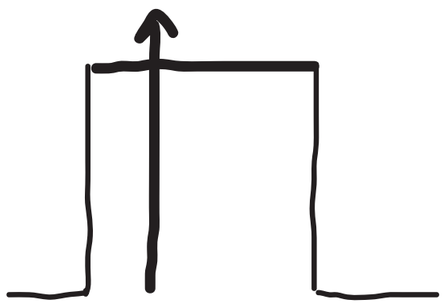
ACCESSIBILITY

Stairs Rooftop Walk (2022)

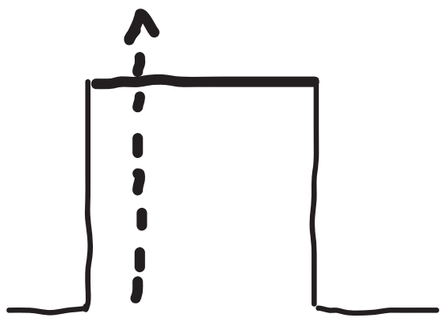
ACCESSIBILITY



(public/communal)
outdoor access via
staircase or elevator



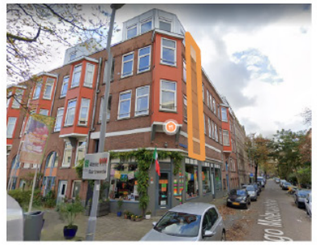
(public/communal)
indoor access via
staircase or elevator



(private) indoor
access via staircase
or elevator

POTENTIAL SOCIAL ROOFS

4 Adrien Mildersstraat



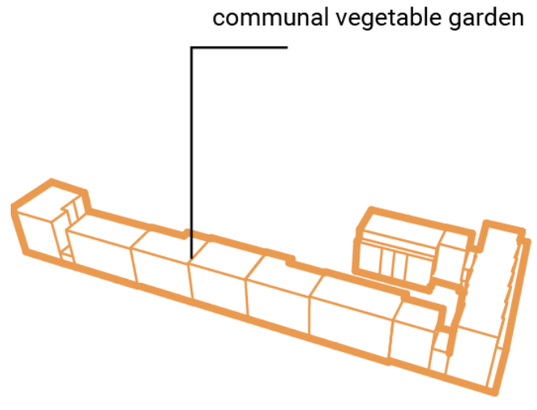
- no existing entrance via porch/facade
- owned by housing corporation

5 Van Oosterzeestraat

- access via two porches
- continuous (communal) space
- owned by housing corporation

6 Gerrit Jan Mulderstraat

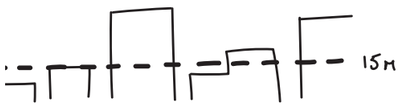
- no existing entrance via porch/facade
- owned by housing corporation
- connect buildings via elevated walkways



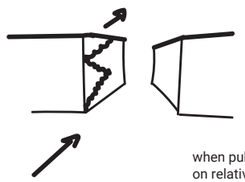
DESIGN RULES

SOCIAL ROOFS

BUILDING HEIGHTS

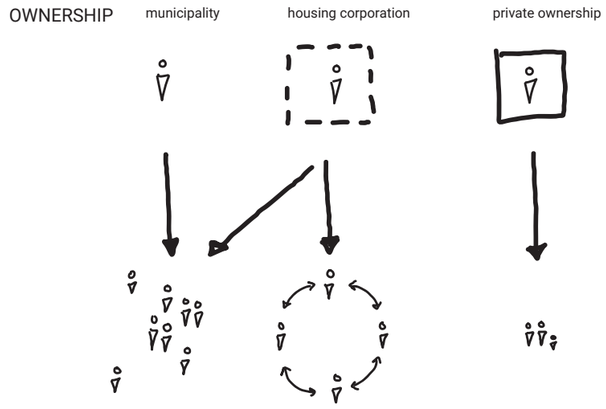


maximum rooftop height for roofs with a public (social) function is 15m

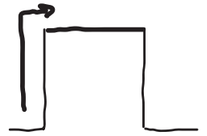


when public social roofs are located on relatively low roofs, there is a smooth connection between the public roofs and the public plinth

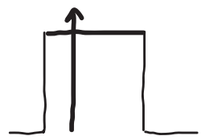
OWNERSHIP x USERS



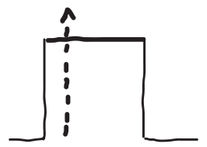
ACCESSIBILITY



(public/communal) outdoor access via staircase or elevator



(public/communal) indoor access via staircase or elevator



(private) indoor access via staircase or elevator

VALUABLE ADDITION TO PUBLIC SPACE

what functions are already there in the neighbourhood and what is valuable to add

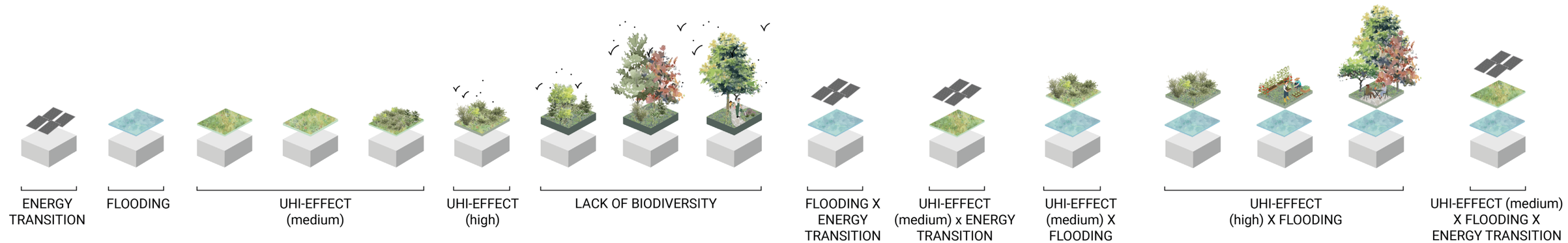
TOOLKIT SOCIAL LAYER

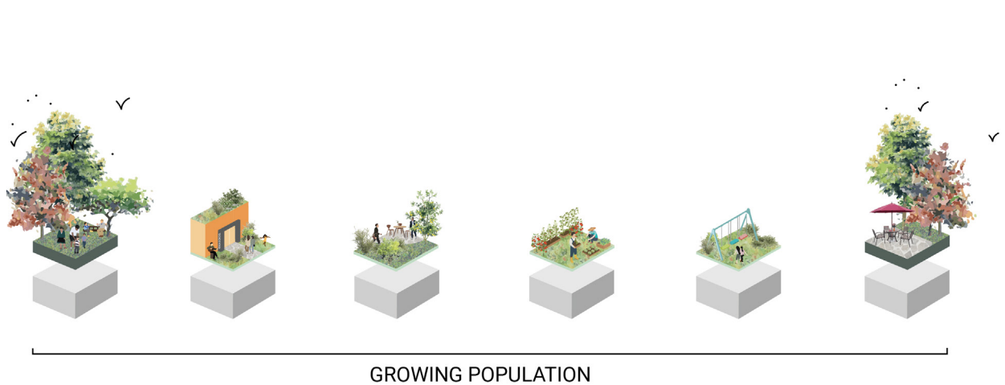
GROWING POPULATION

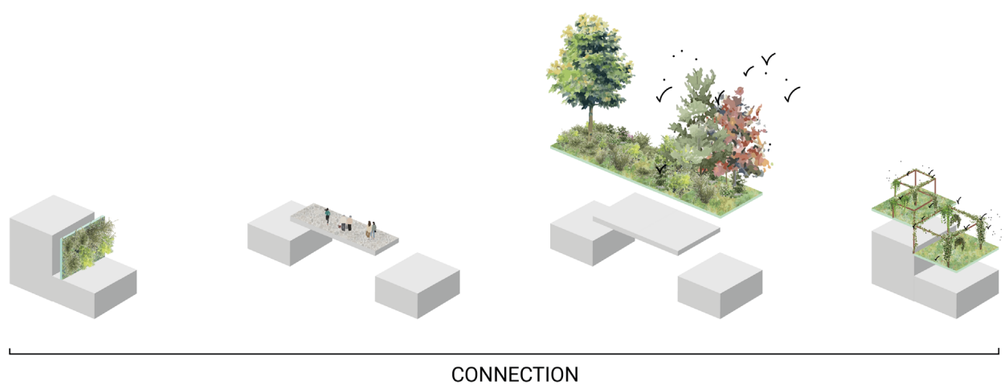
PROPERTIES							
function		green community centre, cafe, yoga school	green, outdoor workspace	vegetable garden	shared rooftop garden, playground	rooftop garden, terrace	public park, event area
accessibility		public	communal	communal	private	private	public
maintenance		municipality	municipality, private ownership	housing corporation	housing corporation, private ownership	private ownership	municipality
building height		<15m	0-40m	0-40m	0-40m	0-40m	<15m
reinforce supporting structure		yes	yes	yes	yes	no	yes
ownership		municipality	property manager	community (residents)	community (residents)	owner	housing corporation, municipality

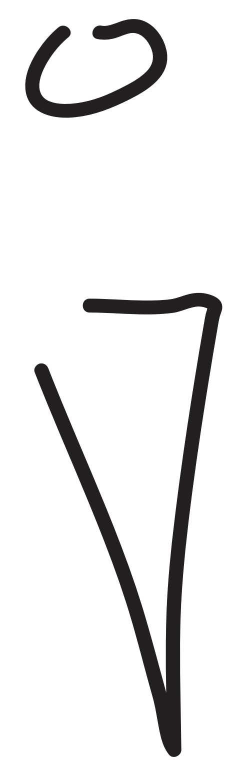
IMPLEMENTATION

TOOLKIT


ENERGY TRANSITION
FLOODING
UHI-EFFECT (medium)
UHI-EFFECT (high)
LACK OF BIODIVERSITY
FLOODING X ENERGY TRANSITION
UHI-EFFECT (medium) x ENERGY TRANSITION
UHI-EFFECT (medium) X FLOODING
UHI-EFFECT (high) X FLOODING
UHI-EFFECT (medium) X FLOODING X ENERGY TRANSITION


GROWING POPULATION


CONNECTION



MANY CHALLENGES

. permits

. roof structure

. high cost

. little subsidy

. ownership

. access

. current uses

. climate (maintenance)

. willingness

CURRENT USES

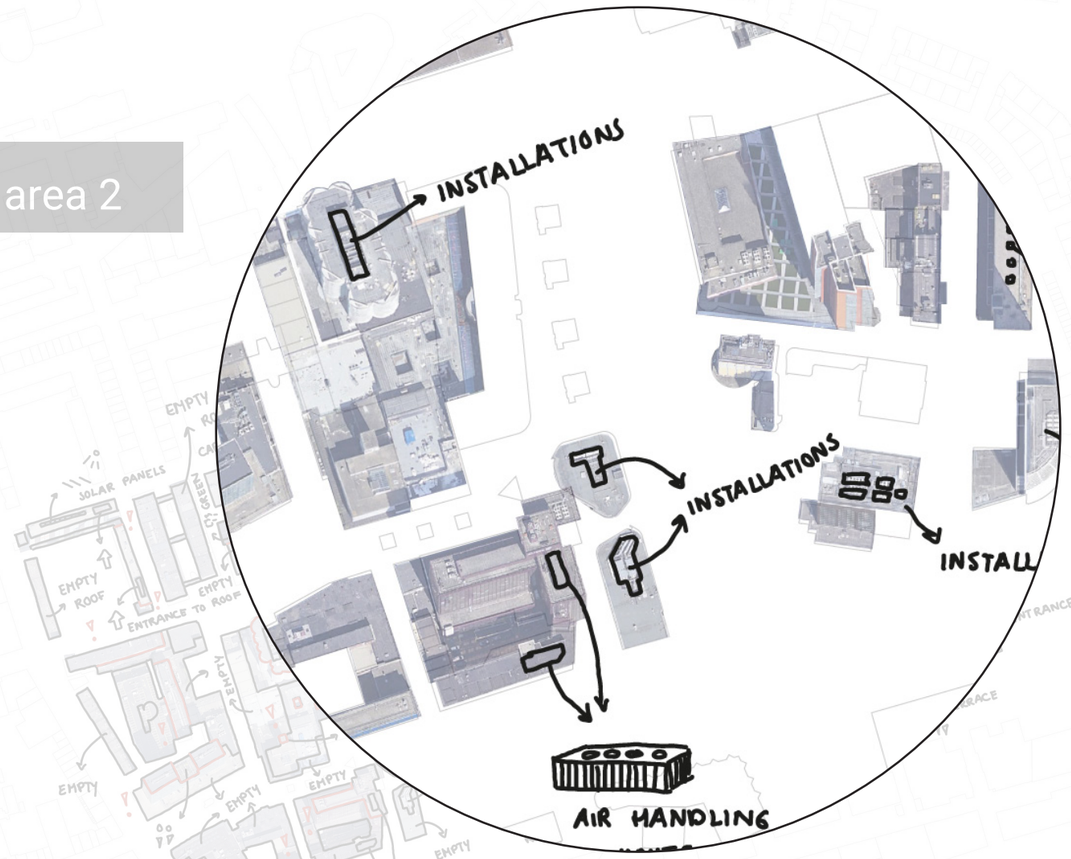
area 1

area 2

CURRENT USES

area 1

area 2



LEGEND

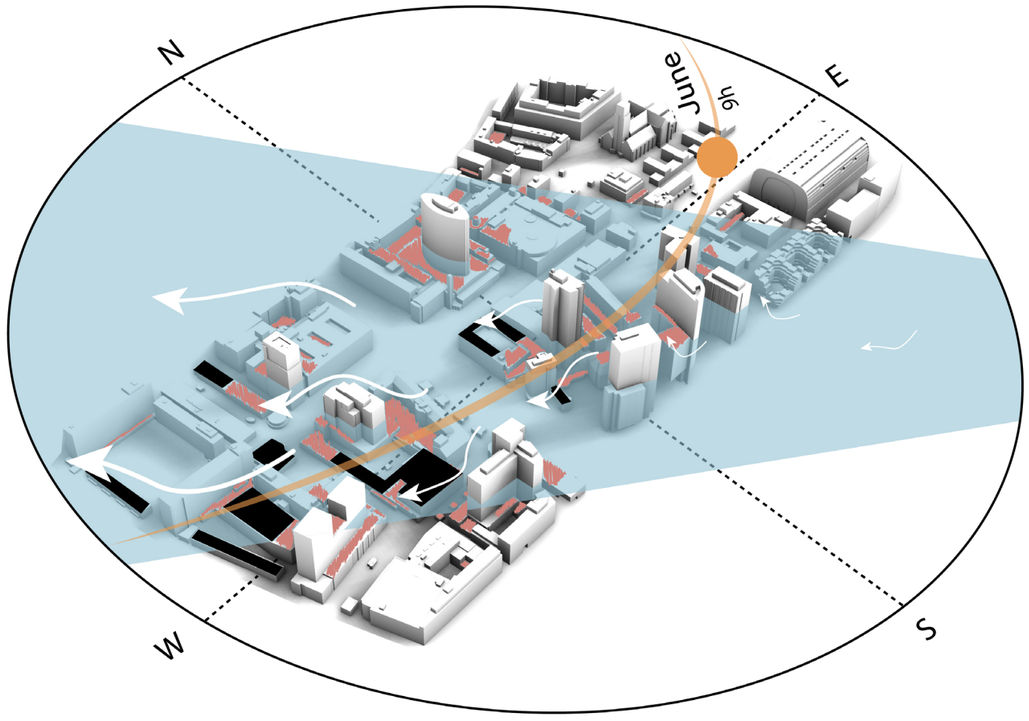
buildings

flat roofs >500m2

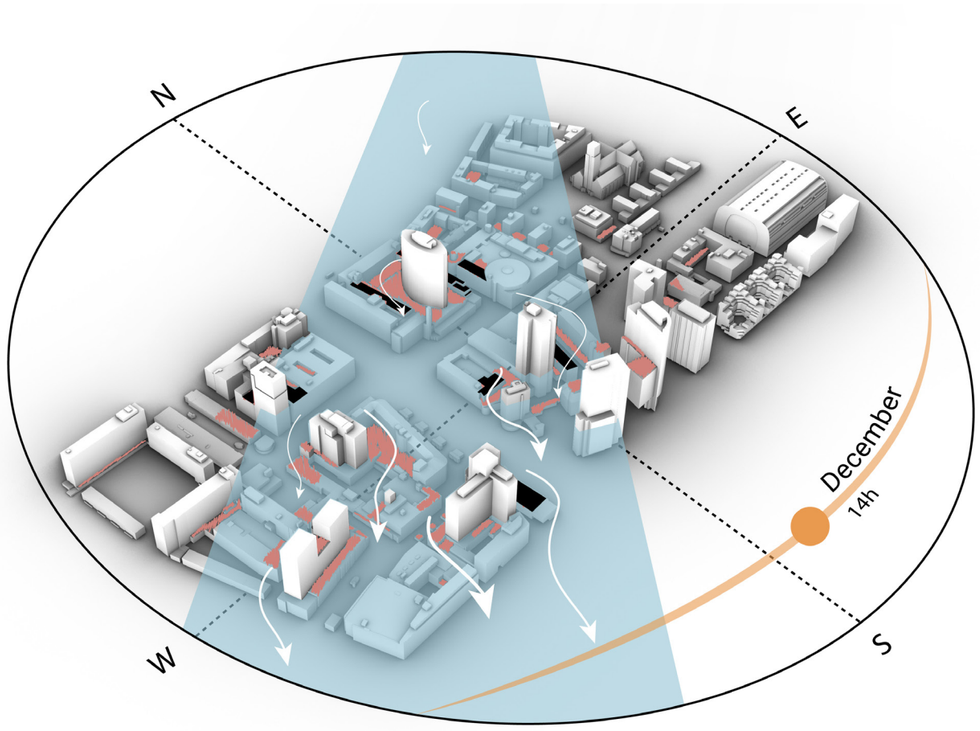
0 200 m

CLIMATE ISSUES

AREA 2



extreme summer situation



extreme winter situation

LEGEND

- wind
- sun
- shadow
- roofs that suffer from cold/ warm wind streams (and shade)

WILLINGNESS

Roof Maassilo (2022)

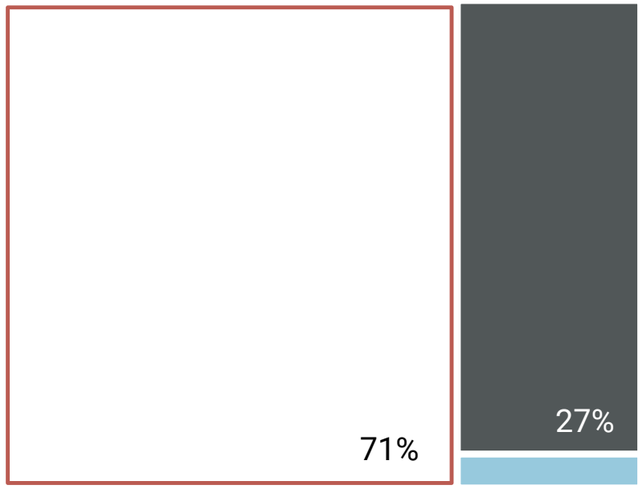
WILLINGNESS

“Met alleen mannen in pak komen we er niet!”

Roof Maassilo (2022)

IT STARTS WITH YOU!

71% PRIVATELY OWNED



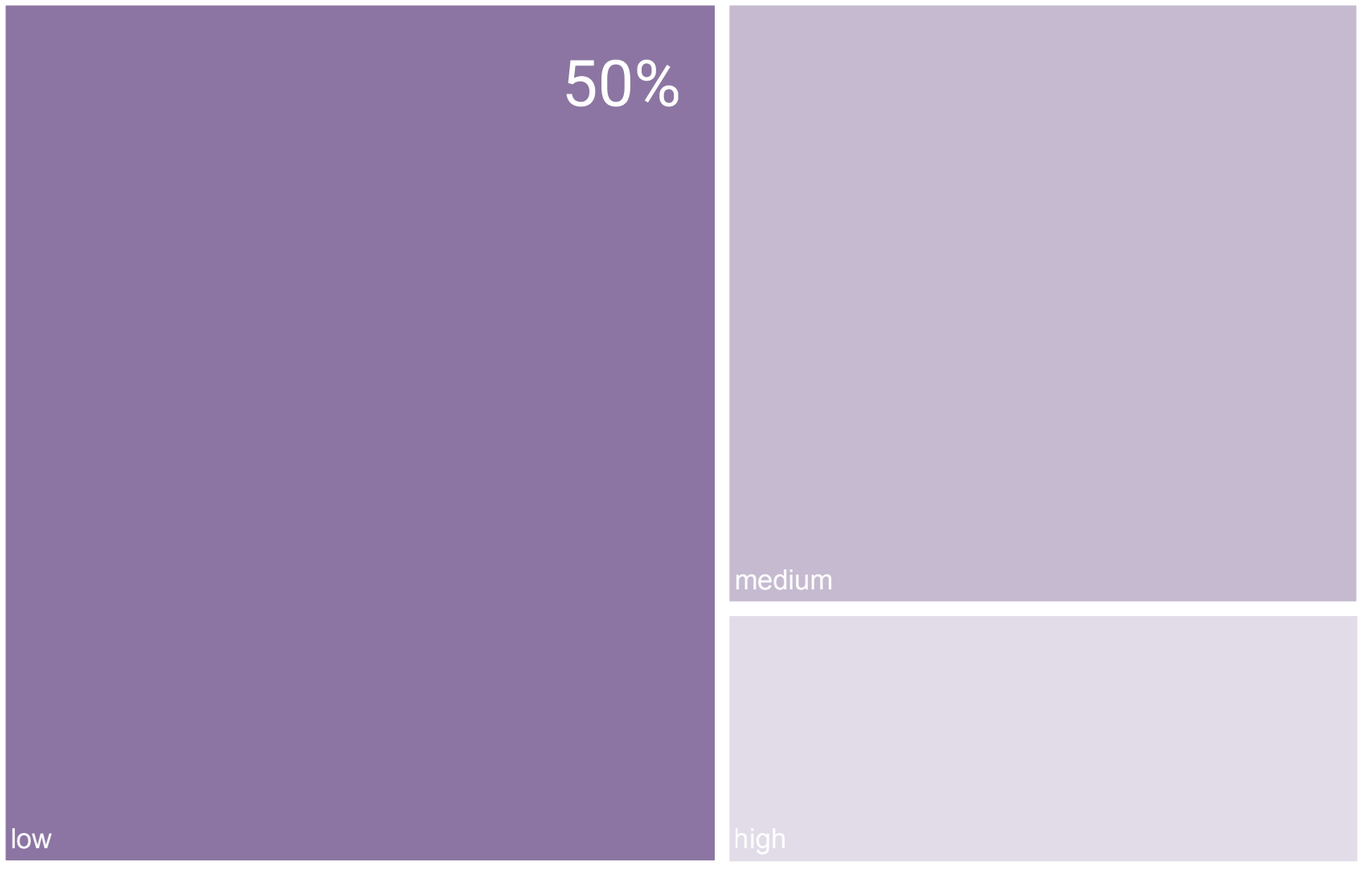
Source: Gemeente Rotterdam (2018)

LEGEND

- privately owned
- owned by housing corporation
- owned by municipality

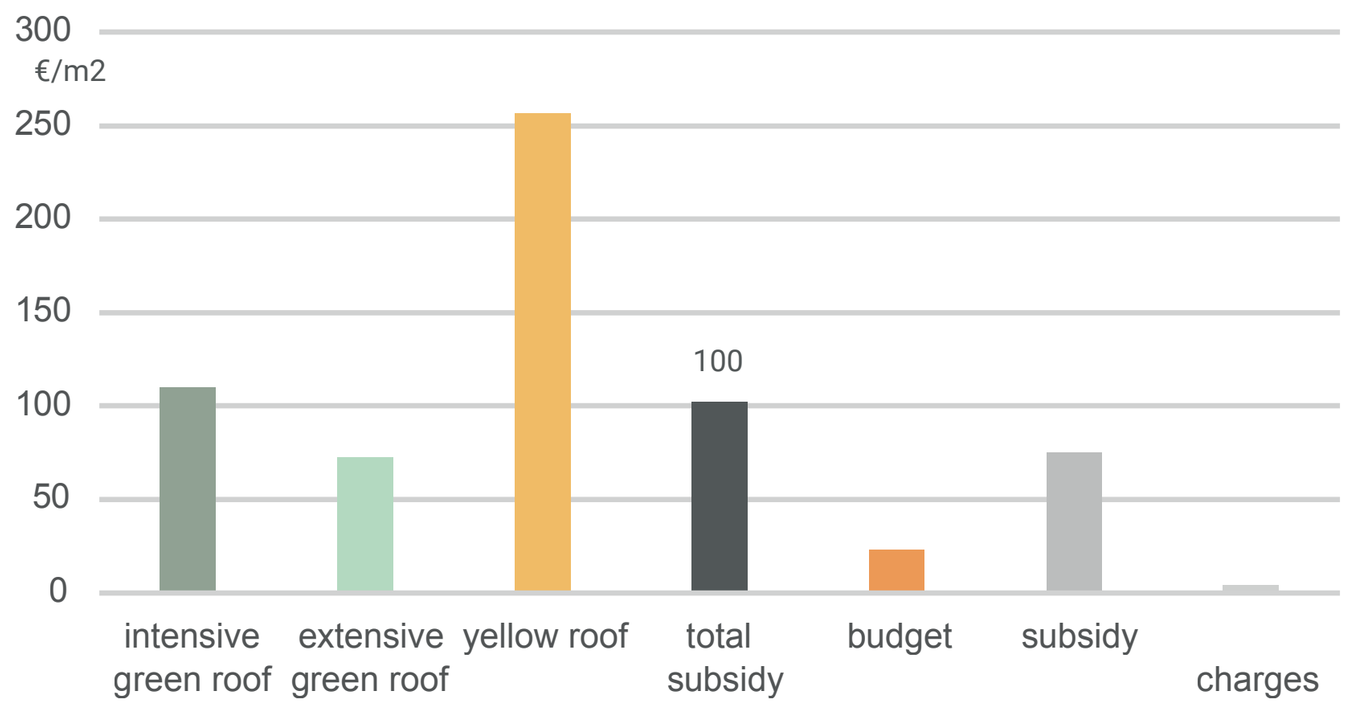
0 200 m

INCOME DISTRIBUTION ROTTERDAM



Source: CBS (2018)

FINANCIAL SUPPORT



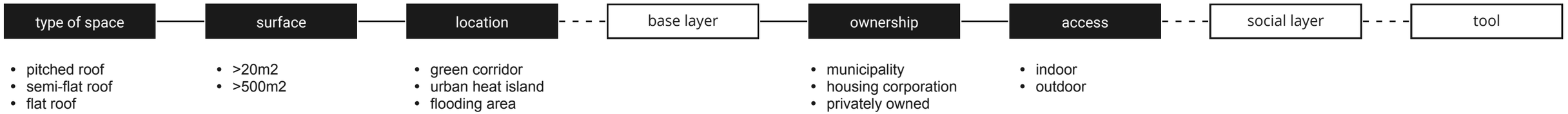
Source: Gemeente Rotterdam (2021), Milieu Centraal (202)

WE HAVE TO DO IT TOGETHER!

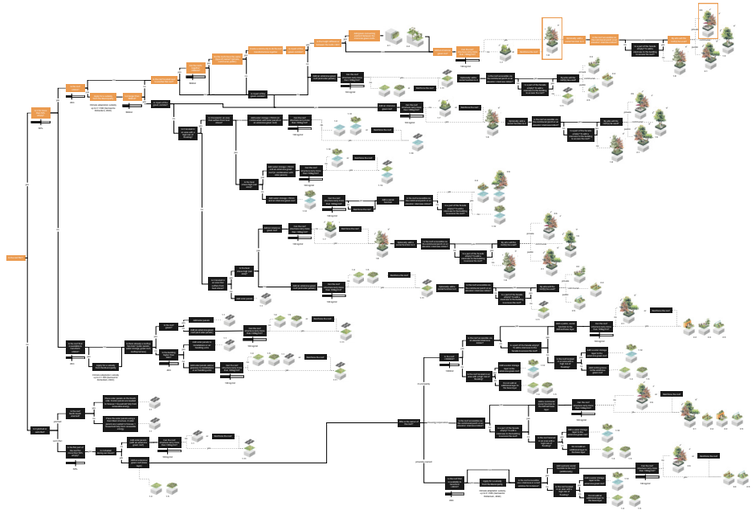
Is the roof flat?
yes
Is it for more than 50% empty?
50%
yes
Is the roof >20m2?
20m
yes
Apply for a subsidy from the Municipality
Climate adaptation subsidy up to € 1.500 (Gemeente Rotterdam, 2022)
Is it larger than 500m2?
500m2
yes
Is the roof located next to another flat roof?
yes
Are the roofs together >500m2?
500m2
yes
Do the roofs have the same (type of) owner? (private, communal, public)
yes
Create a community to do the roof transformations together
yes
Is it part of the green corridor?
yes
Is the height difference between the roofs >9m?
yes
Add green connecting element between the intensive green roofs
3.1
3.4
no
Add an intensive green roof
Can the roof structure carry more than 100kg/m2?
100 kg/m2
no
yes
1.7
or
Reinforce the roof
1.8
Optionally: add a social function to it
Is the roof accessible via the communal porch or an elevator/ staircase indoor?
yes
Is a part of the facade empty? To add a staircase to the building to access the roof?
yes
By who will the roof(s) be used?
private
communal
public
2.6
2.1
1.9
no
1.8
no
Is part of the green corridor?
no
Add an extensive green roof (and solar panels)
Can the roof structure carry more than 100kg/m2?
100 kg/m2
no
yes
1.11
or
Reinforce the roof
Optionally: add a social function to it
Is the roof accessible via the communal porch or an elevator/ staircase indoor?
yes
Is a part of the facade empty? To add a staircase to the building to access the roof?
yes
By who will the roof(s) be used?
private
communal
public
2.3
2.4
2.5
no
1.11
no
Is it part of the green corridor?
yes
Add an intensive green roof
Can the roof structure carry more than 100kg/m2?
100 kg/m2
no
yes
1.7
or
Reinforce the roof
1.8
Optionally: add a social function to it
Is the roof accessible via the communal porch or an elevator/ staircase indoor?
yes
Is a part of the facade empty? To add a staircase to the building to access the roof?
yes
By who will the roof(s) be used?
private
communal
public
2.6
2.1
1.9
no
1.8
no
Is it located in an area with a high risk of flooding?
yes
Is it located in an area that suffers from heat stress?
no
Add water storage >70mm (in combination with solar panels or an extensive green roof)
Can the roof structure carry more than 100kg/m2?
100 kg/m2
no
yes
1.2
1.12
or
Reinforce the roof
yes
Is the heat stress high (red area)?
yes
Add water storage >70mm and an extensive green roof (in combination with solar panels)
Can the roof structure carry more than 100kg/m2?
100 kg/m2
no
yes
1.12
or
Reinforce the roof
1.16
no
Add water storage >70mm and an intensive green roof
1.12
Can the roof structure carry more than 100kg/m2?
100 kg/m2
no
yes
Reinforce the roof
Add a social function
Is the roof accessible via the communal porch or an elevator/ staircase indoor?
yes
Is a part of the facade empty? To add a staircase to the building to access the roof?
yes
2.4
2.6
no
1.12
no
Is the heat stress high (red. area)?
yes
Is it located in an area that suffers from heat stress?
no
Add solar panels
1.1
Add an intensive green roof
Can the roof structure carry more than 100kg/m2?
100 kg/m2
no
yes
1.7
Reinforce the roof
1.8
Optionally: add a social function to it
Is the roof accessible via the communal porch or an elevator/ staircase indoor?
yes
Is a part of the facade empty? To add a staircase to the building to access the roof?
yes
By who will the roof(s) be used?
private
communal
public
2.6
2.1
1.9
no
1.8
no
Add an extensive green roof (and solar panels)
Can the roof structure carry more than 100kg/m2?
100 kg/m2
no
yes
1.3
1.5
Reinforce the roof
1.11
Optionally: add a social function to it
Is the roof accessible via the communal porch or an elevator/ staircase indoor?
yes
Is a part of the facade empty? To add a staircase to the building to access the roof?
yes
By who will the roof(s) be used?
private
communal
public
2.3
2.4
2.5
no
1.11
Is it pitched or semi-flat?
pitched
Is the roof North-South oriented?
yes
Place solar panels on the South-side. 8 solar panels are needed to foresee 1 household fully from renewable energy
1.1
no
Place the solar panels using a East-West structure. 8 solar panels are needed to foresee 1 household fully from renewable energy
1.1
semi-flat
Is the flat part of the roof for more than 50% empty?
50%
yes
Is it shaded during sun hours?
no
Add solar panels (with an extensive green roof)
Can the roof structure carry more than 100kg/m2?
100 kg/m2
no
1.1
or
Reinforce the roof
yes
1.11
yes
Add an extensive green roof (base layer)
1.3
1.5
no
Is the roof that is available to transform >20m2?
20m
no
Apply for a subsidy from the Municipality
Climate adaptation subsidy up to € 1.500 (Gemeente Rotterdam, 2022)
yes
Is there already a rooftop function? (solar panels, water storage, green roof, rooftop terrace)
yes
Is the roof green?
yes
Add solar panels
1.1
no
Add an extensive green roof (and solar panels)
Can the roof structure carry more than 100kg/m2?
100 kg/m2
no
1.3
1.5
or
Reinforce the roof
yes
1.11
no
Is the building higher than 40m?
40m
yes
Add solar panels to installations or air handling units
1.1
no
Add solar panels and/or greenery to installations or air handling units
Can the roof structure carry more than 100kg/m2?
100 kg/m2
no
1.3
1.5
1.1
or
Reinforce the roof
yes
1.11
Who is the owner of the roof?
municipality
Is the roof >1000m2?
1000m2
yes
Is the roof accessible via an elevator/staircase indoor?
yes
Is a part of the facade empty? To add a staircase to the facade to access the roof?
yes
Add a public, social function to the defined base layer
Can the roof structure carry more than 100kg/m2?
100 kg/m2
no
2.1
or
Reinforce the roof
yes
2.2
2.3
2.5
no
Is the roof located in an area with a high risk of flooding?
yes
Add a water storage layer to the extensive green roof
1.12
no
Add nothing more to the extensive green roof
1.3
1.5
no
Is the roof located in an area with a high risk of flooding?
yes
Add a water storage layer to the extensive green roof
1.12
no
Do not add an additional layer to the base layer
1.3
1.5
housing corporation
Is the roof accessible via the communal porch or an elevator/ staircase indoor?
yes
Add a communal social function to the defined base layer
Can the roof structure carry more than 100kg/m2?
100 kg/m2
no
2.6
or
Reinforce the roof
yes
2.1
2.4
2.2
2.5
no
Is a part of the facade empty? To add a staircase to the building to access the roof?
yes
Is the roof located in an area with a high risk of flooding?
yes
Add a water storage layer to the extensive green roof
1.12
no
Do not add an additional layer to the base layer
1.3
1.5
privately owned
Is the roof that is available to transform >20m2?
20m
no
Apply for a subsidy from the Municipality
Climate adaptation subsidy up to € 1.500 (Gemeente Rotterdam, 2022)
yes
Is the roof accessible via a staircase or a roof window for instance?
yes
Add a private social function to the roof (additionally)
Can the roof structure carry more than 100kg/m2?
100 kg/m2
no
2.6
or
Reinforce the roof
yes
2.4
2.5
no
Is the roof located in an area with a high risk of flooding?
yes
Add a water storage layer to the extensive green roof
1.12
no
Do not add an additional layer to the base layer
1.3
1.5

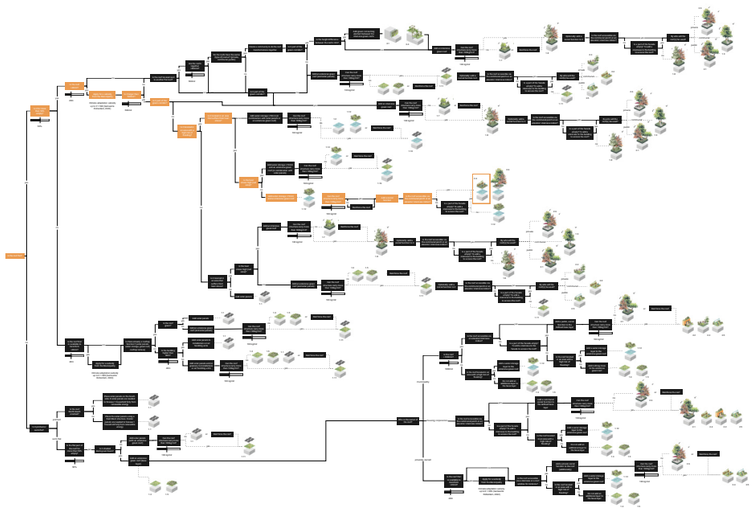
YOU WILL BE GUIDED

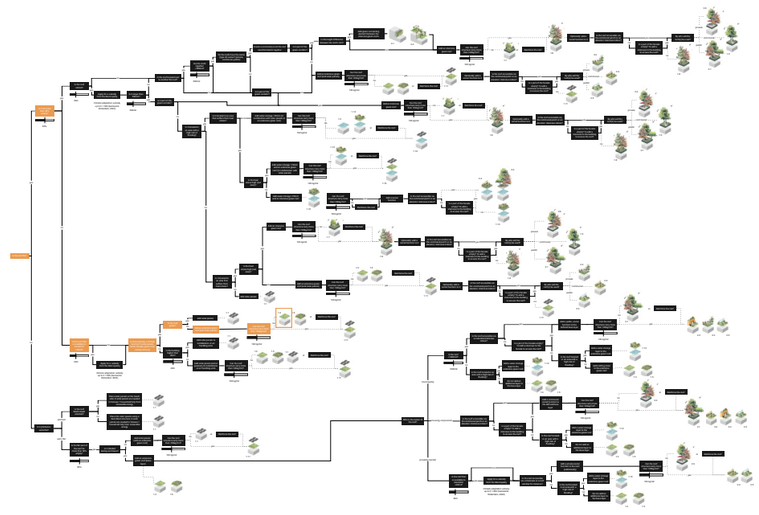
OUTLINE DECISION TREE



DIFFERENT ROUTES







CONCLUDING REMARKS

ROTTERDAM’S ROOFSCAPE

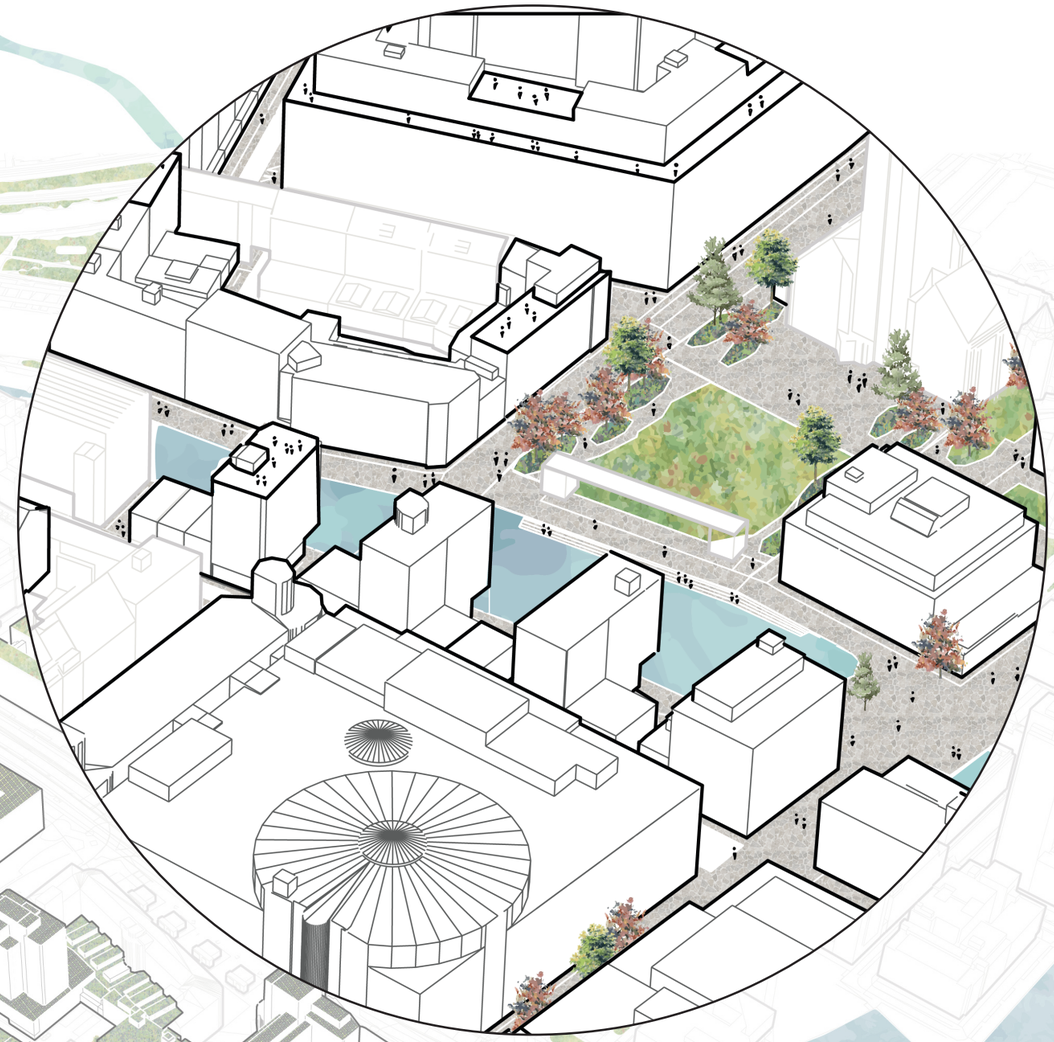
LEGEND

buildings
water
green

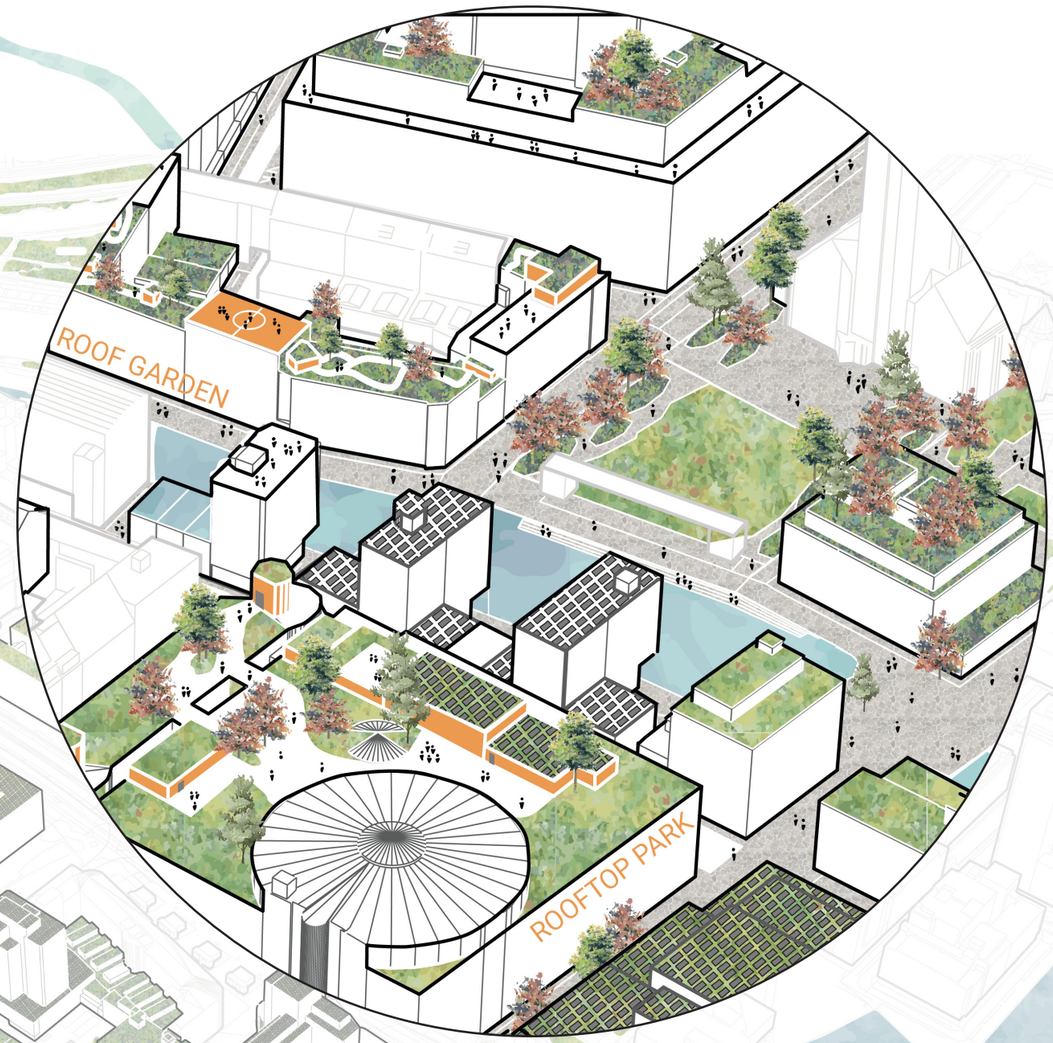
roofs x flooding
roofs x heat stress
roofs x green corridor
roofs x energy transition

0 0,5 km

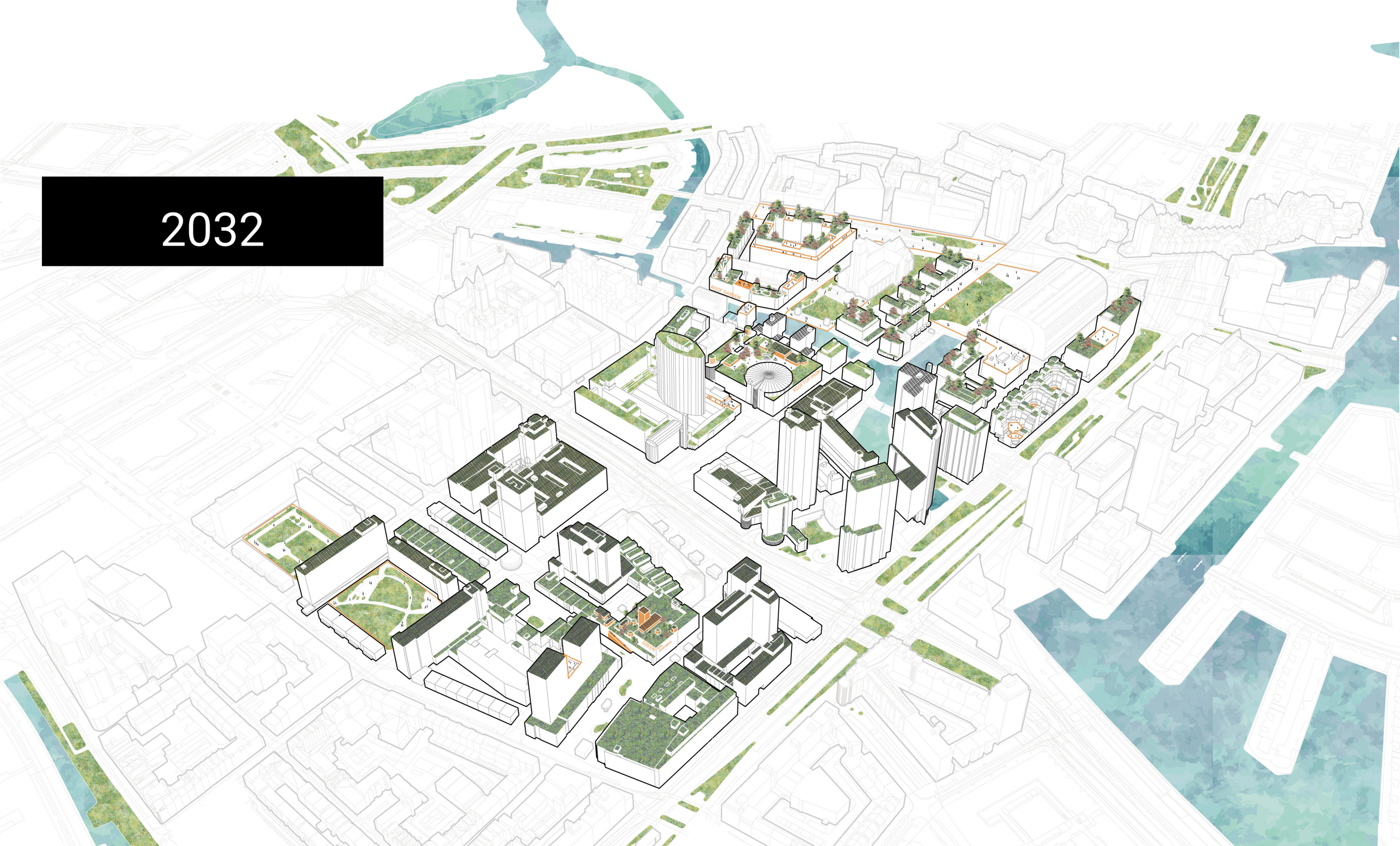
2022

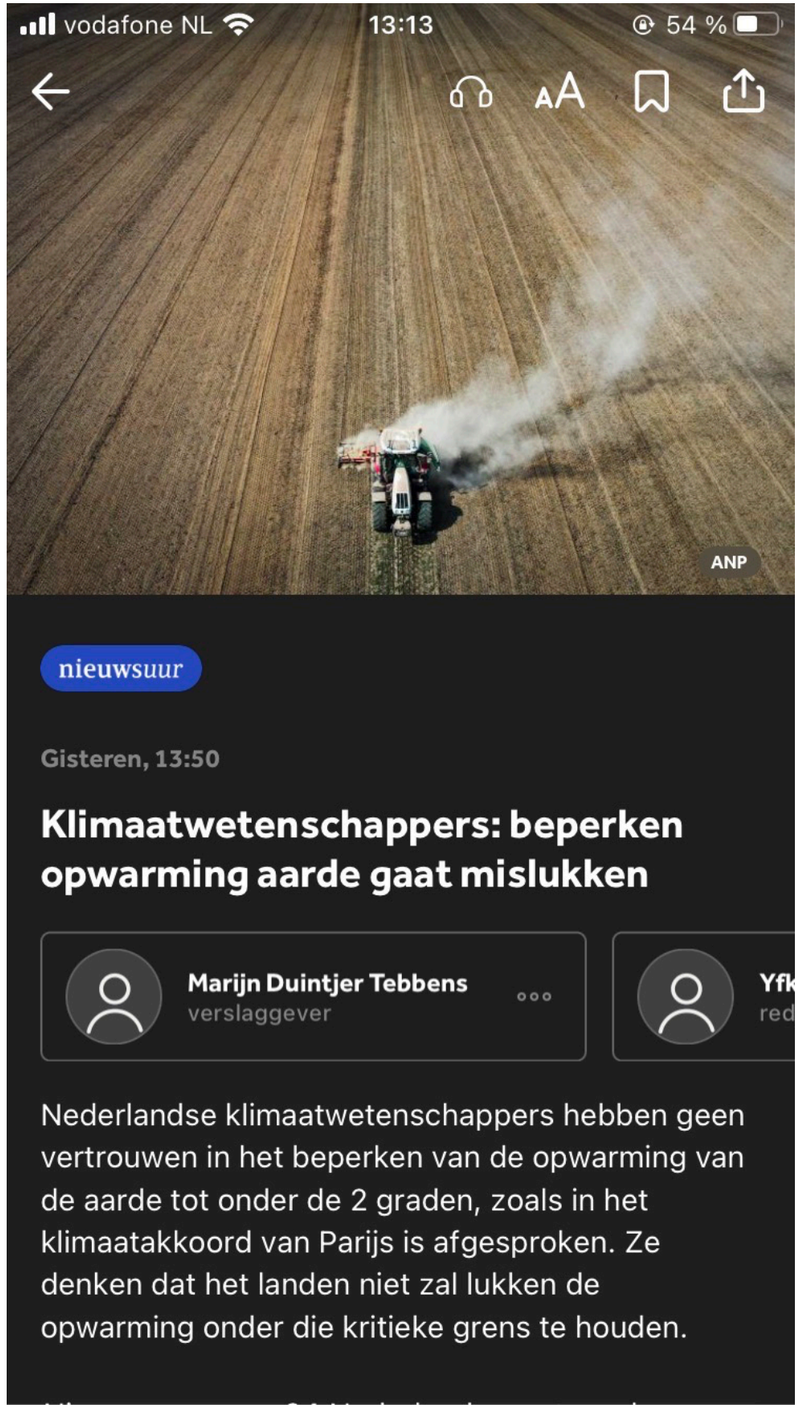


2032

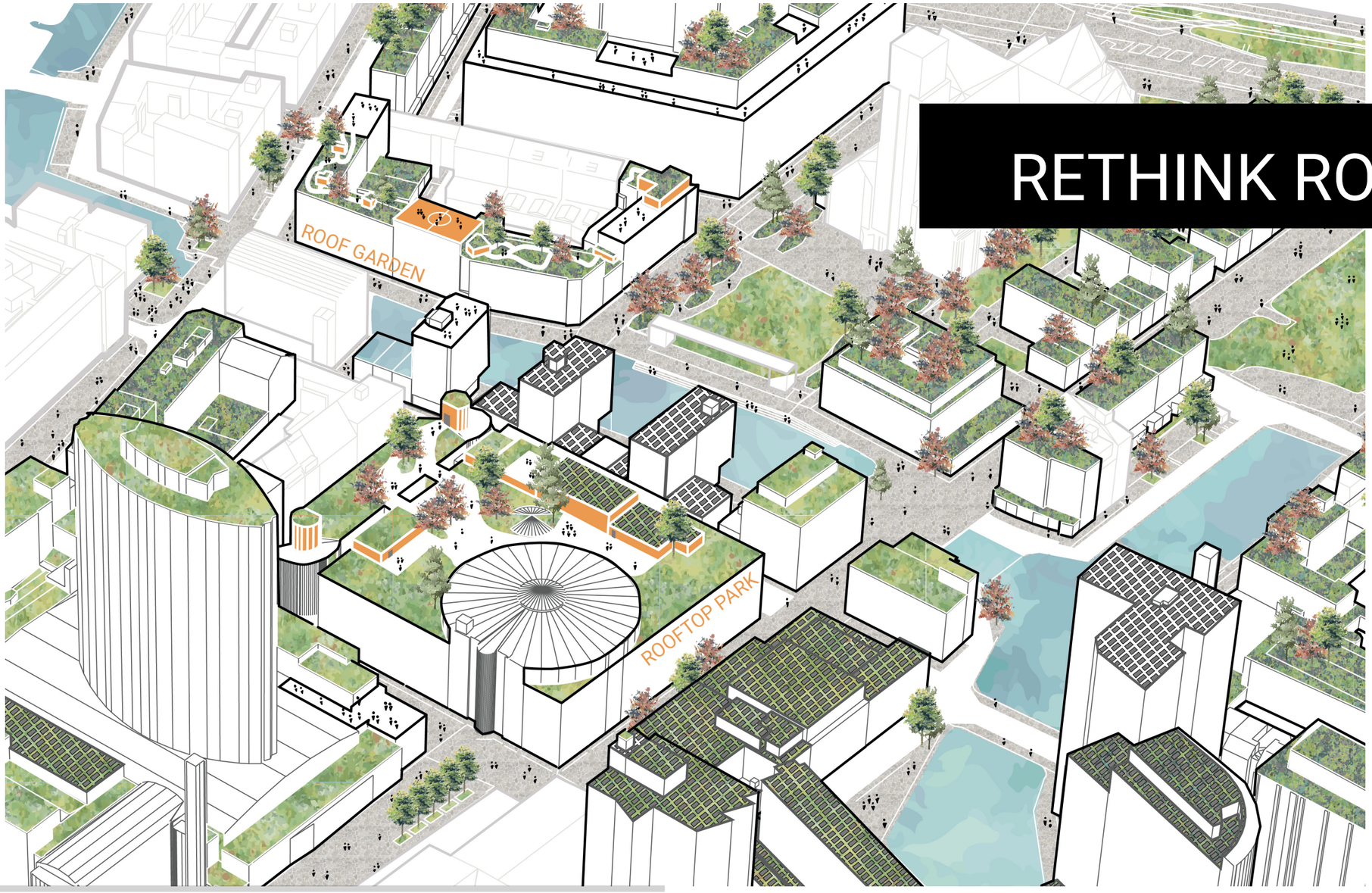


2032





Source: NOS (2022)



RETHINK ROOFS!

NAME

Joëlle Hermans
4610342

MENTORS

Rients Dijkstra
Arjan van Timmeren

STUDIO

The design of the Urban
Fabric

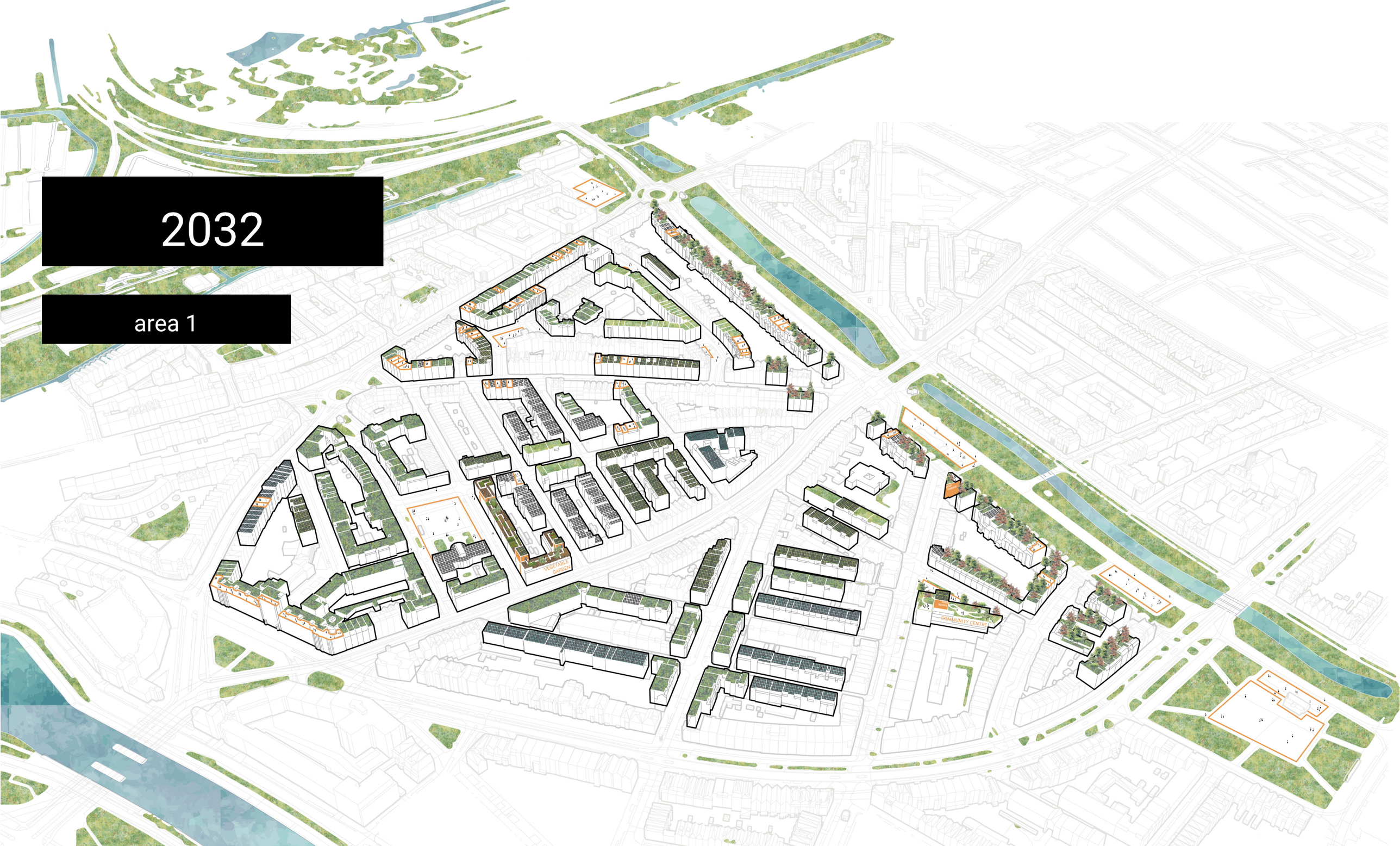
QUESTIONS?

View from Hofpoort (2022)

APPENDIX

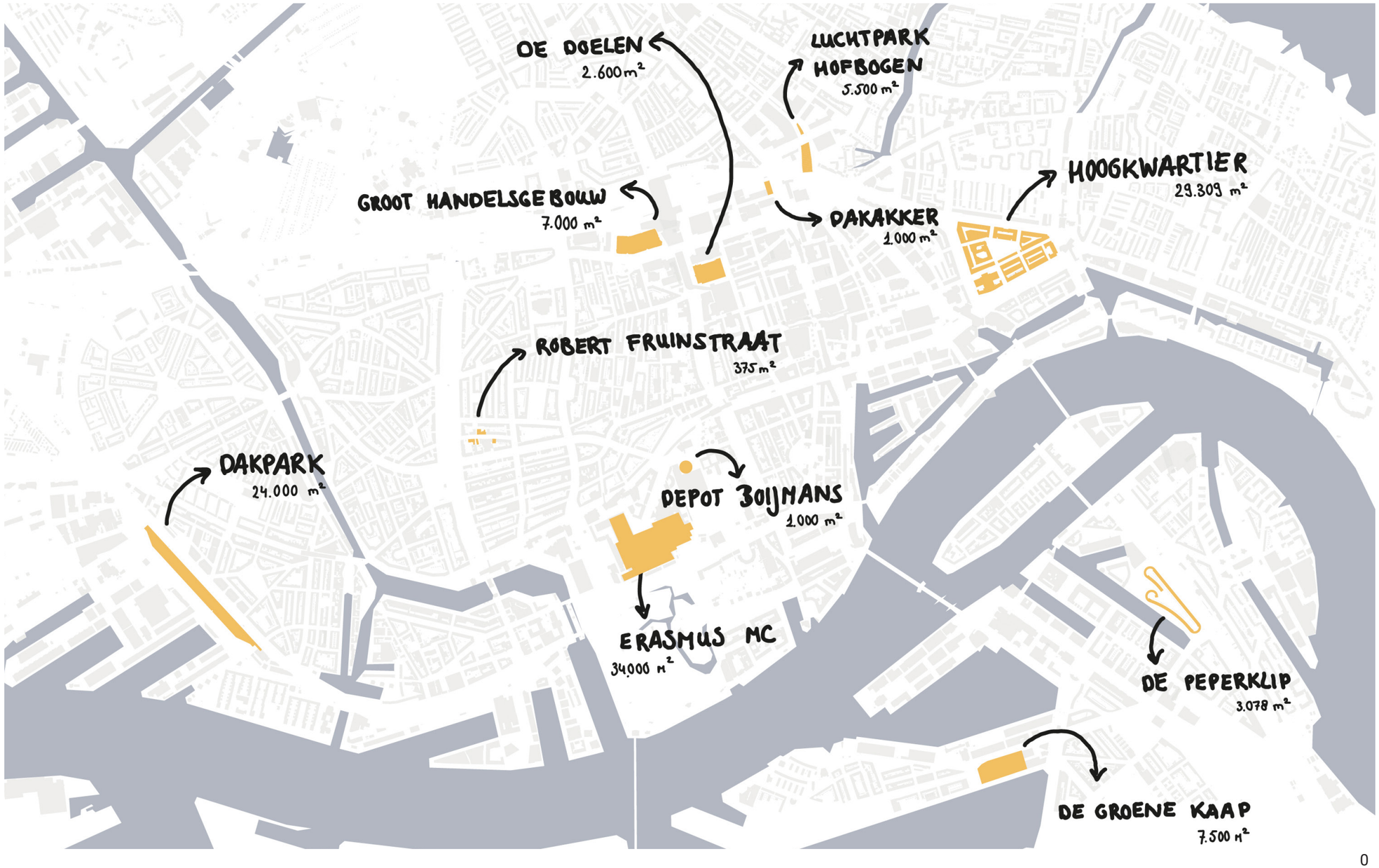
2032

area 1

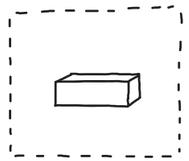


BOOMVEREN

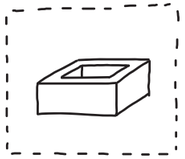
ROOFTOP PROJECTS ROTTERDAM



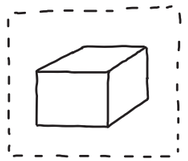
FLAT ROOF SCALES



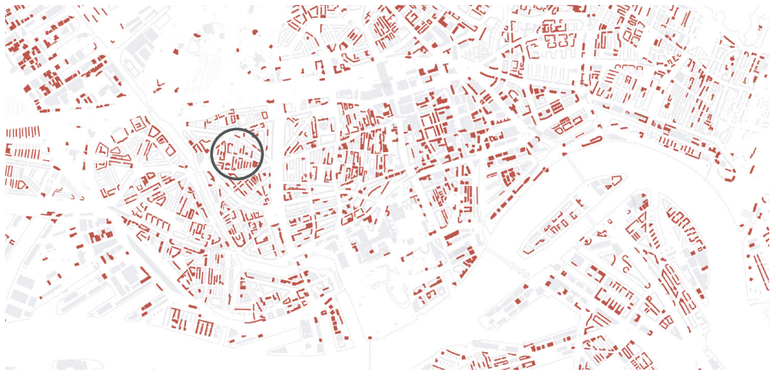
SMALL

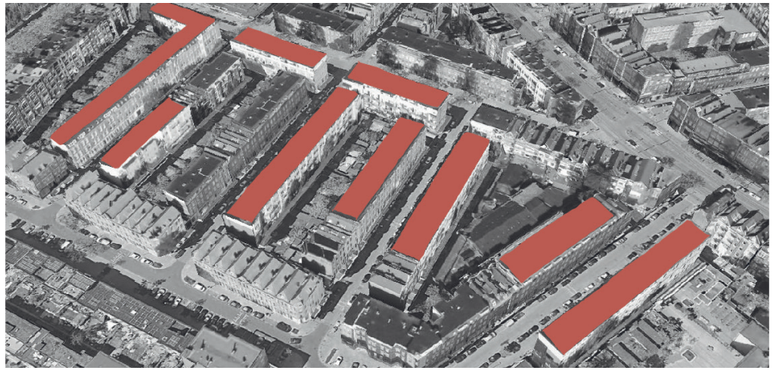


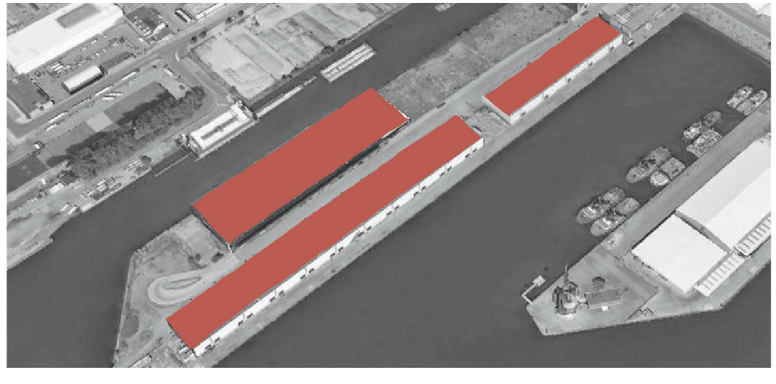
MEDIUM

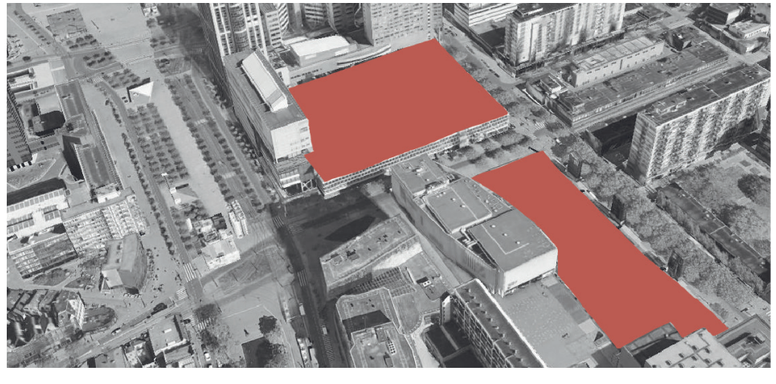


LARGE



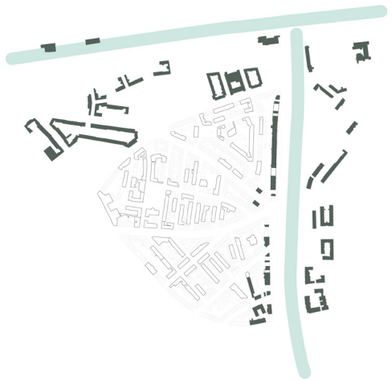






URGENCY MAP

area 1



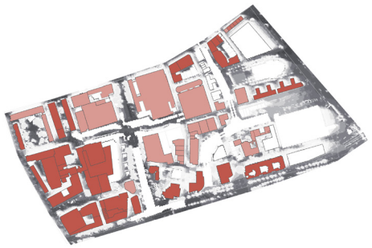
LEGEND

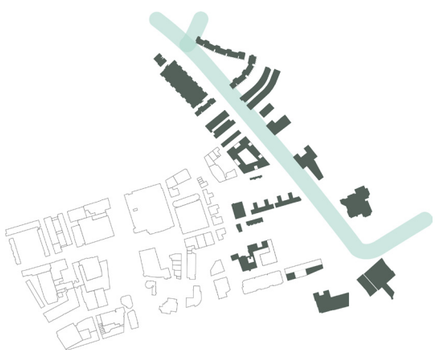
- focus area
- water
- green
- buildings
- roofs >500m2
- roads
- green corridor
- high urgency
- low urgency
- roofs x UHI effect (high)
- roofs x UHI effect (medium)
- roofs x flooding
- roofs x green corridor (>500m2)
- roofs x green corridor (<500m2)
- roofs x energy transition

0 100 200m

URGENCY MAP

area 2



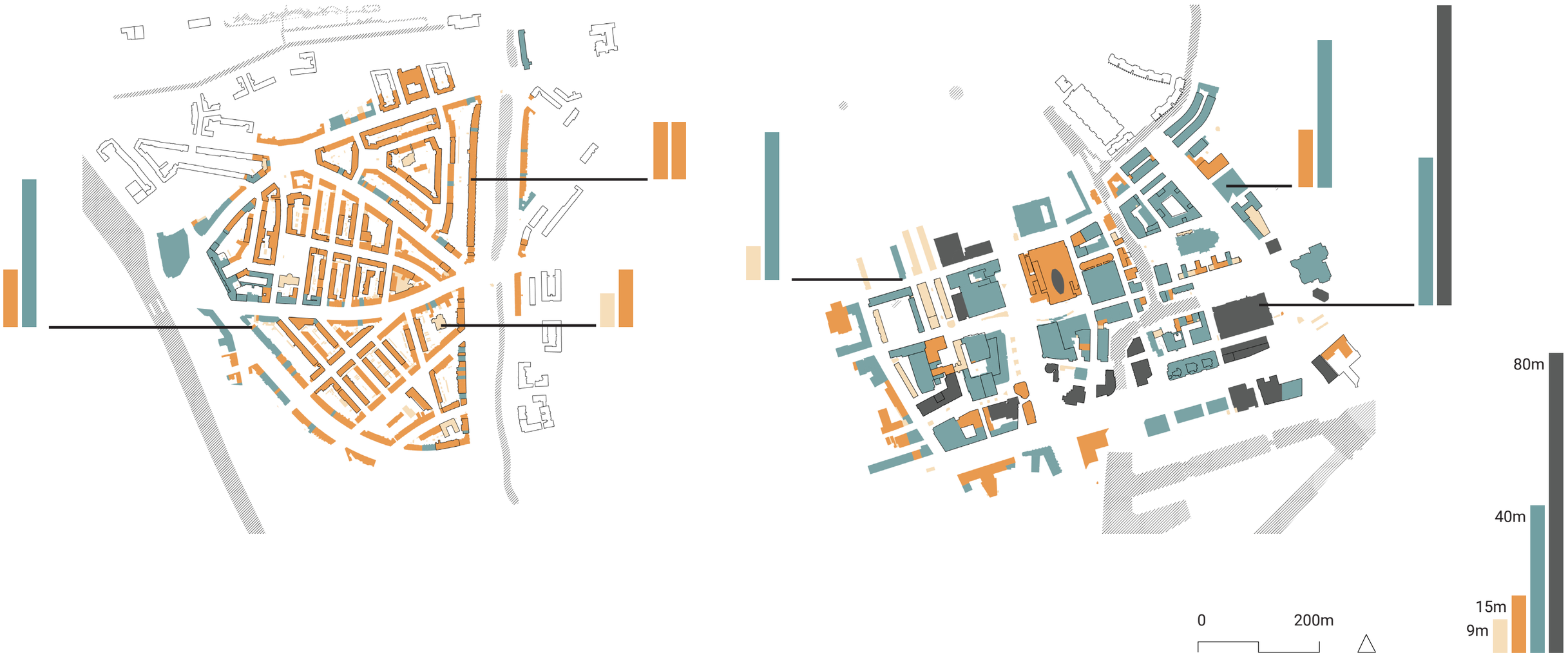


LEGEND

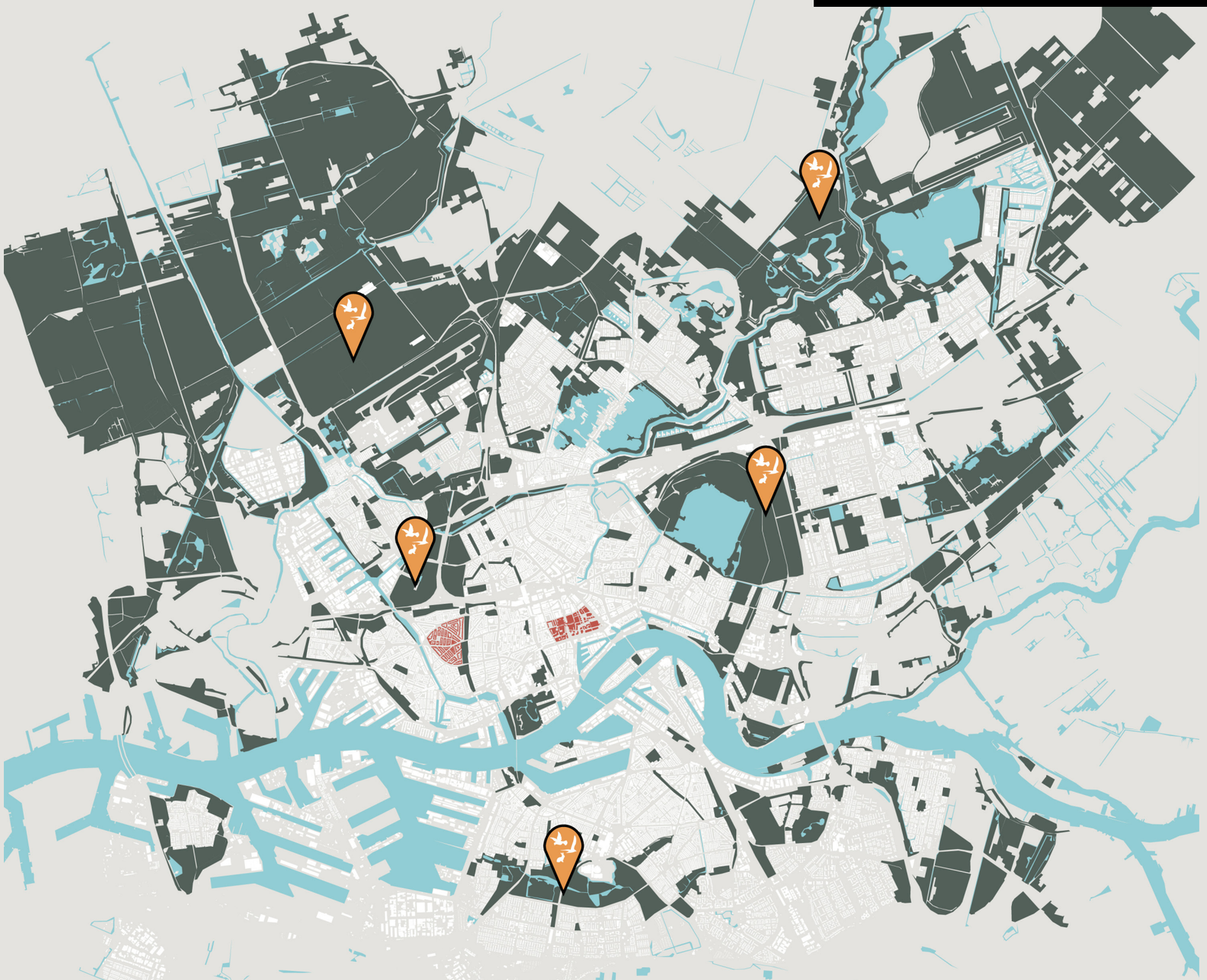
- focus area
- water
- green
- buildings
- roofs >500m2
- roads
- green corridor
- high urgency
- low urgency
- roofs x UHI effect (high)
- roofs x UHI effect (medium)
- roofs x flooding
- roofs x green corridor (>500m2)
- roofs x green corridor (<500m2)
- roofs x energy transition

0 100 200m

BUILDING HEIGHTS

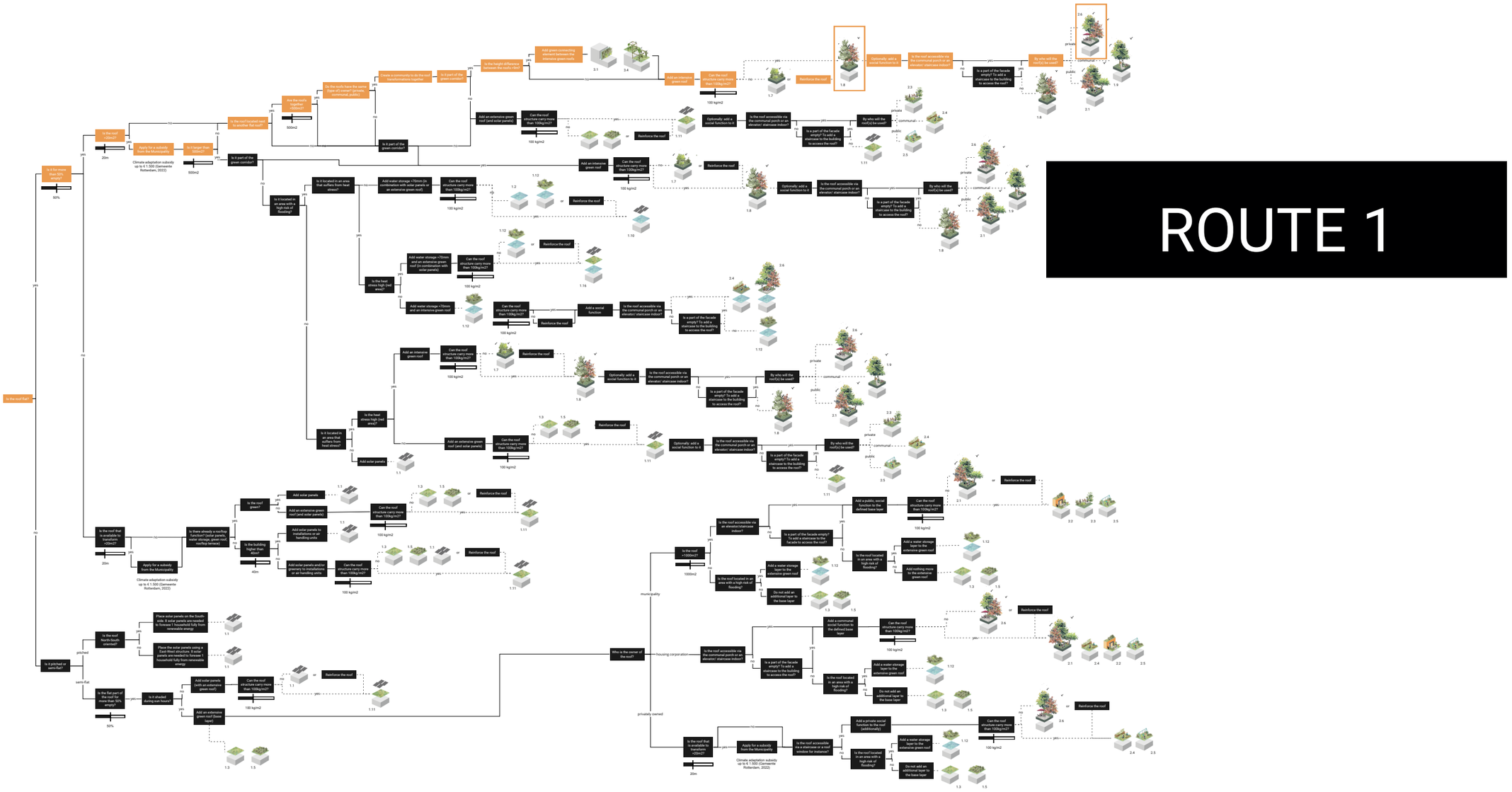


NATURE AREAS



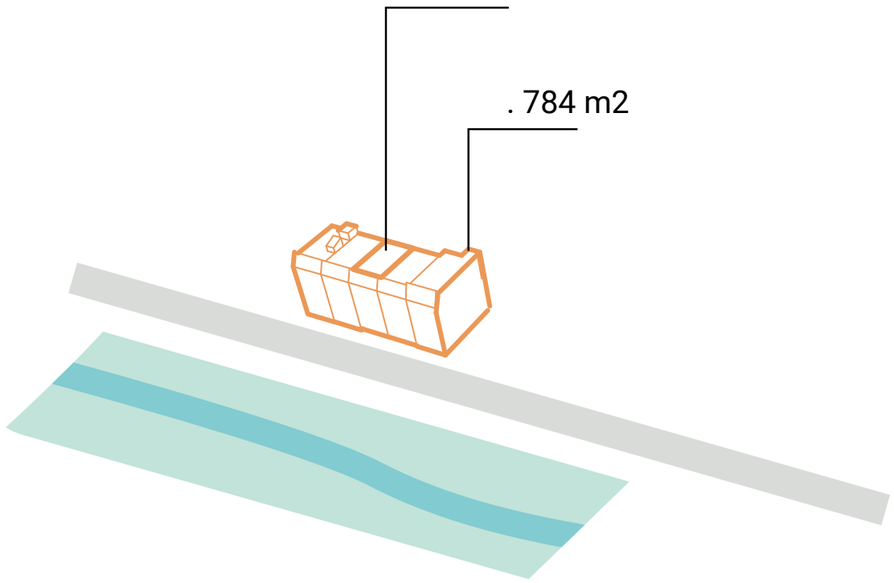
VEGETABLE GARDENS

ROUTE 1



type of space	surface	location	base layer	ownership	access	social layer
• flat roof	• >500m2	• green corridor	• intensive green roof	• privately owned	• indoor	• private roof terrace

. flat roof
. 157 m2
. located in green corridor
. privately owned
. access via roof window



ROUTE 1

. flat roof

. 157 m2

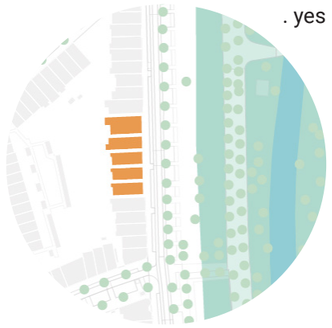
. privately owned

. in area 1

ROUTE 1

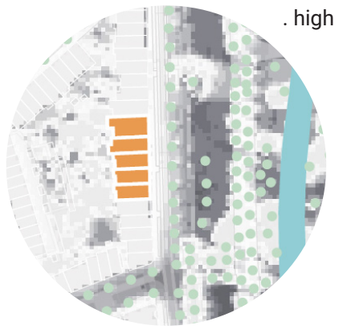
green corridor

. yes



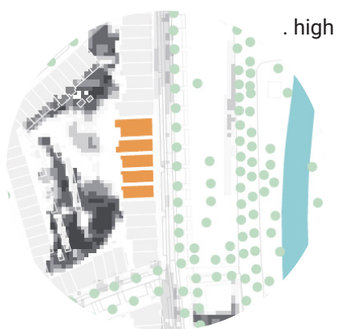
heat stress

. high



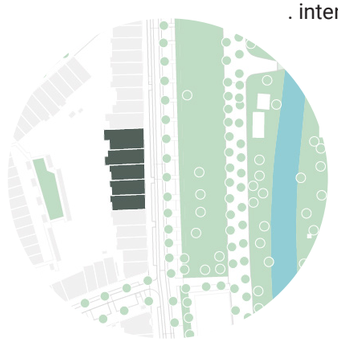
flooding risk

. high



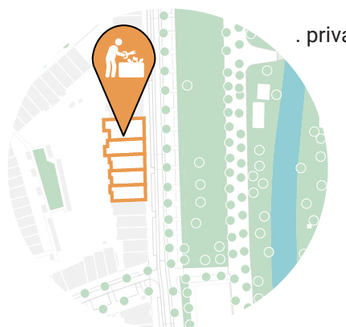
base layer

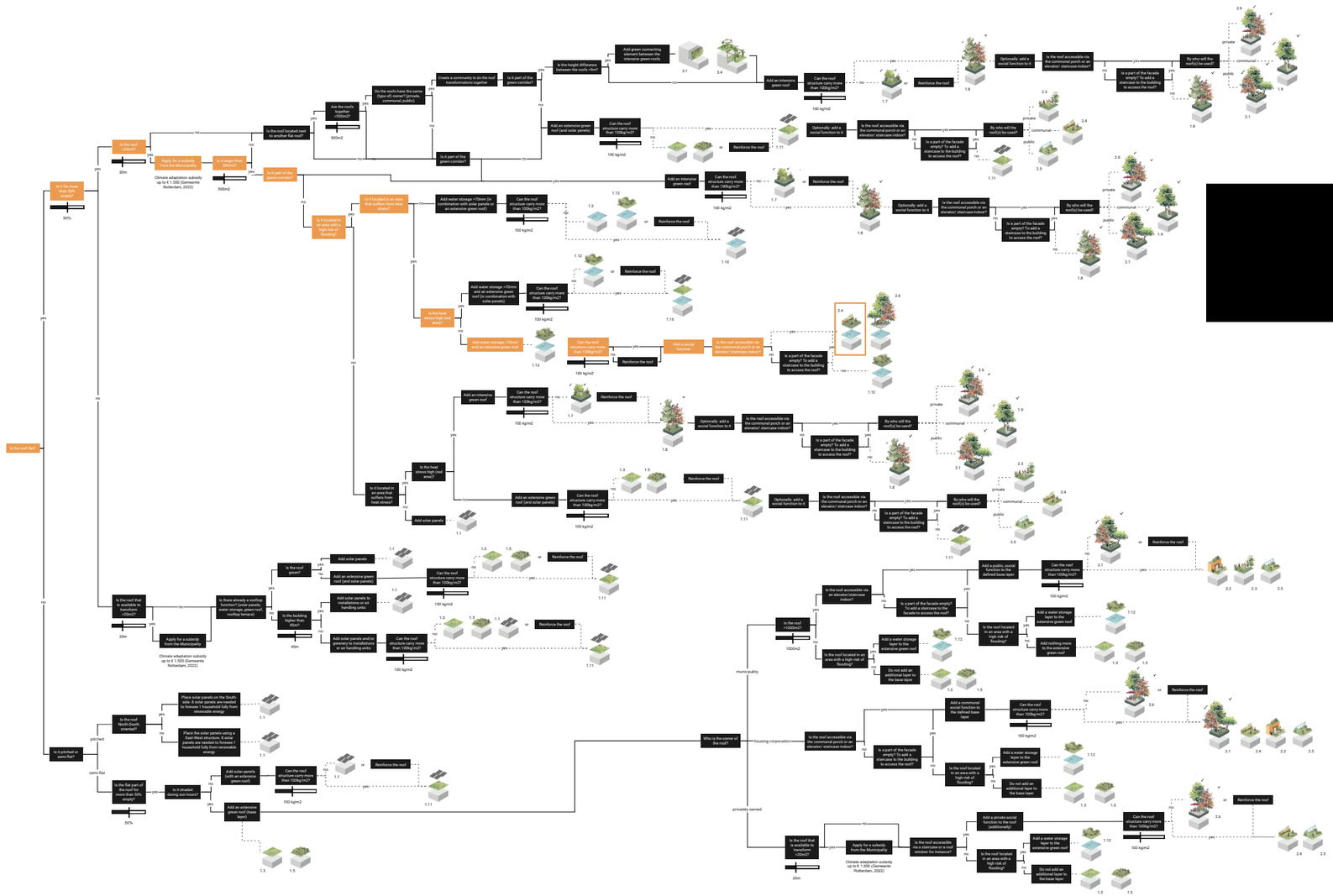
. intensive green roof



social layer

. private roof terrace



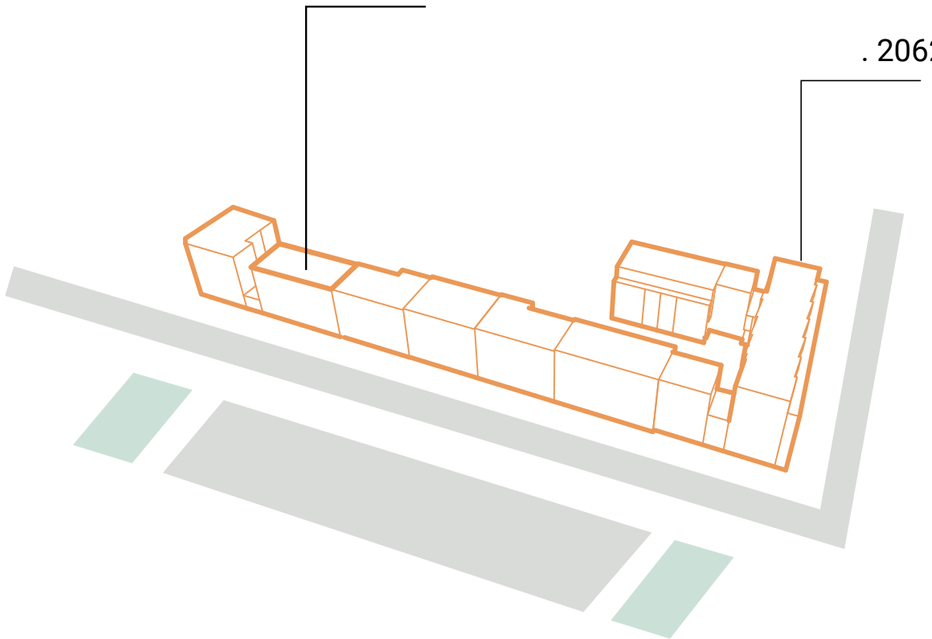


ROUTE 2

type of space	surface	location	base layer	ownership	access	social layer
• flat roof	• >500m2	• urban heat island • flooding area	• extensive green roof • water storage	• housing corporation	• indoor	• communal urban farm

. flat roof
. 204 m2
. located in area that suffer from heat stress and flooding
. owned by housing corporation
. access possible via porch

. 2062 m2



ROUTE 2

. flat roof

. 204 m2

. rental home

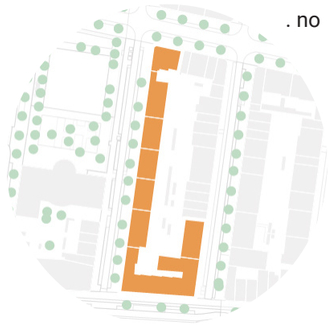
. housing corporation

. in area 1

ROUTE 2

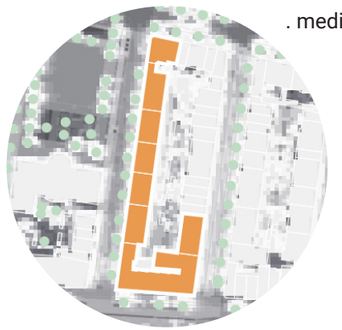
green corridor

. no



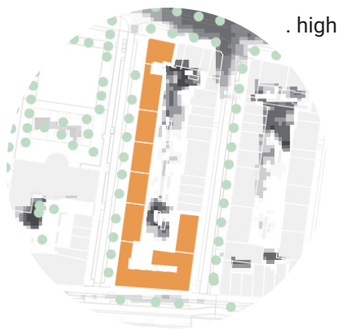
heat stress

. medium



flooding risk

. high

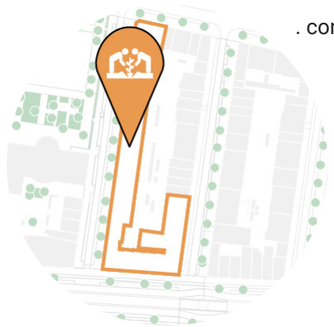


base layer

. extensive green roof
. water storage

social layer

. communal urban farm



VISION MAP

area 1

LEGEND

water
green
buildings
flat roofs >500m2

existing roofs with a roof terrace
existing roofs with solar panels

roofs x intensive green
roofs x extensive green
roofs x water storage
roofs x green corridor
roofs x solar panels

roofs x extensive green x solar panels
roofs x intensive green x water storage
roofs x extensive green x water storage
roofs x water storage x solar panels

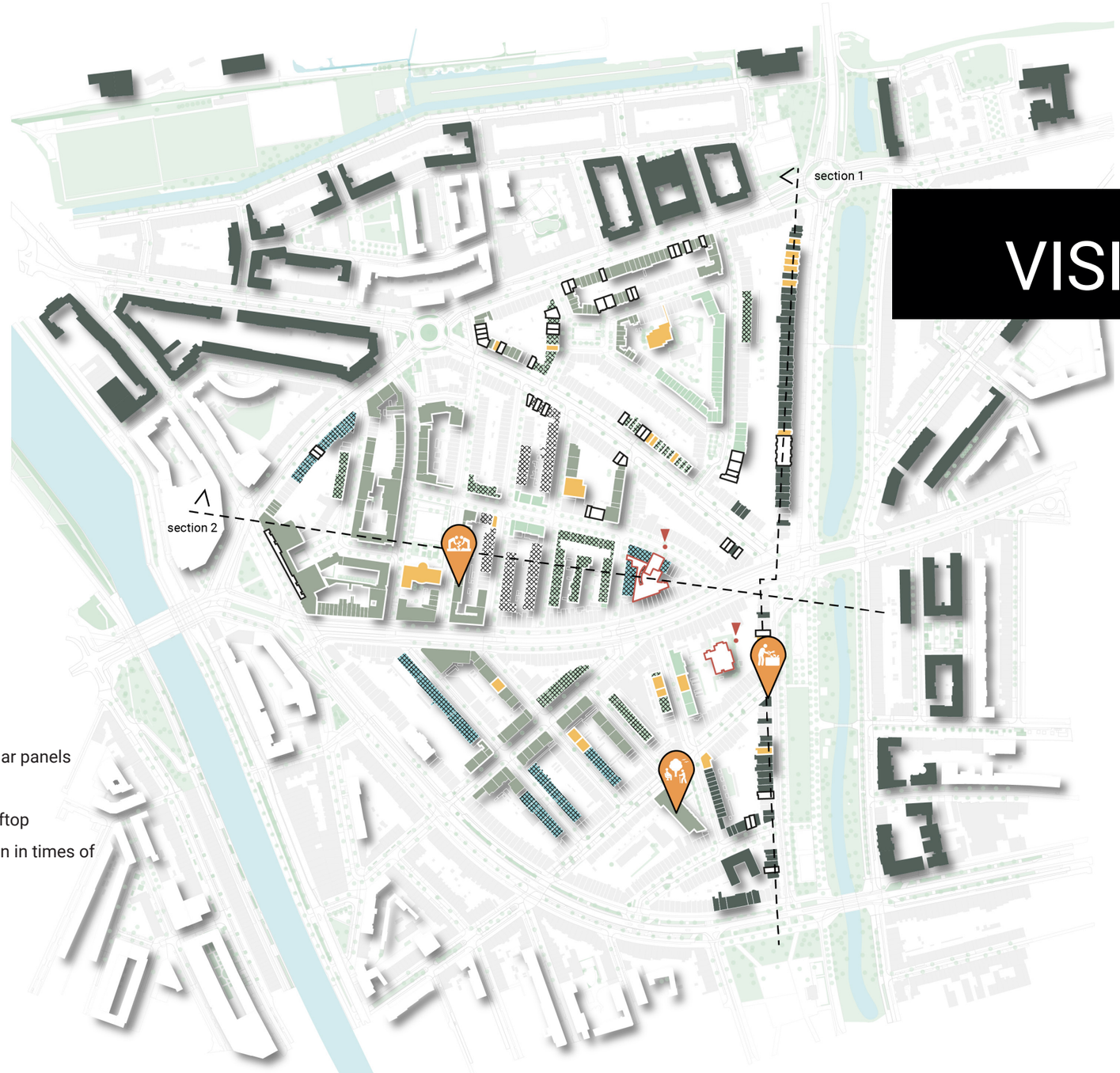
roofs x extensive green x water storage x solar panels

roofs that are unusable for green or blue rooftop functions due to their orientation and location in times of extreme weather circumstances

private rooftop garden

communal vegetable garden

community center



0 200m

VISION MAP

area 2

LEGEND

- water
- green
- buildings
- flat roofs >500m2

- existing roofs with a roof terrace
- existing roofs with solar panels

- roofs x intensive green
- roofs x extensive green
- roofs x water storage
- roofs x green corridor
- roofs x solar panels

- roofs x extensive green x solar panels
- roofs x intensive green x water storage
- roofs x extensive green x water storage
- roofs x water storage x solar panels

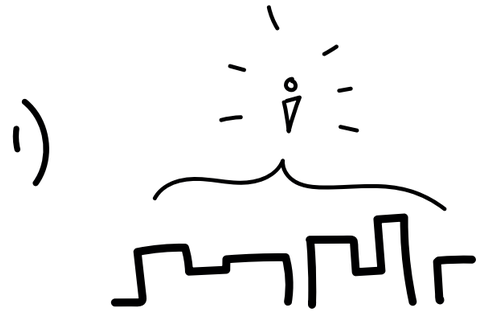
- roofs x extensive green x water storage x solar panels

- roofs that are unusable for green or blue rooftop functions due to their orientation and location in times of extreme weather circumstances

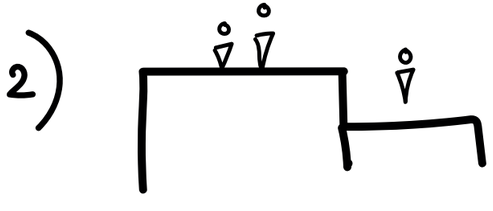
- private rooftop garden
- communal vegetable garden
- community center

0 200m

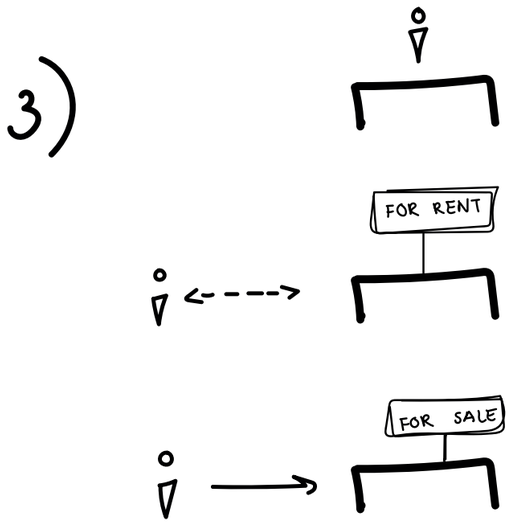
BUSINESS CASES



Municipality claims all flat roofs >500m2
and will transform them



owners are obliged to transform their roof
(with the support of subsidies)

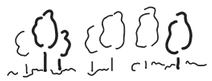


people transform their roofs themselfs (with
support of subsidies)

people rent their roof/a roof to transform (for
renewable energy systems/private garden)

people sell/buy a roof to transform (for renewable
energy systems/private garden)

ASSESSMENT



GREENING

It contributes to the maintenance of (native) species and biodiversity, the purification of air, urban cooling, and drainage systems. It also has a positive impact on the urban image, quality of life, and the economic attractiveness of a city.

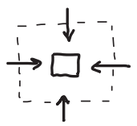
+

DIVERSITY

The research does not bring variety in a broader sense. Diversity is about a range of housing types, building densities, household sizes, ages, incomes, and cultures. This is not what the thesis focuses on.

DENSITY

The thesis does not enlarge the ratio of people or dwelling units to land area. The higher the number of people within a given area, to more interactions and social functions there are sufficient/ viable.



COMPACTNESS

The urban contiguity and connectivity is strengthen by this research. It is about new urban structures that should be adjacent to existing ones. Besides, it refers to intensification (additions, extensions, or redevelopments) and the adjacency of living, working, amenities, and leisure in a city.

+

SUSTAINABLE TRANSPORT

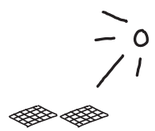
The thesis contributes to the idea of a car free, and pedestrian and bicycle friendly city

+

MIXED LAND USE

It enriches diversity and proximity of functional land use related to transportation, such as industrial, institutional, residential, and commercial. It also enhances security in public places.

+

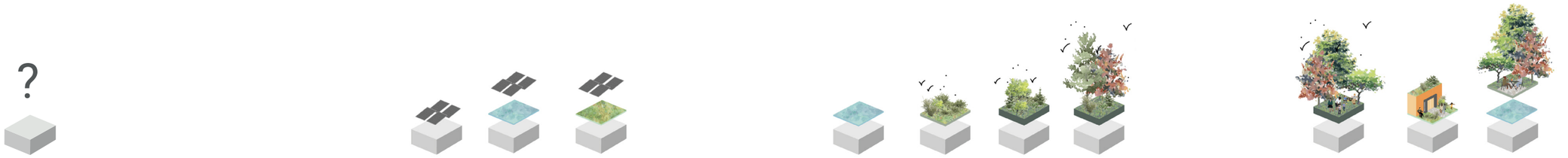


PASSIVE ENERGY DEMAND

This research helps to reduce the demand for energy and the environmental impact city's have. By creating new urban microclimates on top of roofs, heat stress, flooding, and air pollution will be reduced.

+

LIMITATIONS



General limitations

-Urban challenges are place-specific. The possible transformations in this research are based on the urban challenges in the specific areas. Therefore, there is limited freedom in the choice of the base layer of the roofs. While the social layer, it is more about the wishes of the house-owner and the defined base layer.

-Financial support. Who is going to pay for all those transformations? Are it the homeowners themselves, or the municipality?

-The capacity of the roof structures. It is hard to get insight in the bearing capacities of roofs. Therefore, very specific investigations need to be done.

-You can't predict or foresee the future. Urban environmental problems we face at this moment can evolve or change in the upcoming years. Therefore it is important to not transform all roofs in the next 5 years and to stay 'open' to new insights, and adjustments. For instance, 15% of all roofs should be kept free for unforeseen circumstances to really make the city resilient and sustainable.

-Climate (sun and wind) influences strongly the growth potential of green. Therefore, roofs that are completely in shade or experience strong cold/warm wind streams, are less easily to transform.

Limitations yellow roofs

-The amount of solar panels needed to foresee all households in Rotterdam with solar energy is based on the number of households in the municipality right now, it does not foresee new households in the future. However, new-build buildings need to be energy sufficient and often already have solar panels on top of their roofs.

-Only solar panels are considered as renewable energy resources to foresee all households with renewable energy. Other sources such as wind turbines, hydropower, biomass, or geothermal are not taken into account.

-Only looked at flat roofs >500m2. Flat roofs <500m2, and semi-flat roofs are excluded, while these also have a potential to get solar panels.

-The thesis assumes that all flat roofs >500m2 in the harbor area can be used for solar panels. This means that industries there can't use their roof for private uses anymore. Besides, in terms of ownership this is a difficult assumption and not so realistic.

-The carrying capacity of the existing roofs has not been investigated extensively. It has been assumed that each roof can carry a variable load of 100kg/m2 (de Vree, n.d.).

Limitations green and blue roofs

-There is a great difference between the load of different green and blue rooftop functions. The higher the density of vegetation is or the amount of water storage on a roof, the heavier the new roof layer will be. You can not say that every green or blue roof can be implemented anywhere. It depends on the specific roof type and characteristics of that type.

-A major hazard in the case of a water roof is a water leak, which can result in flooding and water damage inside the building. The preparatory phase is therefore very important.

-Open water roofs will suffer from algae in summer. Therefore these roofs must be maintained/cleaned occasionally. Closed water roofs (water storage underneath a green substrate) do not have this problem.

-To achieve rich and diverse vegetation and a range of animal species, a variety of plants on top of the roofs in the green corridor is required. This means that the roofs should be maintained regularly. This should be done by an organisation, neighbourhood initiative, or community for instance.

Limitations multifunctional roofs

-In general, roof constructions are not strong enough to carry multiple roof functions. So therefore the roofs should be reinforced before there can be taken care of.

-Water roofs, social roofs, and dense green roofs should be maintained by the people who own or live in the building underneath.

-Social roofs need to be surveilled during the day (and night). Adding functions such as a cafe, and sports facility can be a natural way to tackle this problem.

-For social functions, ownership of the roofs should be taken into account very carefully. When a roof is not the property of the municipality or a housing corporation, it's not an option to add a communal or public function to it. The target group of the social roof should be adjusted to the ownership of the building.

RECOMMENDATIONS

An elaboration of the implementation phase. This by, for instance, zooming in on a new building block or street and seeing how the strategy and the toolkit in combination with the decision tree work out and what is missing.

1

Zooming in on the toolkit and adding details in roof constructions. What is more specifically needed from the roof construction of existing roofs? What are the requirements of new built roofs to accommodate rooftop functions

2

Translating the strategy and toolkit of this research to new-build buildings, so that from now on all new realised roofs will get a suitable, appropriate rooftop function and directly create a network with each other.

3

Investigation on the bearing capacity of buildings nowadays and how current structures need to be reinforced to accommodate multiple rooftop functions and what the costs will be.

4

Interviewing residents, housing corporations, and the municipality to hear their opinion about redesigning rooftops, and creating communities to realise the ambitions suggested in this thesis.

5

Creating an overview of all rooftop plans, suggestions, and ideas about the roofs in Rotterdam, bringing the creators of those plans together with the municipality, and sharing knowledge to bring the plan of the possible rooftop uses the further to a higher level.

6

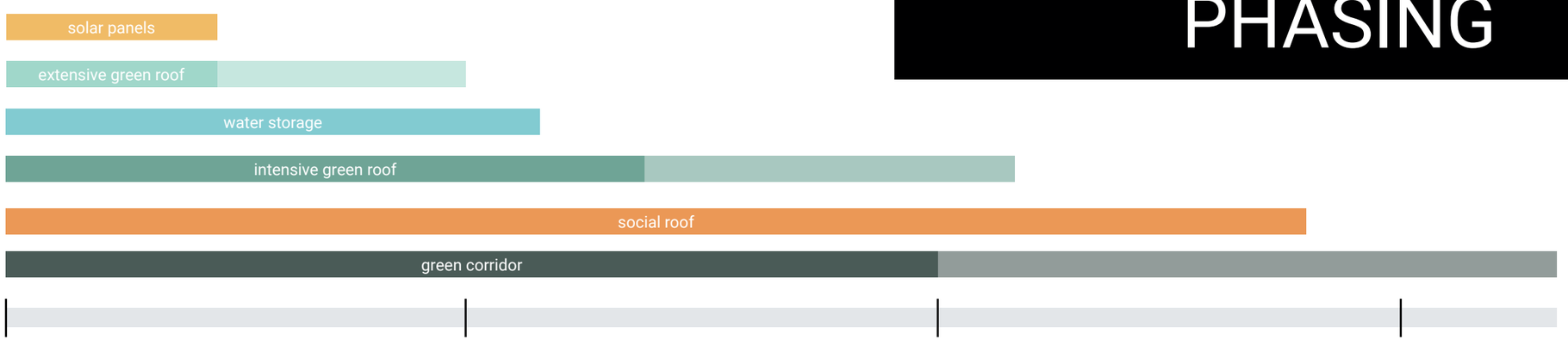
Investigating how the formulated strategy and toolkit could be an addition to the existing Multifunctional Rooftop Program of the municipality of Rotterdam.

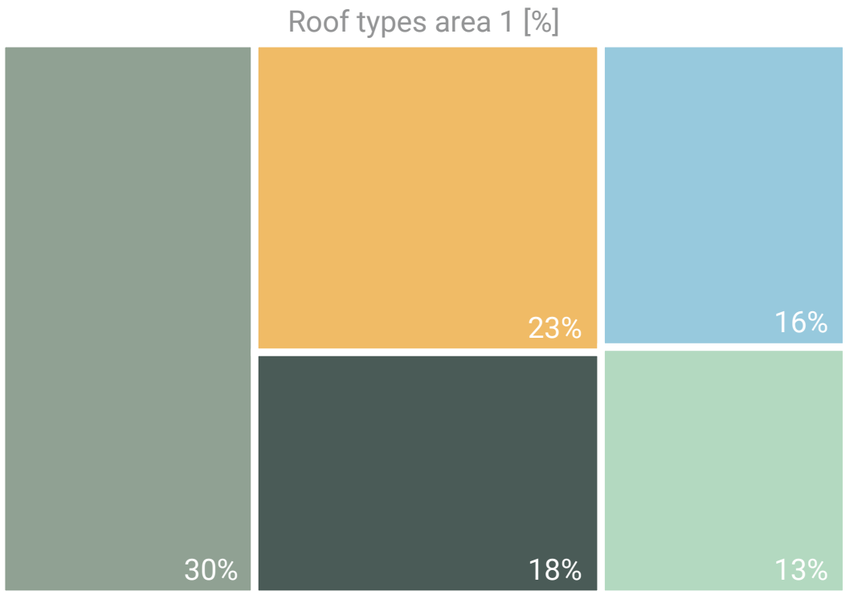
7

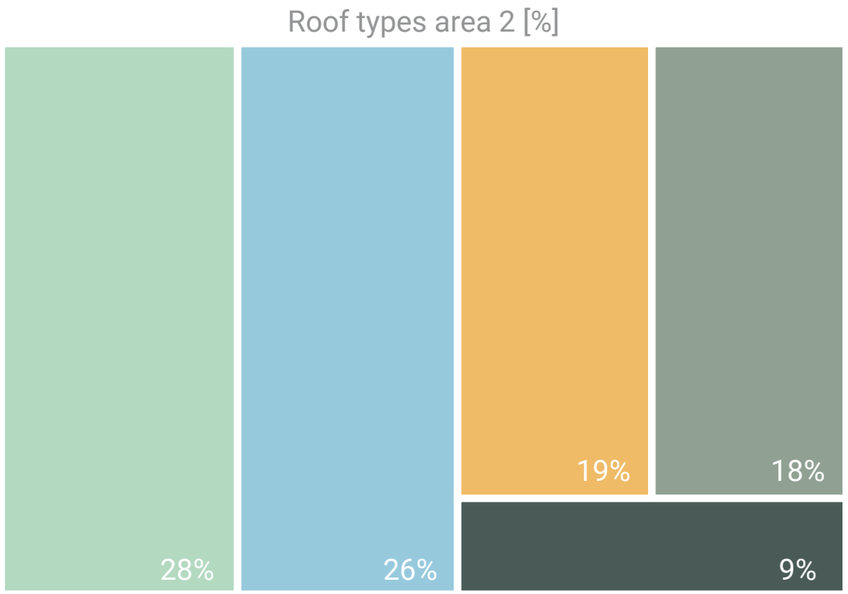
...

...

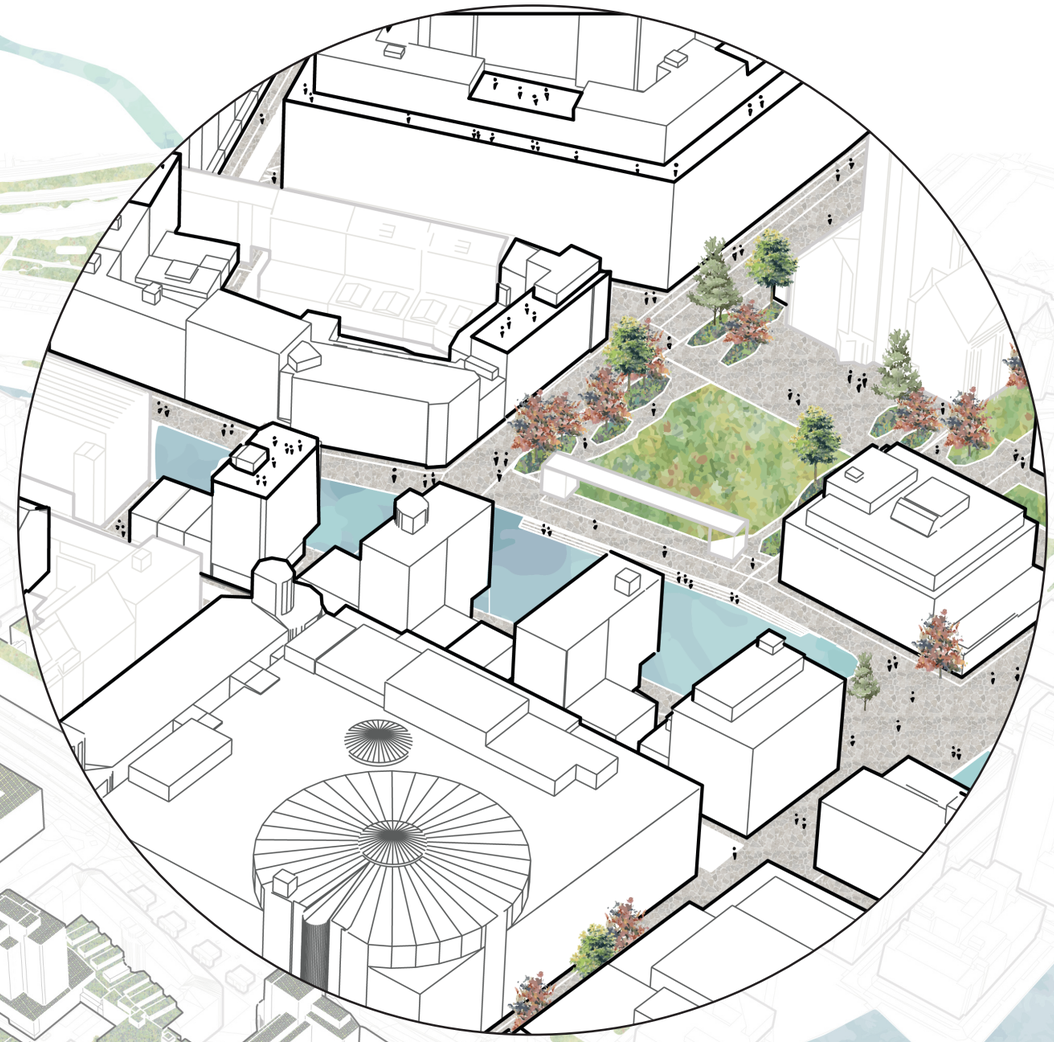
PHASING


solar panels
extensive green roof
water storage
intensive green roof
social roof
green corridor
2 year
4 years
6 years


Roof types area 1 [%]
30%
23%
16%
18%
13%

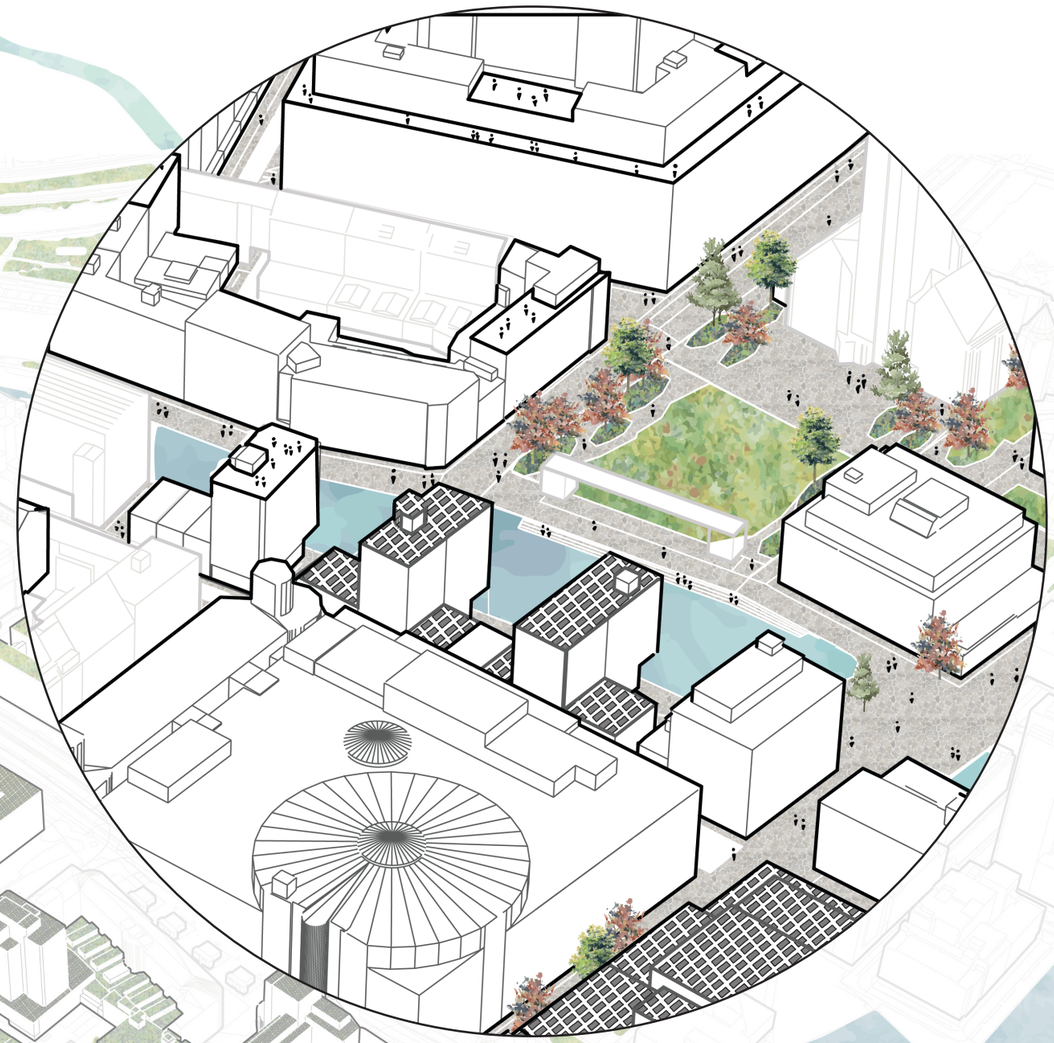

Roof types area 2 [%]
28%
26%
19%
18%
9%

2022



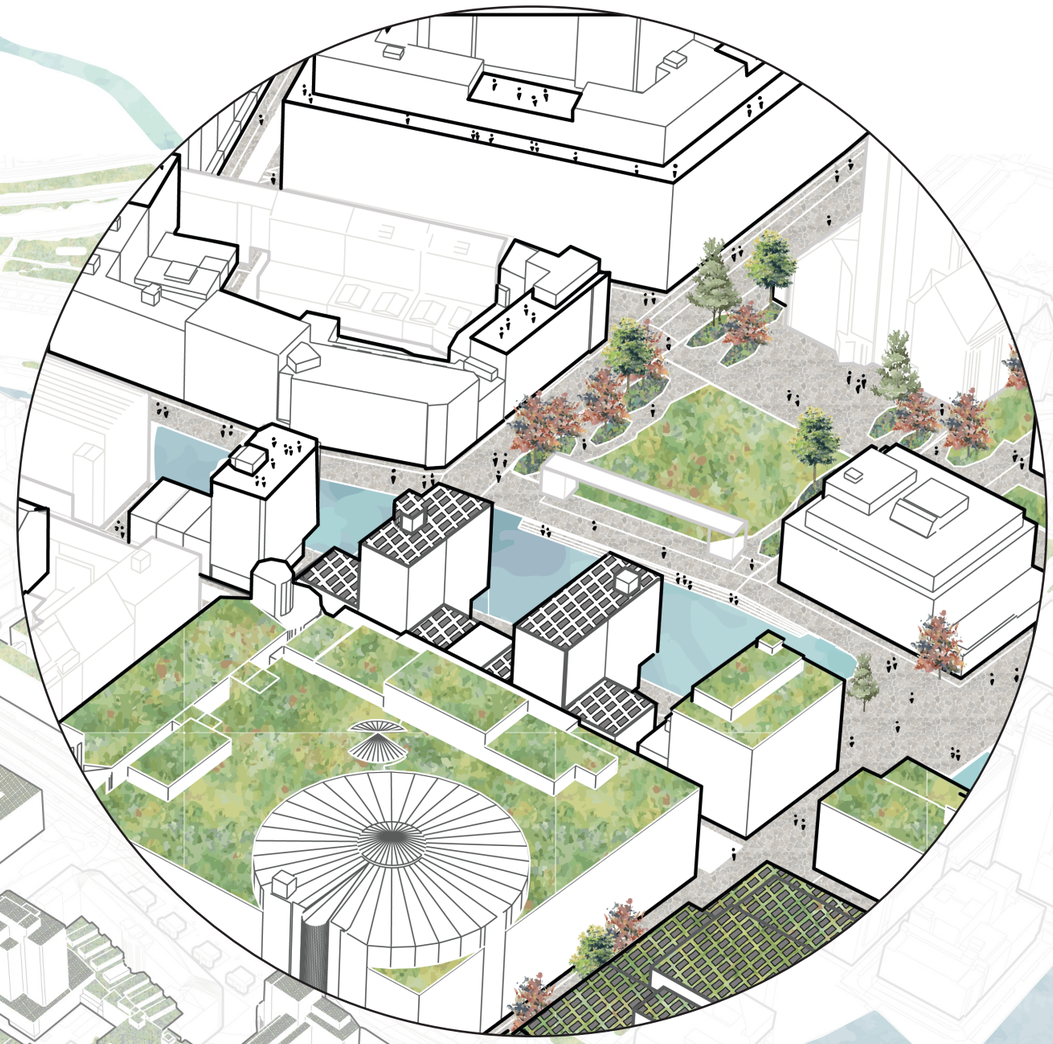
2023

19% solar panels



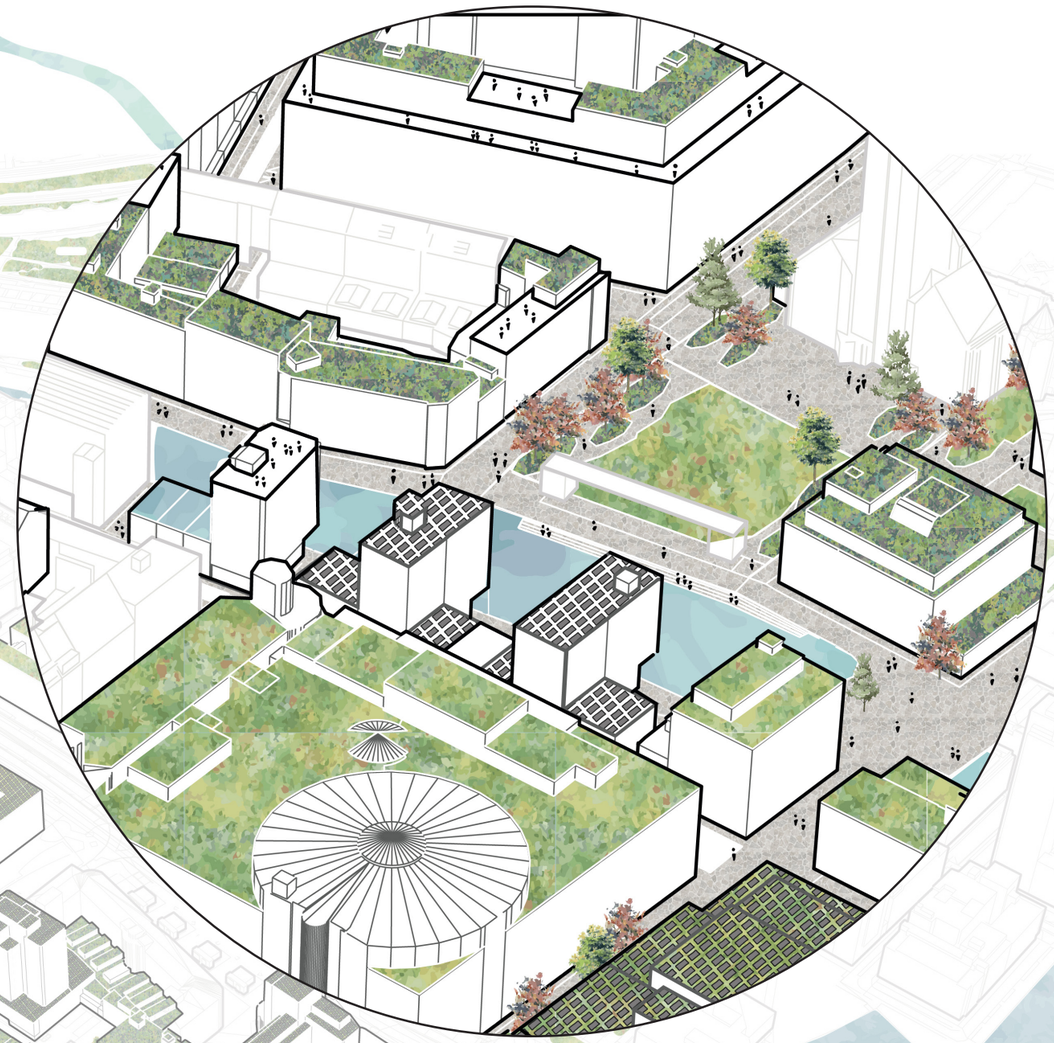
2024

28% extensive green roofs



2027

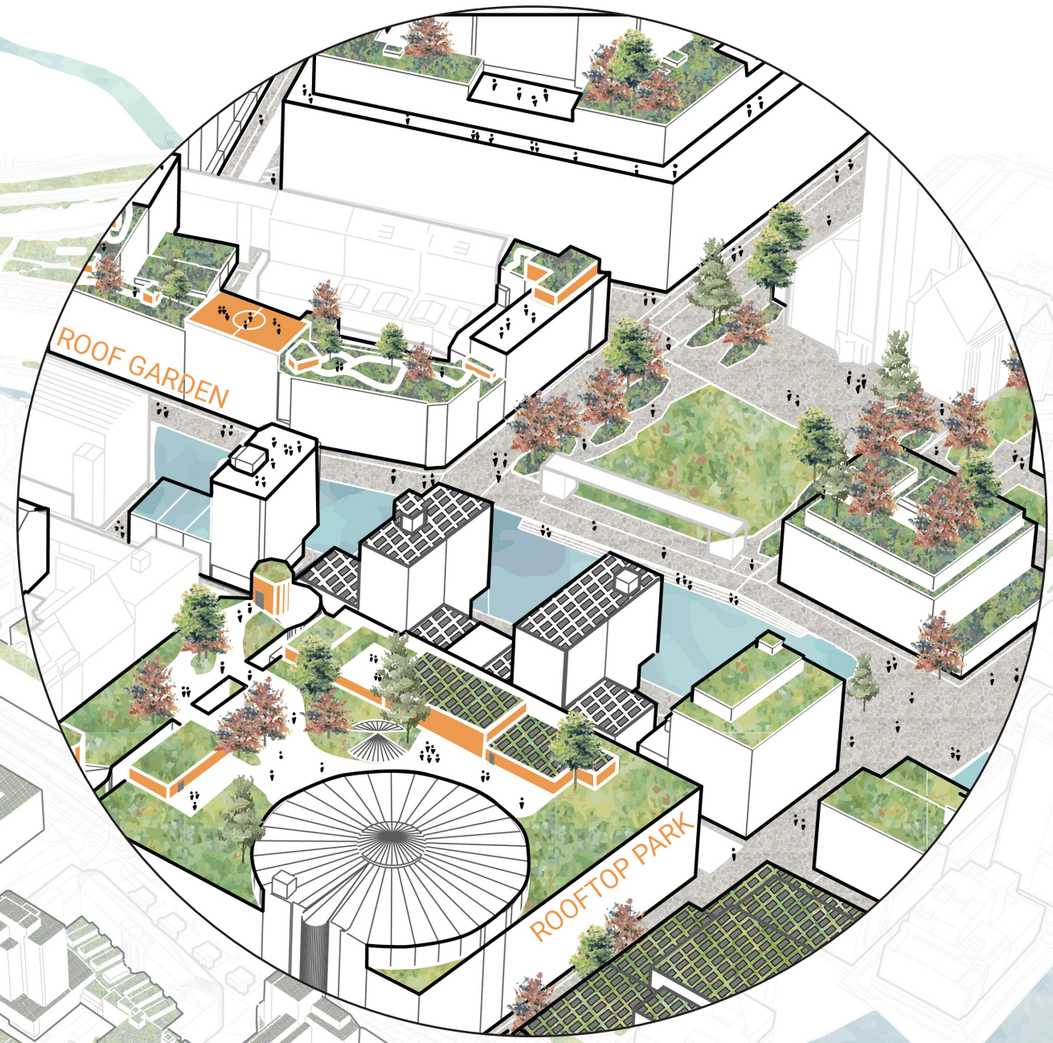
19% intensive green roofs



2032

<1% social roofs

8% green corridor



RESEARCH QUESTIONS

SQ 5

How could the (re)development of rooftops be guided in Rotterdam?

SQ 4

What are suitable functions for Rotterdam's rooftops?

SQ 3

Which roofs in Rotterdam have the most potential to transform?

How can the (re)development of Rotterdam's flat roofs be guided to achieve a significant progress towards a sustainable and resilient Rotterdam?

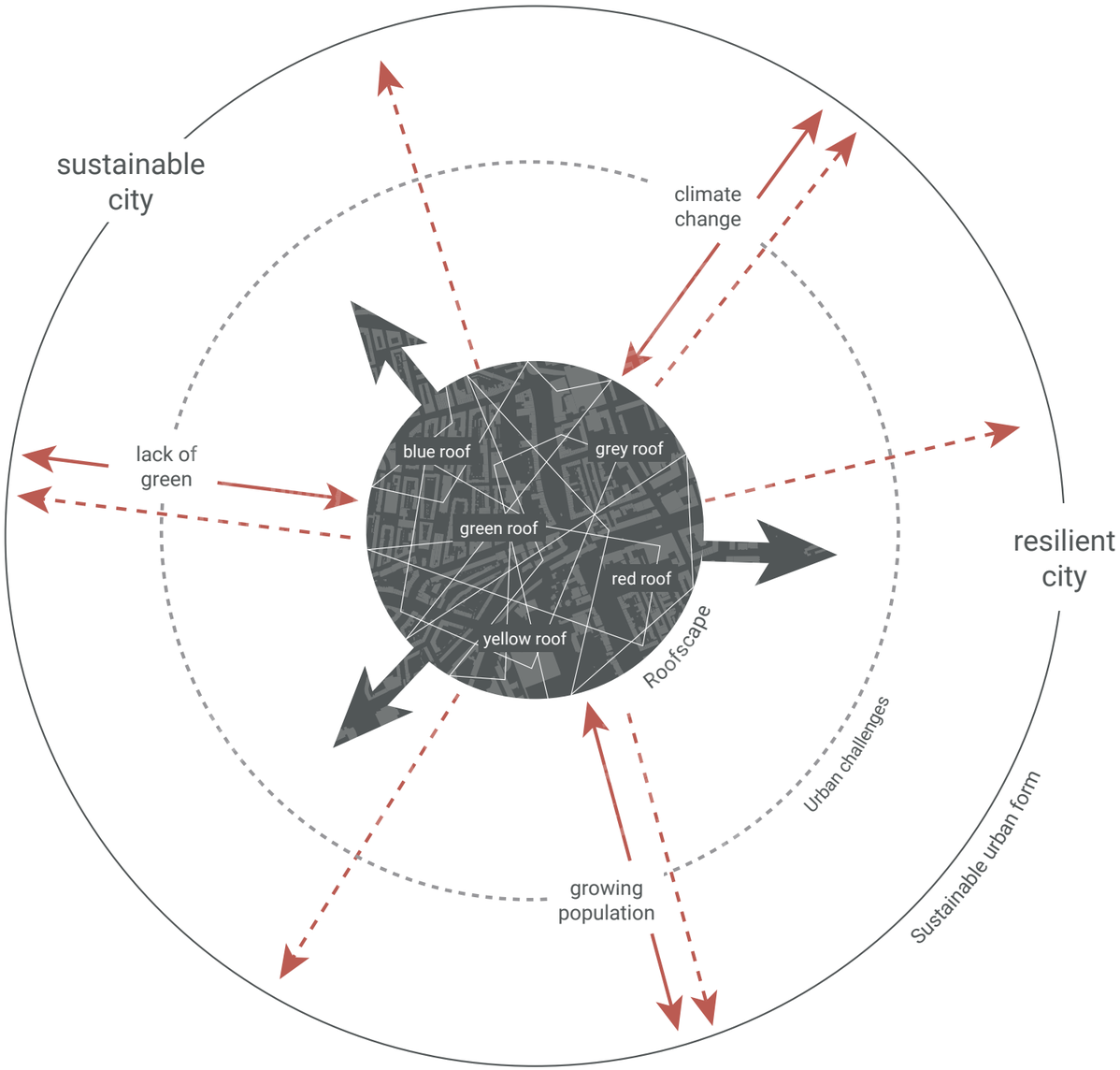
SQ 2

How can rooftops contribute to a sustainable and resilient city?

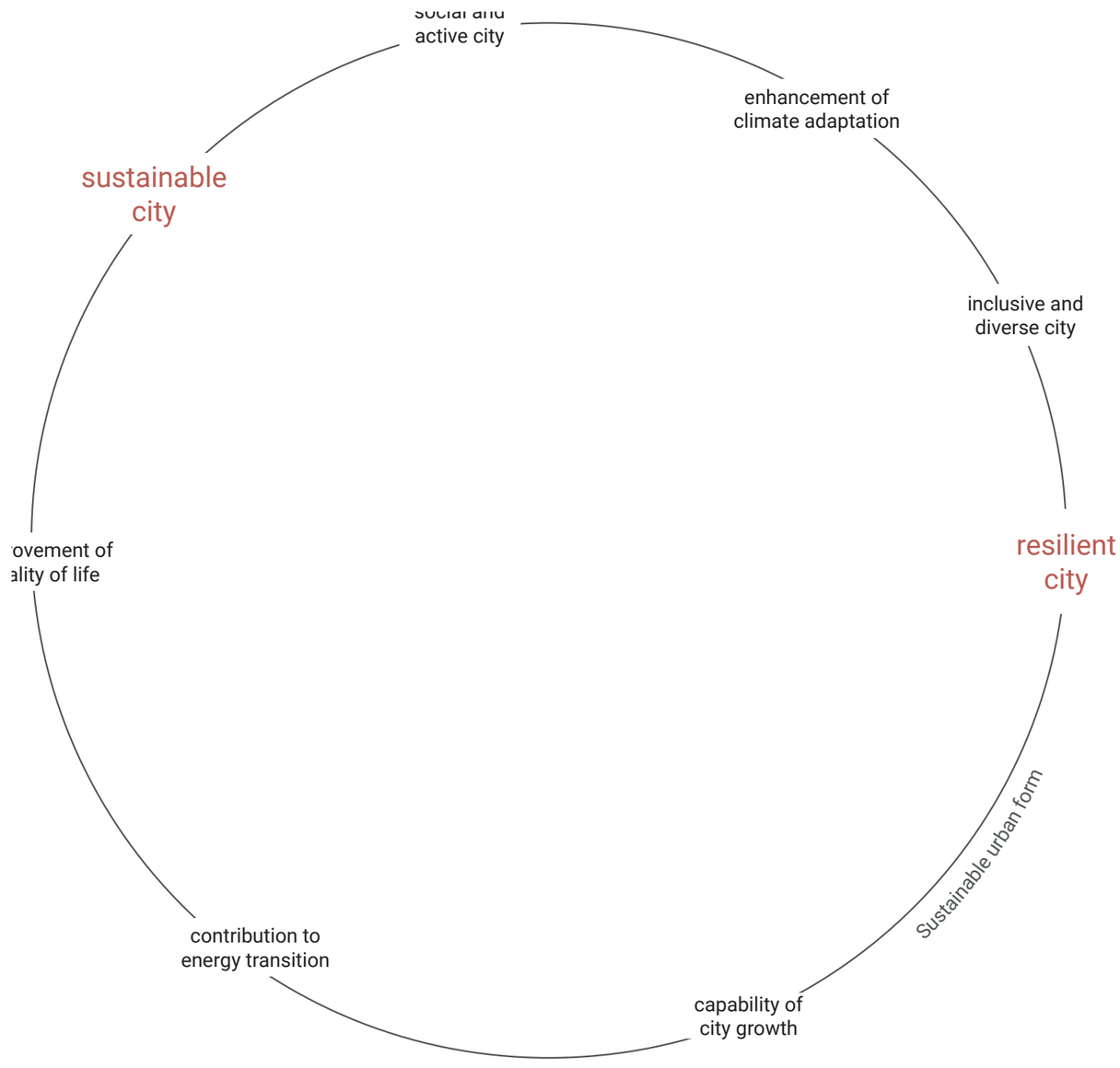
SQ 1

Which indicators define sustainability and resilience in urban context?

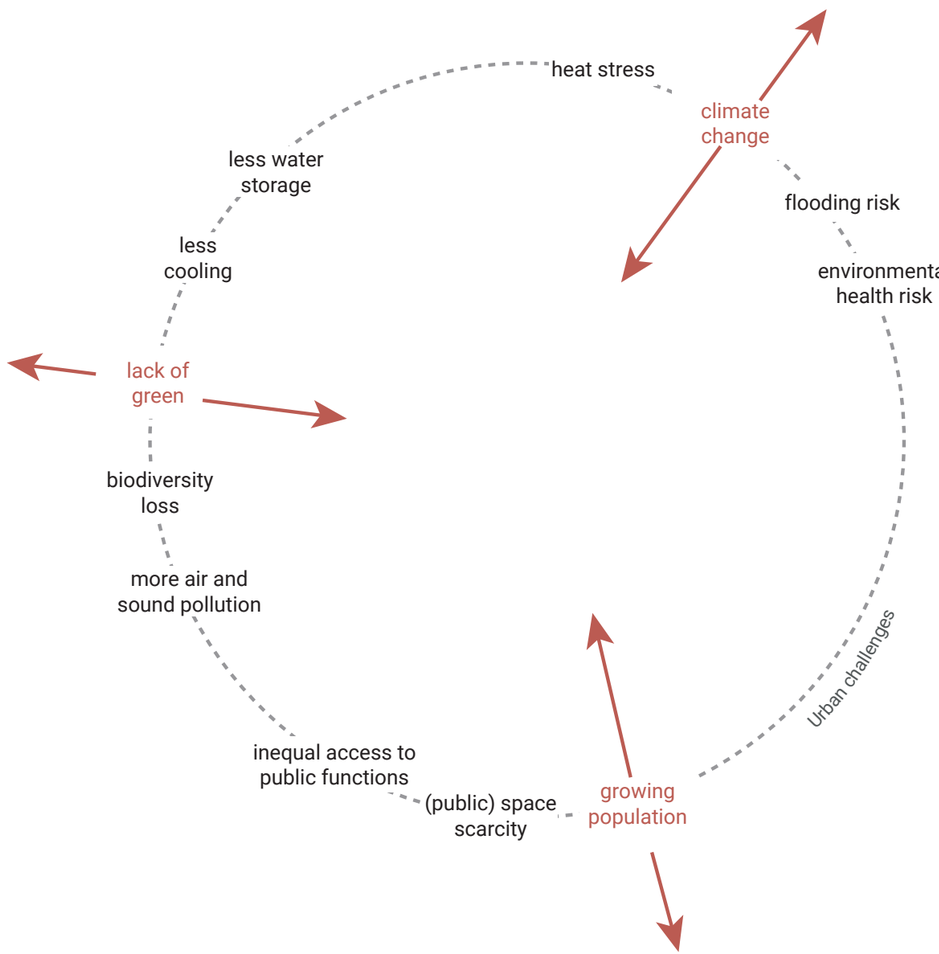
CONCEPTUAL FRAMEWORK



CONCEPTUAL FRAMEWORK



CONCEPTUAL FRAMEWORK



CONCEPTUAL FRAMEWORK