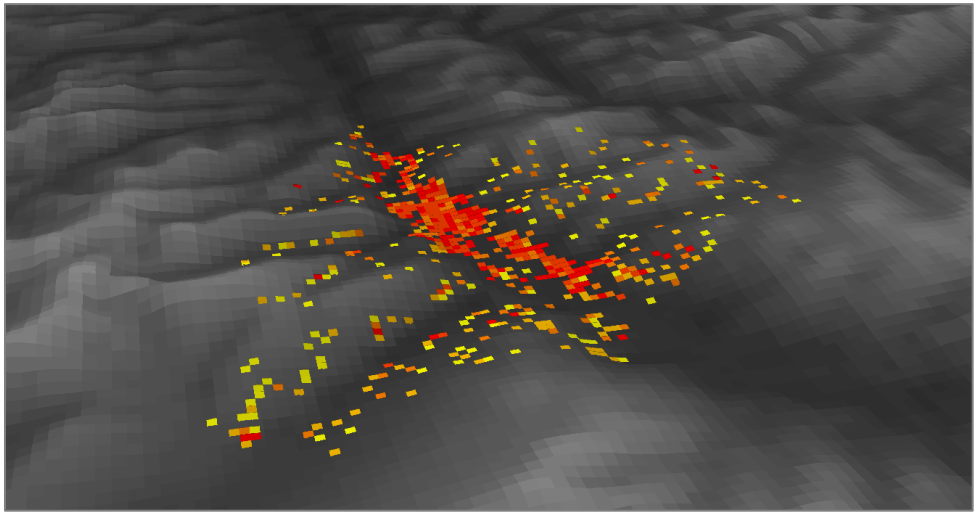
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Multi-Demand Modeling in LCA – The Assessment of Household Consumption in Swiss Communities



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LCA DF 49

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Motivation

- Many Swiss municipalities aim for rational use of energy, energetic autarky, or the achievement of visionary goals (e.g. 2000W and 1 tCO_2 society)
  Büsser (2007). Ökologische Beurteilung verschiedener Energieversorgungsszenarien einer kleinen Gemeinde in der Schweiz.
  Nusch (2010). Sustainable Energy Supply of a Swiss region
- There are significant differences between the environmental impacts from individual households

Motivation

- Comparative assessment of households offers post analyses: e.g. analysis of spatial distribution of impacts, calculation of inequality indices, cluster analysis, structural path analysis etc.
- **Research questions:**
  - **How big is the variability of household environmental impacts?**
  - **How can we model and assess the environmental impacts induced by the consumption patterns of many individual households?**

Goal

To model and assess household consumption:

i. of each household located in a specific spatial area,

ii. on any temporal resolution for a specific reference point in time,

iii. and for various consumption categories.

Why a model?

- Capture all households of a region and not only a representative sample.
- A model allows to investigate scenarios of future demand and/or supply structures.

Methodological choice

	Environmentally Extended Input-Output Analysis (EEIOA)	Life Cycle Assessment (LCA)
Differences	• IOA bases on monetary flows between the sectors of the whole Swiss economy • Indirect emissions can only be accounted for with additional effort (multi-regional EEIOA, in combination with LCA) • Covers comprehensively 43 economic sectors and 20 final demand categories • Spatial resolution: country level • Temporal resolution: year • Uncertainties not considered	• LCA bases physical flows between unit processes of products and services from all over the world • Direct and indirect up- and downstream emissions are accounted for • Covers over 4'000 products and services. Life cycle inventories not available for many consumer products and services (but will change in the future) • Spatial resolution freely selectable • Temporal resolution freely selectable • Uncertainty information available

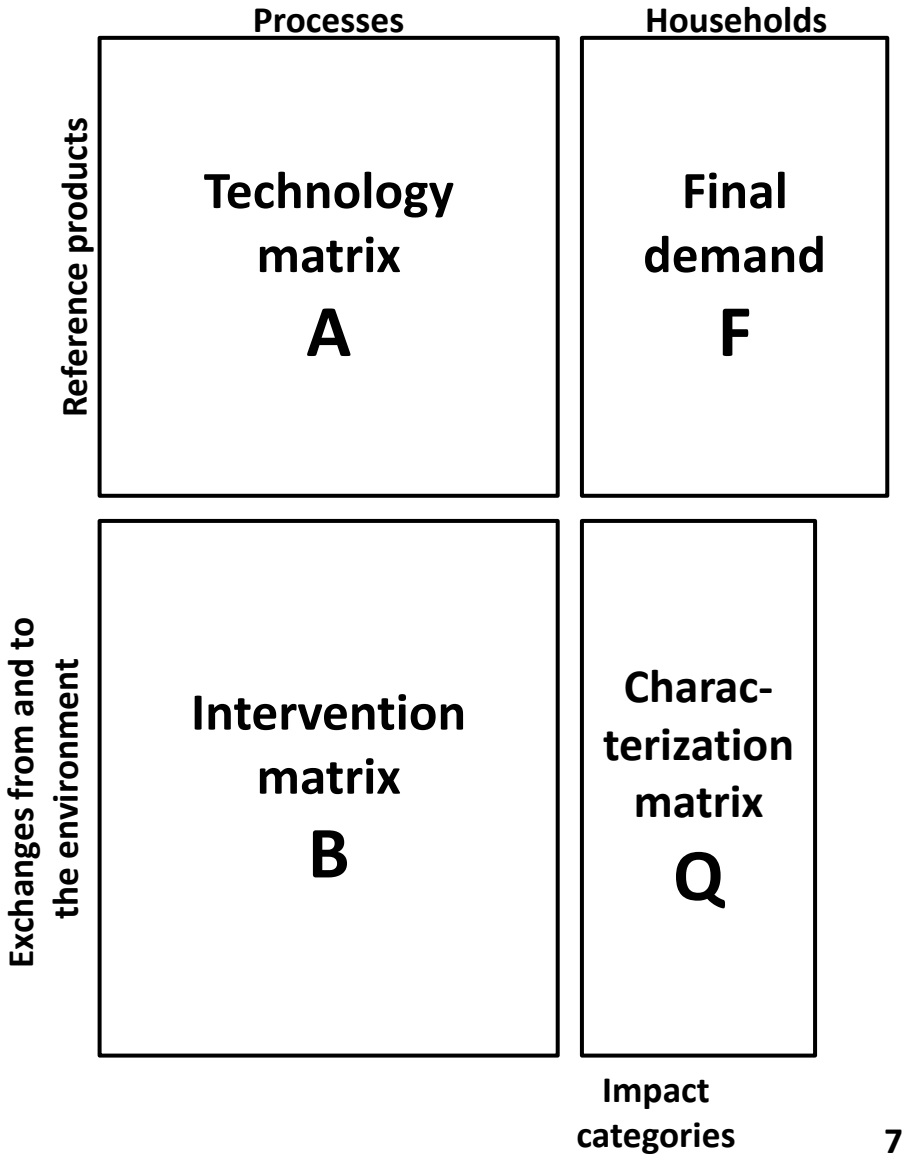
Methodology

- Environmental assessment of household consumption employing LCA:

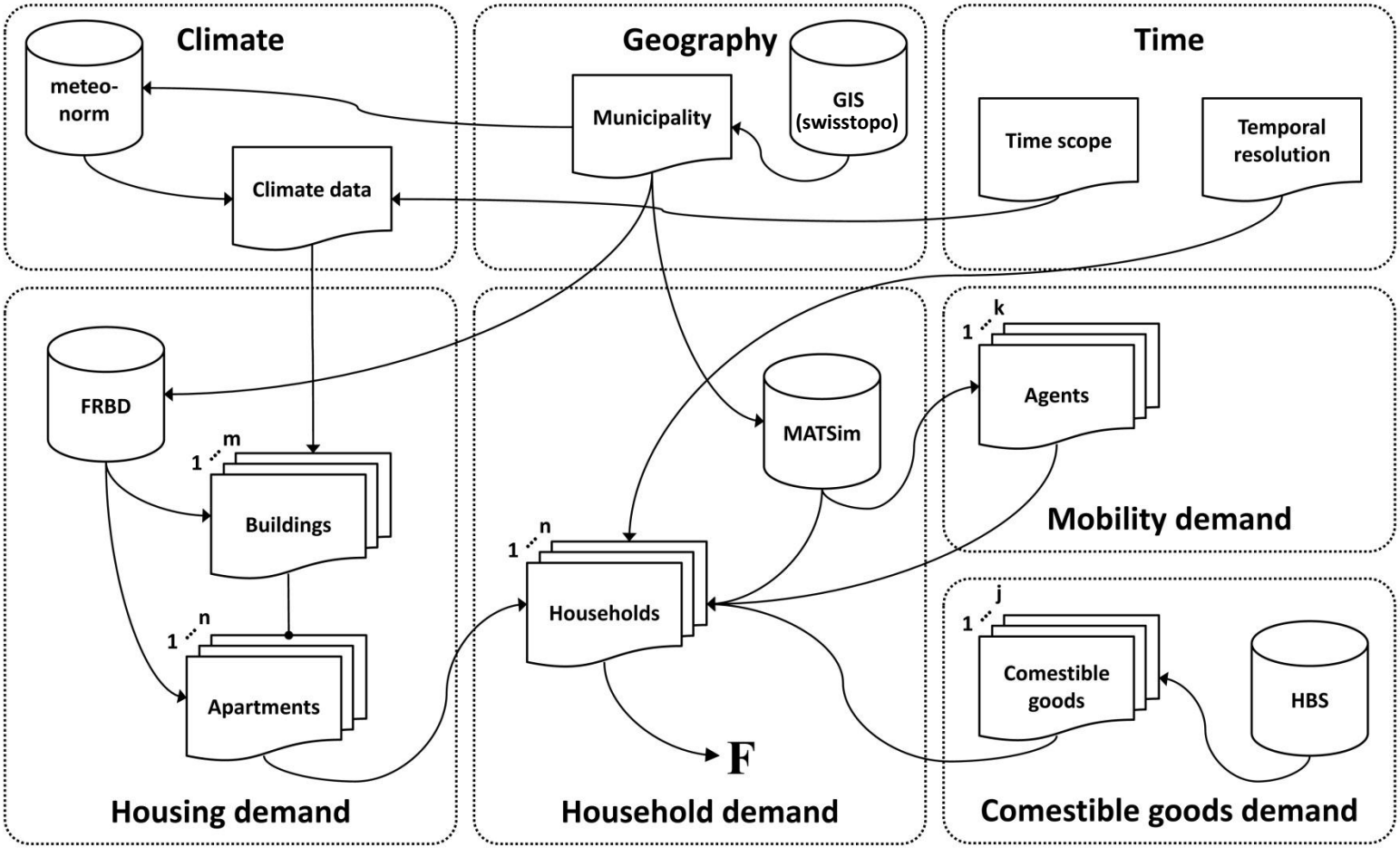
$$\mathbf{h = QBA^{-1}F}$$

- Demand modeling of multitude of households:

$$\mathbf{F = \left(f_1 \mid \ldots \mid f_i \mid \ldots \mid f_N \right)}$$

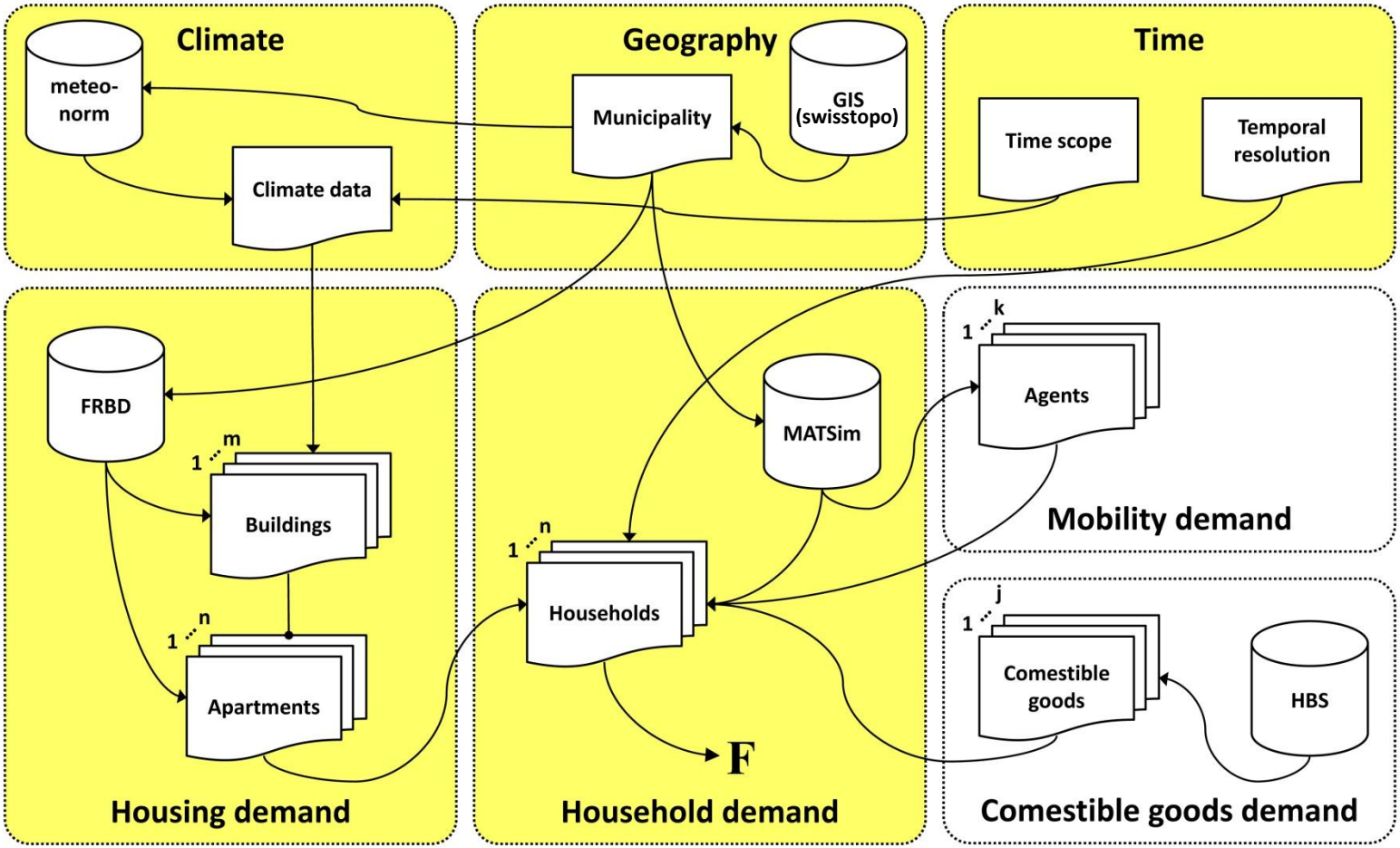


Methodology



FRBD: Federal Register of Buildings and Dwellings
HBS: Household Budget Survey
MATSim: Multi-Agent Transport Simulation

Housing demand



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Housing demand

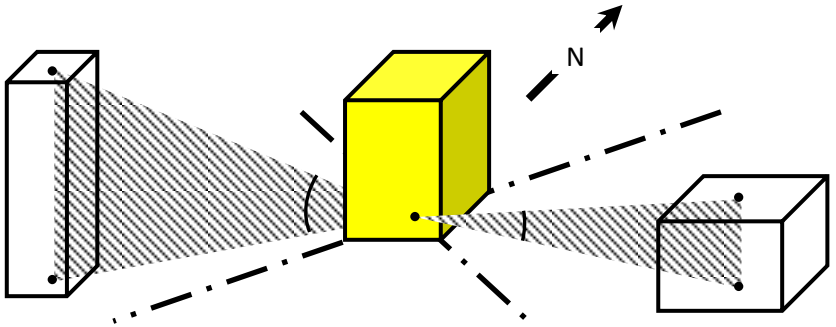
- Heat flux balance of buildings:

Solar gains — Gains due to occupation — Gains due to electricity use

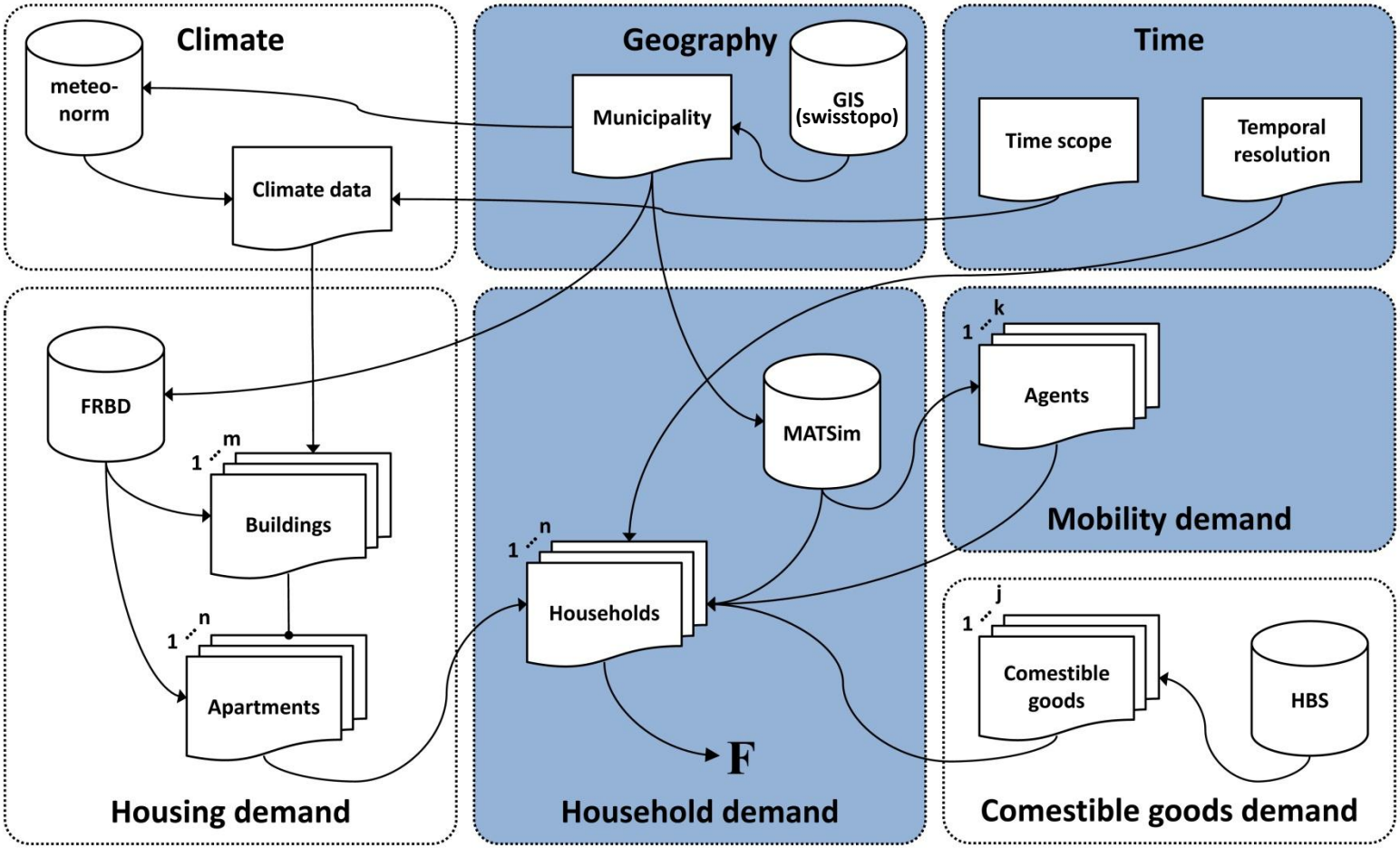
$$Q_h = \sum_{t=t_{begin}}^{t_{end}} \left(Q_{T,t} + Q_{V,t} \right) - \eta_g \cdot \left(Q_{s,t} + Q_{iP,t} + Q_{iEl,t} \right)$$

Heat demand — Transmission losses — Ventilation losses

- Shadows from other buildings:



Mobility demand



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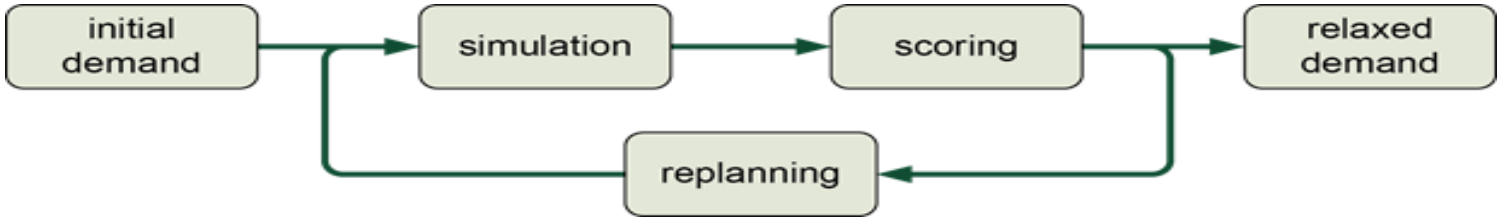
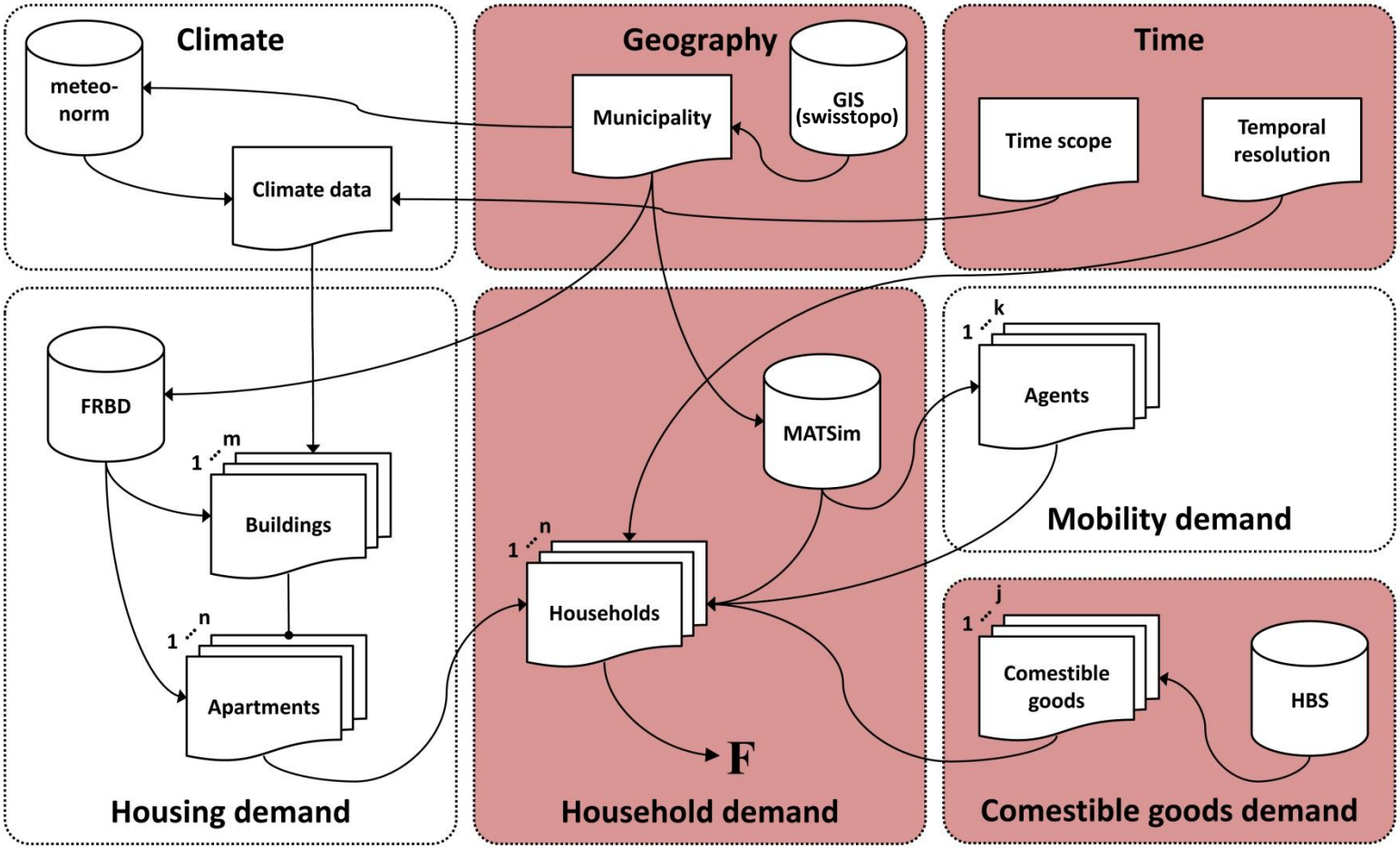
Mobility demand



MATSim:

- Agent-based model
- Models each inhabitant of CH as an agent who has to execute a plan of activities
- Activities (e.g. work, shopping) have properties of approx. start time, duration, and location
- Agents can use different traffic modes for travelling from activity A to activity B
- **Output**: travel distances and used traffic modes per agent.

Food and beverages demand



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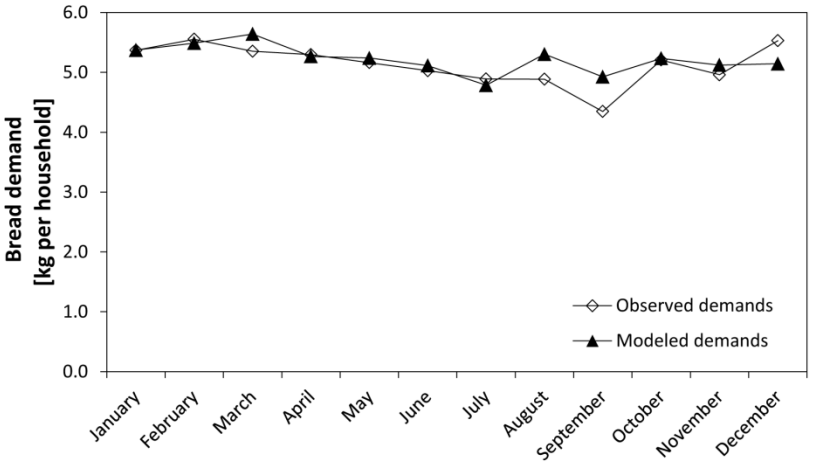
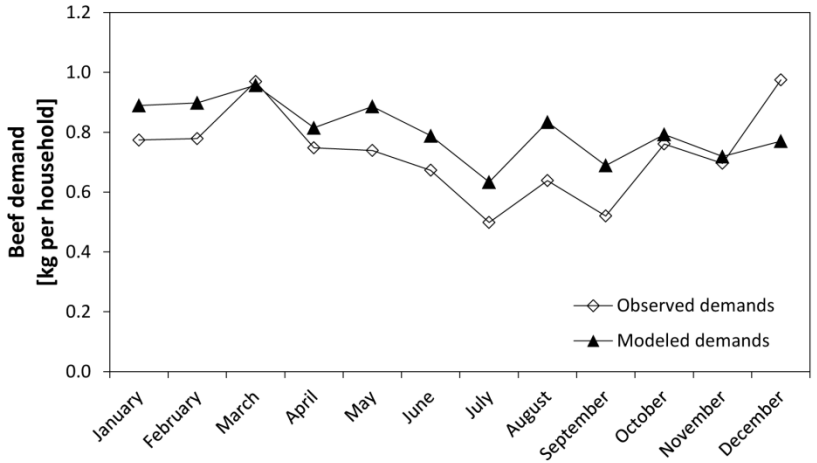
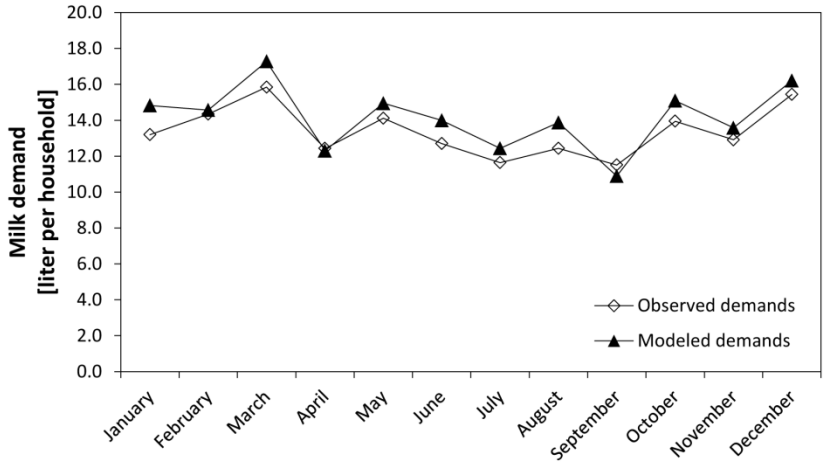
Food and beverages demand

- Multiple linear regression of data from Swiss household budget survey: $$\mathbf{X}\beta = \mathbf{y}$$
- Using easy to determine independent variables **X** like household size, income, age and education of household members, etc.
- Applying Generalized Linear Models allows for other than normal distributed consumption data **y** (e.g. discrete amounts of eggs)
- Two tier approach: Modeling the probability of a good being bought and the amount bought. Leads in expected amount per household.

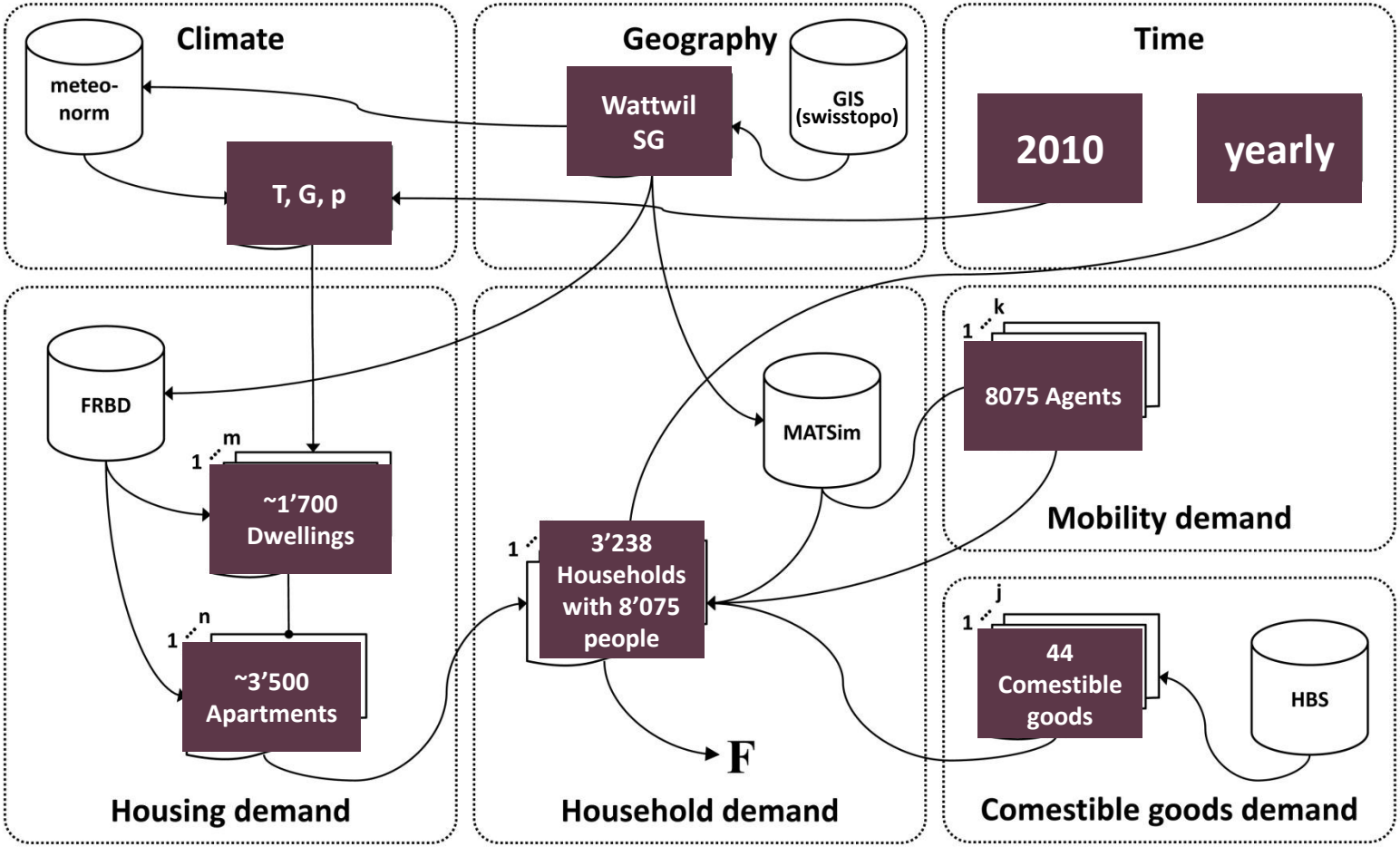
Food and beverages demand



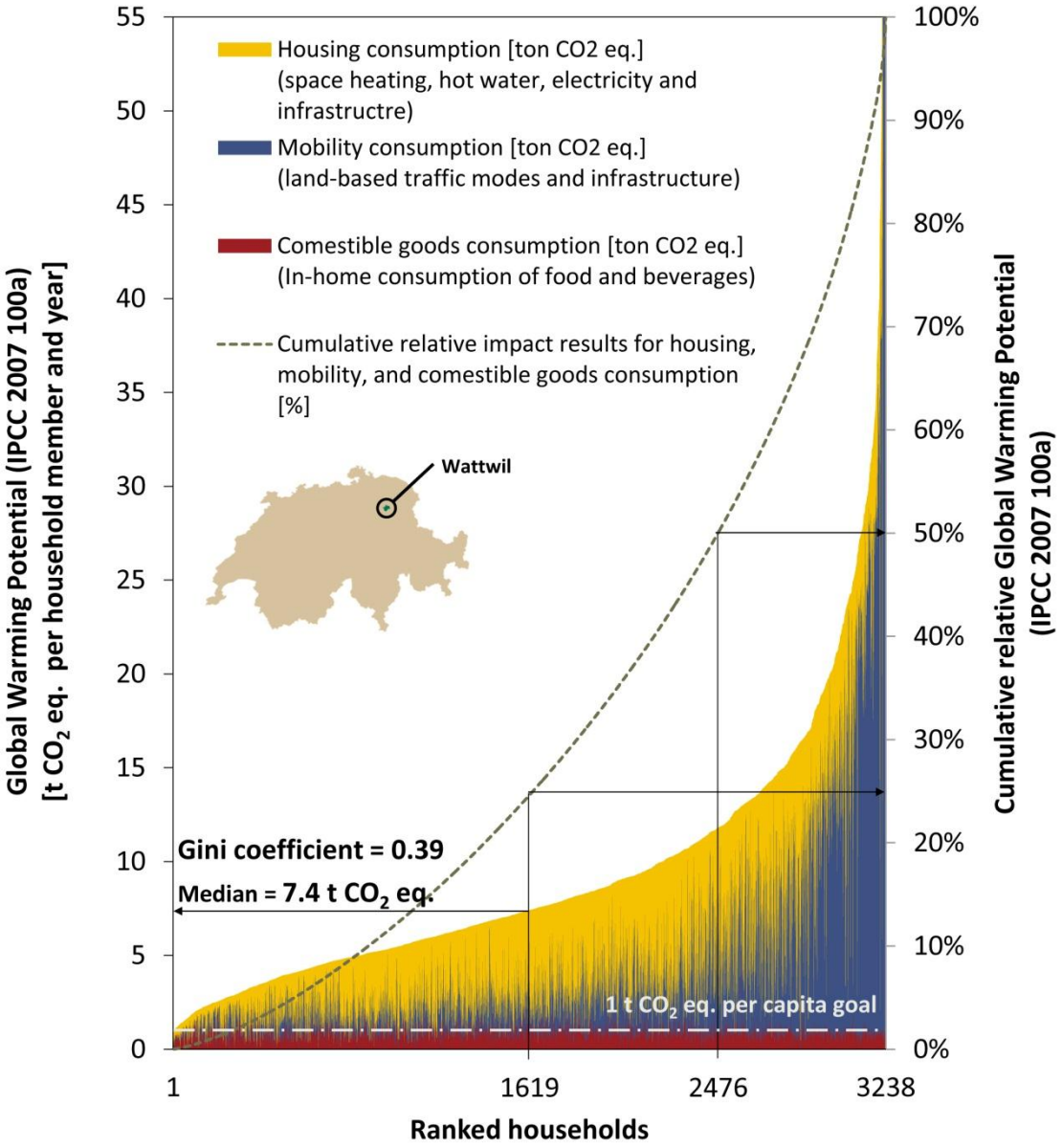




Case study: Wattwil (SG)

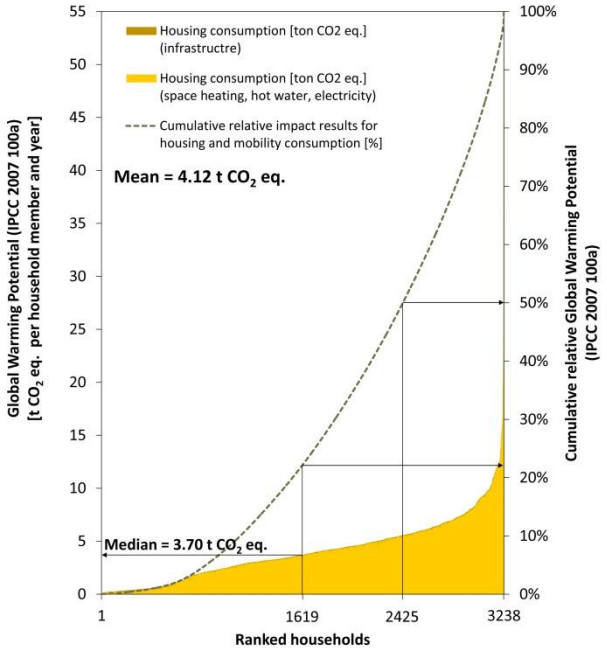


Results

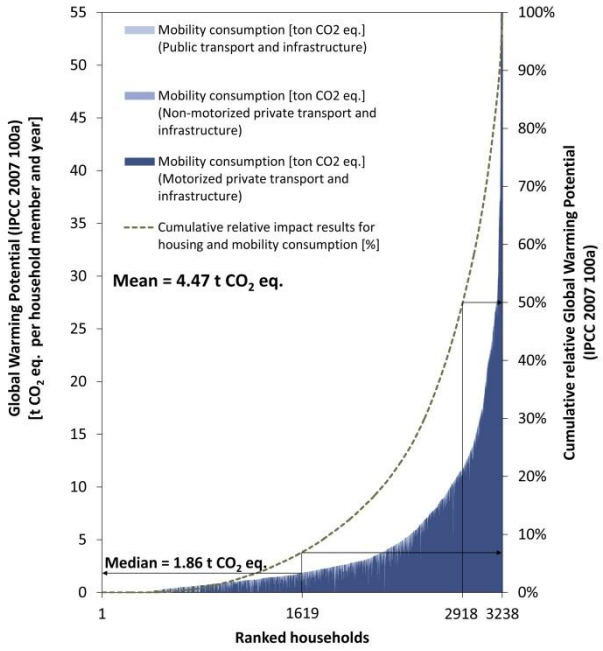

Housing consumption [ton CO2 eq.]
(space heating, hot water, electricity and infrastructre)
Mobility consumption [ton CO2 eq.]
(land-based traffic modes and infrastructure)
Comestible goods consumption [ton CO2 eq.]
(In-home consumption of food and beverages)
Cumulative relative impact results for housing, mobility, and comestible goods consumption [%]
Wattwil
Gini coefficient = 0.39
Median = 7.4 t CO2 eq.
1 t CO2 eq. per capita goal
Global Warming Potential (IPCC 2007 100a)
[t CO2 eq. per household member and year]
Cumulative relative Global Warming Potential (IPCC 2007 100a)
Ranked households
0
5
10
15
20
25
30
35
40
45
50
55
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
1
1619
2476
3238

Results

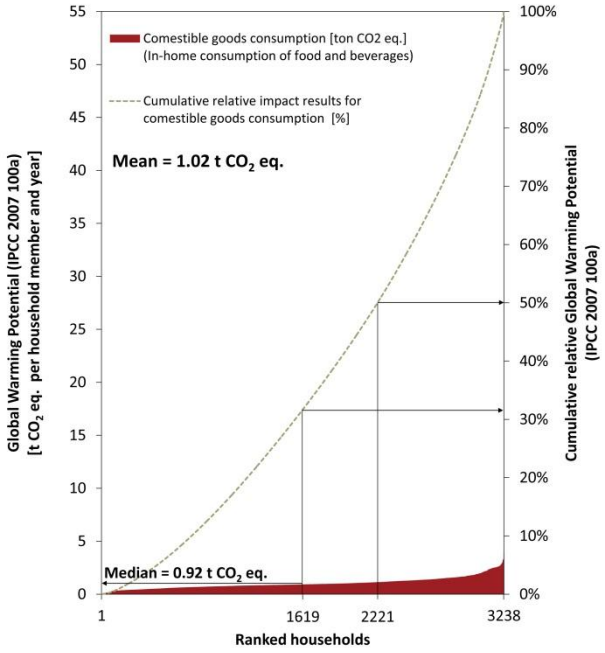
Housing



Mobility



Food and beverages



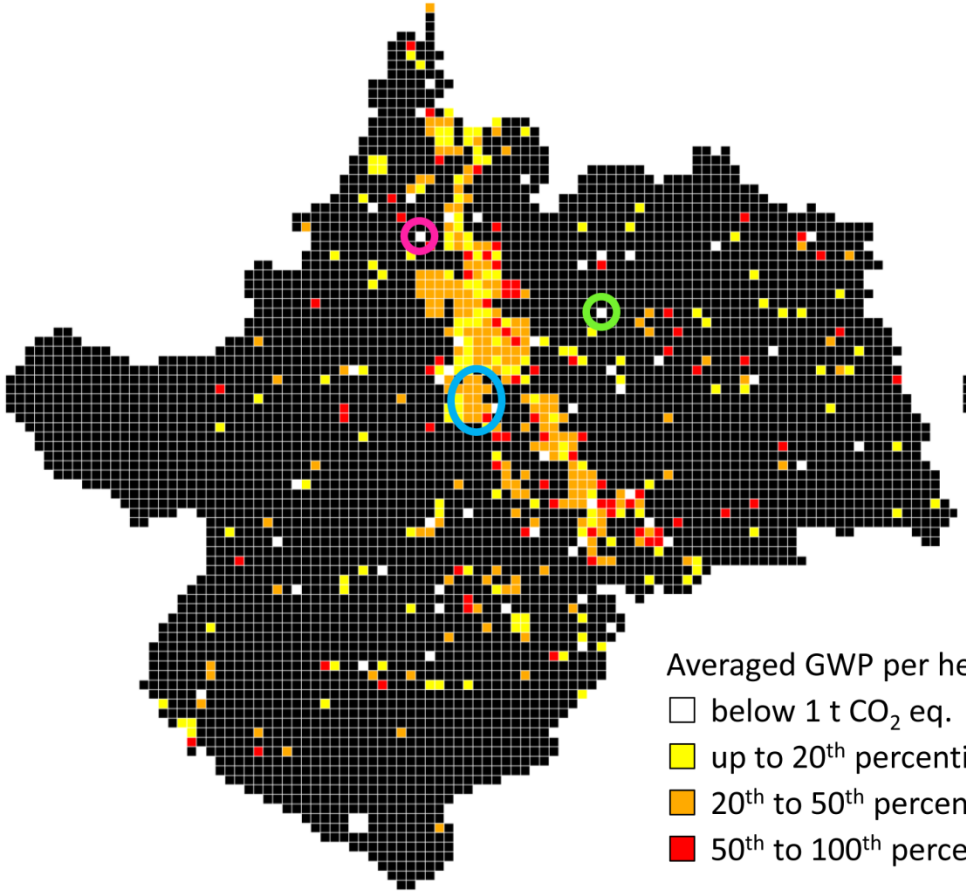
Wattwil average:

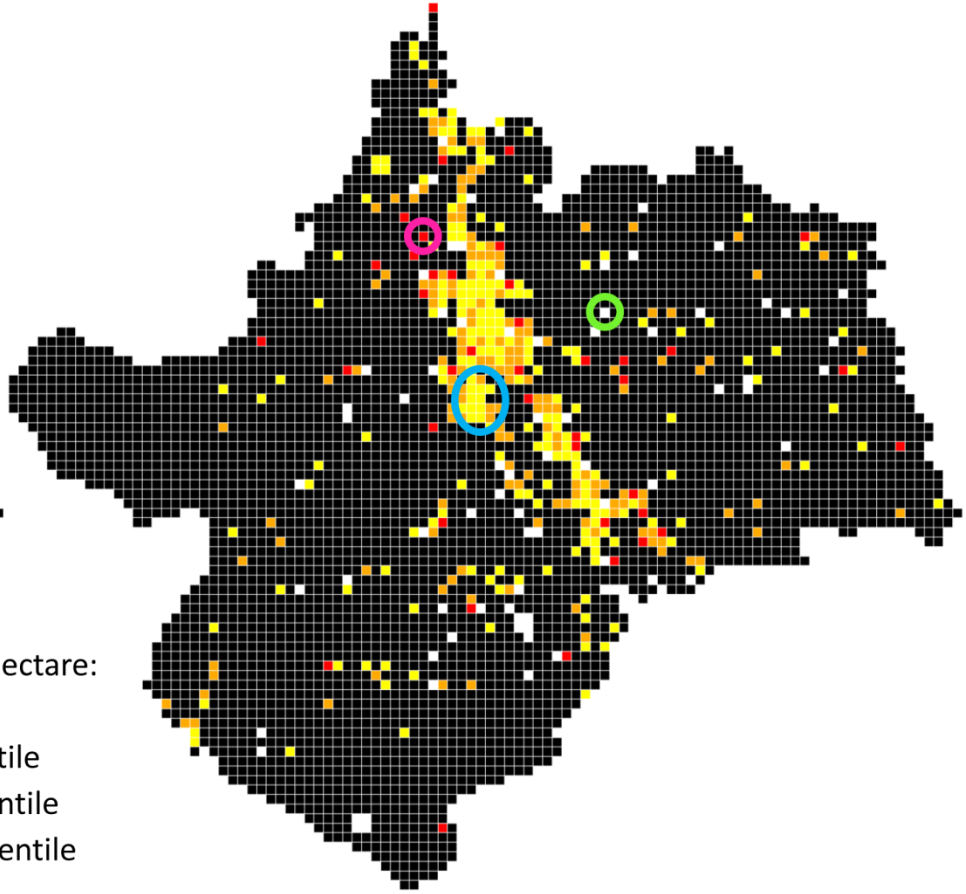
Housing	Mobility	Food and beverages
4.1 t CO_2 eq./capita·year	4.5 t CO_2 eq./capita·year	1.0 t CO_2 eq./capita·year

Swiss average (Jungbluth et al. 2011):

Housing	Mobility	Food and beverages
3.0 t CO_2 eq./capita·year	2.4 t CO_2 eq./capita·year	2.1 t CO_2 eq./capita·year

Results





Averaged GWP per hectare:
- below 1 t CO_2 eq.
- up to 20th percentile
- 20th to 50th percentile
- 50th to 100th percentile

Housing consumption

Mobility consumption

Results in brief

- Housing impacts are generally high, variability is rather small.
- Mobility impacts are highly unequally distributed.
- Variability of food/beverages impacts is small.
- Variability among households is driven by mobility and housing.
- There are trade-offs between the housing and mobility.

Conclusions and limitations

Only considering greenhouse gas emissions:

- Wattwil should focus on households with high demand of motorized individual mobility.
- Then focus should be led on demand and supply of heating.

Variability of food and beverages impacts might be small because:

- For food and beverages yearly CH supply mixes are used.
- Seasonally different impact of food production are not considered.

Outlook

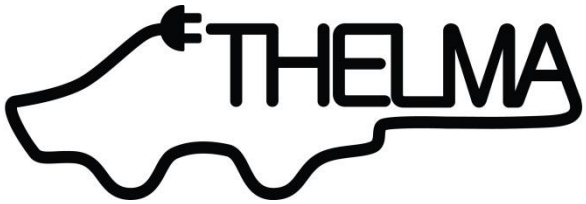
- Assessment of prospective scenarios of household consumption:
  - Changing demand (e.g. better insulation of buildings)
  - Changing supply (e.g. plug-in hybrid electric vehicles, etc.)
- Environmental optimization of supply of future household demand under different external constraints (e.g. regional supply constraints of energetic ressources)

Outlook

- Saner D, Jäggi B, Waraich RA, Heeren N and Hellweg S. (in preparation). *Households' Housing and Mobility Demands and their Life Cycle Assessment*.
- Saner D, Stoessel F, Jäggi B, Juraske R and Hellweg S. (in preparation). *FoodPrints of Households*.

Acknowledgement

- Study was performed within:



- Financially supported by:

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Thank you for your attention.

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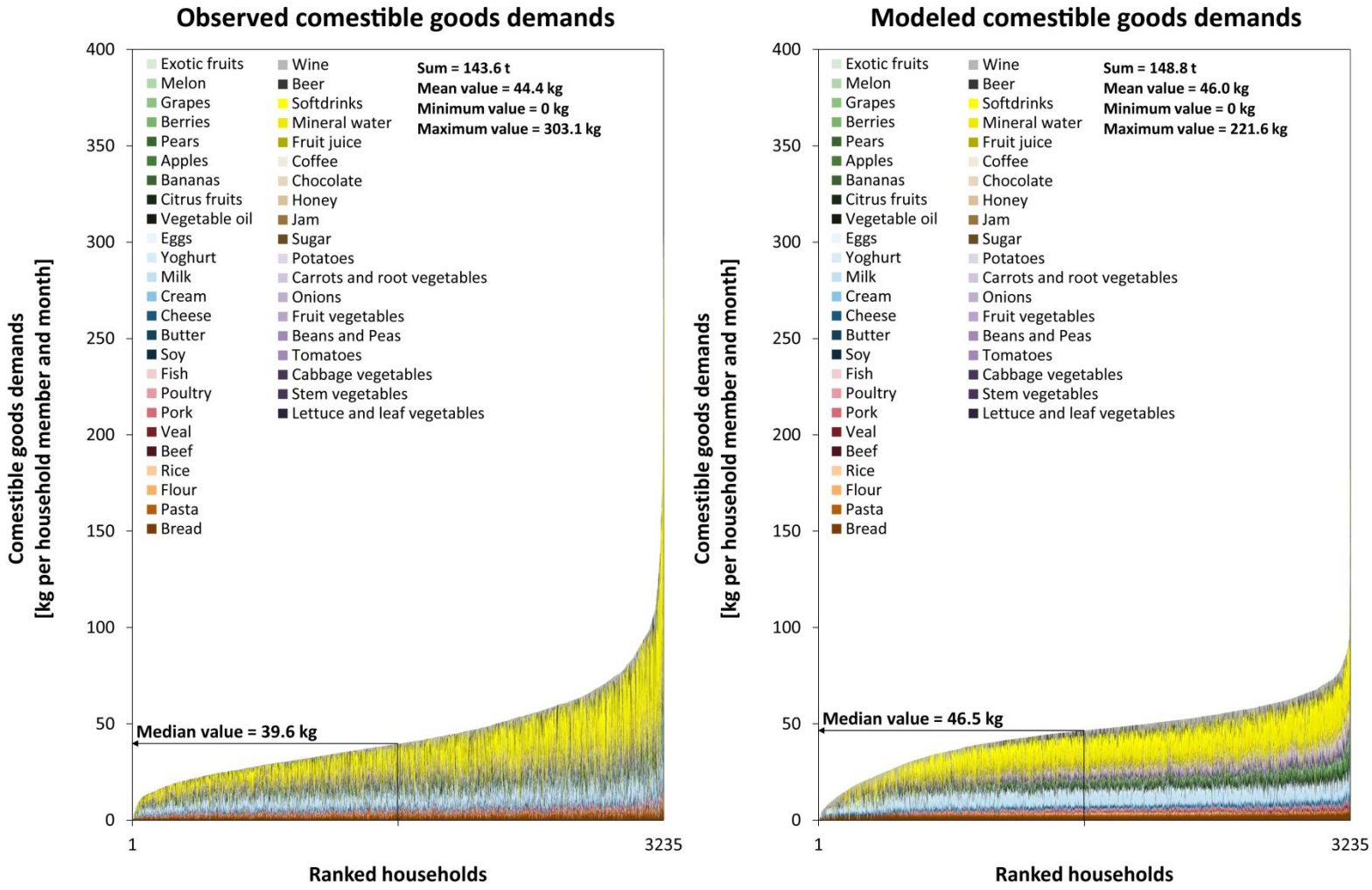
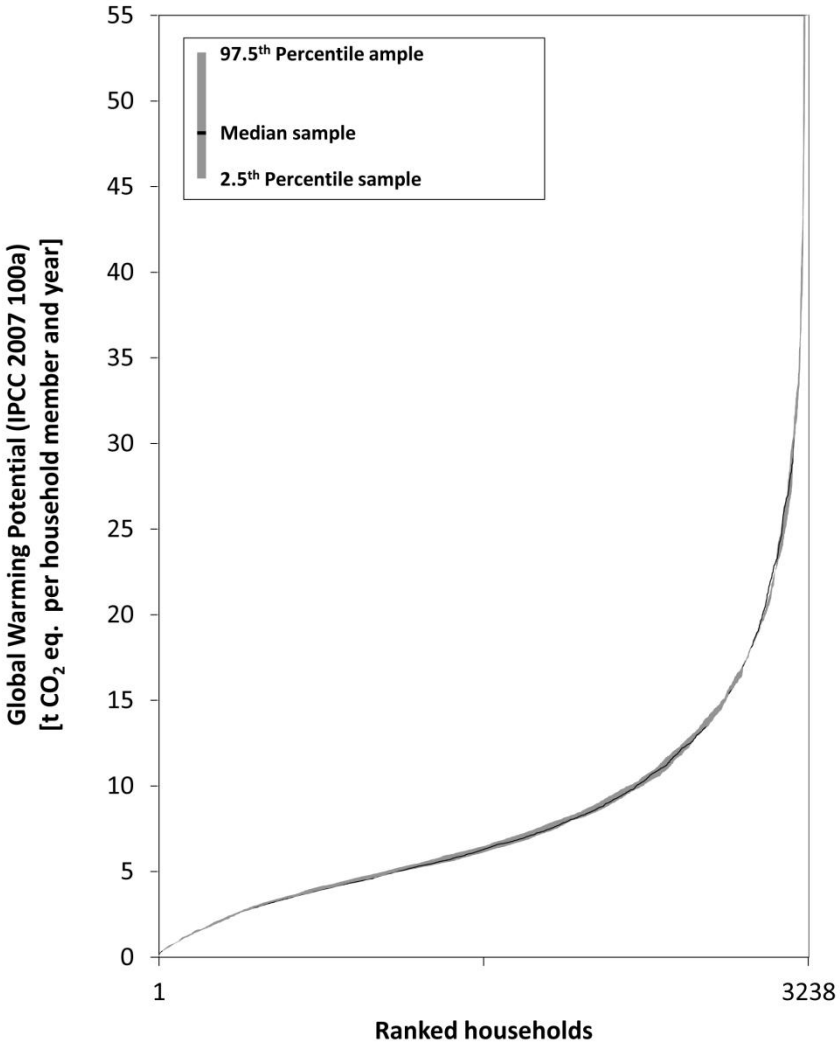
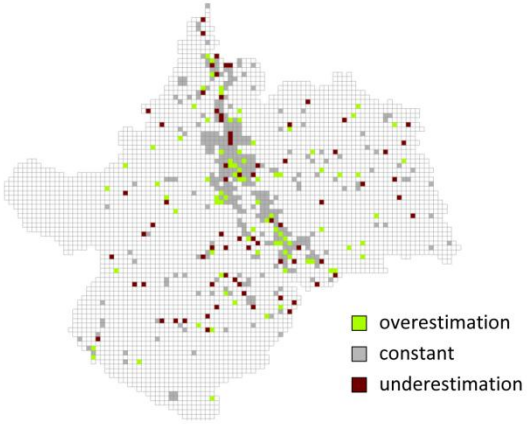
Food and beverages consumption



Uncertainty considerations



Differences in impact results distribution between median and 97.5th Percentile sample



Differences in impact results distribution between median and 2.5th Percentile sample