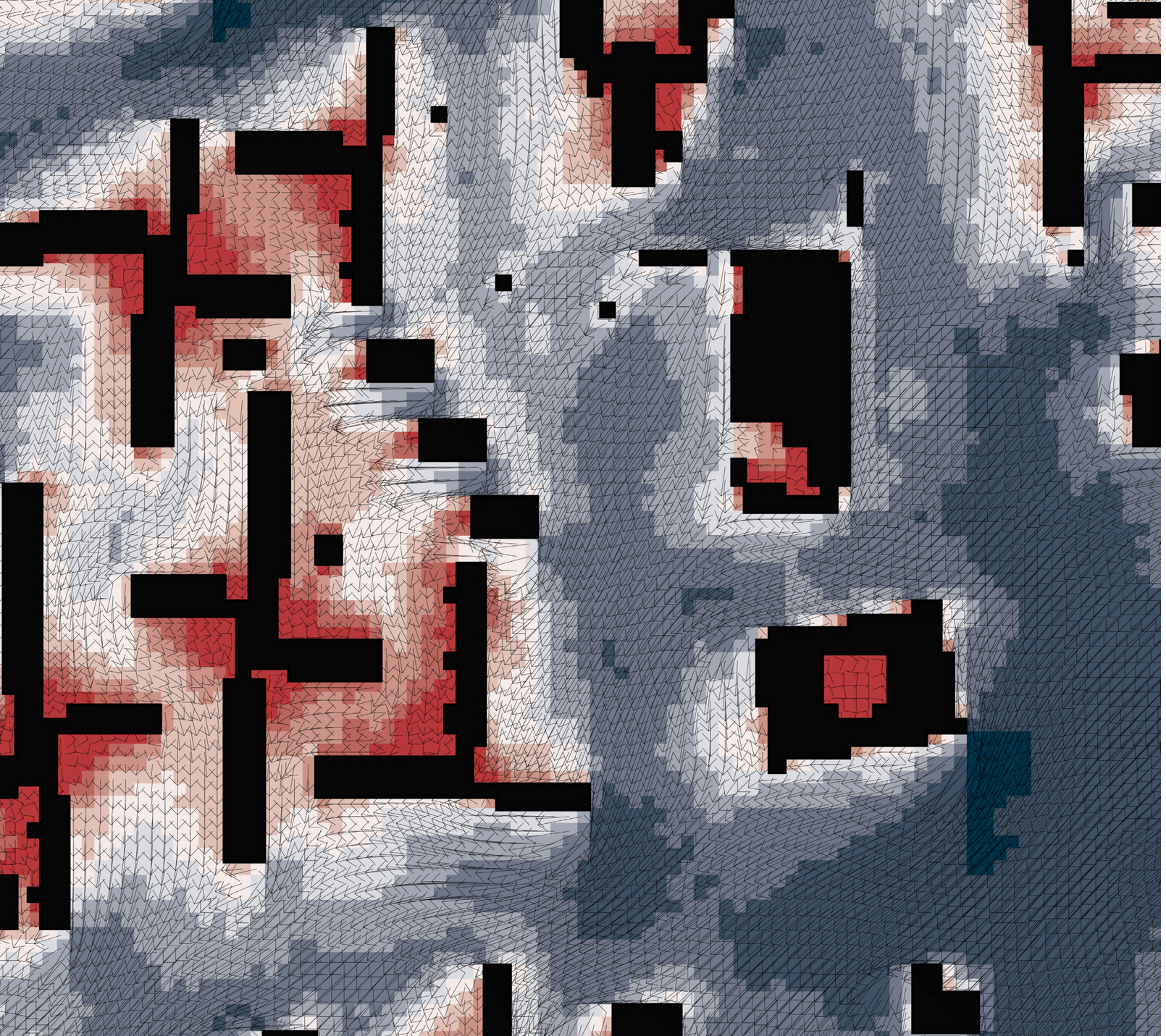


Thermodynamics of Public Space

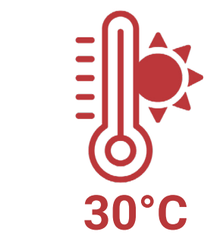
Designing comfortable and social public space adaptive to seasonal temperature extremes in Vilnius, Lithuania

Kristupas Kadys

First Mentor: Dr. Daniela Maiullari
Second Mentor: Birgit Hausleitner
June 17th, 2025

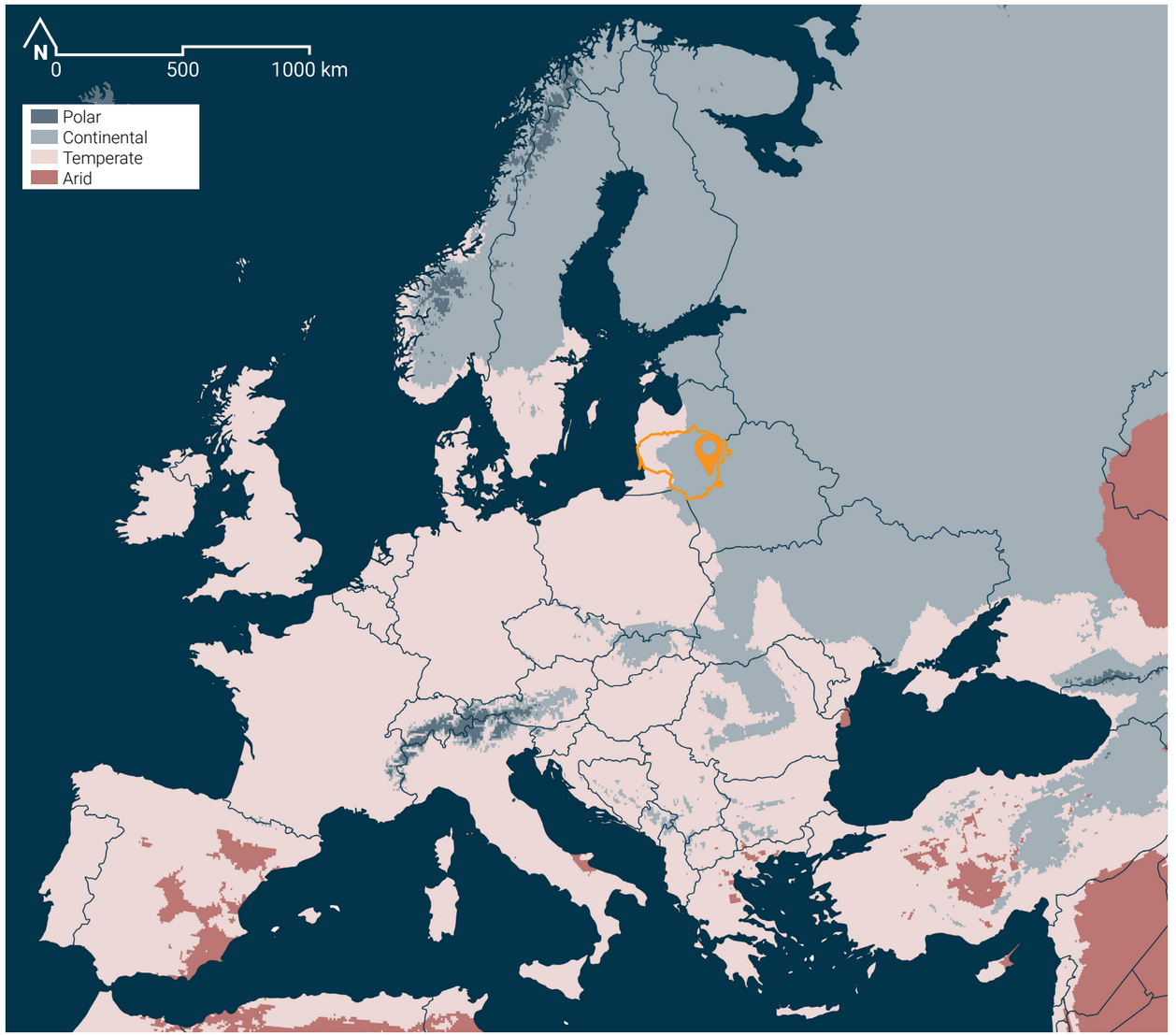
TU Delft
TU Delft BK Bouwkunde Department of Management in the Built Environment

Extreme Cold
Winter in Vilnius
(Lukšis, 2012)



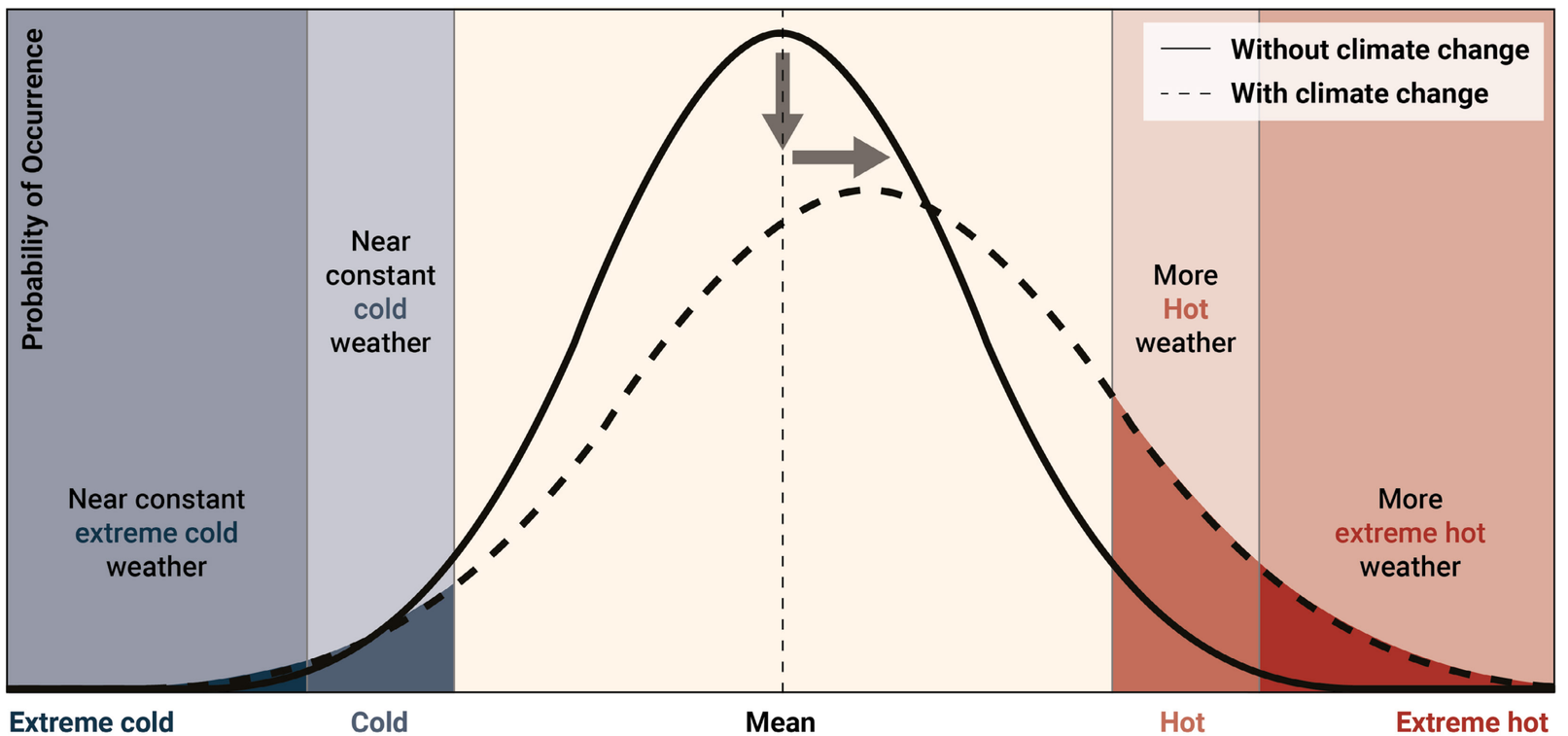
Temperature Extremes

Extreme Heat
Summer in Vilnius
(Grinda, 2023)



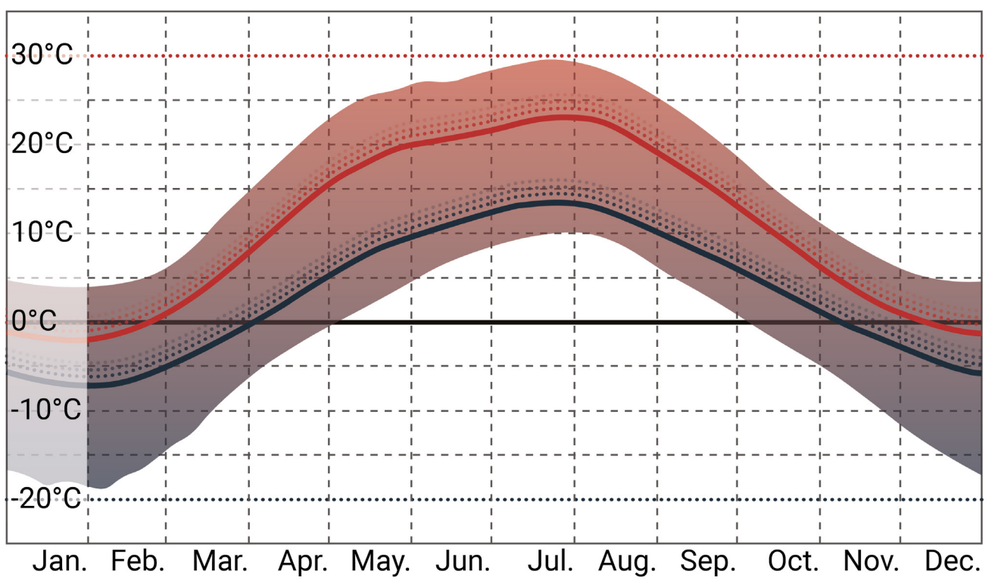
Vilnius situated within European Climate Zones

Updated European Map of Köppen-Geiger Climate Classification Types
(Adapted from Kottek et al., 2017)



Climate Change affect on Temperature Extremes

Conceptual changes in the extremes of the temperature distribution
(Adapted from Sarto & Flandoli, 2024)

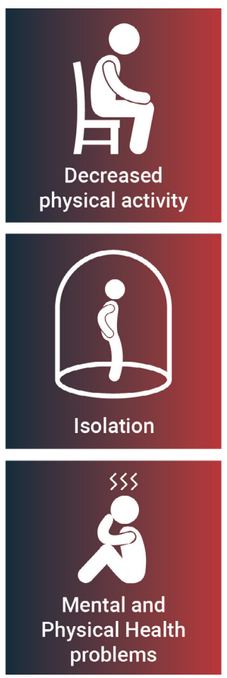


Vilnius Climate
Avarage Temperature in Vilnius (adapted from Weather Spark, 2025)

Today's Situation	Preferred Future (SSP1–1.9)	Plausible Future (SSP5-8.5)
30°C **2.1** Heatwaves/Year	30°C **<3.5** Heatwaves/Year	30°C **7.0** Heatwaves/Year
-15°C **9.5** Coldspells/Year	-15°C **>6.5** Coldspells/Year	-15°C **4.7** Coldspells/Year

Projected Future Climate
Modelled Temperature Extremes
(Ministry of Environment of the Republic of Lithuania, 2024)

Extreme Cold affecting Public Space
Interchange public spaces effected by winter
(Žiūra, 2021)



Problems of Temperature Extremes

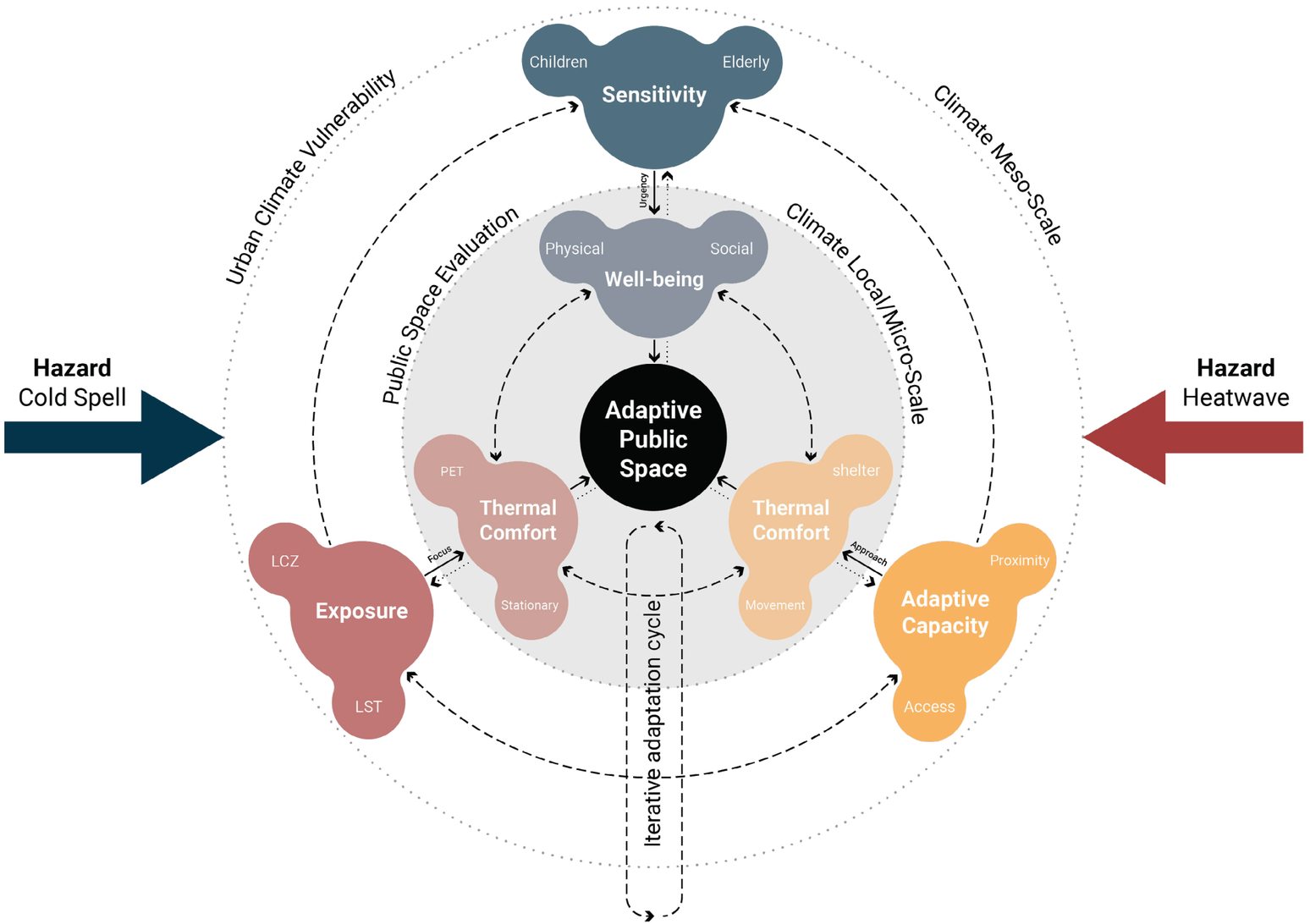
Extreme Heat affecting Public Space
Civic public spaces effected by heatwaves
(Tribouillard, 2021)

Main Research Question:

How could public spaces in Vilnius, Lithuania be adapted to seasonal temperature extremes, while simultaneously fostering social well-being throughout the year?

Temperature Effected Public Space

Public space exposed to cold stress (photo taken by author)


Urban Climate Vulnerability
Public Space Evaluation
Climate Local/Micro-Scale
Climate Meso-Scale
Children
Elderly
Sensitivity
Urgency
Physical
Social
Well-being
Hazard
Cold Spell
Hazard
Heatwave
Adaptive Public Space
PET
Thermal Comfort
Stationary
shelter
Thermal Comfort
Movement
Focus
Approach
LCZ
Exposure
LST
Proximity
Adaptive Capacity
Access
Iterative adaptation cycle

Vulnerability

Exposure

+

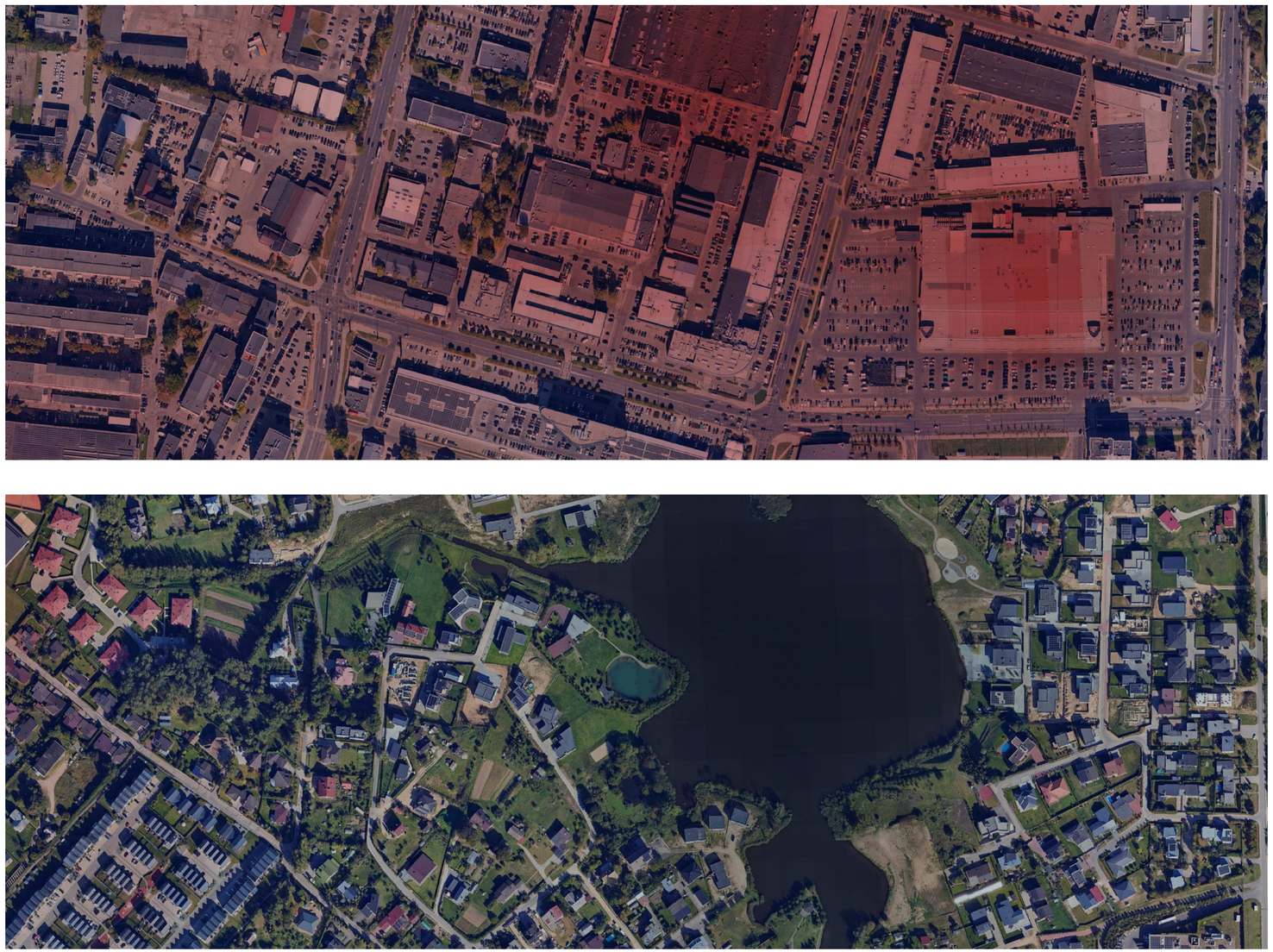
Sensitivity

-

Adaptive Capacity

Exposure

The uneven distribution of heat across urban areas, that is amplified or suppressed by the reflective, heat-storing, and conductive properties of urban materials and vegetation.

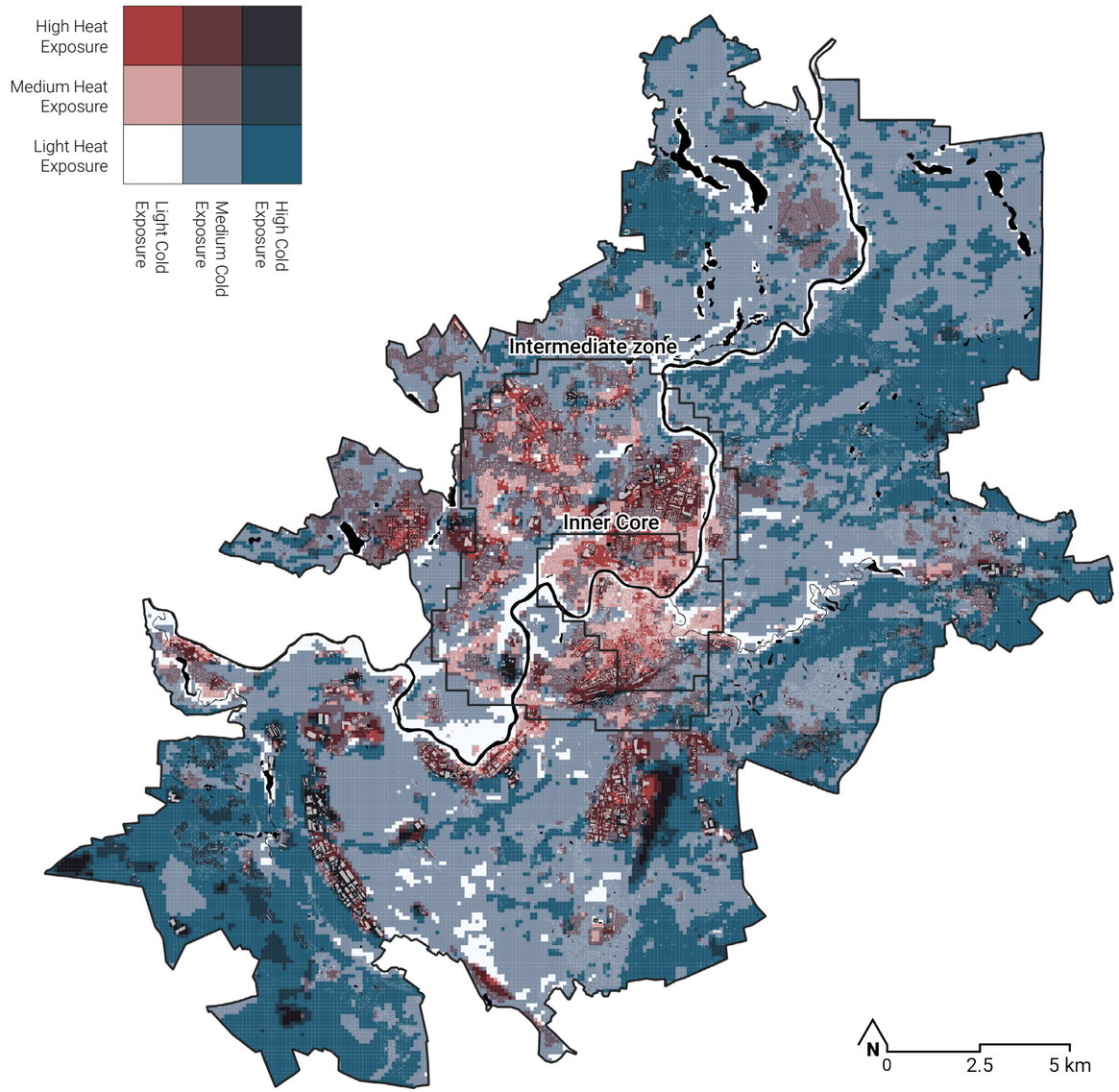


Heat in the Built Environment

Different urban environments with their overlayed Land Surface Temperature

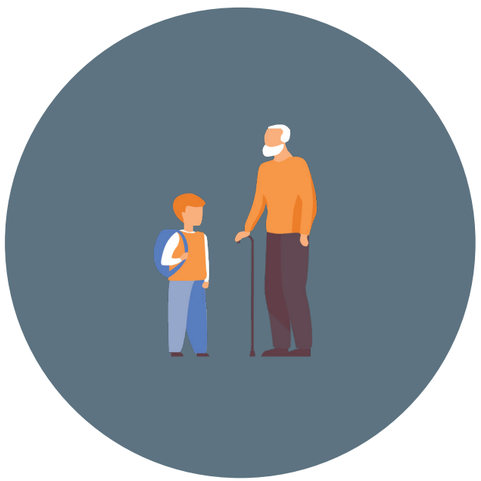
Temperature Exposure Overlap Diagram

Exposure classification levels, that allow a comparison between temperature extremes within a matrix



Temperature Extreme Exposure Map

Spaces with exacerbated Temperature Extremes due to urban morphology

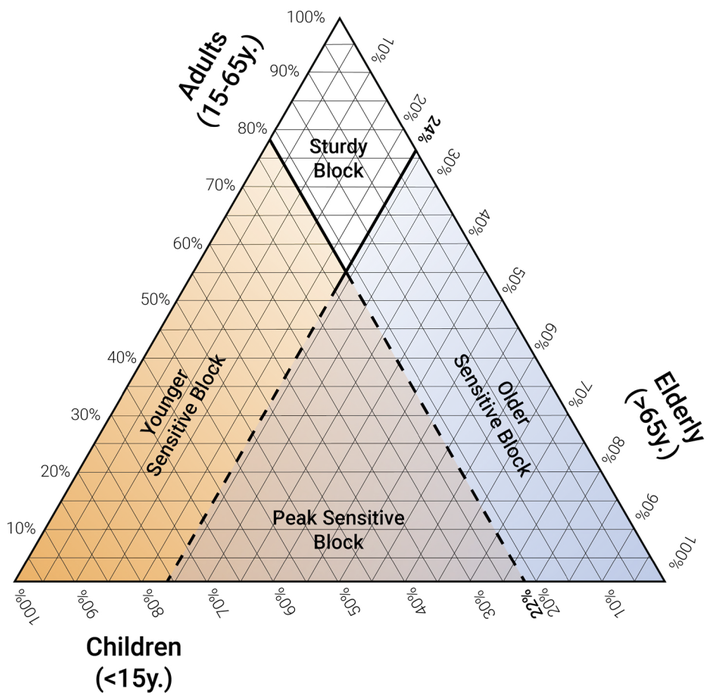


Sensitivity

The degree to which a system or population can endure its effects without experiencing lasting harm. It varies depending on socio-economic and health factors, with vulnerable groups.

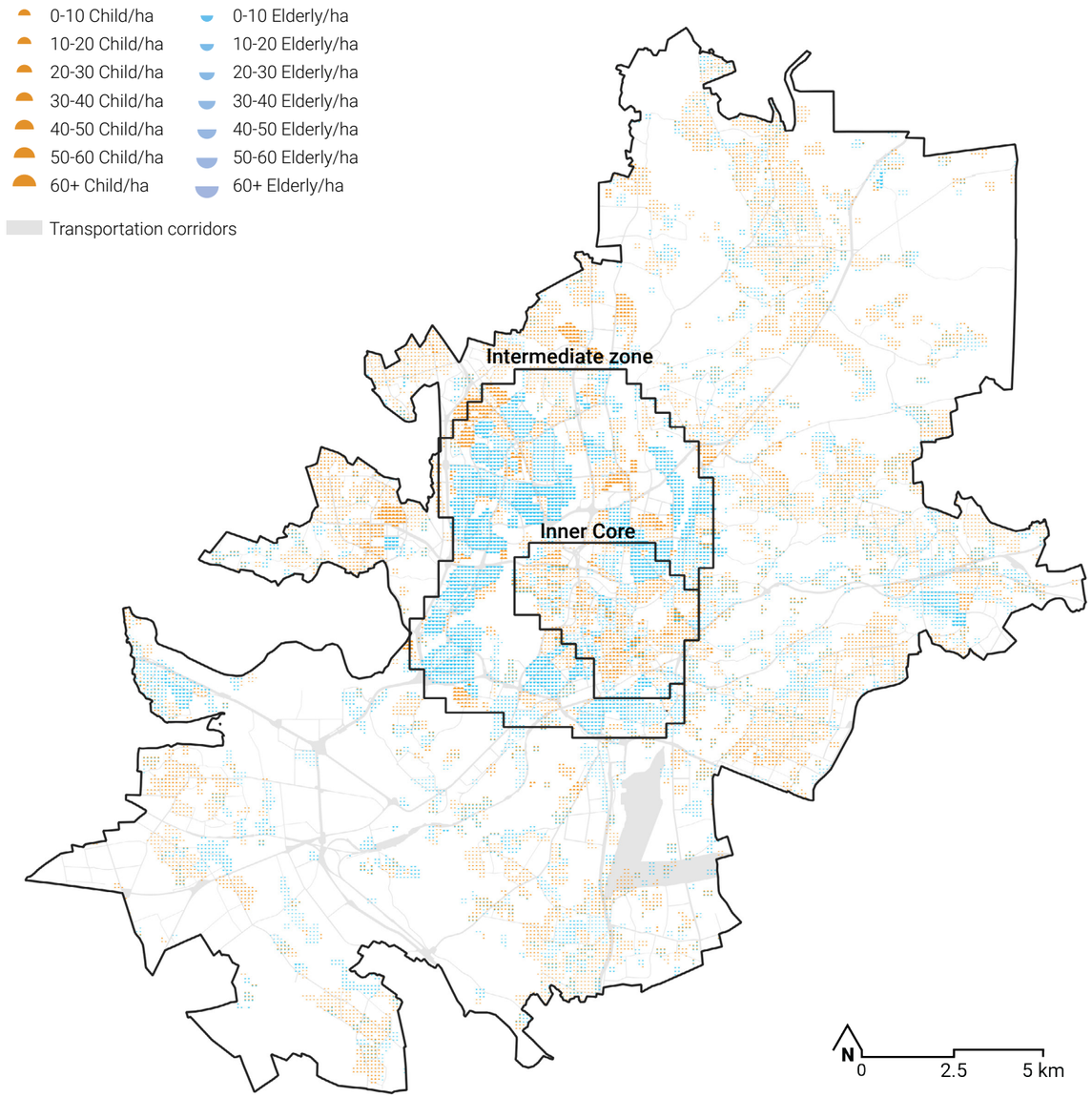
Sensitive Demographics

Elderly experiencing heat (Garcia & Bloomberg, 2022) and A child adapting to winter (taken by author)



Urban Block Sensitivity Diagram

Ternary Diagram illustrating an urban block's demographic proportions

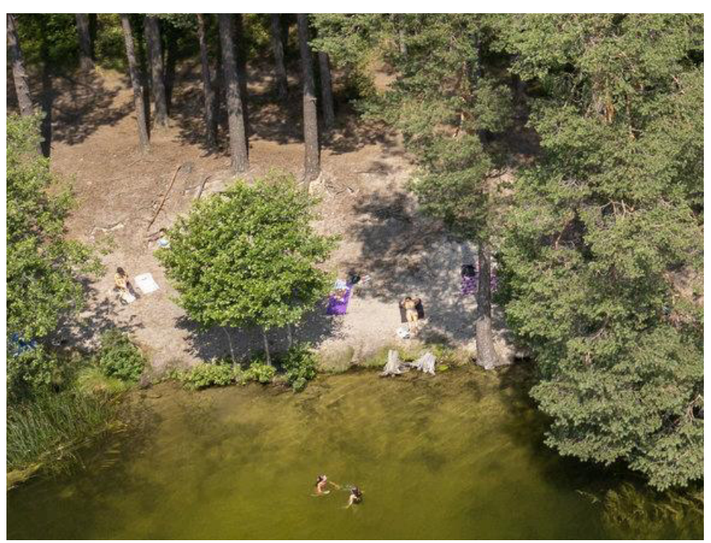


Temperature Extreme Sensitivity Map

Map showing areas with high proportions and densities of sensitive groups

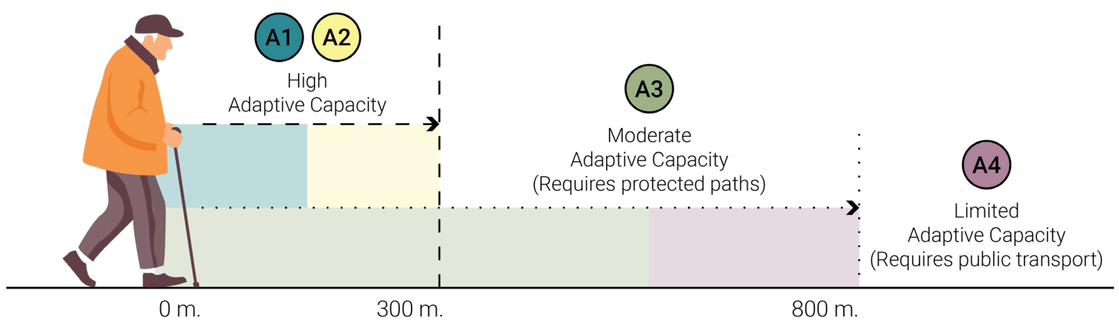
Adaptive Capacity

The ability of a system or population to adjust its characteristics and behaviour to better manage current and future stresses. It includes strategies such as leveraging social networks, taking up protective behaviours, and accessing cooling or heating resources.



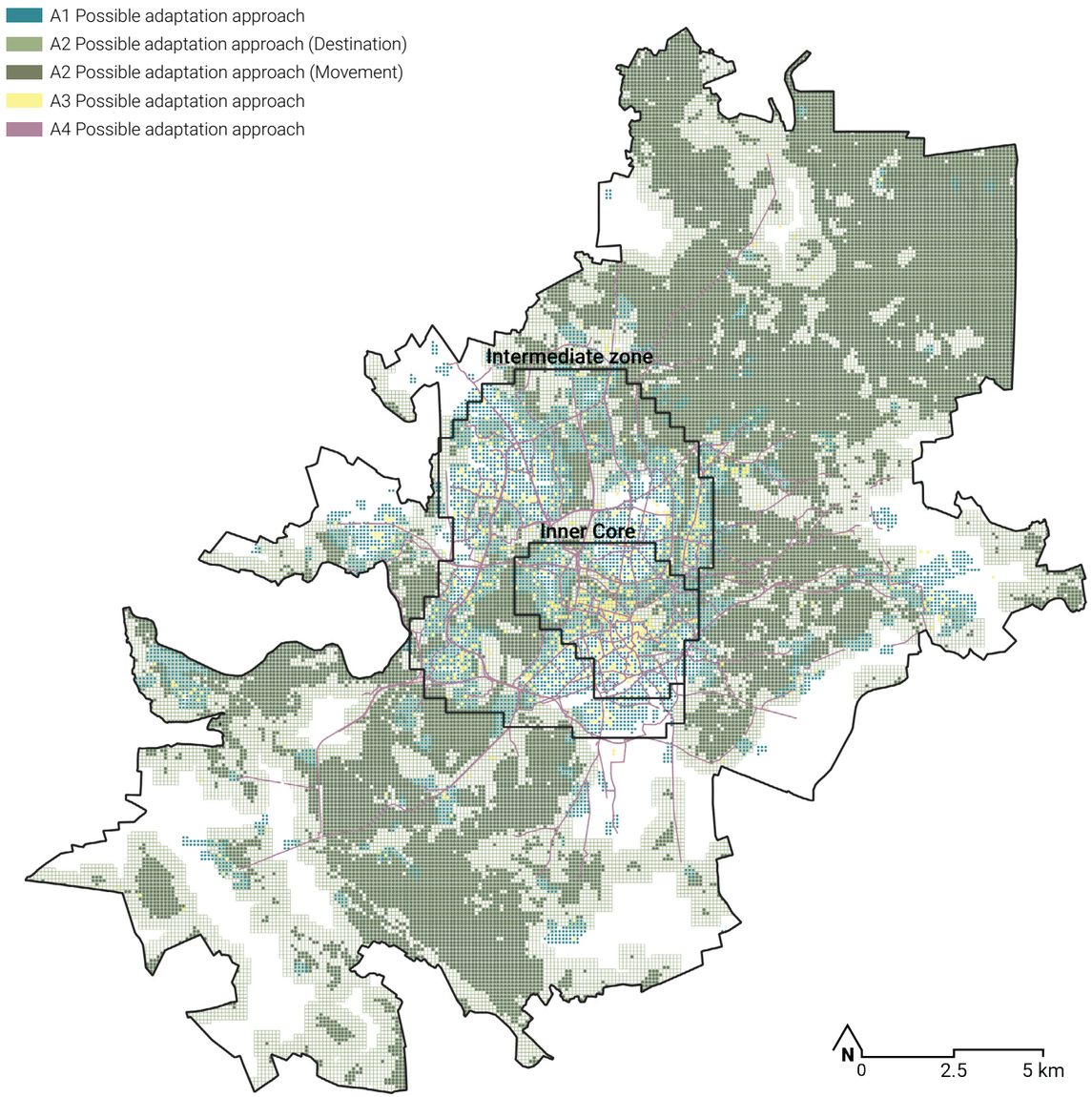
Mobility & Accessibility to Shelters

Top left - covered stairs in Trails, Canada (Bertrand, 2020); Top right - climate Shelter Network in Barcelona (Barcelona for Climate, n.d.); Bottom left - sustainable rapid public transport (Vilnius Green Capital, 2025); Bottom right - natural spaces suitable for recreation (Balandis & LRT, 2021)



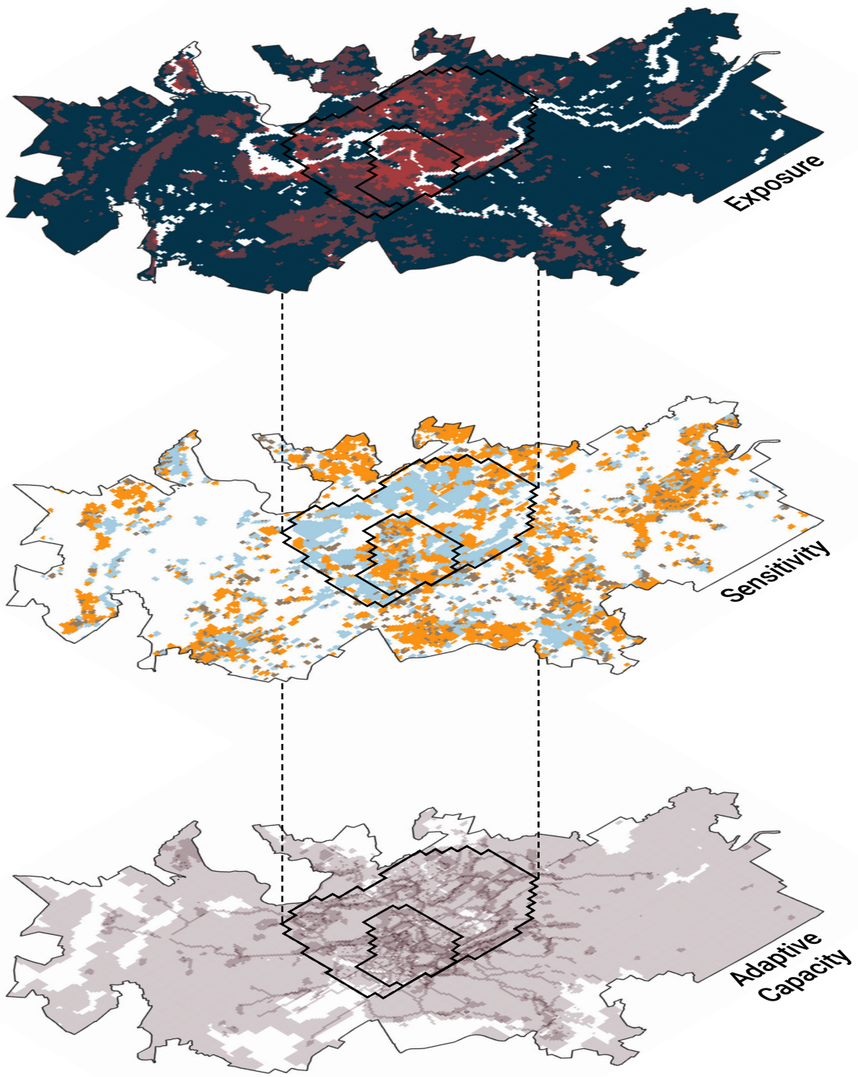
Proximity Adaptive Capacity Diagram

Distances and ranges that define the available adaptive capacity approaches



Adaptive Capacity to Temperature Extremes Map

Map showing the spaces that increase a person's adaptive capacity



Vulnerability to Temperature Extremes

Vulnerability framework, which examines the risk of temperature extremes from 3 aspects: Exposure, Sensitivity and Adaptive Capacity

Vulnerable City Core

Due to high heat exposure and medium sensitivity, although the region does exhibit high adaptive capacity (Činga, n.d.)

Vulnerable City Periphery

Due to high cold exposure, high sensitivity, and most limited adaptive capacity (photo taken by author)

Built Types

Compact Highrise (LCZ 01)

15 ha (0.1%)
725 Residents (0.1%)

Compact Midrise (LCZ 02)

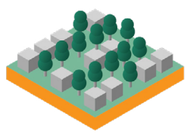
392 ha (2.8%)
26798 Residents (4.8%)

Open Highrise (LCZ 04)

50 ha (0.3%)
13739 Residents (2.5%)

Open Midrise (LCZ 05)

3203 ha (23.2%)
377734 Residents (67.6%)



Open Lowrise (LCZ 06)

5833 ha (42.3%)
101297 Residents (18.1%)

Large Lowrise (LCZ 08)

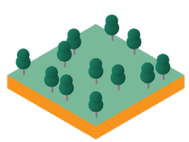
2606 ha (18.9%)
11502 Residents (2.1%)

Sparsely Built (LCZ 09)

1676 ha (12.4%)
26885 Residents (4.8%)

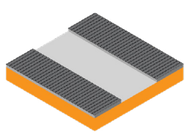
Land Cover Types

Dense Trees (LCZ A)

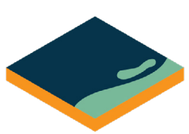


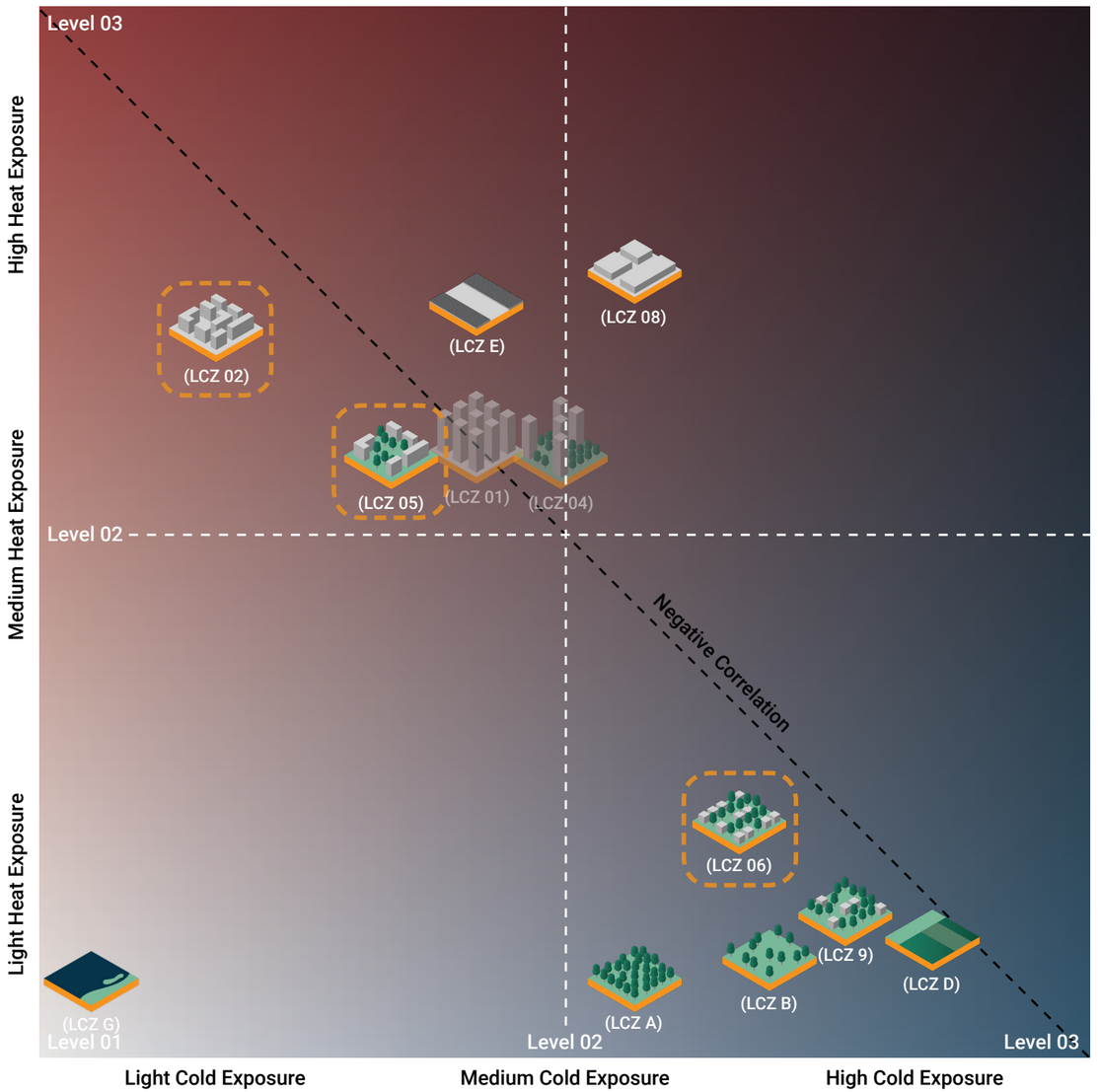
Scattered Trees (LCZ B)

Low Plants (LCZ D)



Bare Rock / Paved (LCZ E)





Urban Form & Climate Types in Vilnius

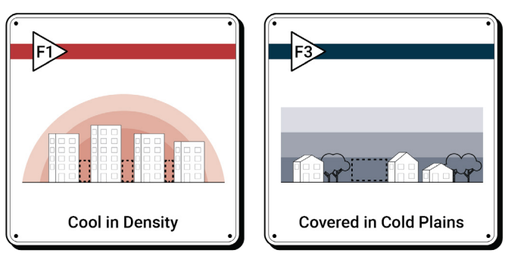
Classification scheme of Built types (above) and Land cover types (below) (adapted from Stewart and Oke, 2012)

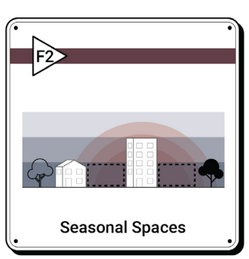
Exposure Assessment

Levels of Exposure of each Local Climate Zones in Vilnius, represented in a spatial matrix

Exposure Indicator

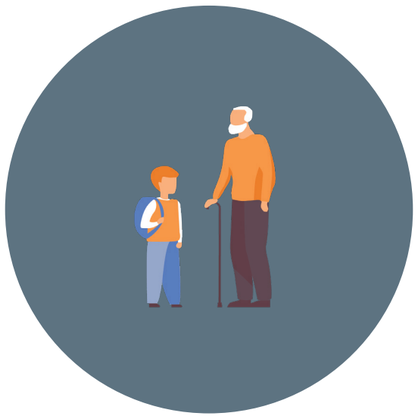
Required Focus Goals





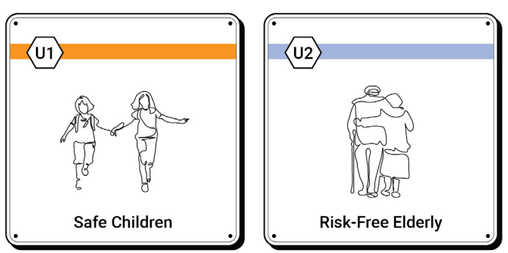
Adaptation Focus Goals

Temperature Adaptation Goals relating to urban morphology



Sensitivity Indicator

Required Urgency Goals

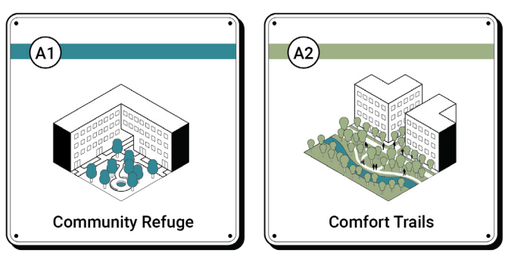


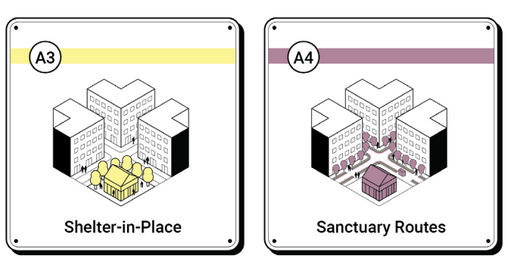
Adaptation Urgency Goals

Temperature Adaptation Goals for sensitive groups

Adaptive Capacity Indicator

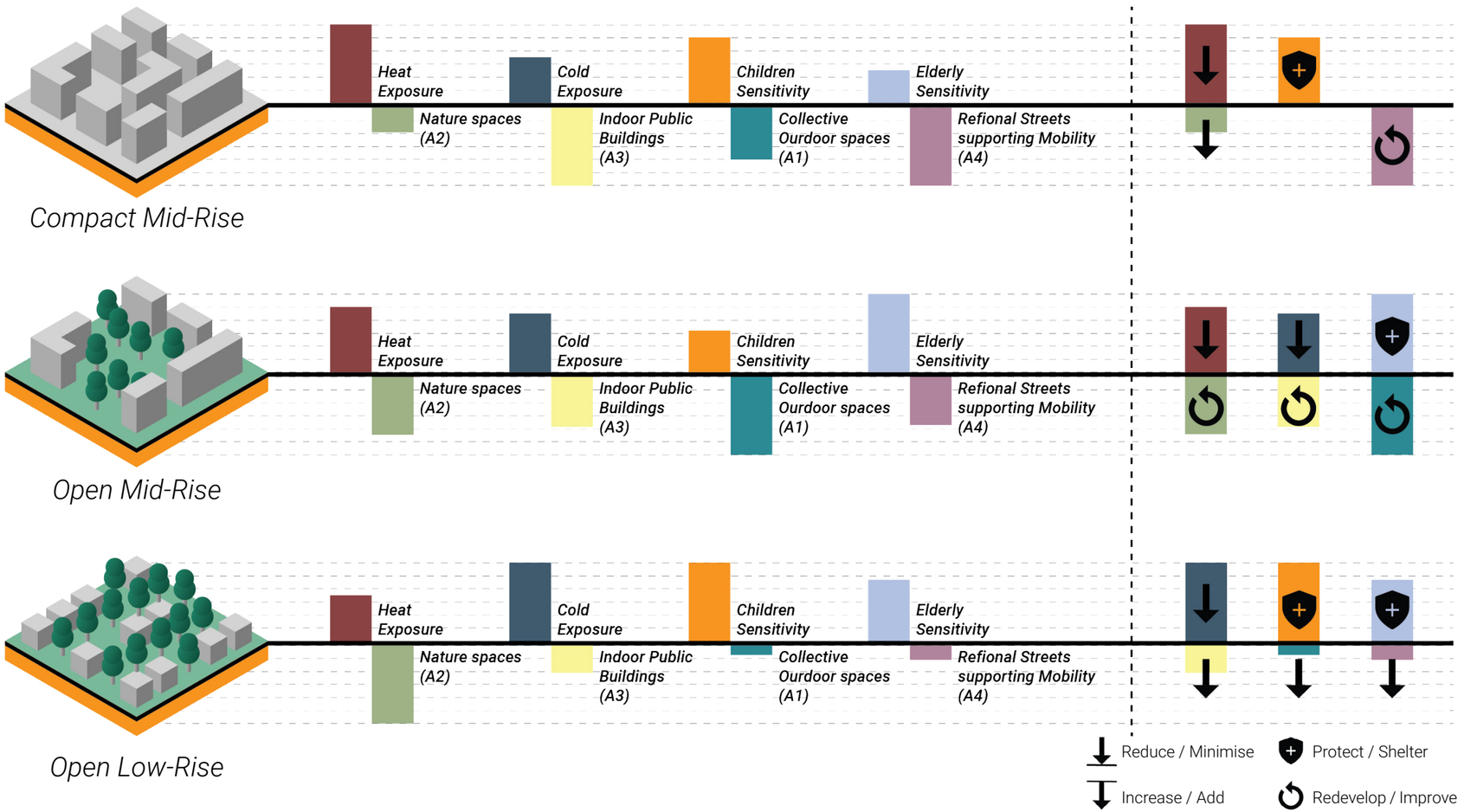
Possible Adaptation Approaches





Adaptation Approach Goals

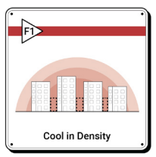
Possible Approach Goals to Temperature Adaptation



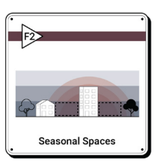
Vulnerability based on Vilnius Urban Form

Vulnerability results contextualised within the 3 major Vilnius Urban Climate Types

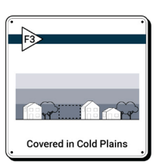
Site 01 - *Naujamiestis Blocks*



Site 02 - *Karoliniškės Residential Neighbourhood*

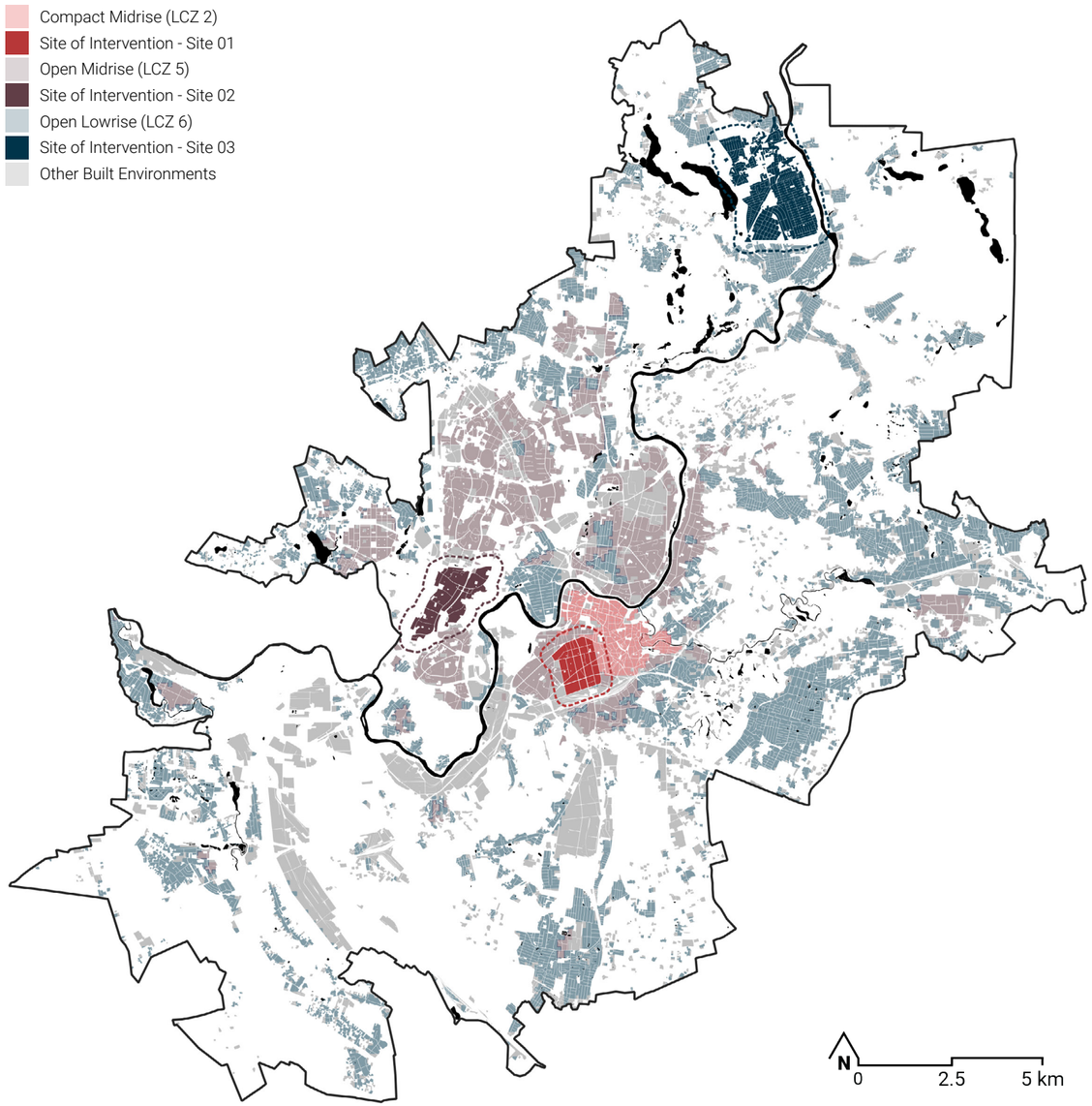


Site 03 - *Northern Verkiai Territory*



Sites of Interventions

Chosen sites with typical characteristics of the studied Urban Climate Types

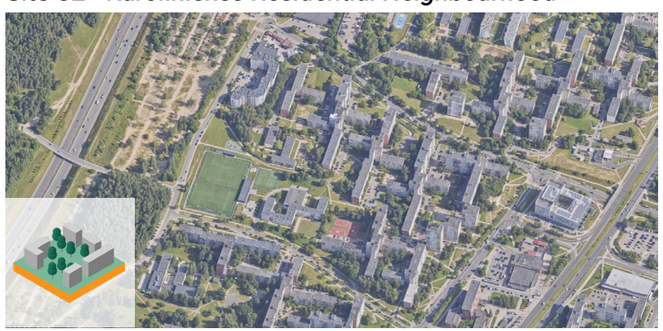


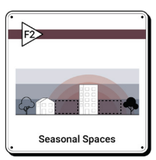
Sites located in Vilnius

Vilnius urban fabric classified to the three main Urban Climate Types

Site 01 - *Naujamiestis Blocks*

Site 02 - *Karoliniškės Residential Neighbourhood*

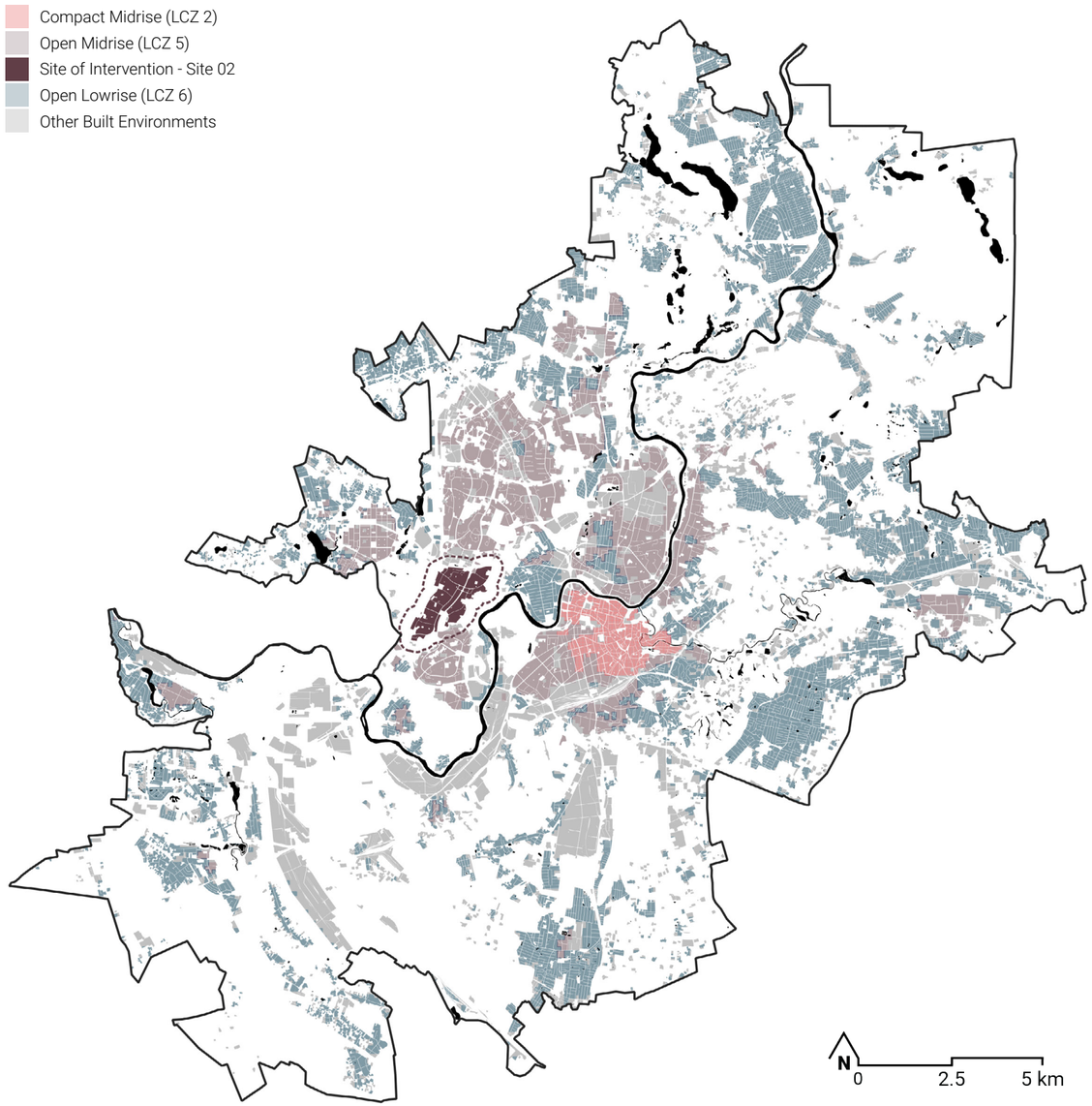




Site 03 - *Balsiai District*

Site of Interventions

Chosen sites with typical characteristics of the studied Urban Climate Types



Site located in Vilnius

Vilnius urban fabric classified to the three main Urban Climate Types

Exposure → **Focus Goal** → **Exposure Reduction**

F1

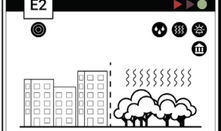
Cool in Density

Cooling strategies within the public realm lowers health risks and increases comfort during heatwaves or hot periods in dense and compact environments.

Explanation:
Dense and compact urban environments absorb and retain heat, amplifying the urban heat island (UHI) effect. This problem arises due to the heat-absorbing materials like asphalt and concrete, limited vegetation, and restricted airflow caused by closely situated buildings. As a result, urban spaces can become overheating zones, particularly during heatwaves, leading to increased health risks such as heat exhaustion and dehydration, especially for sensitive populations. To ensure outdoor comfort, encourage social activities, physical exercise and economic activity, these compact urban environments have to primarily focus on reducing exposure to heat.

Aligned patterns are marked with the associated symbol:

E2



Staying on the Edge

Developing near natural areas while preserving their integrity ensures easy access to high quality green spaces, promoting well-being and ensuring thermal comfort.

Empirical Back-up:
Forests reduce heat through shading and evapotranspiration, lowering temperatures by up to 1.5°C. Field studies have shown that larger green spaces provide higher temperature reduction, with the effects extending over a 350m distance from the green space boundary.

Practical Implications:
Urban expansions or densification should prioritise development around large urban forests, while integrating connectivity to these areas. Zoning laws should define a forest boundary, promoting a transitional green space to limit human intrusion and ensure local ecological preservation.

(Aram et al., 2019).

Sensitivity → **Urgency Goal** → **Social Well-being**

U2

Risk-Free Elderly

Sheltered meeting spaces provide an opportunity for residents, that do not have adequate adaptation possibilities and are more susceptible, such as elderly, to adapt to temperature extremes.

Explanation:
Older people are sensitive to temperature extremes due to age-related health conditions. Pensioneers typically have less adaptive capacity for their reduced mobility and limited resources. Many elderly individuals rely on nearby public spaces for exercise, social interaction and daily routines, although these areas often lack temperature adaptations that ensure comfort and safety. Adapting public spaces with temperature responsive design can promote active aging and ensure social cohesion for spaces that have older populations.

Aligned patterns are marked with the associated symbol:

S1

Courtyard Gardening

Interactive green spaces encourage participation and communal working, fostering community ownership. Additionally, increased and maintained greenery reduces exposure to heat.

Empirical Back-up:
Urban gardens integrate nature-based solutions into the built environment, supporting social cohesion, mental well-being and ecological resilience. Gardens act as microclimate buffers reducing urban heat and improving the air quality. Additionally, these spaces provide opportunities for urban agriculture and environmental education.

Practical Implications:
Only design the placement of gardening spaces and allow residents to decide and manage these locations. Situate urban gardens in transitionary spaces to allow these green spaces to work as filtering buffers. Provide sheltered seating to encourage people to spend their time in these environments.

(Hanson et al., 2021;
One More Tree Foundation, 2024)

Adaptive Capacity → **Approach Goal** → **Coping Networks**

A3

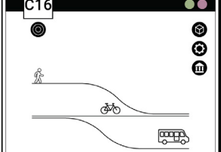
Shelter-in-Place

Adapting nearby indoor public services as shelters from temperature extremes creates accessible and prepared refuges, that are equally managed.

Explanation:
Adapting public services as shelters from temperature extremes ensures that vital community spaces, such as libraries, parks, schools, community centres or transit hubs, can function as climate-prepared refuges for local residents and visitors alike. These spaces can provide relief during extreme heat, while also serving as warm shelters. Adapting existing public buildings is a more efficient, sustainable, and equitable strategy by directing resources towards infrastructure improvement. Although, to address current spatial inequalities in some areas, expansion of well-managed shelter network enhances climate resilience, ensuring no community is left behind.

Aligned patterns are marked with the associated symbol:

C16



Multi-Modal Routes

Designing multi-modal routes enhances connectivity by integrating walking, cycling, and public transport options, ensuring adaptable movement across the city.

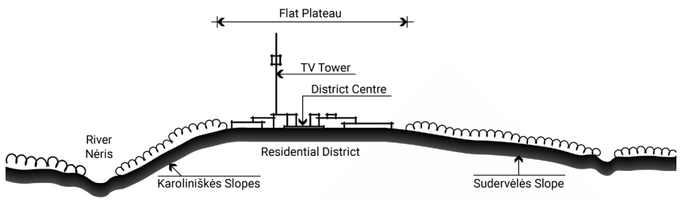
Empirical Back-up:
Multi-modal transport refers to a person's use of many modes of travel to reach their destination instead of a single mode, such as private vehicles. While this method is a more environmentally beneficial and increases the use of public transport systems, its success is dependent on comfortable transitions and transforming car-oriented habits. Multi-modal systems are essential for people to travel with limited movement abilities.

Practical Implications:
Design interconnected routes that allow continuous transitions between different modes of travel. Ensure paths connect to interchange nodes and are designed for universal access, accommodating strollers, wheelchairs, and slower walkers. Include supporting amenities, such as bike parking and repair services.

(Environmental Resilience Institute, 2025;
Fu et al., 2024)

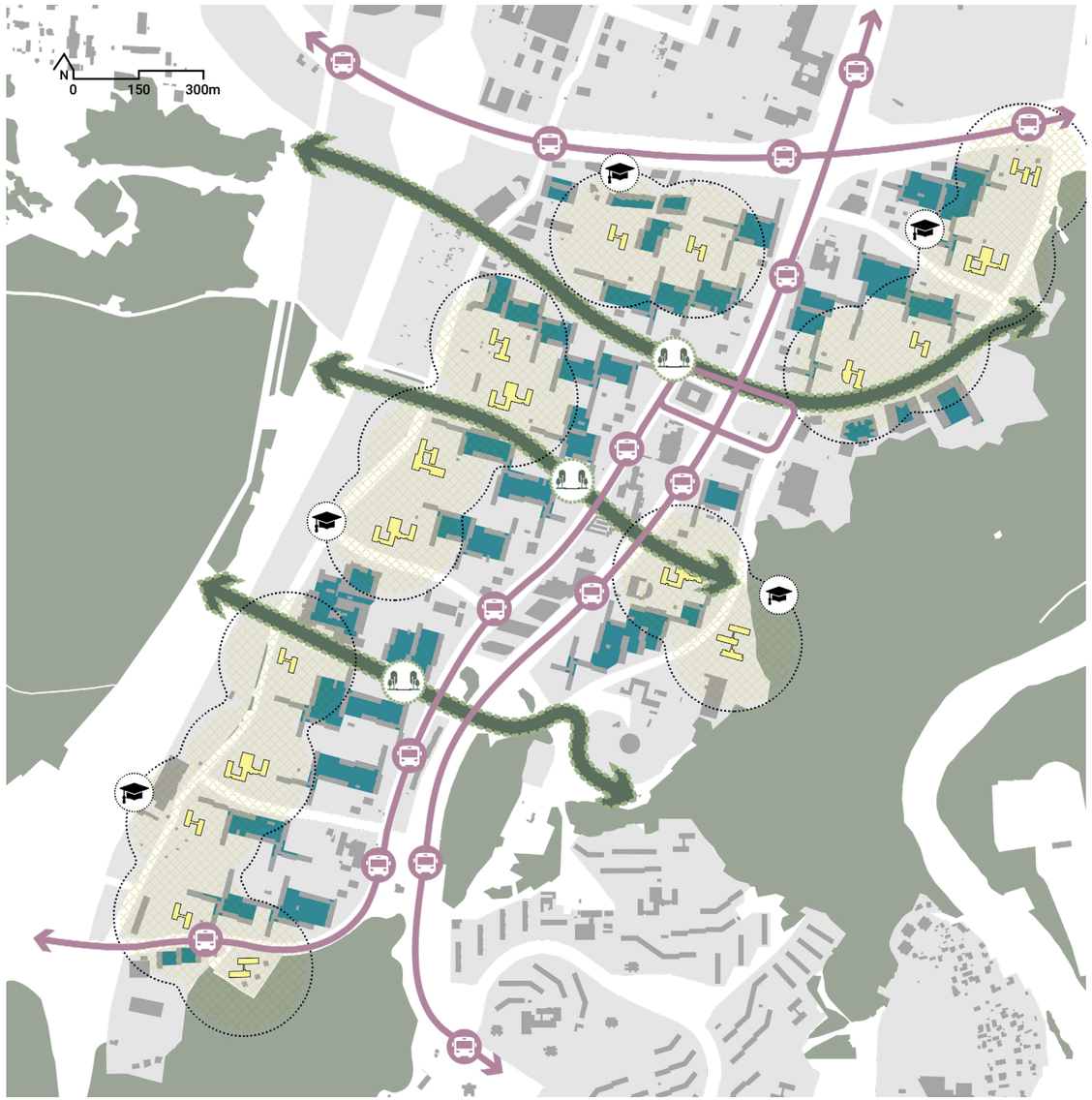
Example Patterns in each Category

Pattern categories, that regulate temperature through their design elements, offer user-selected spaces, that improve social or physical well-being, and design measures that improve a person's ability to adapt, by ensuring better movement, accessibility to shelters, temporary exposure reductions or designs encouraging community resilience

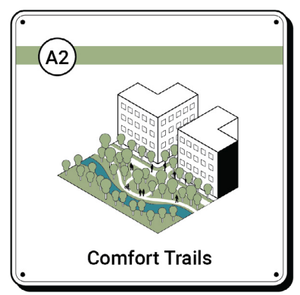


Karoliniškės Neighbourhood

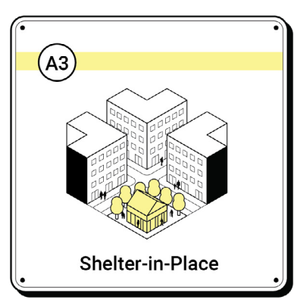
Exploring the Modernist housing areas (Photo: Bauras, n.d.)

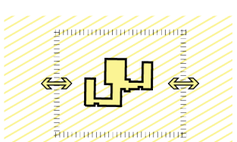


Garden Communities



Oasis Corridor





Schools for Everyone

Potential Spaces for Adaptation

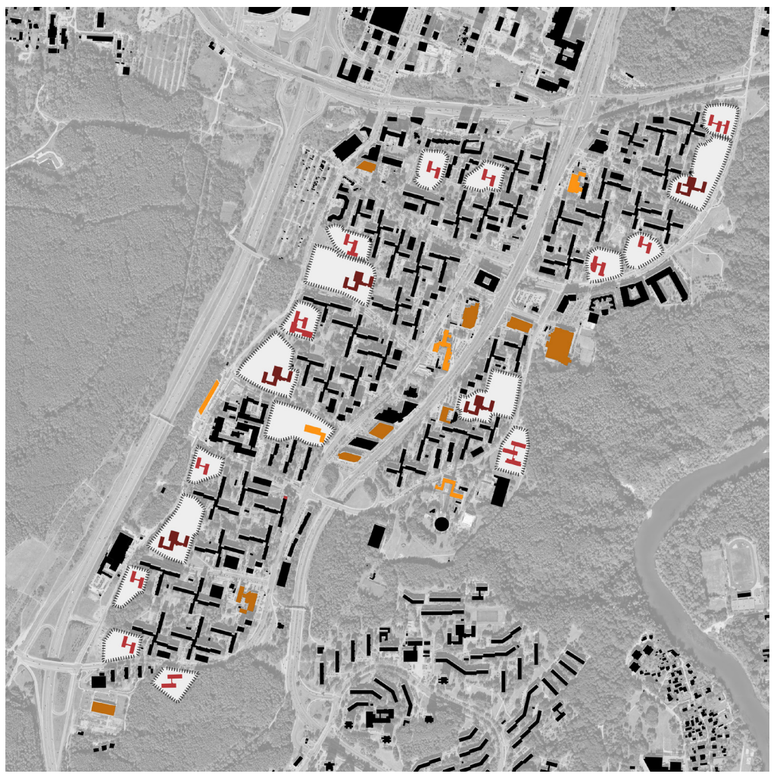
Karoliniškės residential district with Adaptation Goals and design strategies building up to new Structure Patterns

Nature Structures

Environmental Analysis - Natural cool places

N 0 250 500m

- Natural areas / Forests
- Natural water bodies
- Buildings
- Contour line & Ground elevation

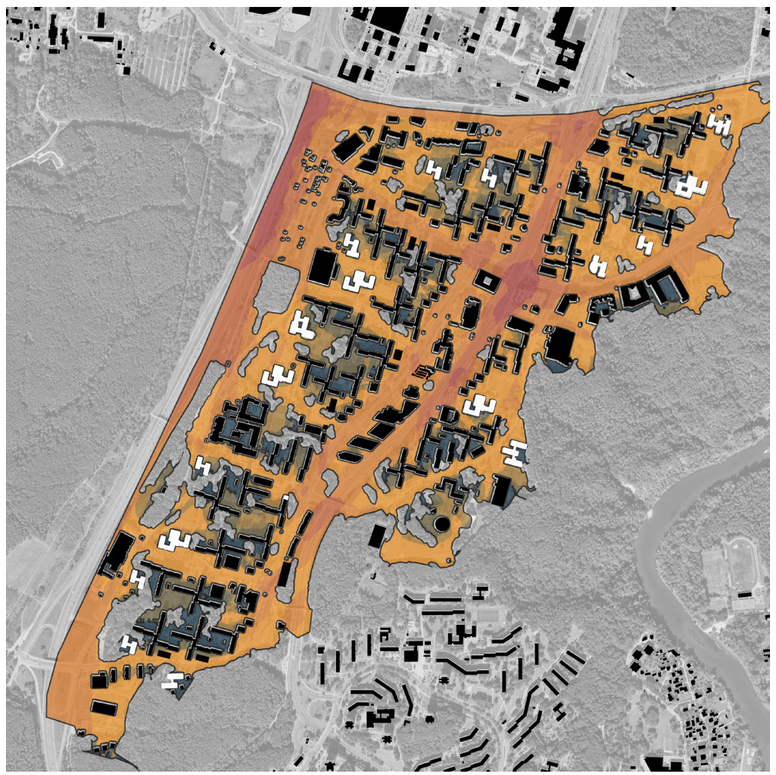


Public Buildings

Public Service Analysis - Possible indoor shelters

N 0 250 500m

- Buildings
- Public kindergarten (possible shelter)
- Public school (possible shelter)
- Retail services (possible shelter)
- Retail services (possible shelter)
- Public buildings (shelters)
- Restricted education grounds

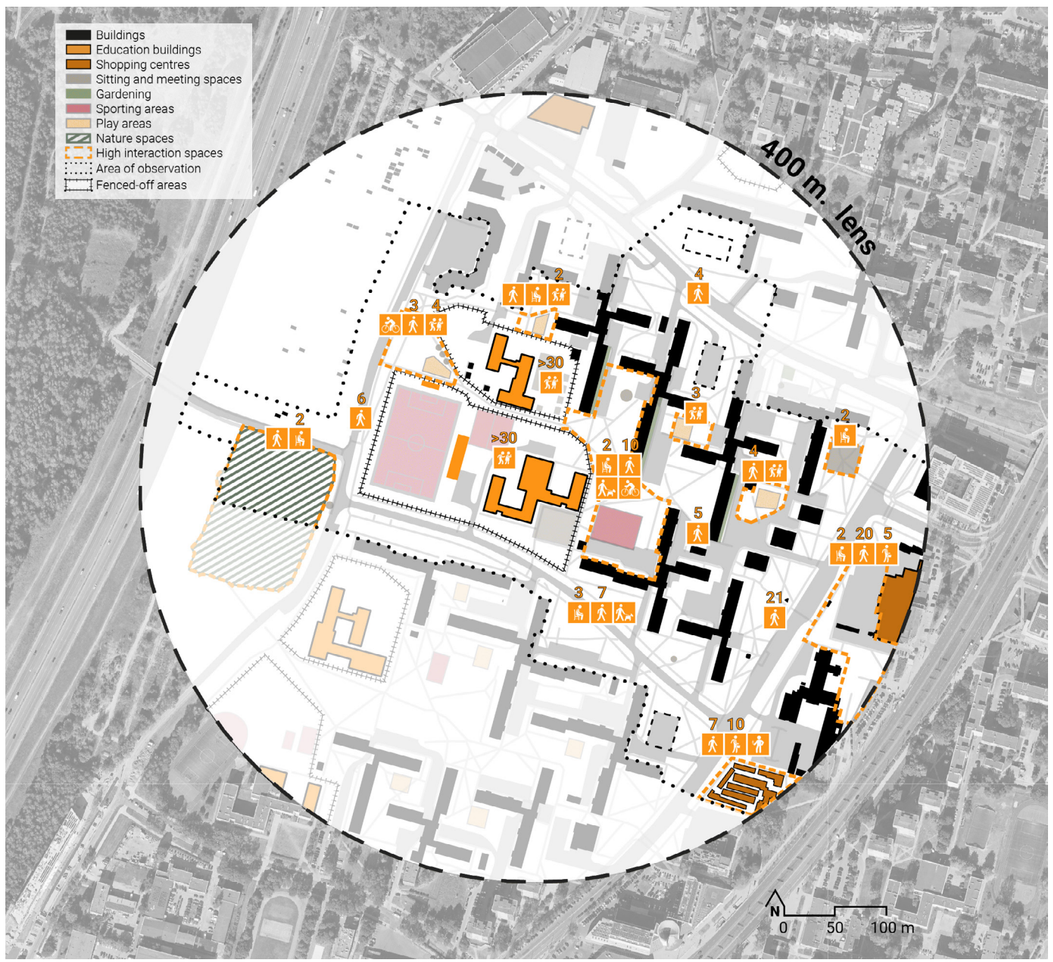


Public - Private Spaces

Neighbourhood visibility analysis - Personal adaptation spaces

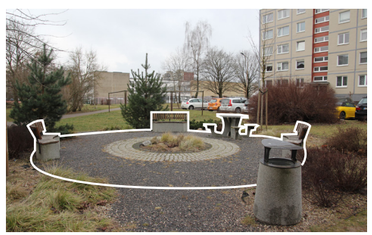
N 0 250 500m

- Education buildings (shelters)
- High visability - Open Public
- Low visability - Enclosed Private

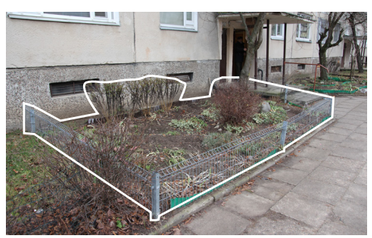


Neighbourhood's Social Spaces
Public space distribution and valued social spaces

Entrance interface



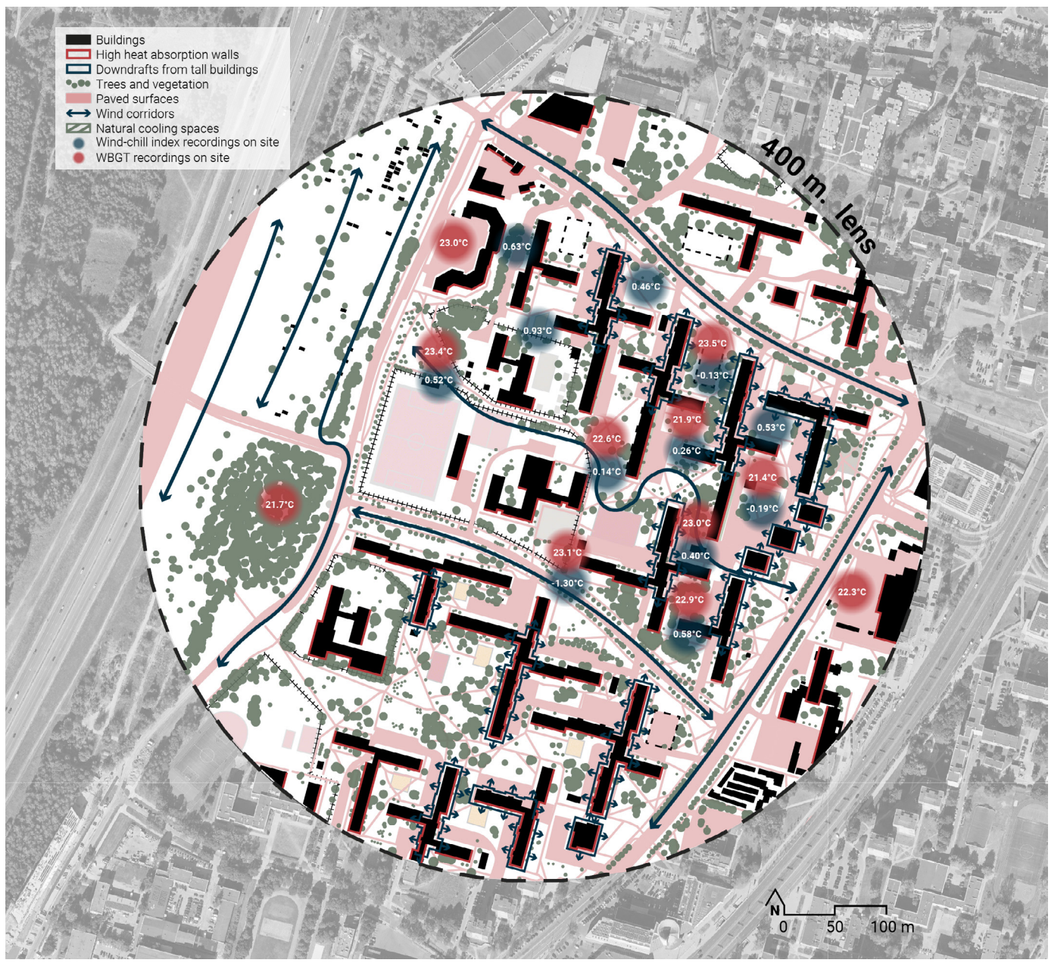
Community seating



Apartment front gardens

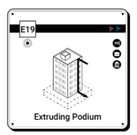
Schools & Kindergartens

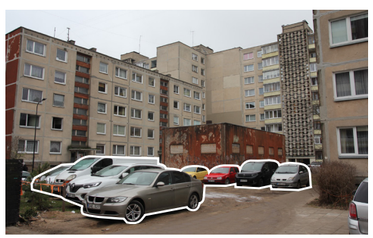
Dominant Spaces
Fieldwork documenting spaces and choosing patterns



Neighbourhood's Thermal Comfort
Form properties that influence space thermal quality

Tall building downdraft

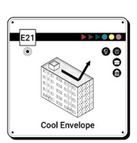




Vehicle dominated space

Unutilised old trees

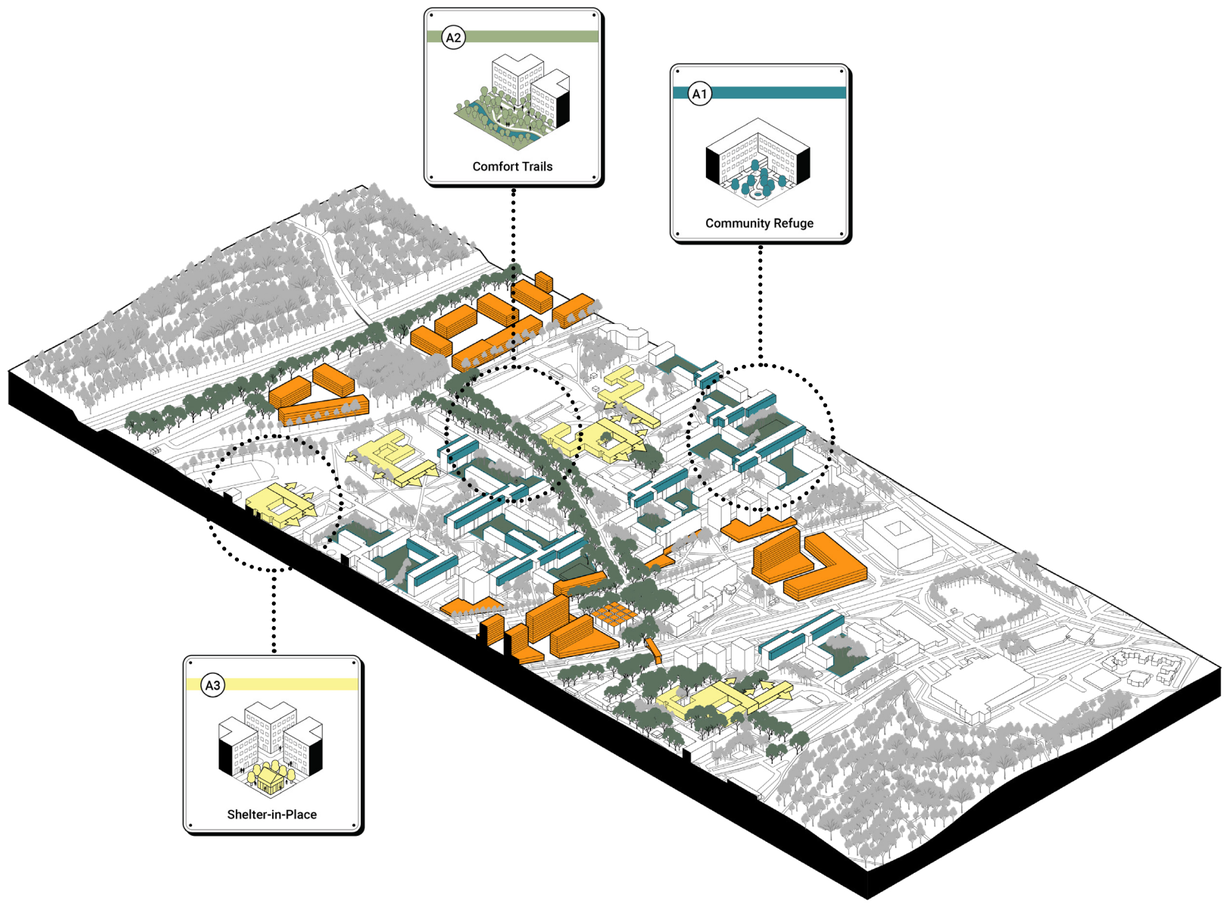
Heat sink surfaces



Dominant Form Qualities
Fieldwork documenting spaces and choosing patterns

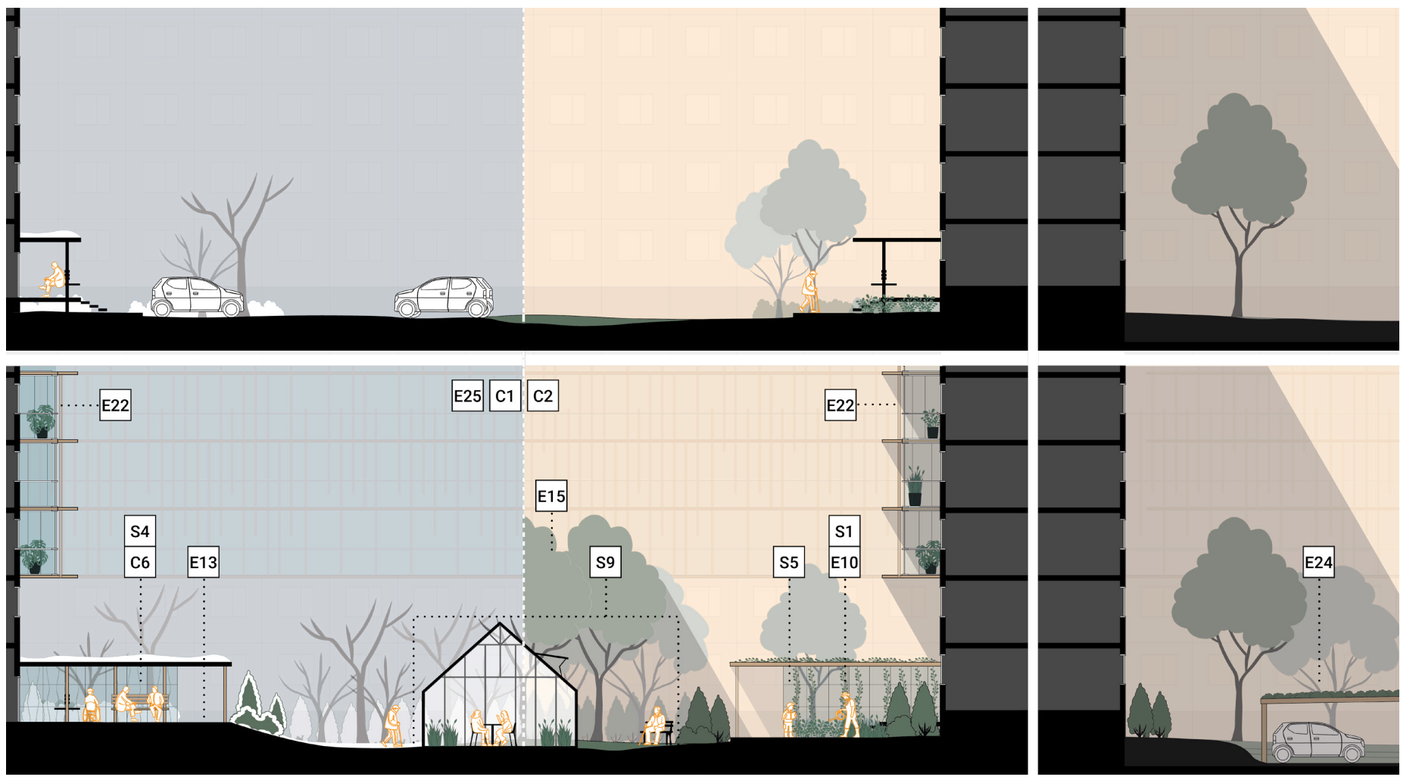
Potential Adaptation Vision

Karoliniškės residential district with possible large-scale adaptations strategies



Open Mid-rise Transect

Axonometric drawing of public space adaptation strategies



Comfortable social indoor spaces

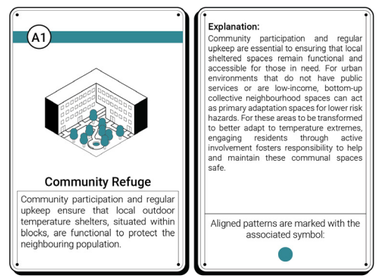
Comfortable social outdoor spaces

Service spaces designated outside the courtyard

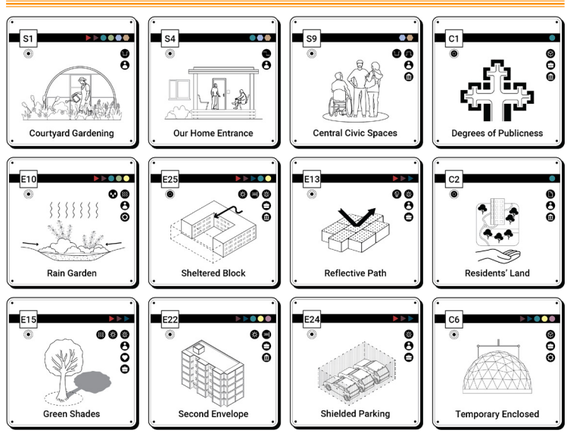
Community Garden Adaptation

Modernist micro-district courtyards adaptated for both temperature extremes

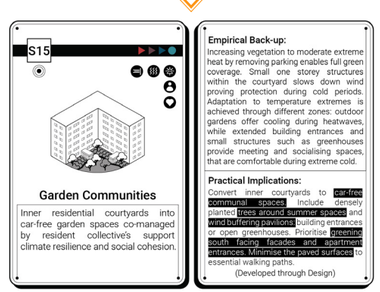
Adaptation Goal

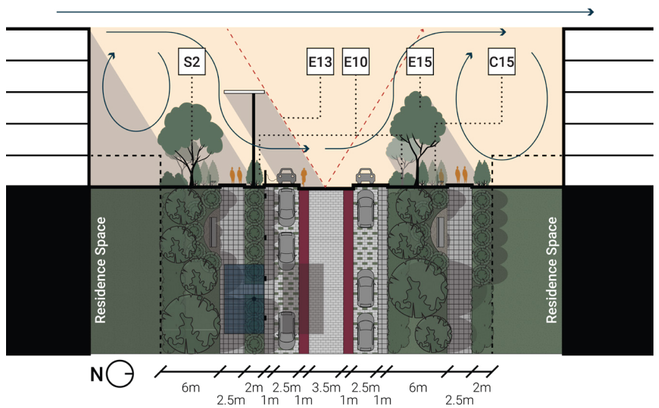


Solution Patterns integrated within the Strategy

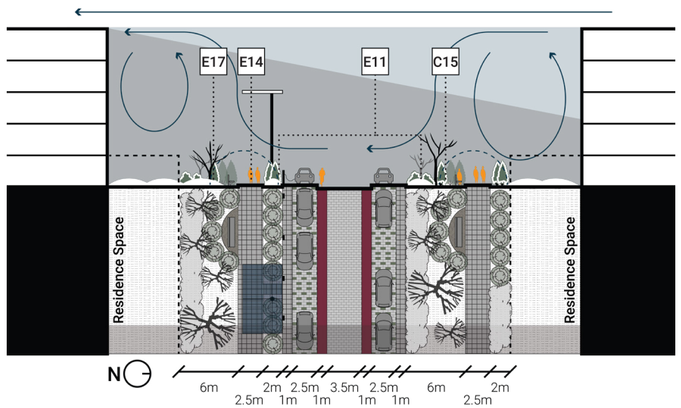


New (Site-specific) Developed Pattern





Safe connecting spaces during heatwaves

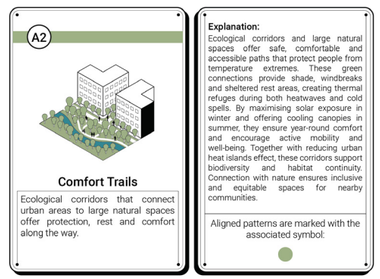


Safe connecting spaces during cold spells

Oasis Corridors Adaptation

Irregular canyon transformation into an "Oasis Corridor" and optimisation for a heatwave and coldspell conditions at noon (H/W = <0.30)

Adaptation Goal



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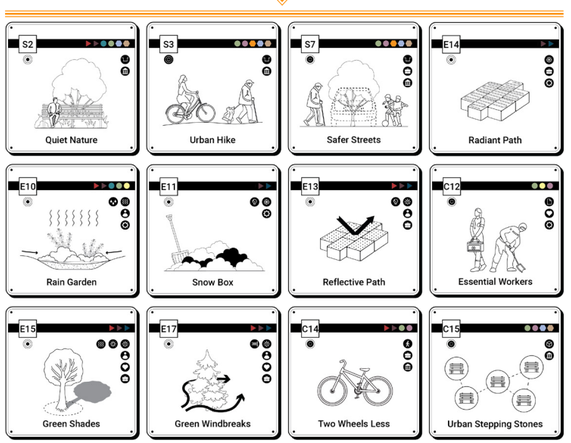

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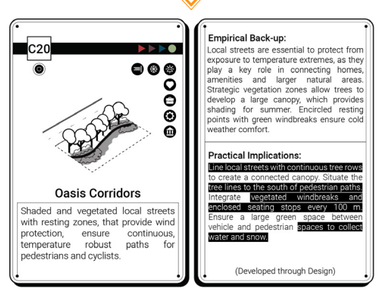
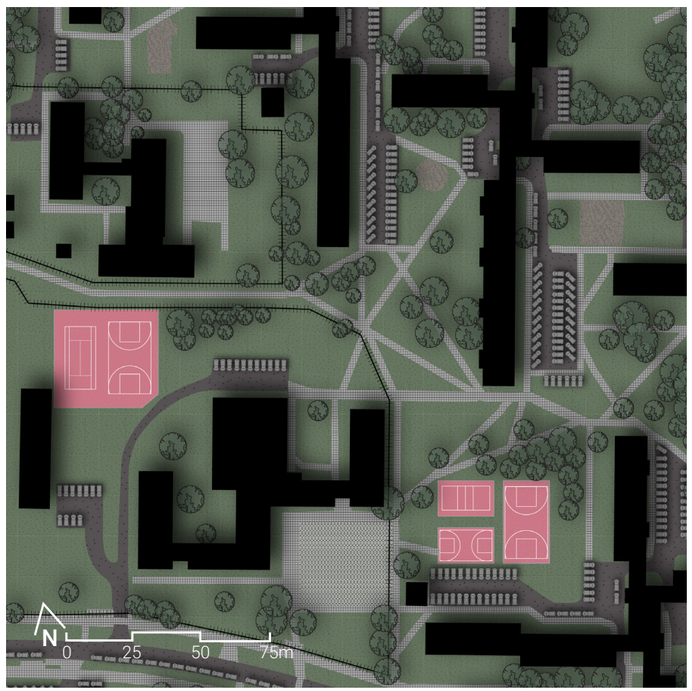
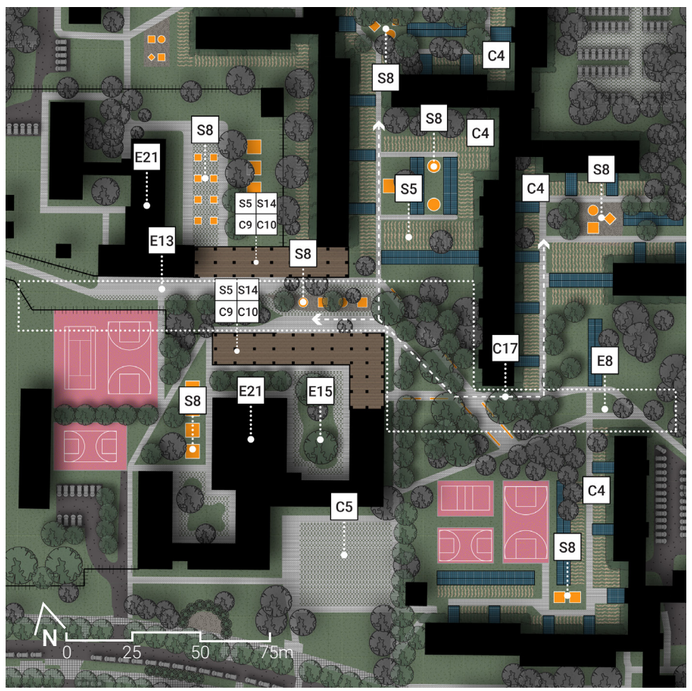




Enclosed and fenced-off education grounds

Large open left-over spaces from modernist urban planning



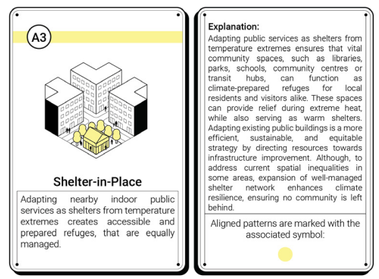
Distinction between private education grounds and shared grounds between two schools and the residential block

Adding functions to the residence, such as a centre park and gardens rows.

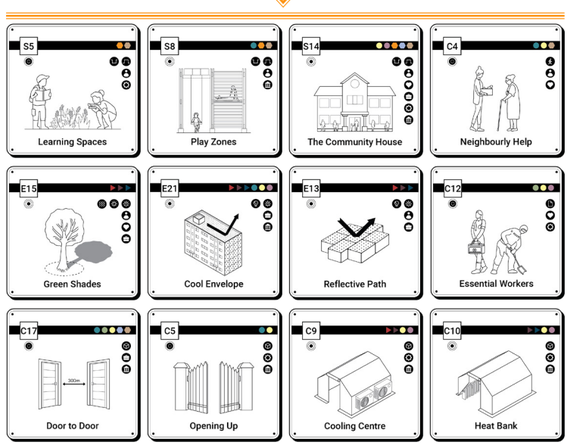
Schools for Everyone Adaptation

Education grounds transformation into "Schools for Everyone" illustrated in plan

Adaptation Goal



Solution Patterns integrated within the Strategy



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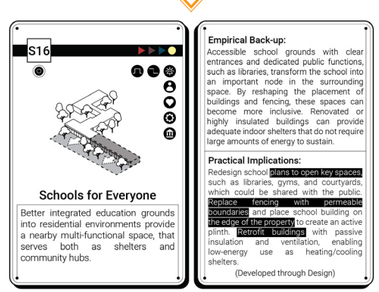
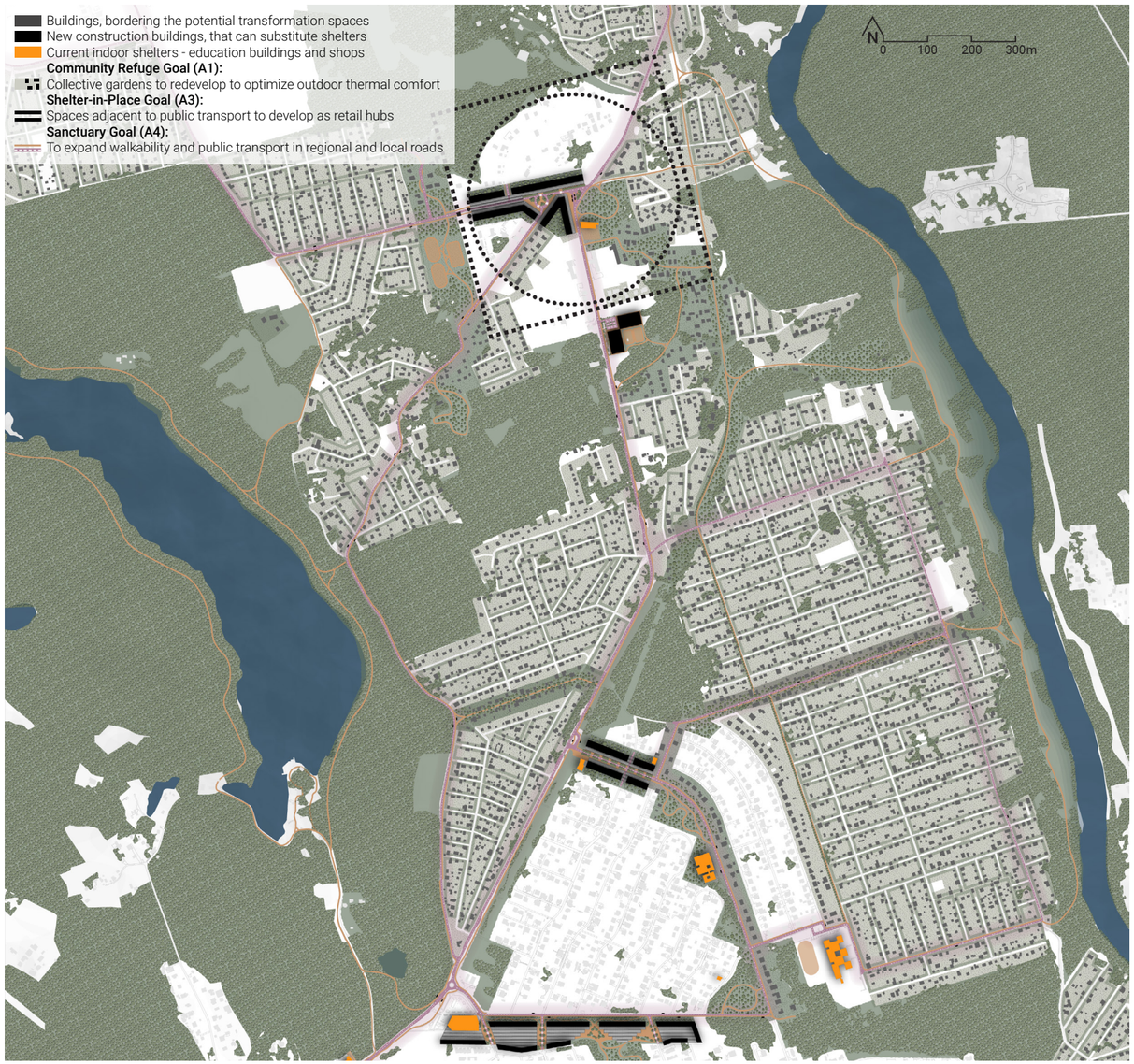


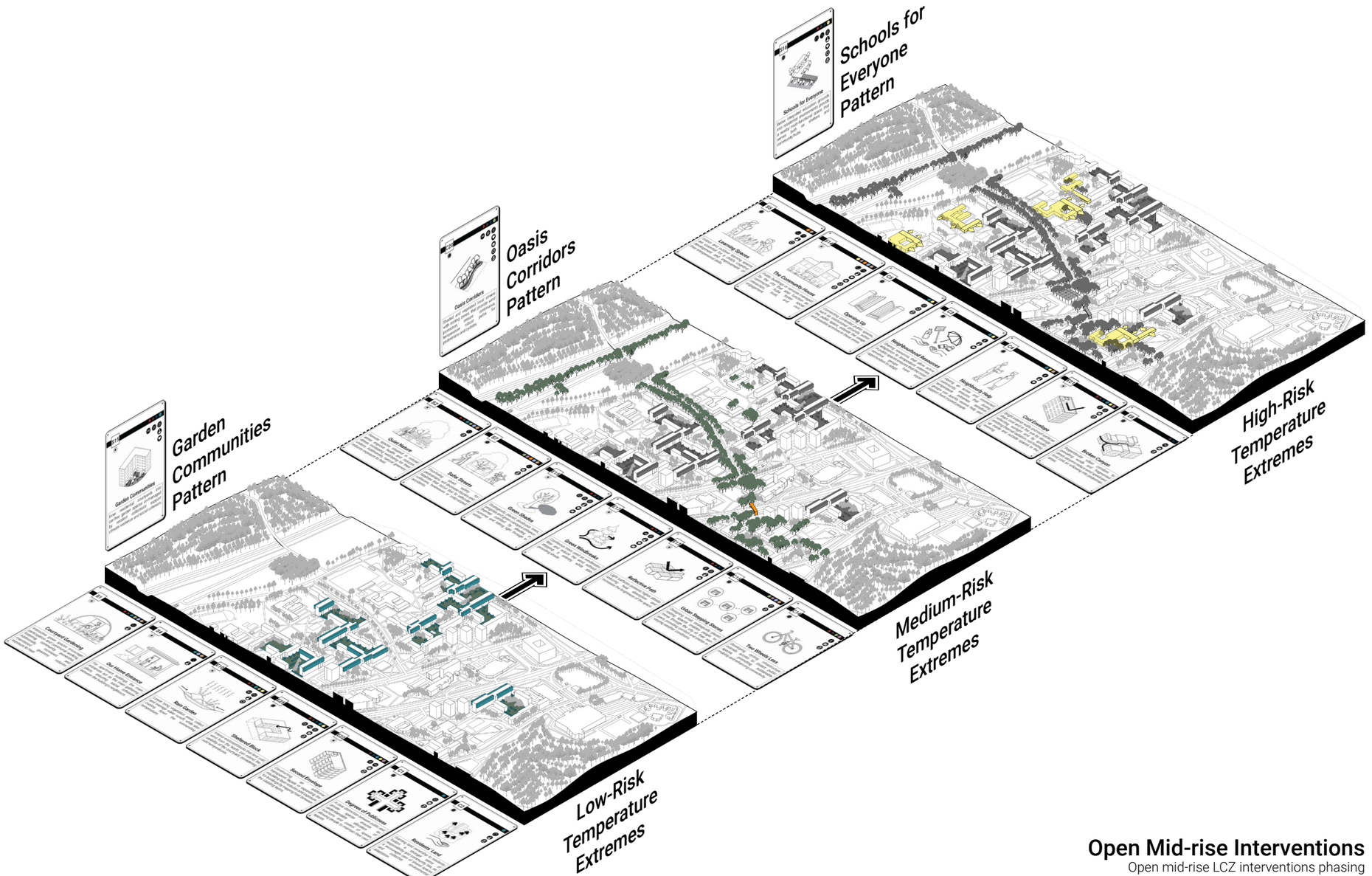
Transformation Vision for a Compact Mid-rise Environment

Naujamiestis eighbourhood with possible large-scale adaptations strategies



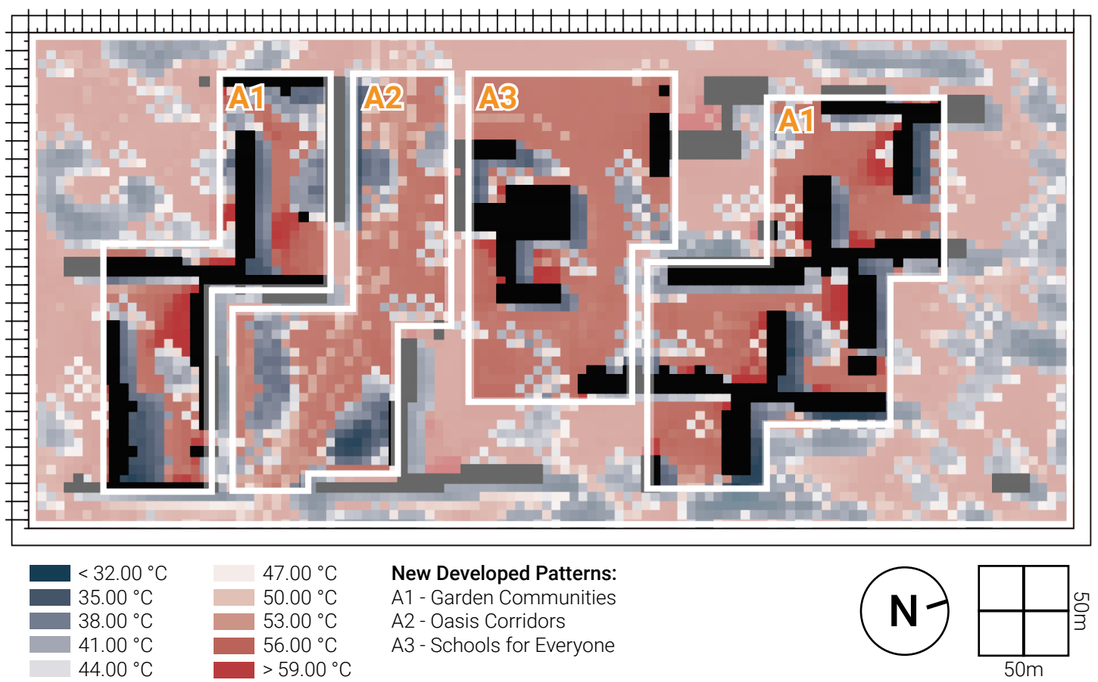
Transformation Vision for an Open Low-rise Environment

Northern Verkiai Territory residential district with possible large-scale adaptations strategies



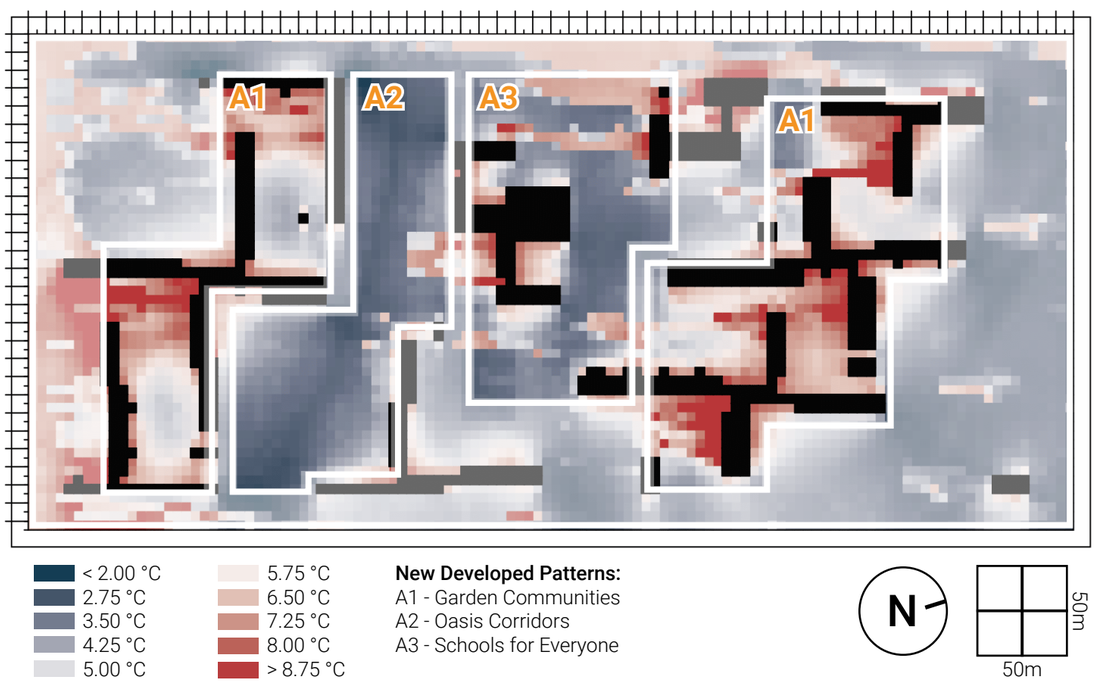
Open Mid-rise Interventions

Open mid-rise LCZ interventions phasing dependant on future risks



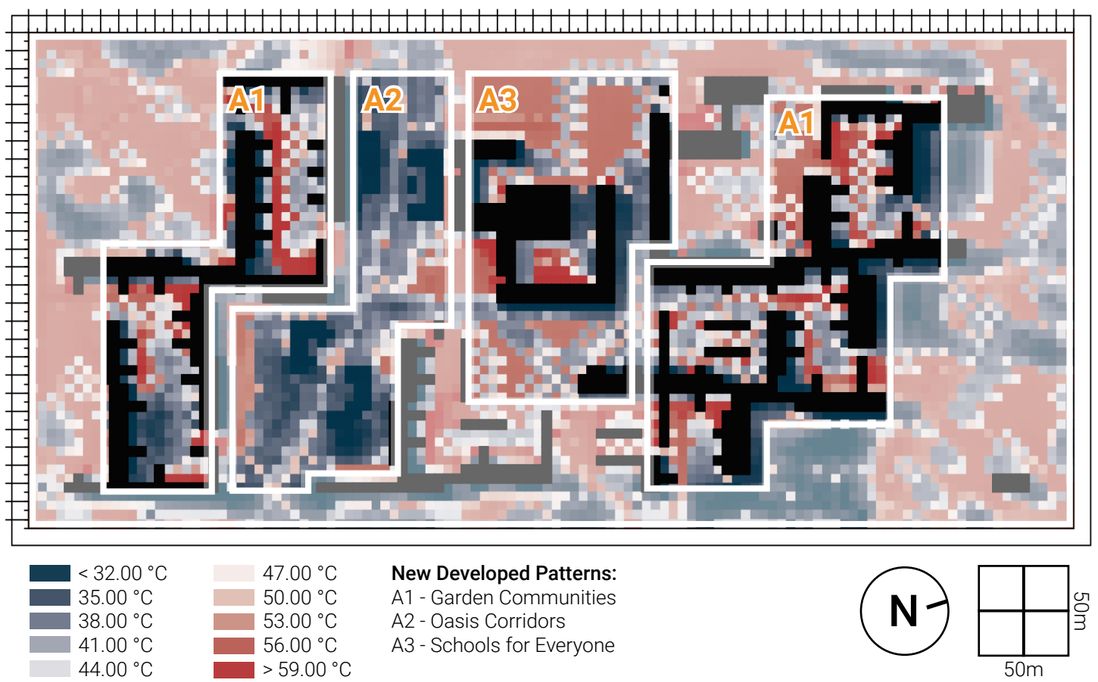
Current Situation during a Heatwave

Perceived temperature values during a typical heatwave



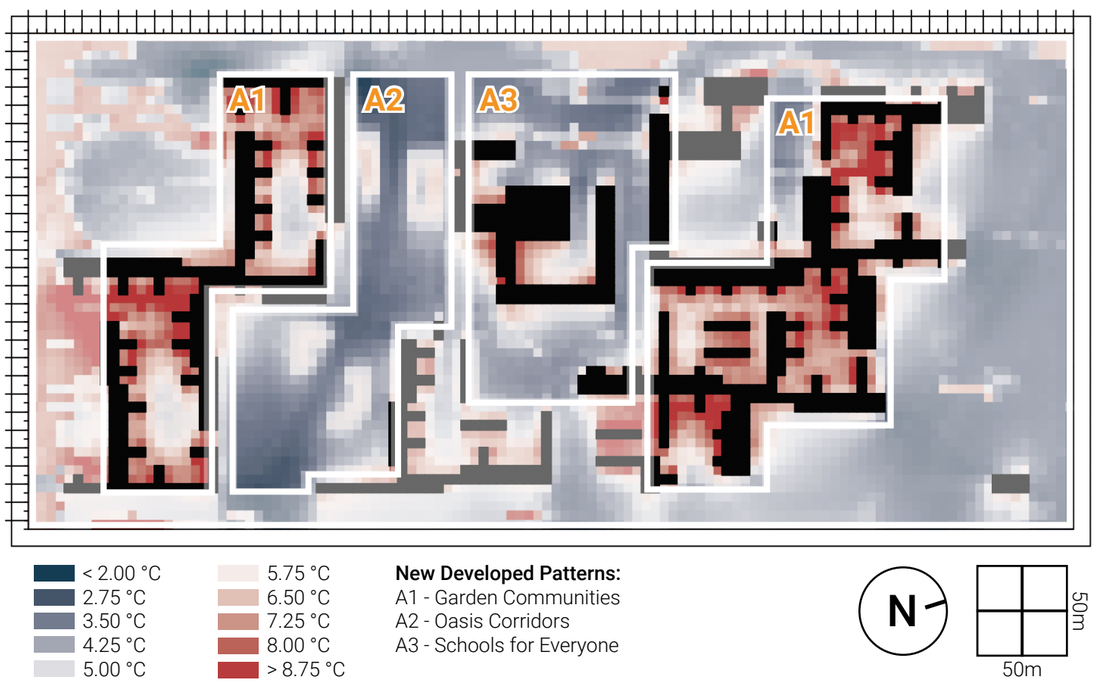
Current Situation during a Cold spell

Perceived temperature values during a typical cold spell



Transformed Situation during a Heatwave

Perceived temperature values during a typical heatwave after Implementing adaptation strategies

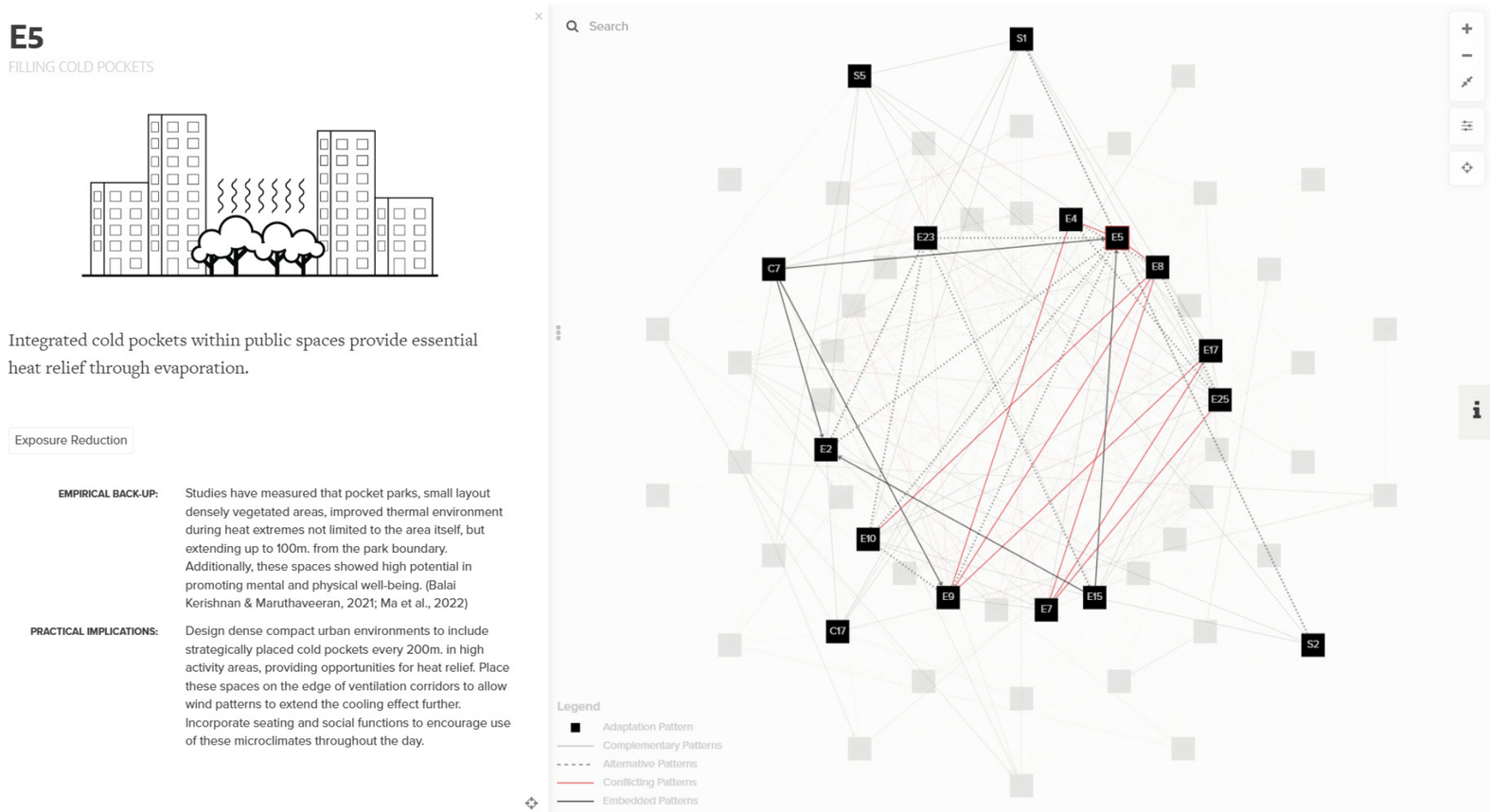


Transformed Situation during a Cold spell

Perceived temperature values during a typical cold spell after Implementing adaptation strategies

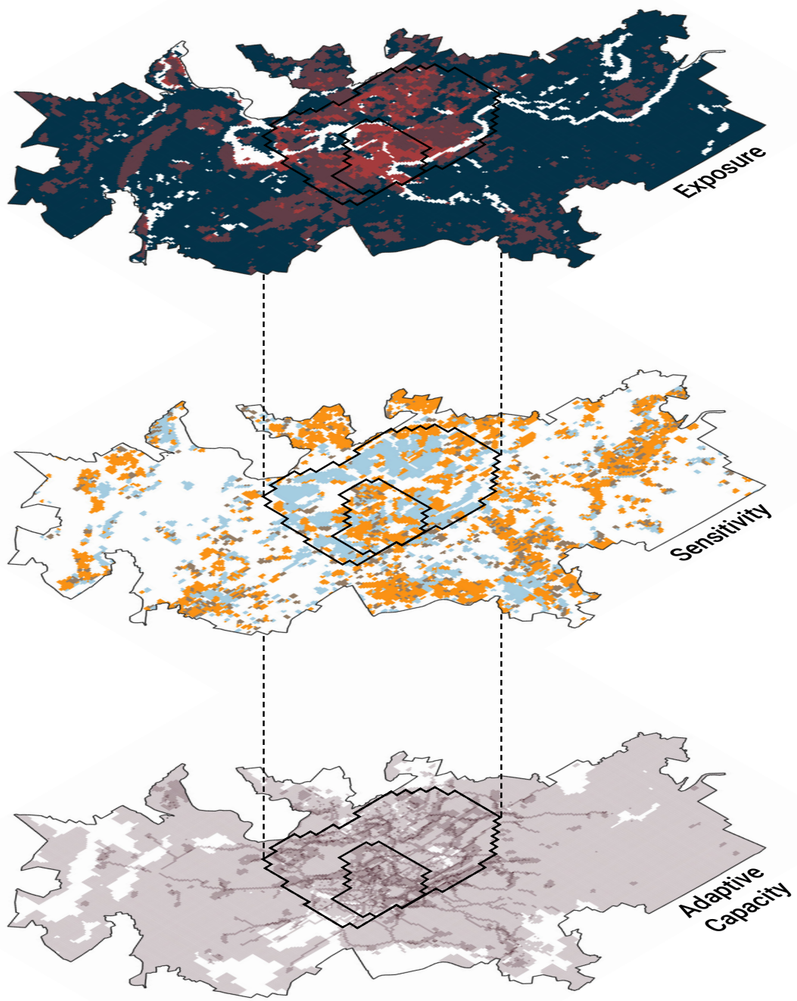
Pattern Workshop
Testing the usability and clarity of the developed patterns
(taken by author)

Scan Me!



Pattern Atlas Interactions

Illustrating Complementary patterns, that synergies together, Alternative patterns, that can be substituted, Conflicting patterns, that require compromising and Embedded links, which specify patterns that are necessary for the other pattern to operate.

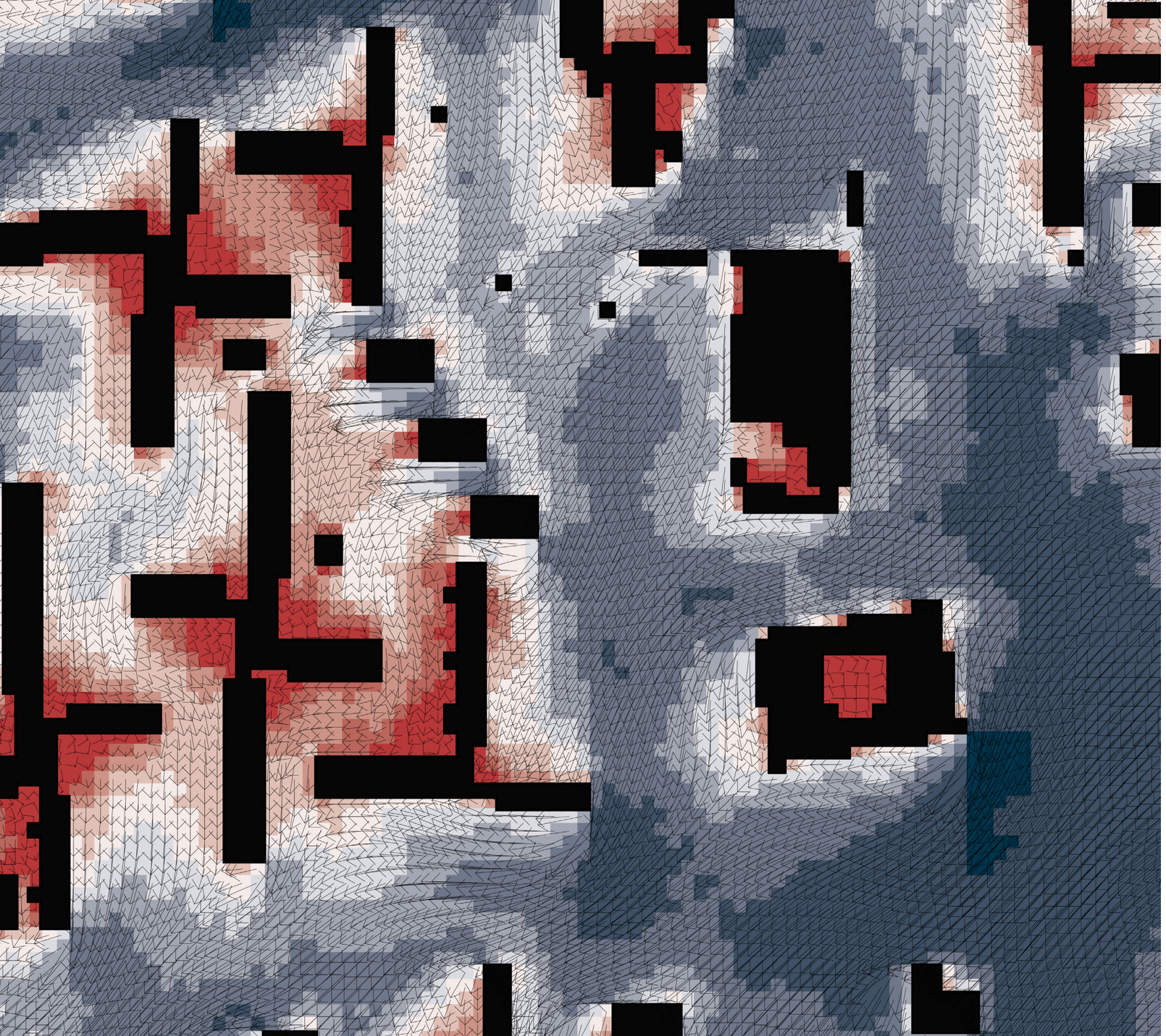


Incorporate Vulnerability within Adaptation Planning

Incorporate Vulnerability frameworks within future urban adaptation plans, green action plans and city development plans

Utilise the developed Adaptation Patterns as Urban Design Tools

Utilise the developed Adaptation Patterns to adapt public spaces and transform the current urban systems to become temperature robust or adapted urban systems. (Photos: Vilnius Green Capital, 2025)



Thank you

Kristupas Kadys

First Mentor: Dr. Daniela Maiullari
Second Mentor: Birgit Hausleitner
June 17th, 2025

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