sccer | future energy efficient buildings & districts

Spatial analysis of DHN potential in Switzerland

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Supported by

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
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Swiss Confederation

Innosuisse – Swiss Innovation Agency

Research aims

- SCCER FEEBD **"National energy solutions"**

- Aim to produce maps of technical solutions which can be cross-linked to produce local and national recommendations
- What is the relation between District Heat Networks (DHN) potential and renovation scenarios?
- What is the potential for supply of DHN using Industrial Excess Heat (IEH)

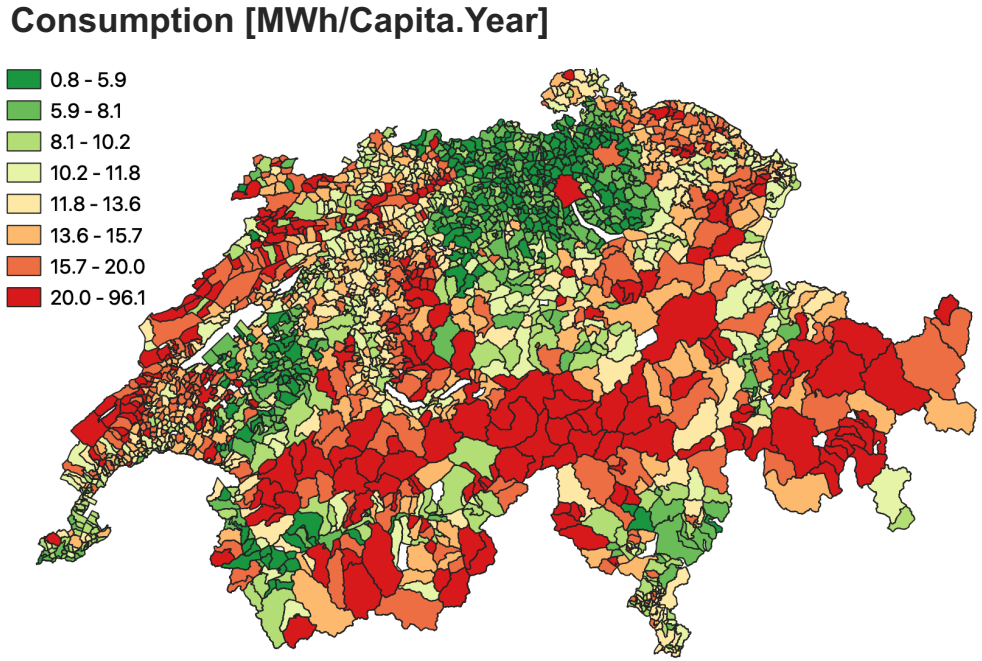
Chambers, J., Narula, K., Sulzer, M., Patel, M.K., 2019. Mapping district heating potential under evolving thermal demand scenarios and technologies: A case study for Switzerland. Energy 176, 682–692.

Chambers, J., Zuberi, J.S., Narula, K., Patel, M.K., 2019. Mapping district heating potential under evolving thermal demand scenarios and technologies: A case study for Switzerland. Energy (Under Review)

District Heat Networks Mapping

- Compared DHN potential map under different demand scenarios
  - Current demand
  - SwissRes retrofit solution packages
- Compare High and Low temperature DHN
  - HTDH
  - LTDH

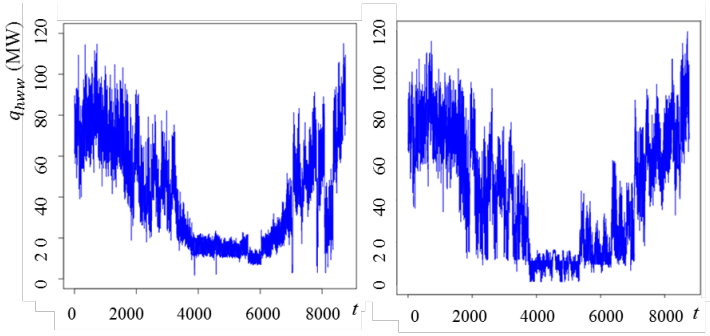
Spatio-temporal characterisation of **heat** demand



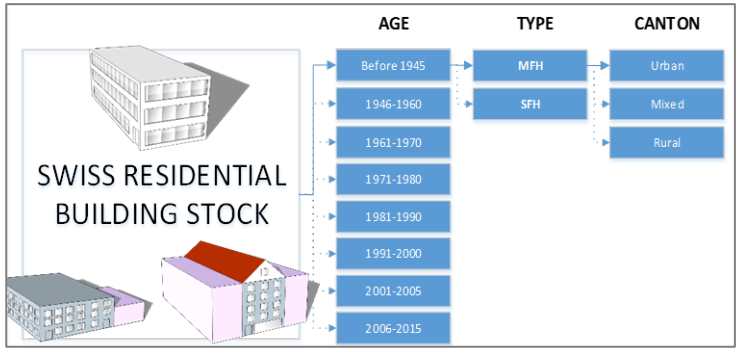
Total yearly heat demand per capita

Three approaches for spatio-temporal analysis (ongoing work):

- **Regression** analysis based on measured data



- **Static building model** (SwissRes)

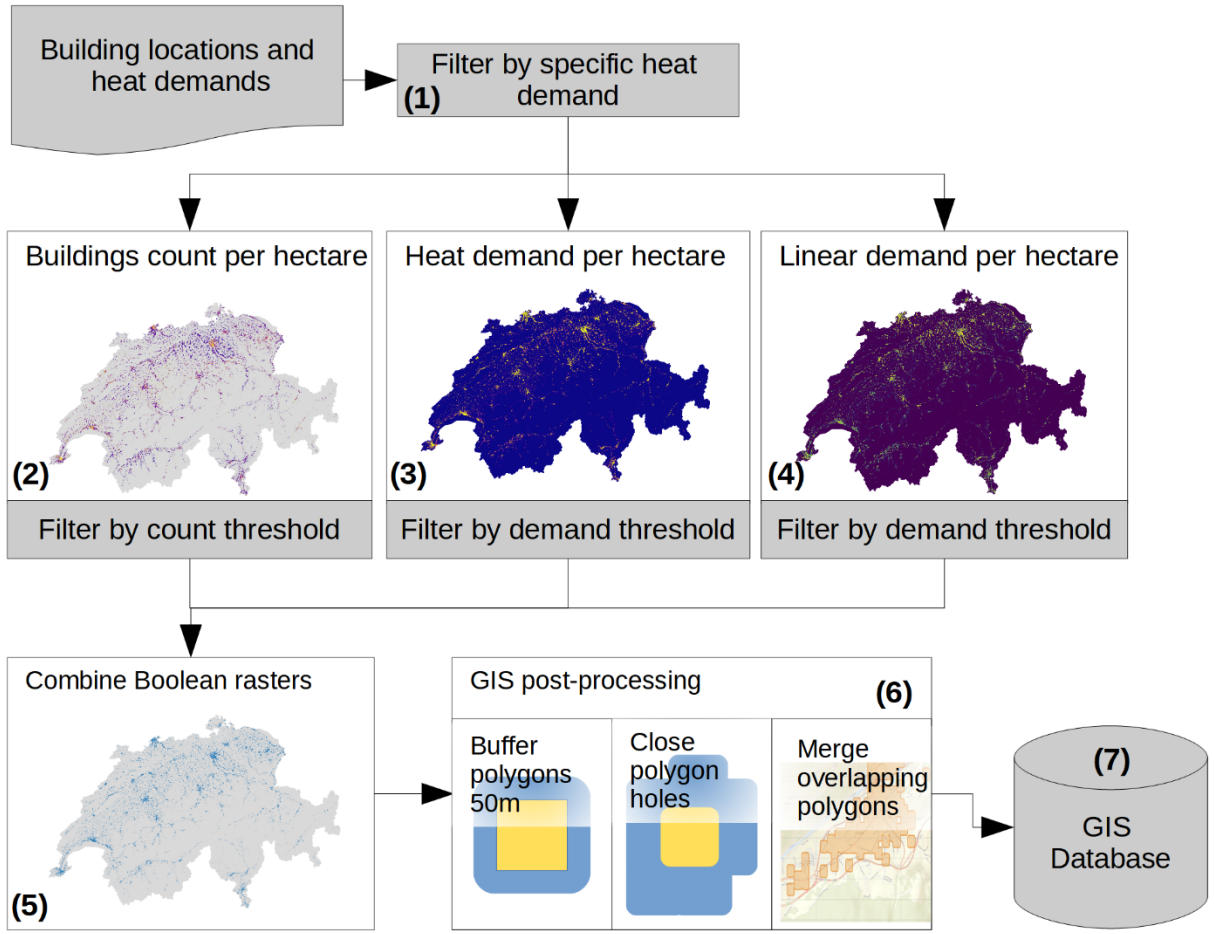


- **Dynamic model** (collaboration ETHZ)

Schneider et al., 2017; Schneider et al., 2019
Streicher et al., 2019 a,b

District Heat Networks Mapping Method

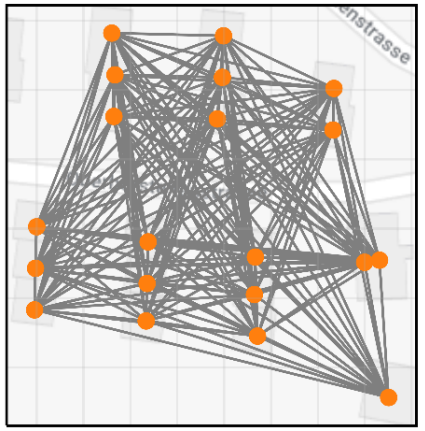
- Apply a 'decision matrix' on spatial data
- Building density from RegBL
- Specific heat from building model
- Spatial heat density from gridded analysis
- New method to estimate linear heat density



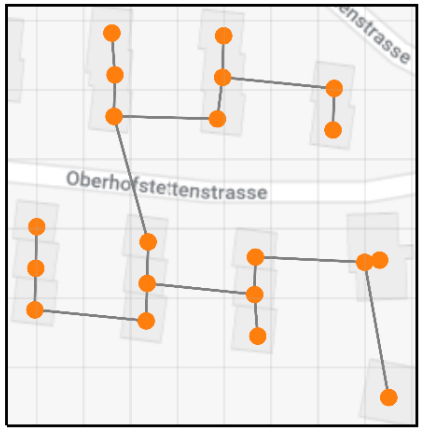
Linear heat density

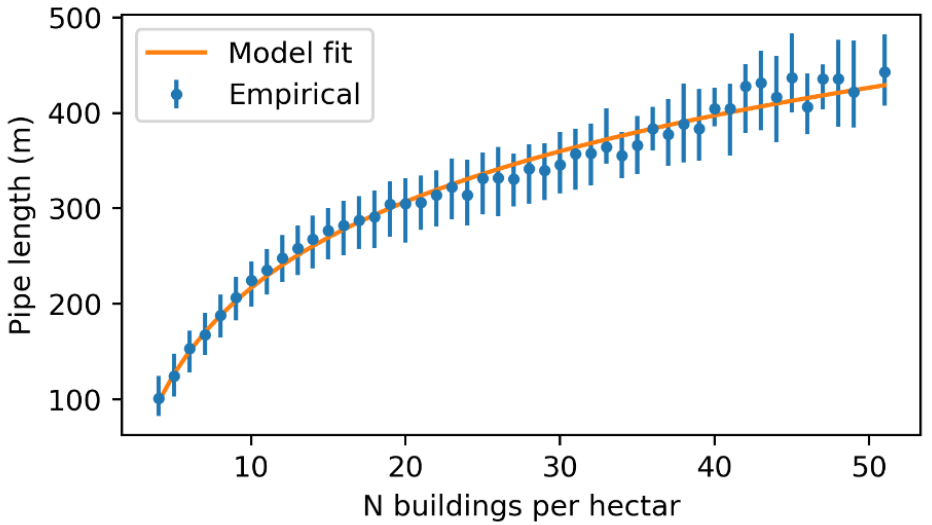
- Calculating pipe length for every pixel is unnecessary
- Only determinant for MST length is number of buildings per hectare
- Calculate pipe length over a range of buildings per hectare
- Fit a function to rapidly estimate minimum pipe length per hectare

a) Fully connected network



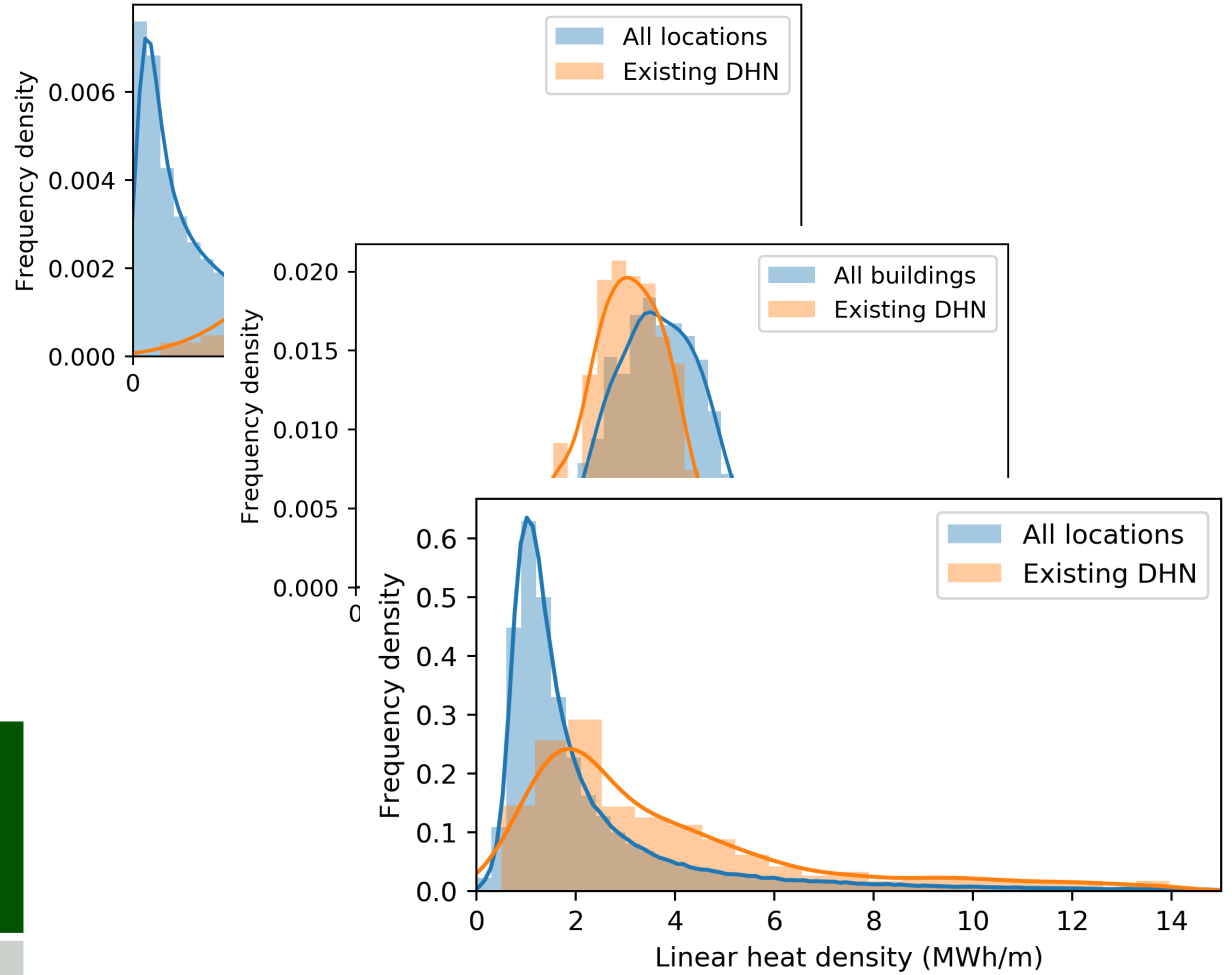
b) MST network





Validate decision matrix against existing DHN

- Combine literature results and observations to generate a decision matrix
- HTHN and LTHN heat networks with different thresholds
- Use values from literature cross-referenced with observed values

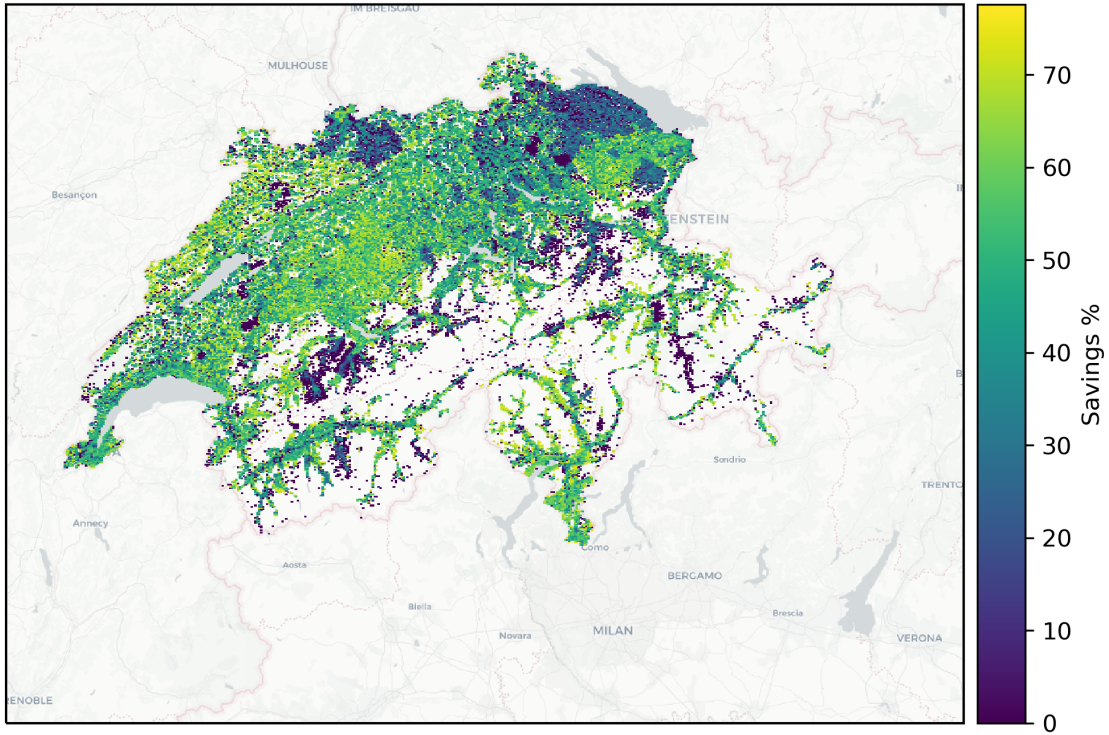


DHN Type	Spatial head demand density (MWh/ha)	Specific heat demand density (kWh/m2)	Linear demand density threshold (MWh/m.yr)
HTHN	>150	>40	2
LTHN	>150	0-60	1

Retrofit model

- Technical potential scenarios
- All buildings renovated.
- SwissRes Scenario (Streicher et. al 2017)
- Archetype based retrofit model
- All buildings to Minergie standard
- Match retrofit package to individual buildings based on archetype

Map of SwissRes projected space heating savings %



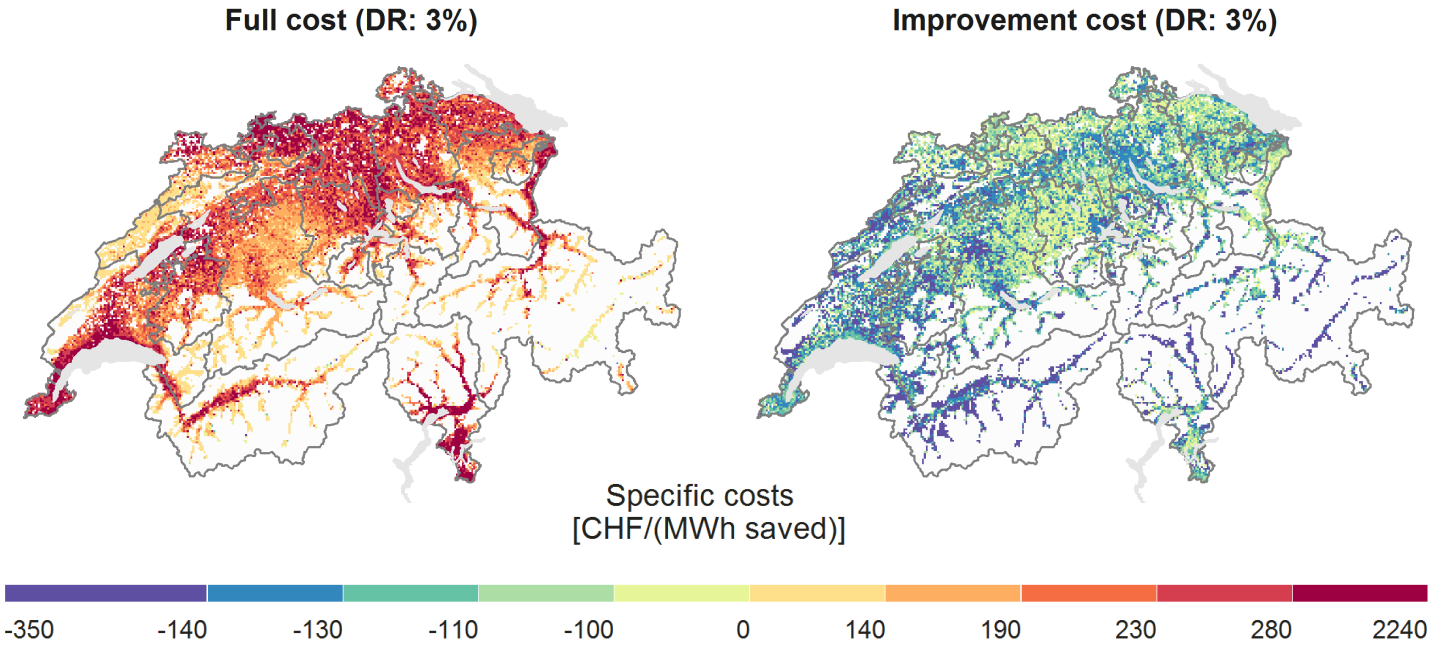
Map illustrating varying spatial distribution of space heating savings percentages in the SwissRes scenario.

Streicher, K.N., Parra, D., Buerer, M.C., Patel, M.K., 2017. Techno-economic potential of large-scale energy retrofit in the Swiss residential building stock. Energy Procedia 122, 121–126.

Building retrofit potentials

- **Energy retrofit** to Minergie standard

- **Three approaches** for **cost-effectiveness** analysis:
  - **"Full cost":** Total cost of retrofitting
  - **"Improvement cost":** Additional cost relative to standard renovation (i.e., Total cost minus "Anyway-cost")
  - **"Depreciation approach":** assigns a residual value to old buildings, leading to increased cost for early energy retrofit



- "Depreciation approach" may be considered as most realistic
- Results of "Depreciation approach" lie in-between "Full cost" and "Improvement cost"

Streicher et al., 2018, Streicher et al., 2019a,b

Building retrofit potentials

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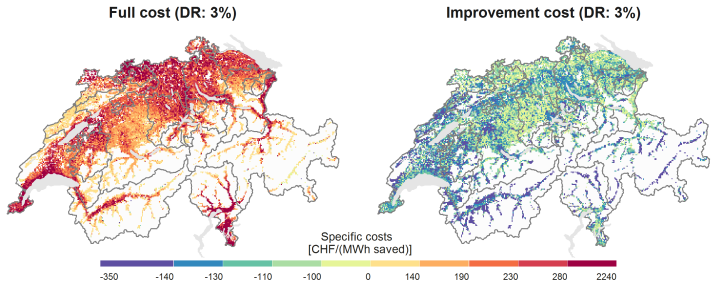
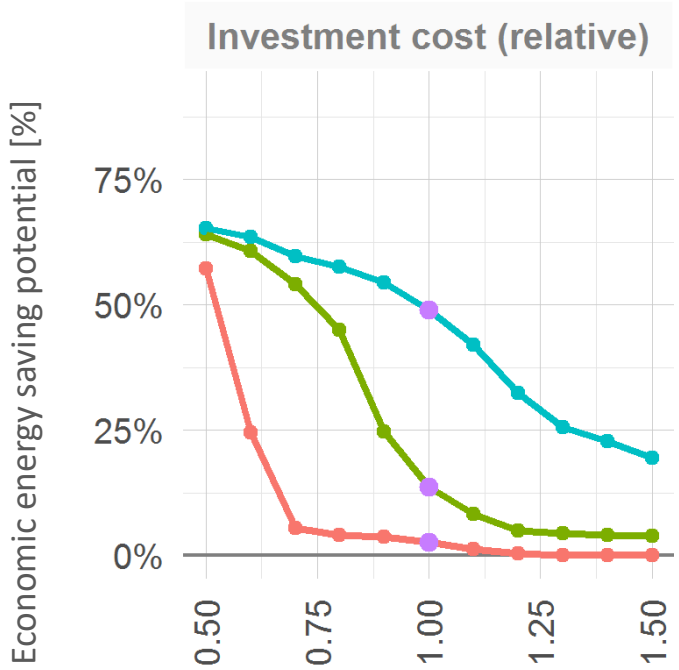
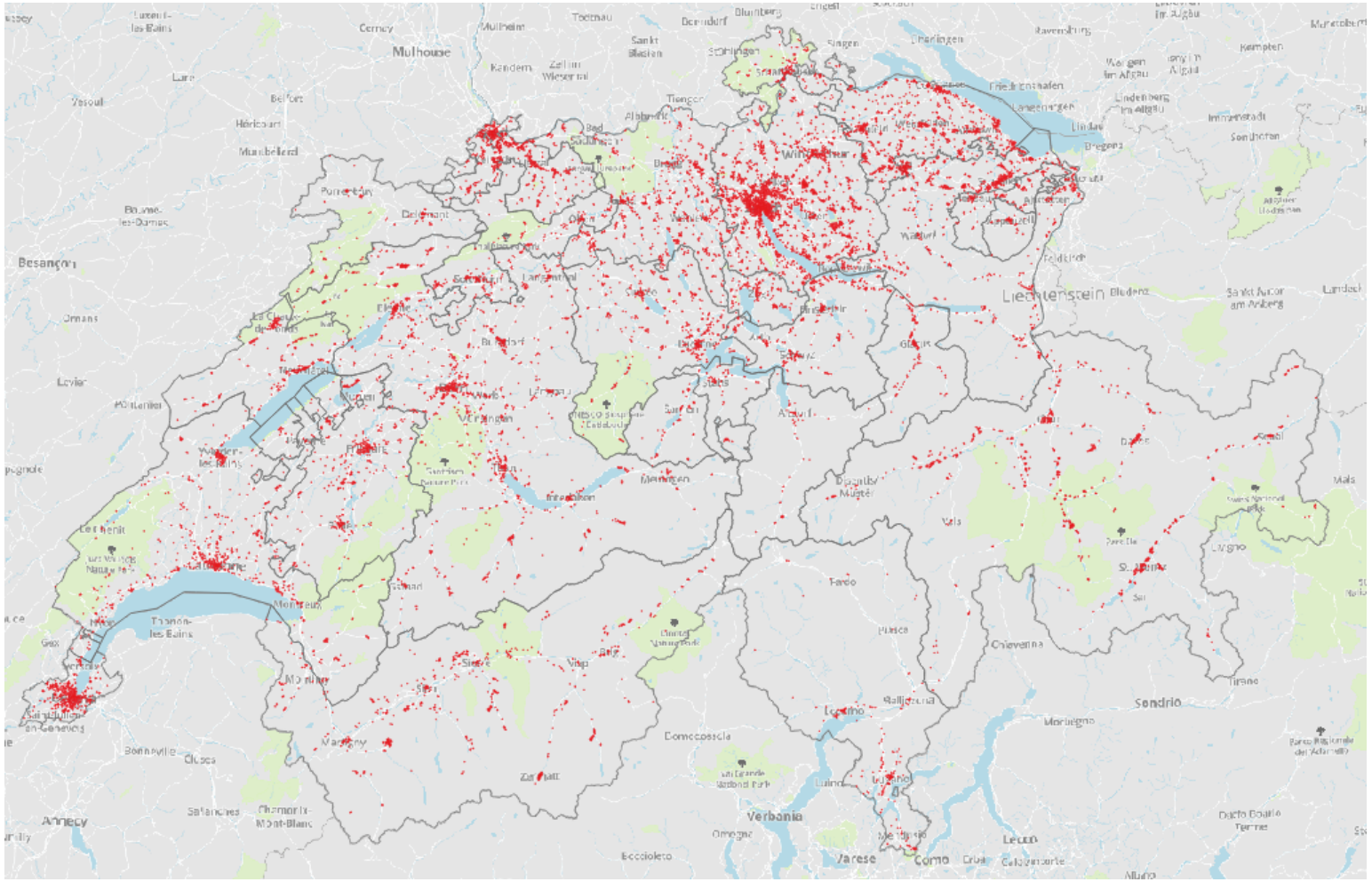
- **Sensitivity analysis**
  - Large impact of high Swiss investment costs relative to rest of Europe
  - Increased openness to European market could decrease costs





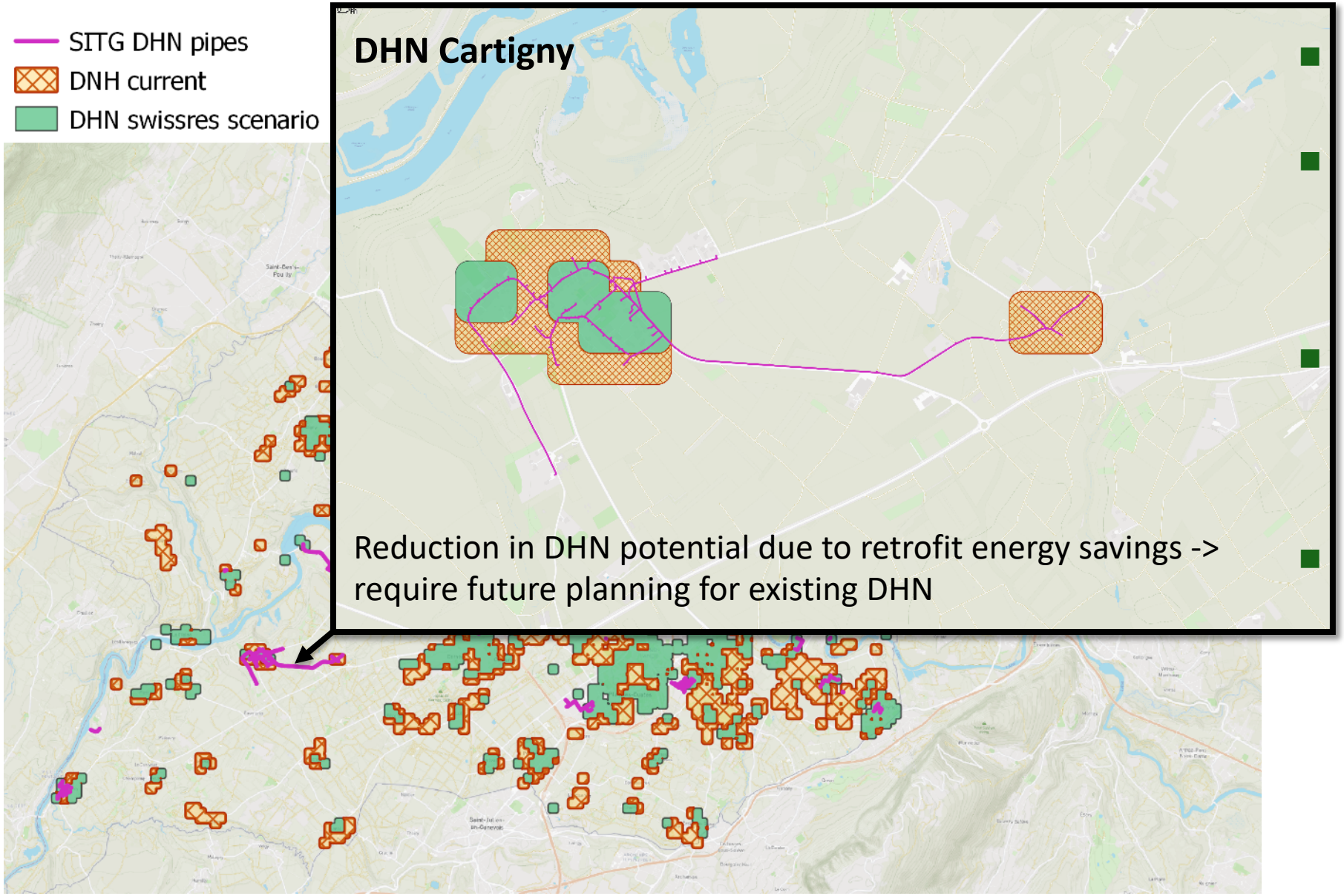
Streicher et al., 2018, Streicher et al., 2019a,b

National map of DHN hotspots



- Example map showing potential regions using current (high temperature) DHN, after energy demand reduction by retrofit (Swissres model).
- Evidence of ‘mega clusters’ (e.g. Zurich region)

Change in DHN potential under renovation scenarios



- Zoom into Geneva region
- Compare DHN area before and after application of retrofit model
- Demonstrate that reduced energy density leads to reduction in potential area
- Show that existing networks are affected

Change in DHN potential under renovation scenario

	Current HTHN	Current LTHN	Swissres HTHN	Swissres LTHN
Total heat demand all buildings TWh	94.3	94.3	59.2	59.2
Total heat demand in DHN TWh	61.7	2.3	44.4	38.2
Percent heat demand in DHN	65.4%	2.44%	74.9%	64.5%
Number of DHN	7773	1019	6412	3956
Number of buildings in DHN	898716	33951	484882	511343
Percent of buildings in DHN	45.2%	1.71%	24.4%	25.7%

Both total heat decreases but percentage increases!

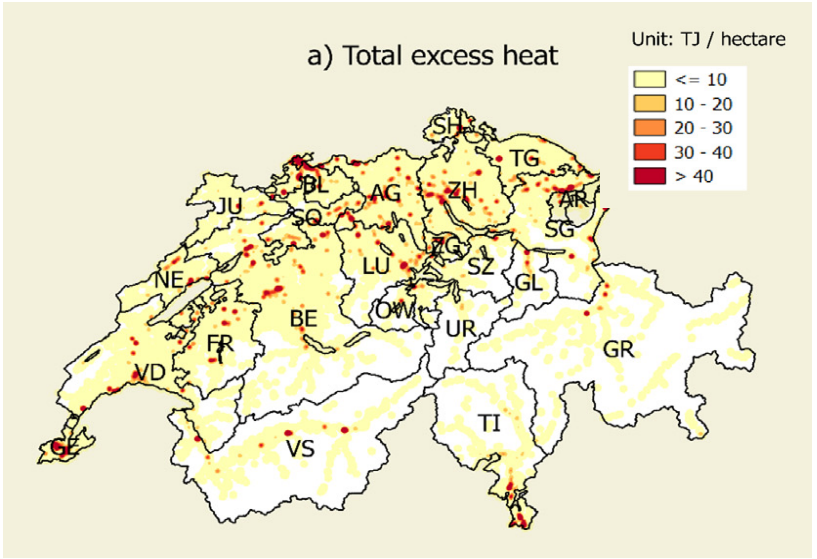
Large reduction in percentage of buildings

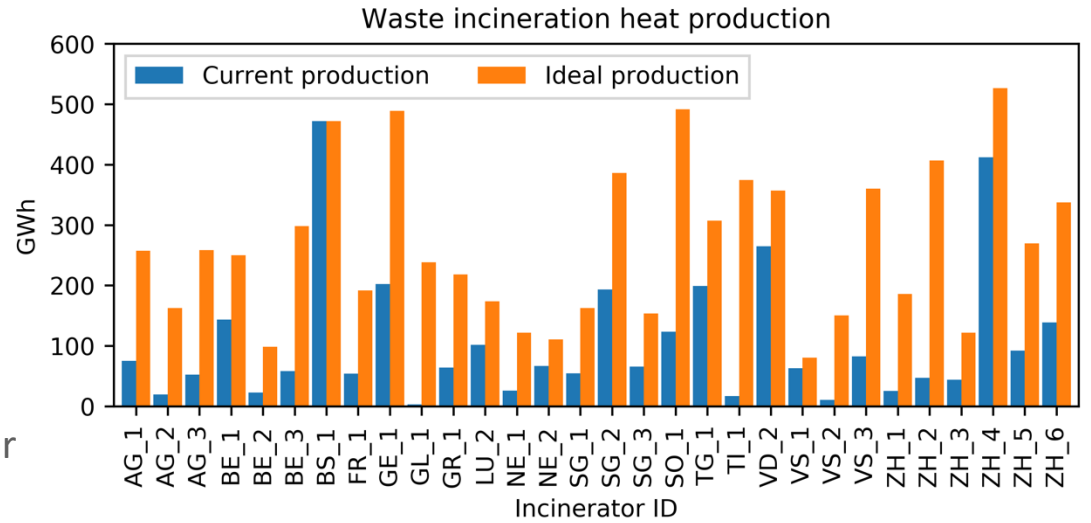
DHN applies mostly to high density areas

Currently very small % suitable for LTHN, but could grow substantially

Spatiotemporal analysis of industrial excess heat supply for district heat networks in Switzerland

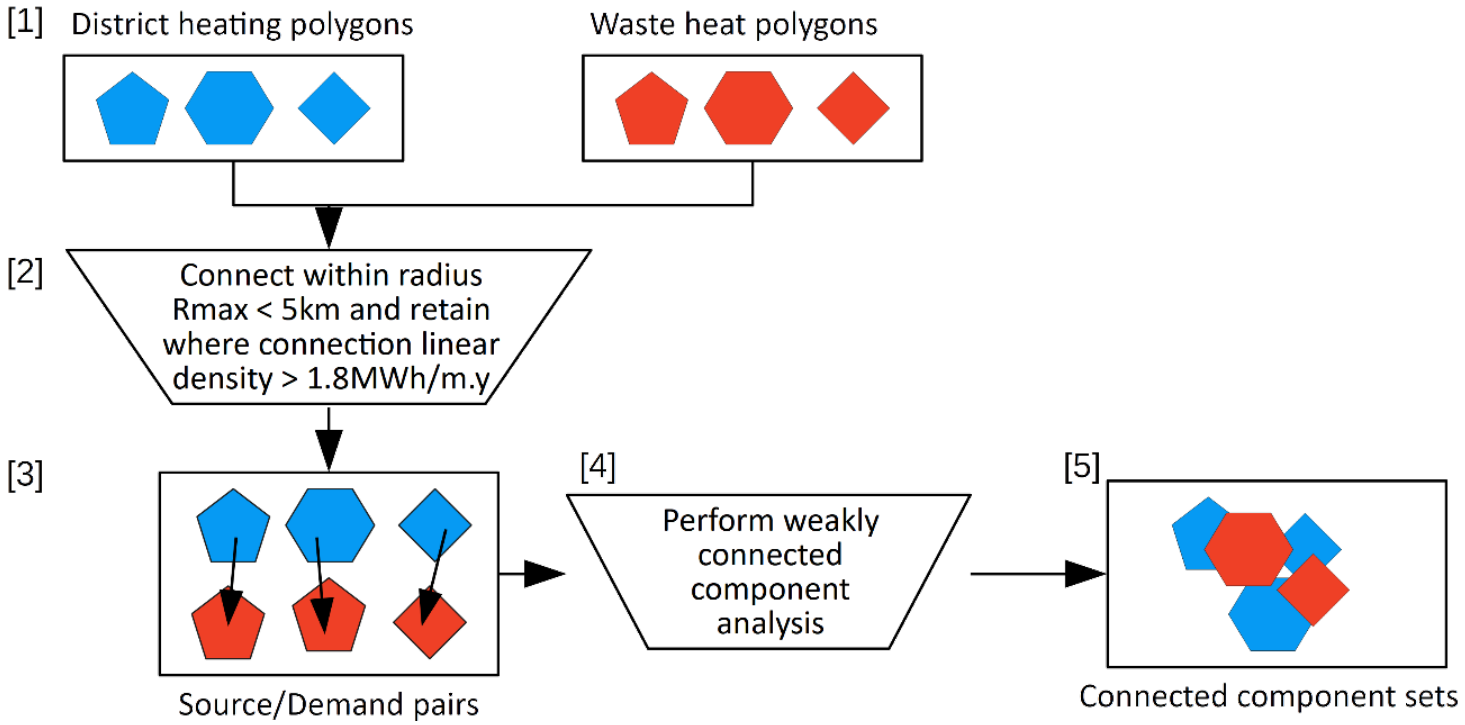
- 12TWh/year IEH supply
  - 8TWh from waste incineration
  - 4TWh from industrial processes (Zuberi et. al 2018)
- Spatial clustering using graph theory to group heat sources and demands
- Calculate monthly heat balance per cluster to determine usable IEH
- Compare current demand and SwissRes retrofit scenario

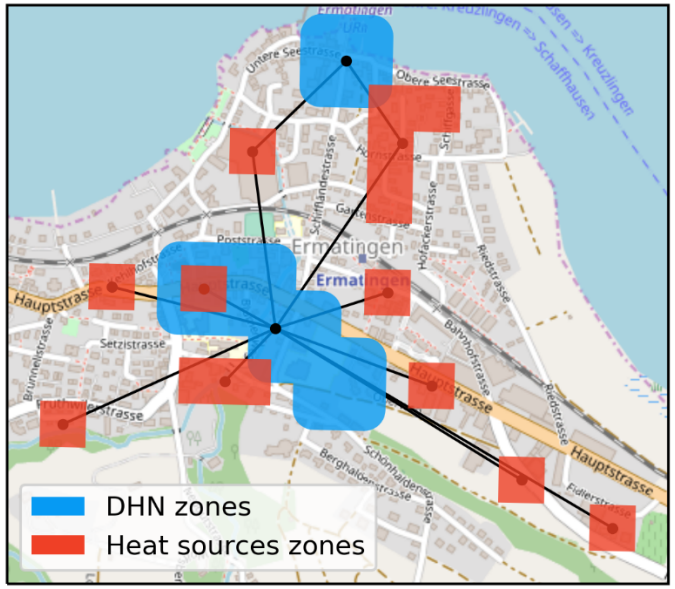




Zuberi, J.S., Bless, F., Chambers, J., Arpagaus, C., Bertsch, S.S.S., Patel, M.K.M.K., 2018. Excess heat recovery: An invisible energy resource for the Swiss industry sector. Appl. Energy 228, 390–408.

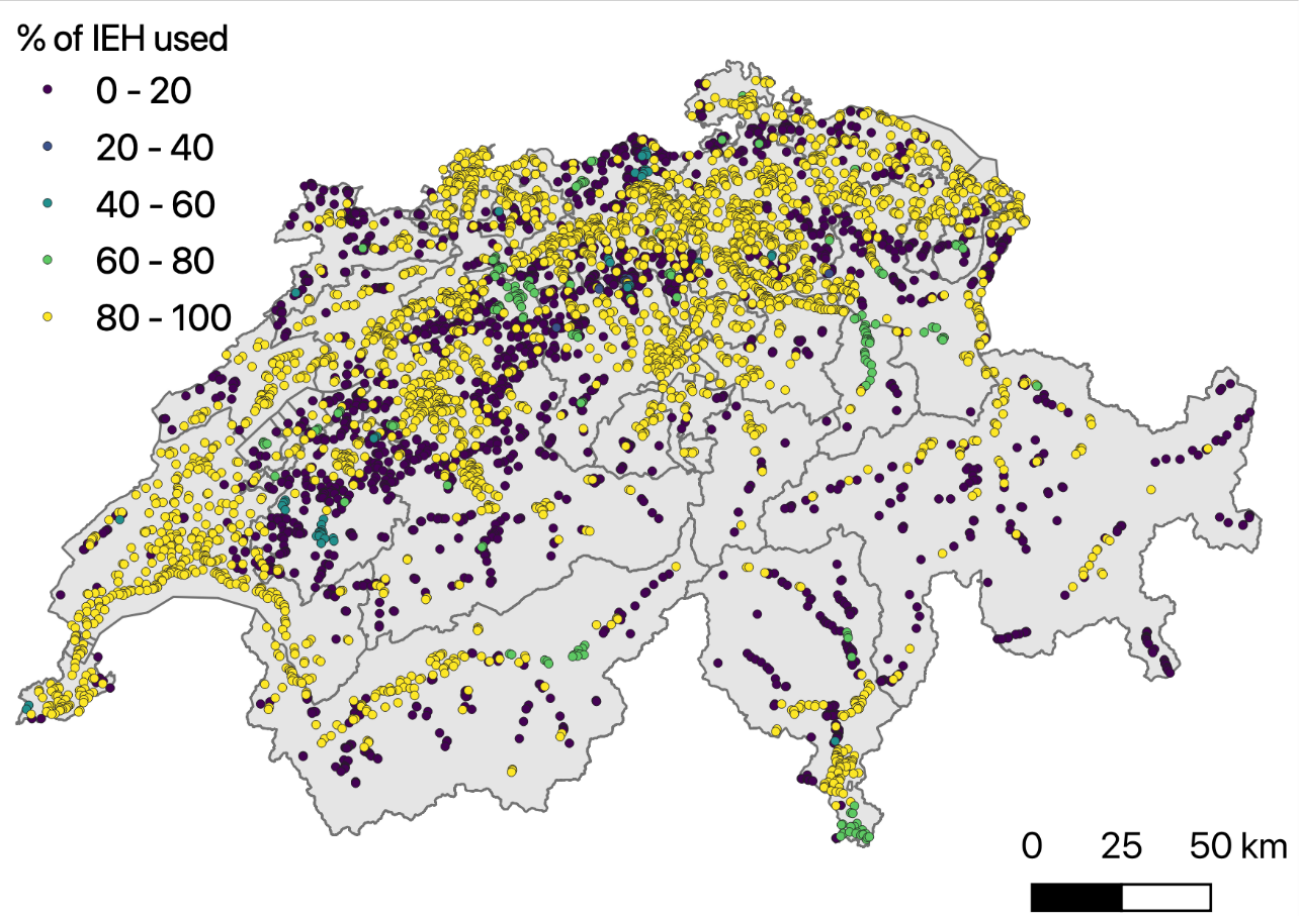
Clustering supply and demand using graph theory

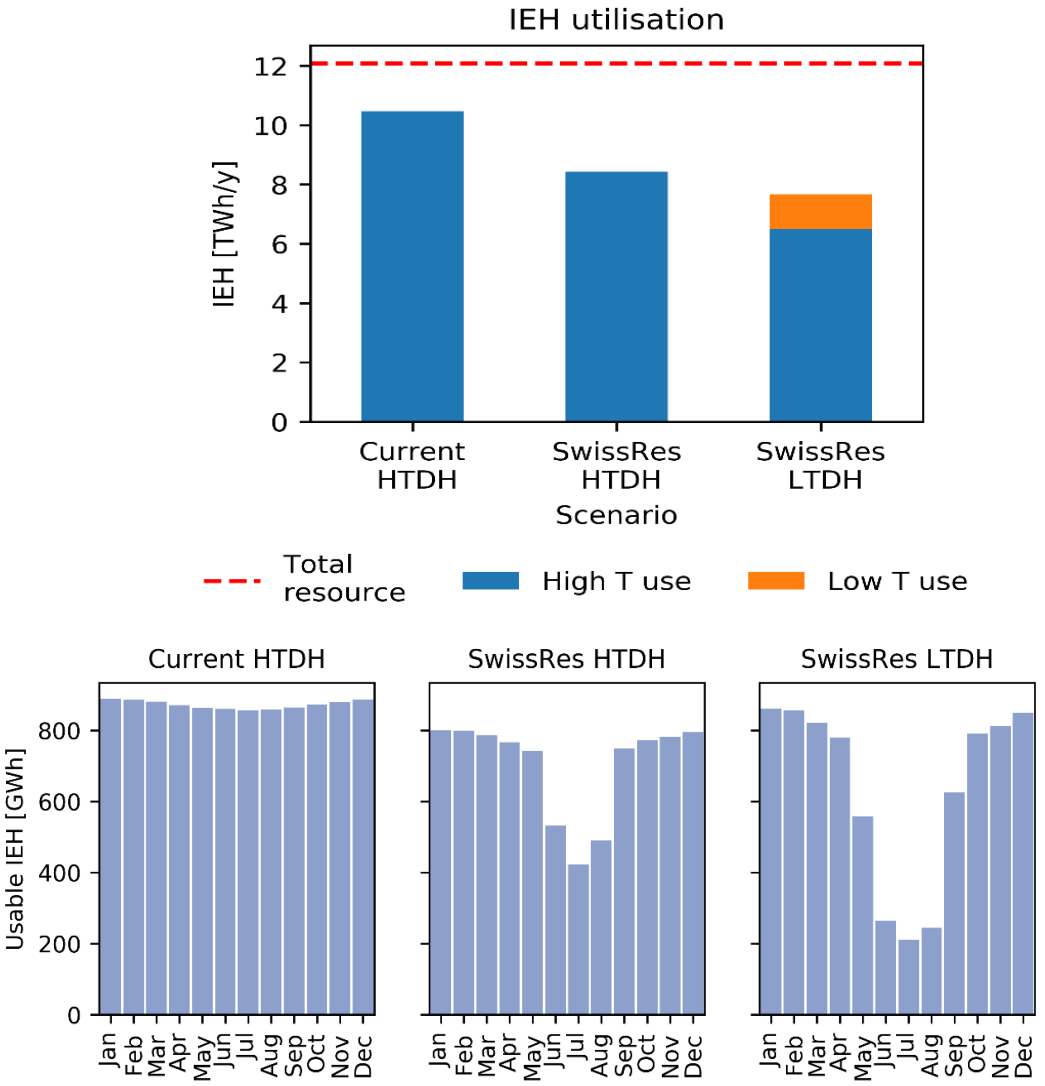




Direct theoretical IEH utilization

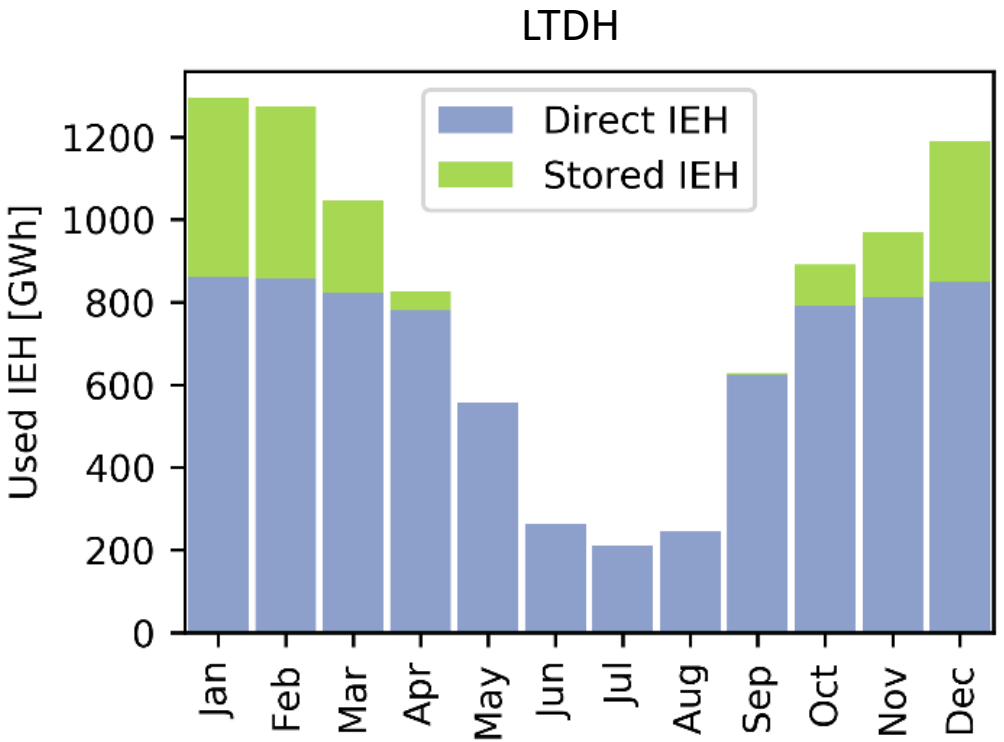
- Not all IEH can be used in any scenario due to spatial and temporal constraints





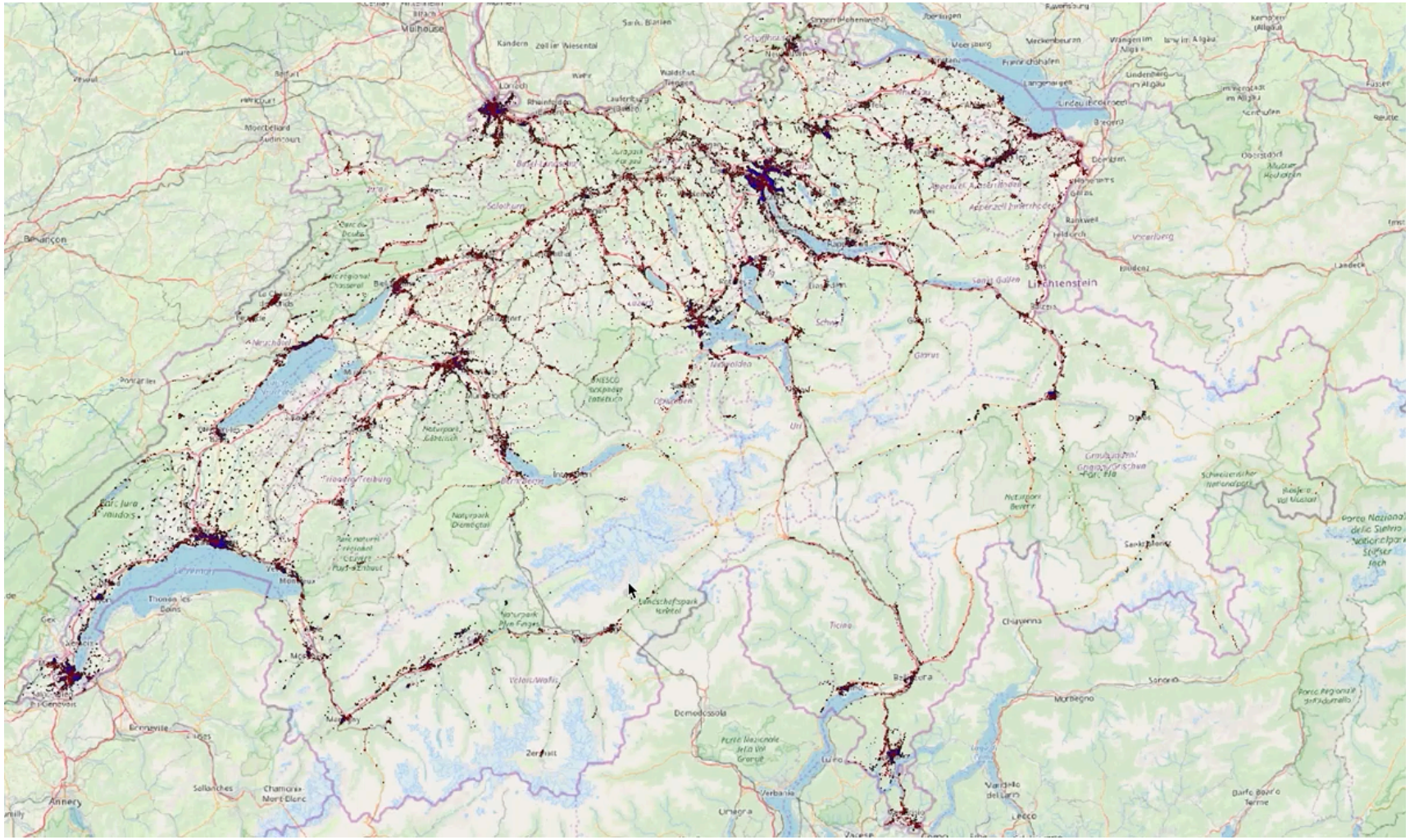
Potential for seasonal storage

- Calculate surplus IEH in summer
- Redistribute to winter months
- Mainly useful for LTDH
  - 1.72 TWh potential for stored IEH
  - Small contribution to covering total demand (extra 3.2%)
  - Allows a significant increase in IEH utilization



LTDH	Total [TWh/y]	Percentage of IEH supply [%]	Percentage of LTDH demand [%]	Percentage of total demand [%]
Direct IEH use	7.67	63.5	61	14.2
Stored IEH use	1.72	14.3	13.7	3.19
Total IEH with storage	9.40	77.8	74.7	17.4

National map of DHN: Zoom In



Brig-Glis case study

Aim

- Validate method developed at national scale with a local case study
- Demonstrate that a national scale map can produce relevant guidance for local authorities
- Highlight value of geospatial approach

Method

- Compare results directly derived from national model with Brig Glis 'Energy Masterplan'

https://www.are.admin.ch/

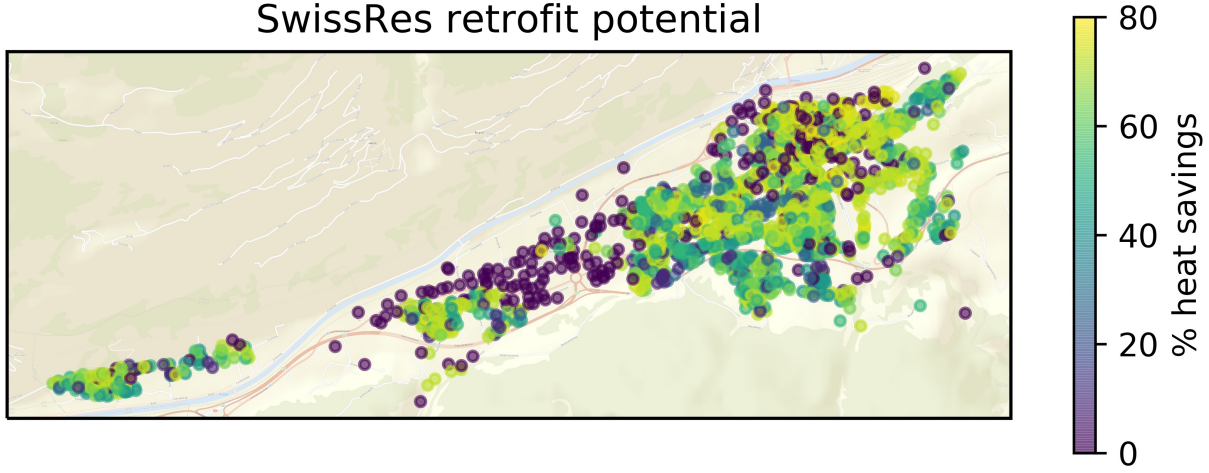
Brig Glis case study: basic validation

- 1764 buildings
- Close agreement between independent methods for current demand
- SwissRes scenario
  - Local variation in retrofit potential

Current total demand in buildings studied

Brig-Glis Masterplan	Chambers et al.	Difference
111.1 GWh	110.8 GWh	0.25%

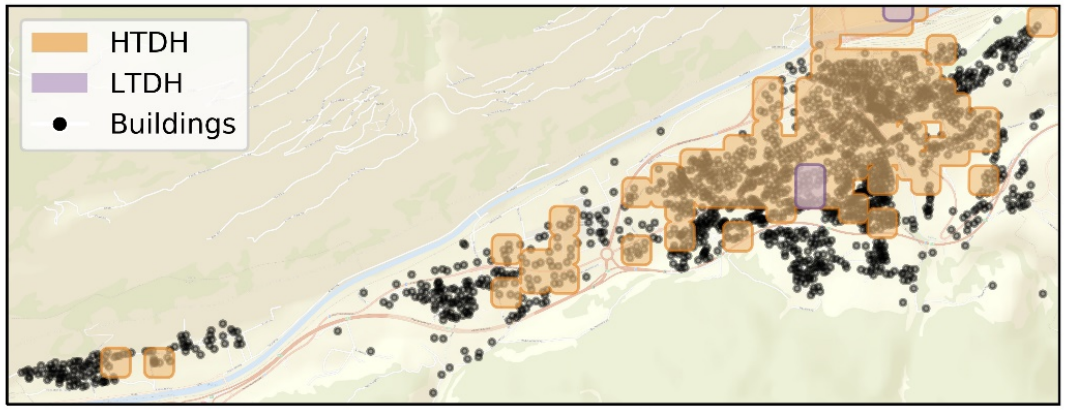
SwissRes retrofit potential



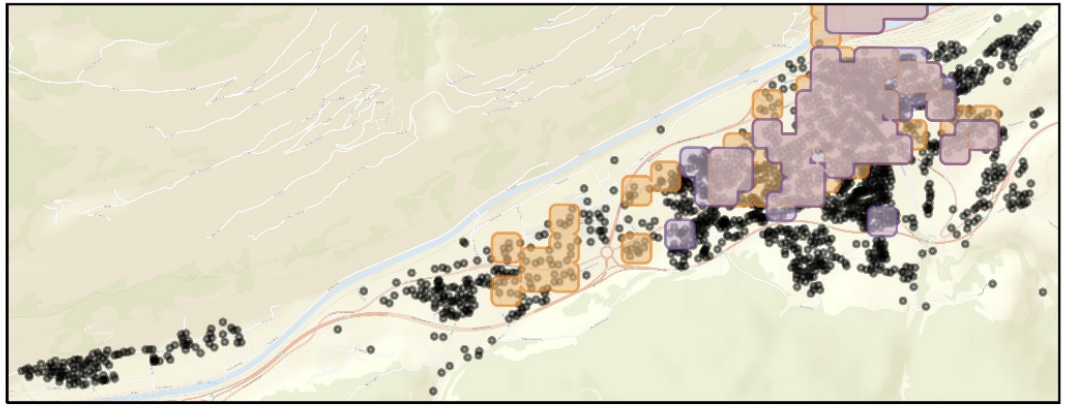
Brig-Glis case study: Scenario results

- Overview of three scenarios
- Compare Masterplan with SwissRes Scenario
- Masterplan
  - DHN covers 33% of the buildings
  - 59% of the total demand (40GWh/yr),
- SwissRes
  - DHN covers 50% of buildings
  - 65% of total demand in either LTHN or HTHN (44GWh/yr)

Current demand

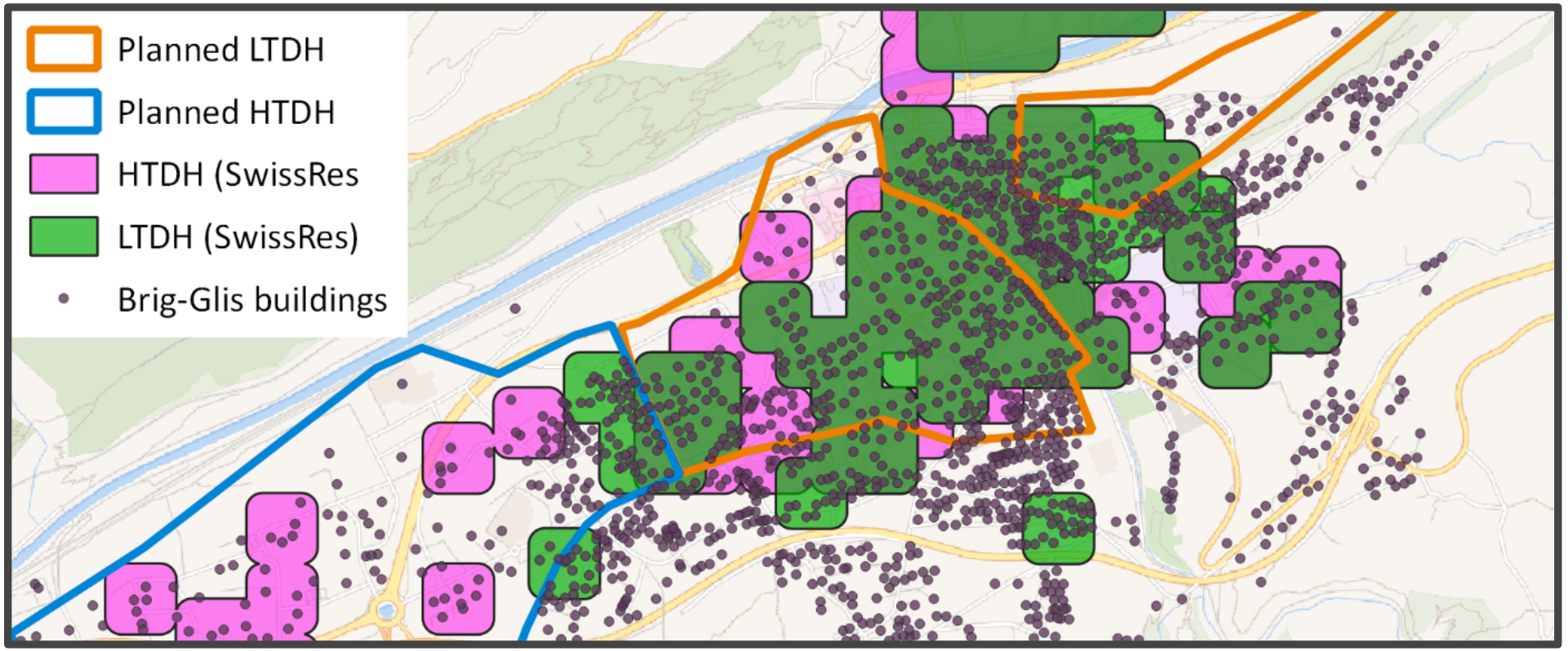


SwissRes scenario



Brig Glis case study: Comparison with Masterplan

Brig Glis case study: Comparison with Masterplan



Conclusions

- Calculated technical potential for DHN in Switzerland for HTDH and LTDH technologies
- Calculated technical potential for utilization of IEH in DHN
- Strong interaction with energy savings due to change in energy density
- Highlight need to consider interactions between different solutions
- Possible to dynamically re-calculate DHN regions based on different criteria
- Validated against Brig-Glis case study
- Demonstrate value of energy mapping
  - Rapid information for local authorities
  - First estimates of potentials from national scale study are reasonably accurate