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Spatio-temporal energy demand modelling at regional and national scale

SCCER School, Shaping the Energy Transition
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Topics

- Why Spatio-temporal energy demand modelling ?
- A Swiss heat demand atlas
- Overview of other GIS data sources
- Concluding remarks / discussion

Why Spatio-temporal energy demand modelling ?

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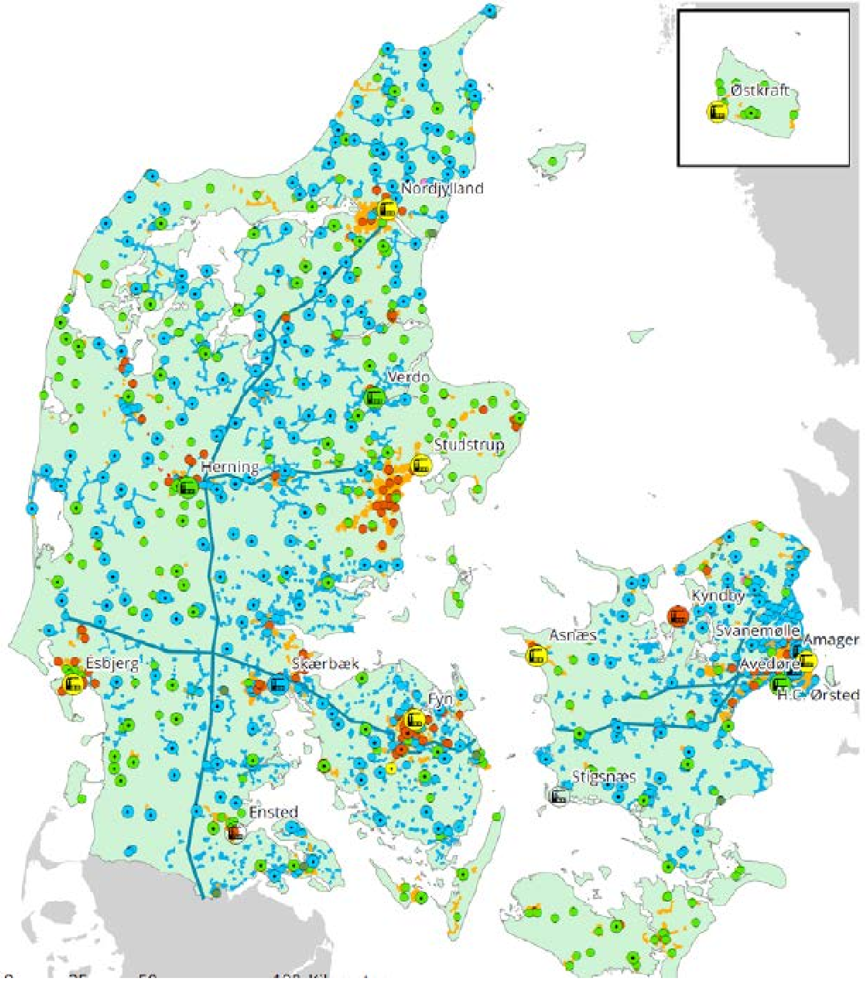
Example 1: the Danish energy transition

Moving from centralized fossil based electricity production to decentralized CHP

"… district heating is a popular choice and environmentally sensible, in particular because 80 per cent of district heat is produced in cogeneration processes, …" [1]



[1] Möller, Bernd. 2008. « A Heat Atlas for Demand and Supply Management in Denmark ». Édité par Nikola Ružinski. Management of Environmental Quality: An International Journal 19 (4): 467-79. doi:10.1108/14777830810878650.

Why Spatio-temporal energy demand modelling ?

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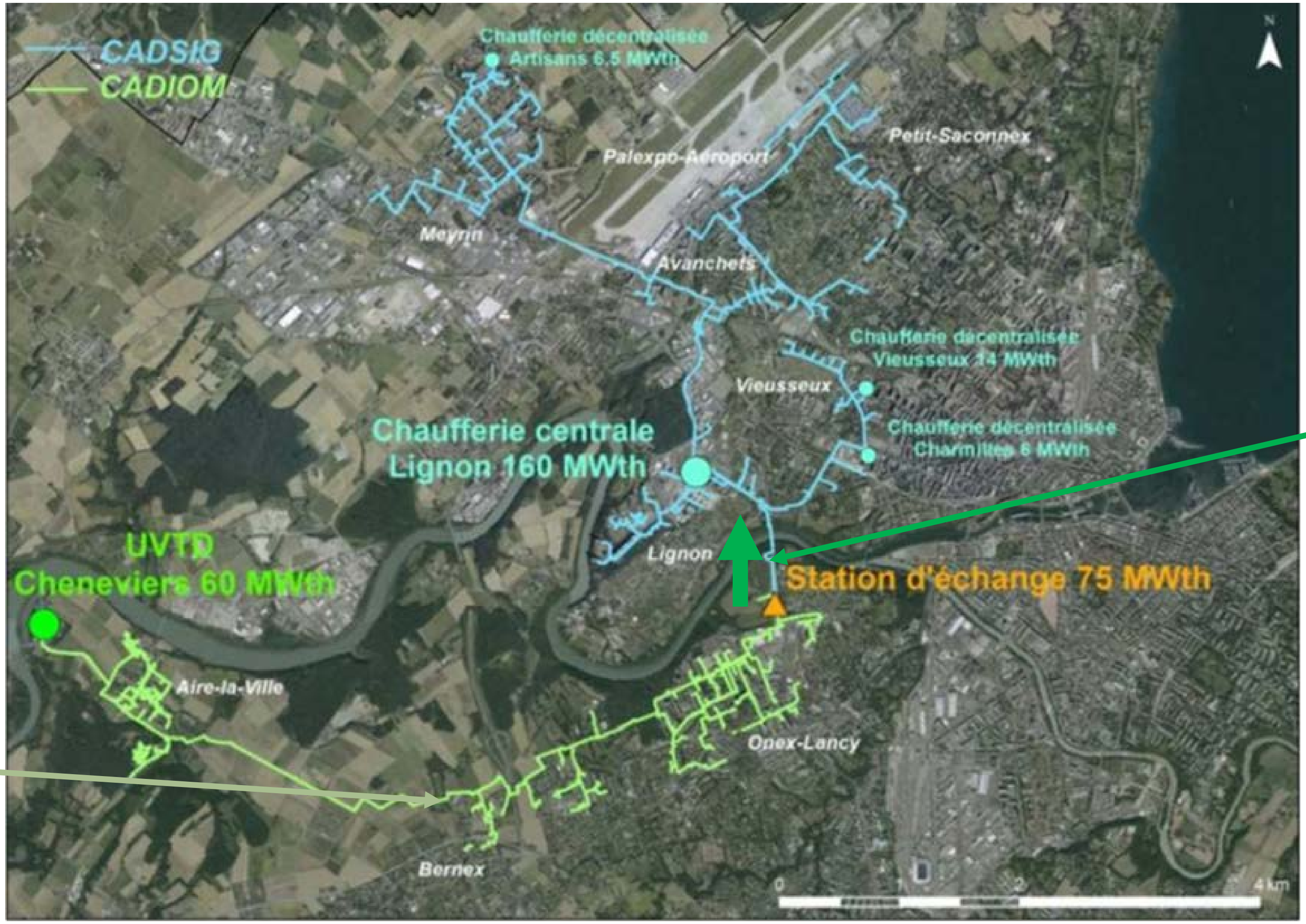
Example 2: Using waste heat, CADIOM CAD-SIG Geneva

300 GWh / year waste heat

220 GWh / year demand

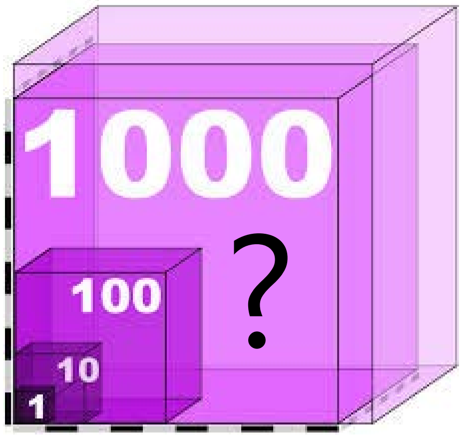


Additional 77 GWh / year saved using the CADIOM CAD-SIG junction [1]

[1] QUIQUEREZ et al. 2016: Valorisation de la chaleur renouvelable et des rejets thermiques: bilan et enjeux de l'interconnexion des deux plus grands réseaux thermiques genevois

A Swiss heat demand atlas

Today's focus: final energy for space heating and domestic hot water production



Number of inhabitants (CH, 2015): ~8.0 10^6

m^2 / cap. : ~50 (m^2)

→Total dwelling surface : 50 * 8.0 10^6 = 4 10^8 (m^2)

Total heated surface:

Dwelling surface + 60% = 1.6 * 4 10^8 = 6.4 10^8 (m^2)

Demand per m^2: ~150 (kWh / m^2 year)

→Total demand: 150 * 6.4 10^8 = 9.6 10^{10} (kWh/year) = 96 (TWh) = 8.25 millions of TEP = 1'370 W/Cap.

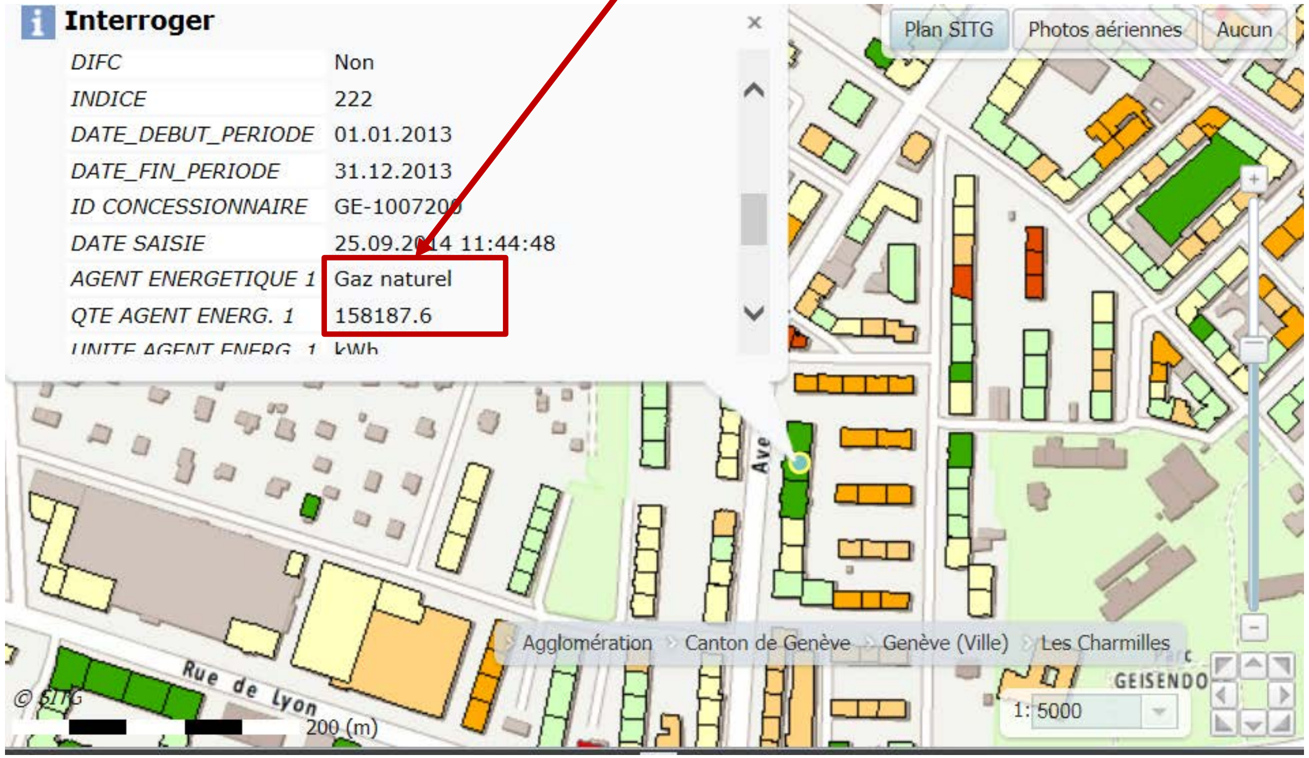
[1] : Prognos table 0-1: 2015: 78 (TWh)

[1] Kemmler, Andreas, Sven Kreidelmeyer, Andrea Ley, Philipp Wüthrich, Mario Keller, Martin Jakob, et Giacomo Catenazzi. 2016. « Analyse des schweizerischen Energieverbrauchs 2000 - 2015 nach Verwendungszwecken ». Bundesamt für Energie Bern.

A Swiss heat demand atlas

Availability of data: ?

158'188 kWh of natural gas



https://www.etat.ge.ch/geoportail/pro/

Regional: SITG IDC

Other regional examples:
- GEAK
- City of Basel
- MEU

At Swiss level: No actual demand data available. → atlas based on a model.

- Bottom-up, building physics
- <u>Bottom-up, statistical extrapolation</u>

A Swiss heat demand atlas

Pioneer work of Eicher&Pauli

Simple approach assuming
120 [kWh/m^2] for residential dwellings and specific values per activity in the industry & services sectors

WebGIS platform
www.fernwaerme-schweiz.ch

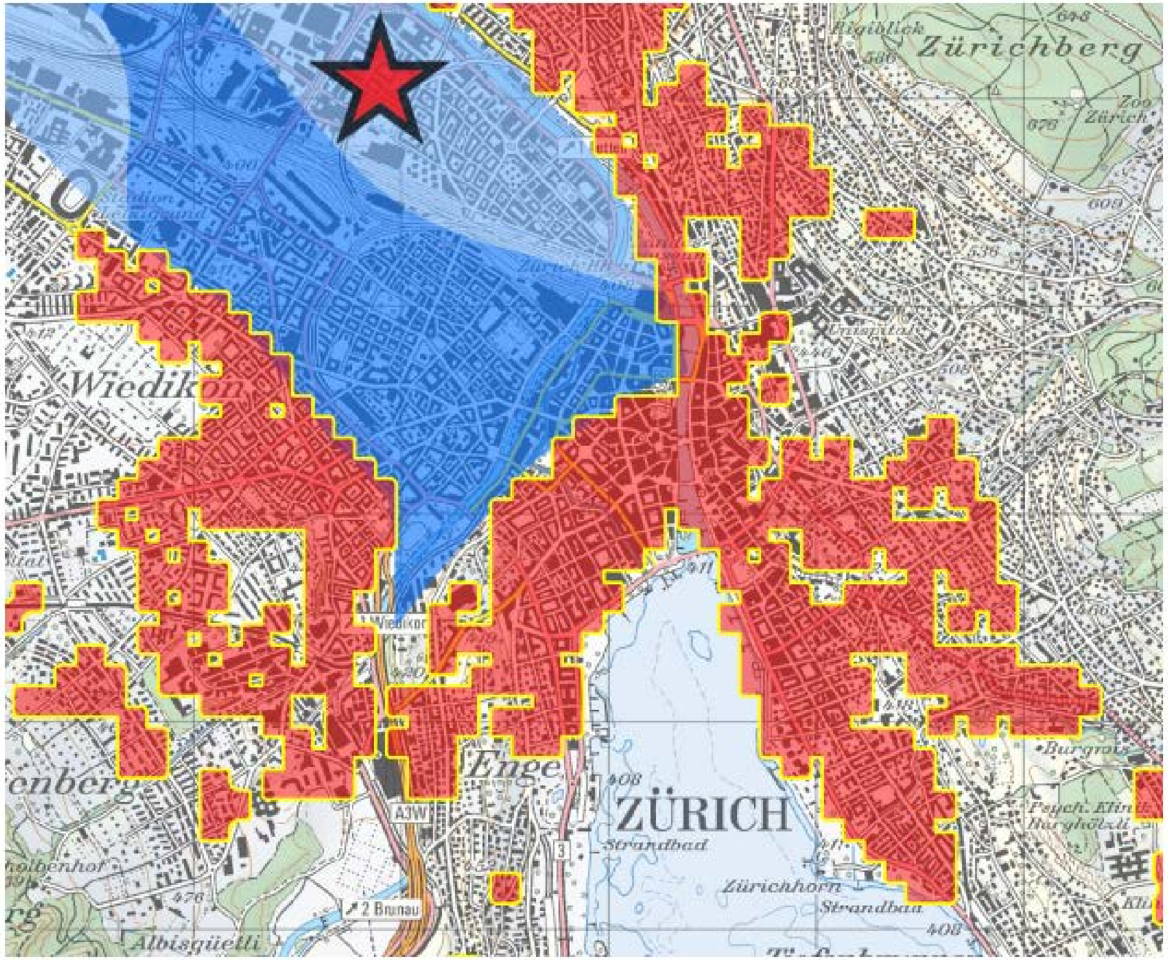


Abbildung 19: Hier zeigt sich exemplarisch, warum städtische Gebiete einen grossen Anteil an den selektierten Gebieten haben.

[1] Eicher, Hanspeter, Hans Pauli, Markus Erb, et Stephan Gutzwiller. 2011. « Ausbau von WKK in der Schweiz WKK-Standortevaluation auf Basis einer GIS-Analyse ». Liestal, Switzerland: Dr. Eicher+Pauli AG planer für Energie und Gebäude Technik.

A Swiss heat demand atlas

SCCER FEEB&D heat demand atlas [2]

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Swiss national building register (GWR)[1]

- *EGID* : National building identifier
- *Type*: Building type
- *Age*: Building age
- A_{Gross} : Ground surface * Nb. floors
- $A_{Dwelling}$: Dwelling surface
- *(x,y)*: Building coordinates
- Main energy carrier

Around 2 millions buildings

Calibration

- SITG IDC Database
- CECB/GEAK Database

Around 27'000 buildings

Estimated heated surface (A_E)

A_E function of
- *Type*: Building type
- A_{Gross}
- $A_{Dwelling}$

Estimated heat demand per m²

E_{hww} function of
- *Type*: Building type
- *Age*: Building age

Estimated heat demand of building

$E = A_E \, x \, E_{hww}$

Estimated heat demand of a Pixel

- Sum of all buildings within a pixel
- Estimation of a confidence interval

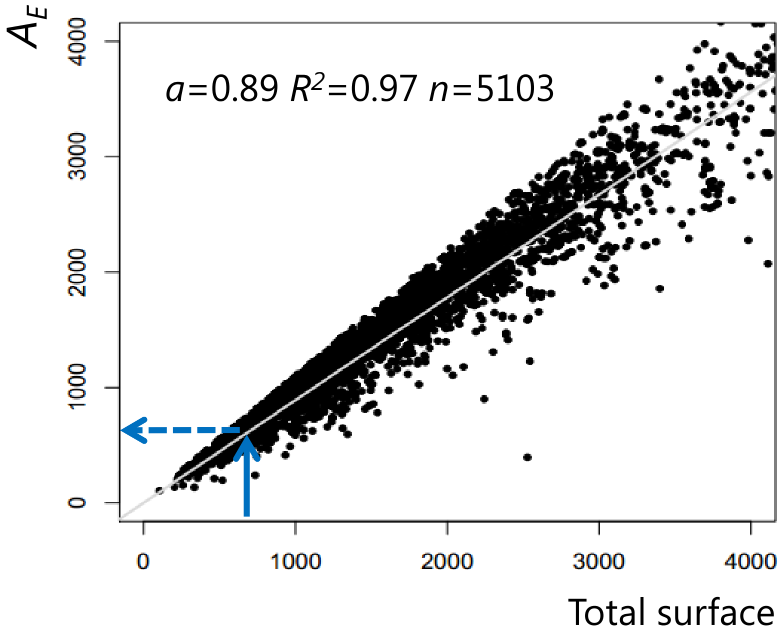
[1] GWR, Swiss Federal Statistical Office

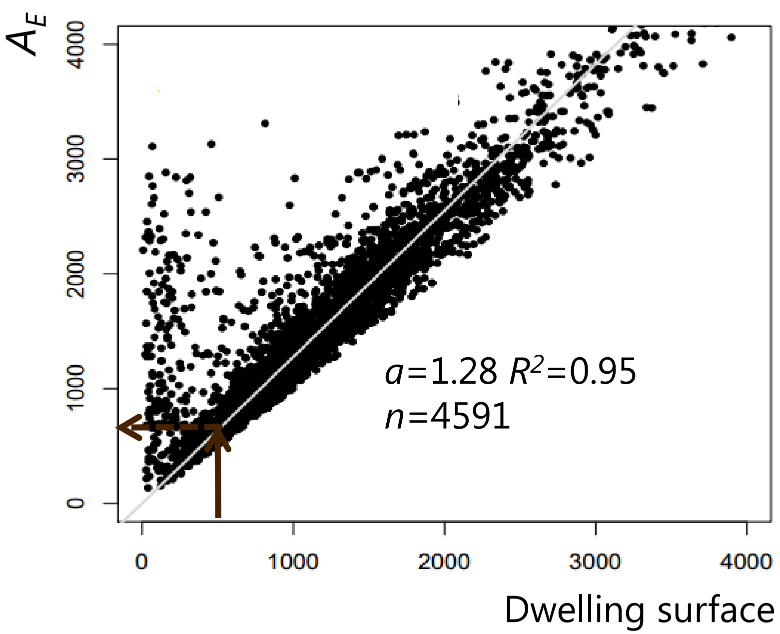
[2] Schneider, Stefan, Jad Khoury, Bernard Lachal, et Pierre Hollmuller. 2016. « Geo-dependent heat demand model of the Swiss building stock ». In Sustainable built environment regional conference. SBE 2016, Zurich, June 15-17. Zurich. doi:10.3218/3774-6.

A_E estimation: an example with a collective residential building

Swiss national building register	
Kanton	BS
EGID	111111111
Address	**Musterstr. 1**
Building type	Collective residential
Building age	1919-1945
Total surface	740
Dwelling surface	492
GKODX	610205
GKODY	267341
Main energy carrier	District heat

Calibration SITG IDC





Heated surface	
Slope of linear regression 1	0.89
Slope of linear regression 2	1.28
Estimation 1 = 0.89 x 740	658.9
Estimation 2 = 1.28 x 492	627.5
Estimation of heated surface	**658.9**

Heat demand estimation: an example with a collective residential building

Swiss national building register	
GDEKT	BS
EGID	111111111
Address	**Musterstr. 1**
Building type	Collective residential
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Total surface	740
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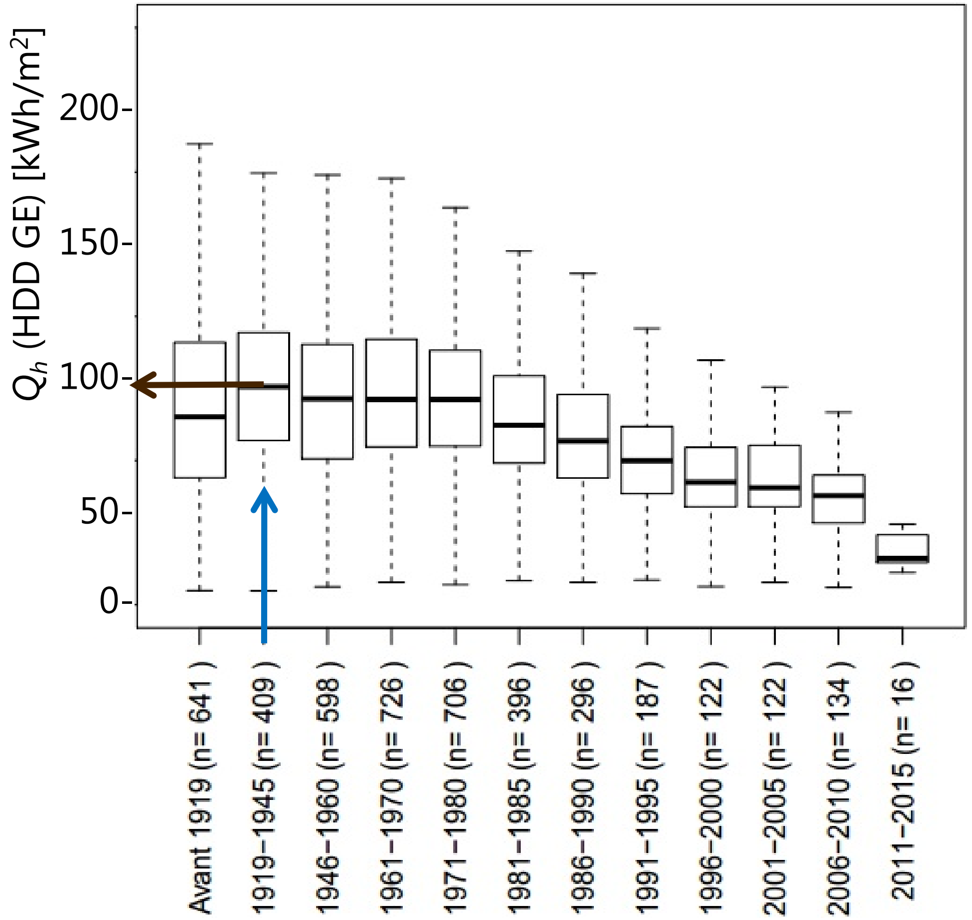
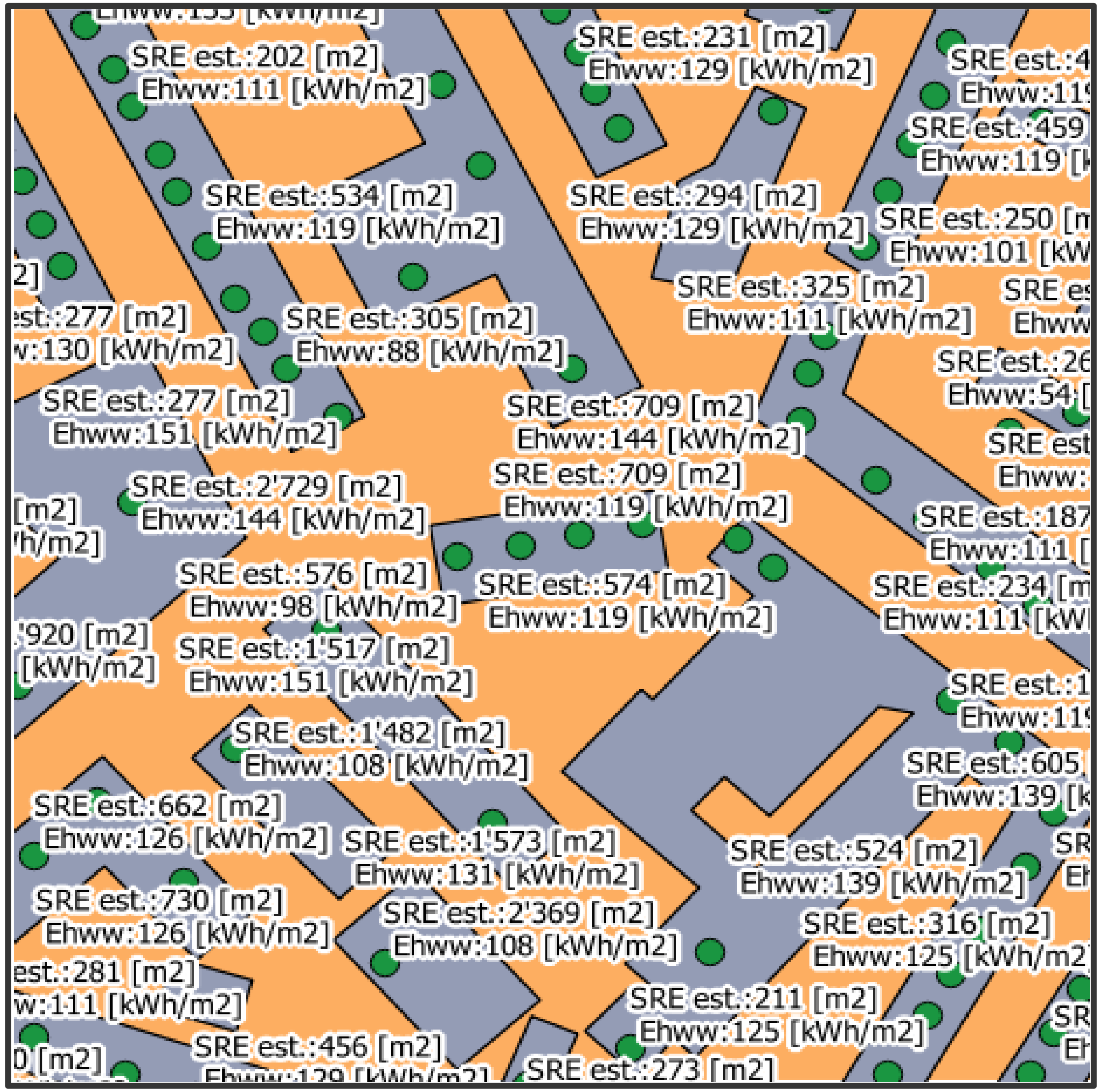
Main energy carrier	District heat

Heat demand		
Q_h (HDD GE)	97	[kWh/m^2]
Heating degree days (GE)	2863	[K Tag]
Heating degree days (BS)	2932	[K Tag]
Climate correction = 2932.3/2863	1.02	
Q_h (BS) = 348.8 x 1.024 =	99	[kWh/m^2]
Q_{ww} (SIA 380/1)	21	[kWh/m^2]
$Q_{hww} = Q_h + Q_{ww}$ = 357.2 + 75 =	120	[kWh/m^2]
$E_{hww} = Q_{hww}$ x 1/Nu	126	[kWh/m^2]
E [kWh / year] = E_{hww} x A_E = 451.9 x 658.9	**82'705**	[kWh]

Calibration GEAK

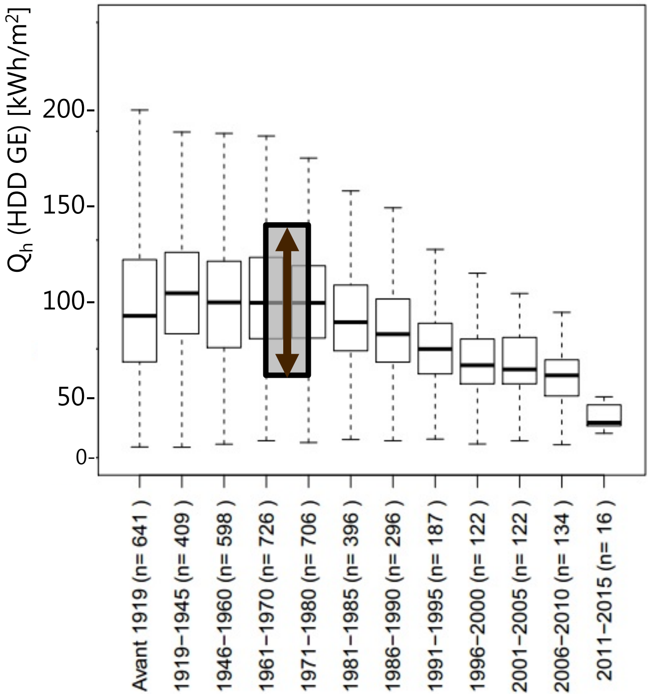


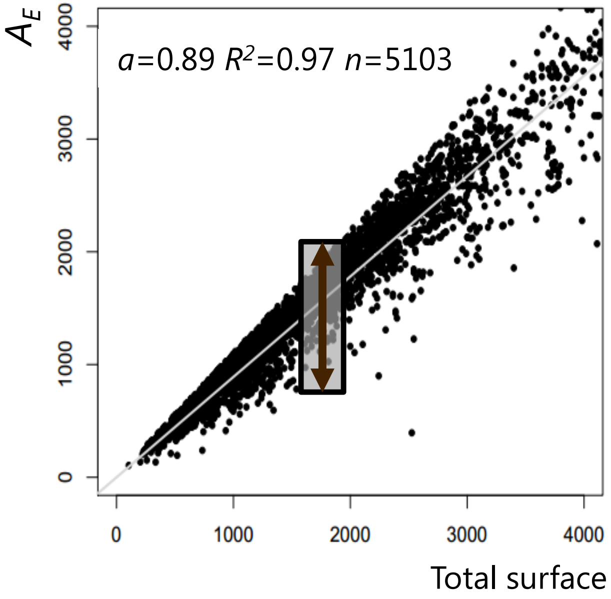
Heat demand estimation: Pixel



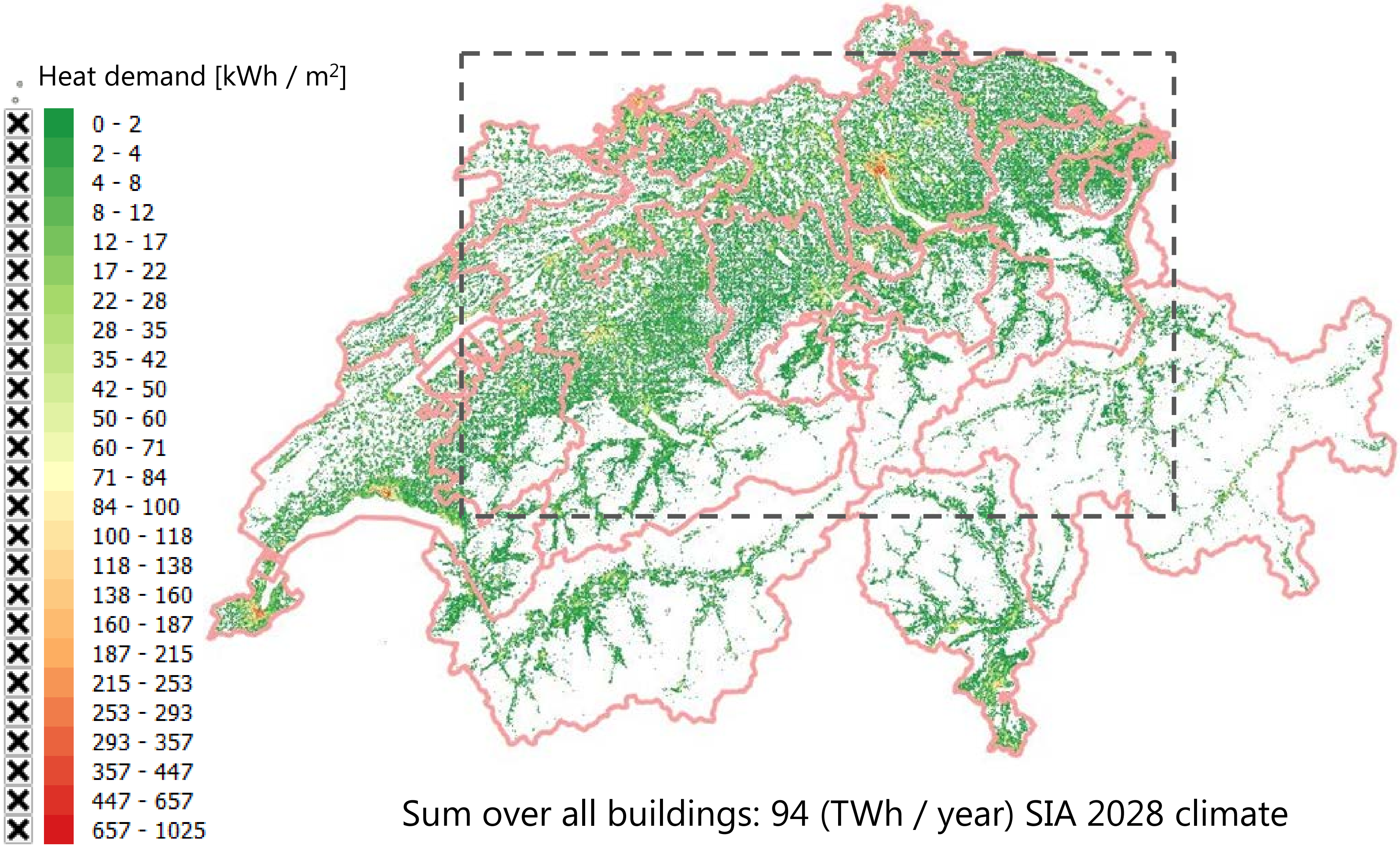
Sum of estimation for each building located in the pixel

Confidence interval computed with a bootstrap resampling algorithm



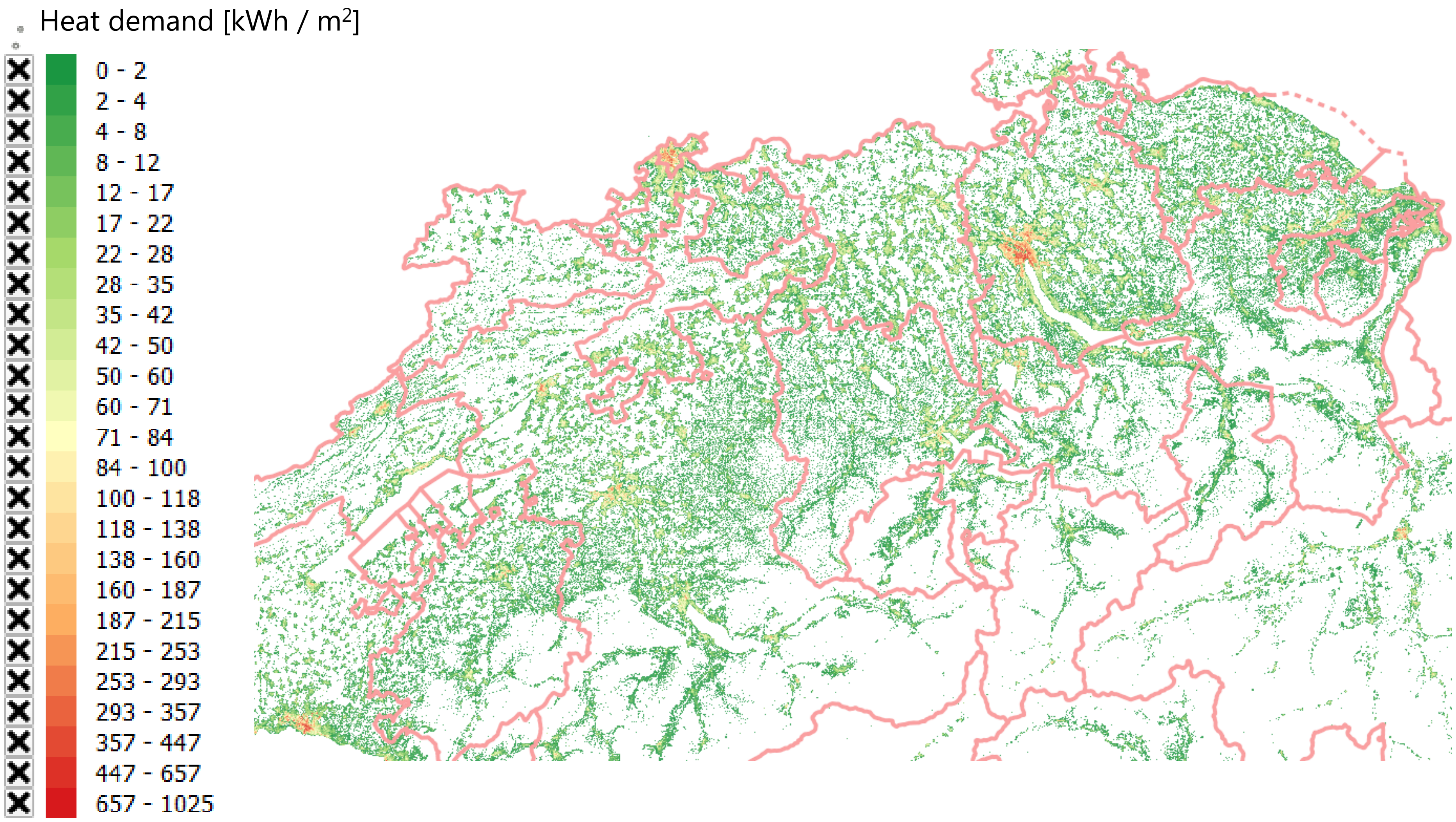


GIS Heat demand bottom-up model

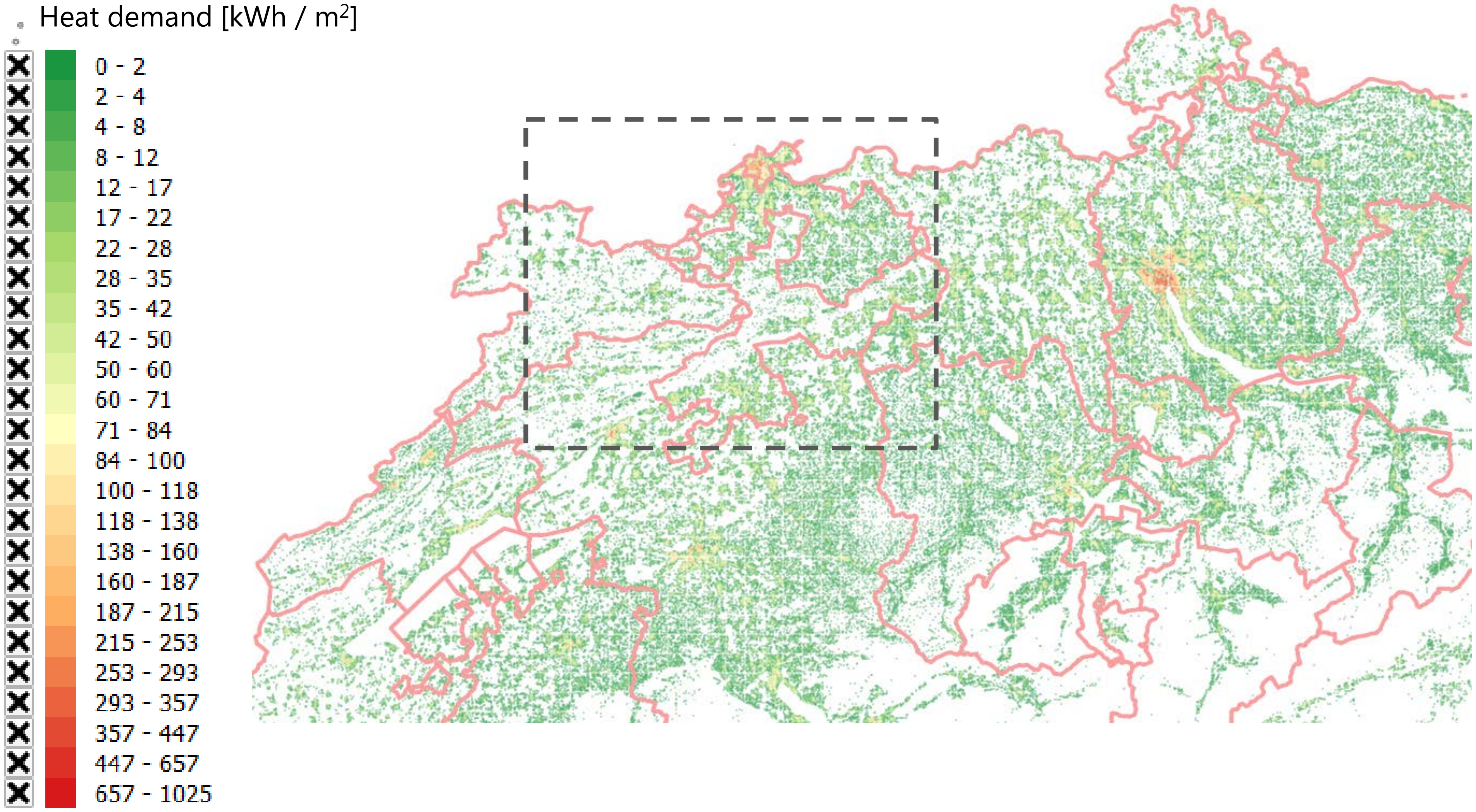


Sum over all buildings: 94 (TWh / year) SIA 2028 climate

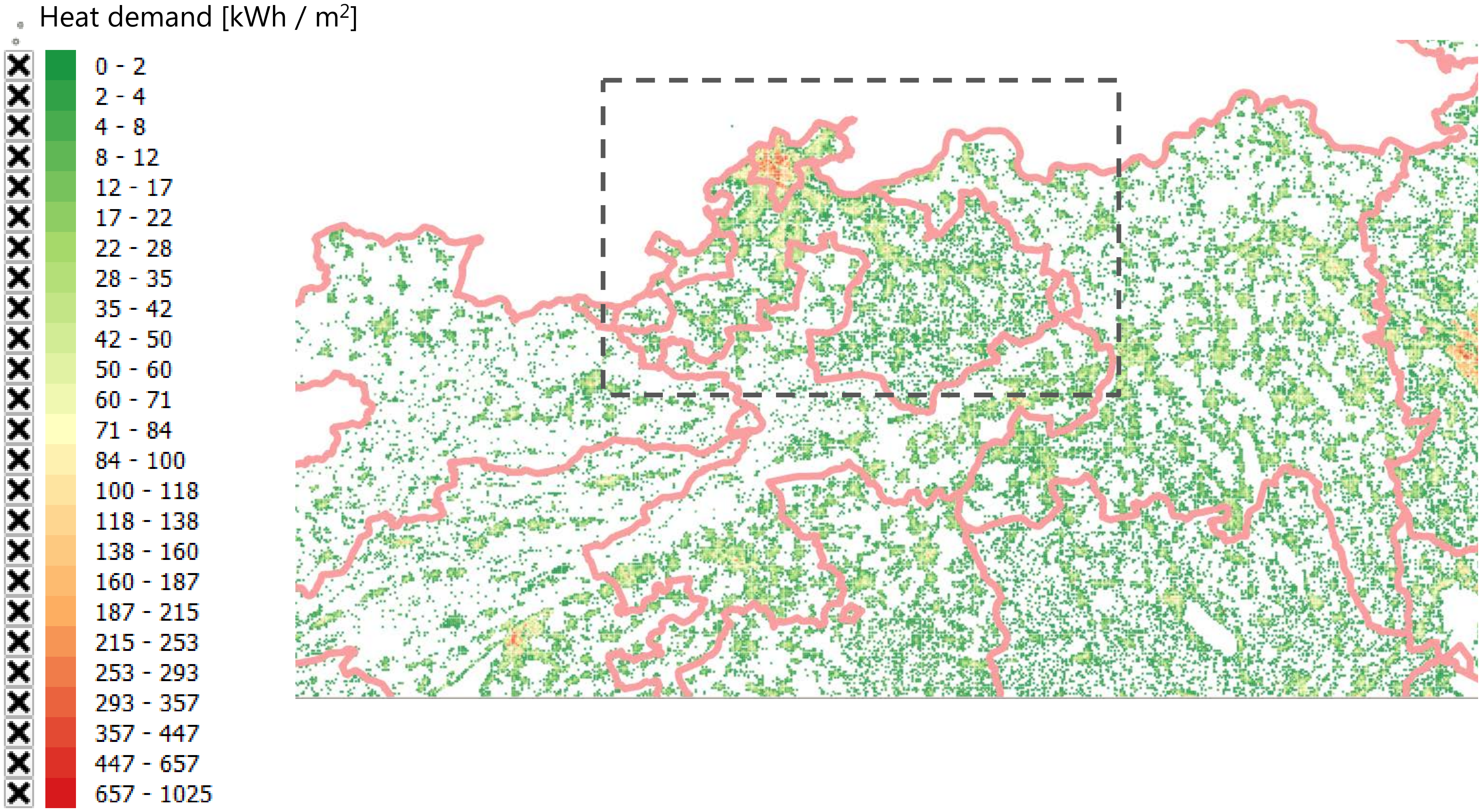
GIS Heat demand bottom-up model



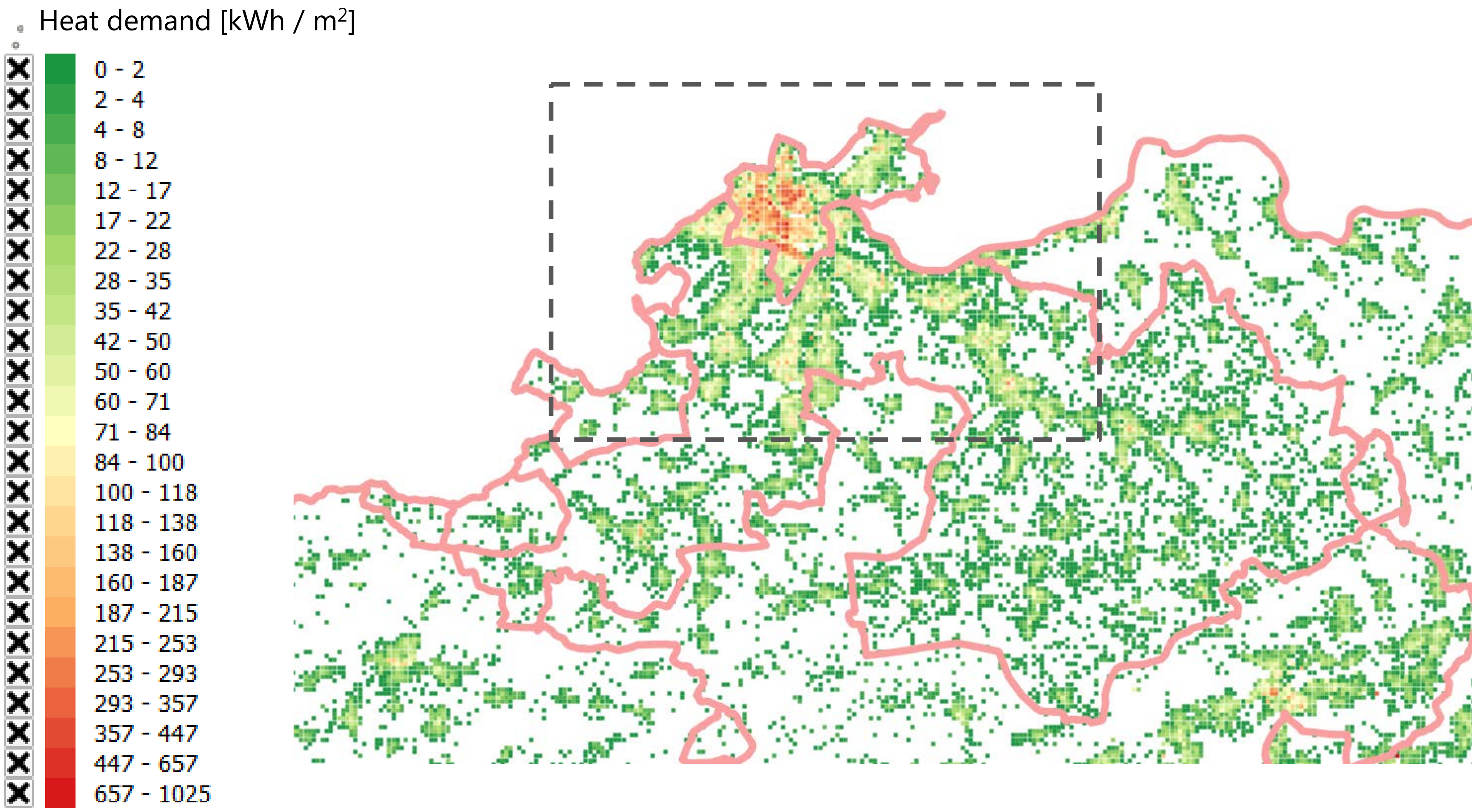
GIS Heat demand bottom-up model



GIS Heat demand bottom-up model



GIS Heat demand bottom-up model



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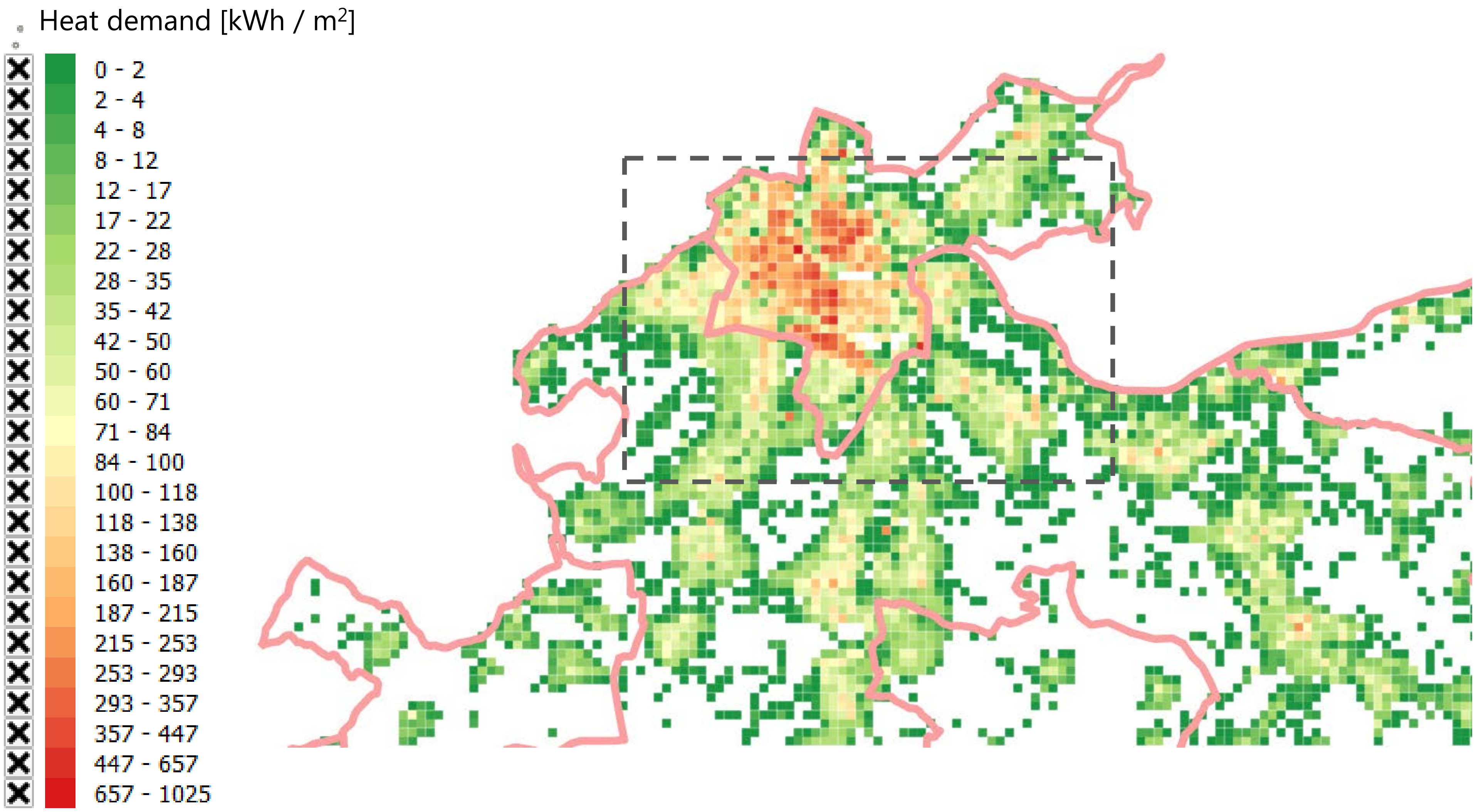

GIS Heat demand bottom-up model

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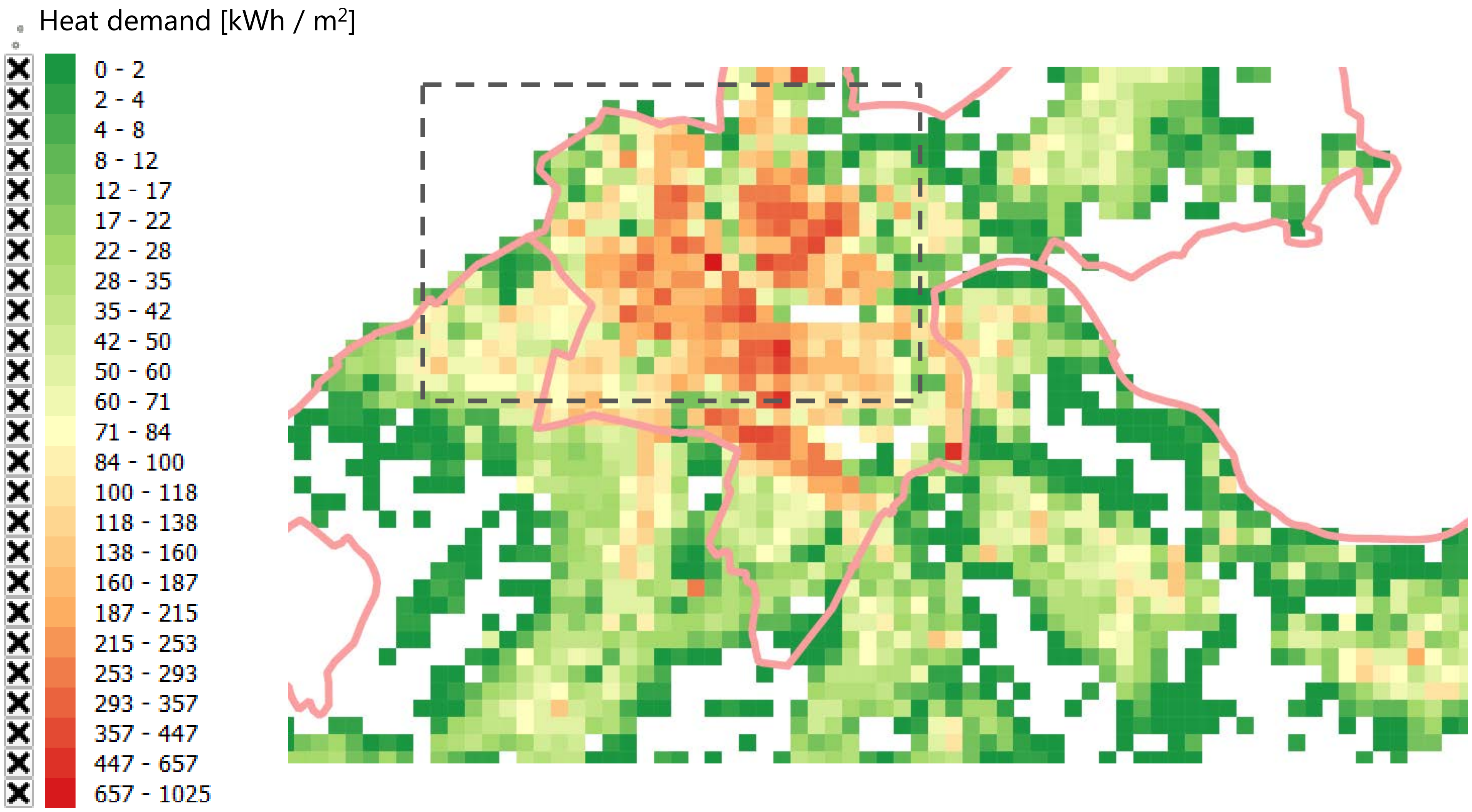
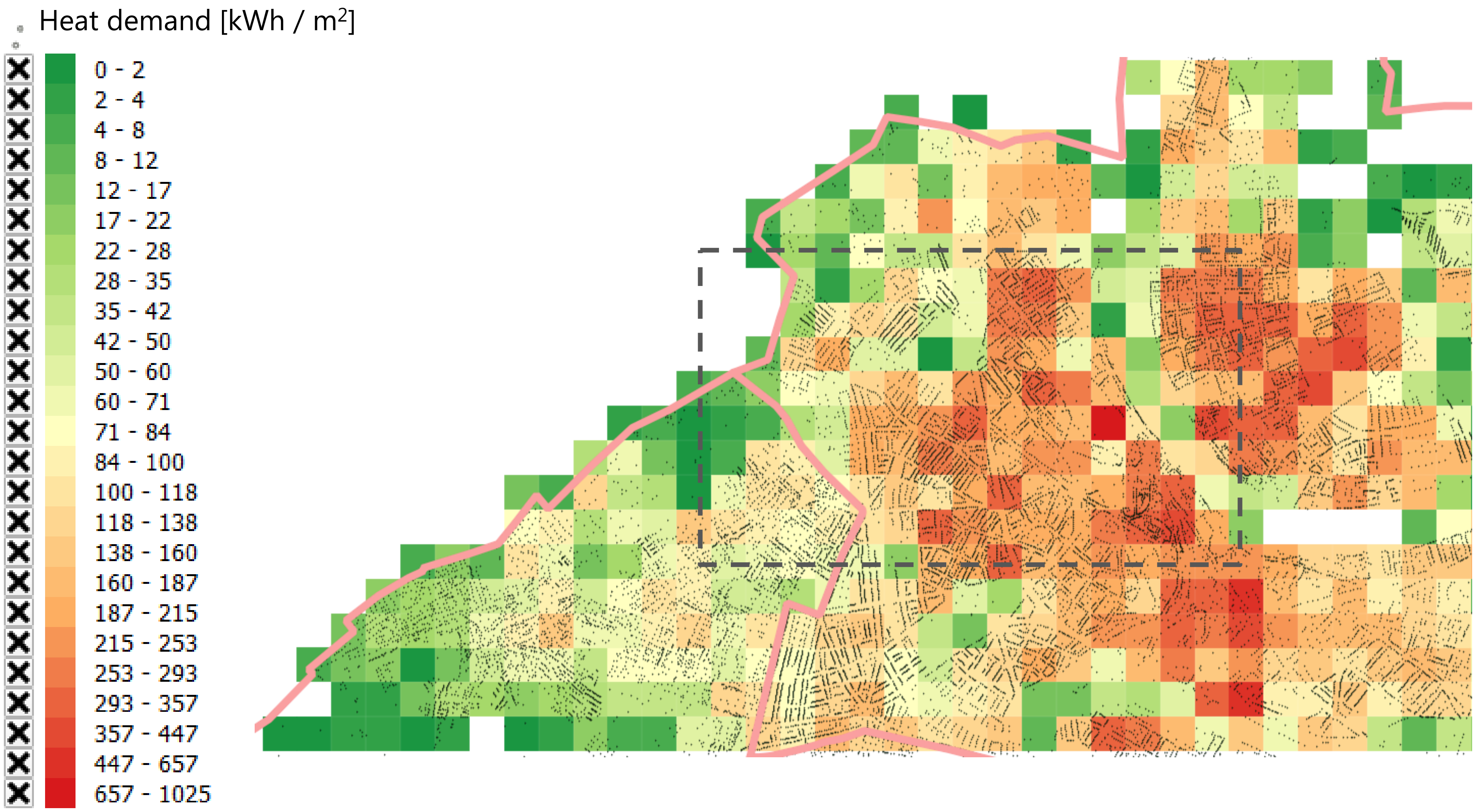


GIS Heat demand bottom-up model



GIS Heat demand bottom-up model

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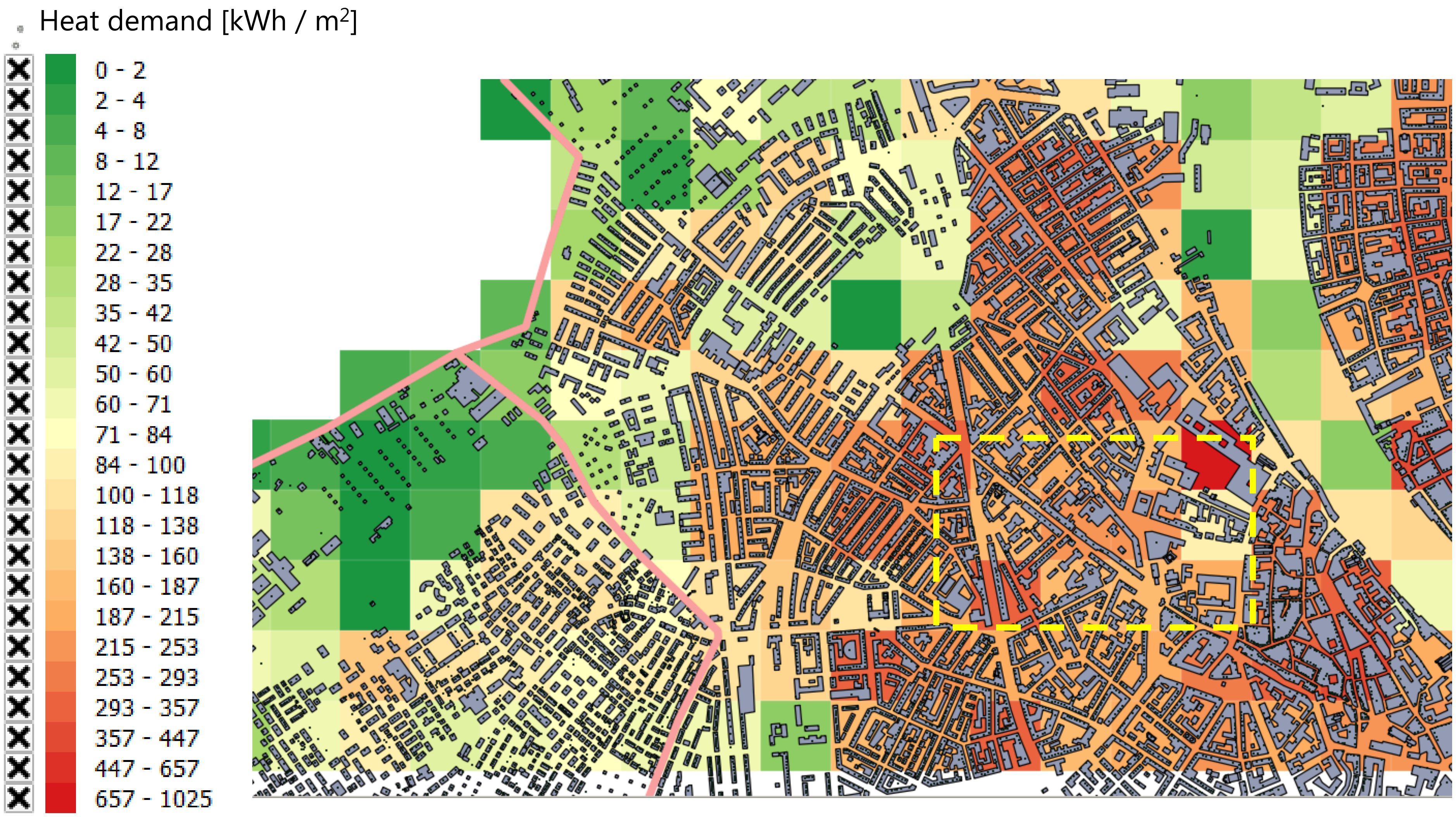

GIS Heat demand bottom-up model

Overview of other GIS data sources, heat and electricity demand

http://potential-erneuerbar.solar4ever.ch

Exemple:
Estimation for the municipality of Geneva
1’528’100 MWh

Actual consumption based on SIG bills 2015: **1’156’866 MWh**

Heat estimation FEEB&D
2’000’300 MWh

Genève

Genève | DE | FR | IT

Start | Zusammenfassung | Effizienz | Sonne | Holz | Biogas | Wind | Wasser | Weitere

Zusammenfassung für Genève

Ist-Zustand

Heutiger Energieverbrauch in MWh pro Jahr

[MWh pro Jahr]	Wärme	Strom	Treibstoffe	Total
Energieverbrauch	2'132'600	1'528'100	809'500	4'470'200
Produktion erneuerbarer Energie	900	20'000	0	20'900
Bilanz (Verbrauch-Produktion)	2'131'700	1'508'100	809'500	4'449'300
Erneuerbarer Selbstversorgungsgrad in %	0	1	0	0

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Overview of other GIS data sources, EU electricity demand

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FORECAST | eLOAD

FORecasting Energy Consumption Analysis and Simulation Tool | energy LOad curve ADjustment tool

http://www.forecast-model.eu/forecast-en/index.php

Jakob, Martin, Sonja Kallio, and Tobias Bossmann. "Generating Electricity Demand-side Load Profiles of the Tertiary Sector for Selected European Countries," 2014.

Overview of other GIS data sources, electricity demand
FEEB&D - SIG model

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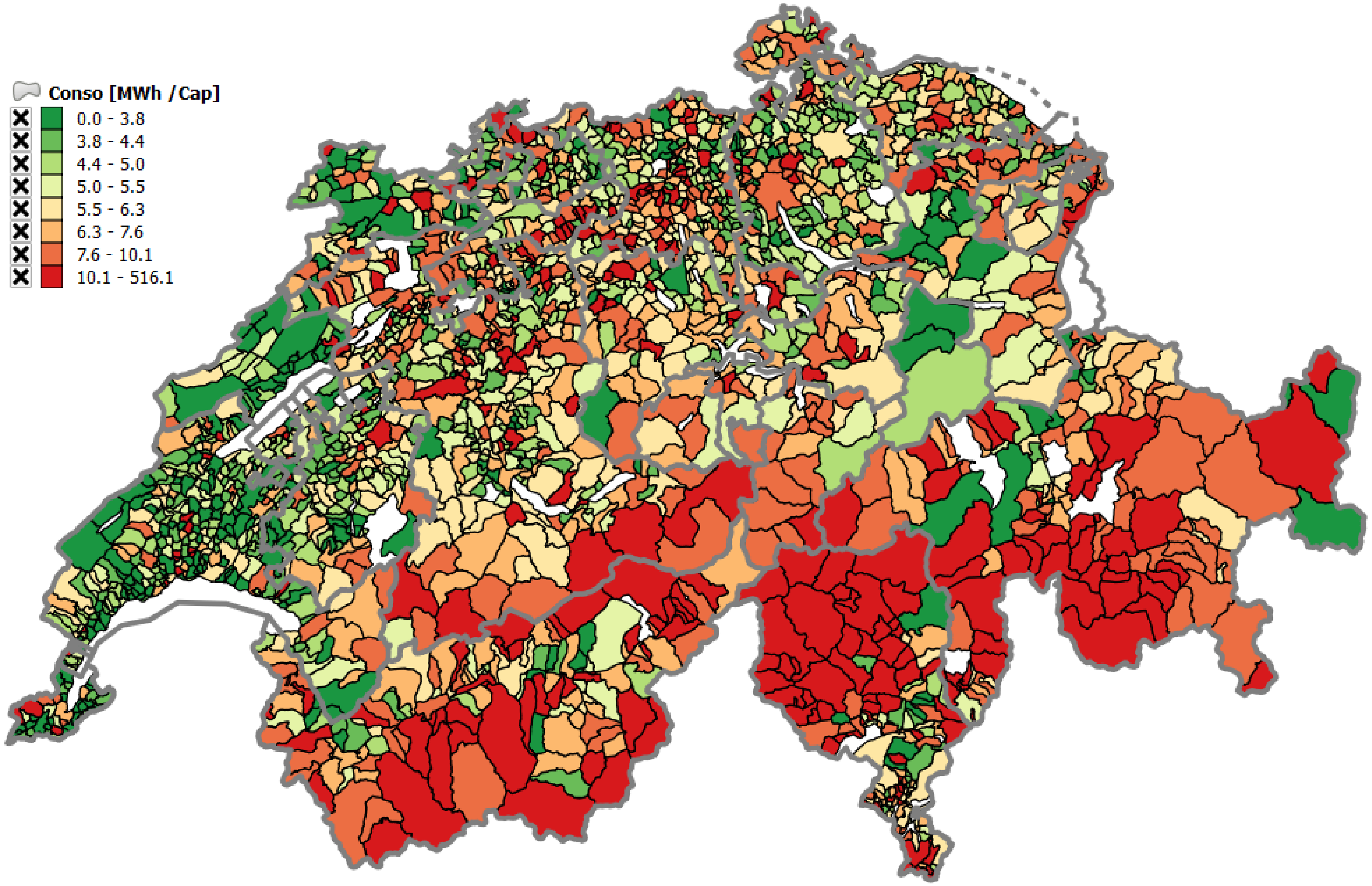
ElectroWhat: Who consumes where, when and for what use



SIG

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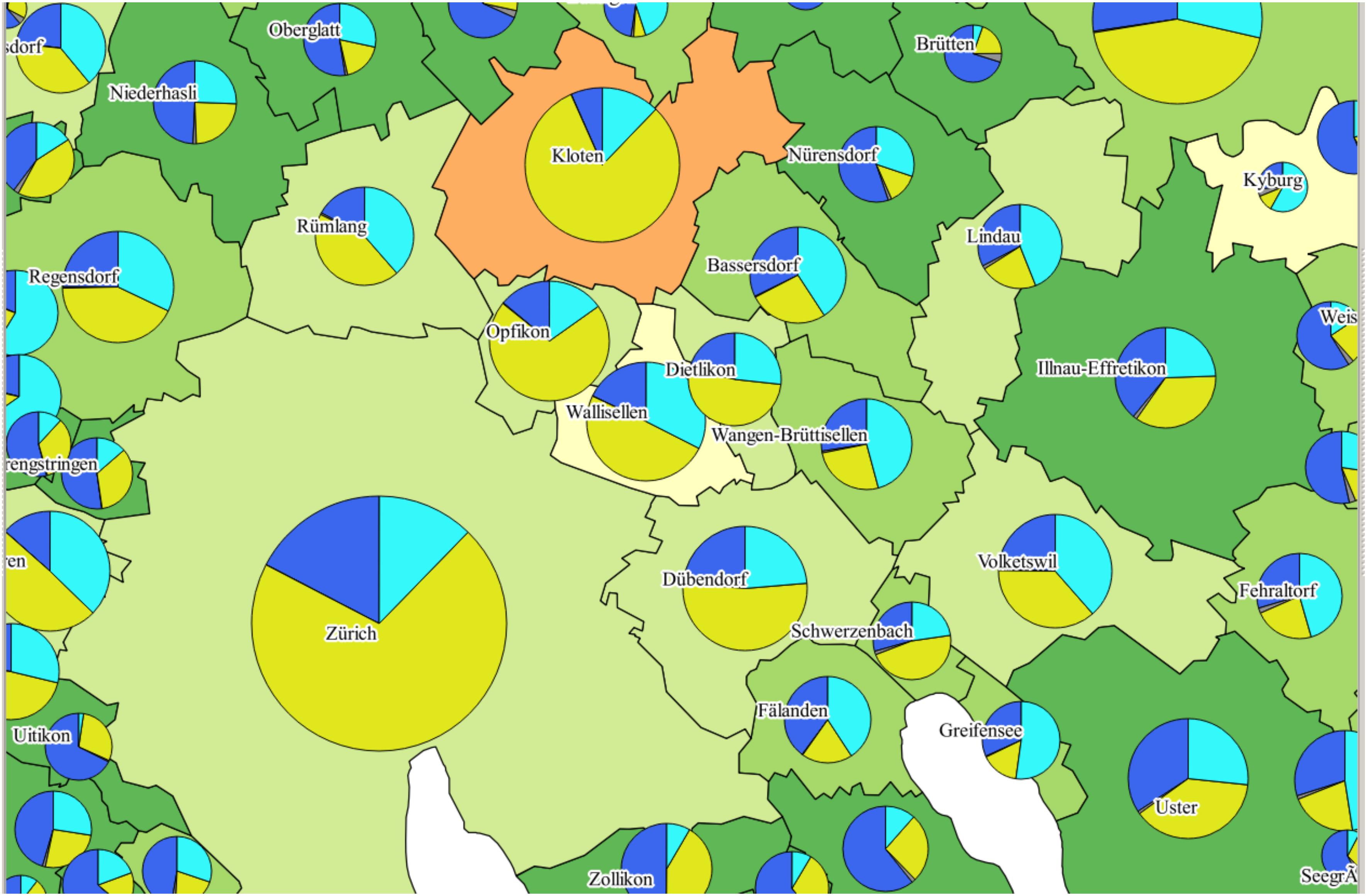
Overview of other GIS data sources, electricity demand
FEEB&D - SIG model

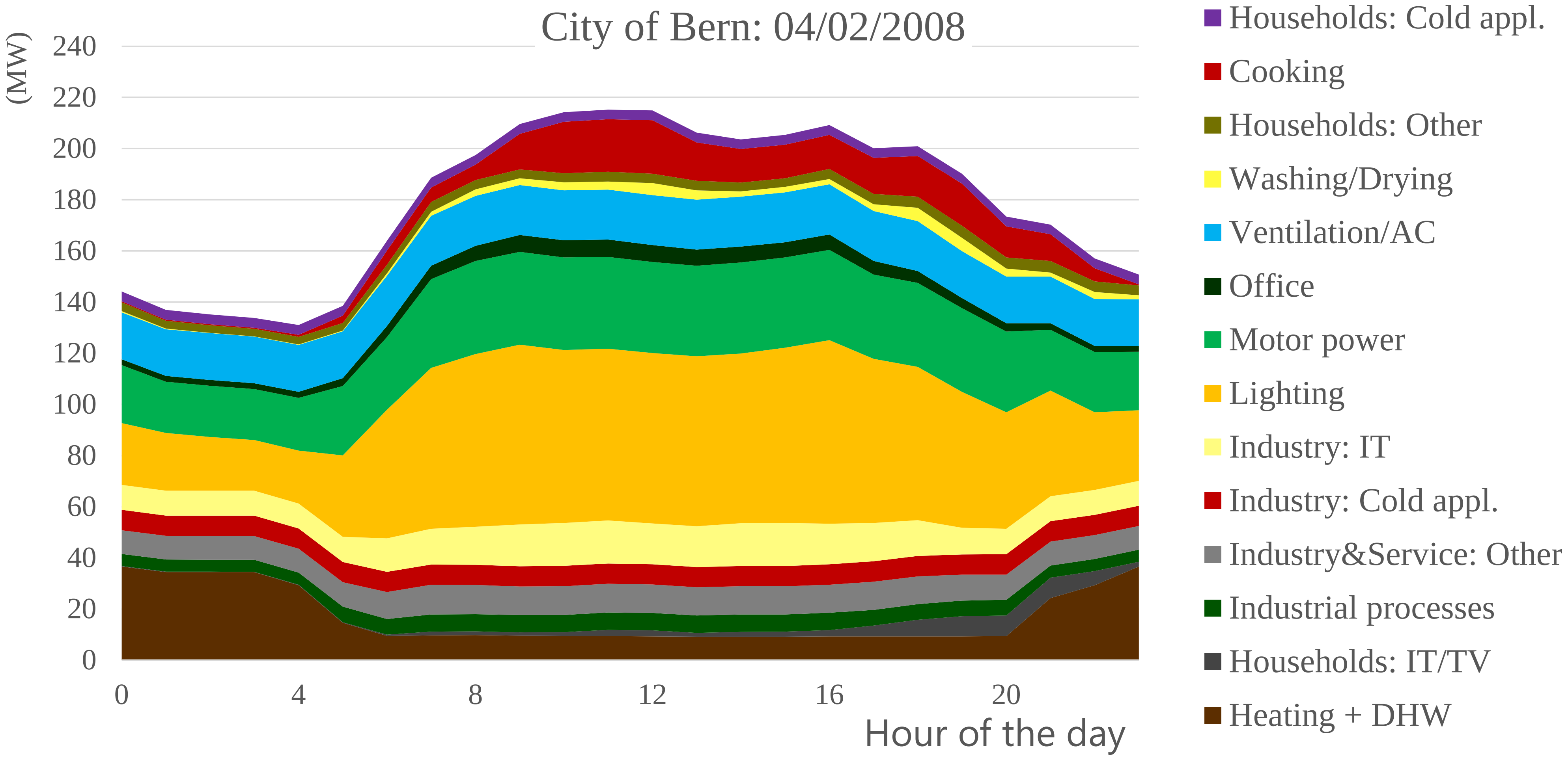
Consumption (MWh/cap.)

- 0 - 3
- 3 - 5
- 5 - 7
- 7 - 10
- 10 - 14
- 14 - 20
- 20 - 30
- 30 - 60
- > 60

- Services
- Residential
- Industry
- Primary



Overview of other GIS data sources, electricity demand FEEB&D - SIG model



Concluding remarks/discussion

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Heat demand, advantages and drawbacks of using a statistical bottom up approach?

- ⊕ Estimation uses as input actual energy demand (takes account of real usage of buildings)
- ⊕ Adequate for aggregated demand of groups of buildings (districts)
- ⊕ Allows estimation of uncertainty
- ⊕ May work with very little information on individual buildings

- ⊖ No generation of dynamic load curves, requires additional approach
- ⊖ Diffusion of model is more difficult
- ⊖ Not accurate at building level

? Additional remarks?

Concluding remarks/discussion

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Electricity demand, in what extend the problem differs with heat demand?

- Much more data on actual electricity consumption: www.stromkennzeichnung.ch, www.swissgrid.ch
- Different spatial-temporal requirements due to constraints
  - Heat difficult to transport → high spatial resolution
  - Electricity difficult to store→ high temporal resolution
- Modelling electricity demand is complex since many usages
- Type of model depends on research question
  - Deterministic model (*ElectroWhat*) → savings and DSM potentials
  - Stochastic models → network planning, energy hub simulations

References

Swan, Lukas G., et V. Ismet Ugursal. 2009. « Modeling of end-use energy consumption in the residential sector: A review of modeling techniques ». Renewable and Sustainable Energy Reviews 13 (8): 1819-35. doi:10.1016/j.rser.2008.09.033.

Topic: Classification of energy demand models

Allegrini, Jonas, Kristina Orehounig, Georgios Mavromatidis, Florian Ruesch, Viktor Dorer, et Ralph Evins. 2015. « A review of modelling approaches and tools for the simulation of district-scale energy systems ». Renewable and Sustainable Energy Reviews 52 (décembre): 1391-1404. doi:10.1016/j.rser.2015.07.123.

Topic: comprehensive review of modelling approaches and associated software tools that address district-level energy systems.

Schneider, Stefan, Jad Khoury, Bernard Lachal, et Pierre Hollmuller. 2016. « Geo-dependent heat demand model of the Swiss building stock ». In Sustainable built environment regional conference. SBE 2016, Zurich, June 15-17. Zurich. doi:10.3218/3774-6.

Topic: Heat demand model named SCCER FEEB&D heat demand atlas in this presentation

Schneider, Stefan, Pascale Le Strat, et Martin Patel. 2017. « ElectroWhat: A platform for territorial analysis of the electricity consumption ». In . EPFL Lausanne, Switzerland: EPFL. doi:10.1016/j.egypro.2017.07.376.

Topic: Electricity demand model "ElectroWhat" of this presentation

Thank you!

GIS data available on http://wisesccer1.unige.ch/ and http://hues.empa.ch

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Further information at www.sccer-feebd.ch

In cooperation with the CTI

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Swiss Competence Centers for Energy Research

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