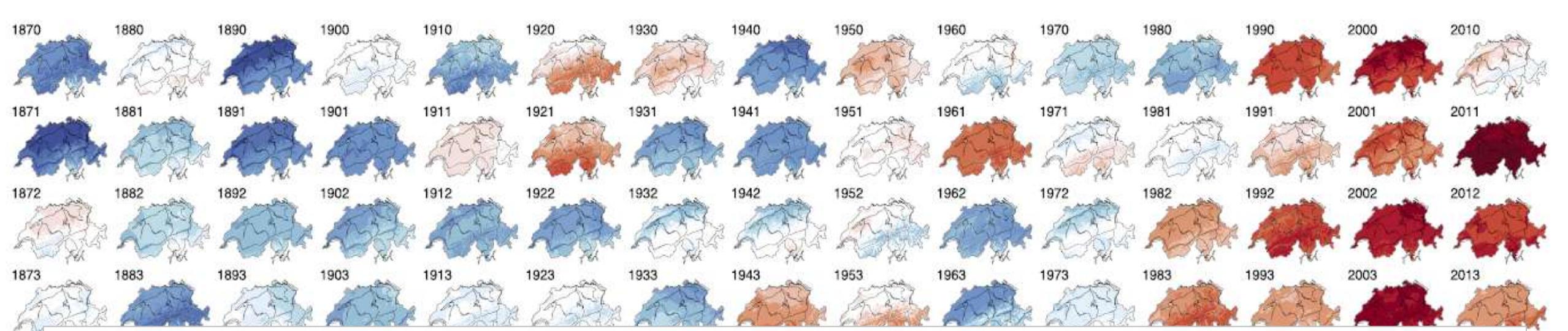


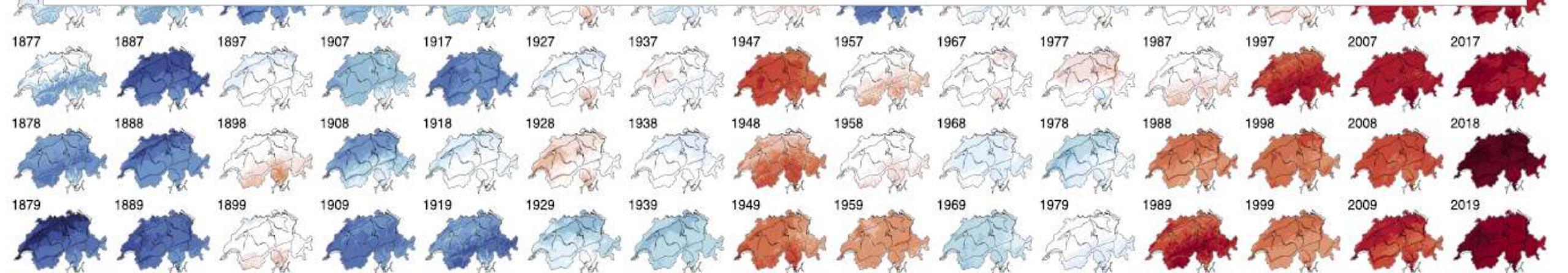
# **Mitigating and counteracting Urban Heat Waves and Heat Island Effects**

- Introduction to heat waves and heat island effects
- The integrated Heat Reduction Strategy of the city of Zurich (CH)

Yves Kazemi, Monday 21 March 2025



# Effets des changements climatiques sur la température





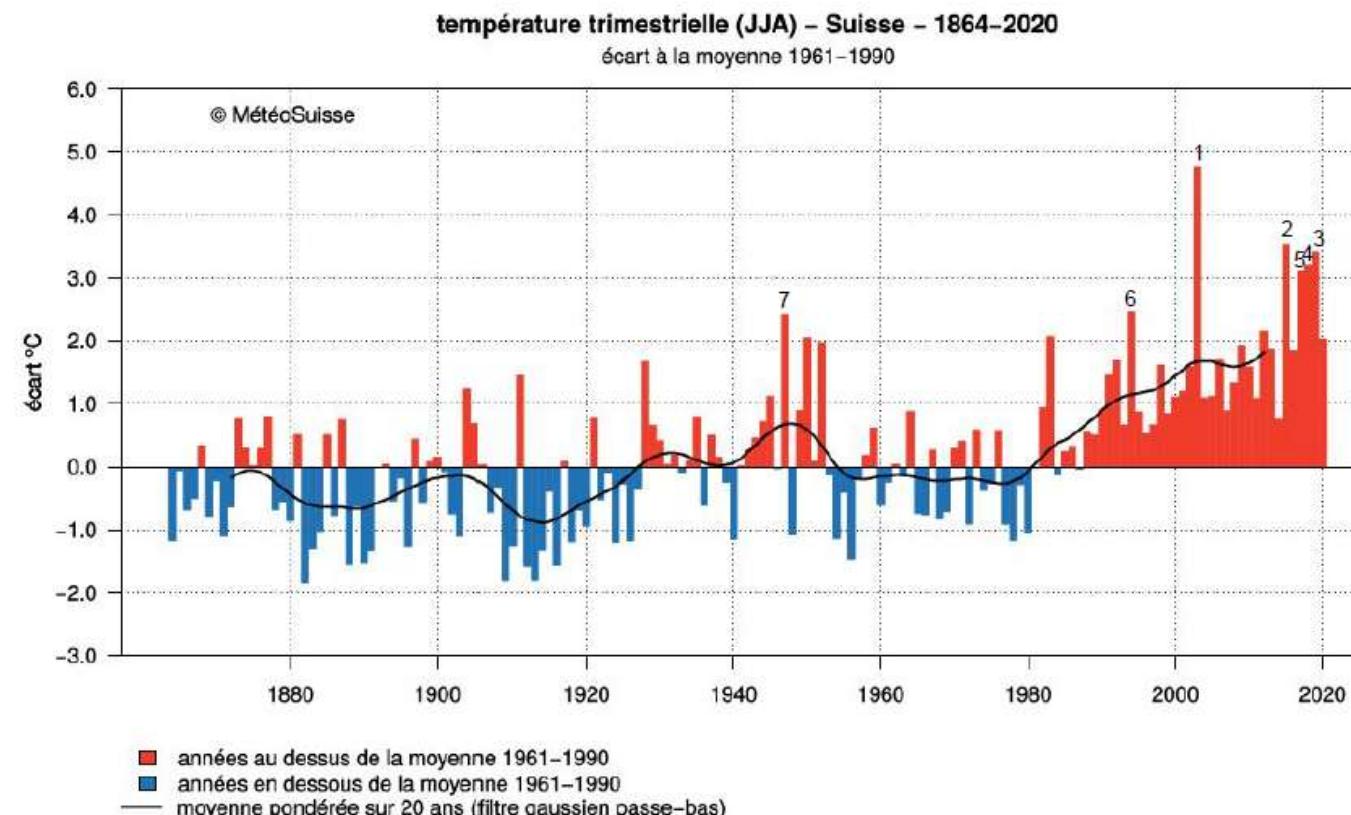
Slide courtesy of L. Tudesco

## LE CLIMAT DE LA SUISSE CHANGE



### Température estivale moyenne

Caputin





Slide courtesy of L. Tudesco

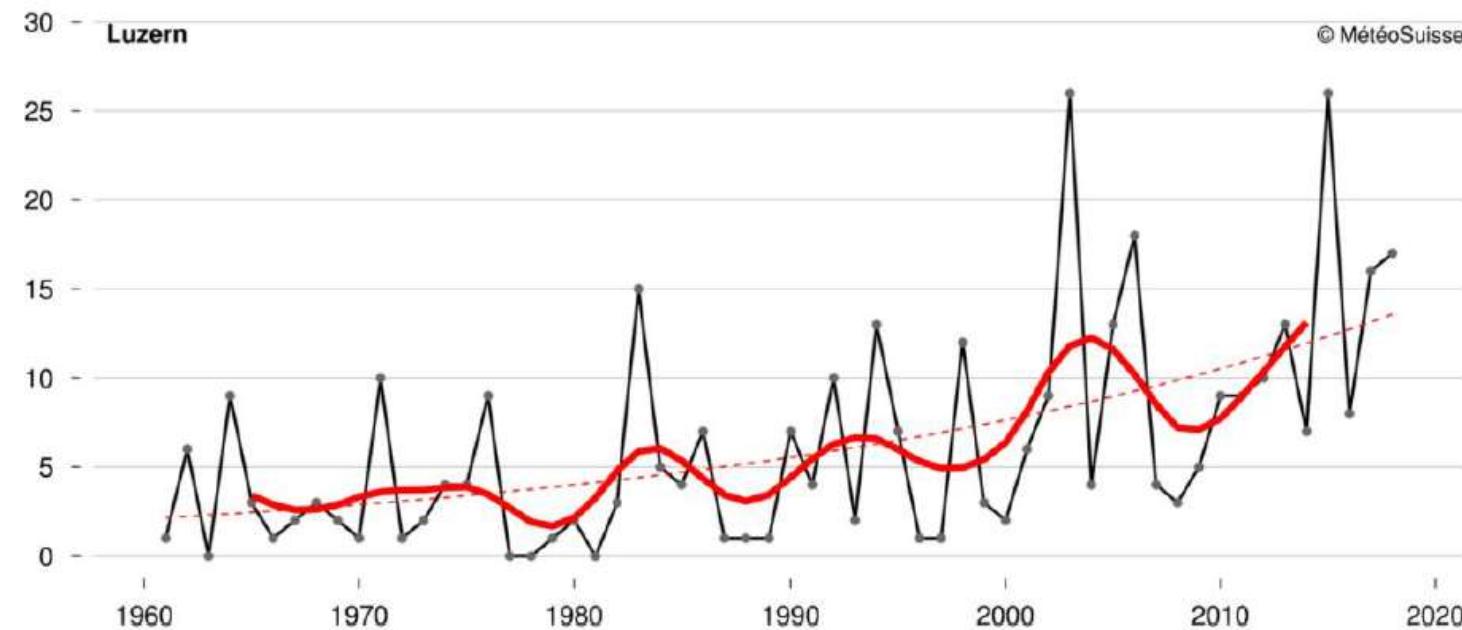
## LE CLIMAT DE LA SUISSE CHANGE



### Jours tropicaux ( $T_{\max} > 30^{\circ}\text{C}$ )

Capture recto

Jours tropicaux [ $T_{\max} \geq 30^{\circ}\text{C}$ ] (jours)  
année calendaire (jan.-déc.) 1961–2018



ClimAnaTool: clim.ind (evoclim) / 17.01.2019 07:58



Slide courtesy of L. Tudesco

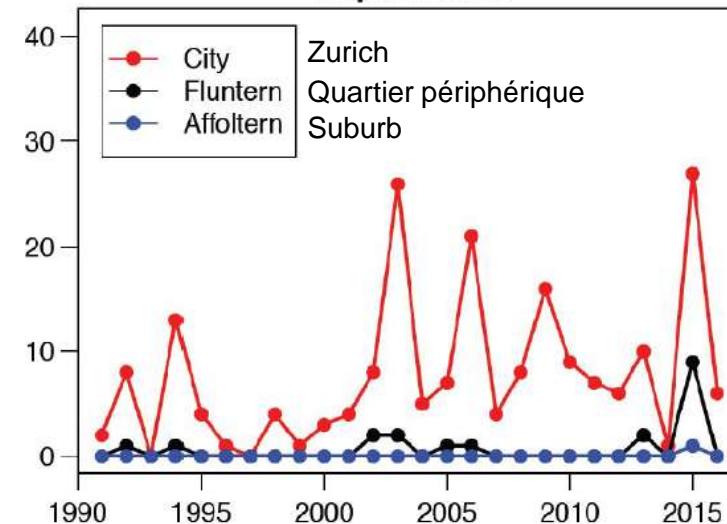
## LE CLIMAT DE LA SUISSE CHANGE



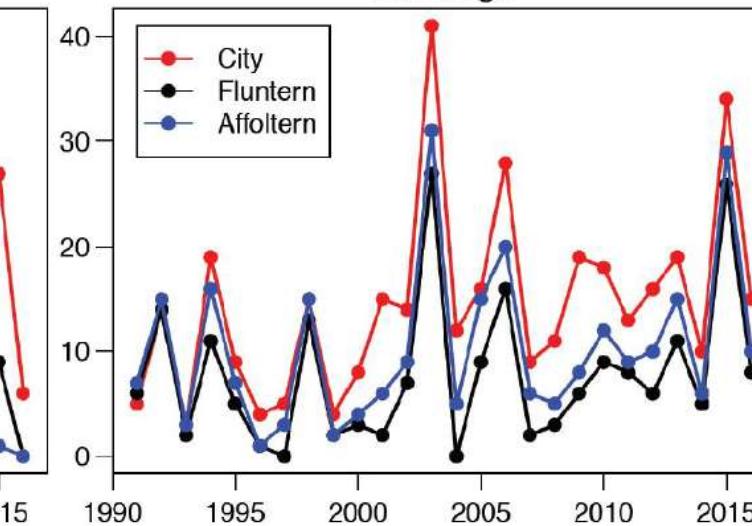
### Des nuits tropicales

$T > 20^\circ C$

Tropennächte



Hitzetage



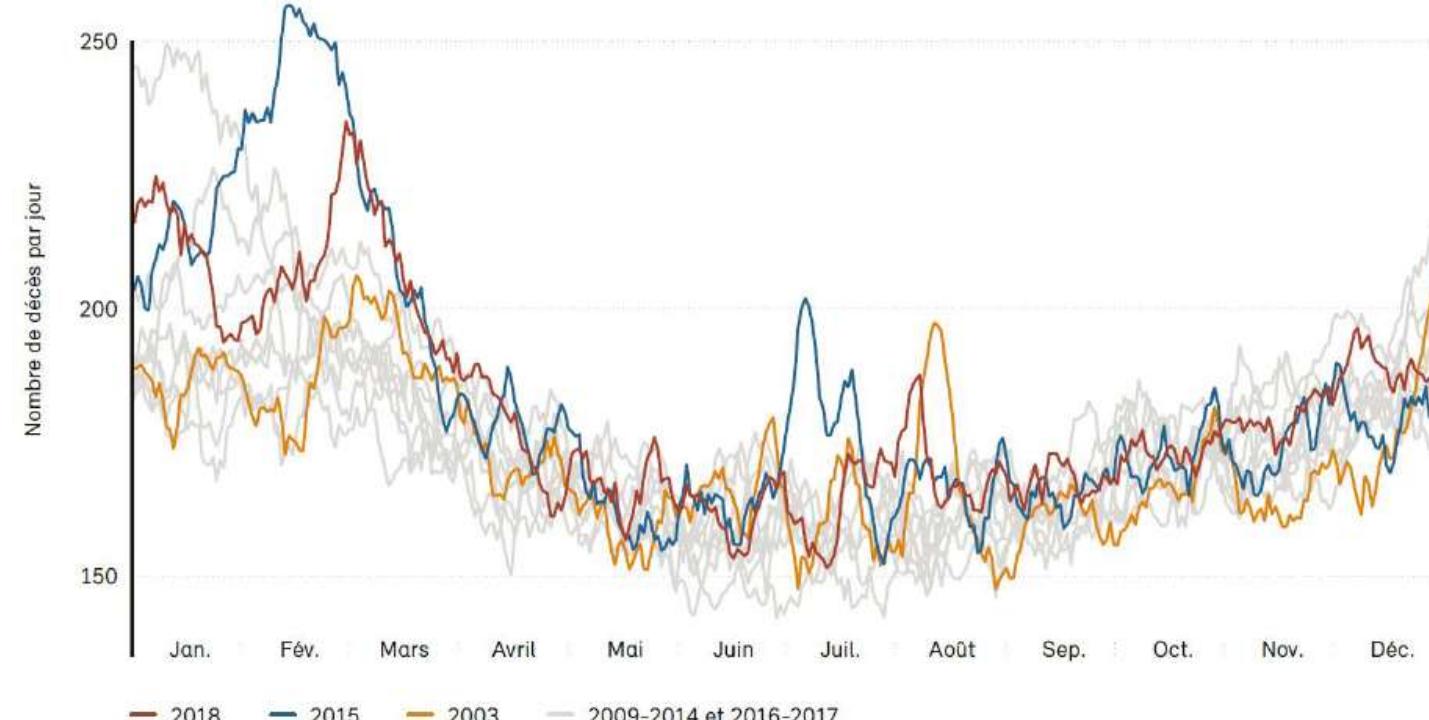


Slide courtesy of L. Tudesco

## LE CLIMAT DE LA SUISSE CHANGE

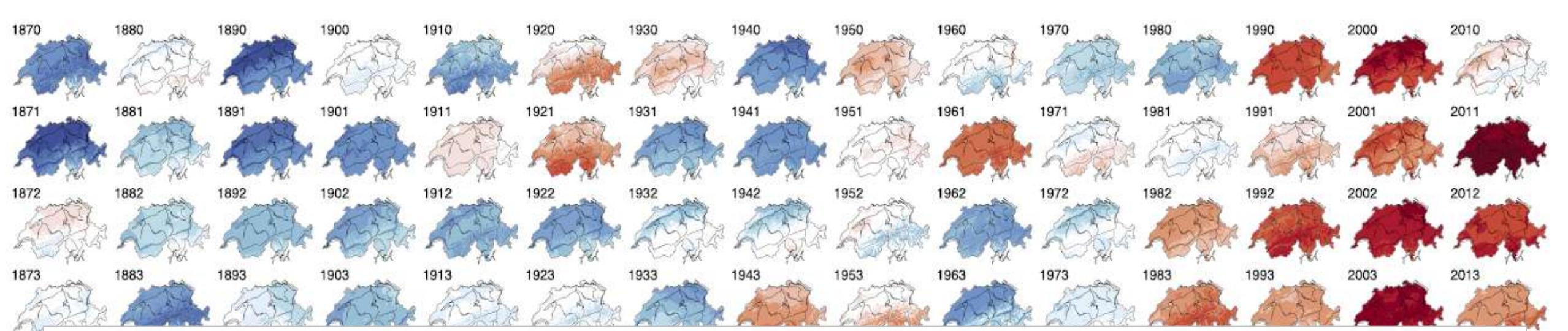


### Surmortalité liée aux vagues de chaleur Étés 2003, 2015 et 2018

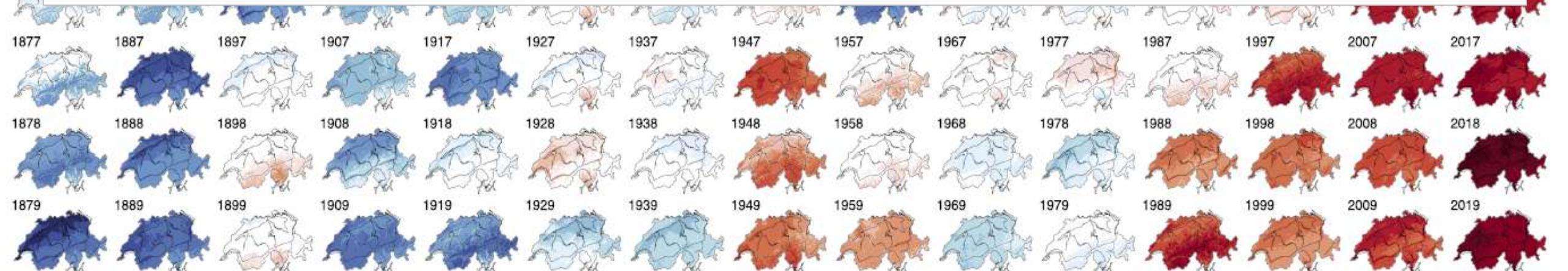


Source: SwissTPH

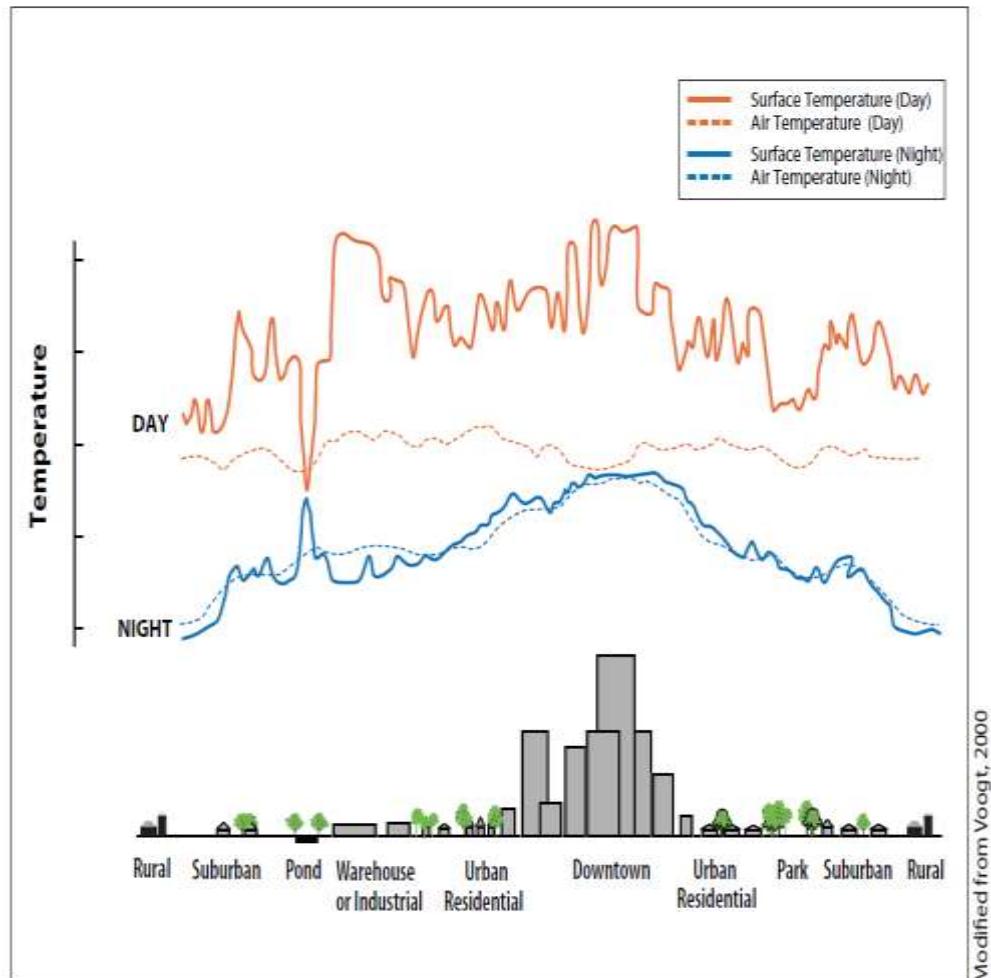
OFEV, 2020



# Introduction to Heat Waves and Heat Island Effects



# Urban Heat Island (UHI): DEFINITION

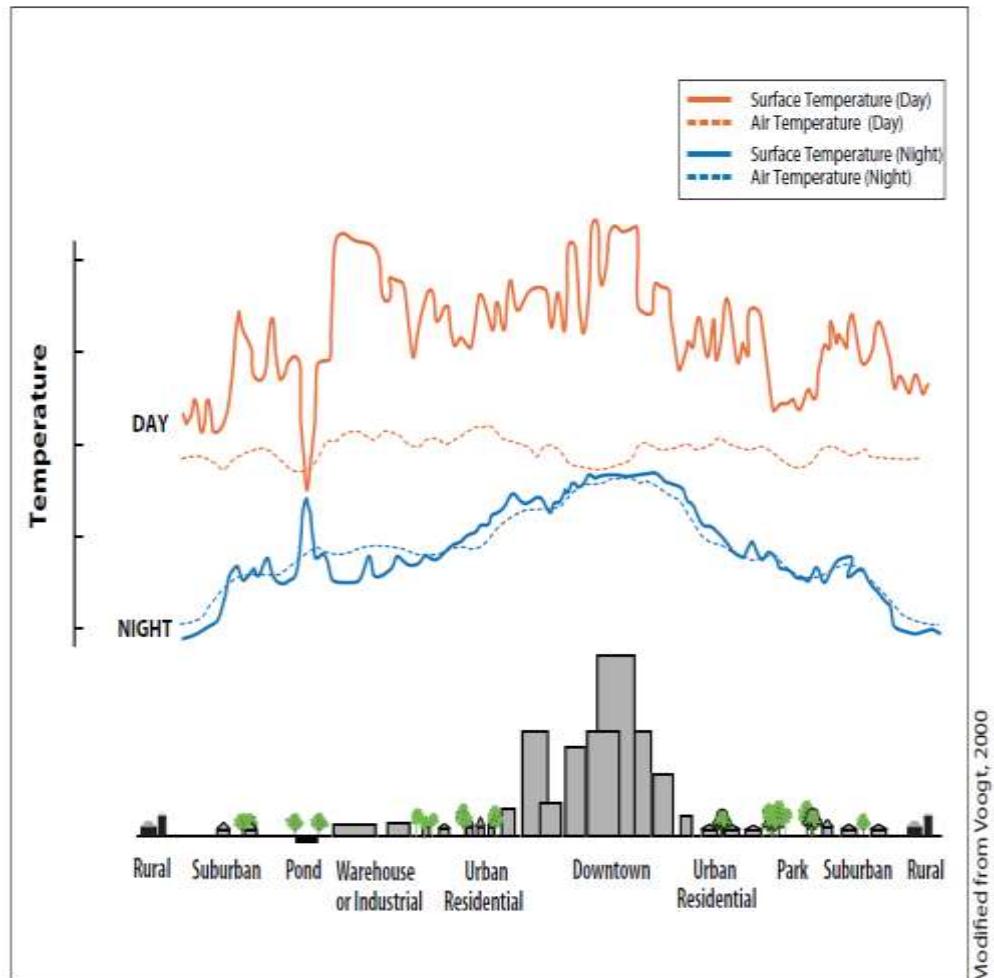


(US EPA 2008, p.4)

- Urban heat island (UHI)<sup>[1]</sup>  
The relative warmth of a city compared with surrounding rural areas, associated with changes in runoff, effects on heat retention, and changes in surface albedo.
- Surface Heat Islands<sup>[2]</sup>  
These heat islands form because urban surfaces such as roadways and rooftops absorb and emit heat to a greater extent than most natural surfaces. Surface heat islands tend to be most intense during the day when the sun is shining.
- Atmospheric Heat Islands<sup>[2]</sup>  
These heat islands form as a result of warmer air in urban areas compared to cooler air in outlying areas. Atmospheric heat islands vary much less in intensity than surface heat islands.
- Tropical night<sup>[3]</sup>  
When the minimum temperature in a day (including at night time) does not fall below 20°C.

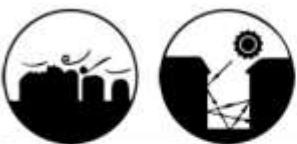
[1] IPCC 2013, Glossary (p.185 and ss.); [2] US EPA 2008 (p.12-13); [3] OFEV 2018 (p.11)

# Urban Heat Island (UHI): PRINCIPLES



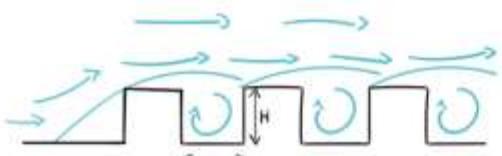
- Elevated surface and atmospheric temperatures in urban and suburban areas compared to the rural surroundings.
- Accentuated daytime warming and reduced nighttime cooling in urbanized areas.
- Surface temperatures vary more than air temperatures during the day, but they both are fairly similar at night.
- Surface temperatures are most intense during the day and in the summer.
- Air temperatures are most intense at night or predawn and in the winter
- Surface temperatures (ST) have an indirect, but significant, influence on air temperatures (AT):
  - *Parks and vegetated areas, have cooler ST, and contribute to cooler AT.*
  - *Dense built-up areas, have hotter ST that leads to warmer AT.*

(US EPA 2008 , p.1-5)



## Caractéristiques morphologiques urbaines

Circulation de l'air ralenti



Source : Gandemer, J. & Guyot A. (1976)  
redessiné par LECEA

Ravonnements piégés



Source : Ademe

Faible vue du ciel

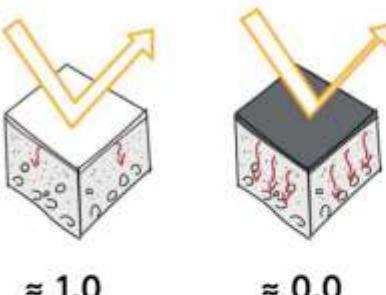


Source : photos hémisphériques © LECEA



## Caractéristiques surfaciques urbaines

Faible albédo



Source : Ademe redessiné par LECEA

Forte inertie thermique

Faible inertie

Métal



Bois



Forte inertie

Granite



Béton



Faible couvert végétal et perméabilité des sols



© LECEA



## Caractéristiques anthropiques

Source de chaleur supplémentaire



Climatisation / chauffage

Pollution de l'atmosphère urbaine



Ciel dégagé



Atmosphère polluée



Trafic urbain

Source : photos hémisphériques © LECEA

L'ensemble de ces caractéristiques font que les milieux urbains emmagasinent davantage de chaleur la journée et dissipent moins de chaleur la nuit.

Il y a donc une répartition de la chaleur plus importante en milieu urbain que sur l'ensemble du territoire.

# Urban Heat Island (UHI): PROCESS

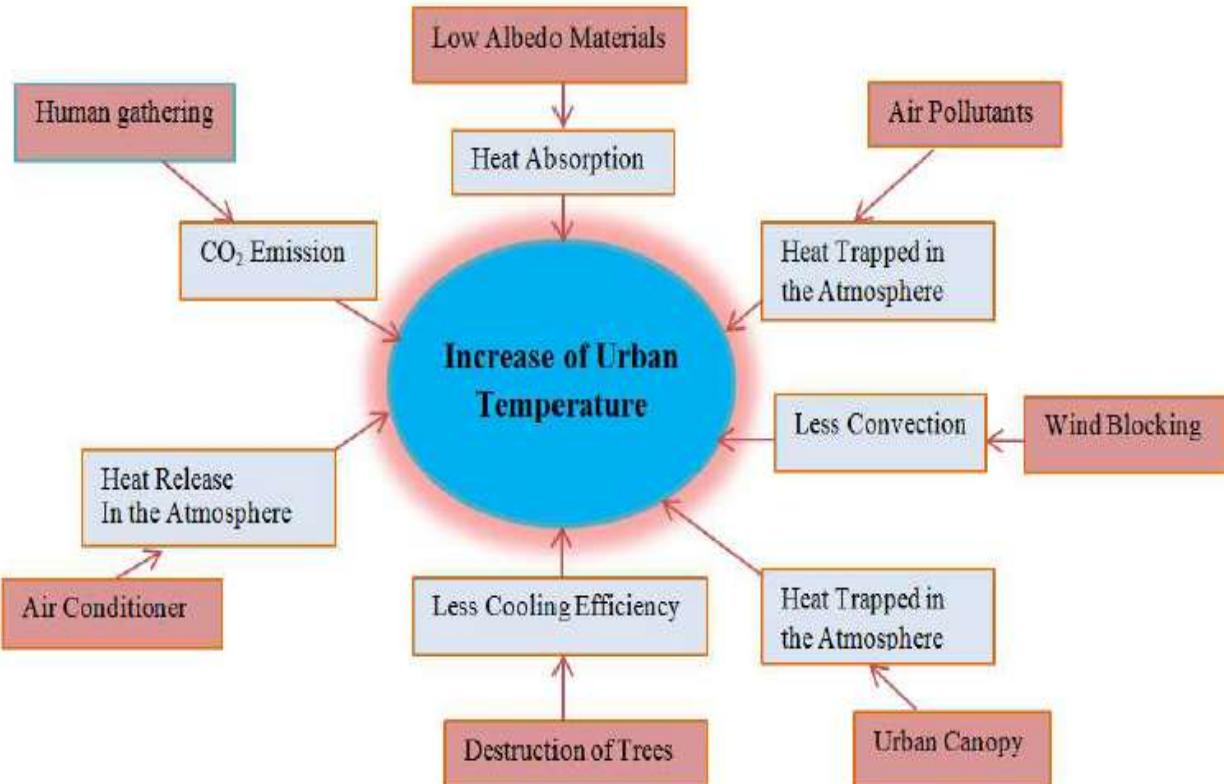


Figure 1. Process of Urban Heat Island (UHI) Formation.

(Nuruzzaman 2015, p.68)

## UHI Factors

- Climatic and meteorological conditions
- Geographic location
- Urban and architectural geometry
- Thermal trapping and ventilation
- Properties of urban materials
- Increased impervious surfaces
- Reduced vegetation and permeable surfaces
- Anthropogenic heat emissions
- Air pollution and local greenhouse effect

(OFEV 2018 and US EPA 2008)

# Urban Heat Island (UHI): EFFECTS

## Compromised human health and comfort

Higher daytime temperatures, reduced nighttime cooling, and higher air pollution levels contribute to heat-related deaths and illnesses (e.g. general discomfort, respiratory difficulties, heat cramps, heat exhaustion, etc.).

## Increased energy consumption

Elevated summertime temperatures in cities increase energy demand for cooling and add pressure to the electricity grid during peak periods of demand

## Elevated air pollutants and greenhouse gases

Higher temperatures can increase energy demand, which generally causes higher levels of air pollution and greenhouse gas emissions.

## Impaired water quality

Rapid temperature changes in aquatic ecosystems resulting from warm stormwater runoff can be particularly stressful and even fatal to aquatic life.

(US EPA 2008, p. 1-5)

*Excess mortality attributed to heat and cold: a health impact assessment study in 854 cities in Europe (Masselot et al. 2023, p.7)*

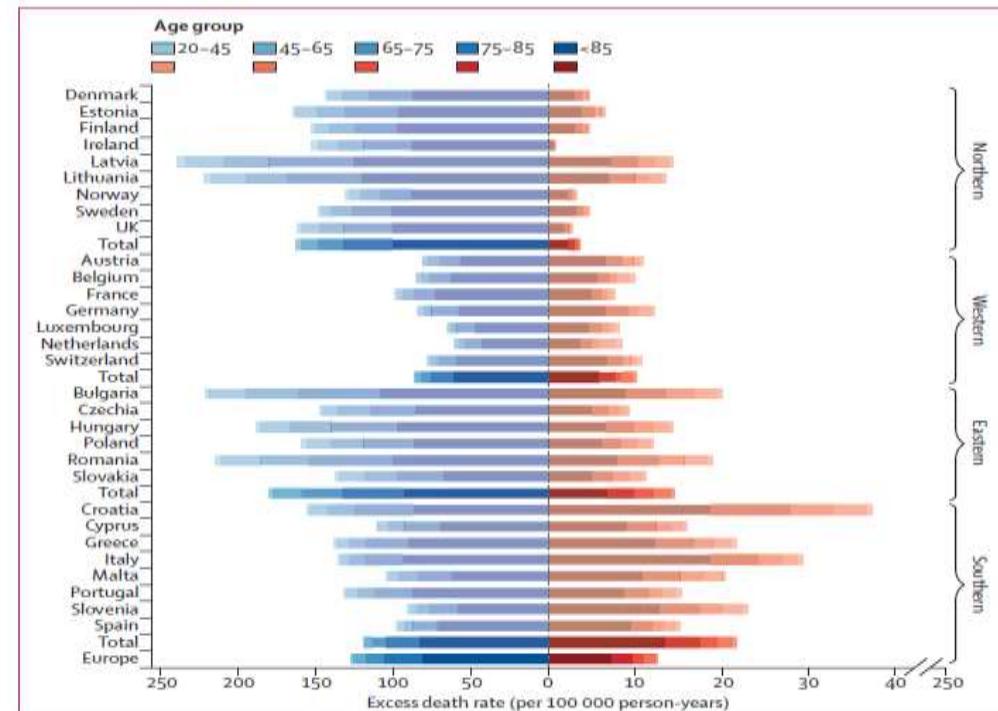
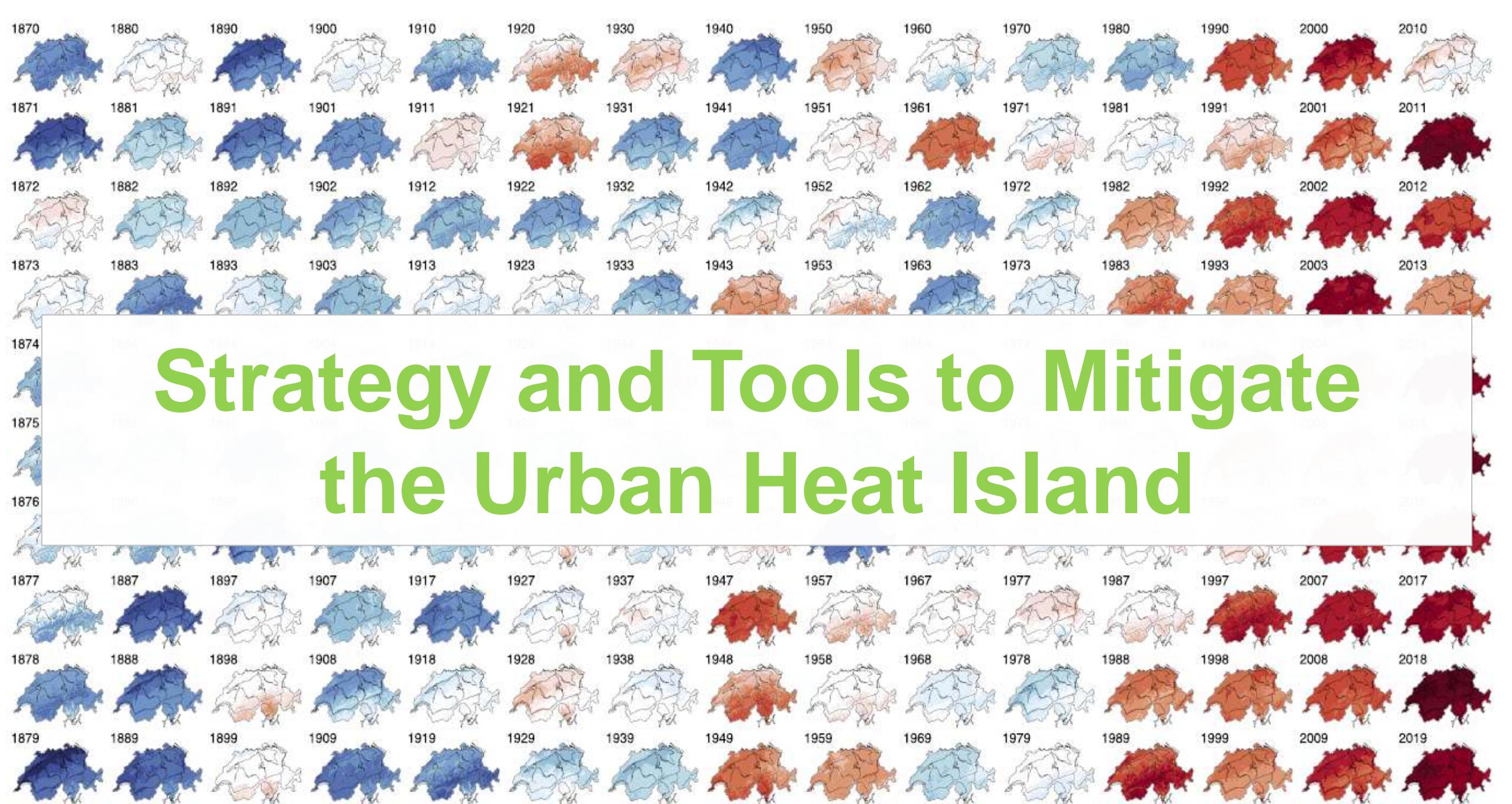


Figure 3: Country-level cold (in blue) and heat (in red) annual raw death rates broken down by age group

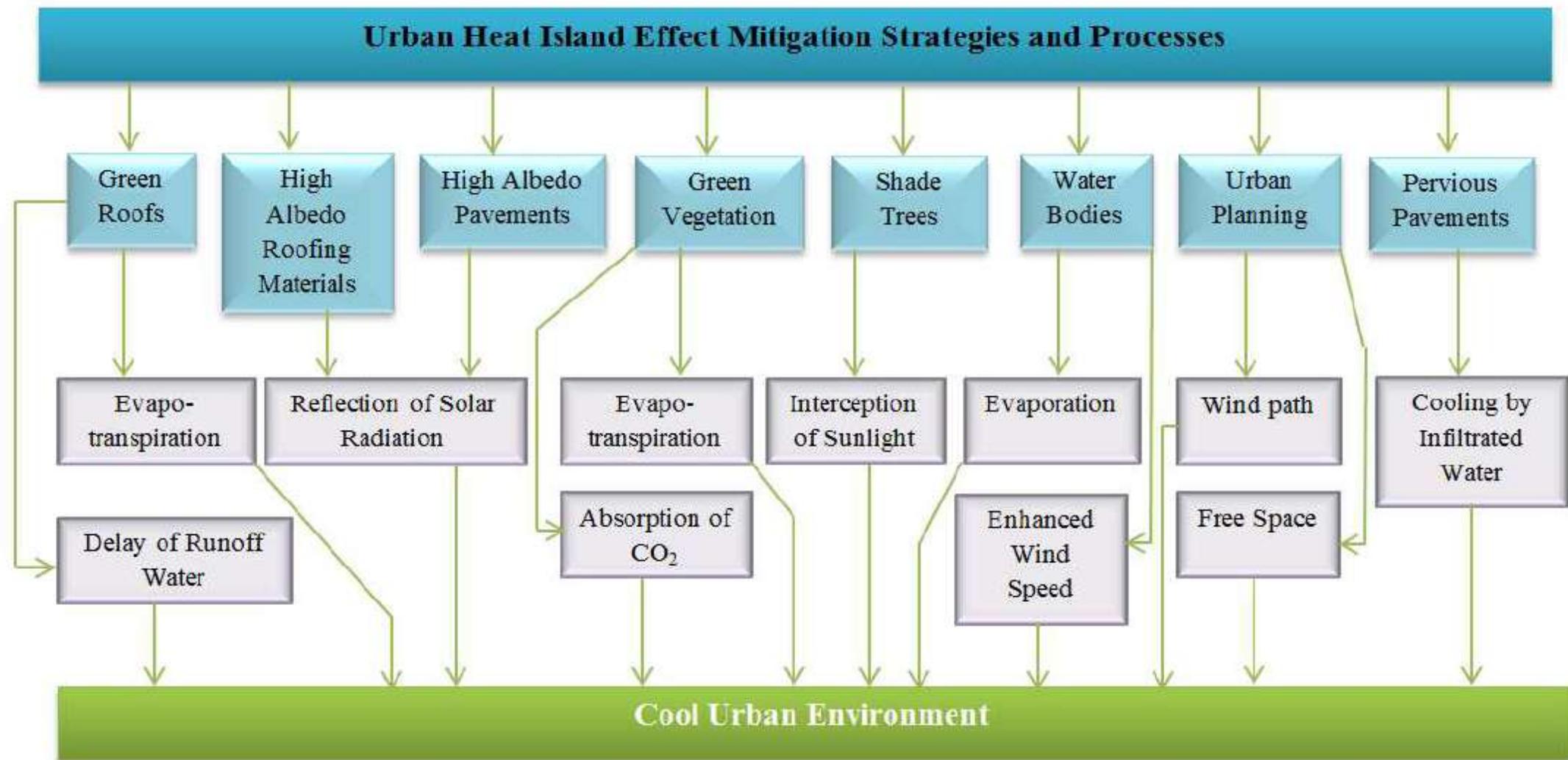
**Poor city dwellers and vulnerable communities are more exposed to climate change impacts !**

(Filho et al. 2021)



# Strategy and Tools to Mitigate the Urban Heat Island

# UHI Mitigation Strategies and Process



# Urban Heat Mitigation by Green and Blue Infrastructure

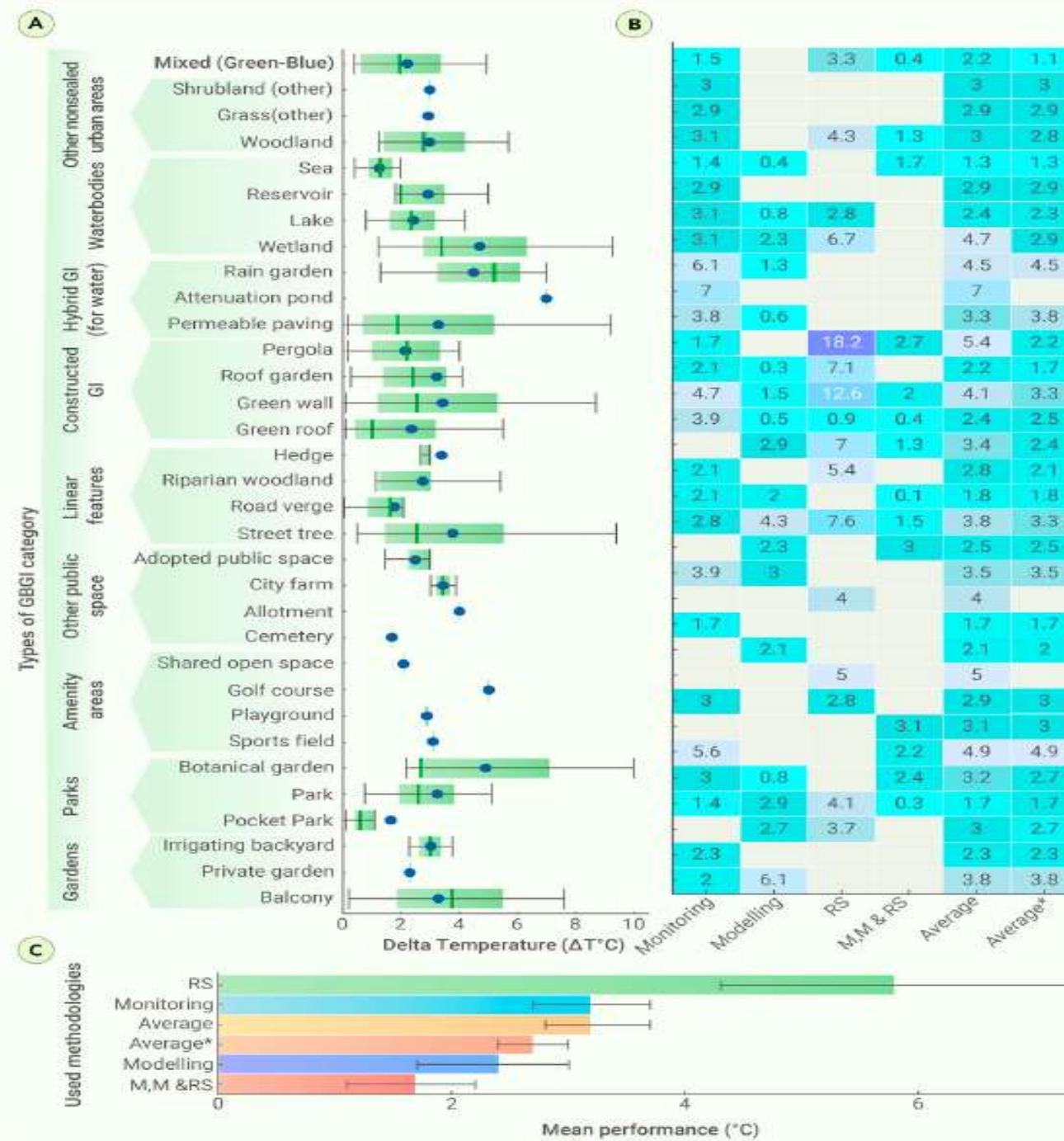
(Kumar et al. 2024 , p.1)

## GRAPHICAL ABSTRACT



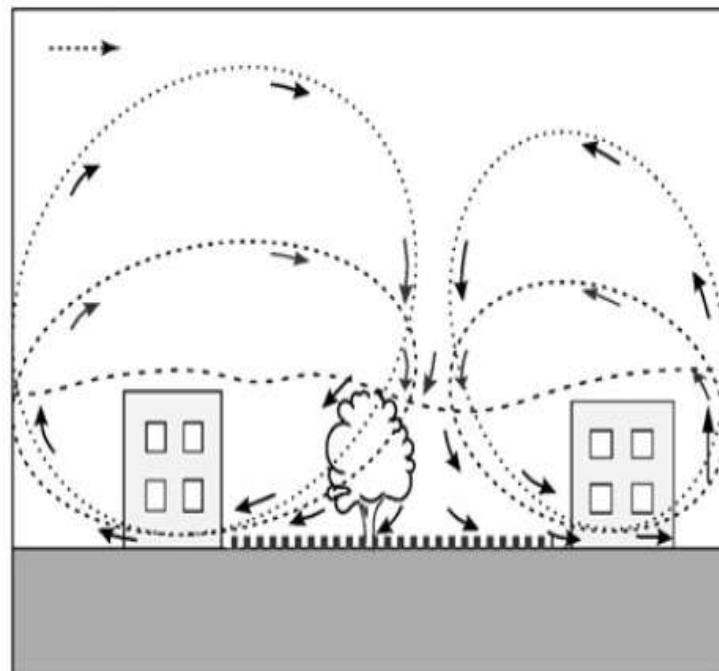
# Urban Heat Mitigation by Green and Blue Infrastructure

(Kumar et al. 2024 , p.13)

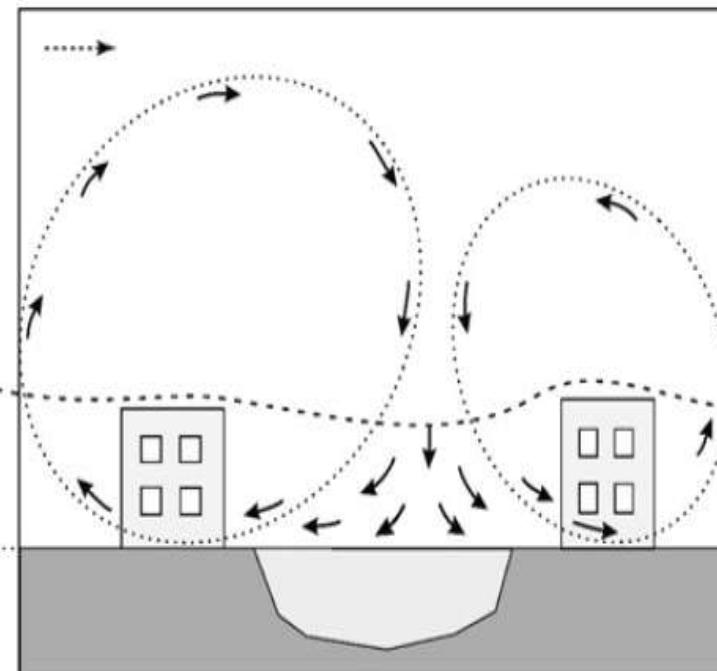


EPFL **Green-space and Blue-space Interaction with the Urban Climate**

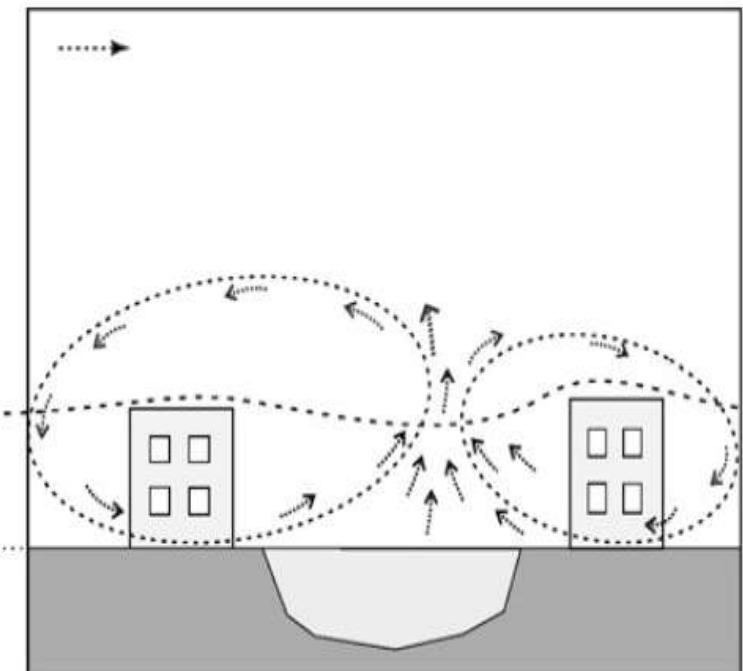
Microscale



**Park breeze system (high by day, low by night)**



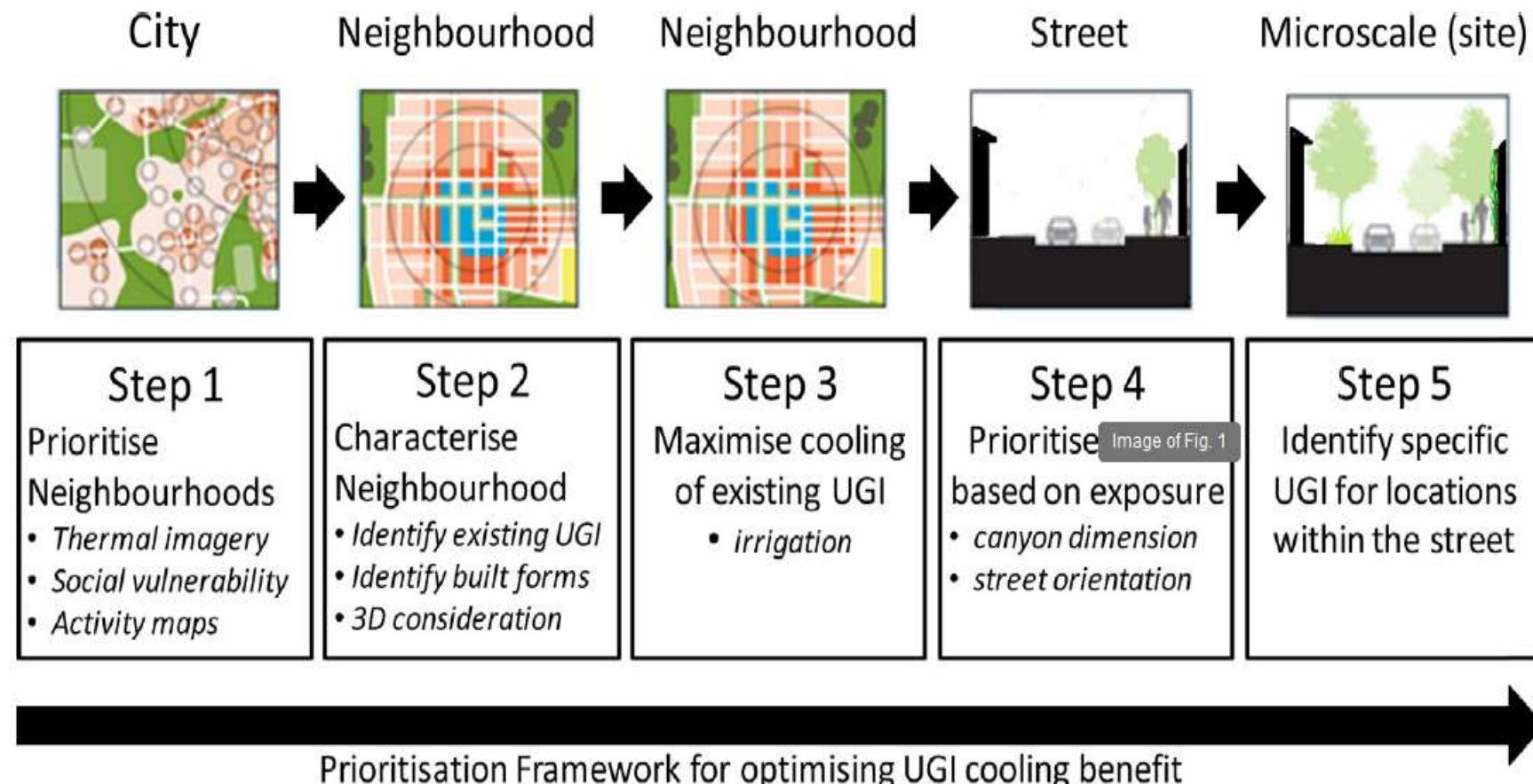
**Waterbody breeze system (daytime cooling)**



**Waterbody breeze system (night-time warming)**

**Fig. 6.** Illustration of greenspace and bluespace interactions with the urban climate, expanded from Fig. 4.

# EPFL Planning Strategy for Cooler City (1)

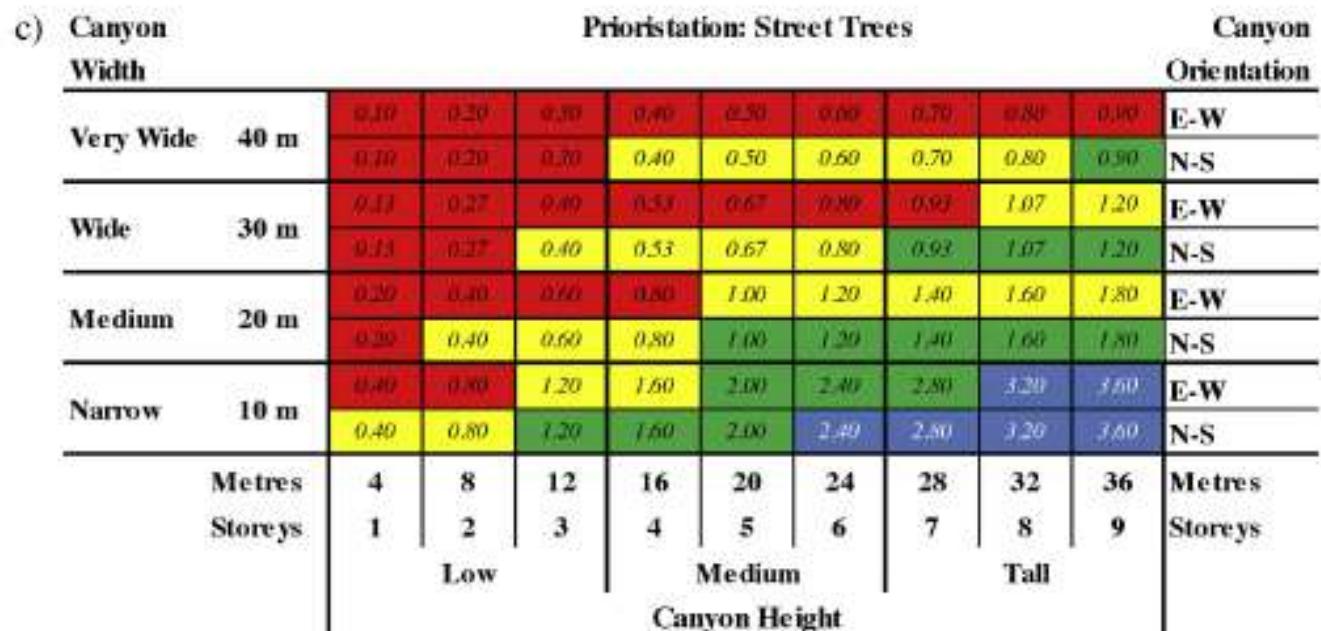
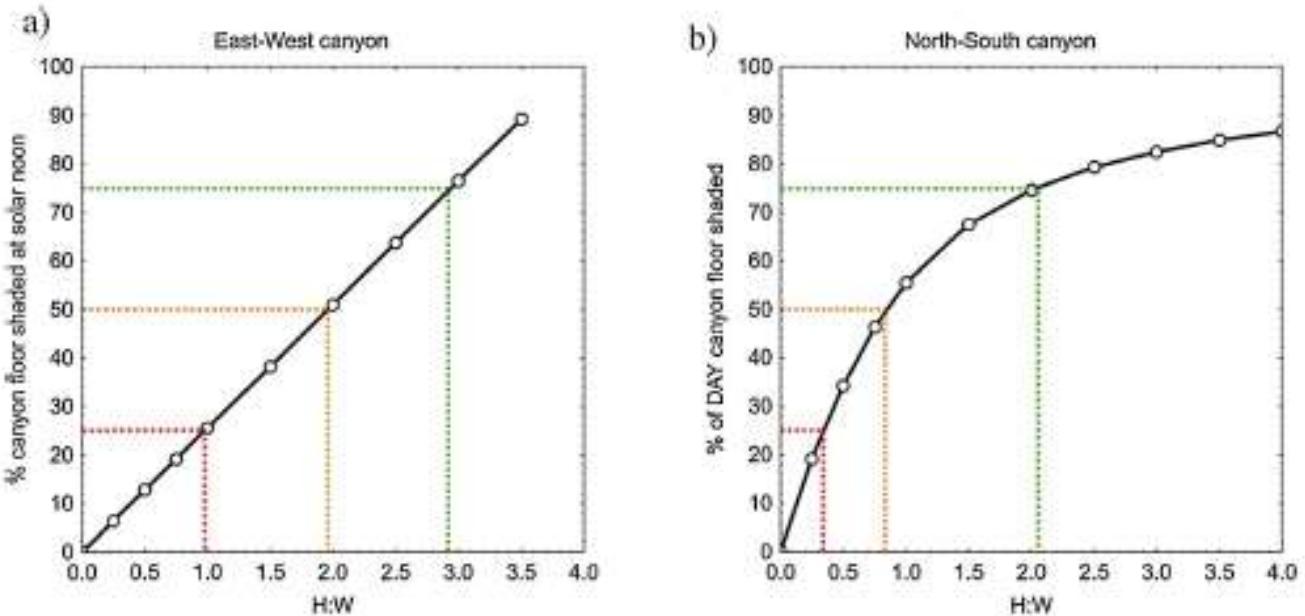


**Fig. 1.** The steps in the prioritisation operate at the neighbourhood scale (Steps 1–3), where the physical environment and people's vulnerability are characterised for the area; and the street (Step 4) and microscales (Step 5), at which scales UGI that is fit for place is selected and implemented. See text for details.

Norton et al. 2015 (page 129)

# Planning Strategy for Cooler City (2)

Norton et al. 2015 (page 130)



High priority



Moderate priority



Lower priority



Not a priority

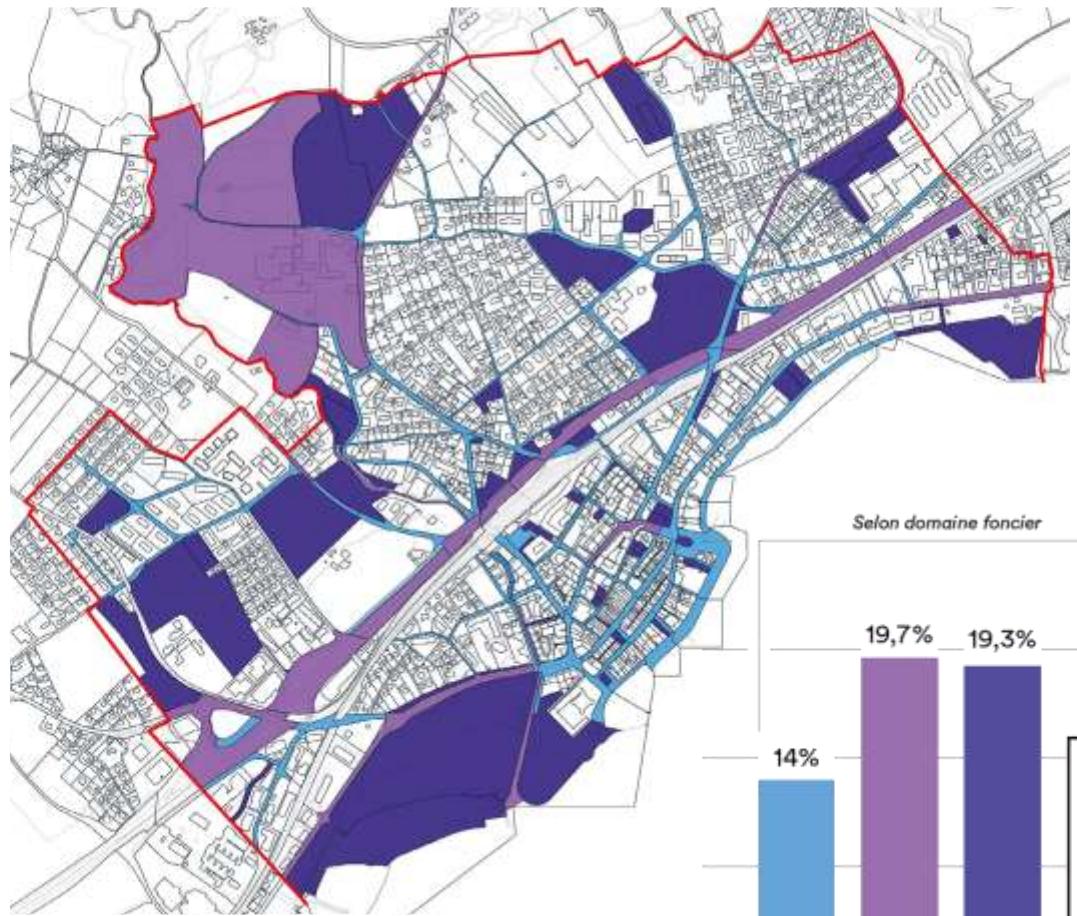
# EPFL Planning Strategy for Cooler City (3)

**Table 2**

Modes of cooling provided by different urban green infrastructure options during summer and priority locations to optimise those cooling benefits.

UGI	Green open spaces	Trees	Green roofs	Vertical greening
Shades canyon surfaces?	Yes, if grass rather than concrete	Yes	Shades roof, not internal canyon surfaces	Yes
Shades people?	Yes, if treed	Yes	No, only very intensive green roofs	No
Increases solar reflectivity?	Yes, when grassed	Yes	Yes, if plants healthy	Yes
Evapo-transpirative cooling?	Yes, with water	Yes (unless severe drought)	Yes, with water when hot	Yes, with water when hot
	No, without water		No, without water	No, without water
Priority locations	<ul style="list-style-type: none"> <li>Wide streets with low buildings – both sides</li> <li>Wide streets with tall buildings – sunny side</li> </ul>	<ul style="list-style-type: none"> <li>Wide streets, low buildings – both sides</li> <li>Wide streets, tall buildings – sunny side</li> <li>In green open spaces</li> </ul>	<ul style="list-style-type: none"> <li>Sun exposed roofs</li> <li>Poor insulated buildings</li> <li>Low, large buildings</li> <li>Dense areas with little available ground space</li> </ul>	<ul style="list-style-type: none"> <li>Canyon walls with direct sunlight</li> <li>Narrow or wide canyons where trees are unviable</li> </ul>

# Des stratégies différencierées

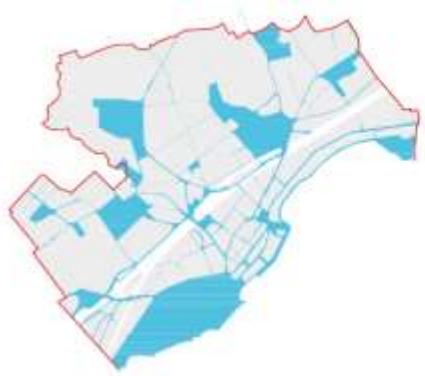


Slide courtesy of J. Pellet

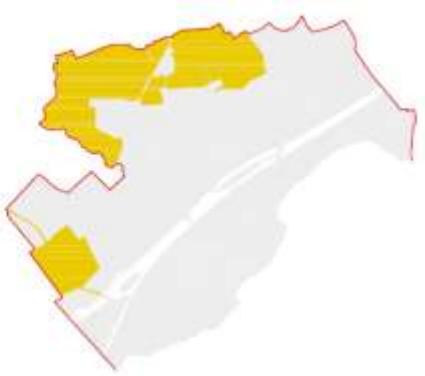


# Des stratégies différenciées

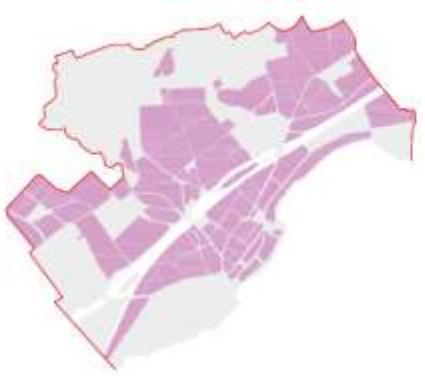
Slide courtesy of J. Pellet



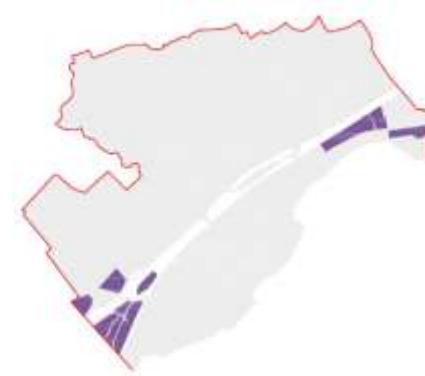
1.  
**DOMAINE PUBLIC COMMUNAL,  
PARCELLES COMMUNALES  
ET DOMAINE PUBLIC CANTONAL**



2.  
**FRANGES AGRICOLES  
PÉRIURBAINES**

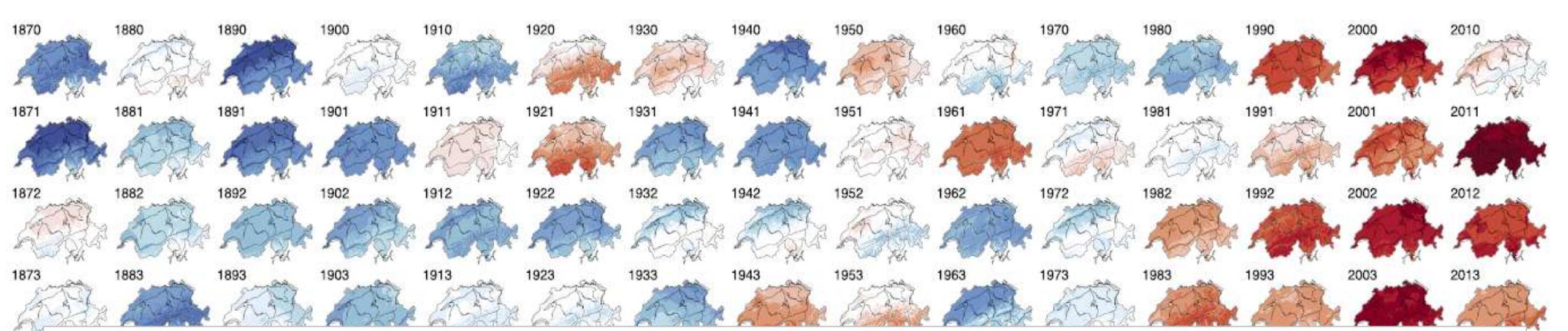


3.  
**QUARTIERS D'HABITATION**

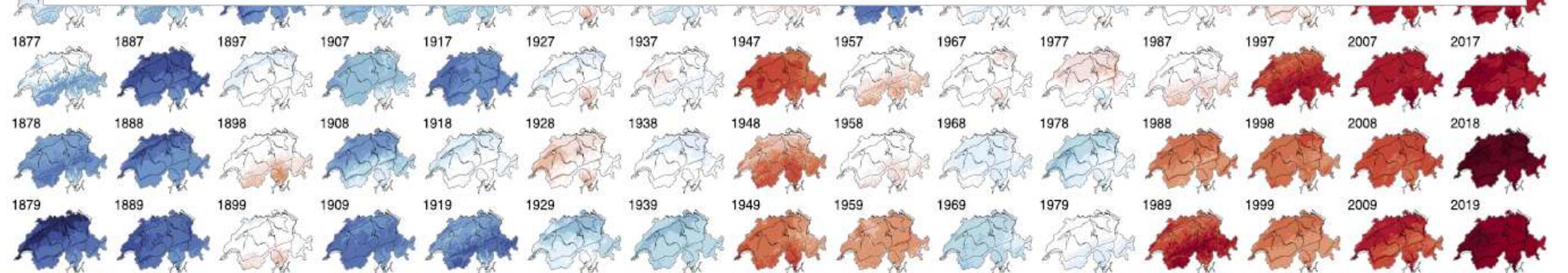


4.  
**ZONES INDUSTRIELLES  
ET ARTISANALES**



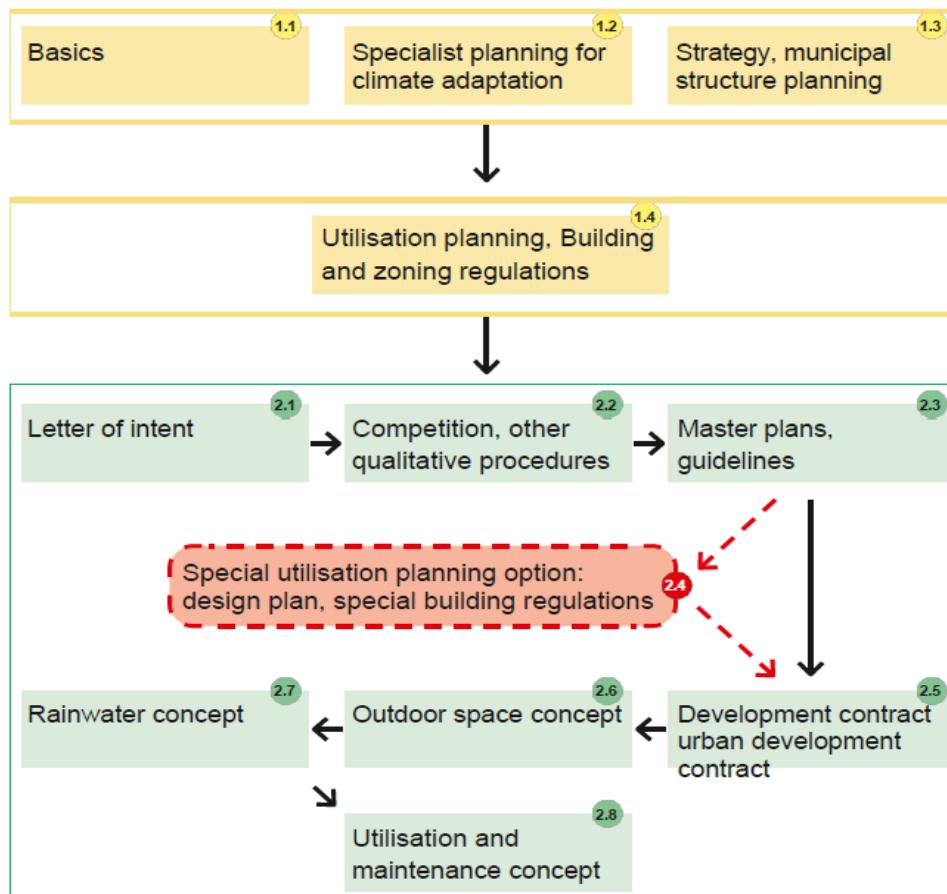


# The integrated Heat Reduction Strategy of the City of Zurich (CH)



# Canton of Zurich, Climate-Adapted Planning and Desing Process

## Climate Adaptation Planning Process (Baudirektion Kanton Zürich, 2022)



### 1 Planning principles

- 1.1 Basics
- 1.2 Specialised planning for climate adaptation
- 1.3 Strategy, Municipal Development Planning
- 1.4 Utilisation planning, building and zoning regulations

### 2 Site developments

- 2.1 Statement of Intent
- 2.2 Expert competition or other qualitative procedures
- 2.3 Master plans, guidelines
- 2.4 Special development planning/design plan or special building regulations
- 2.5 Urban development contract; development contract
- 2.6 Outdoor space concept
- 2.7 Rainwater concept
- 2.8 Utilisation and maintenance concept

**Measures in area development**

Mögliche...

- 01 Ensure cold air circulation +
- 02 Reduce the underconstruction of open spaces +
- 03 Facades shade +
- 04 Unshaded open spaces through buildings +

**Measures at the building**

Mögliche...

- 05 roofs to be green +
- 06 Roofs climate-adapted to construct and design +
- 07 Facades green +
- 08 Facades climate-adapted design and design +
- 09 Optimizing heat storage and cooling +
- 10 building heat dissipated +

**Measures in the outdoor space**

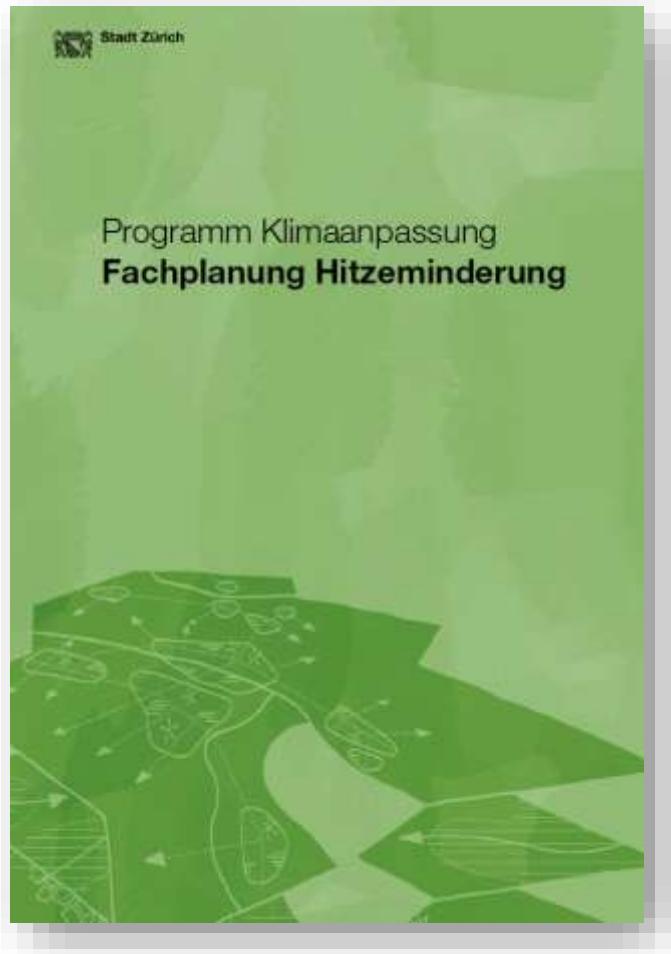
Mögliche...

- 11 green spaces plan and design +
- 12 walk-in and passable surfaces unsealable +
- 13 Reduce heat storage of surfaces +
- 14 Gross crown trees preserved and planted +
- 15 shading elements provided +
- 16 Implementing Innovative Irrigation Solutions +
- 17 Planning rainwater management +
- Making 18 Waters come alive +

Source: Website, Kanton Zürich, Umwelt & Tiere, Klima, Hitze im Siedlungsraum, Massnahmen gegen Hitze (as of 21.03.2024):  
<https://www.zh.ch/de/umwelt-tiere/klima/hitze-im-siedlungsraum/massnahmen-gegen-hitze.html#:~:text=Die%20Massnahmen%20gegen%20die%20Hitze%20im%20Siedlungsraum%20sind%20in%2018%20Schritte%20unterteilt.>

# City of Zurich, 2020 Specialised Planning for Heat Mitigation: OBJECTIVES AND DOCUMENTS

## 1 Integrated Strategy



## 3 Main objectives: Avoid, relieve, maintain

### 1. Avoid overheating in the entire urban area

The heat mitigation sub-plan is an area-wide plan which identifies and connects possible actions to all types of urban structures and open space categories with their respective portfolios.

### 2. Provide targeted relief for vulnerable urban areas

The relief system sub-plan forms a dedicated system of different open spaces and open spaces and corresponding shaded paths. It is dedicated to vulnerable areas, so-called hotspots and their respective catchment area of 400 m (buffer).

### 3. Preserve the existing cold air system of the city of Zurich

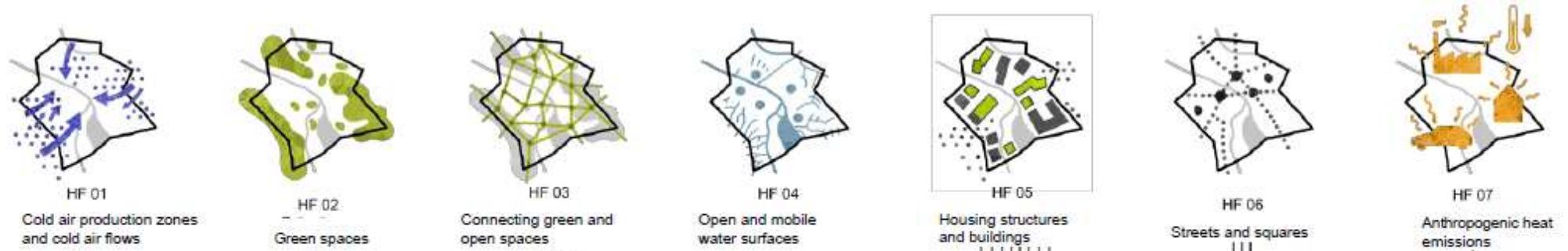
The sub-plan for the cold air system depicts the still largely functioning cold air system in Zurich and initial recommendations for climate-optimised planning and construction.

## 3 Sub-plans

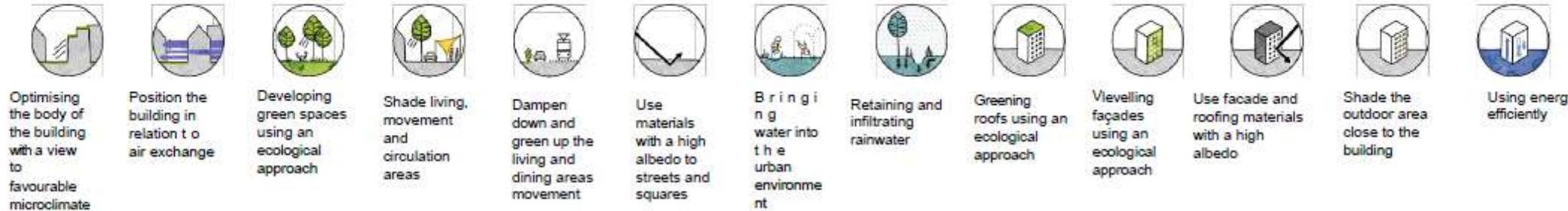


# City of Zurich, 2020 Specialised Planning for Heat Mitigation: FIELDS AND LINES OF ACTION

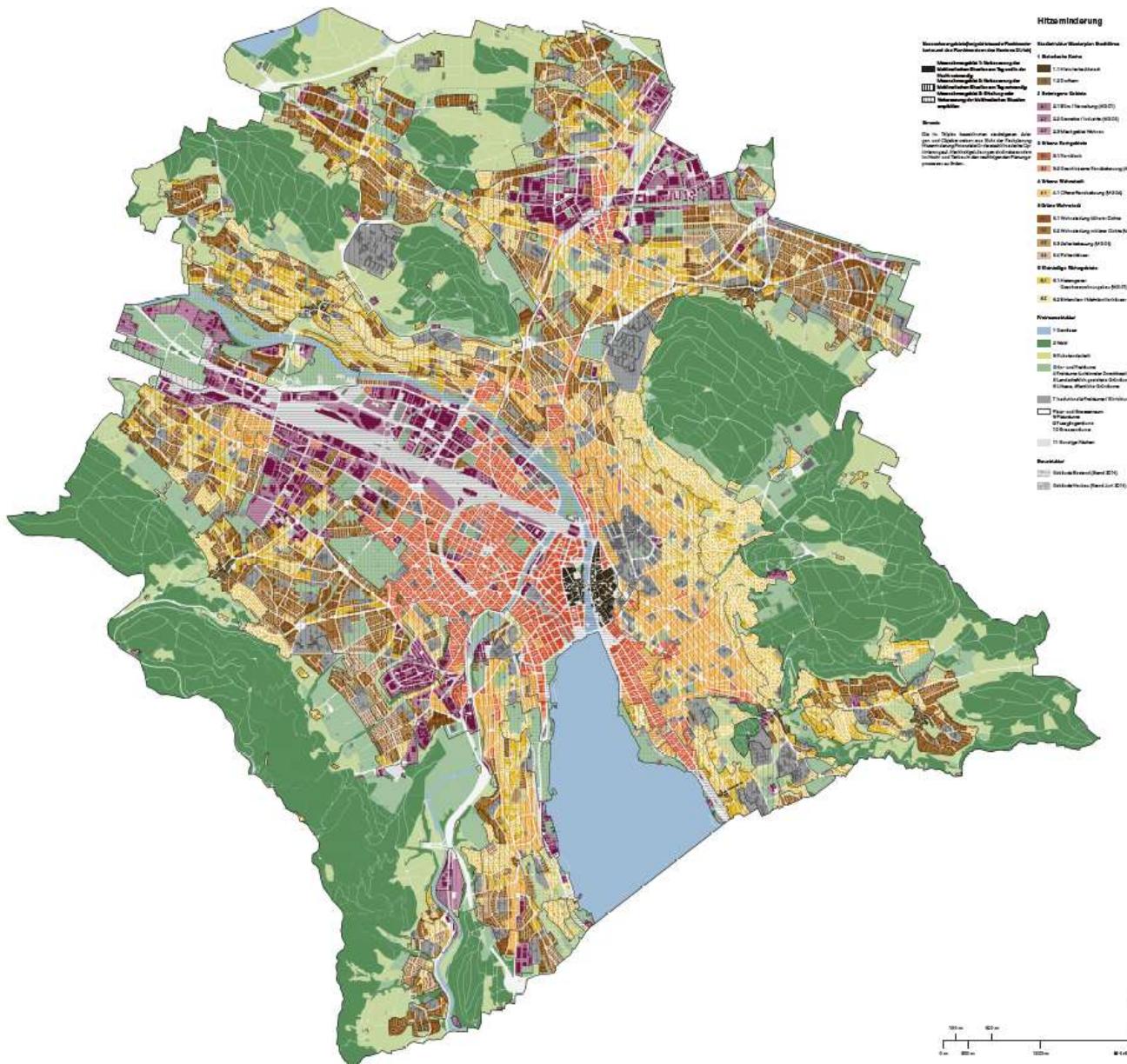
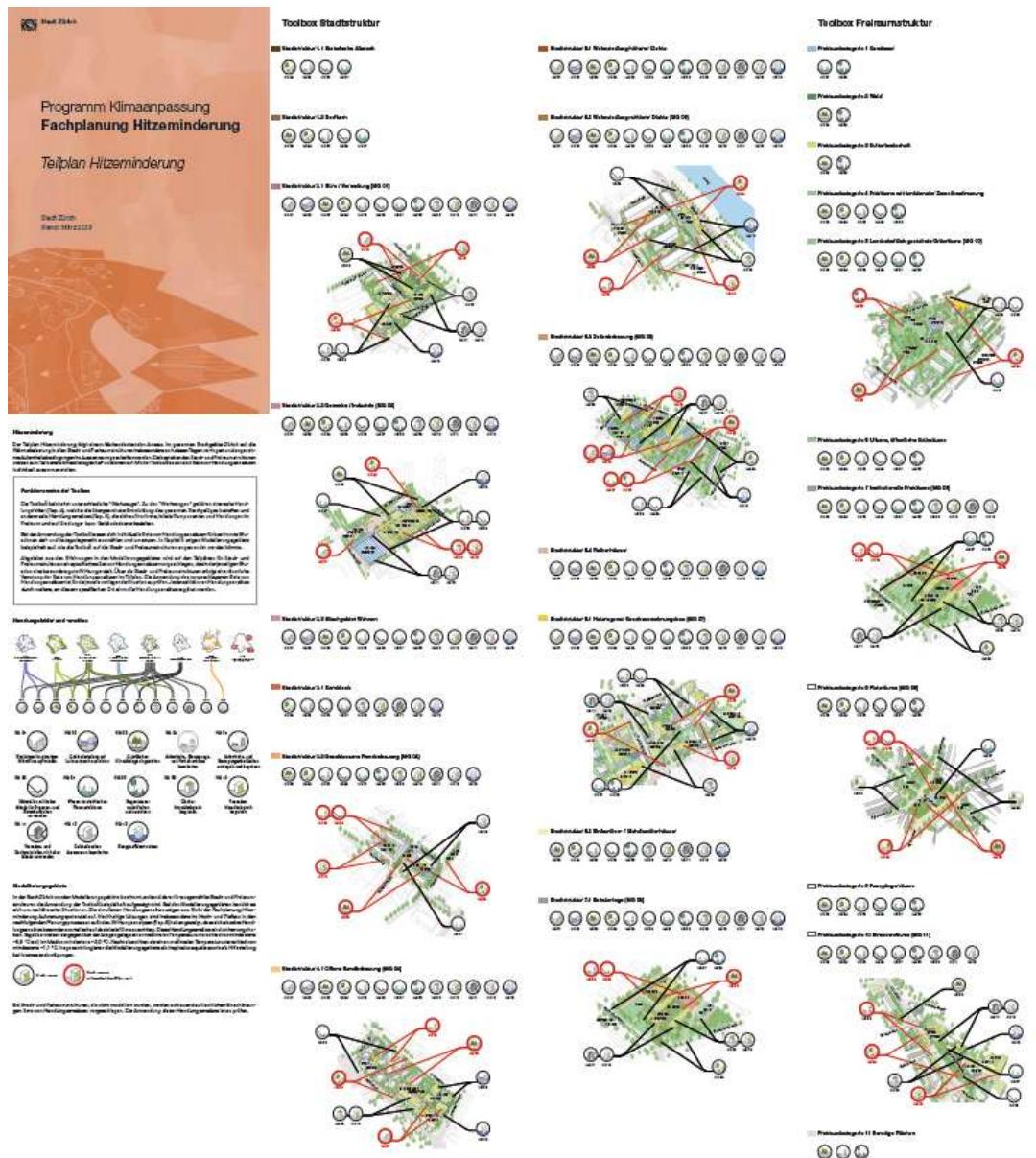
7 Fields of action →



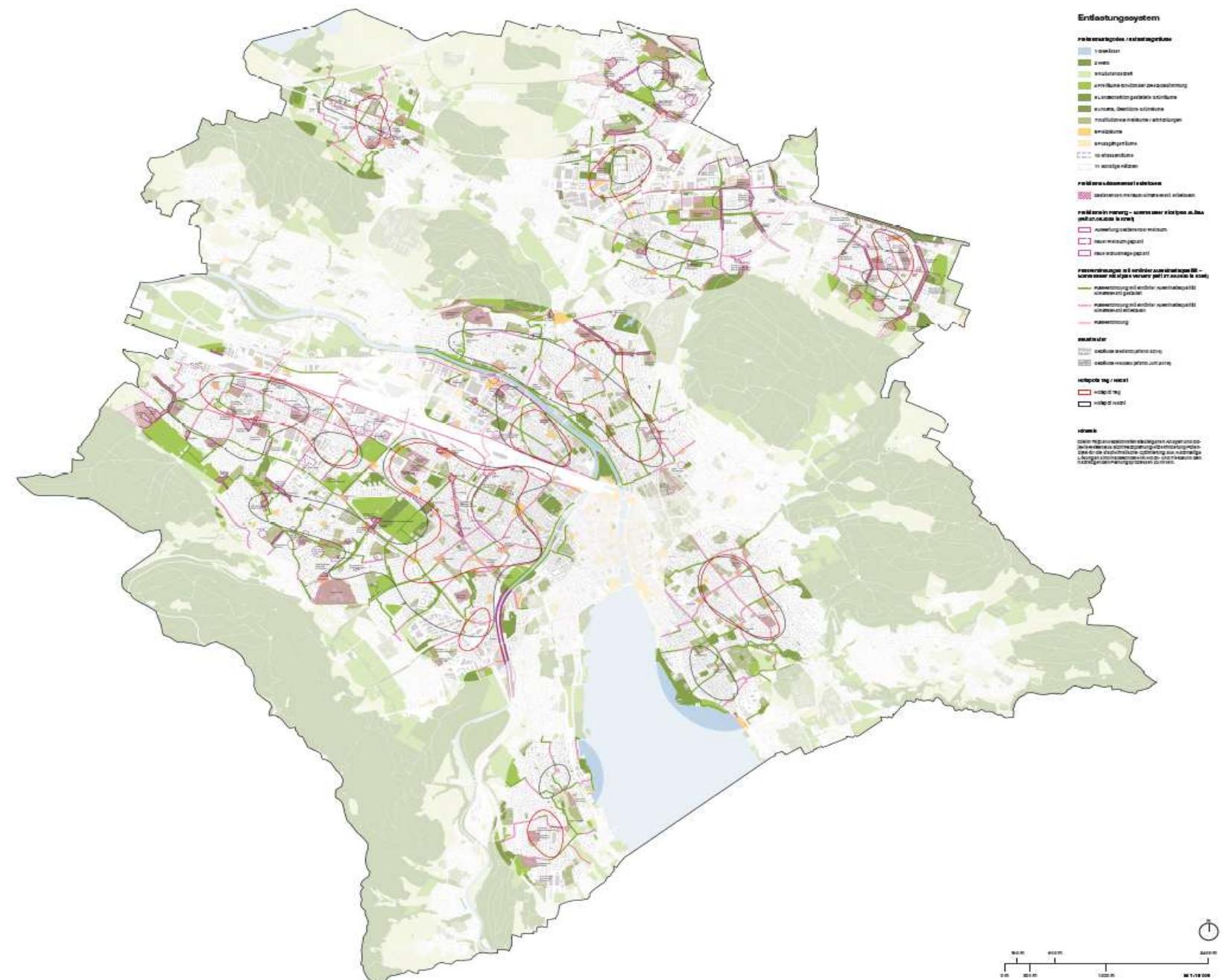
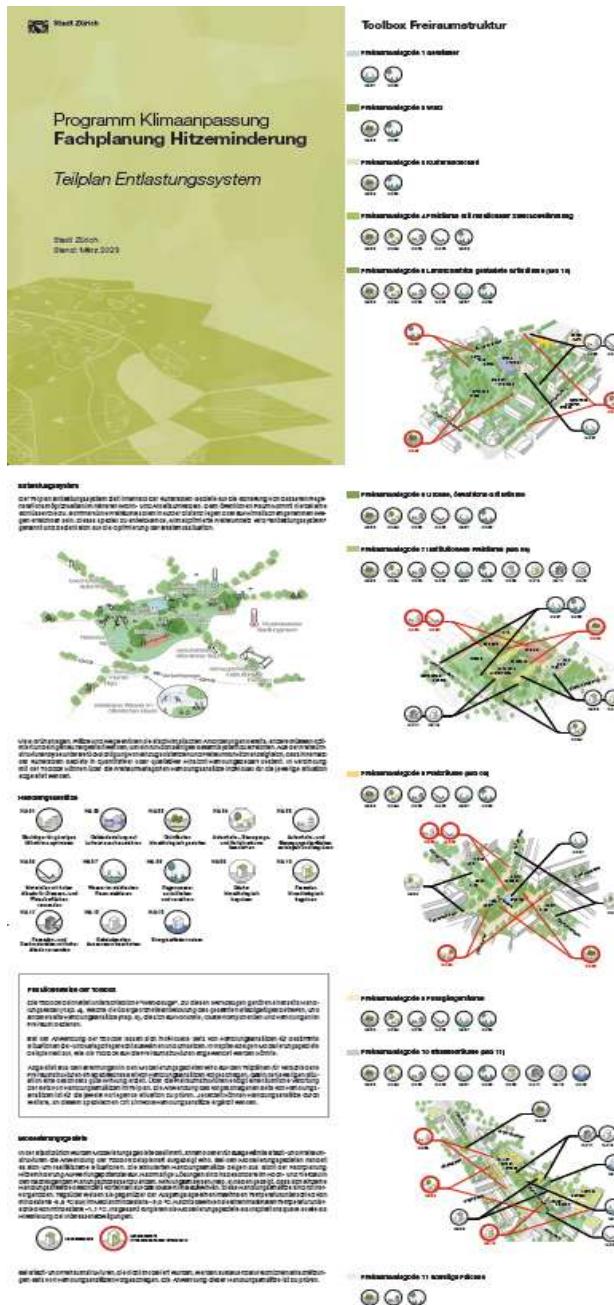
13 Lines of action →



## Heat mitigation sub-plan



## Relief system sub-plan



## **Sub-plan for the cold air system**

