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Conférences énergie-environnement printemps, Université de Genève

Rethinking Swiss urban infrastructure systems in times of crisis

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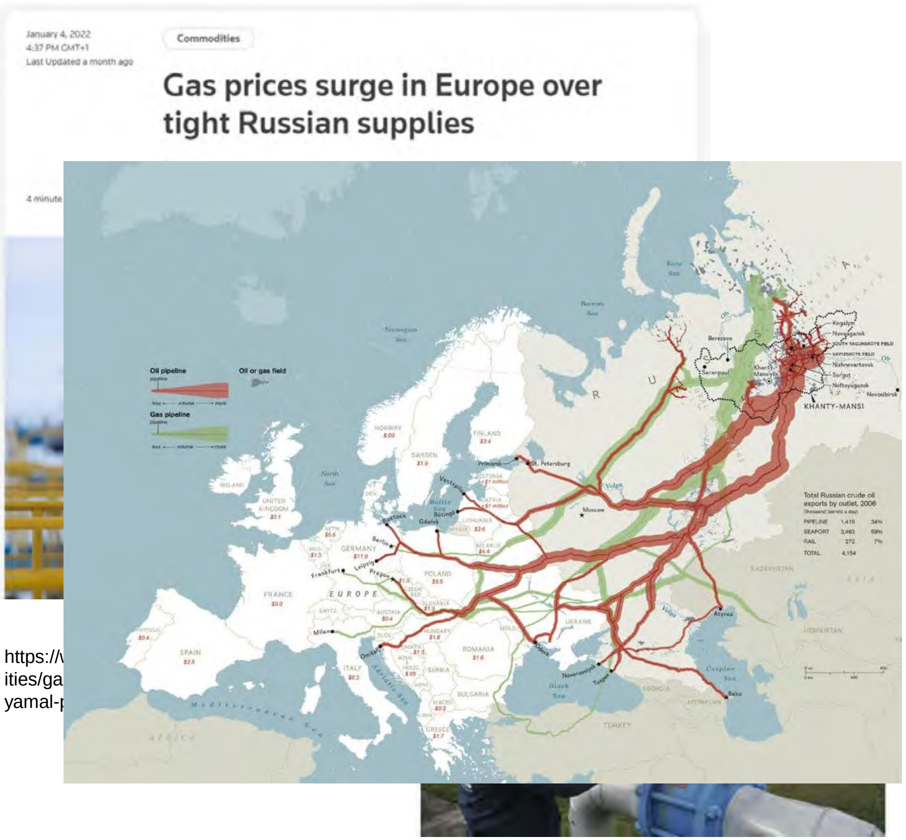
Scientist, Urban Energy Systems Laboratory

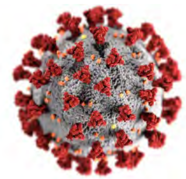
EMPA Dübendorf

Switzerland

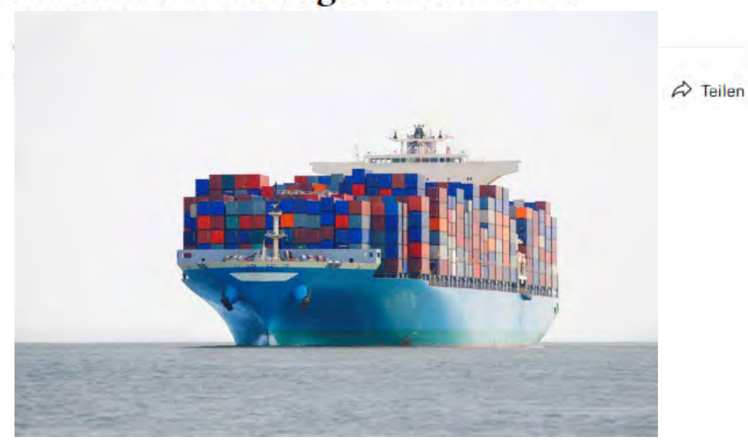
Times of crisis



Neue Zürcher Zeitung



Mysteriöse Lungenkrankheit in Zentralchina ausgebrochen – einige Stimmen befürchten einen erneuten Ausbruch der Lungenseuche Sars



https://www.nzz.ch/panorama/mysterioese-lungenkrankheit-in-zentralchina-ausgebrochen-einige-befuerchten-einen-erneuten-ausbruch-der-lungenseuche-sars-ld.1531501

- Many different types of crisis
- Impacts on complex interacting & interconnected infrastructure systems
- Opportunity to re-think *modus operandi*

Source: https://www.nationalgeographic.org/photo/europe-map/

I

Urbanization

Opportunities for sustainable densification

II

Climate Change

Climate change and building cooling demand

III

Urban Green space

Superblocks: transformation street space

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Opportunities for sustainable densification

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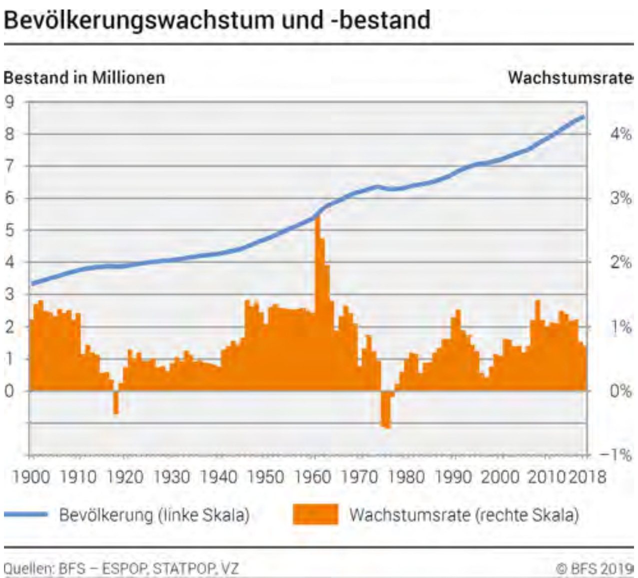
European context

- 68% of the world population will be living in cities by 2050
- In Europe, on average only 13% of total land use was «recycled»
- Increasing pressure on cities, limited availability of land

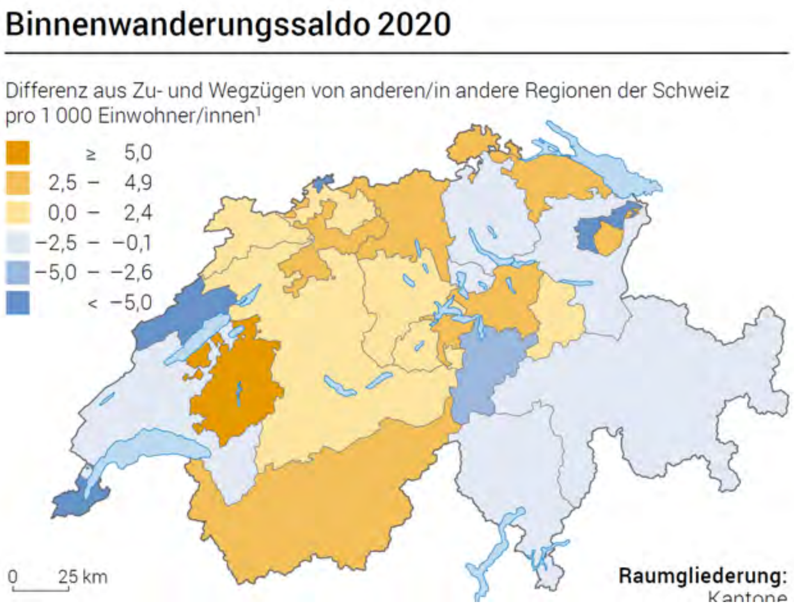
  → Need for increasing density in established residential areas and inward development

Swiss densification context

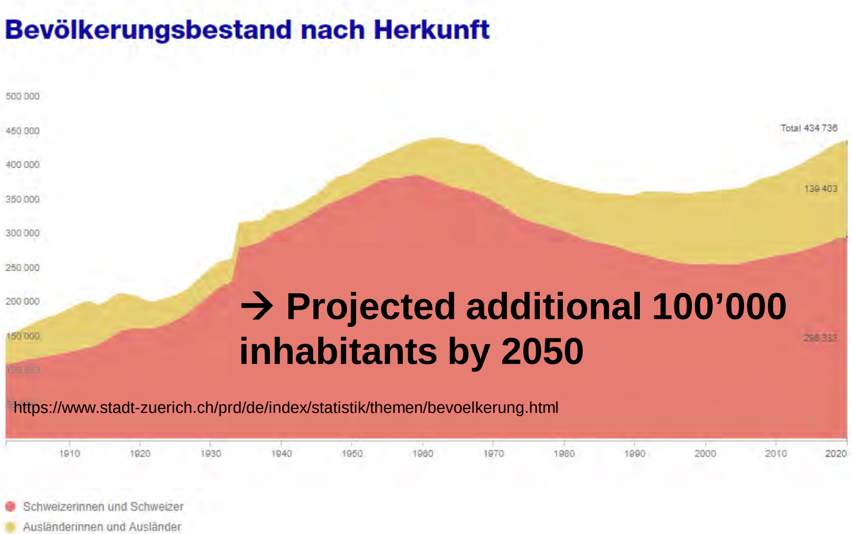
- Increasing population
- Urbanization
- COVID impacts (?)



Switzerland



Zürich



→ **Projected additional 100'000 inhabitants by 2050**

https://www.stadt-zuerich.ch/prd/de/index/statistik/themen/bevoelkerung.html

https://www.atlas.bfs.admin.ch/maps/13/de/13662_4275_93_70/22030.html

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Swiss densification context

Buttisholz, Luzern 2005

Source: FSO 2011

Bundesgesetz über die Raumplanung

(Raumplanungsgesetz, RPG)[1]

vom 22. Juni 1979 (Stand am 1. Januar 2019)

Die Bundesversammlung der Schweizerischen Eidgenossenschaft,

gestützt auf die Artikel 22^{quater} und 34^{sexies} der Bundesverfassung[2],[3] nach Einsicht in eine Botschaft des Bundesrates vom 27. Februar 1978[4],

beschliesst:

– 1. Titel: Einleitung

– **Art. 1** Ziele

[1] Bund, Kantone und Gemeinden sorgen dafür, dass der Boden haushälterisch genutzt und das Baugebiet vom Nichtbaugebiet getrennt wird.[1] Sie stimmen ihre raumwirksamen Tätigkeiten aufeinander ab und verwirklichen eine auf die erwünschte Entwicklung des Landes ausgerichtete Ordnung der Besiedlung. Sie achten dabei auf die natürlichen Gegebenheiten sowie auf die Bedürfnisse von Bevölkerung und Wirtschaft.

[2] Sie unterstützen mit Massnahmen der Raumplanung insbesondere die Bestrebungen:

a. die natürlichen Lebensgrundlagen wie Boden, Luft, Wasser, Wald und die Landschaft zu schützen;

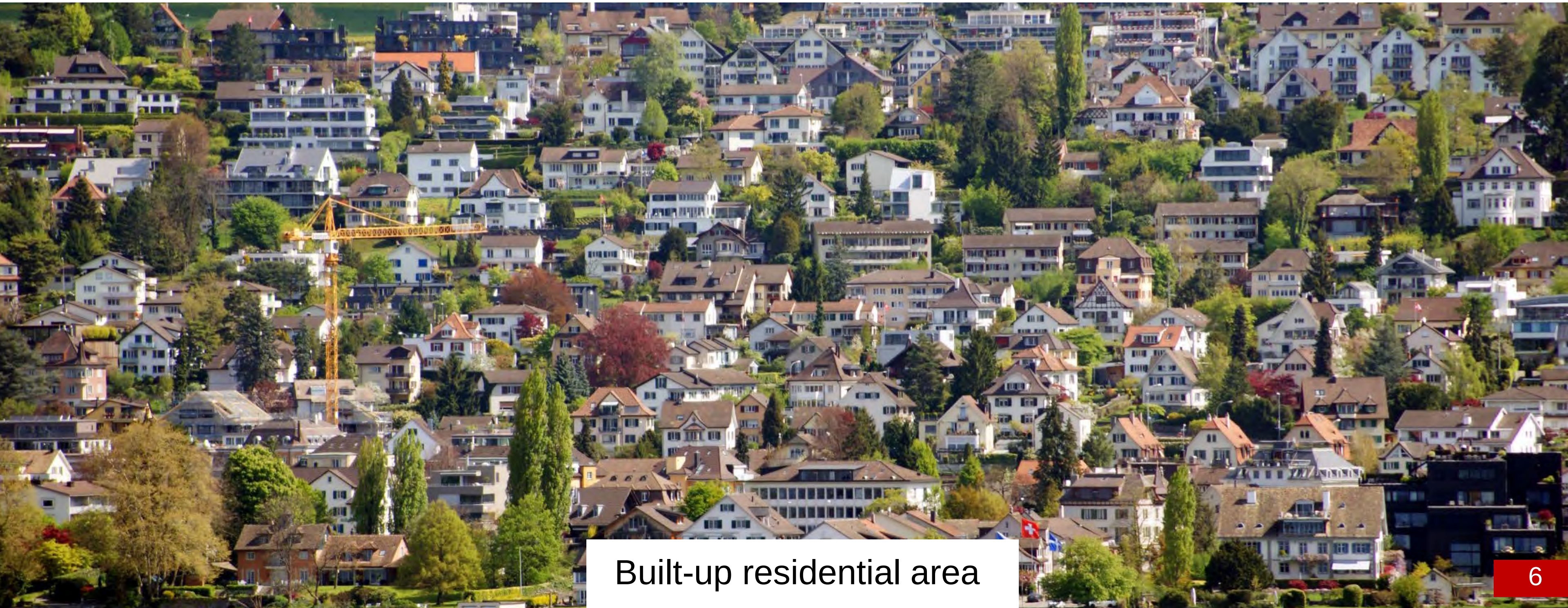
a^{bis}.[2] die Siedlungsentwicklung nach innen zu lenken, unter Berücksichtigung einer angemessenen Wohnqualität;

b.[3] kompakte Siedlungen zu schaffen;

Re-thinking where to build

Greenfield

Industrial wasteland

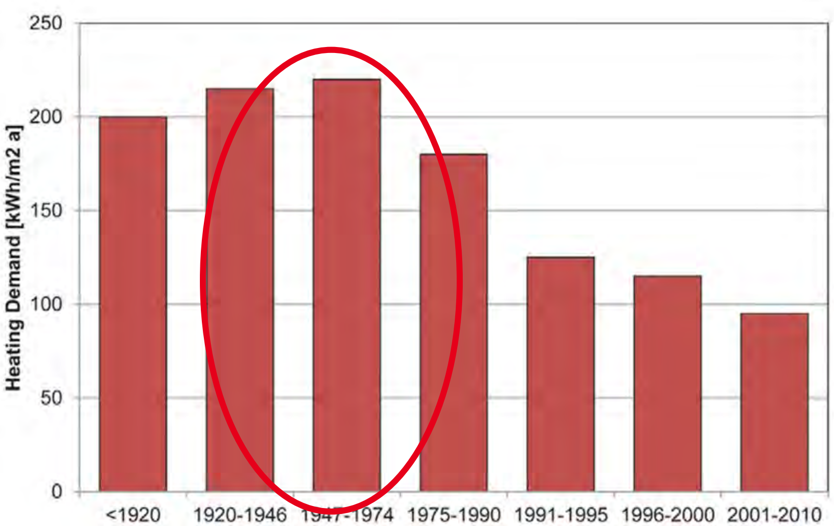


Built-up residential area

Source: https://www.nzz.ch/schweiz/schoene-neue-raumordnung-ld.1453214, Image: ETH-Bildarchiv / Stiftung Luftbild Schweiz / Swissair Photo / CC BY-SA 4.0

Re-thinking where to build

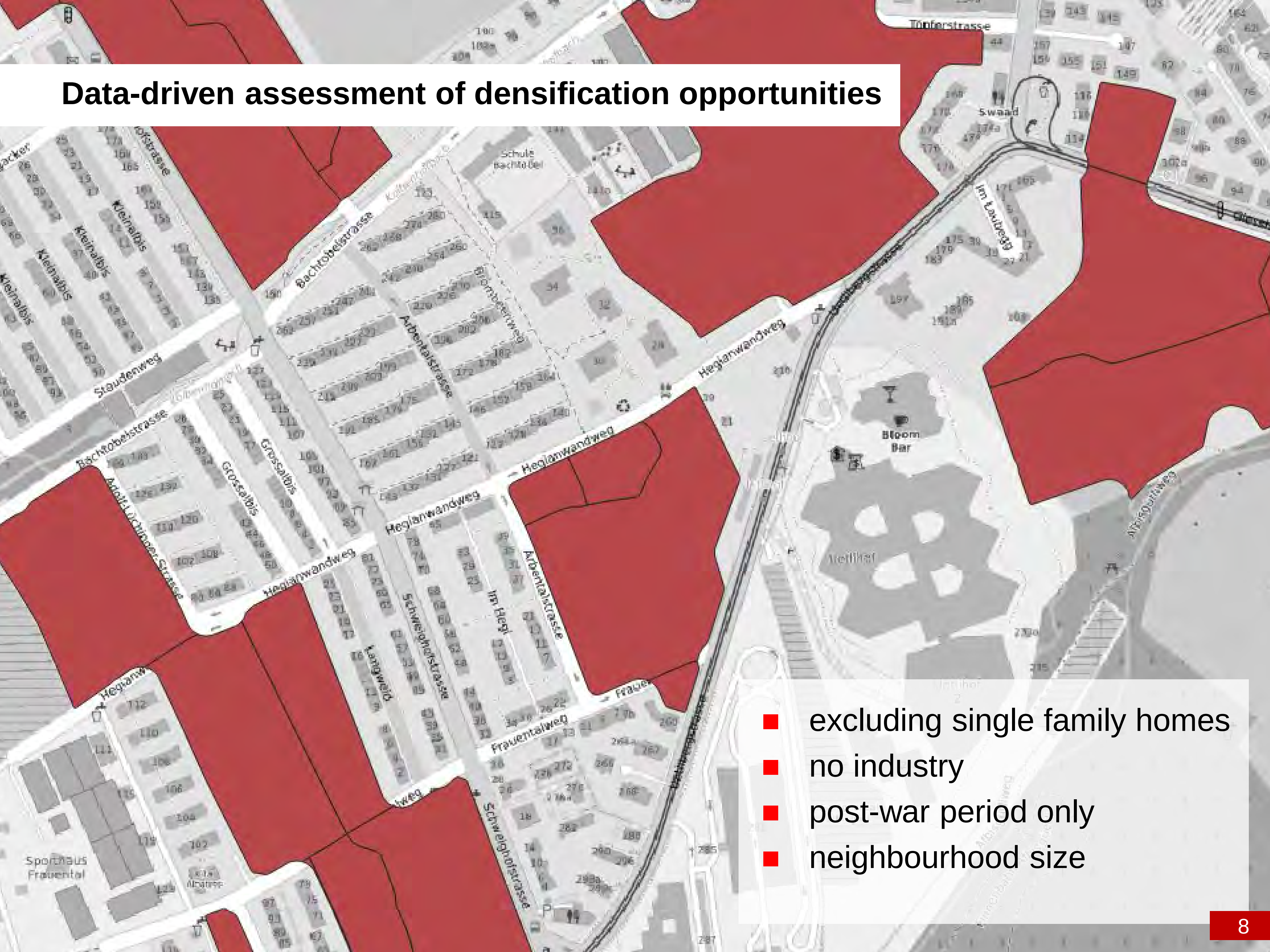
- **Post-war (1945–1980) urban neighbourhoods**
  - ~25% of building stock
  - Second renovation cycle
  - Poor energy performance → Densification co-benefits
- **Already built-up area** (≠ industrial wasteland or building zones)
  - Prevents green-field development
  - Central locations promise sustainability gains
- **Neighbourhoods** (≠ single family homes)
  - Coordination challenges are smaller



Ostermeyer et al. 2018

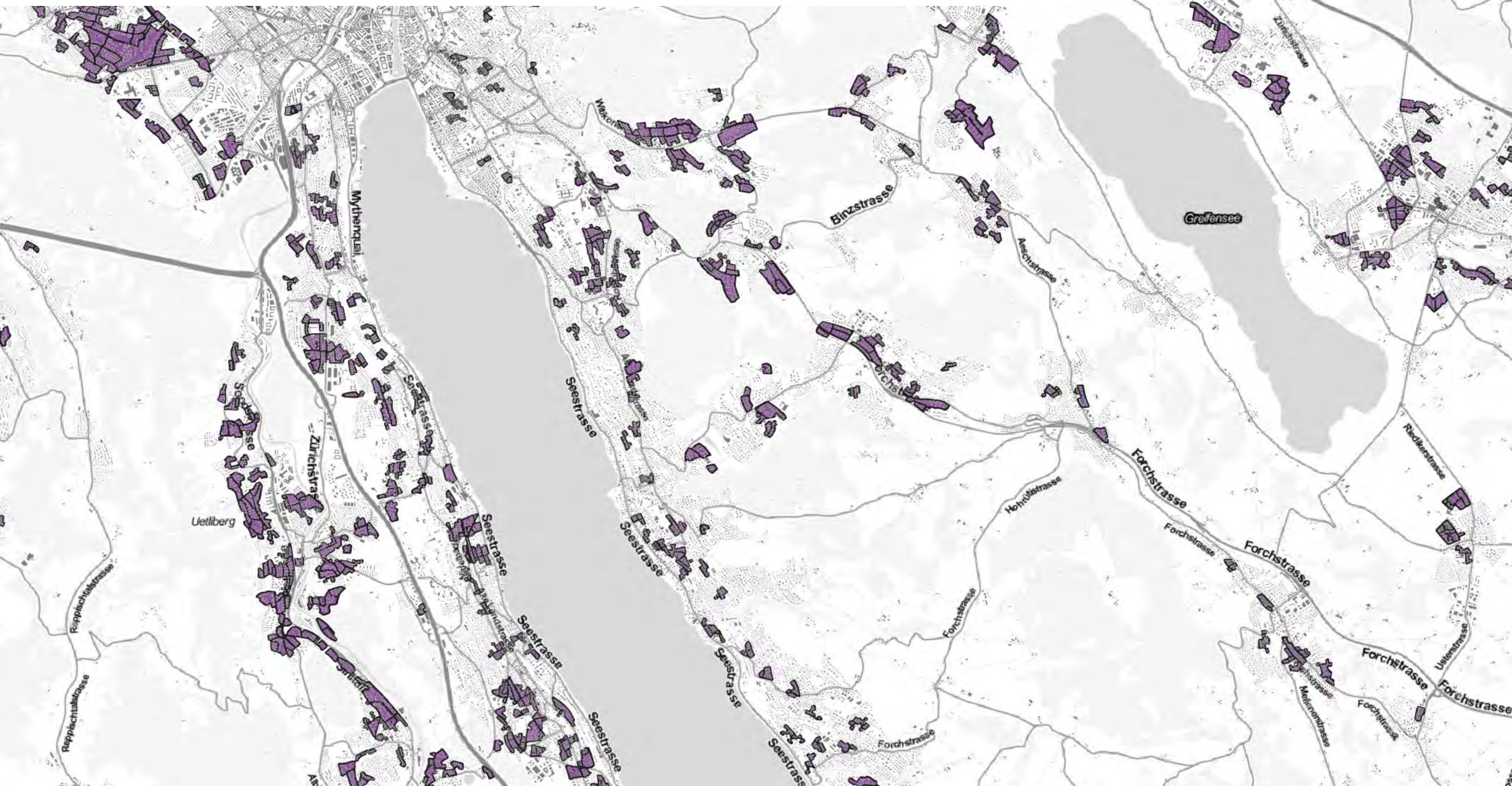
Data-driven assessment of densification opportunities

Data-driven assessment of densification opportunities



- excluding single family homes
- no industry
- post-war period only
- neighbourhood size

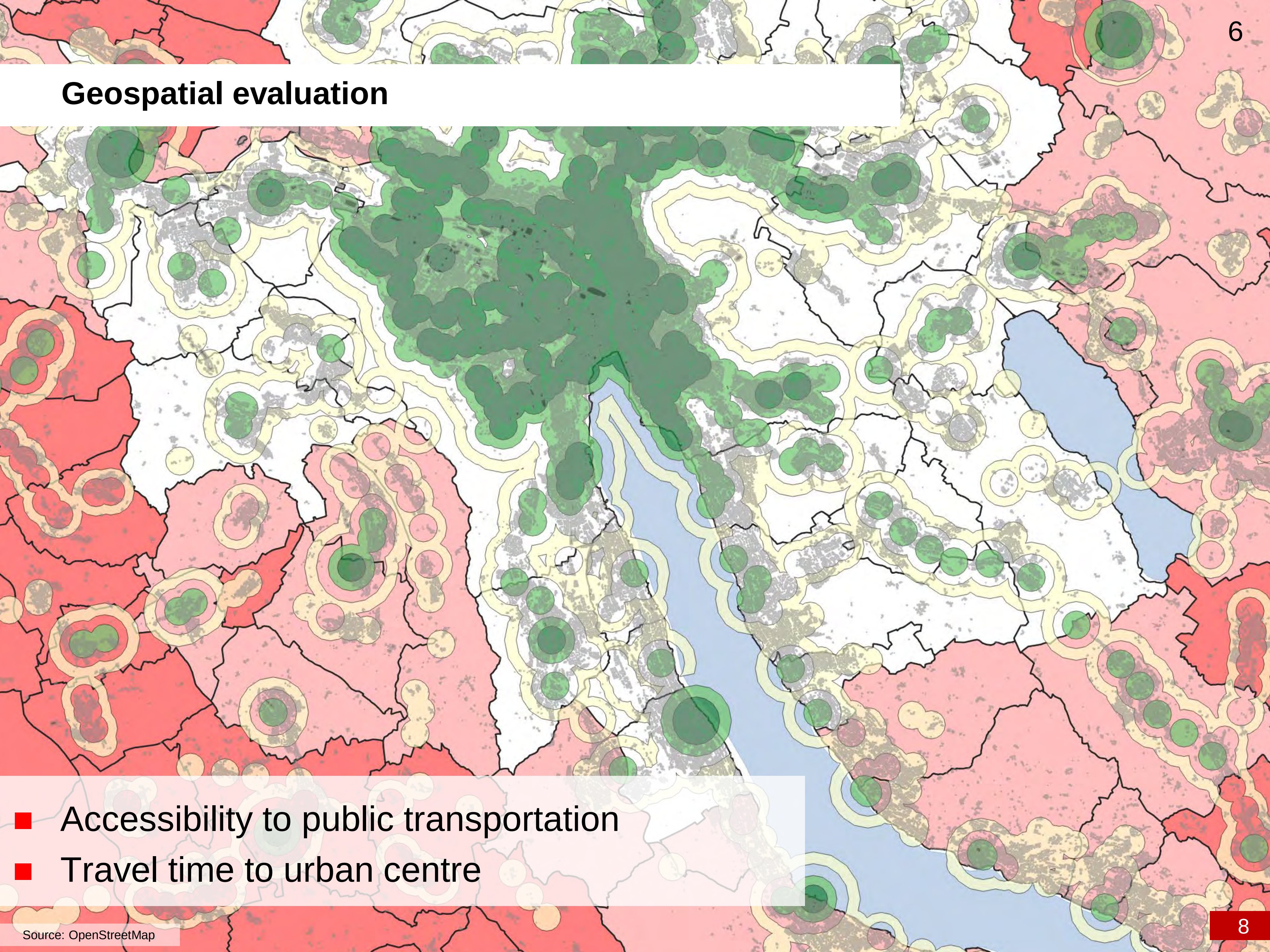
Data-driven assessment of densification opportunities



- Neighbourhood all across Switzerland
- Where is densification most sustainable?

Source: OpenStreetMap

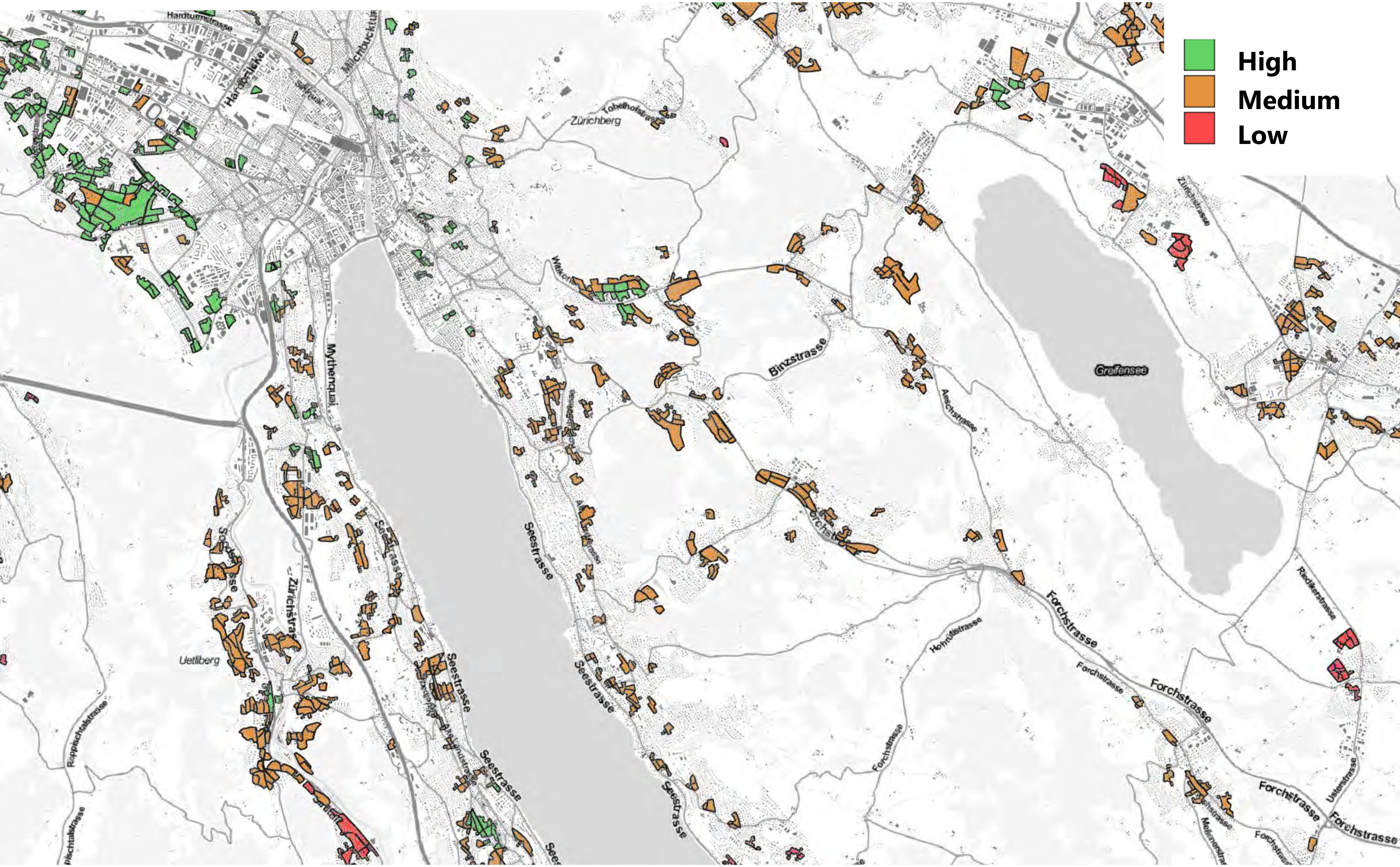
Geospatial evaluation



- Accessibility to public transportation
- Travel time to urban centre

Source: OpenStreetMap

Suitability classification for densification



Source: OpenStreetMap

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Accessibility and connectivity

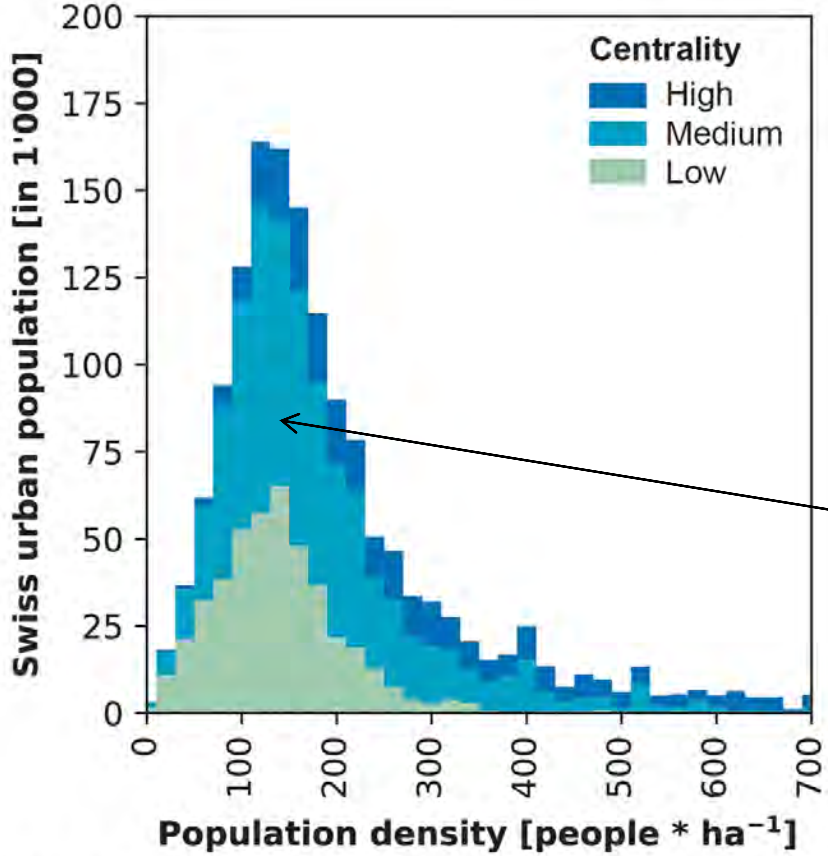

Fig. 5. Population density and geographic location of all identified Swiss urban post-war neighbourhoods.

- Neighbourhoods with high accessibility and centrality have typically higher densities
- Many central / medium neigbhourhoods with relatively low density values

Eggimann et al. (2021): https://doi.org/10.1016/j.scs.2021.103068

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Post-war neighbourhood archetypes

- Archetype definition by architects

A1

A2

A3

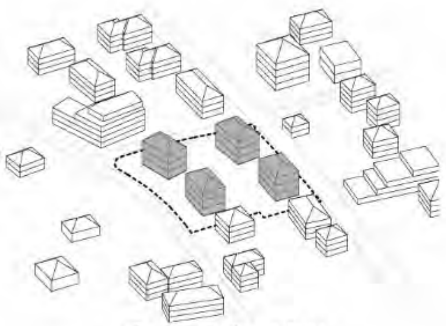
A4

A5

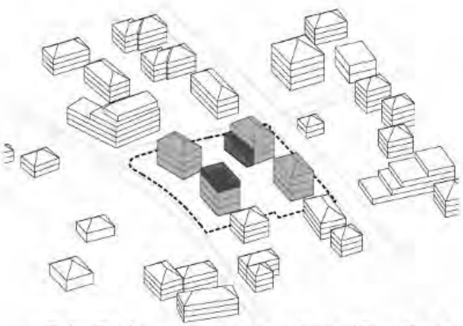
- Supervised classification

Neighbourhood morphology

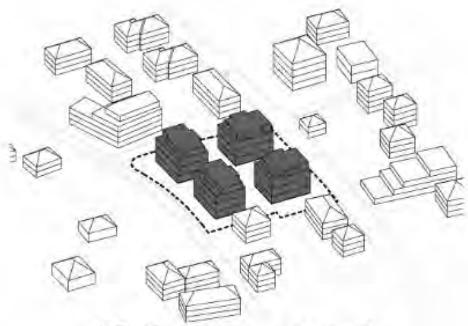
- Densification strategies



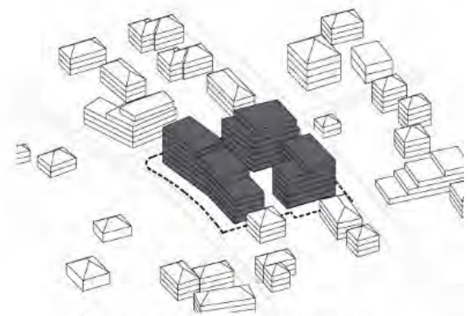
Current situation



S1: Below-average densification



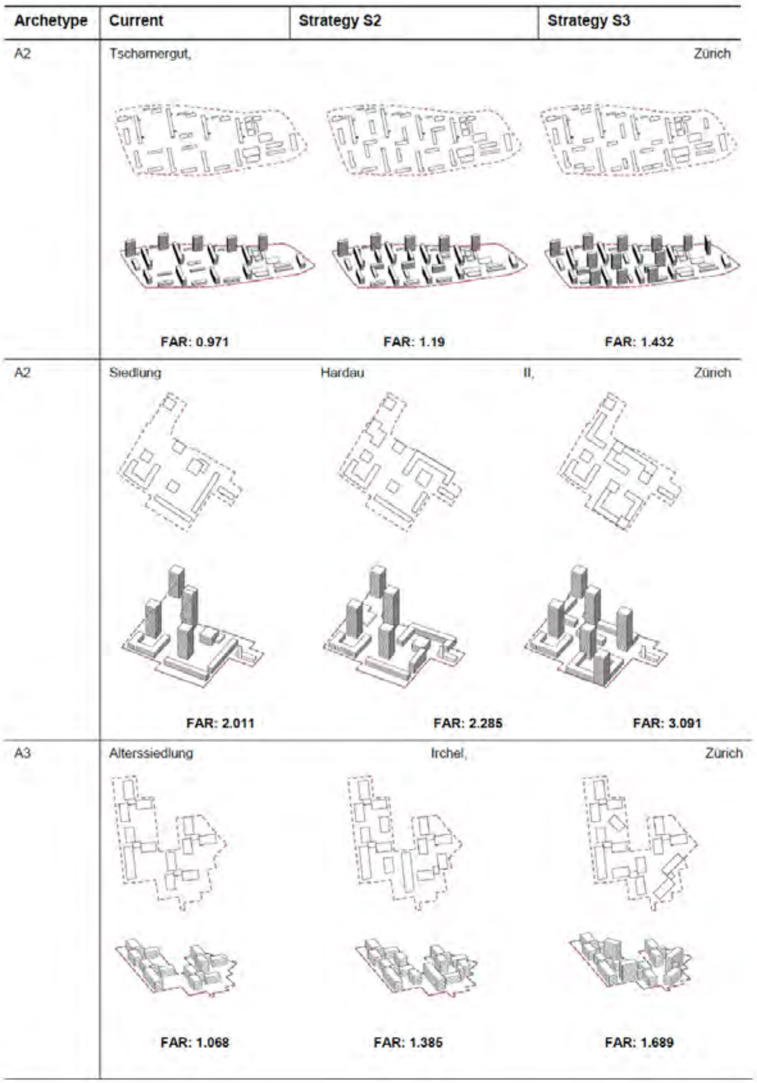
S2: Business as usual



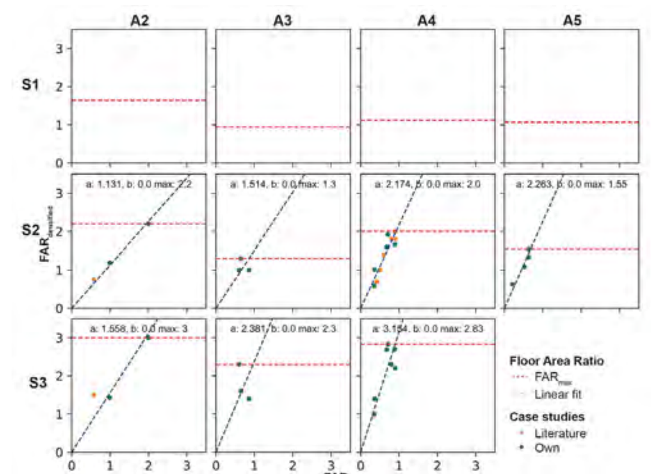
S3: Concentrated density

Eggimann et al. (2021): https://doi.org/10.1016/j.scs.2021.103068

Urban design catalogue to assess floor area ratios



Maximum **floor area-ratios** per densification strategy and neighbourhood archetype



Additional inhabitants calculated based on change in FAR

Eggimann et al. (2021): https://doi.org/10.1016/j.scs.2021.103068

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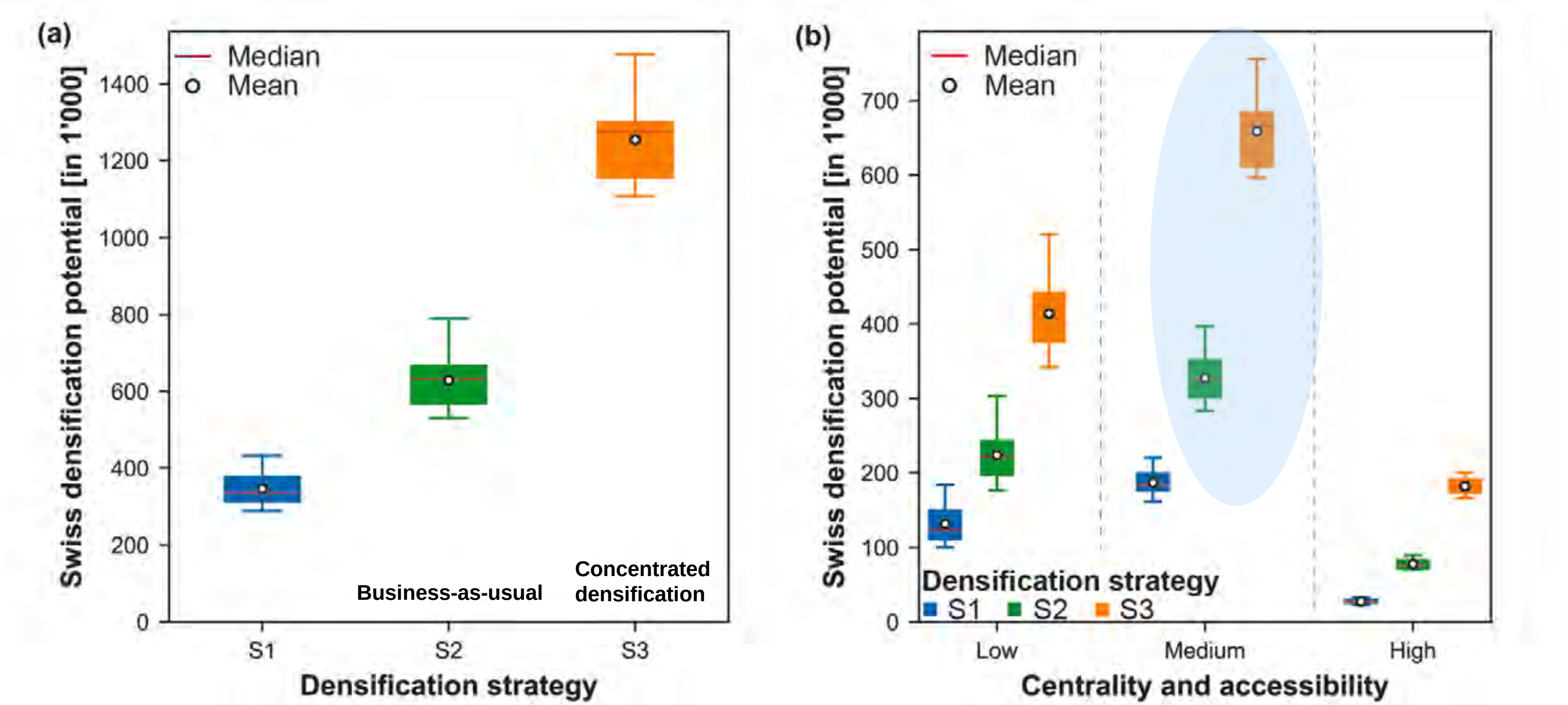
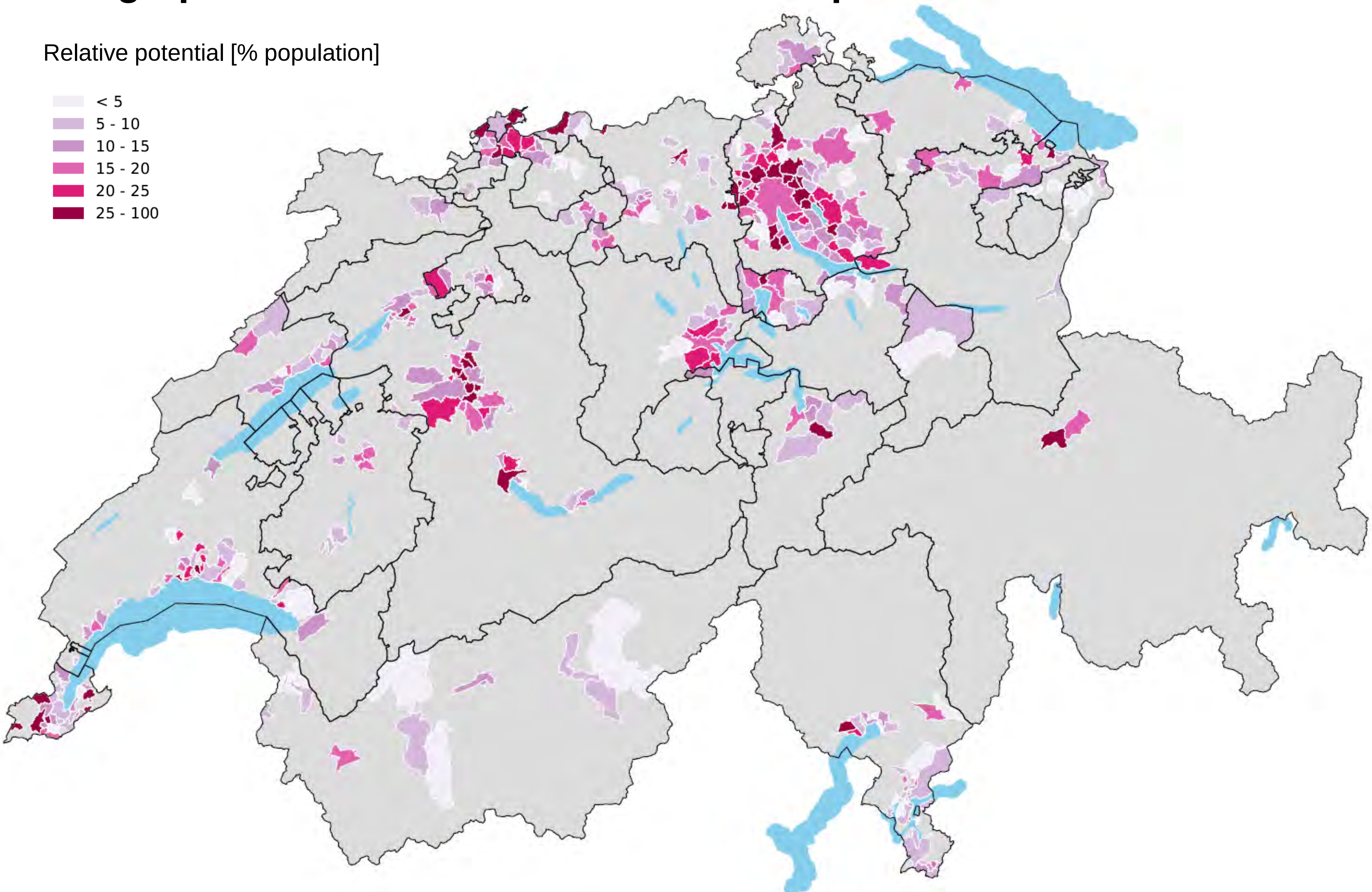
Swiss densification potential of post-war neighbourhoods



- **4 – 15% of current Swiss population** could be accommodated in post-war neighbourhoods (0.35 – 1.24 million people)
- Particularly locations with «medium» accessibiliy and centrality are interesting. **Business as usual** densification (S2) would be an **opportunity lost.**
- **> 50% of potential** is in favourable locations

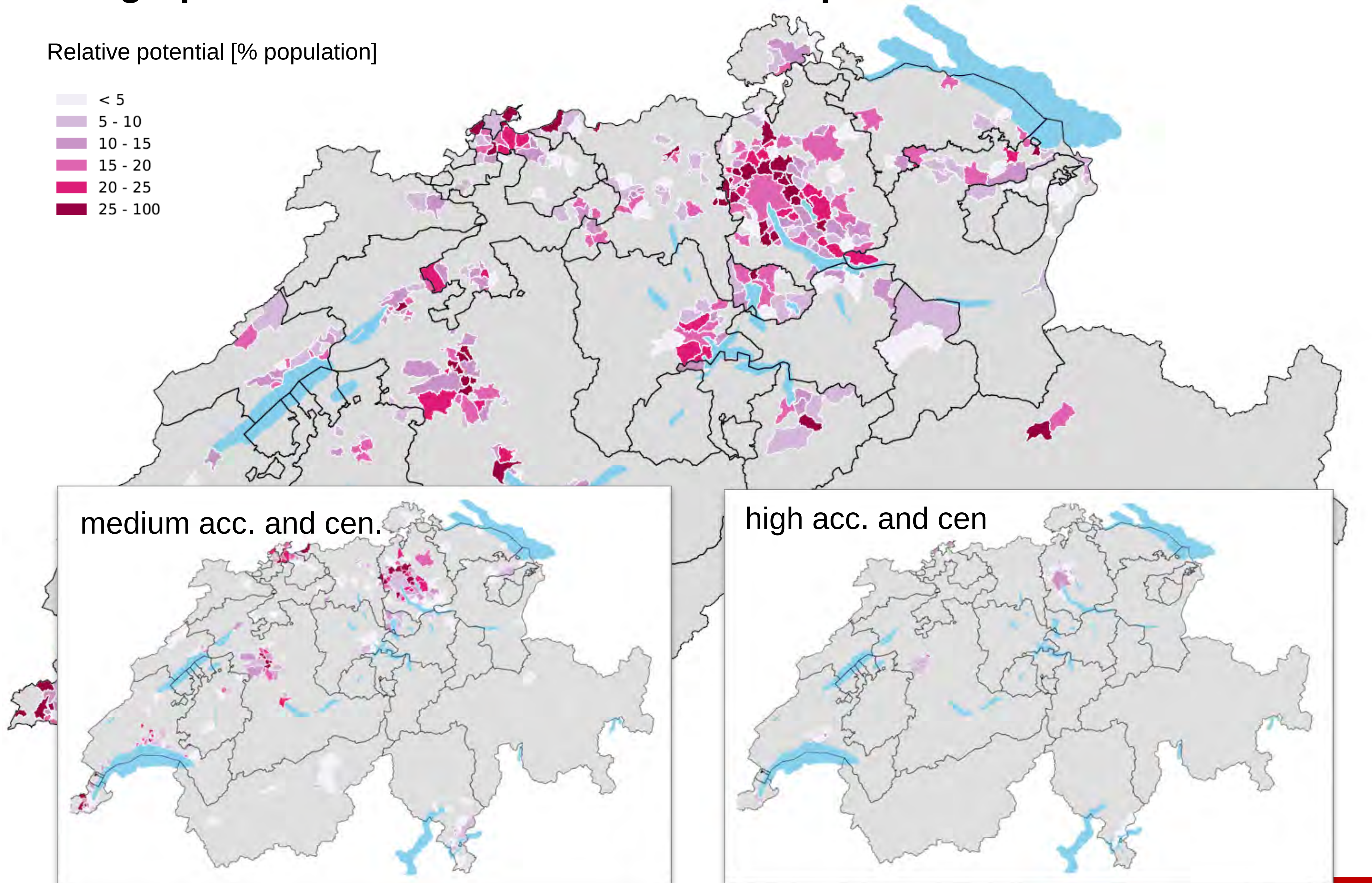
Eggimann et al. (2021): https://doi.org/10.1016/j.scs.2021.103068

Geographical distribution of densification potential



Eggimann et al. (2021): https://doi.org/10.1016/j.scs.2021.103068

Geographical distribution of densification potential



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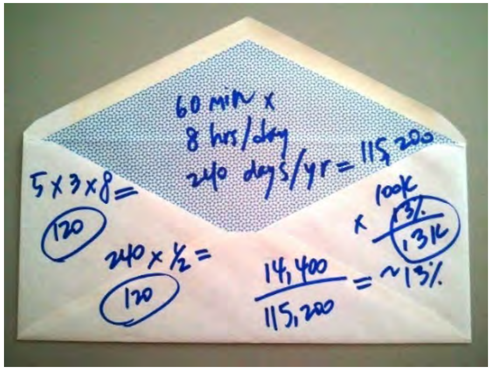
Energy implications of densification



Densification scenario versus urban sprawl scenario

- number of inhabitants
- building type (SFH vs MFH)
- floor area per person

→ 18 – 73 km^2 additional floor area on greenfield sites
→ Savings of annual operational energy of 0.3 – 1.3 TWh

Eggimann et al. (2021): https://doi.org/10.1016/j.scs.2021.103068

Energy implications - A multi-sectorial challenge

- Efficiency depends on **urban density**
  (e.g. energy density, economies of scale and density)

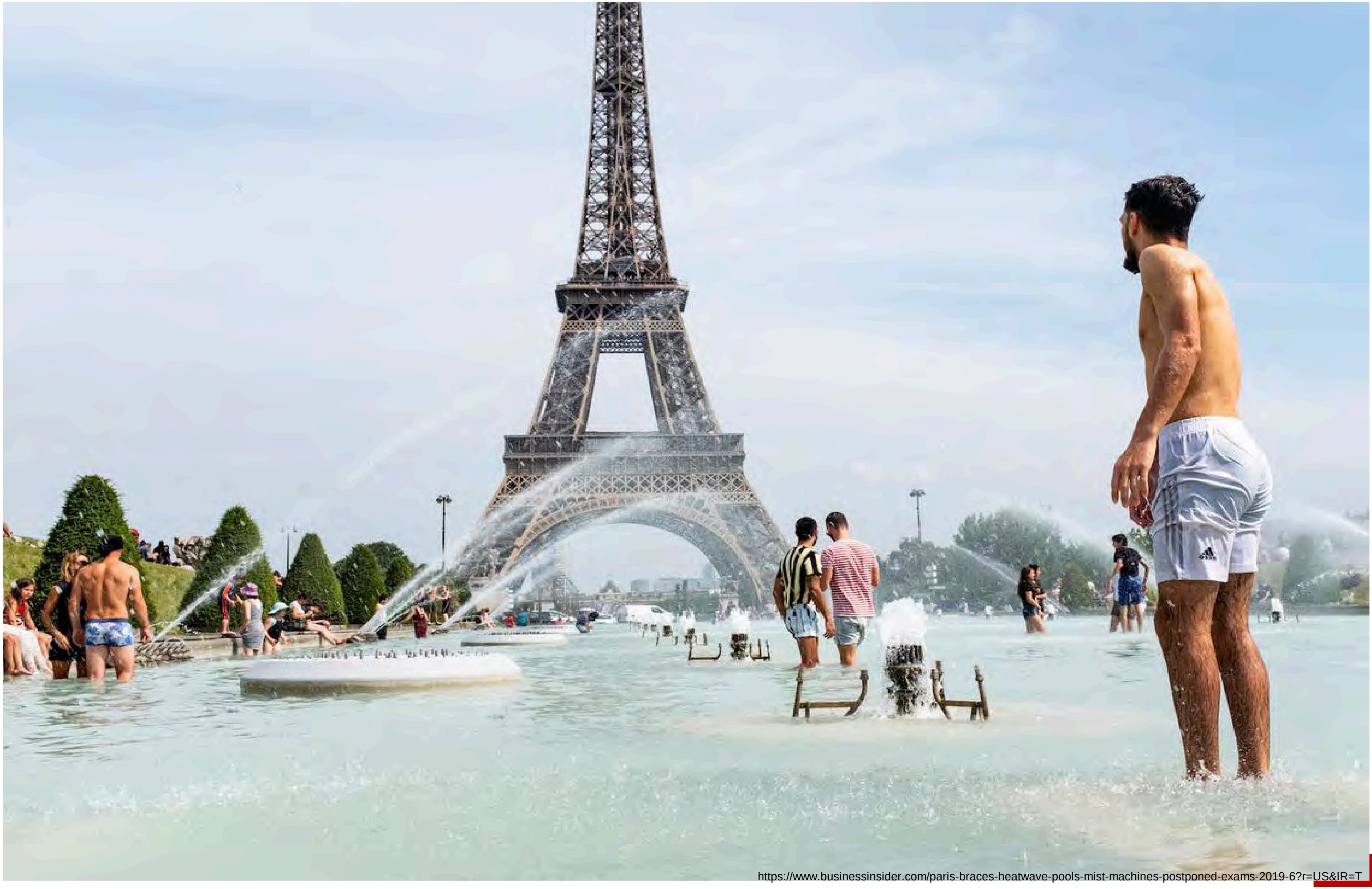
- Where will we **live and work**? (15-minute city?)

- **Multiple infrastructure systems**
  - Mobility (car ownership, public transportation)
  - Drinking water, telecommunication, wastewater ...

Lessons learnt for re-thinking neighourhood densification

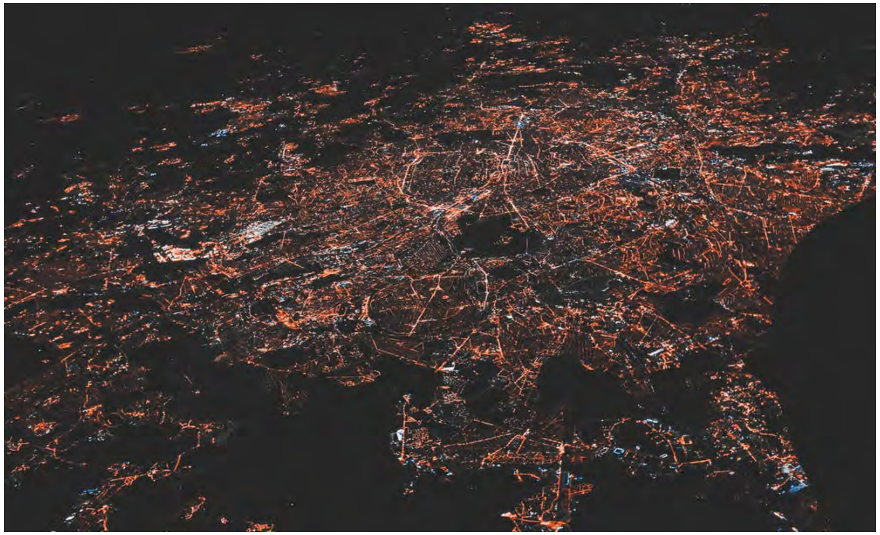
- **Post-war neighbourhoods** are critical for sustainable densification. Considerable densification **potential in already built-up neighbourhoods**.
- Geographic evaluation enables **prioritisation** of densification sites.
- Business as usual is an opportunity lost: **targeted densification** in most suitable locations
- A **multi-sectorial** approach is necessary for more holistic evaluation of densification and sustainability (particularly mobility).
- **Socio-technical system: Floor area per person** is single-most critical factor to improve sustainability of densification (e.g. empty nesters, flat size).

Climate change and building cooling demand



https://www.businessinsider.com/paris-braces-heatwave-pools-mist-machines-postponed-exams-2019-6?r=US&IR=T

Times of crisis – Energy and climate change



https://www.zuonline.ch/wie-zuerich-die-hitze-bekaempfen-will-724648800732

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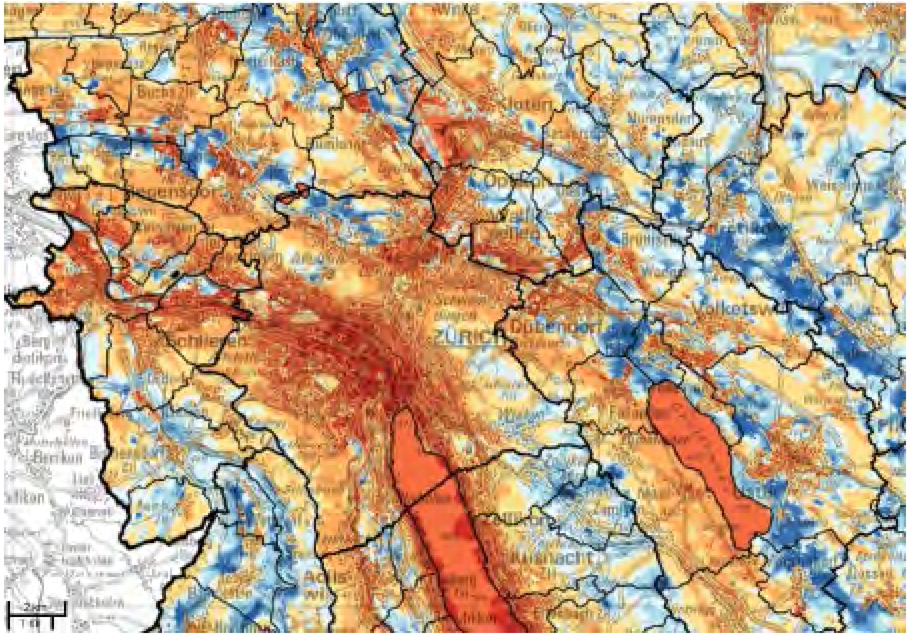
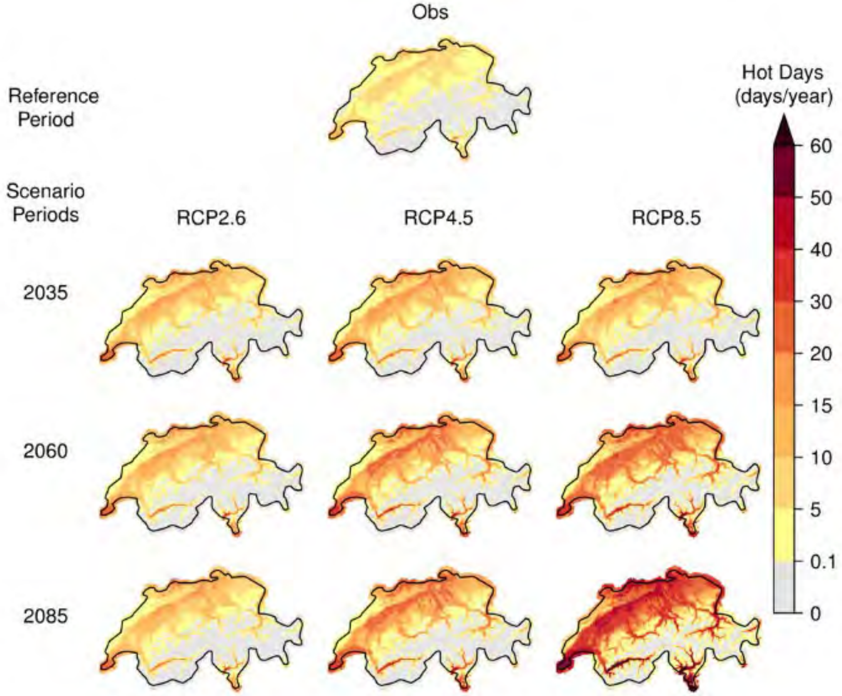
Climate change in Switzerland

- **Air temperature** has increased by ~2°C between 1864 – 2017
- The **zero-degree line** has risen by 300 – 400 m since the 1960s
- This warming has led to more frequent and more intense **heat waves**
- **Urban heat island** effect



Burgstall (2019): Link



Source: CH 2018: Link

Source: CH 2018

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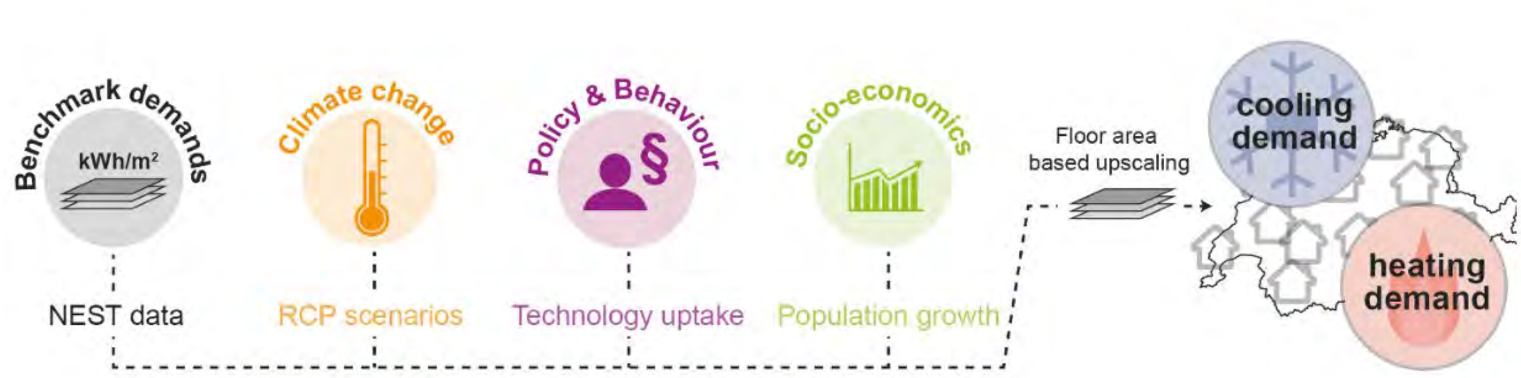
Future building cooling demand in Switzerland – a problem?

- Combining factors that determine thermal building energy demand



NEST Building as reference

Population weighted climate scenarios

Device uptake

Population growth

Mutschler et al. (2021): https://doi.org/10.1016/j.apenergy.2021.116636

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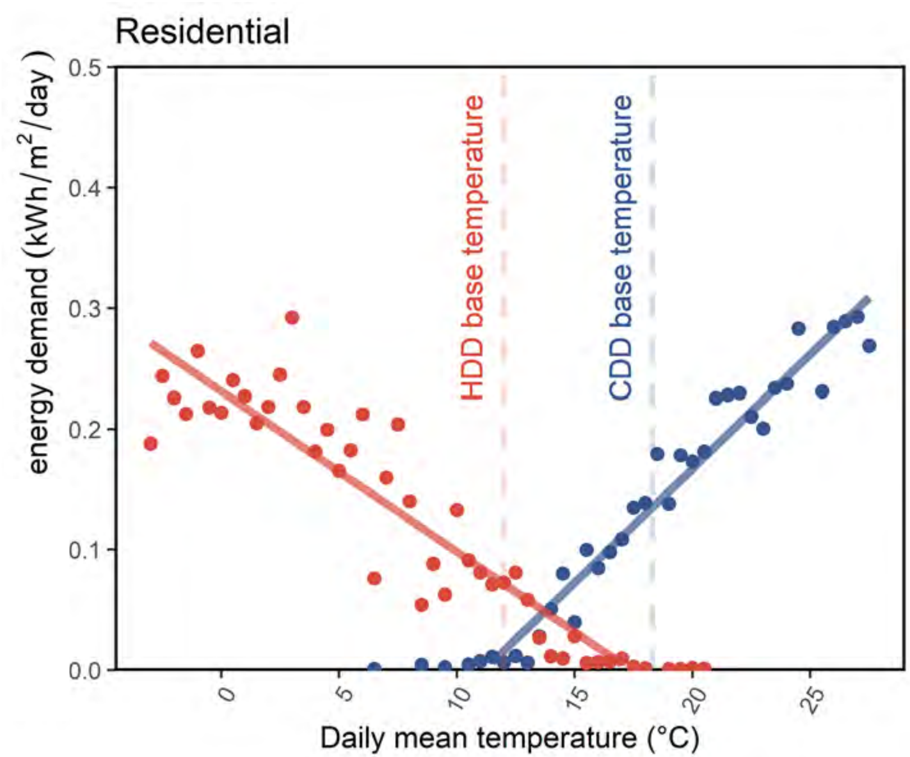
Benchmarking demands: Energy signature

NEST energy signature

Ambient temperature to thermal demand correlation



Mutschler et al. (2021): https://doi.org/10.1016/j.apenergy.2021.116636

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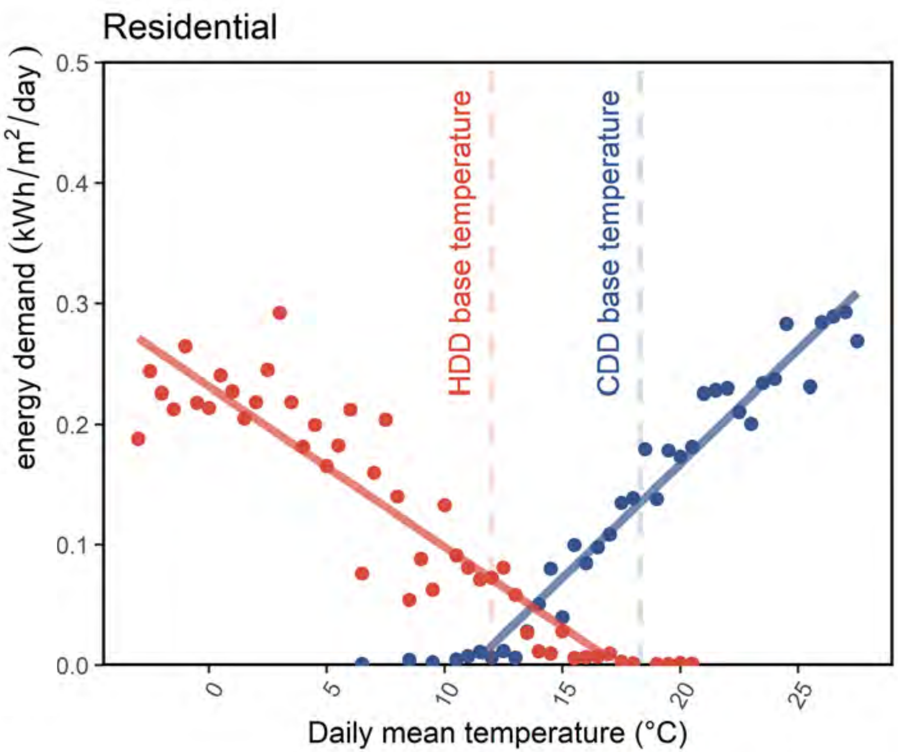
Benchmarking demands: Energy signature

NEST energy signature

Ambient temperature to thermal demand correlation



Swiss energy signatures per buildling type and buildling age

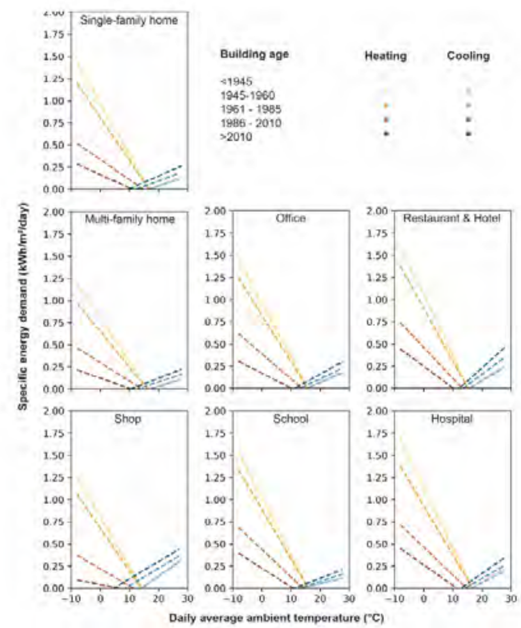


Table 3
Simulated building type and building age class-specific cooling and heating energy demands for the year 2016.

cooling demand (kWh/m²/year)

Building age	< 1945	1945 - 1960	1961 - 1985	1986 - 2010	> 2010	All
Single-family home	2.3	2.6	2.0	7.4	14.7	4.2
Multi-family home	2.2	2.1	1.8	6.5	11.9	3.8
School	2.8	3.0	2.7	5.6	10.7	3.8
Restaurant & Hotel	4.8	5.4	5.0	12.0	[illegible]	7.0
Hospital	4.4	4.7	4.2	8.6	13.5	5.7
Shop	10.1	10.6	10.6	[illegible]	41.0	16.8
Office	3.6	4.0	3.9	8.3	14.0	5.8
All						5.1

heating demand (kWh/m²/year)

Building age	< 1945	1945 - 1960	1961 - 1985	1986 - 2010	> 2010	All
Single-family home	[illegible]	159.6	[illegible]	49.9	20.6	111.0
Multi-family home	[illegible]	117.8	95.1	43.5	13.8	89.5
School	[illegible]	[illegible]	[illegible]	62.9	25.5	[illegible]
Restaurant & Hotel	167.5	[illegible]	[illegible]	62.1	25.8	[illegible]
Hospital	169.1	184.4	[illegible]	65.8	32.2	[illegible]
Shop	109.5	111.9	93.9	25.8	2.8	71.9
Office	[illegible]	[illegible]	[illegible]	54.0	17.8	100.1
All						98.7

Mutschler et al. (2021): https://doi.org/10.1016/j.apenergy.2021.116636

Eggimann et al. (202): 10.1016/j.enbuild.2022.111844

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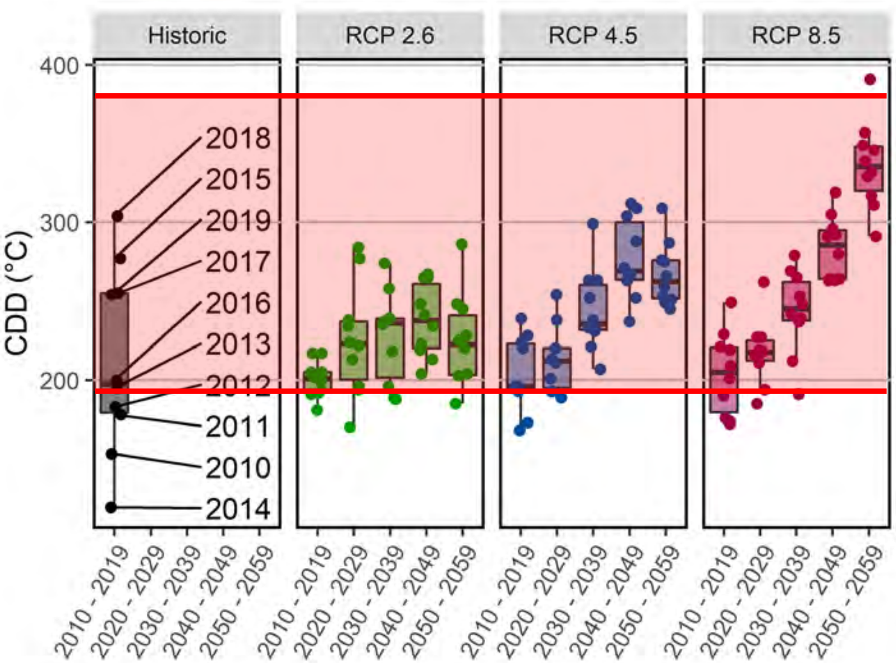
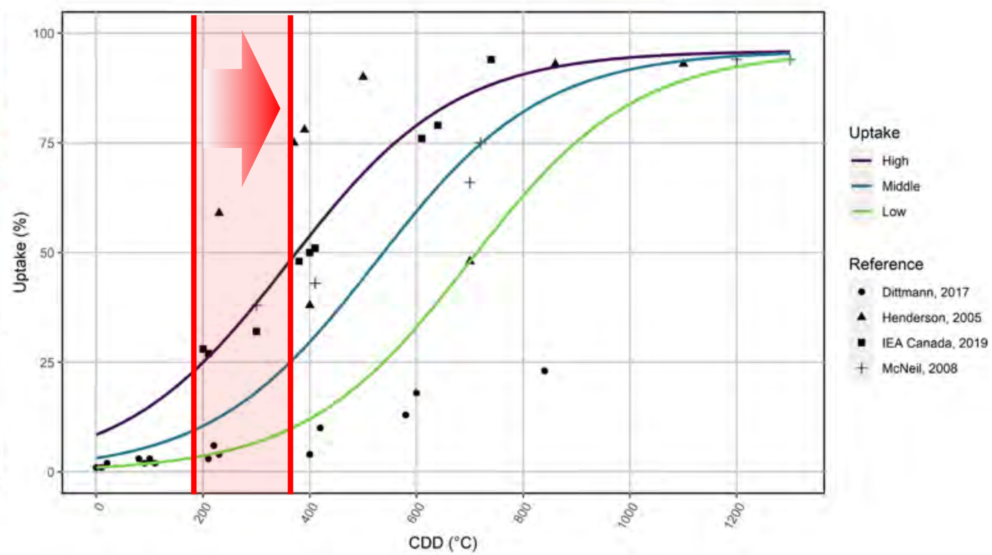
Climate change and cooling device uptake

- Cooling Degree Days (CDD) for different RCP scenarios
- Distribution of reverse cycle heat-pumps or air conditioning





- for $T_i > 18.3$ °C:
- $\text{CDD}\ [°\text{C}] = \frac{\sum_{i=1}^{24} T_i\ [°\text{C}] - T_{CDD}\ [°\text{C}]}{24}$

200 CCD: 5 – 25% cooling devices
400 CDD: 10 – 55% cooling devices

Mutschler et al. (2021): https://doi.org/10.1016/j.apenergy.2021.116636

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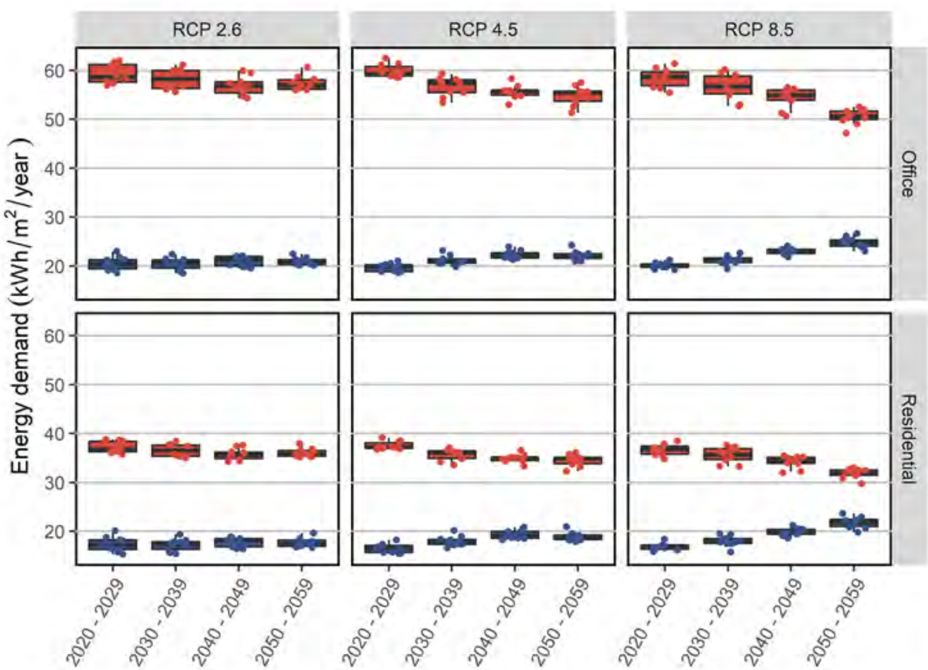
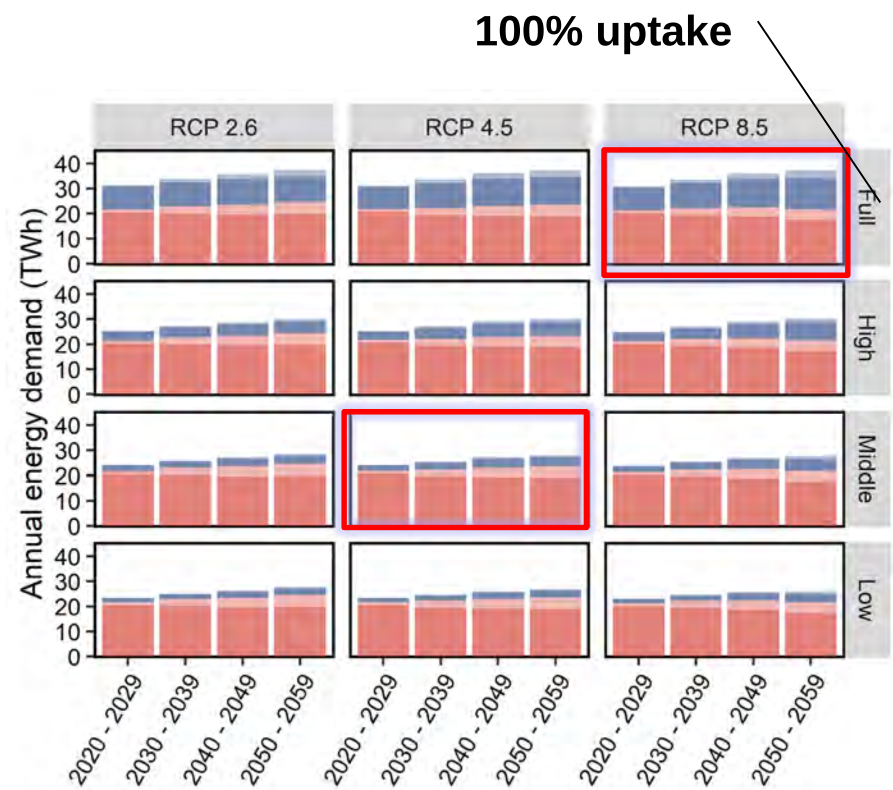
Future energy demand scenarios



Specific space heating and cooling energy demands of highly efficienty Swiss buildling



Swiss heating and cooling energy demand scenarios*

- Heating demand still dominates in Switzerland
- 5 TWh with reversible heat pumps → 2 TWh extra electricity demand (1 large power generation plant with 1 GW running for 2000 hours)

*Cooled floor area (m^2) per capita: Residential: 46, Office: 7, Service: 4.5
Moderate popultaion growth (10.4 million people by 2050)
Service 50 – 90% bin 2050, middle uptake scenario for residential

Mutschler et al. (2021): https://doi.org/10.1016/j.apenergy.2021.116636

BREAKING NEWS Efstratia Mavrapidou, one of the symbol Grannies of Lesvos, passes away

Home / FEATURED / Greeks urged to limit power consumption amid heatwave to avoid blackout

GREEKS URGED TO LIMIT POWER CONSUMPTION AMID HEATWAVE TO AVOID BLACKOUT

August 2, 2021 FEATURED, Greece 16 Comments

Tweet Merken Share 19

Greeks were urged on Monday to limit the use of electricity amid a 11-day-long heatwave that strike the country with temperatures of 44-45 degrees Celsius. Reason is the energy grid's warning of a power blackout.

The country's Energy Ministry issued a statement urging citizens to limit power and thus at the peak hours of the heatwave 1:00-3:00 pm and 6:00-10:00 pm when the concrete in the urban

- System level impacts
- Role of PV?

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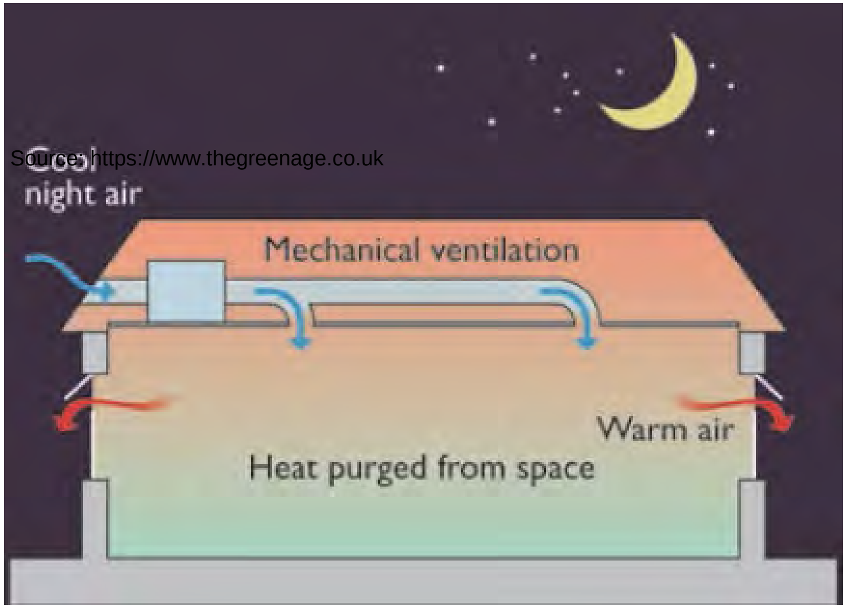
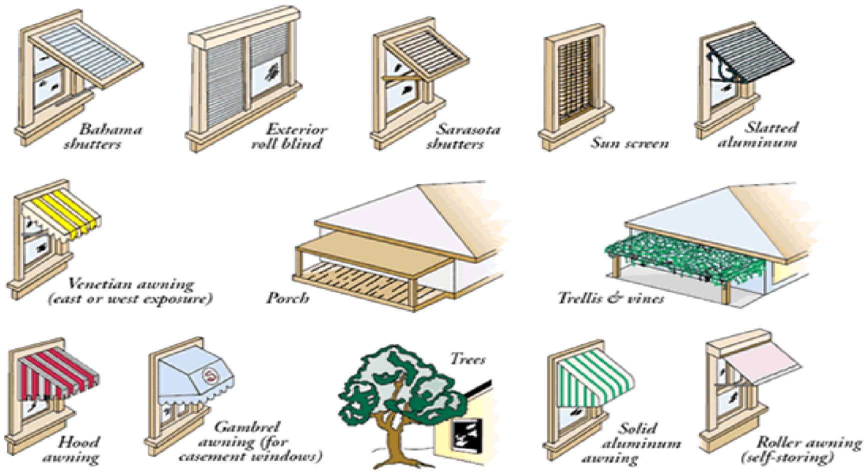
Re-thinking cooling: Sustainable cooling?

Night ventilation



Source: https://www.thegreenage.co.uk

Window shading



Source: http://www.fsec.ucf.edu

Silva et al. (2021): http:/www.doi.org/10.1016/j.buildenv.2021.108574

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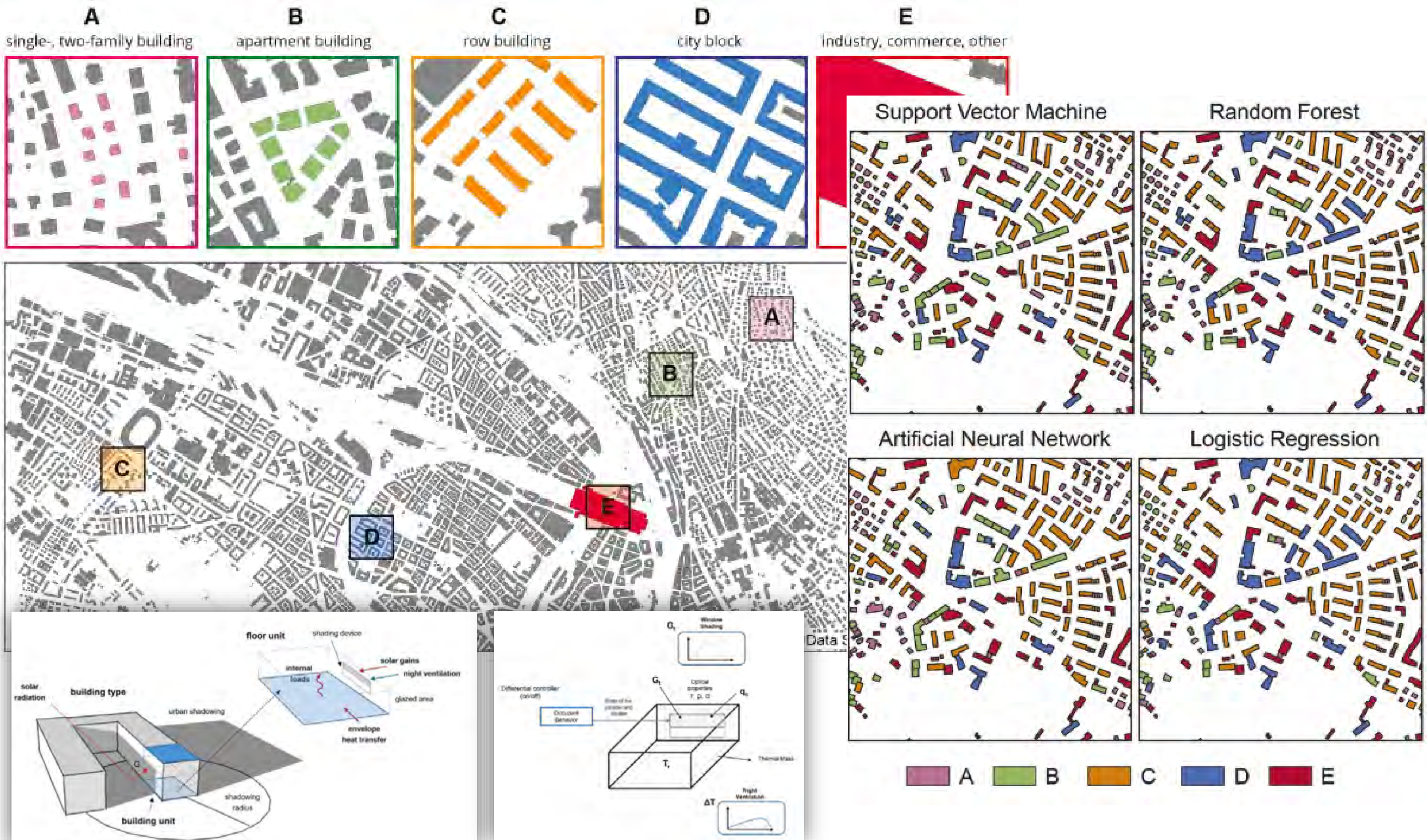
Bottom-up building simulation

- Swiss building stock is classified into different building archetypes



Silva et al. (2021): http:/www.doi.org/10.1016/j.buildenv.2021.108574

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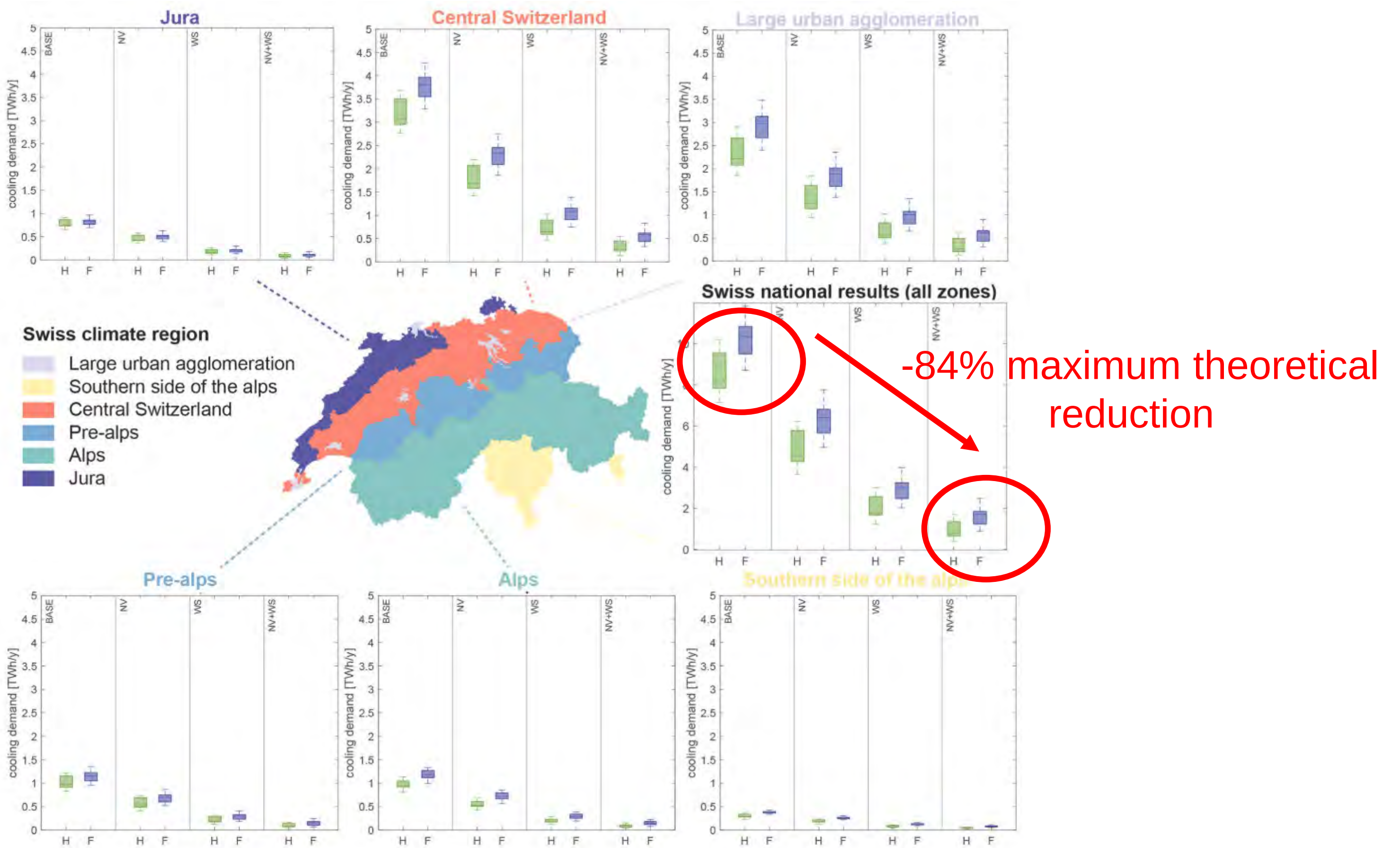
Alternative to mechanical cooling (demand side)

- Cooling energy demand is driven by modern buildings (> 50% current demand)
- Night ventilation and windows shading have a maximum theoretical potential to reduce national cooling energy demand by 84%.



→ Urban heat island?

Silva et al. (2021): http:/www.doi.org/10.1016/j.buildenv.2021.108574

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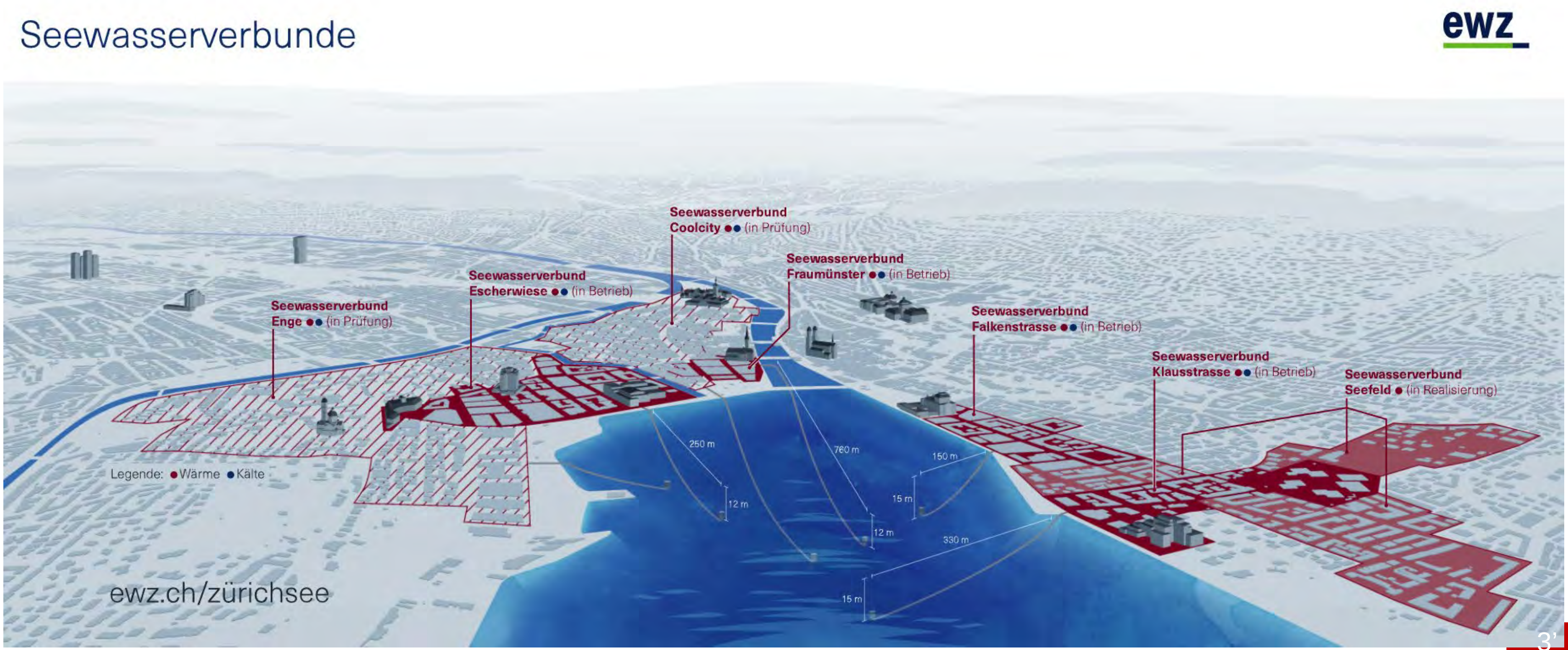
Re-thinking cooling (supply side)

- Central versus decentral approaches



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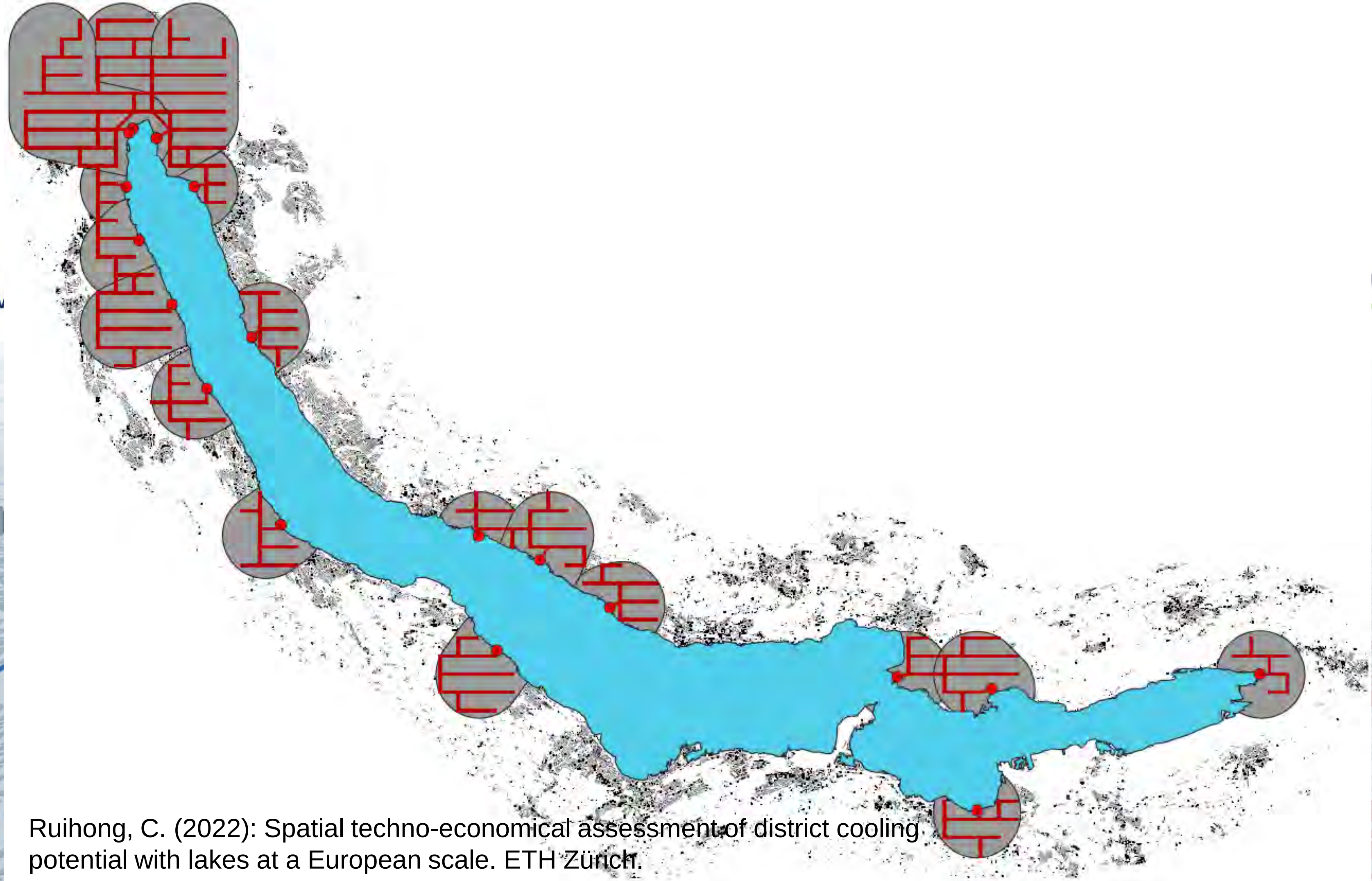
Re-thinking cooling (supply side)

- Central versus decentral approaches

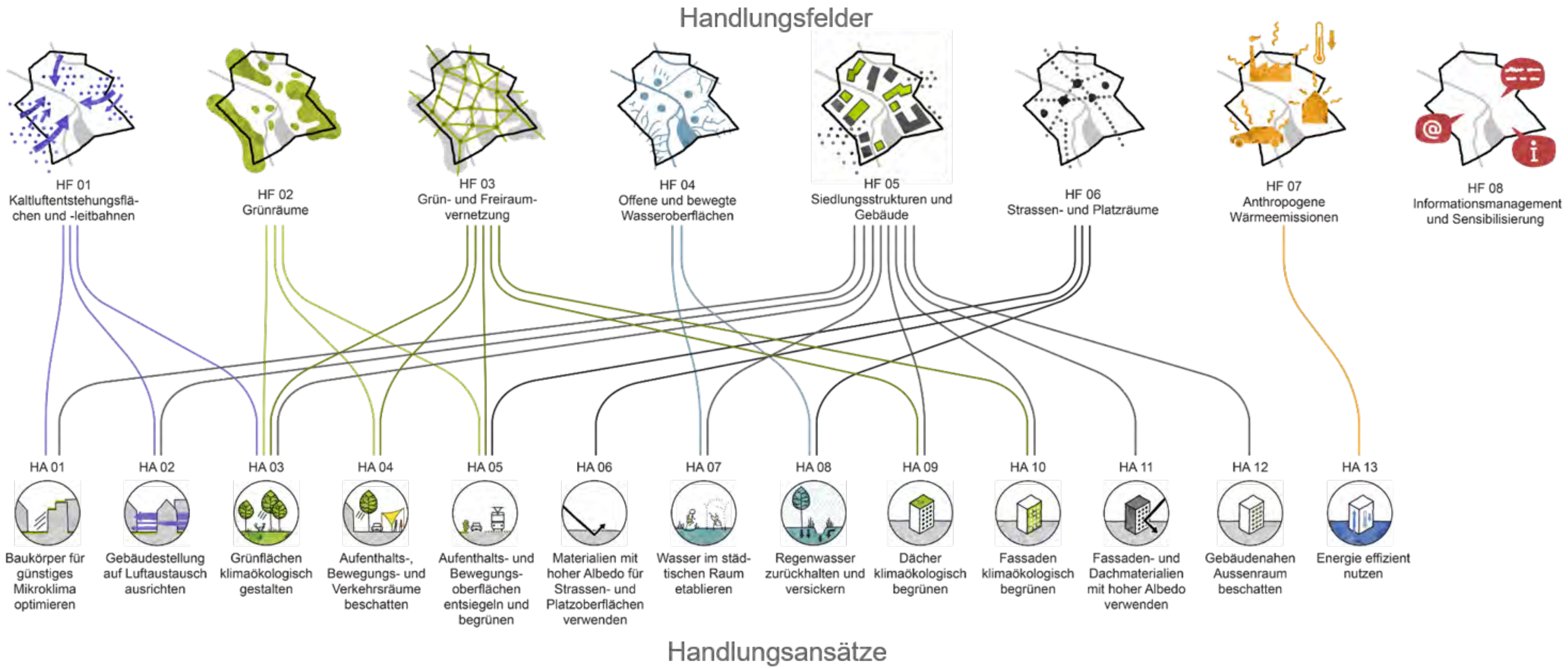


Ruihong, C. (2022): Spatial techno-economical assessment of district cooling potential with lakes at a European scale. ETH Zürich.

Re-thinking cooling

- Heat adaptive city planning

https://www.zuonline.ch/wie-zuerich-die-hitze-bekaempfen-will-724648800732



https://www.stadt-zuerich.ch/ted/de/index/gsz/planung-und-bau/fachplanung-hitzeminderung.html

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Lessons learnt for addressing the cooling challenge

- **Heating still dominates**, but cooling is becoming more important
- System level impact and the search for most **sustainable solution**. E.g. heat pumps and peak electricity demand, role of PV
- No solution fits all for addressing cooling challange.
  Passive cooling, city design, buildling construction/retrofit strategies….

  → Consider both supply and demand side.
- **Socio-technical system:** Cooling regulations, user behaviour…

Fostering urban green space with superblocks
Recycling of urban land and alternative street use

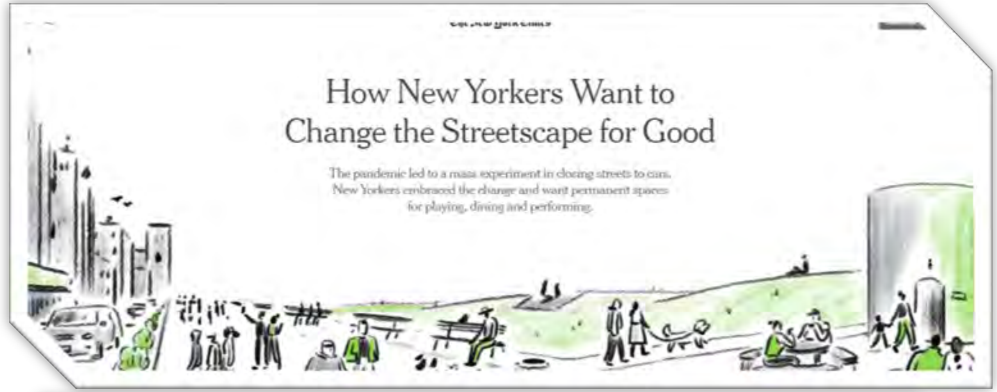
Rethinking infrastructure in times of crisis


Neue Zürcher Zeitung

Corona zwingt Städte wie Paris, Mailand oder San Francisco zum Umdenken

In der Corona-Krise bauen viele Städte die Velowege aus und suchen neue Konzepte für urbane Mobilität.

Hören Merken Drucken Teilen


How New Yorkers Want to Change the Streetscape for Good

The pandemic led to a mass experiment in closing streets to cars. New Yorkers embraced the change and want permanent spaces for playing, dining and performing.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Milan announces ambitious scheme to reduce car use after lockdown

Laura Laker


CITYLAB

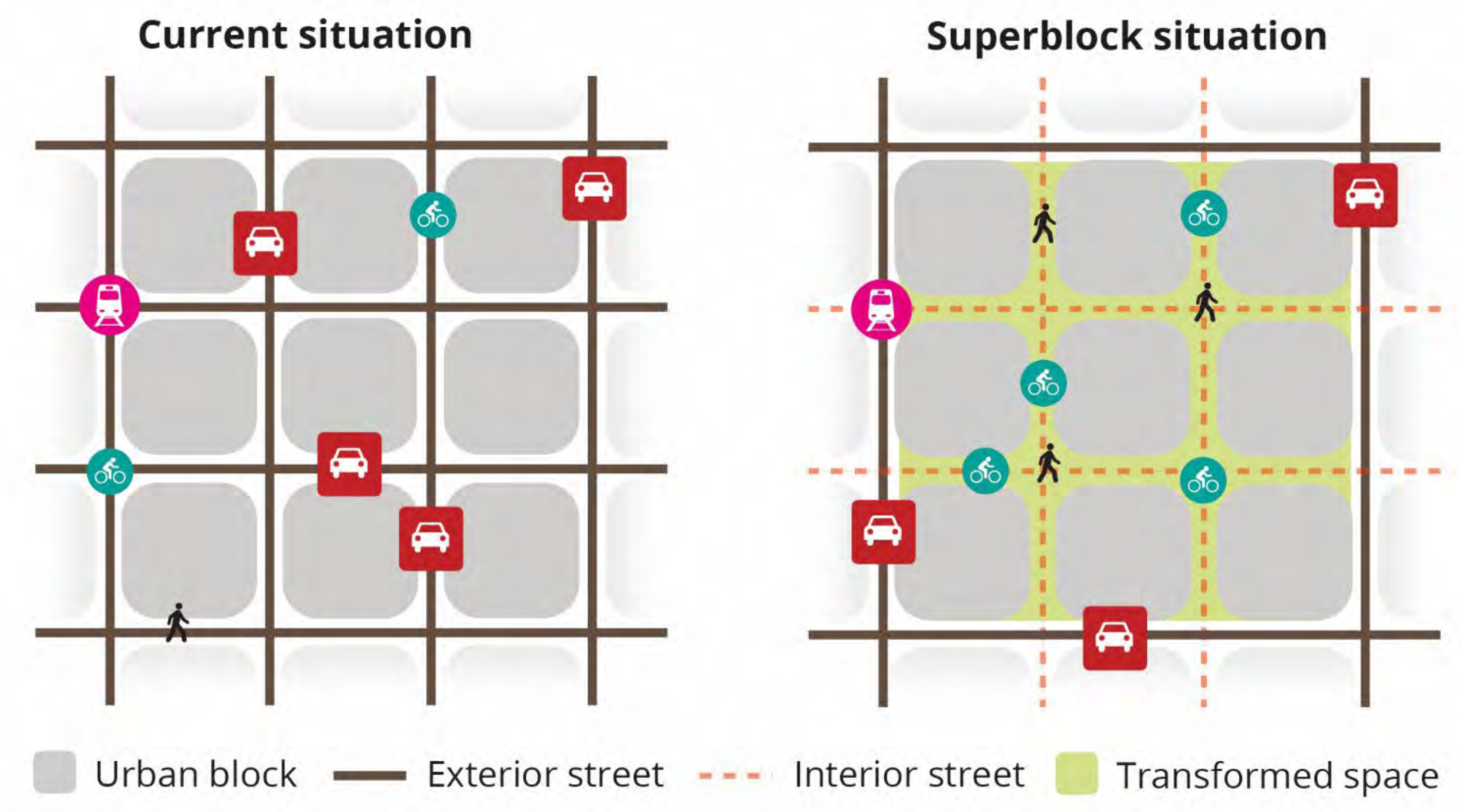
Barcelona Will Supersize its Car-Free 'Superblocks'

The Catalan capital's celebrated pedestrian-first zones are expanding to cover most of the city center, Mayor Ada Colau announced.

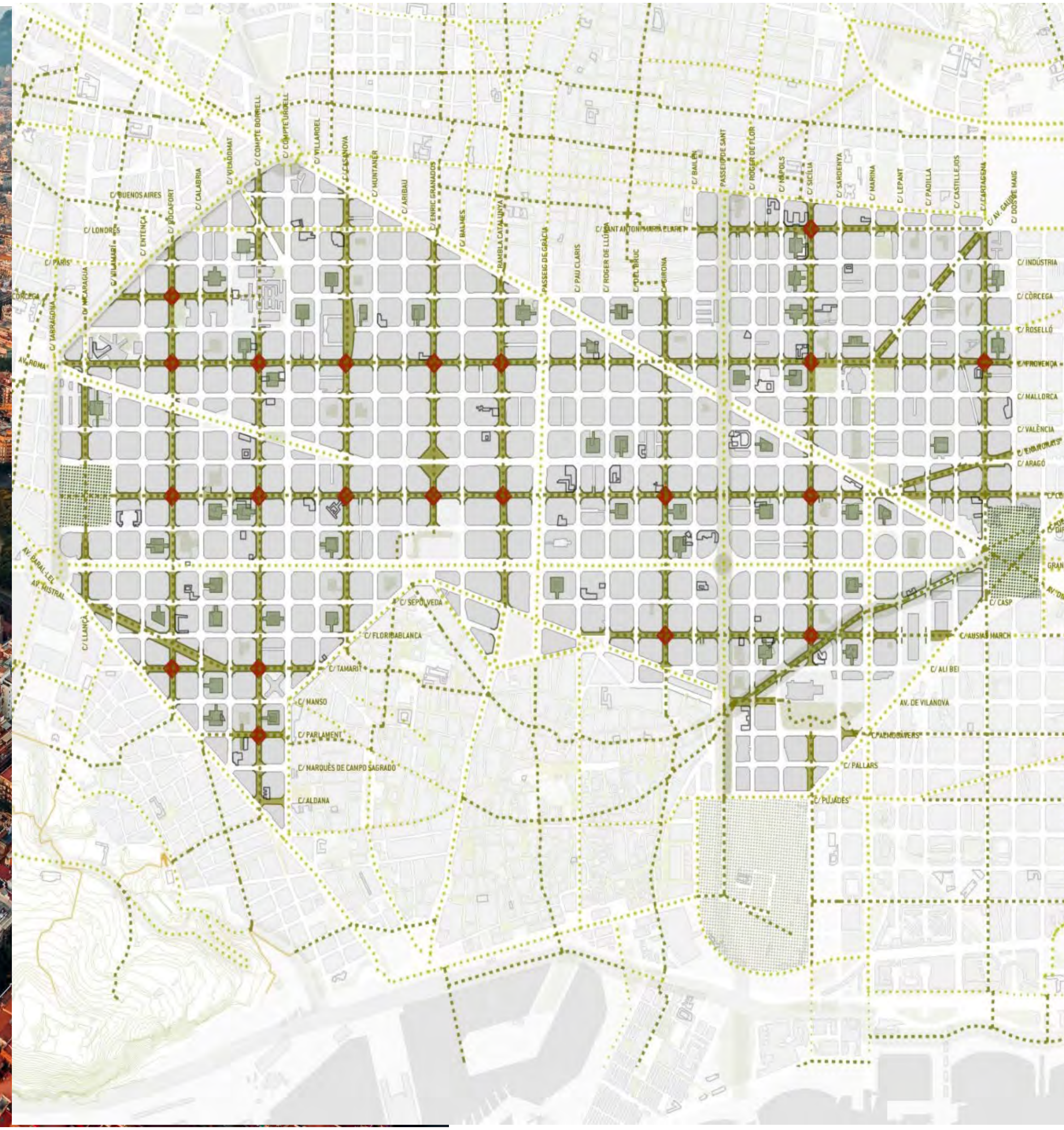
By Feargus O'Sullivan

11. November 2020, 20:51 MEZ

The superblock model



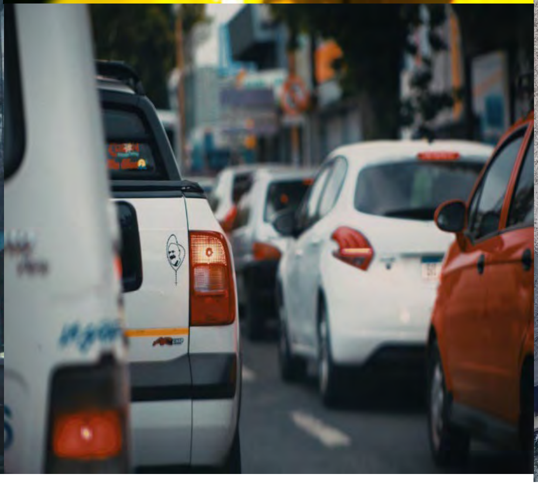
Barcelona case study

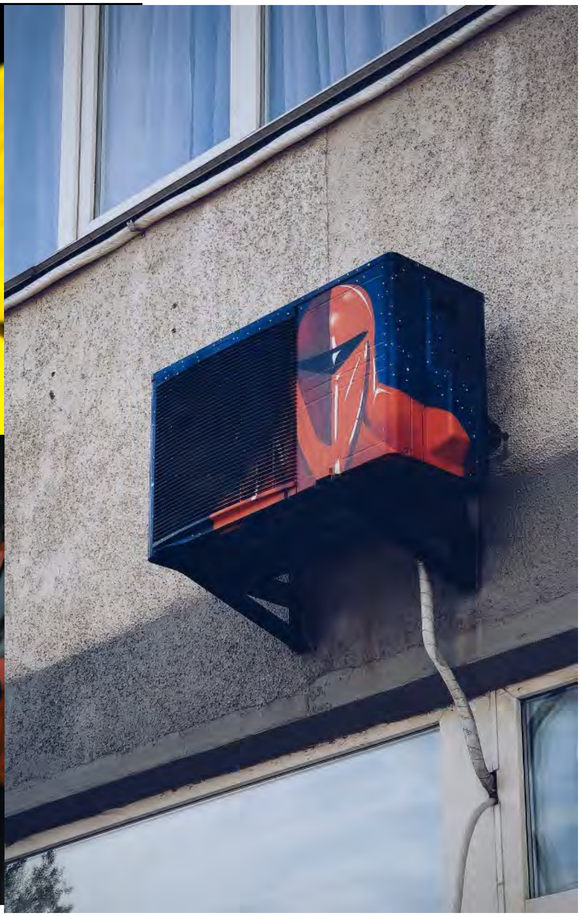


https://www.bloomberg.com/news/articles/2020-11-11/barcelona-s-new-car-free-superblock-will-be-big https://www.nytimes.com/2016/10/02/nyregion/what-new-york-can-learn-from-barcelonas-superblocks.html

Fostering urban green spaces with superblocks?

- Cities define canopy coverage goals
- Mininum number of green space per person
- Accessibilty to public green space for inhabitans





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Call for integrated thinking: Affects multiple infrastructure systems

- Mobility, buildings, water …

- Multiple implications
  - Ecology (e.g. biodiversity)
  - Energy (urban heat island)
  - Water
  - Noise
  - Mobility
  - …

Ecosystem services
&
Disservices

https://www.bloomberg.com/news/articles/2020-11-11/barcelona-s-new-car-free-superblock-will-be-big

Re-thinking streets

Rotwandstrasse

Rotwandstrasse

https://www.stadt-zuerich.ch/ted/de/index/taz/gestalten/brings_uf_d_strass.html

https://www.bild-video-ton.ch/bestand/objekt/Sozarch_F_5146-Fb-1199

Spielstrasse Aegerten-/Erlachstrasse, provisorisch", Zürich 1974

Multifunctional streets and urban green

Source: https://medium.com/dark-matter-and-trojan-horses/daylighting-melbourne-how-we-can-transform-our-cities-street-by-street-2345410741


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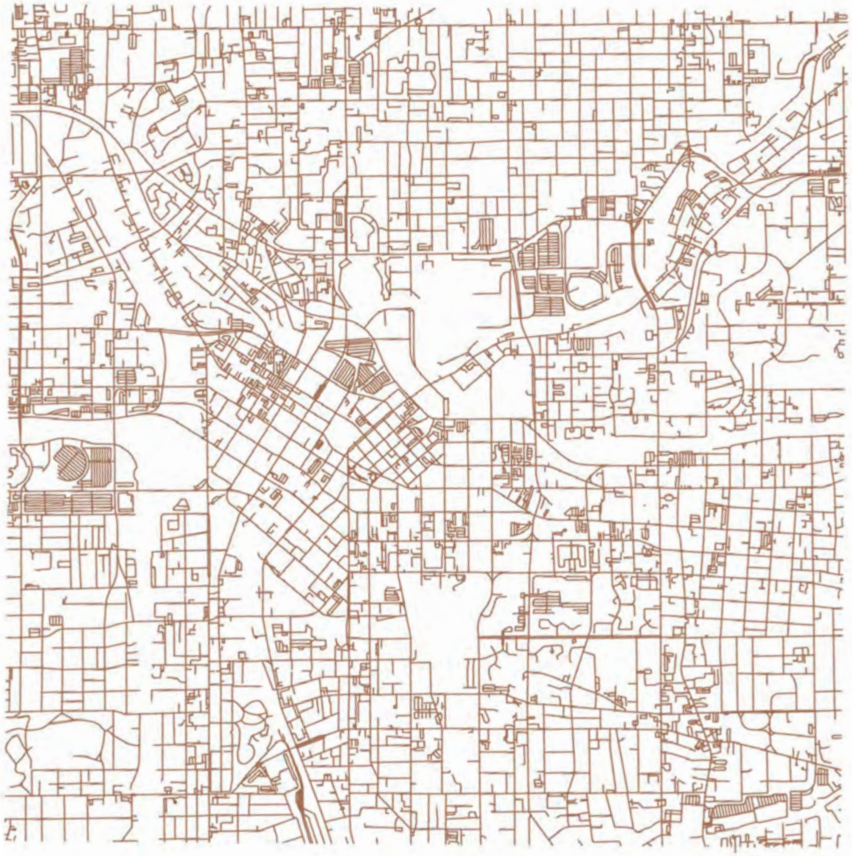
Where?



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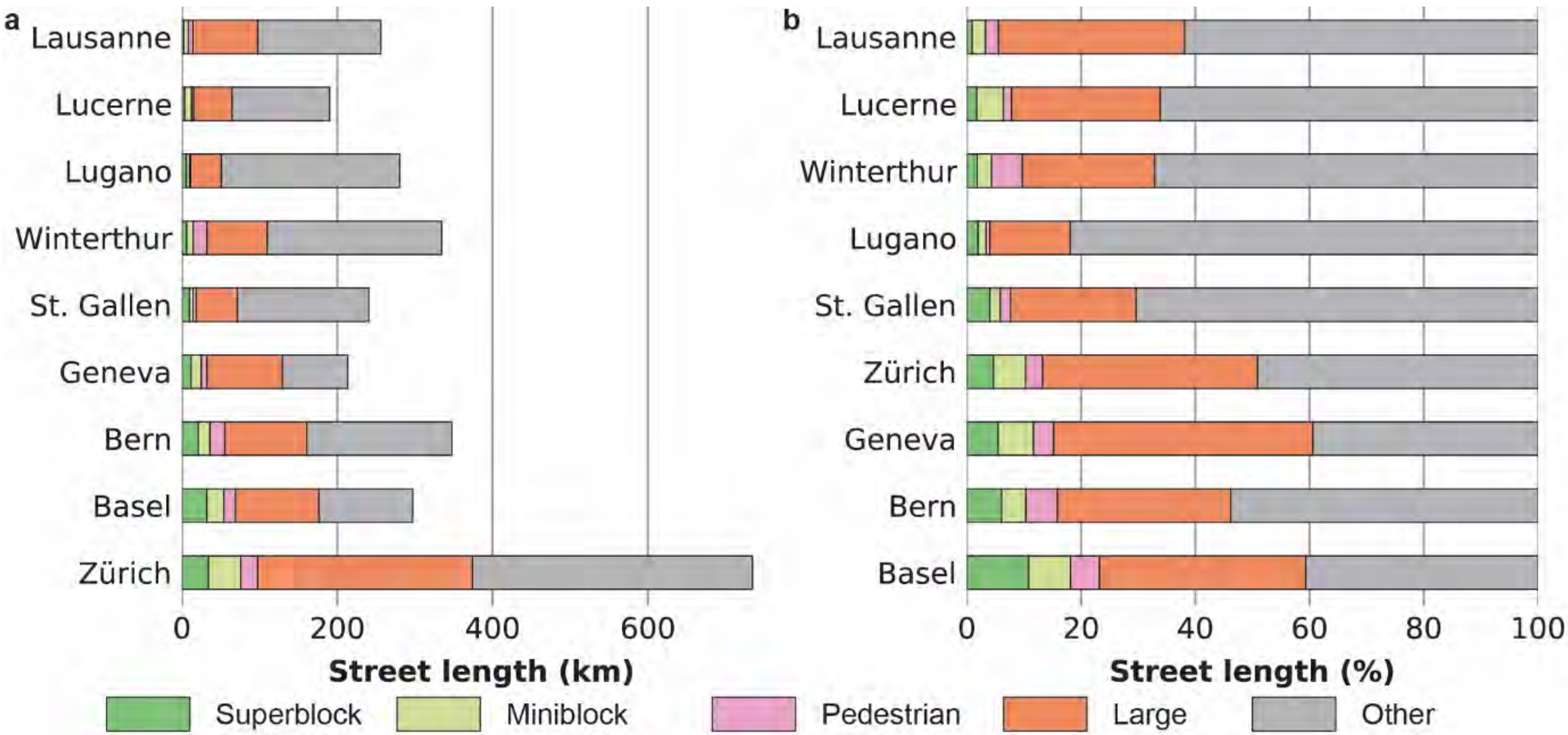
Superblock opportunities in Switzerland



- Between **3 – 18%** of street network potentially suitable for superblock design

Eggimann (under review): Expanding urban green space with superblocks

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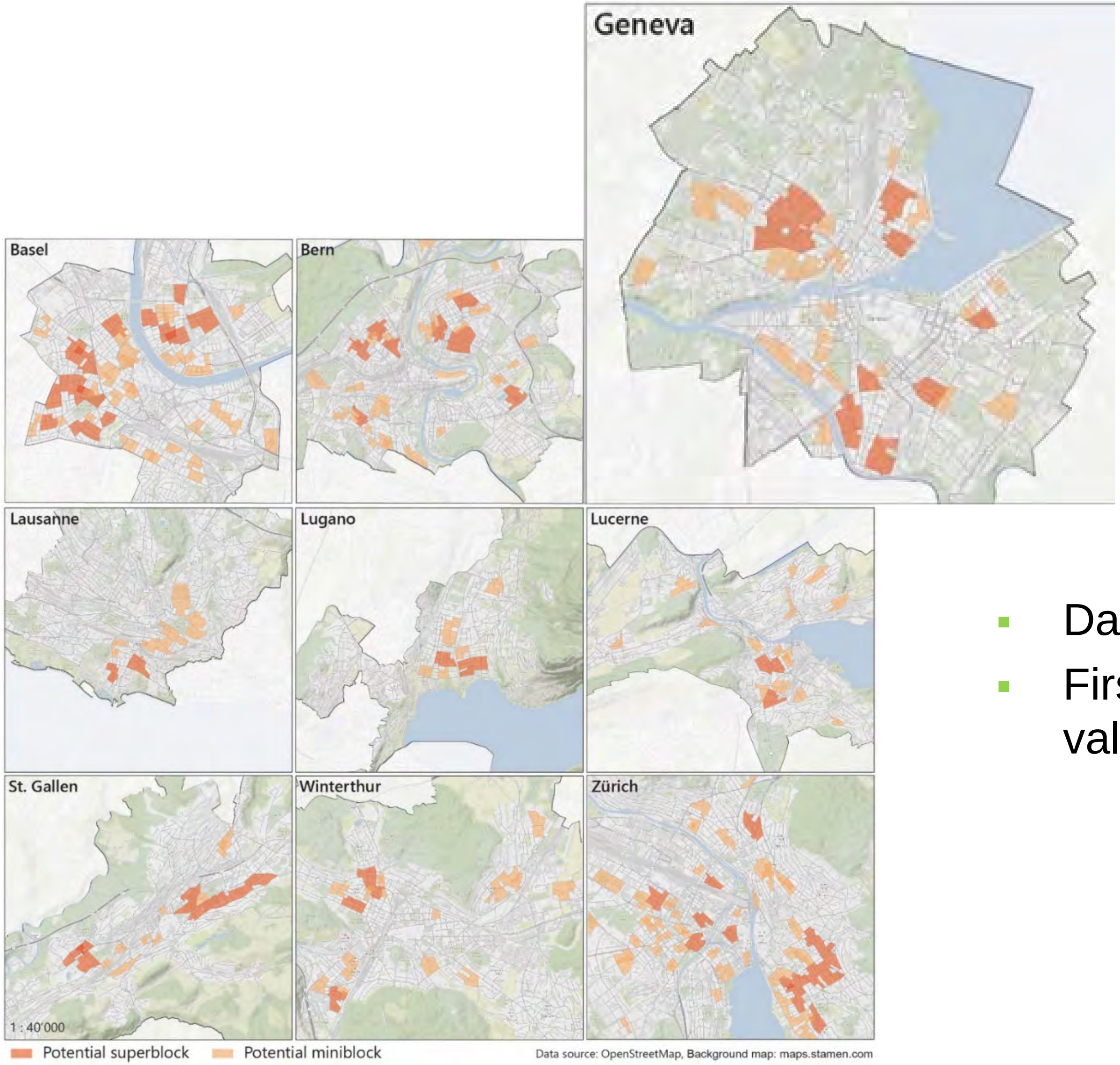
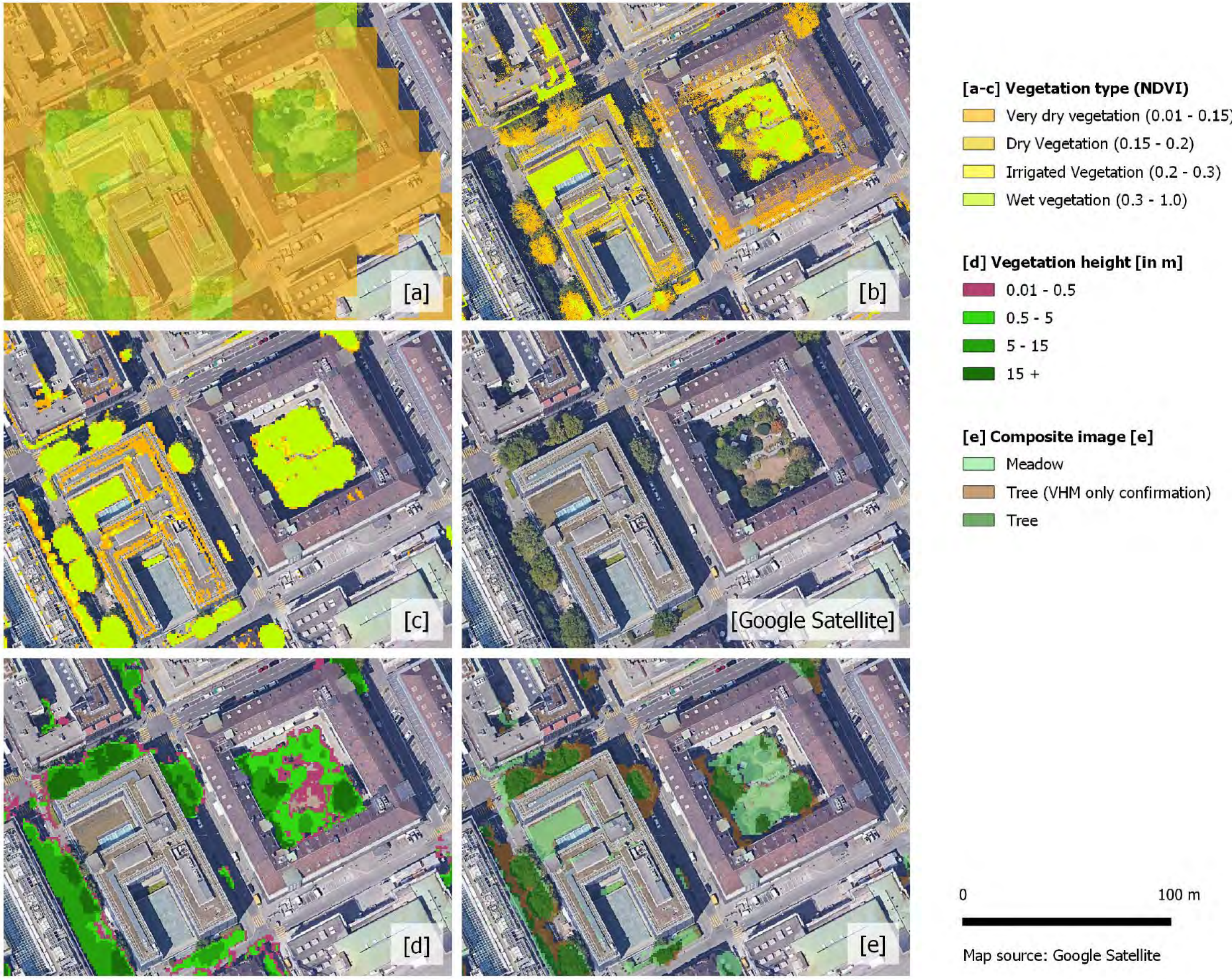
Identification of superblock design opportunities



- Data-driven identification
- First screening for follow-up validation

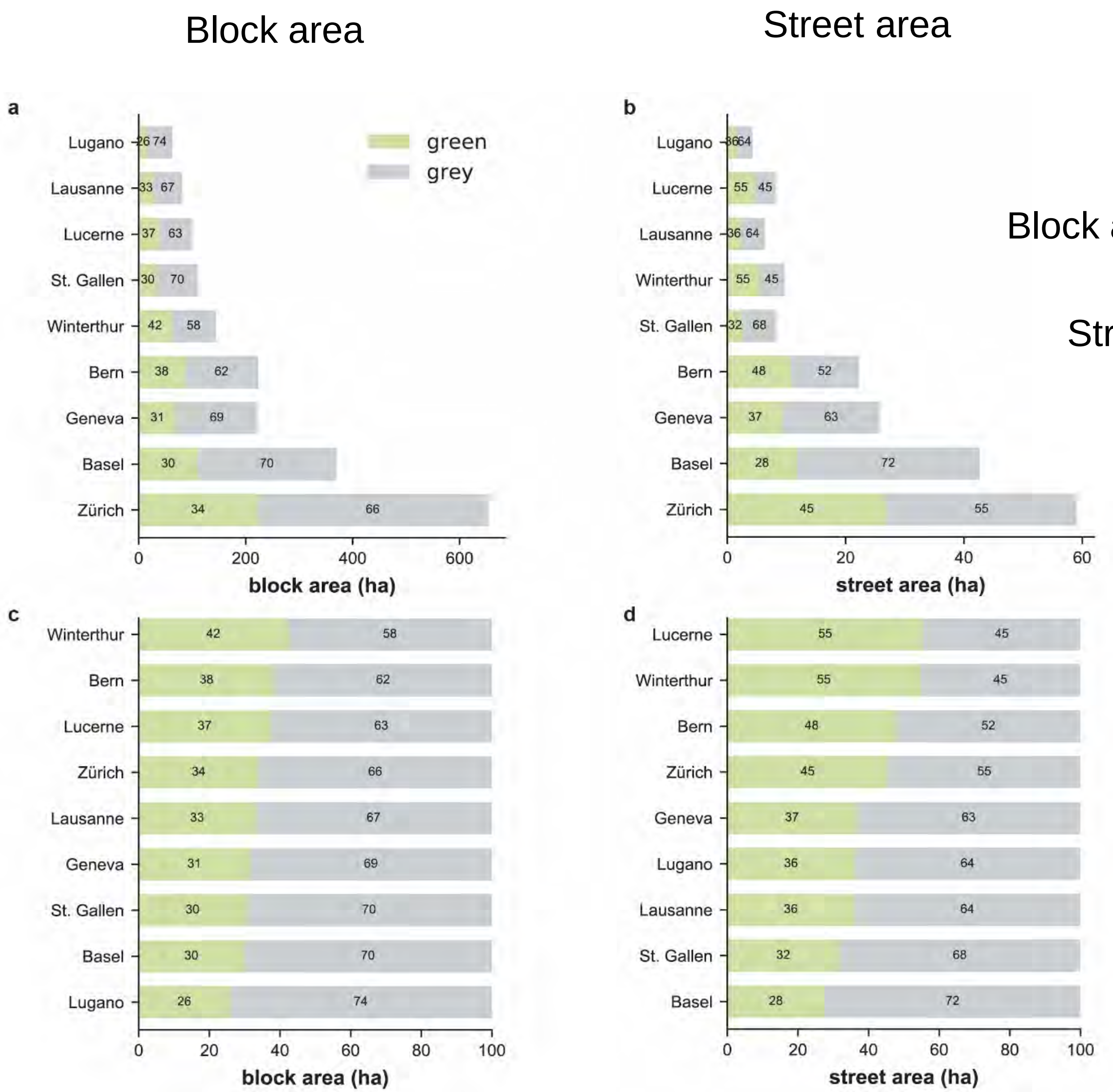
Eggimann (under review): Expanding urban green space with superblocks

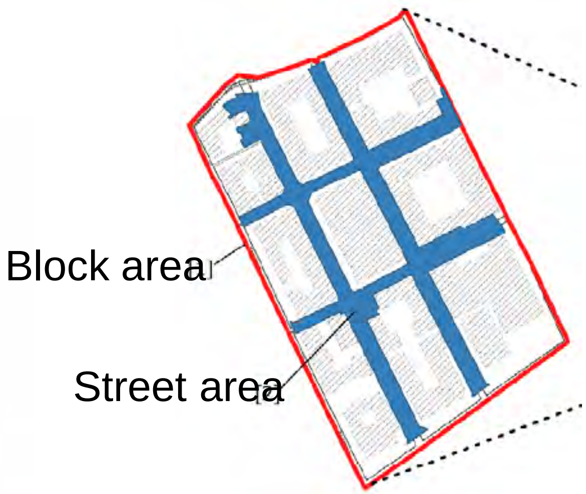
Analysis of current urban green



Lischer (2021)

Urban green space in superblocks





- Street area is smaller than block area
- Largest absolute potential street space in Zürich and Basel
- Street space greenest in Lucerne, least green in Basel

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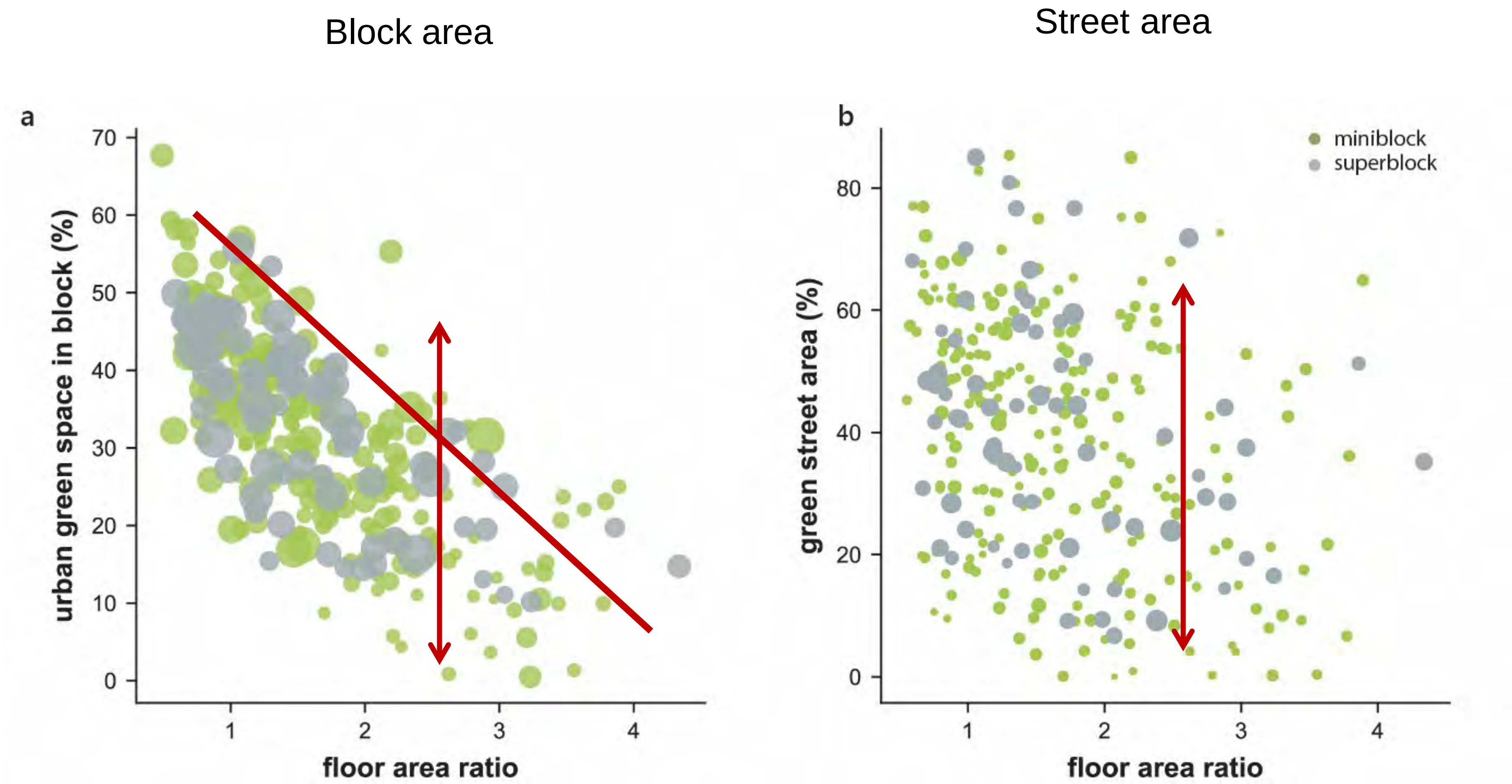
Densification and urban green space



- Perceived density and urban green space
- Urban green space as an argument against densification

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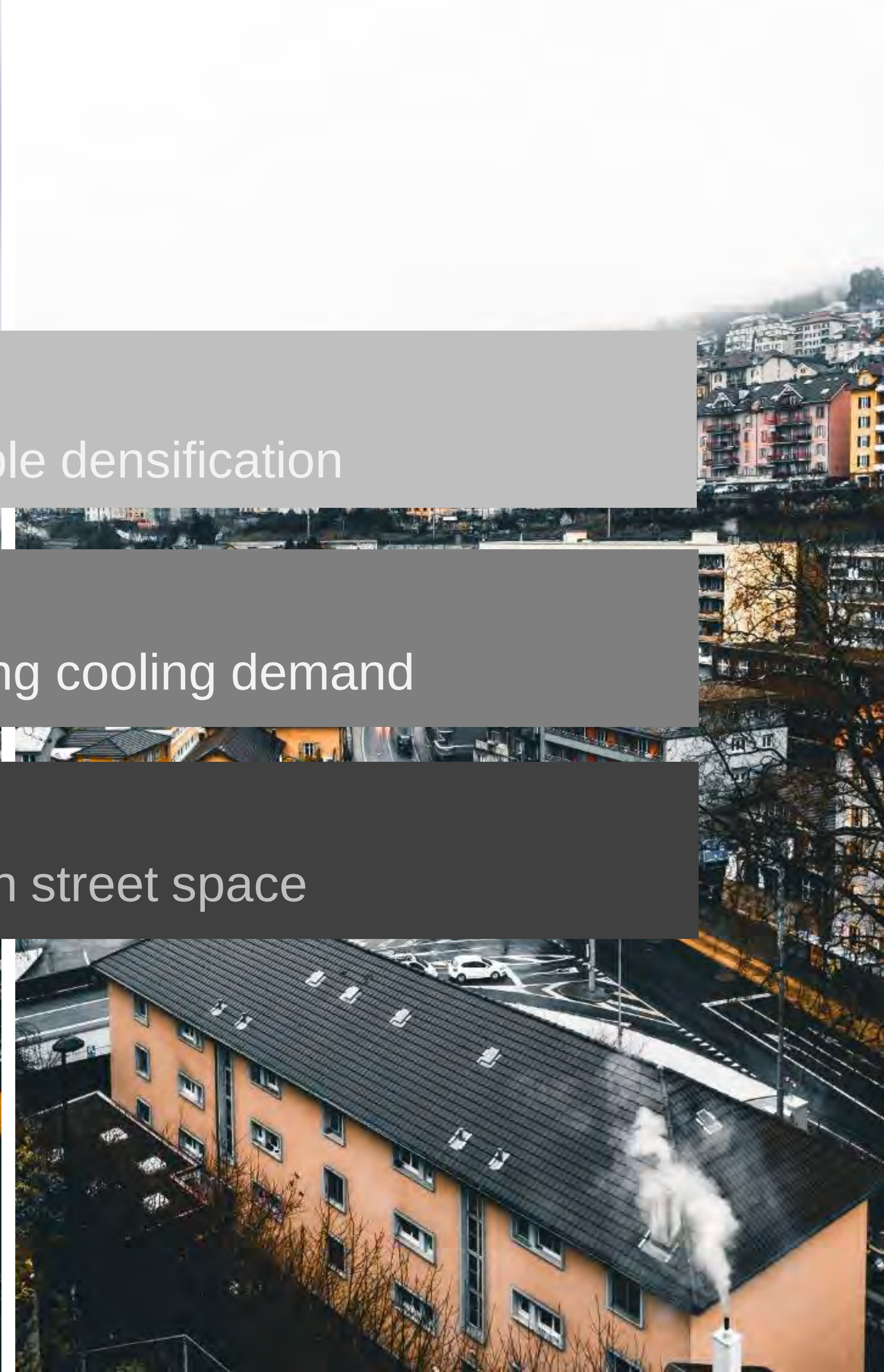
Sweden says goodbye to parking spaces, hello to meeting places

Where have all the cars gone?   Image: LundbergDesign/ArkDes/Elsa Soläng

Lessons learnt

- Superblocks are an **interesting opportunity** to foster urban green in cities
- Green and dense: **Trade-off** was identified, but street space can potentially reduce this trade-off.
- System-of-system analysis: **Integrated tackling** of challanges (mobility, urban heat, densification,…)
- **Socio-technical system**: Manifold implementation challenges lie ahead



Urbanization

Opportunities for sustainable densification

Climate Change

Climate change and building cooling demand

Urban Green space

Superblocks: transformation street space

Concluding remarks

- Cities and infrastructure systems require **fast sustainability** transition to address multiple and complex challenges.
- Re-thinking current infrastructure systems requires **embracing novel paradigms**
  - Urbanization: Geography of densification
  - Cooling challenge: Consider supply and demand side
  - How we design cities: Climate change adaptation and mitigation with urban green infrastructure
- Call for research **bridging** other infrastructure sectors and disciplines
  - Integrated analysis of multiple infrastructure sectors
  - Socio-technical systems
- Times of crisis as a window of opportunity to drive change