ECEEE Summer Study
1-6 June 2009


# 3353
# Energy demand in city-regions - methods to model dynamics of spatial energy consumption

Sébastien GIRARD, Christian KEIM, Markus PETER

# Agenda

Introduction to urbanisation and its dynamics

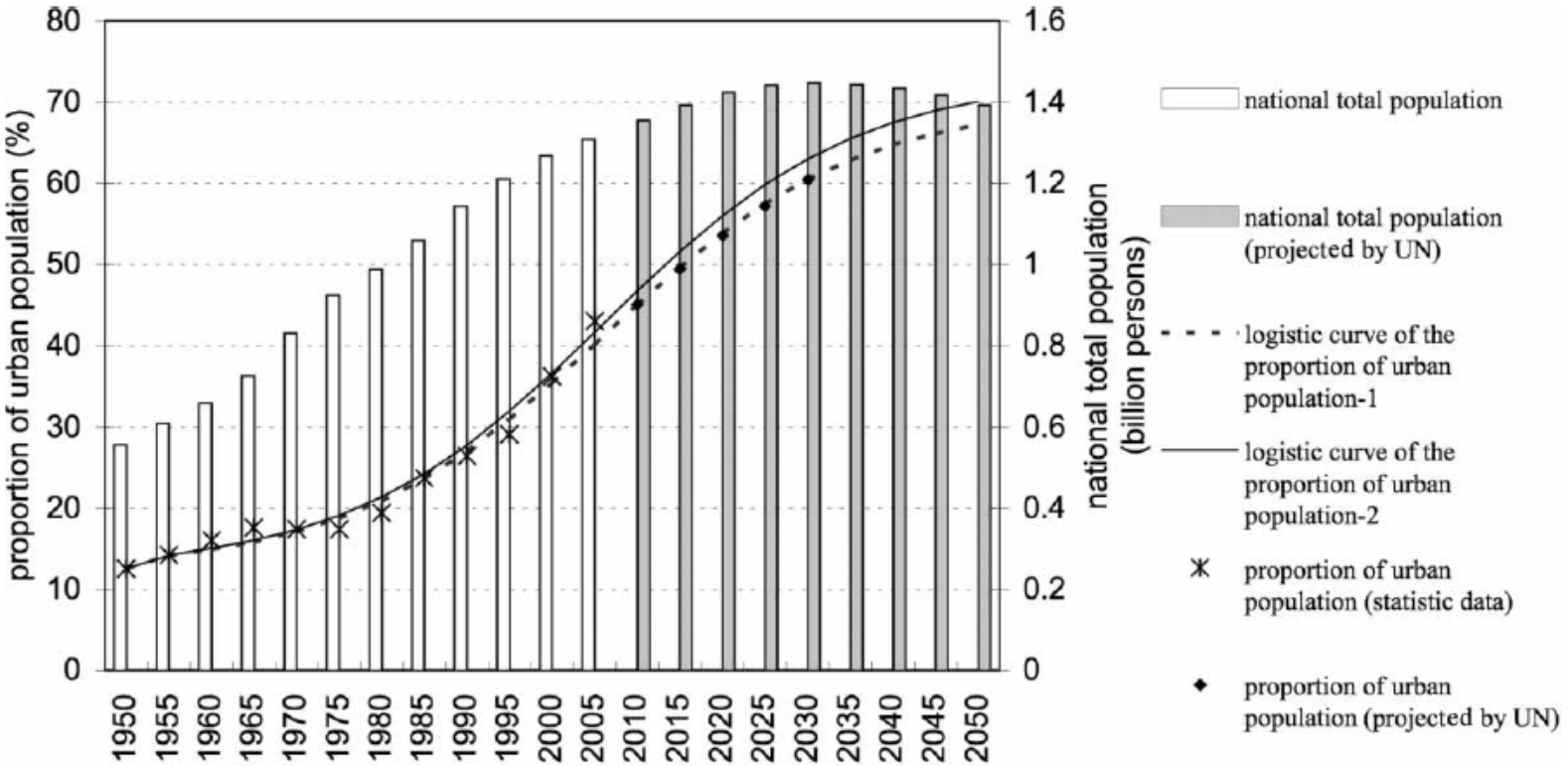
Urbanisation and energy – scale and interaction

- Scales of assessment and localisation
- Localisation of energy demand
- Dynamics of urban development
- Modelling and simulating the time and spatial evolution of urban spaces

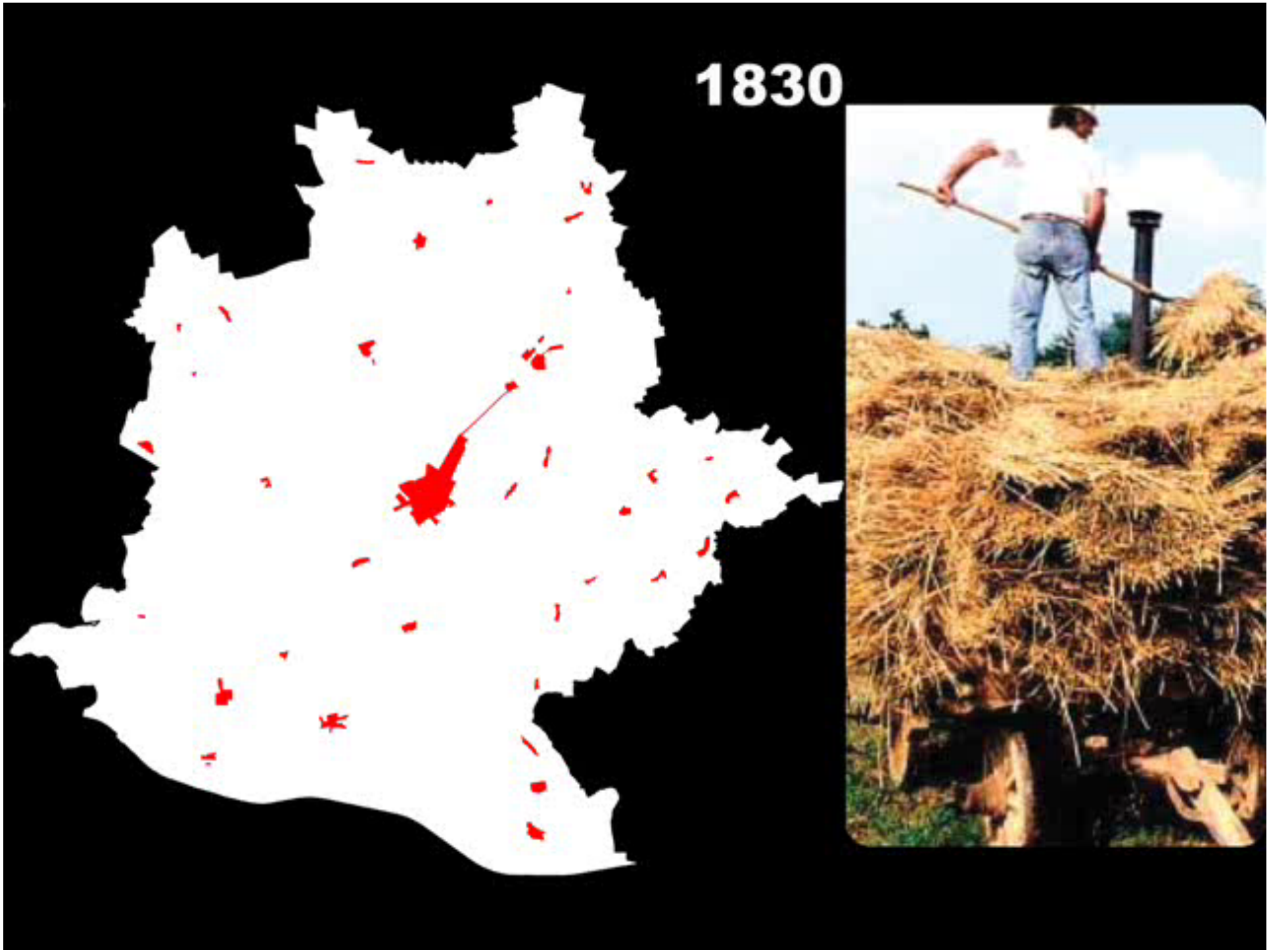
Conclusion

# Urbanisation

# Growing urban population

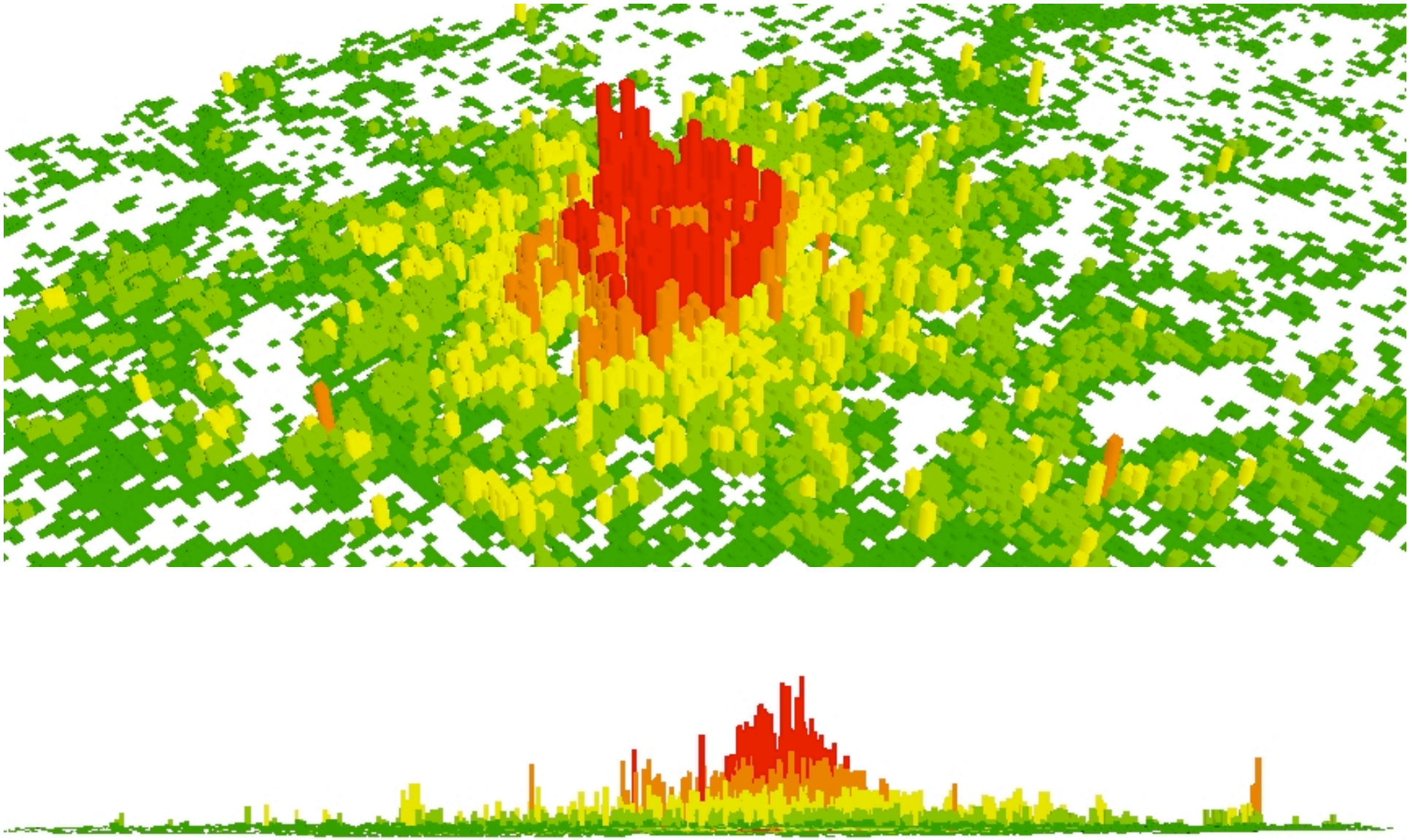



National Bureau of Statistics of China (BVSC), 2006
United Nations Population Division (UNPD), 2006


1830

EIFER

# Building density in Ile de France - Paris

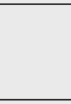
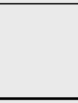


# Patterns of former greenfield development

EIFER

# Building stock

# Building typologies

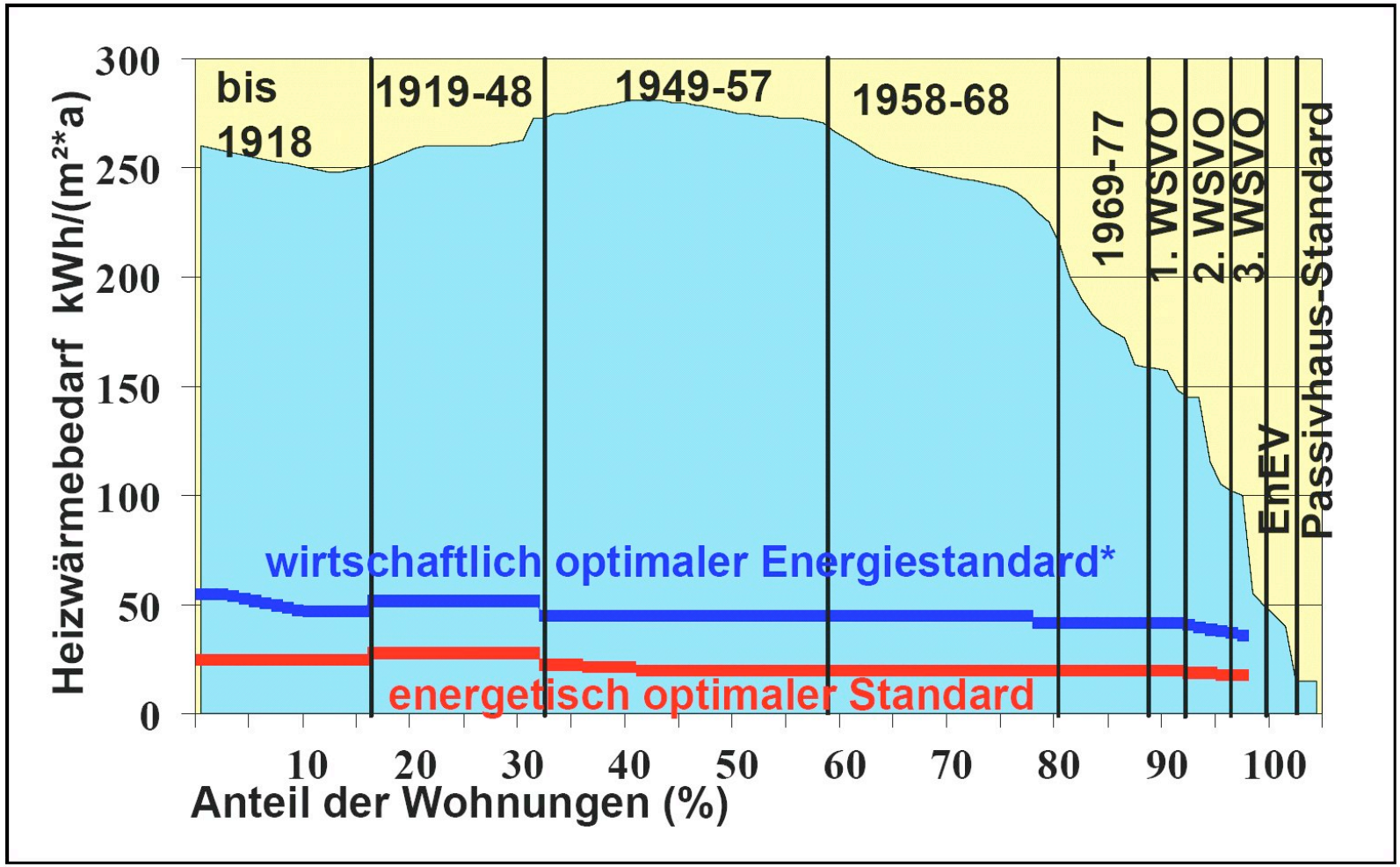
| Baualtersklasse | | | EFH | RH | MFH | GMH | HH |
|---|---|---|---|---|---|---|---|
| A | vor 1918 | Fachwerk |  | |  | | |
| B | vor 1918 | |  |  |  |  | |
| C | 1919-1948 | |  |  |  |  | |
| D | 1949-1957 | |  |  |  |  | |
| E | 1958-19 | | | | | | |
| F | 1969-19 | | | | | | |
| G | 1979-19 | | | | | | |
| H | 1984-19 | | | | | | |
| I | 1995-20 | | | | | | |
| J | nach 20 | | | | | | |

**Deutsche Gebäudetypologie – Häufigkeit von Gebäudetypen unterschiedlichen Baualters**

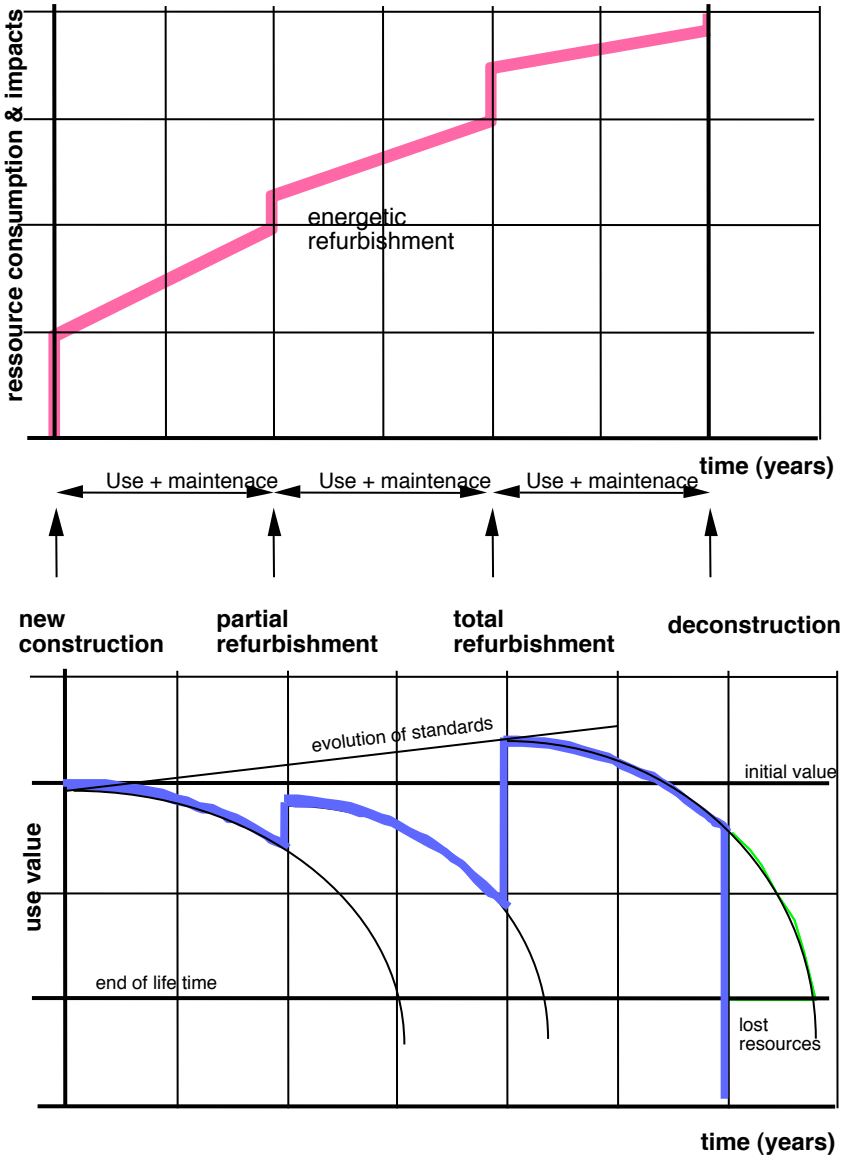
| Gebäudetypen* | | Baualtersklassen | | | | | | | | | | Summe | *Anteil* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | vor 1918 | vor 1918 | 1919 - 1948 | 1949 - 1957 | 1958 - 1968 | 1969 - 1978 | 1979 - 1983 | 1984 - 1994 | 1995 - 2001 | 2002 - 2006 | | |
| | | A | B | C | D | E | F | G | H | I | J | | |
| | **EFH** |  |  |  |  |  |  |  |  |  |  | | |
| | Wohnfläche in Tsd. m² | 81.503 | 148.776 | 168.937 | 174.251 | 235.409 | 223.135 | 112.631 | 236.441 | 255.280 | 103.208 | **1.739.571** | *52%* |
| | Anz. Wohneinh. in Tsd. | 916 | 1.707 | 2.010 | 1.915 | 2.274 | 1.867 | 936 | 2.055 | 1.994 | 671 | **16.345** | *42%* |
| | **RH** | |  |  |  |  |  |  |  |  |  | | |
| | Wohnfläche in Tsd. m² | | 14.543 | 31.450 | 21.993 | 35.996 | 61.478 | 24.503 | 32.951 | 33.366 | 11.675 | **267.955** | *8%* |
| | Anz. Wohneinh. in Tsd. | | 145 | 326 | 231 | 348 | 517 | 202 | 281 | 285 | 83 | **2.418** | *6%* |
| | **MFH** |  |  |  |  |  |  |  |  |  |  | | |
| | Wohnfläche in Tsd. m² | 31.974 | 109.337 | 135.827 | 117.051 | 149.881 | 122.930 | 61.044 | 118.019 | 154.740 | 24.267 | **1.025.070** | *31%* |
| | Anz. Wohneinh. in Tsd. | 462 | 1.501 | 2.034 | 1.912 | 2.210 | 1.677 | 821 | 1.712 | 2.240 | 296 | **14.865** | *38%* |
| | **GMH** | |  |  |  |  |  | | | | | | |
| | Wohnfläche in Tsd. m² | | 31.549 | 10.160 | 38.936 | 47.501 | 46.124 | | | | | **174.270** | *5%* |
| | Anz. Wohneinh. in Tsd. | | 448 | 169 | 703 | 784 | 697 | | | | | **2.801** | *7%* |
| | **HH** | | | | |  |  | | | | | | |

Institut für Wohnen und Umwelt (IWU), Darmstadt

# Energy standards

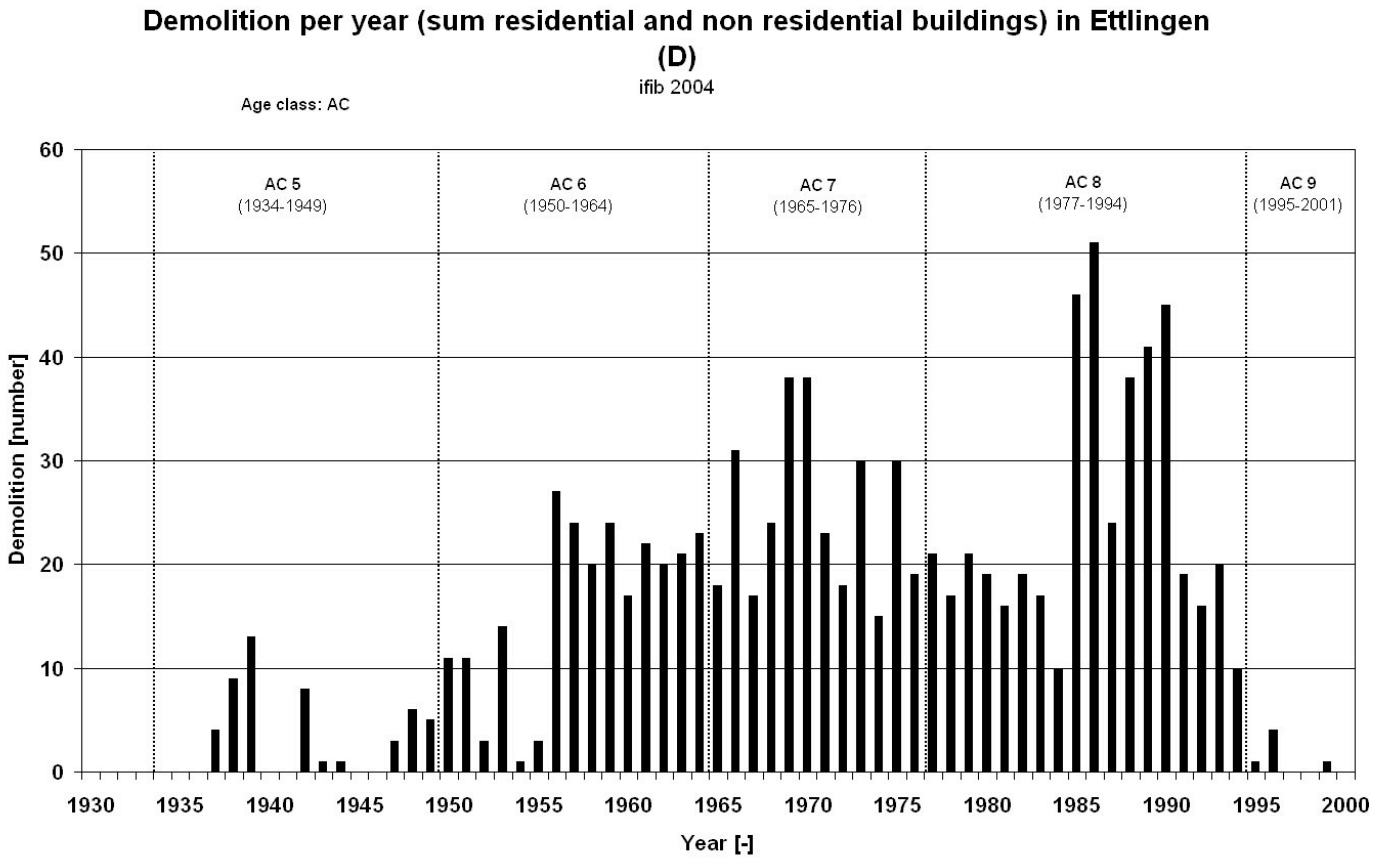


# Life cycle analysis of buildings



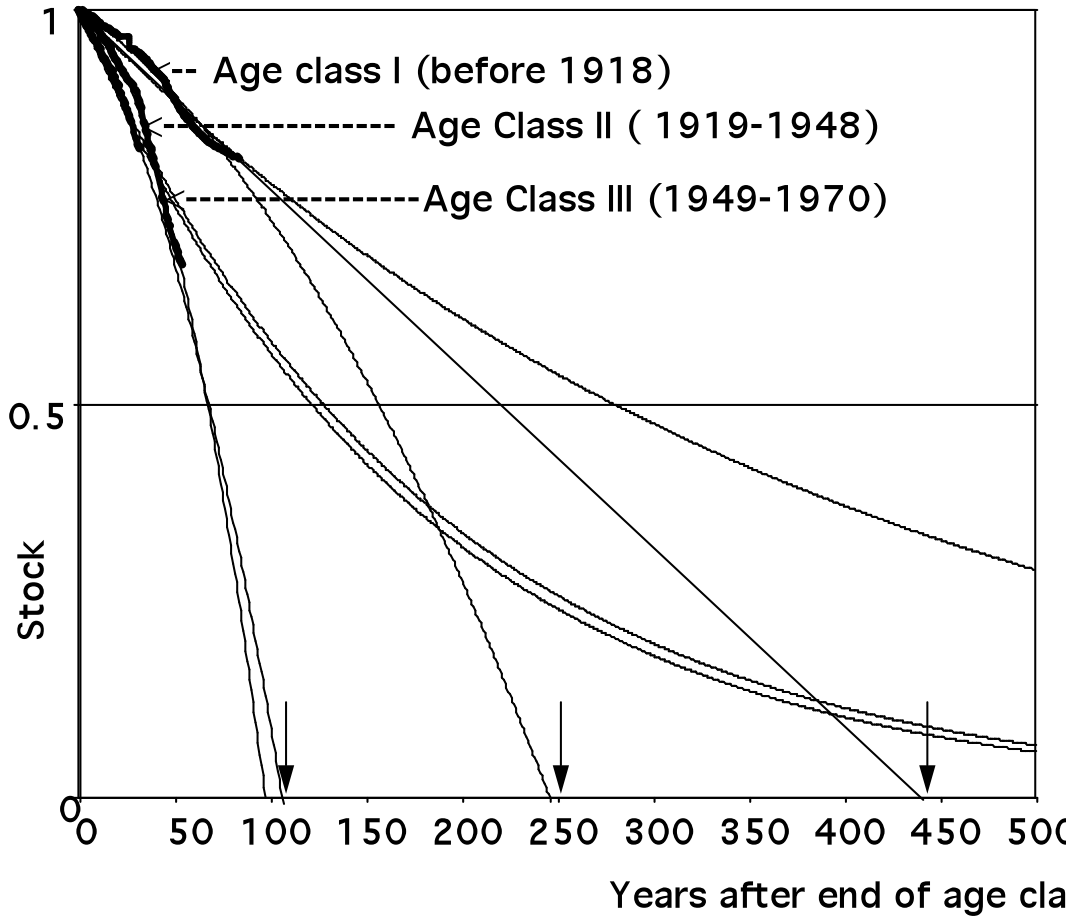

Kohler, N. (2003). Lebenszyklusanalyse im Planungsprozess von Gebäuden. Darmstadt.

# Demolition rates




Hassler, U. and N. Kohler (2004). Das Verschwinden der Bauten des Industriezeitalters: Lebenszyklen industrieller Baubesta¨nde und Methoden transdisziplinärer Forschung. Berlin, Wasmuth.

# Survival function




Bradley, P., E. K. N. Buergel-Goodwin, et al. (2005). "Survival functions of building stocks and components."

# Localisation / Simulation

# Modelling and simulation

Demand and supply depend on various local characteristics

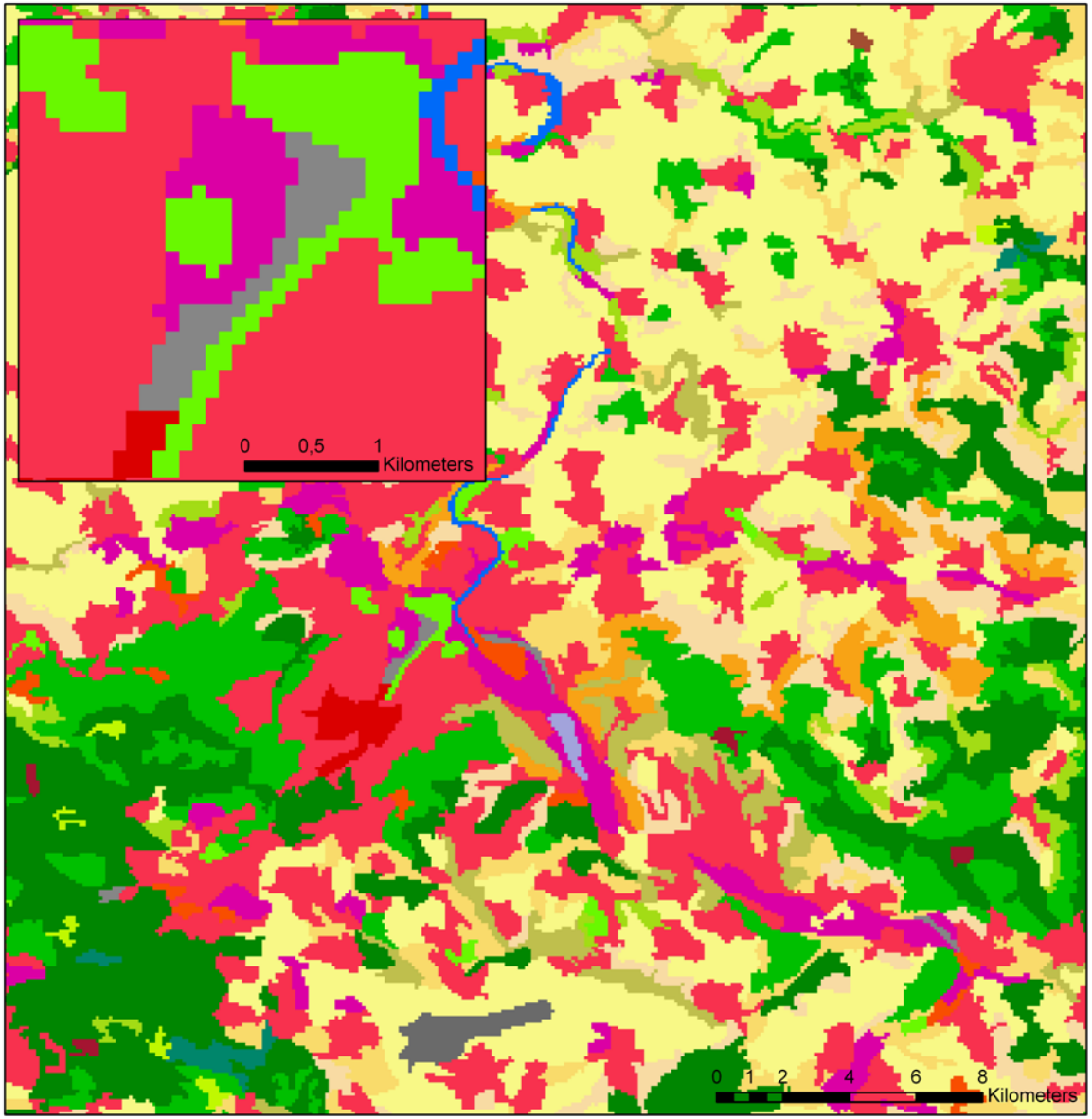
Time and space simulation: land use evolution, interaction between components of the urban system

Geographical Information Systems (GIS)

Cellular automata

Agent-based modelling (ABM)

# CORINE Land Cover (100 m*100 m)

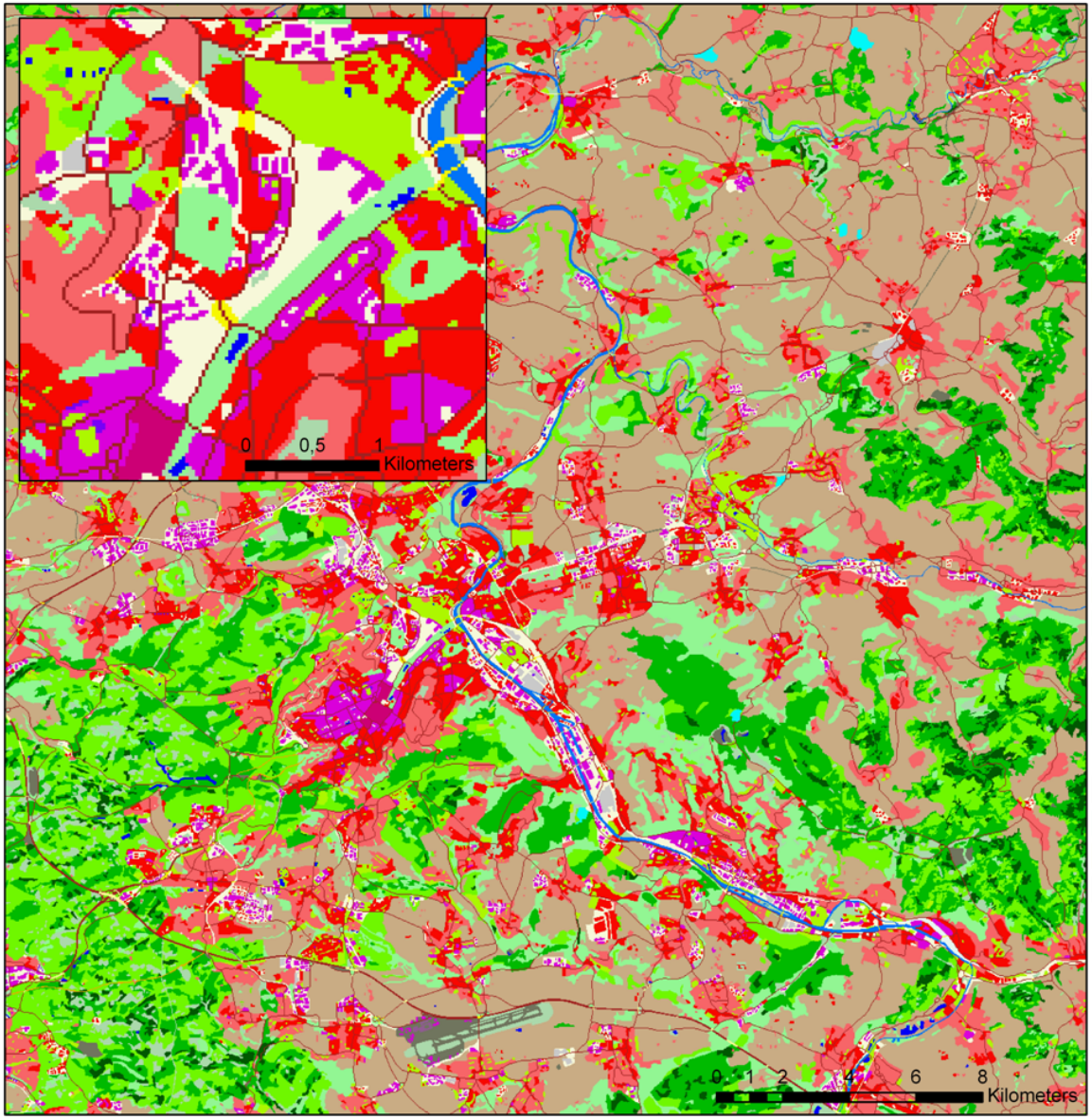



**CORINE-2000**

**Bodenutzungsklasse**

- Durchgängig städtische Prägung
- Nicht durchgängig städtische Prägung
- Industrie- und Gewerbeflächen
- Straßen, Eisenbahn
- Hafengebiete
- Flughäfen
- Abbauflächen
- Deponien und Abraumhalden
- Baustellen
- Stästische Grünflächen
- Sport- und Freizeitanlagen
- Nicht bewässertes Ackerland
- Weinbauflächen
- Obst- und Beerenobstbestände
- Wiesen und Weiden
- Komplexe Parzellenstrukturen
- Landwirtschaft und natürliche Bodenbedeckung
- Laubwälder
- Nadelwälder
- Mischwälder
- Natürliches Grünland
- Heiden und Moorheiden
- Wald- Strauch- Übergangsstadien
- Strände, Dünen und Sandflächen
- Felsflächen ohne Vegetation
- Flächen mit spärlicher Vegetation
- Gletcher und Dauerschneegebiete
- Sümpfe
- Torfmoore
- Salzwiesen
- In der Gezeitenzone liegende Flächen
- Gewässerläufe
- Wasserflächen
- Lagunen
- Mündungsgebiete
- Meere und Ozeane
- no data

# Infoterra LaND 25 (25 m*25m)

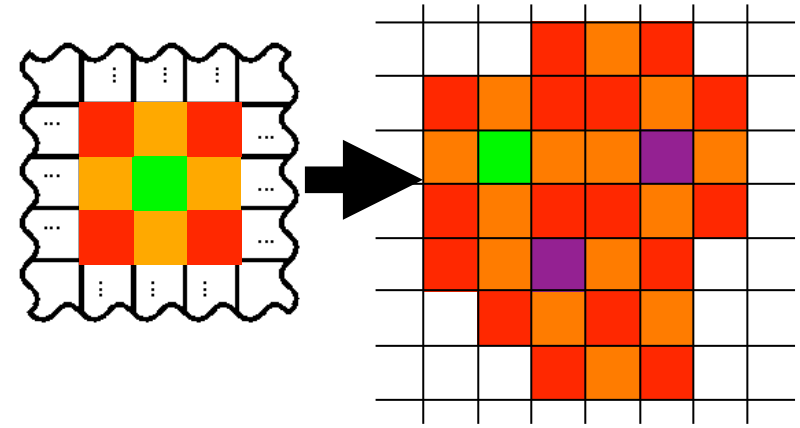


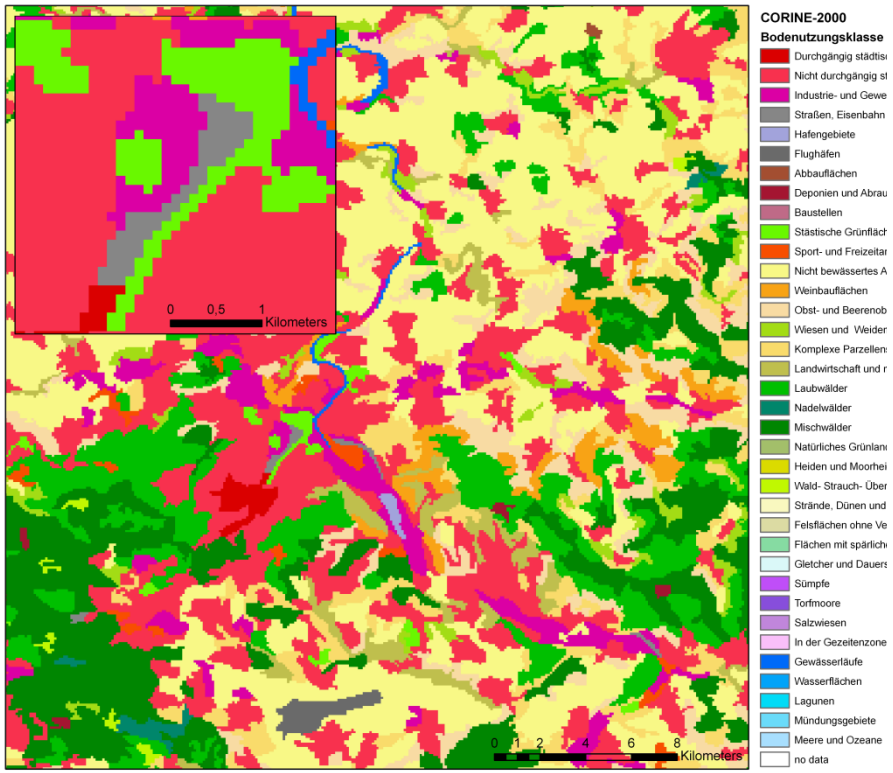

**LaND25**

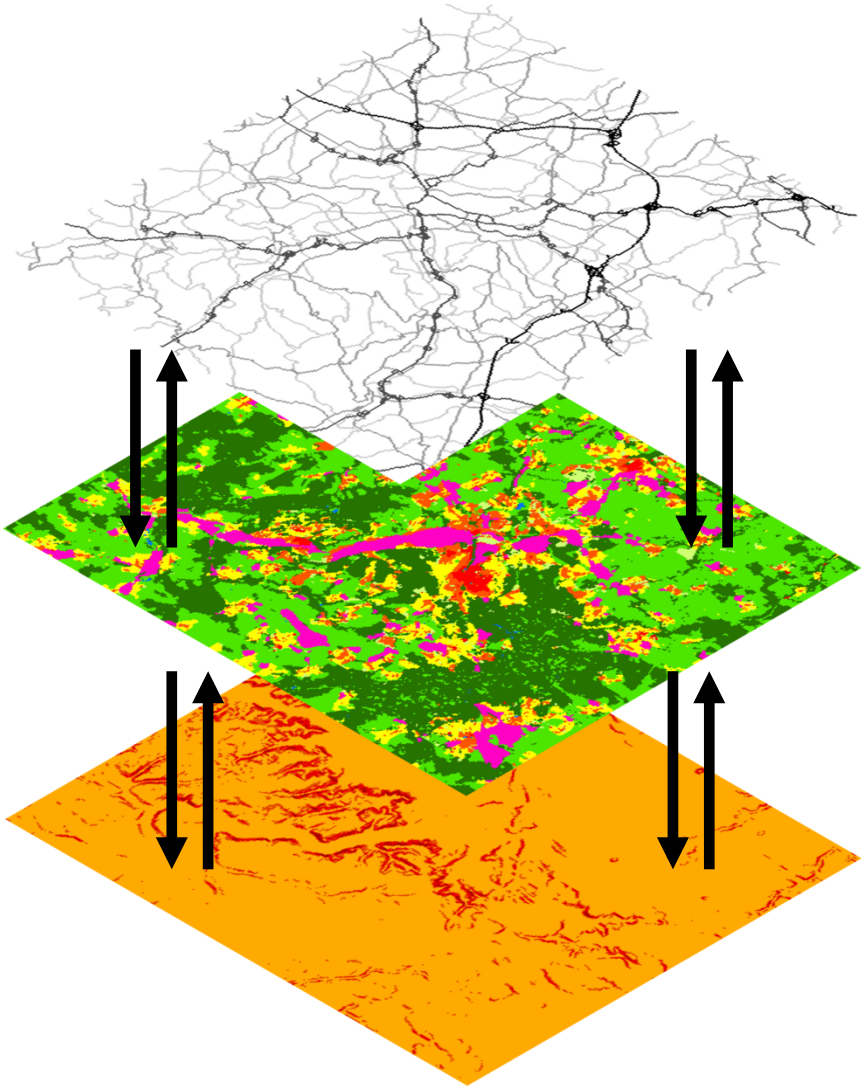
**Klassenbeschreibung**

- Urban: Extremely dense urban
- Urban: Extremely dense urban High Buildings
- Urban: Dense urban
- Urban: Dense urban high buildings
- Urban: Urban fabric
- Urban: Village and Suburban
- Urban: Urban green
- Urban: Sealed areas
- Ind.Com.Transport: Industrial and commercial
- Ind.Com.Transport: Airport buildings
- Ind.Com.Transport: Urban bridges
- Ind.Com.Transport: Non-urban bridges
- MinesDumpsConstructionSites: Mineral extraction si
- Non-urban: Other sealed areas
- Forest: Coniferous forest
- Forest: Deciduous forest
- Forest: Mixed forest
- Forest: Spacious forest
- Agriculture: Agriculture, grassland
- Natural vegetation: natural other open areas
- Natural non-vegetated area: Rocks,snow
- Continental waters: Water bodies
- Continental waters: Stream courses
- Roads: Roads through forest
- Roads: Teleatlas Roads

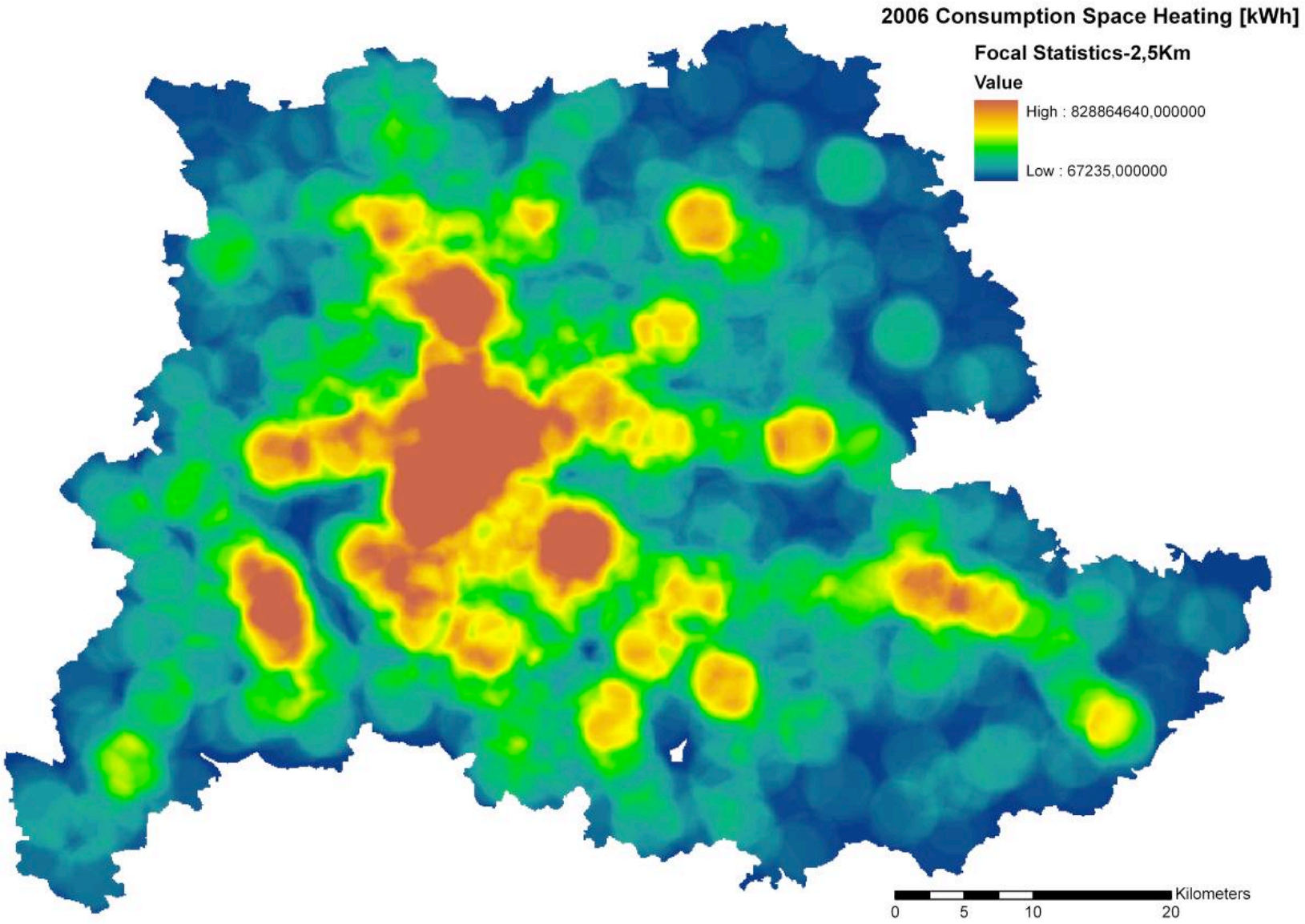
# Basics of spatial simulation



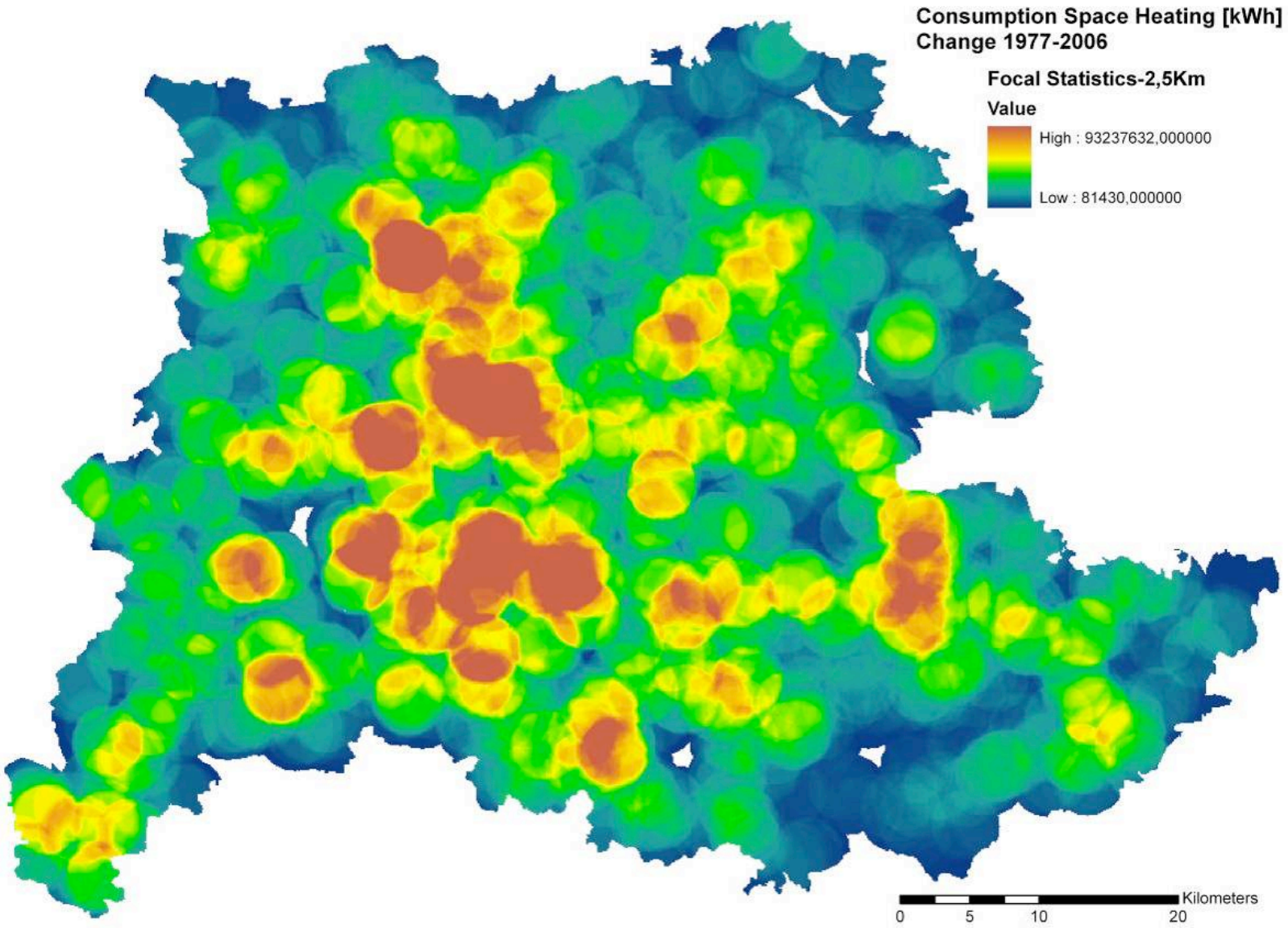


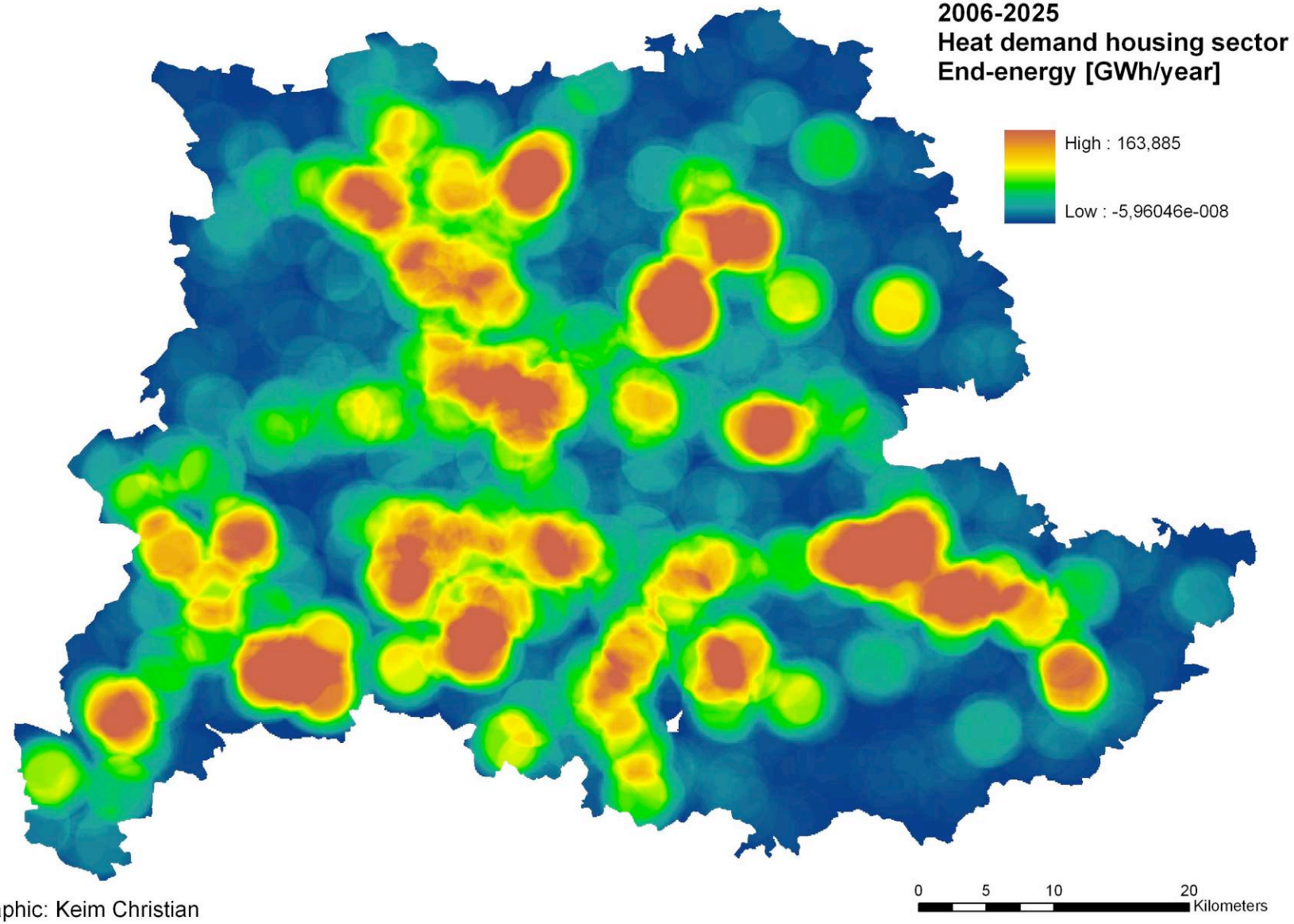
# Energy demand mapping



# Energy demand mapping

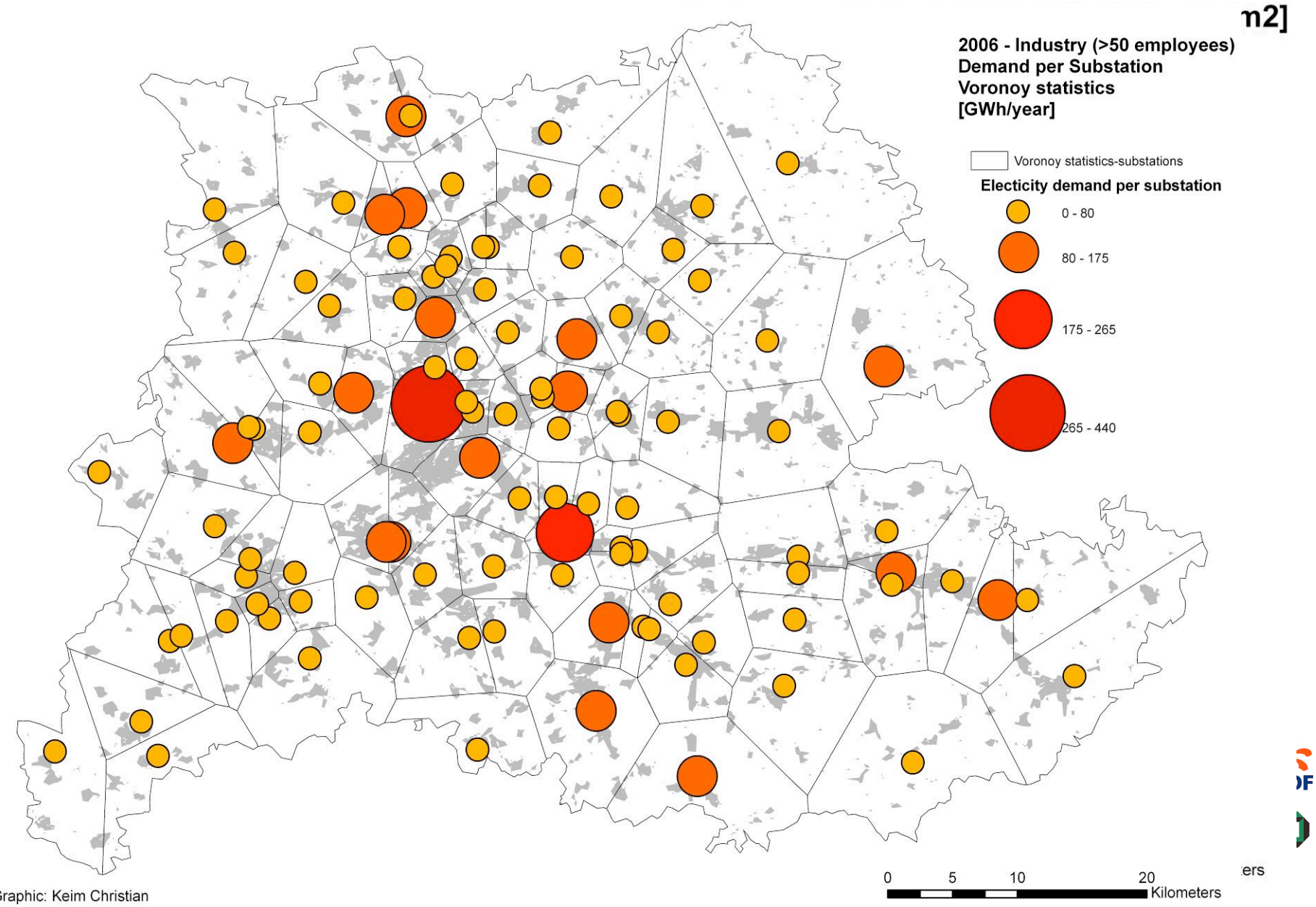


# Energy demand mapping



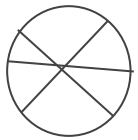
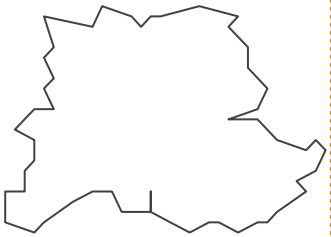
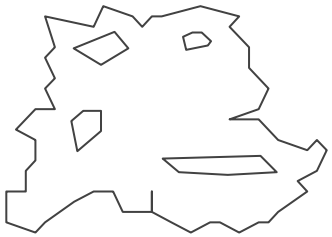
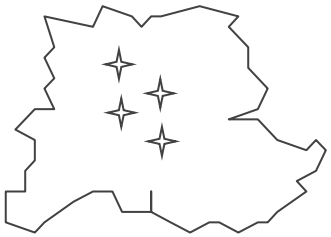
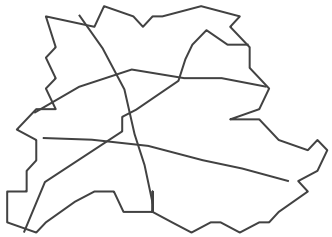

Graphic: Keim Christian

# Localisation

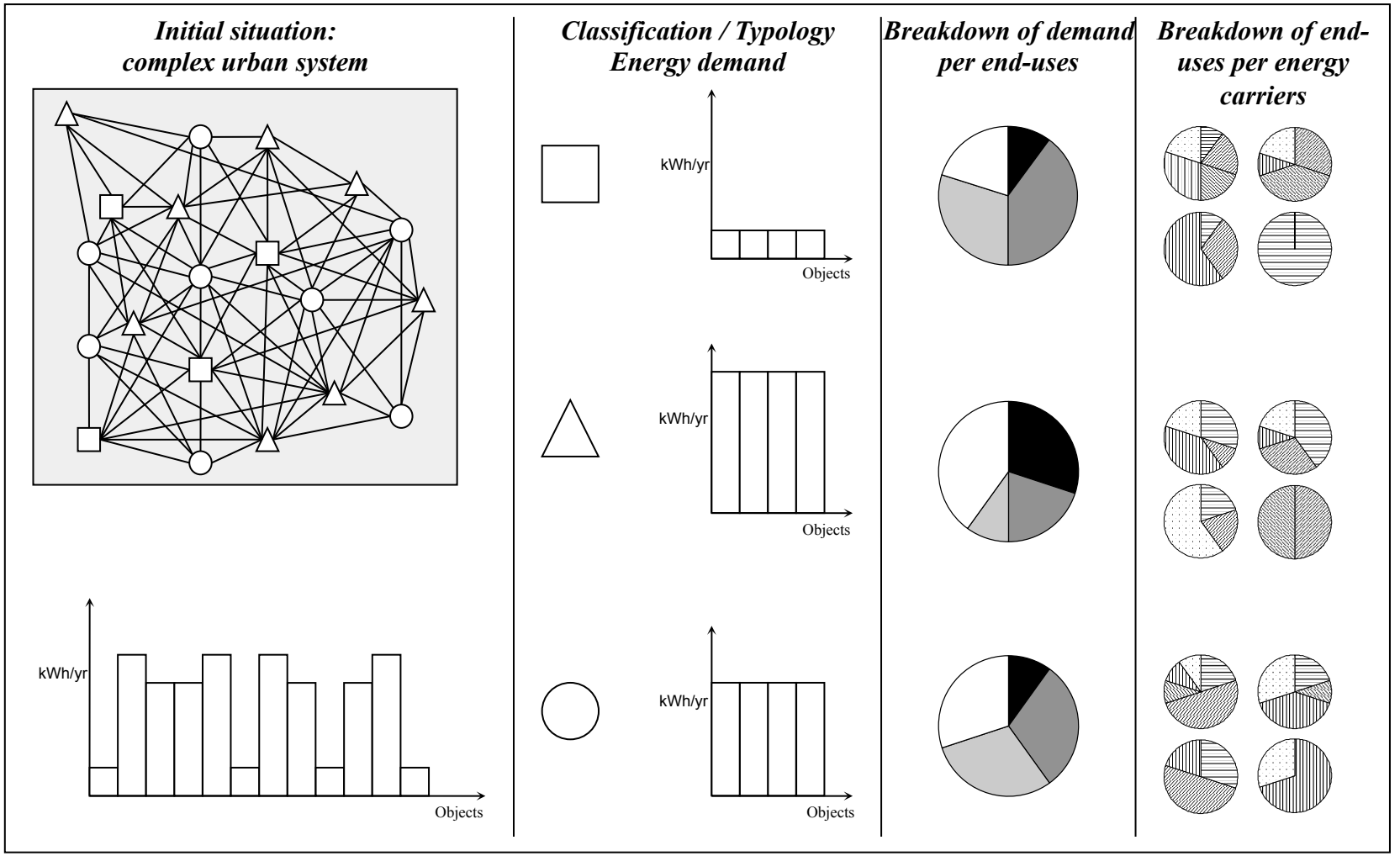



Graphic: Keim Christian

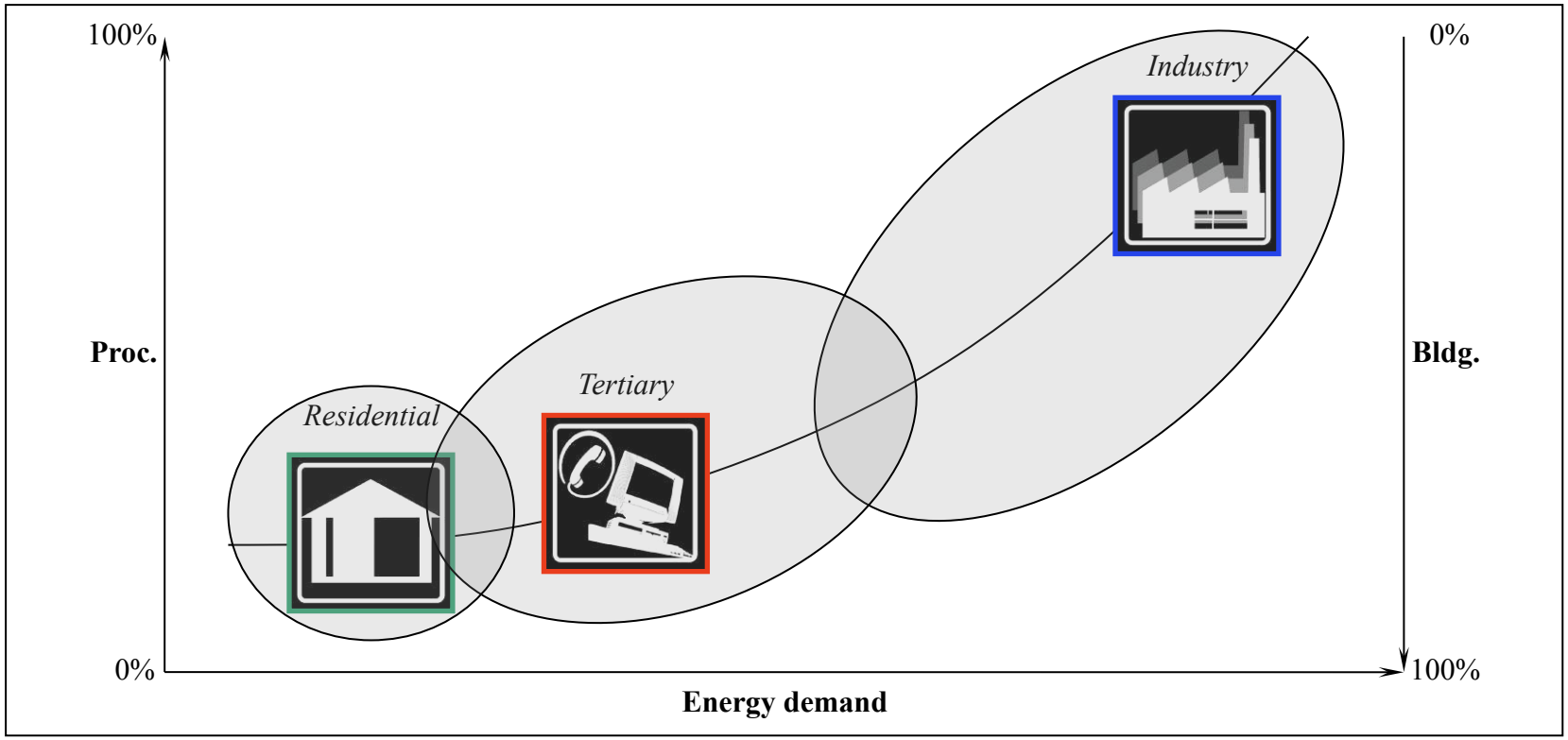
# Sectoral dynamics

| 0 City | 1 Habitation | 2 Industry | 3 Tertiary | 4 Infrastructure |
|---|---|---|---|---|
| **energy consumption** | about 30% | about 30% | about 10% | about 30% |
|  |  |  |  |  |
| **appropriate spatial scale** | **500 – 1000 m** | **2 - 4 km** | **500 – 1000 m** | |
| **time scale** | **30-60 years** | **5-30 years** | **5-30 years** | **50-100 years** |
| **adaption process** | **slow**<br>based on private decisions<br>split private ownership | **fast**<br>based on global decisions<br>“unified” ownership | **fast**<br>based on global decisions<br>“unified” ownership | **slow**<br>based on political decisions |

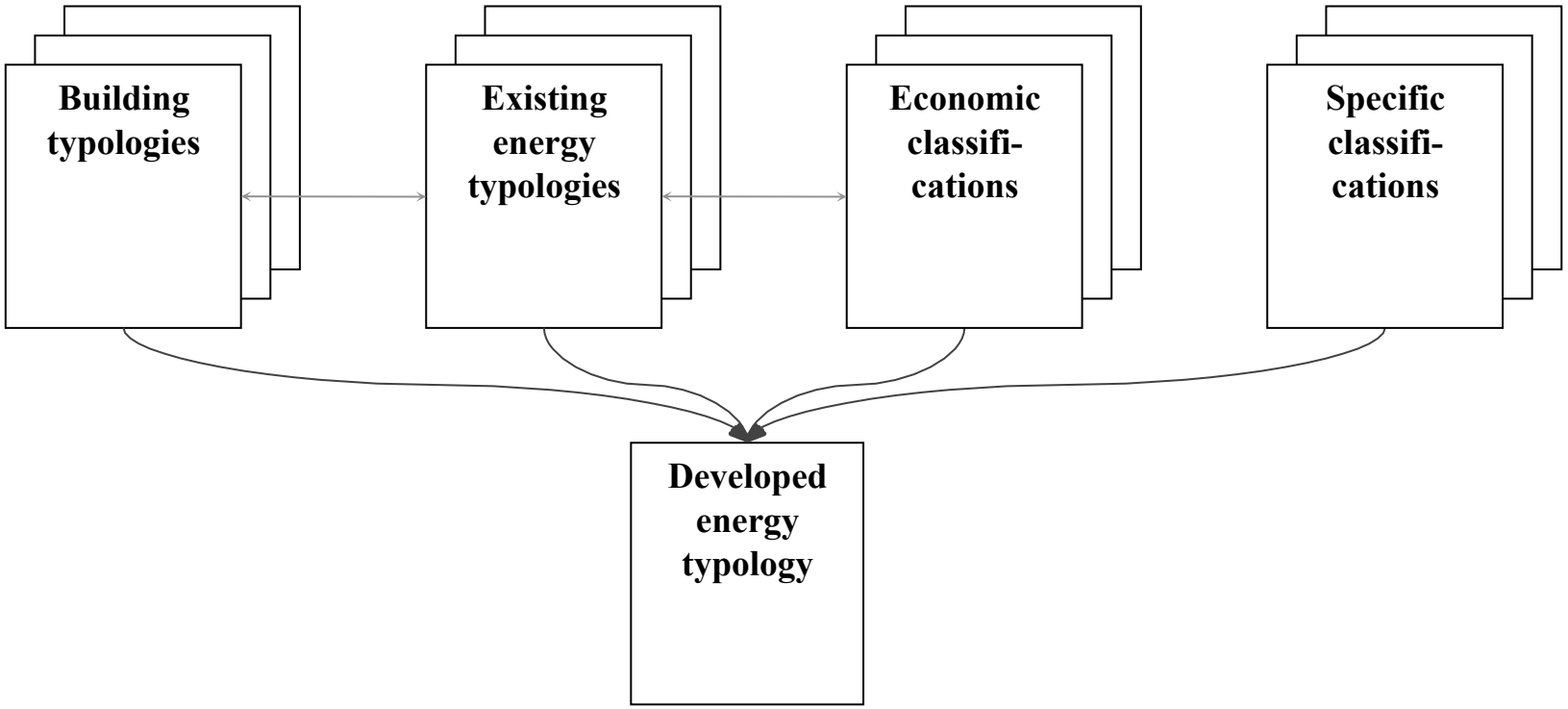
# Energy typology of urban space



# Buildings and processes



# Constitution and sources of energy typology

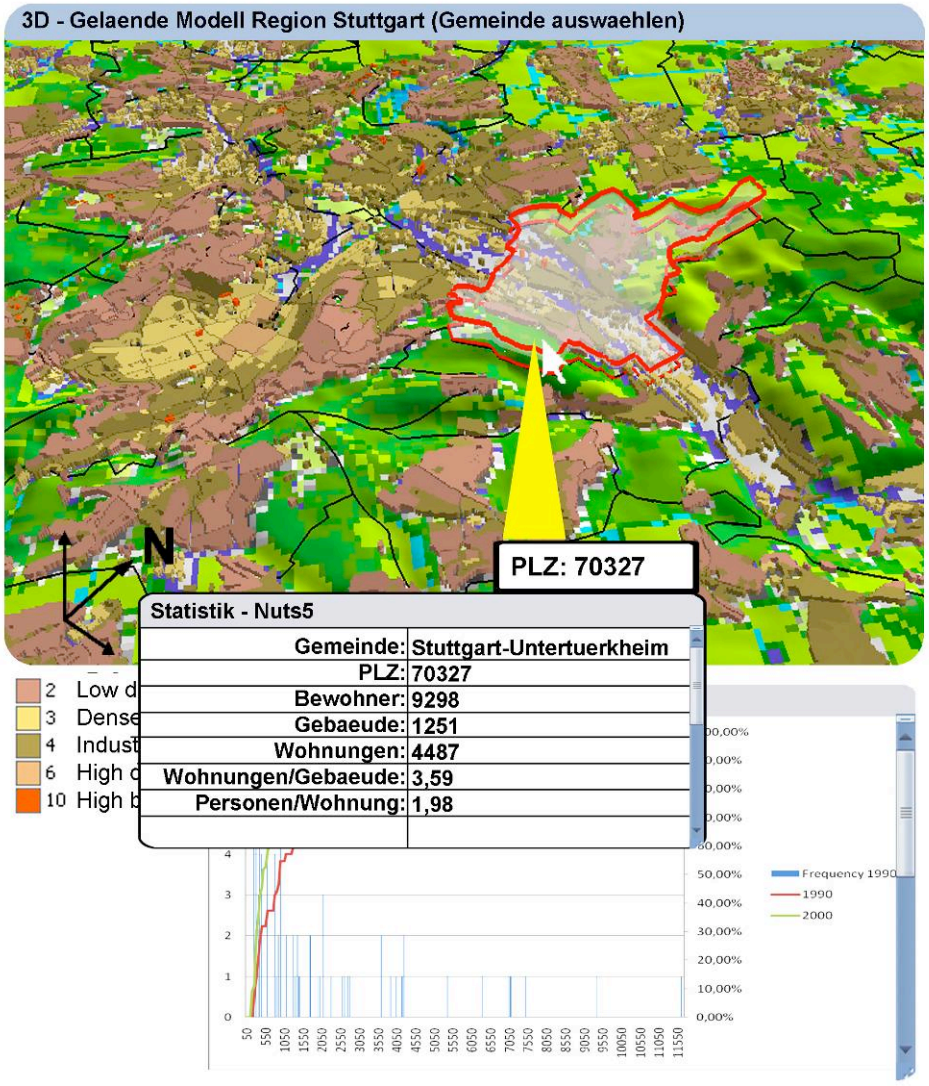


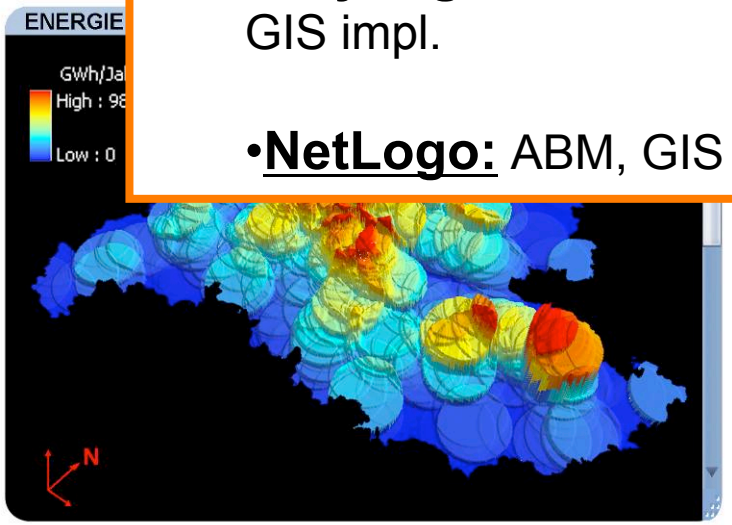
# EIFER Tool development

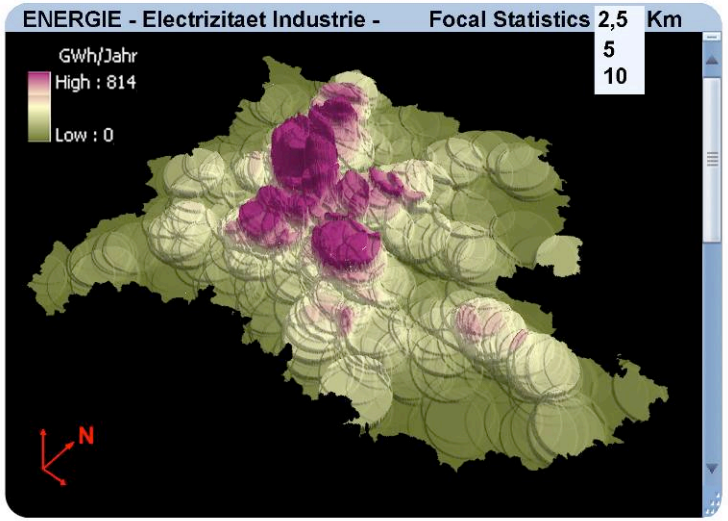
**Software resources:**

- **AnyLogic:** ABM, SD, DE, GIS impl.
- **NetLogo:** ABM, GIS impl.

## ENERGIE - Raeumliche Verteilung von Energiebedarf



# Conclusion

Localisation of energy demand

Methods of simulation on different scales

Prognosis of urban development and resulting energy needs

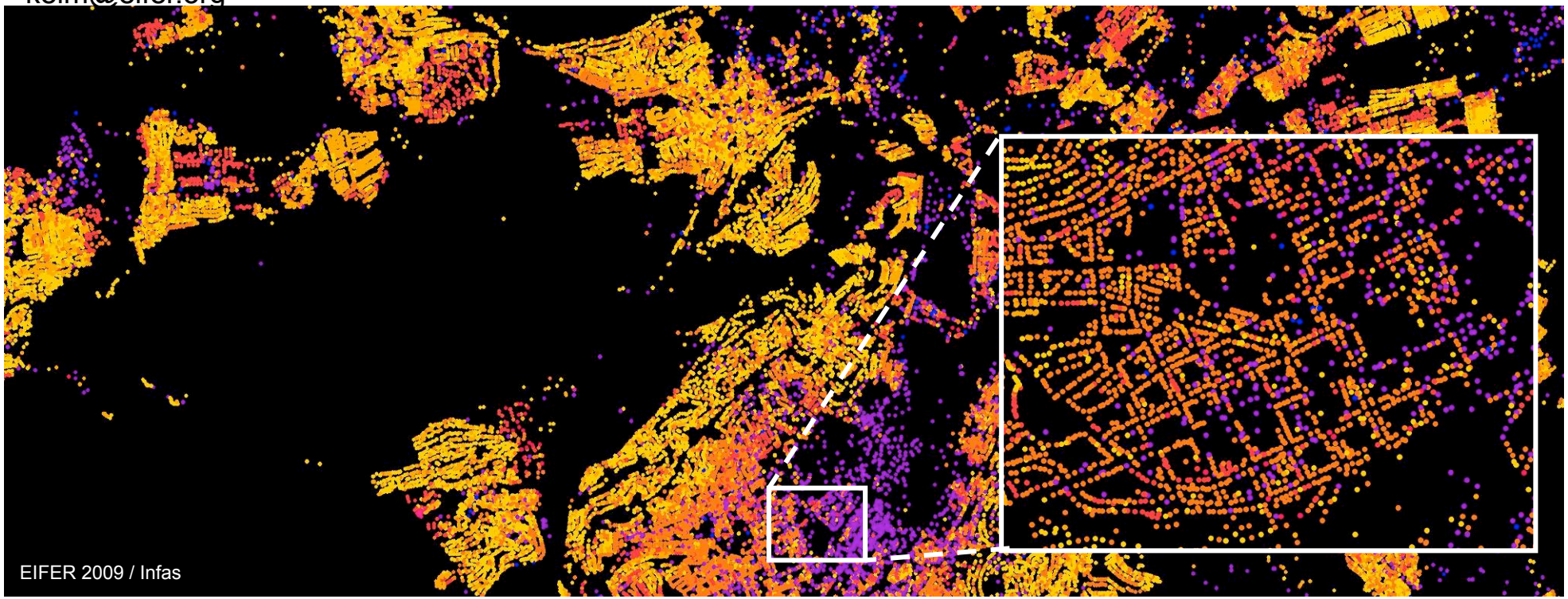
Integration to existing methods

Communication to local authorities and spatial and energy planners

EIFER

# Thank you for your attention !

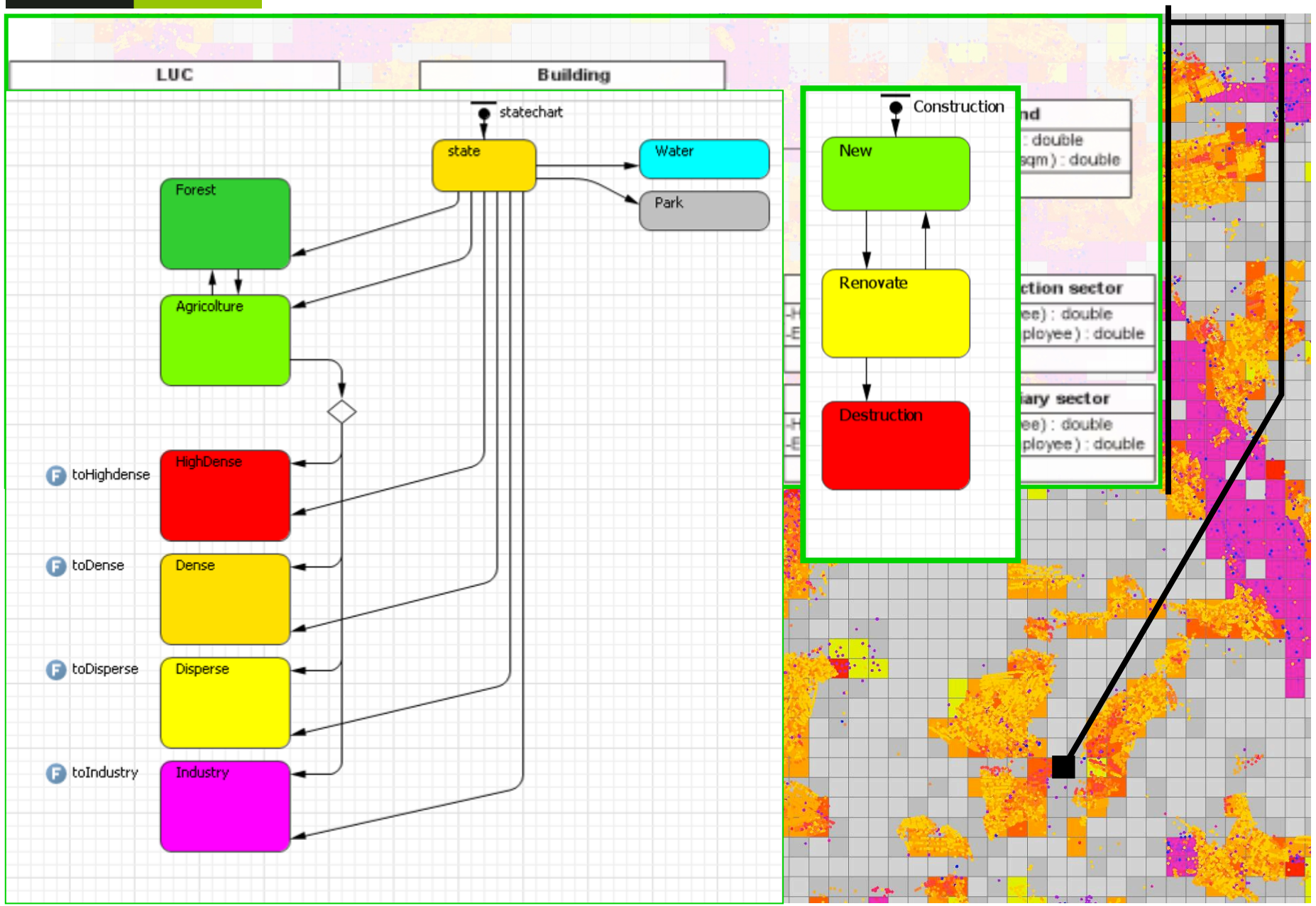
**Contact:**
peter@eifer.org
girard@eifer.org
keim@eifer.org

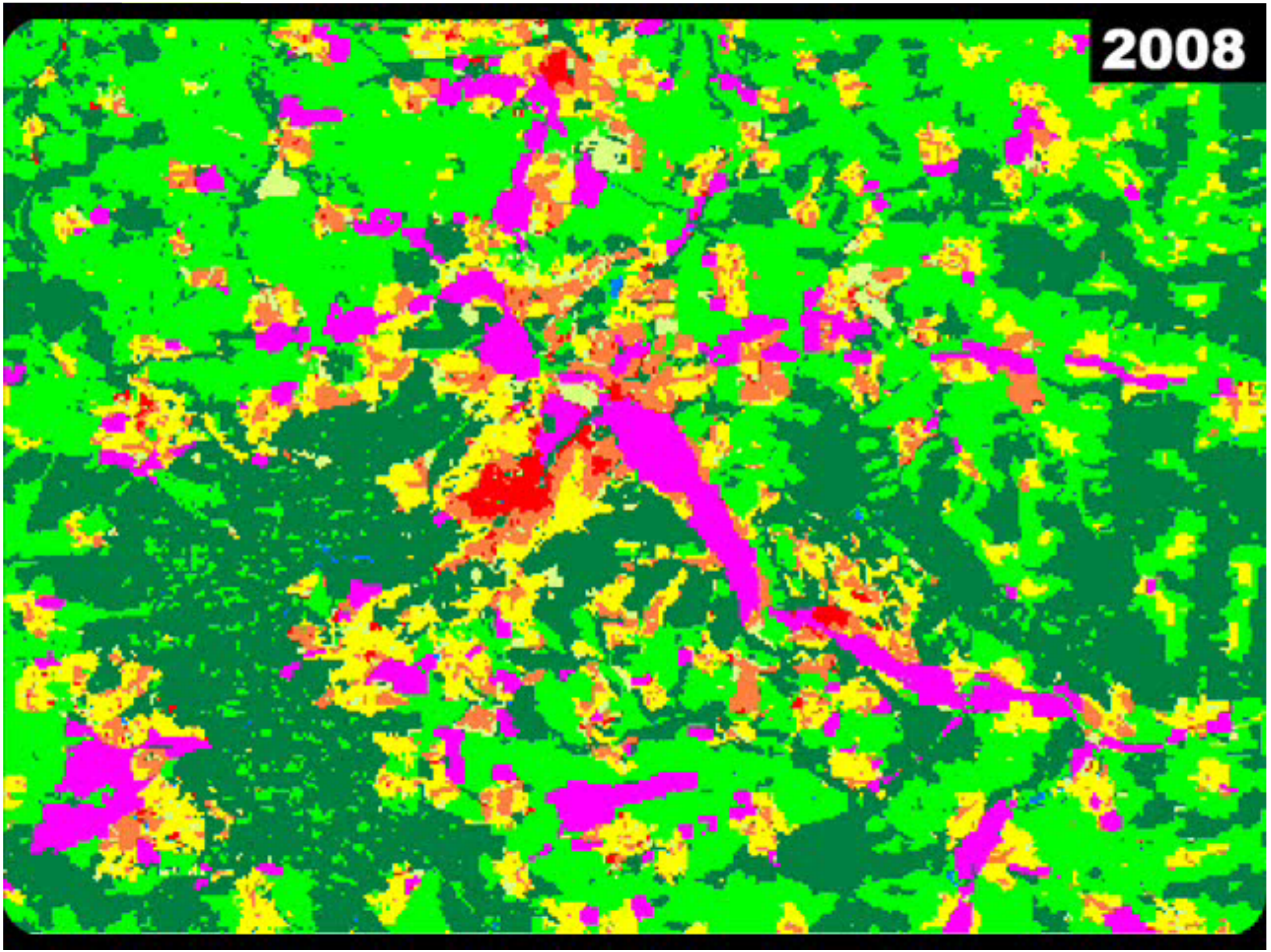



EIFER

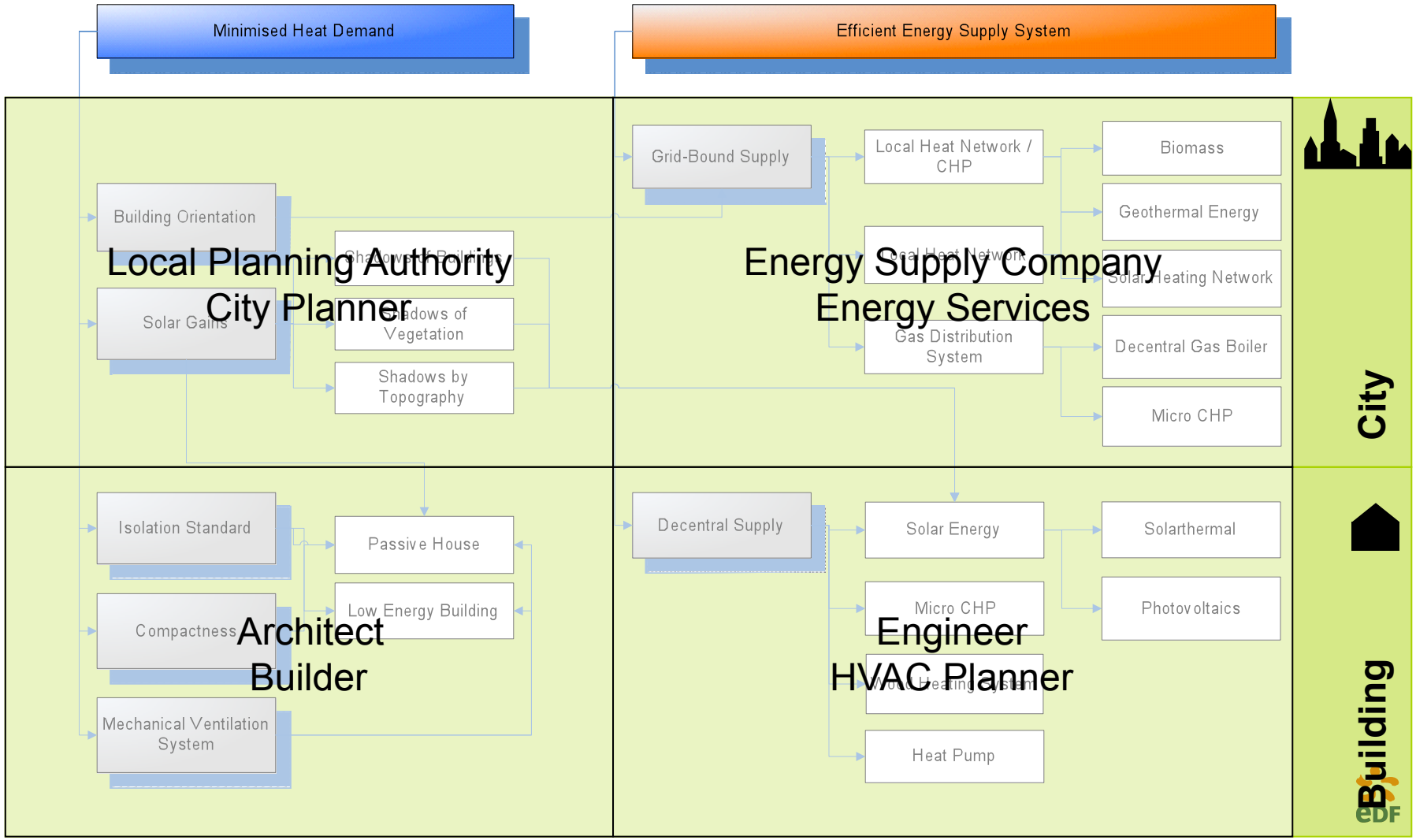

EDF

# Cell fuzziness – 250x250 aggregation




2008

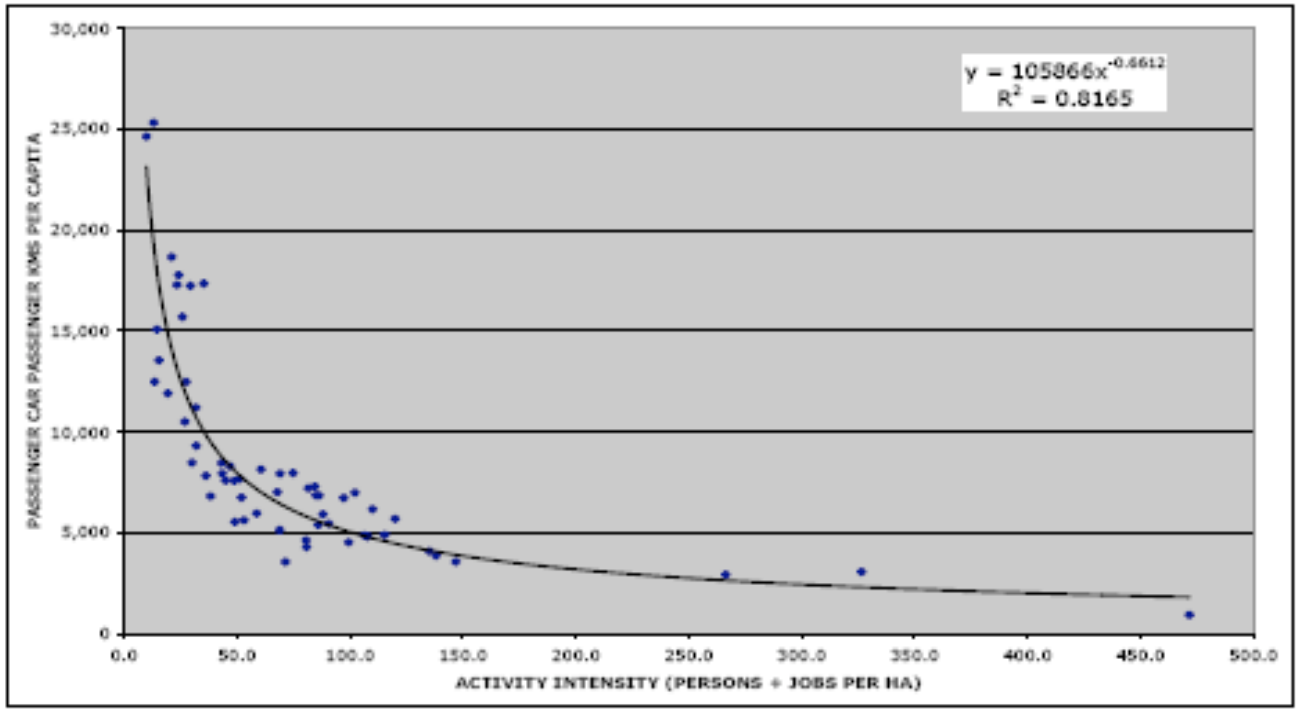
# Integrated urban planning




Source: EIFER 2008

# Dichte

Figure 2. Activity Intensity versus Passenger Car Use in 58 Higher-Income Cities, 1995



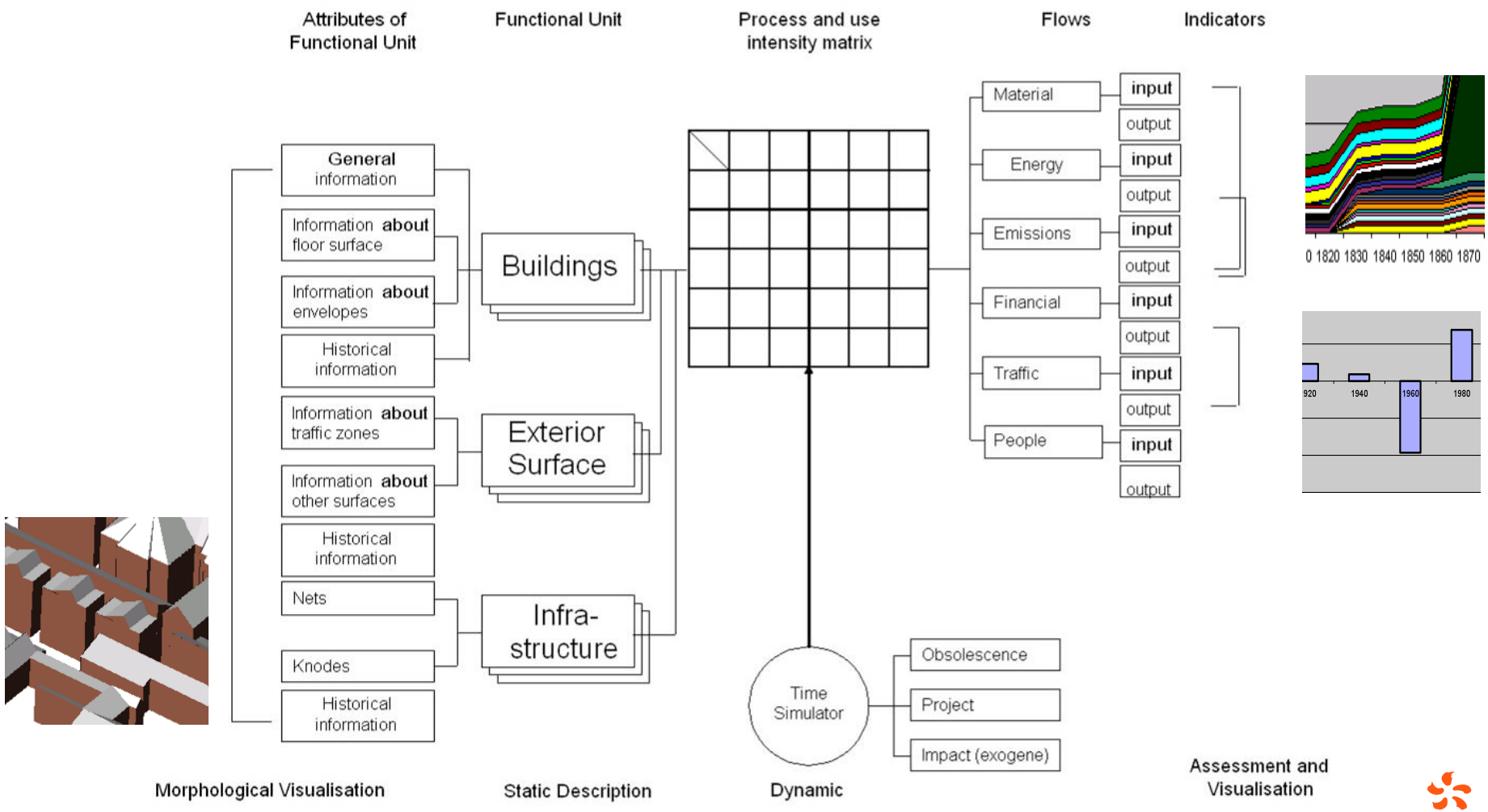

Dichteparameter als Grundlage für die Energienachfrage

EIFER

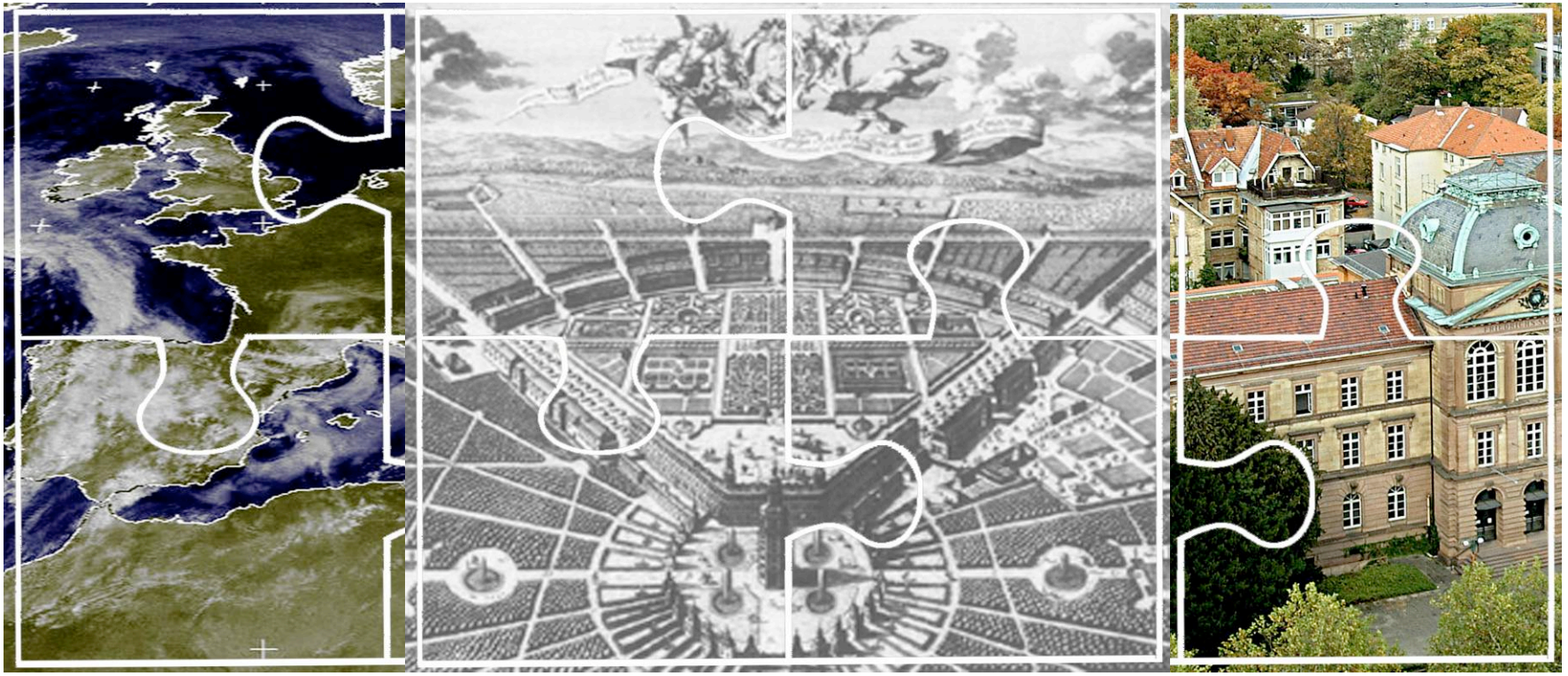
## Outlook

- Simulation to predict urban development
- Moduls of Visualisation
- Complementary knowledge to urban development (EnyCity)
- Communication to planners and local authorities
- Basics for local energy planning

# Life cycle model of urban fragments

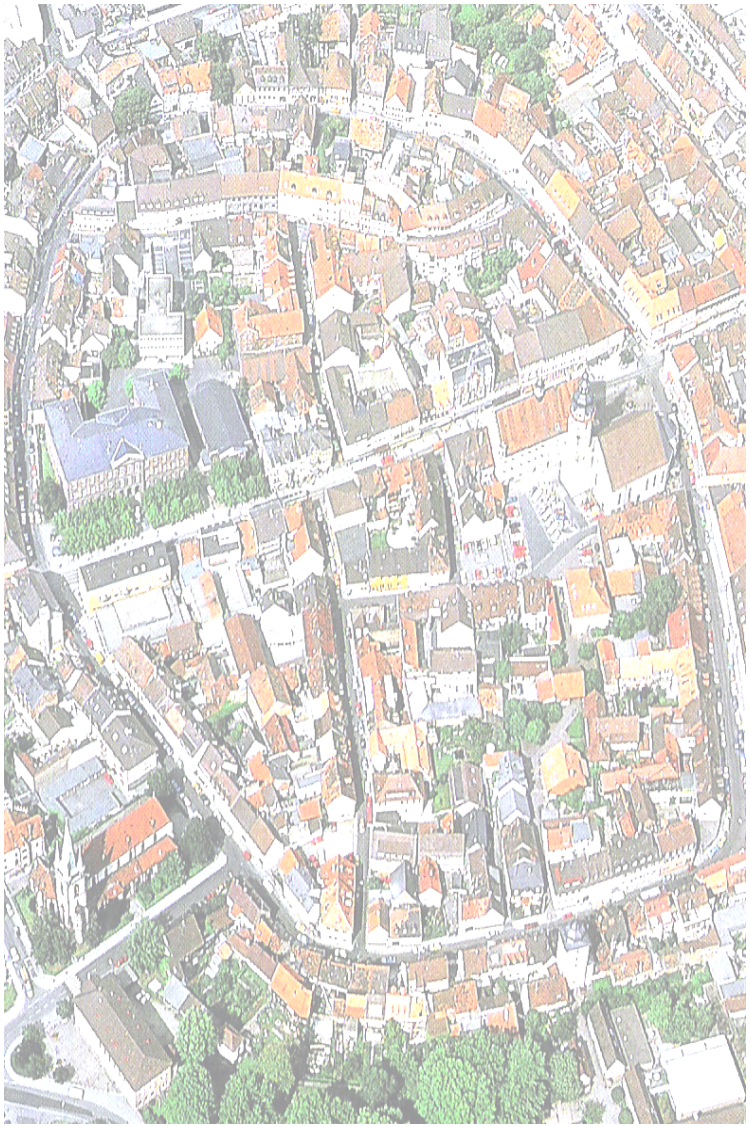


# Introduction to urban spaces



The infrastructure and building stock is one of the largest physical, economical and cultural capital of European societies.

# Urban dynamics



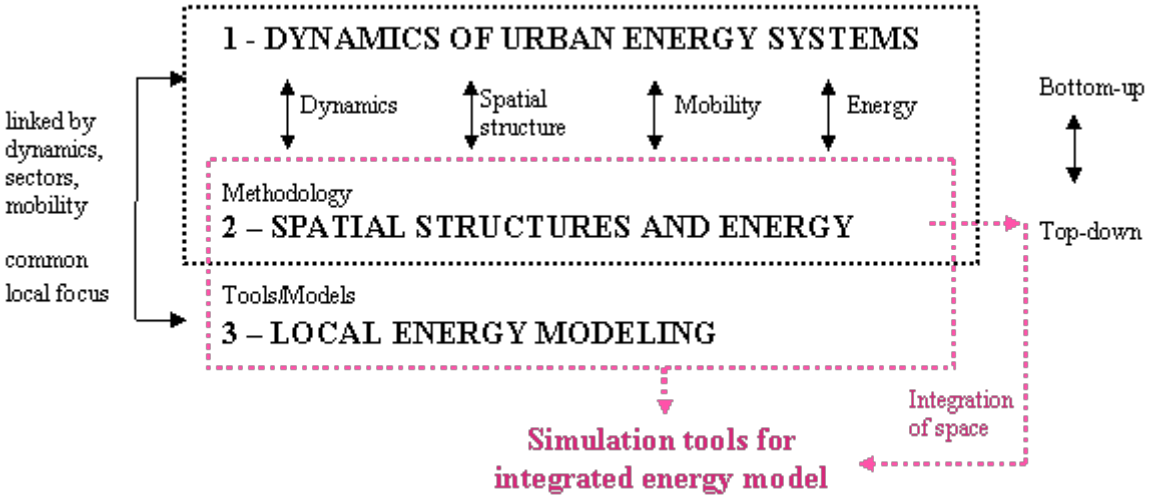
- **Main questions**
  - Which are the driving forces for urban transformation?
  - Which are the resulting energy demands?
  - Which data are usable for the simulations?
- **Methods**
  - Regional spatial analysis
  - Model of the transformation of building stock
  - Possible influences of transportation
  - Case-study Metropolregion Stuttgart
  - Definition of criteria for adaptation and classification of existing tools
- **Simulation methods**
  - Develop an allocation methodology of energy demand (data management, spatial statistics)
  - Create a simulation and visualization methodology in a forecasting approach (Geosimulation)
  - Develop a tool in a regional energetic and urban planning framework

# Agenda

- Auswirkungen der Stadtentwicklung auf die Energienachfrage

# Agenda

- Auswirkungen der Stadtentwicklung auf die Energienachfrage



# Research scheme

| Views | Content | Methods |
|---|---|---|
| Scope of Building stocks | buildings, job market, urban structure | statistics, random sample, cluster analysis |
| | Land use, fallow ground, infrastructure | statistics, random sample, ALK, aerial view |
| Composition of building stocks | Type of buildings, infrastructures | Product-modelling, building research, building history |
| | Construction technique, morphology | Building history, statistics, production of building material |
| Dynamic of Building stocks | Dynamic of one building | Alternative model, history of buildings, renovation of buildings, survival functions |
| | Dynamic of building stocks | Building history, urban geography, survival functions, pattern analysis |
| Localisation of Building stocks | Urban fragments, towns | GIS, maps, plans, land register, ALK, aerial view |
| | Building stocks | cluster analysis, satellit views, historical research |

# Adressaten: Levels and actors

| | |
|---|---|
| Buildings | owners, developers, users, facility managers, planning professions, construction industry. |
| Groups of buildings | owners, users, facility managers, planners, construction industry. |
| Towns, Neighbourhoods | owners,developers, planers, users, state administration, political parties |
| Infrastructures | utility companies, state administration and technical service, planning authorities. |
| Actual and virtual systems | utility companies, IT companies, state admnistration, users |

# Kritische Bestands Parameter

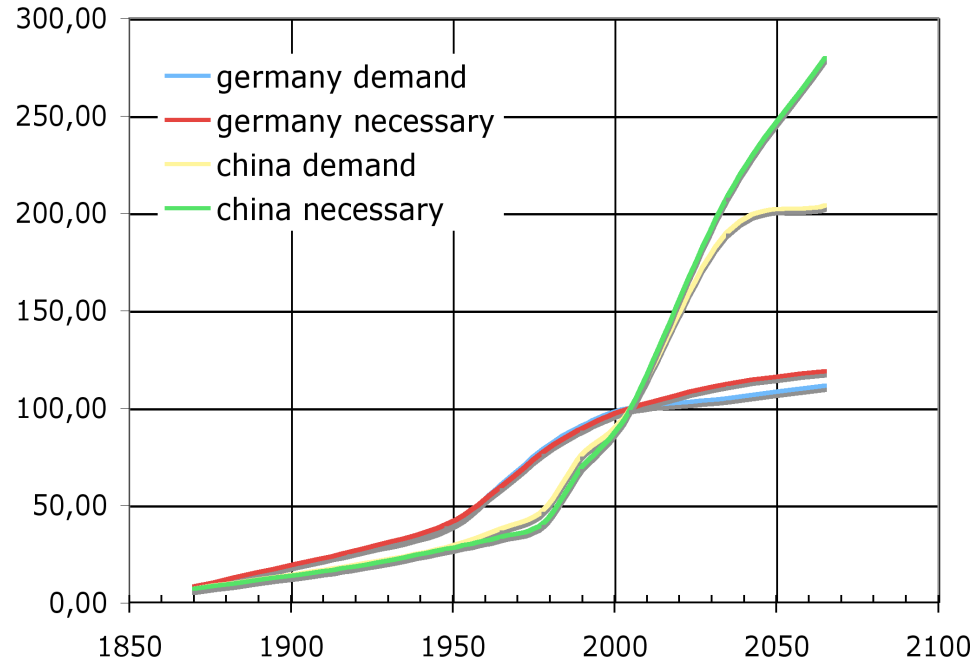
*Überalterung*

*Demographie*

*Urbanisierung*

*Anforderungen*

*Energieversorgung*




*Zustand Bestand*

*Ökosystem*

*Altersvorsorge*

*Kulturerbe*

*Umwandlungsgeschwindigkeit*

*Institutionelle Regimes*

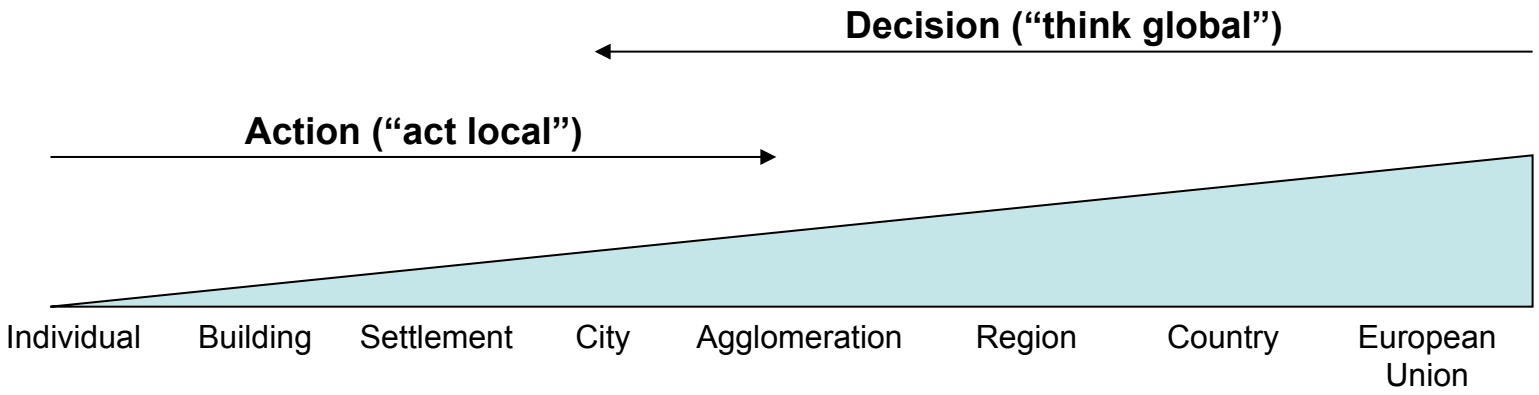
*Finanzierungsmodelle*

# Technologien auf Quartiersebene

# Fields of acting – what should we know

# Multiples scales of decision and action

- Various dimensions:
  - Structural characteristics
  - Infrastructures
  - Demographic aspects
  - Social aspects
  - Decision-making and actors, ...
- Interactions between components of the urban system
- Energy balance
- Scale effect



# Assessing and implementing energy efficiency in urban spaces

1. Multiple scales of decision and action
2. Localization of energy demand
3. New supply systems and new potentials
4. Modelling and simulation of time and spatial dynamics of the urban space

# Agenda

- Auswirkungen der Stadtentwicklung auf die Energienachfrage

- Levels of implementation of energy efficient technologies and strategies

## Urban dynamics and energy demand - 2009

- Prototyp Agend based modeling: urban development and influences to the local energy demand
- Local economic drivers - integration of building stock model
- Evaluation and verification of developed simulation model
- Implementation based on DB GIS models – platform
- Scenarios for urban transformation
- Simulation modules and standards
- Energy models of economical segments and building stock
- Data mining region Stuttgart
- Contact to local authorities
- Transferability - fingerprint and indicators

# Definition - Content

Energy efficiency is closely connected to buildings technology and urbanisation

The urbanisation processes are related to possible future energy demand

Understanding urbanisation processes leads to a better knowledge and possible quantification of Energy Efficiency potentials

A consistent building stock model + its dynamics acts as a basis for predicting future energy demand

*Hereafter some examples:*

*Simulation of urbanisation processes*

*Localisation of the energy demand*

*Urban morphology vs energy performances*

*Building density vs energy efficiency*

# New supply systems and new potentials

- More efficient demand impacts energy supply
- Implantation of traditional solutions e.g. natural gas networks less profitable
- Increasing fossil fuel prices
- Rapid development of decentralized generation

# Dynamics of urban spaces

- Diffusion of innovations (decentralized generation)
- Life cycle analysis on several scales
- Land use evolution