Could urban climate modelling systems provide urban planning guidelines in the context of building energy performance issues?

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Nowadays **cities are about 70%** of the total world energy consumption (*source: IEA, 2008*)

In France:

- Buildings use **44% of the energy consumed in cities**, in which 68% for the space heating
- Buidling energy consumptions contribute to **25% of the CO_2 emissions** (*source: ADEME, 2012*)

Mostly in buildings for air cooling or heating !

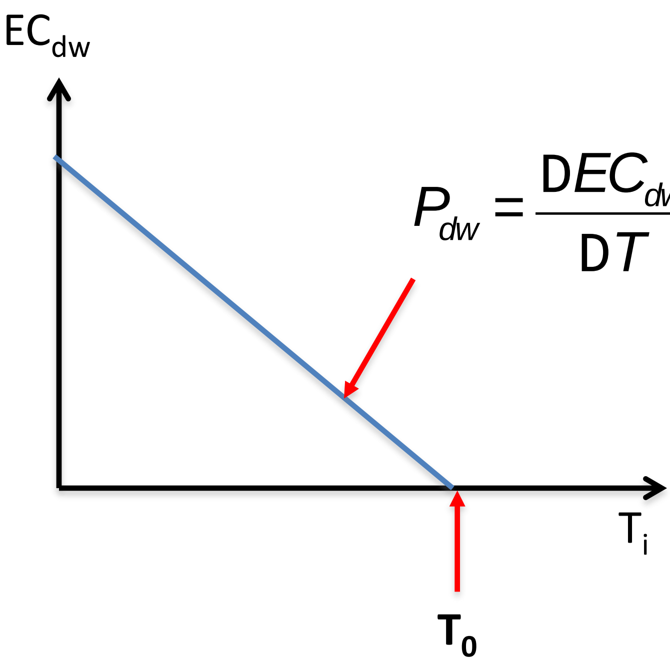
Local autorities are more and more involved in energy saving strategies designed to cope with the climate change impacts and the fossil fuel depletion. Which role have the urban planning strategies on the building energy consumption? How much energy is consumed in each city?

Need of adapted tools to assess the building energy performance at city scale !

Methods used to estimate building energy consumption at city scale (1)

- <u>Bottom-up statistical approach: the degree-day method</u>

For a dwelling type:



$$P_{dw} = \frac{\Delta EC_{dw}}{\Delta T}$$

Dwellings profiles (*e.g.* types, age, fuel types, floor area) ***(P_{dw})***

Degree-day calculation (Met. model)
$D=\Sigma \min(0,T_i-T_0)$
With predefined T_0 ***(D)***

Building energy consumption for one dwelling type

$$EC_{dw} = P_{dw}.D$$

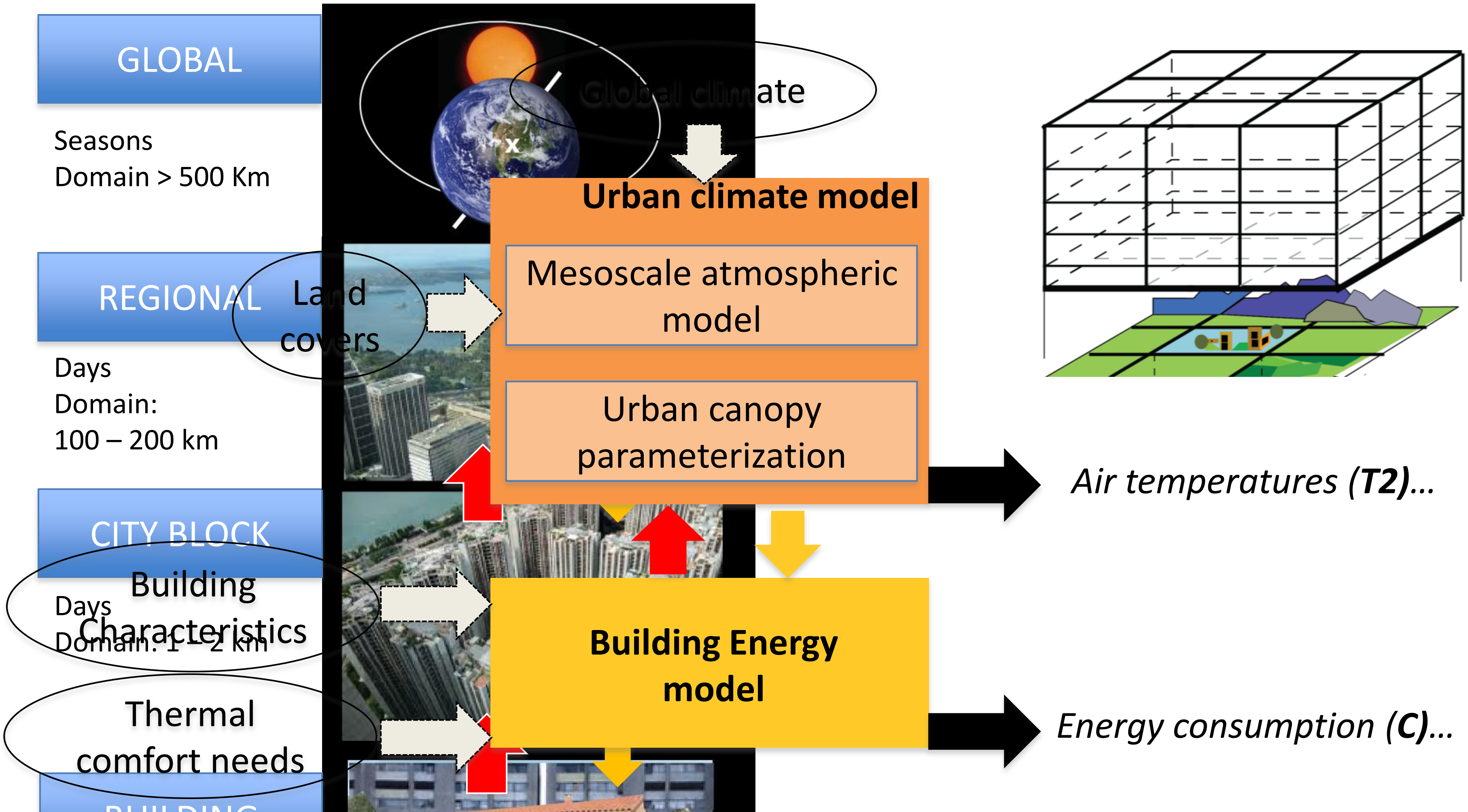
Building energy consumption for the city

$$\sum_{dw}^{ndw} P_{dw}.D = EC_{city}$$

Regional energy consumption

Methods used to estimate building energy consumption at city scale (2)

- Numerical approach based on climate modeling systems like WRF-BEP +BEM

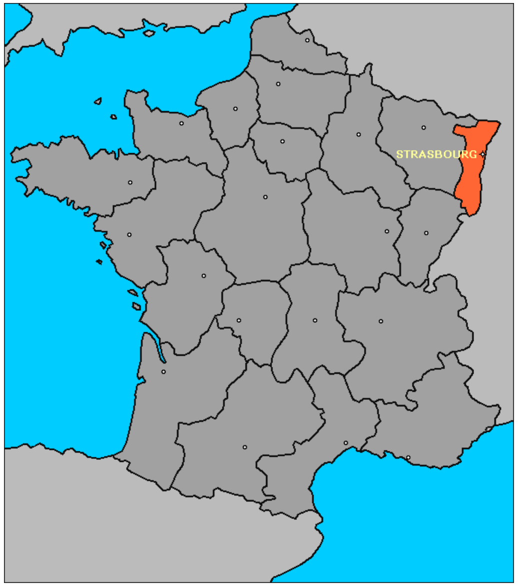


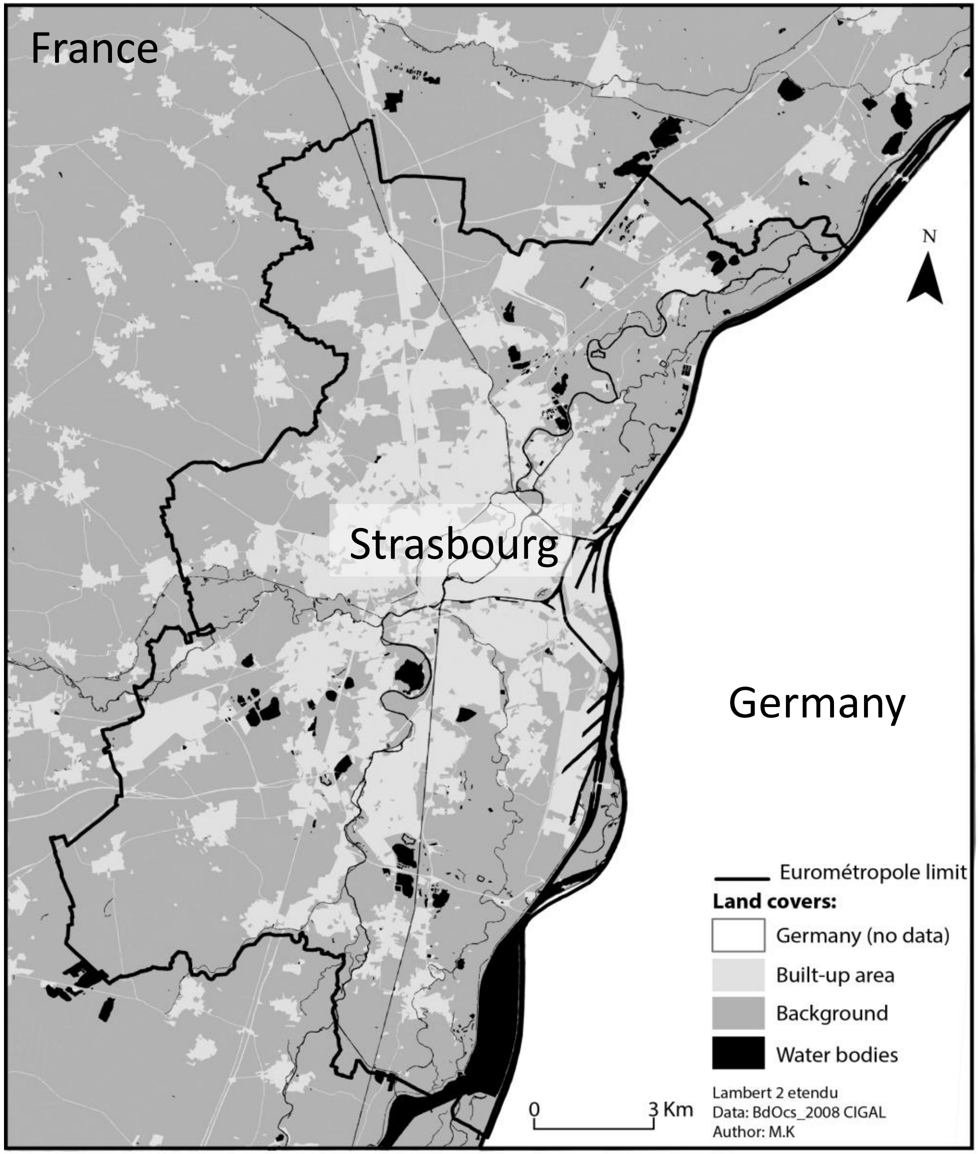
➢ **Objective: Test the ability of the numerical urban climate modeling system to account for urban planning policies on the building energy needs.**

The study case: the Strasbourg urban region

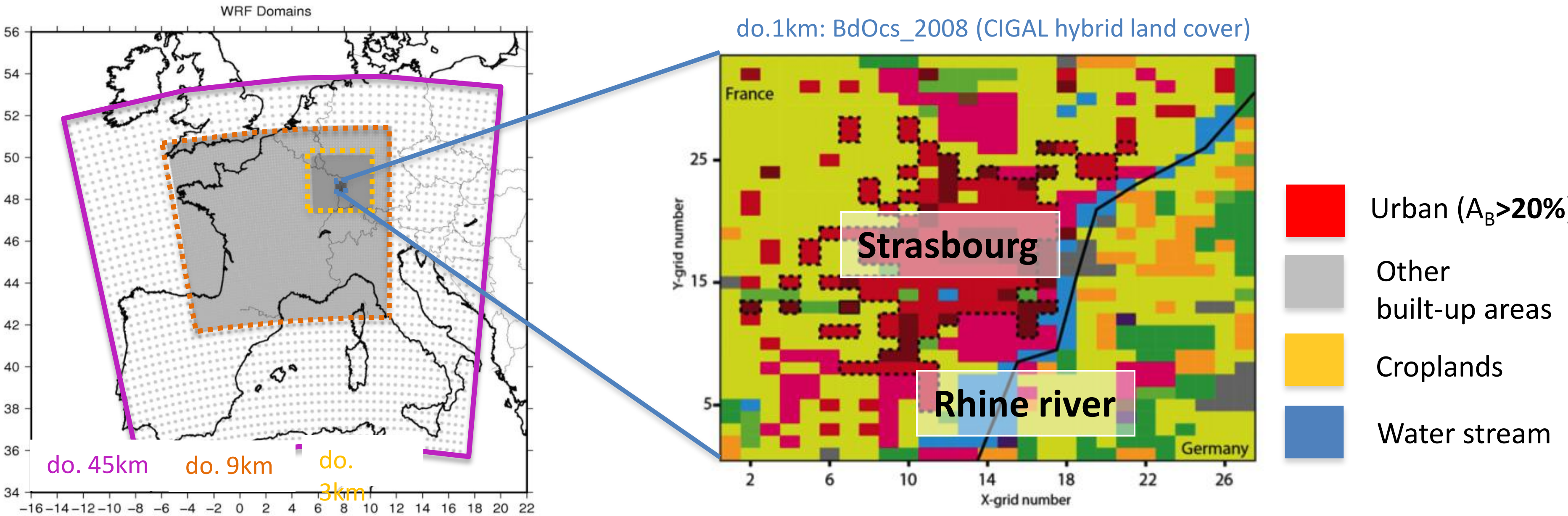
Strasbourg
- Area: 315.93 km^2
- Population: 468,000 inhab.
- Loss of attractivness

Toulouse:
- Area: 460 km^2
- Population: 740,000 inhab.
- Attractivity

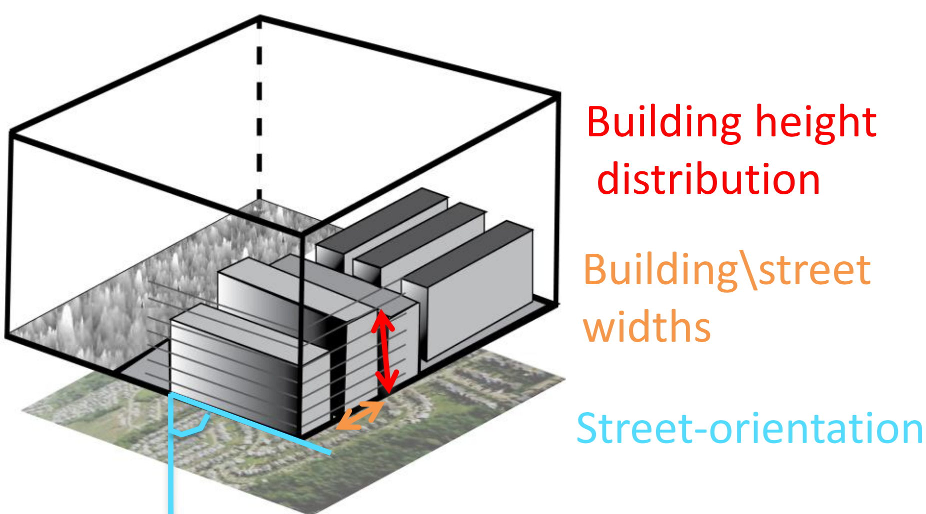




The WRF/ARW-BEP+BEM climate modeling system: the 2010 base case



Building Effect Parameterizations (BEP):
(*BDtopo2008, IGN, Google Earth*)



Building Energy Model (BEM):

Ventilation rate
0.75

Equipments
36 W/m²

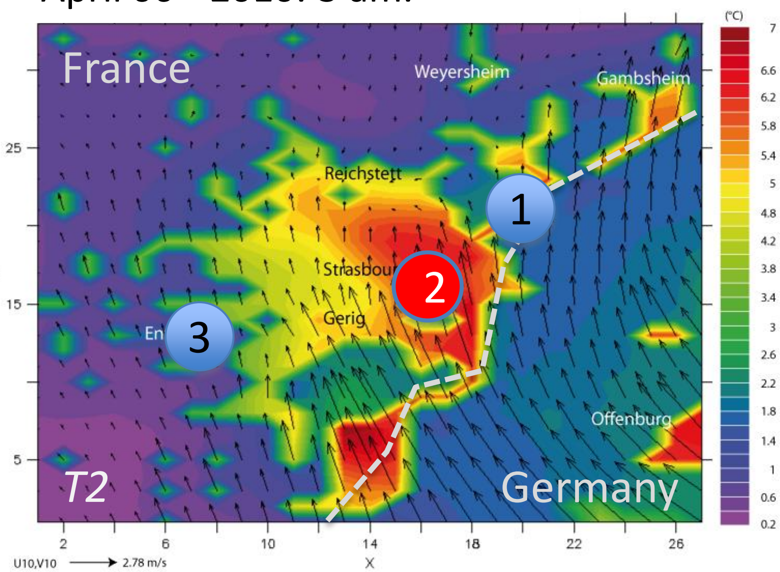
Thermostat
19.85° C

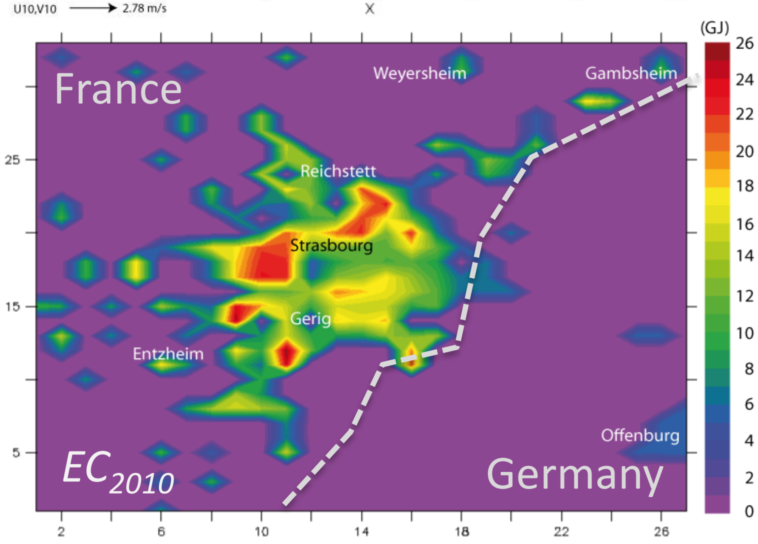
Persons per floor:
INSEE 99

Validation of the climate and building energy simulations (base case)

Period: year 2010
Spin up time: 5 days/Time step: 100 s

April 06th 2010: 3 am.





Comparison with Météo France T2 observations

1. La Wantzenau

MB=0.01° C, RMSE=2.15 ° C, R=0.96

2. Strasbourg-Botanique

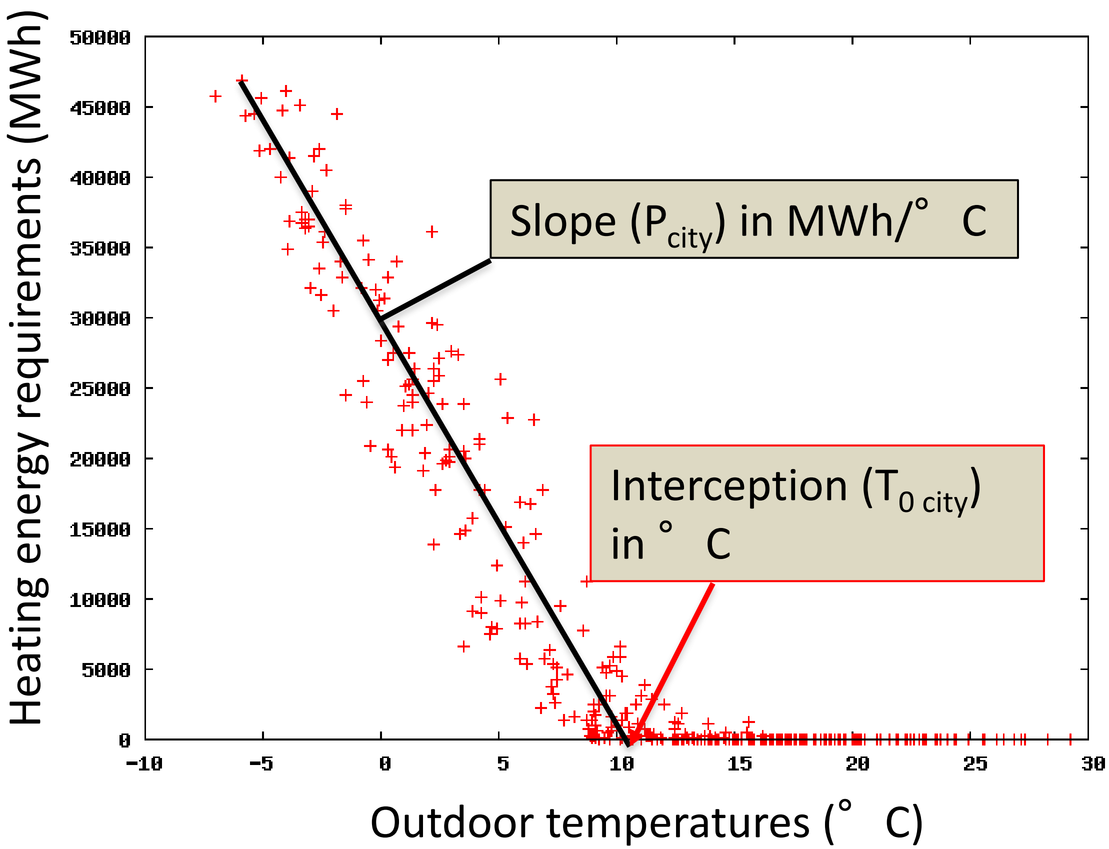
MB=1.71° C, RMSE=2.80 ° C, R=0.96

3. Entzheim

MB=-0.93° C, RMSE=2.29 ° C, R=0.96

Eurometropole 2010 heating energy requirements (C_{2010})

	ASPA	WRF	$\Delta_{WRF/ASPA}$
C_{2010}	15,274,755 GJ	12,055,372.6 GJ	-21.07%



For a year, J=350 days:

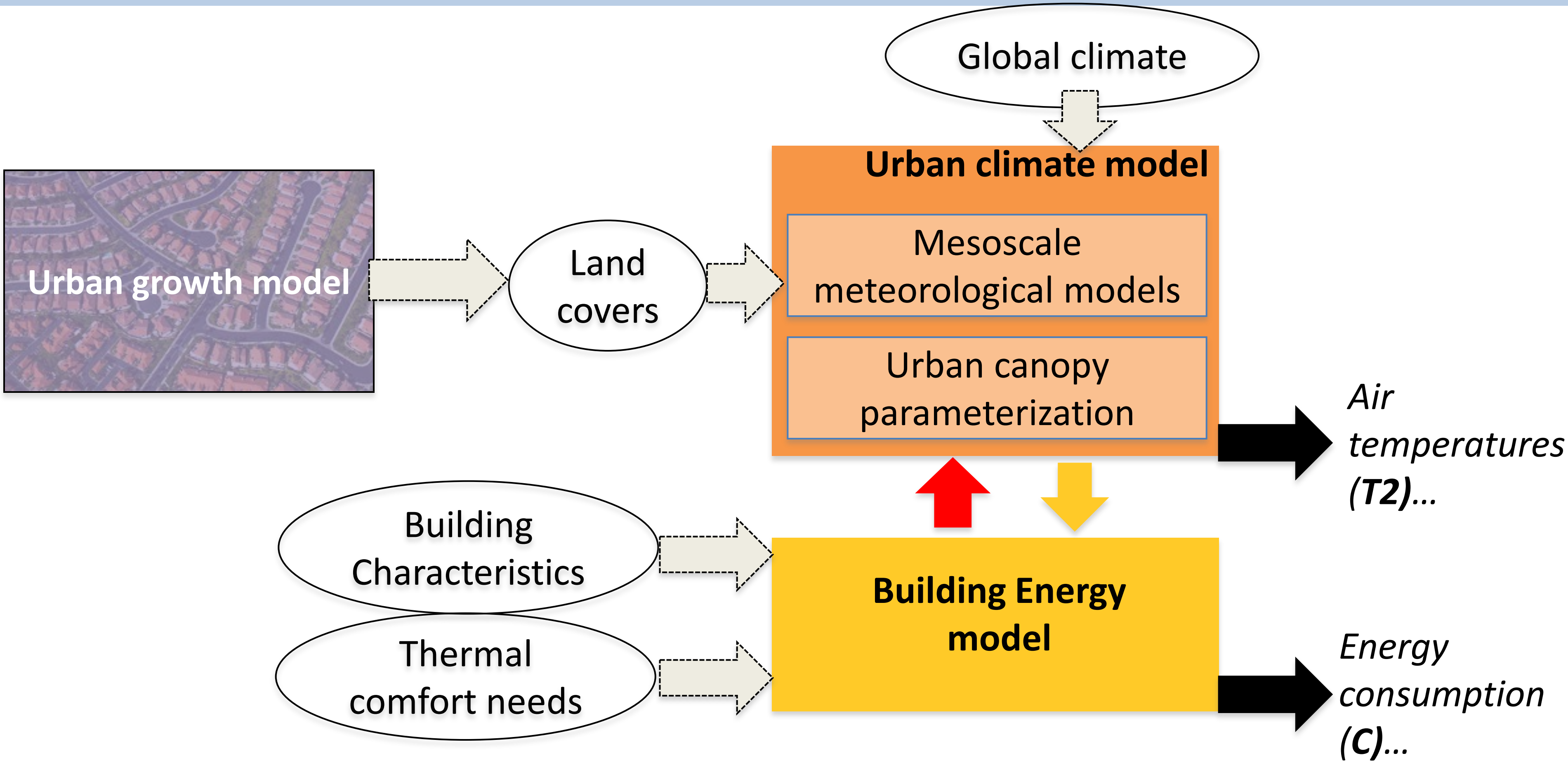
$$C_J = P_{city}\sum_{j=1}^{J}\min(T_i - T_{0,city};0)\ \forall\ T_i \le T_{0,city}$$

Deduced P_{city} and $T_{0\ city}$

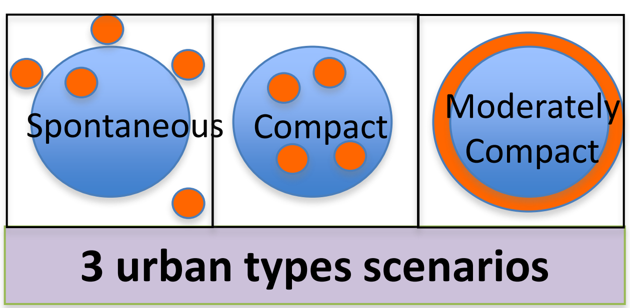
Optimization, J=3 months (P_{city}, $T_{0\ city}$)

February, March, September

Influence of the residential development on the building energy requirements



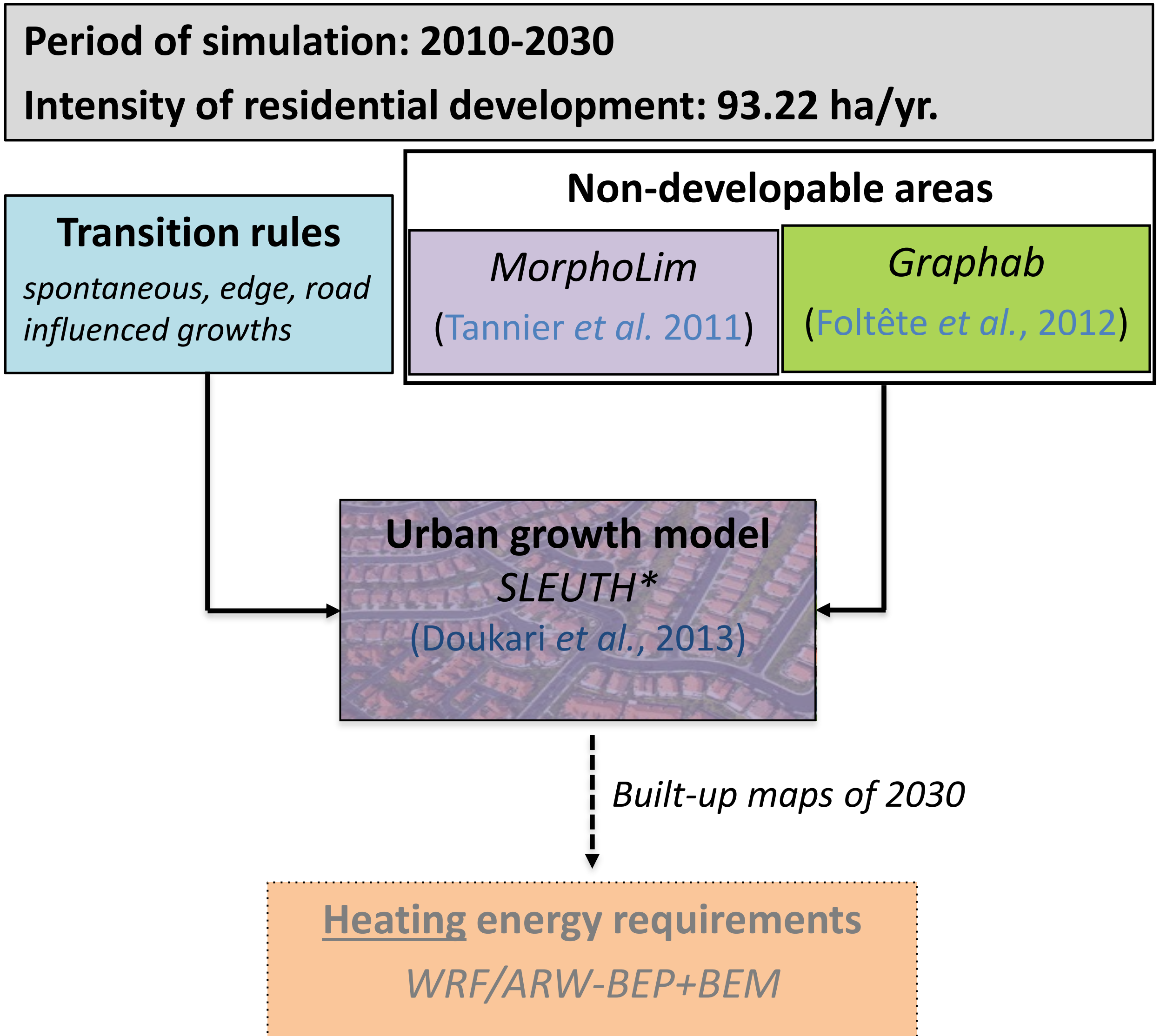
- **<u>6 scenarios of archetypal residential development:</u>**



+ Preservation of the ecological network

+ No preservation of the ecological network

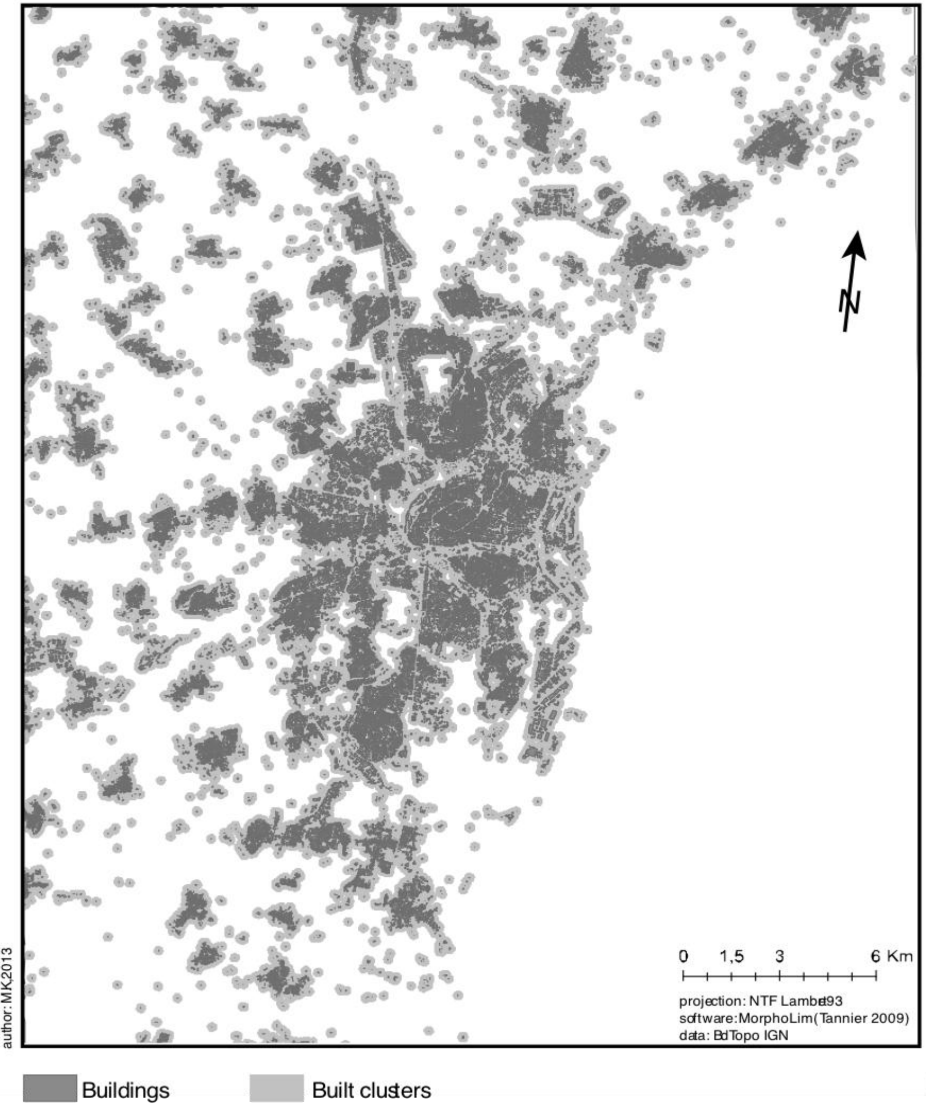
Modeling the residential development over the study area



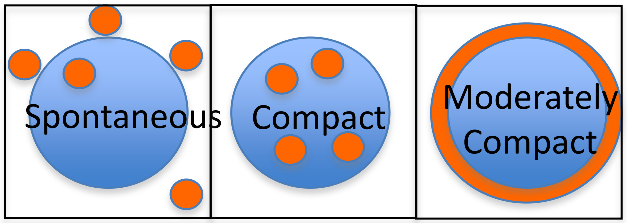
MORPHOLIM (Tannier *et al.* 2011)

→ *identify the limit of the built-up areas*

→ Based on the fractal geormetry (Frankhauser et al. 2007)

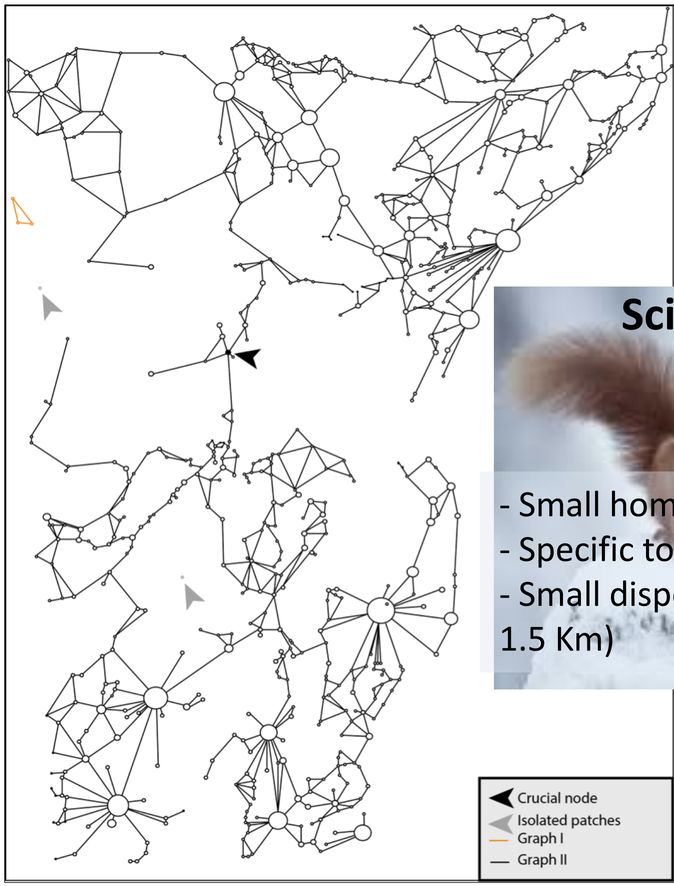


Constraint the residential development according to 3 urban types scenarios



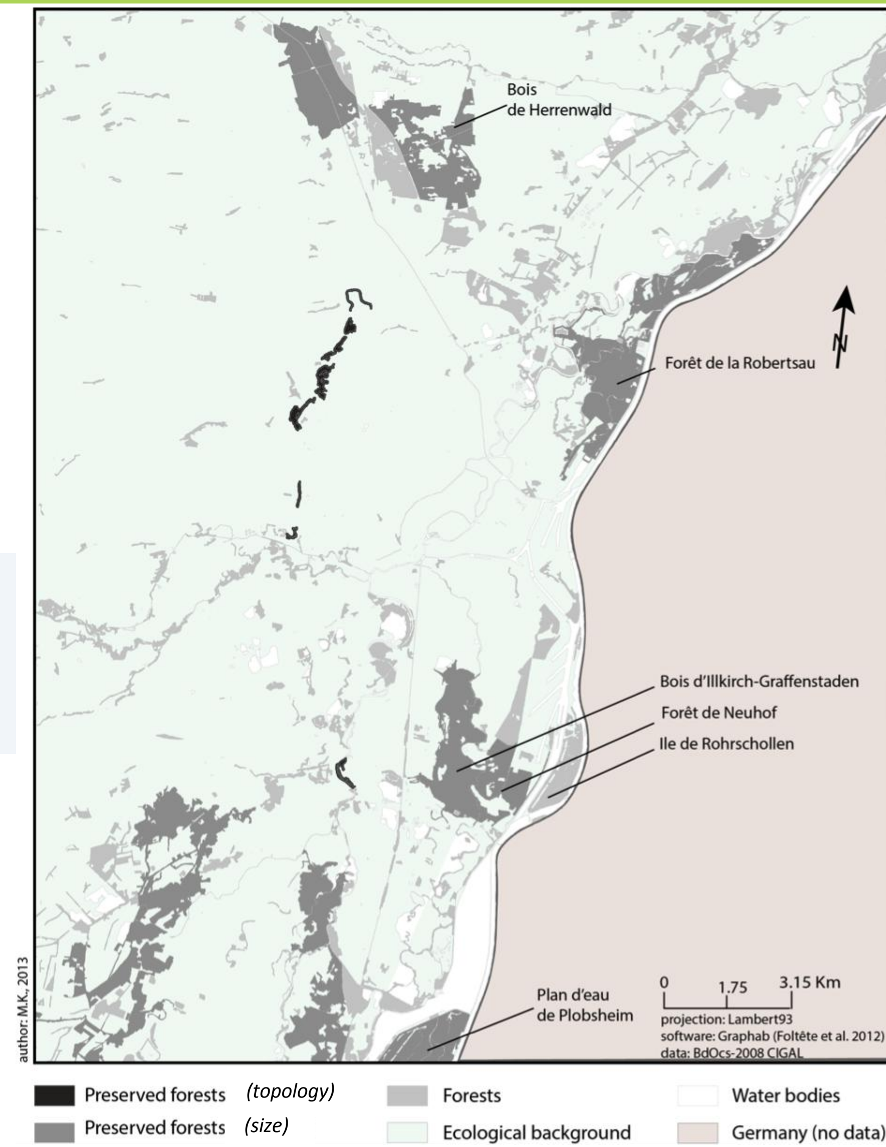
GRAPHAB (Foltête *et al.*, 2012)

→ *identify relevant forested areas for the connectivity of theregional ecological network*
→ Based on the graph theory (Saura and Rubio 2010)

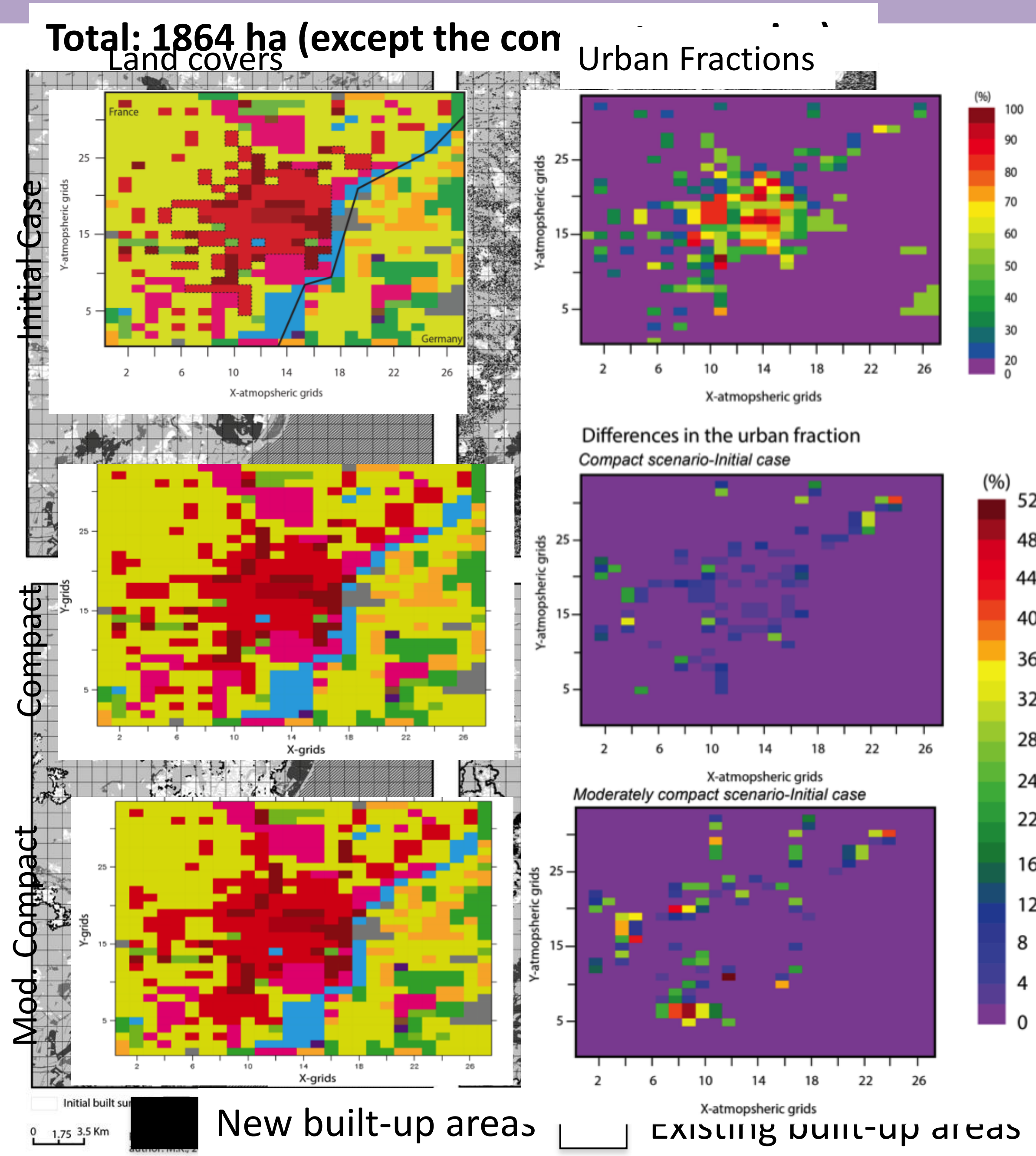


Sciurus vulgaris

- Small home range (<10 ha)
- Specific to forested area
- Small dispersal distance (1.5 Km)



RESULTS: the residential development simulations

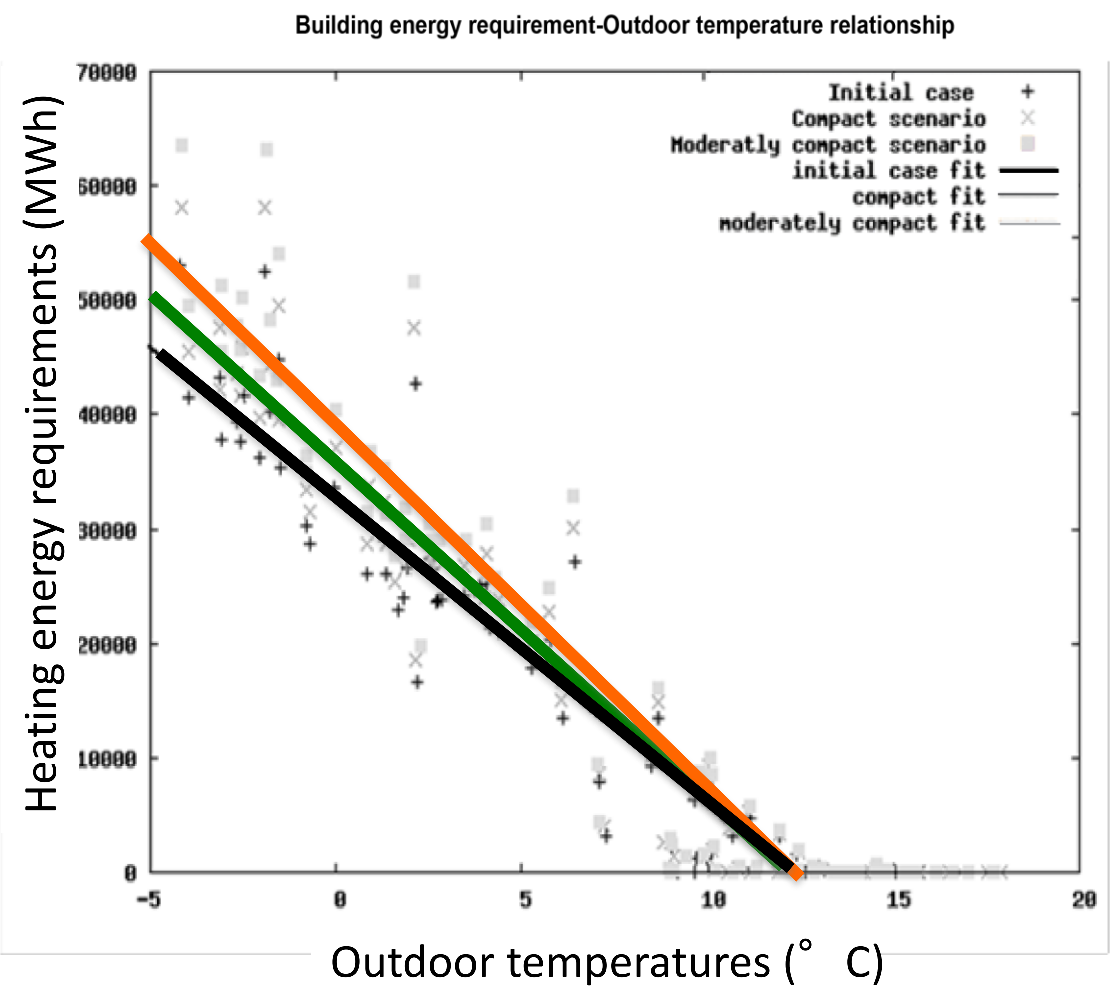


1) Few differences induced by the ecological preservation

2) Dominant land cover approach fails to reproduce scattered built up patterns (FRC_URB>20%)

2 urban types scenarios
(Compact/ Mod. Compact)

RESULTS: city-scale building energy requirements-temperatures relationship (1)

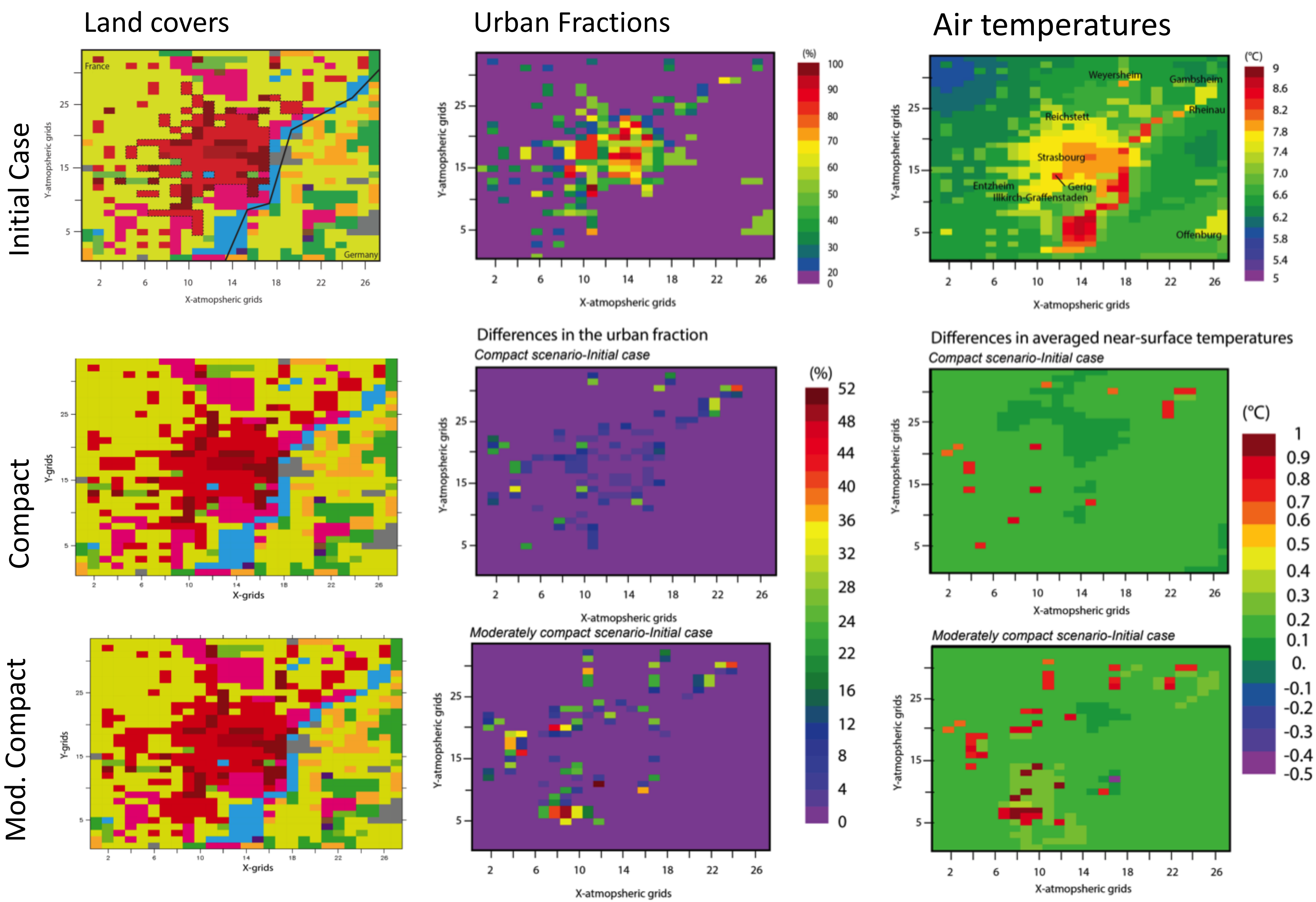


Initial case: C=4,285,202 GJ
P_{city}=-2,668.78 MWh/° C
$T_{0\ city}$=12.20° C

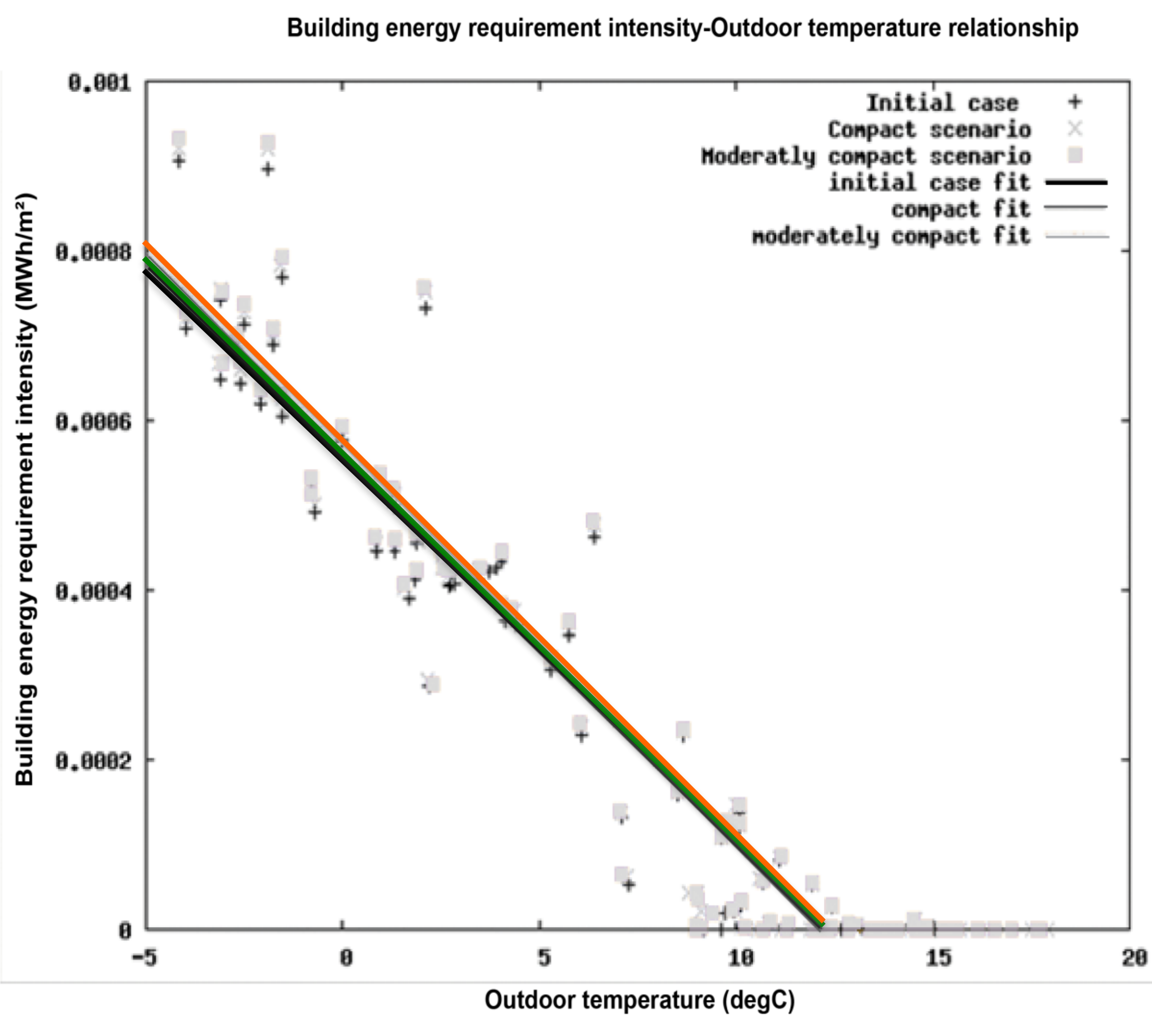
Compact: C=4,977,521 GJ
(+14.94%)
P_{city}=-2,922.6 MWh/° C
$T_{0\ city}$=12.26° C

Mod. compact: C =5,424,813 GJ
(+23.47%)
P_{city} =-3,179.2 MWh/° C
$T_{0\ city}$=12.30° C

Simulated temperatures (2010 meteorology and building properties)



RESULTS: city-scale building energy requirements-temperatures relationship (2)



Floor areas:

Scenarios	Floor areas (m^2)
Initial case	58,419,796
Compact	63,145,968
Mod. compact	68,172,584

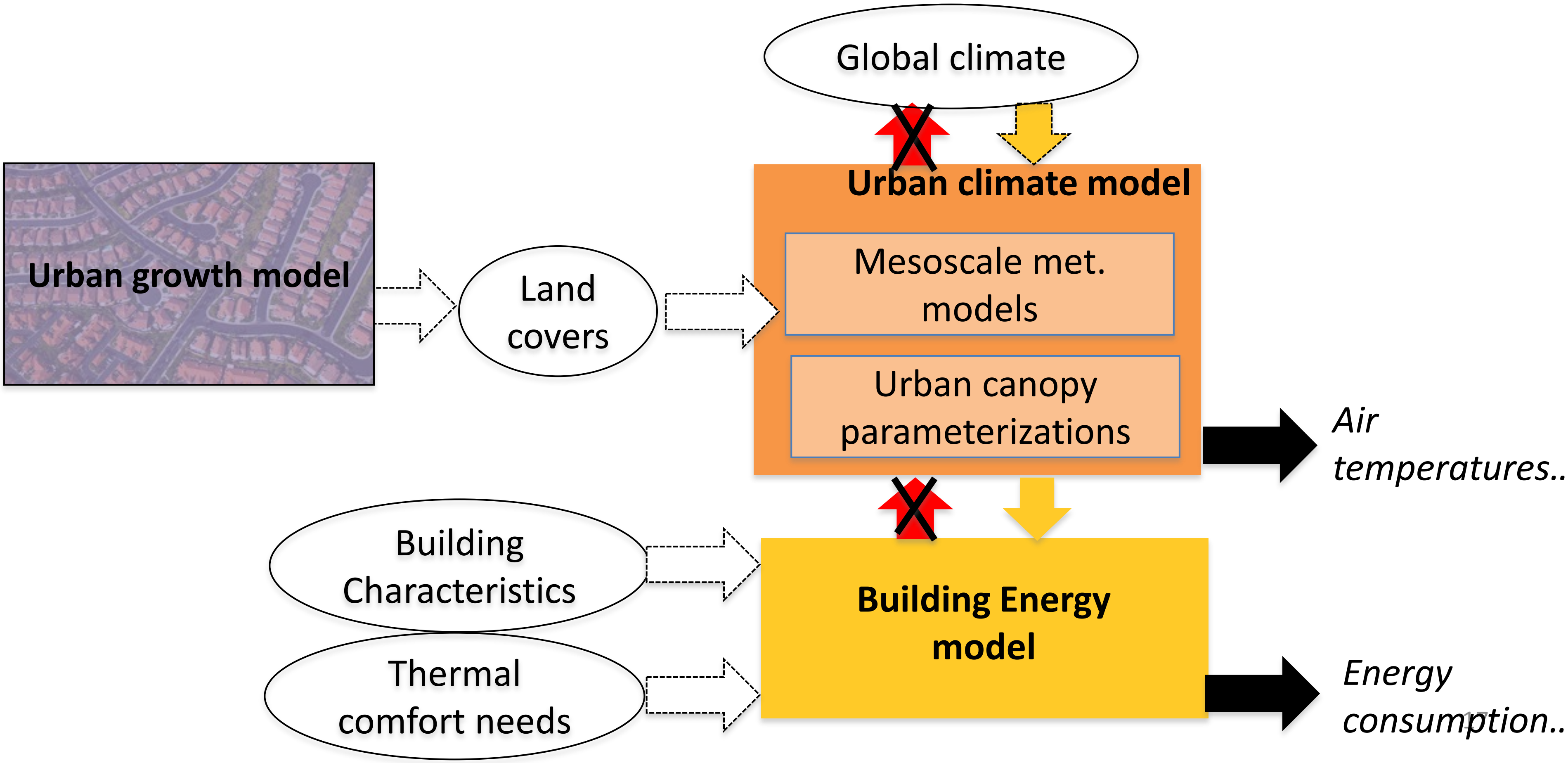
→ The urban form does not influence the heating energy requirements.

Can urban climate modeling systems provide urban planning guidelines to urban planners?

- Yes, we need urban climate models to provide the air temperatures in cities (heat stress, and the degree-days).

BUT,

- In this study case, building energy requirements can be estimated by using building energy models which are running independantly from urban climate models (no interactions).



Perspectives

- **Perform other case study (different intensities of residential development, operation of cooling system since local meteorological conditions> synoptic conditions in summer).**

- **Increase the horizontal atmospheric grid resolution for considering the scattered built-up patterns**

  → Can we continue to neglect the advection of the thermal and moisture plume at neighborhood scale (spatial topological informations)?
  → Are climate modeling system the right tools for this? (CFD, mircoscale climate model)

- **Urban planning seems to have no significant role compared to other building characteristics** (*e.g. thermostat set point temperature, and the wasted heat produced by the equipments*)

  → Which is the role of the urban form on the urban dweller behaviors (thermal comfort sensation)?

Thank you !

Acknowldegments:

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Contact: 1kohlerm@gmail.com (for any informations, and also if you are looking for a postdoc candidate ;) !

Comparison with the ASPA study

	ASPA	WRF	Differences
EC_{2010}	15,274,755 GJ	12,055,372.6 GJ	-21.07%
Equations	$EC_{2010} = \sum_{dw}^{ndw} P_{dw}.D$	$EC_{2010} = \sum_{i=1}^{Dt} P_{city}.D_{city}$ C, P_{city}, $T_{0,city}$, D	
P	-2493.94 MWh/° C	-2316.39 MWh/° C	-7.38%
D	-1701,31 ° Ch	-1445.64 ° Ch	-15.02%

October to May	*All the year*	*0.1%*
$T_{0,city}$ predefined: ***17° C***	*$T_{0,city}$ not predefined:* ***12.05° C***	*-9.3%*
$T_i = \frac{T_{max} - T_{min}}{2}$	$T_i = \frac{1}{24}\sum_{1}^{24} T_{hourly}$	*-13.3 %*

The results: simulated UHI intensity

(° C)	ΔUHI	ΔUHI_night			ΔUHI_day		
Period	**2010**	***Feb.***	***March***	***Sep.***	**Feb.**	**March**	**Sep.**
Initial case	0.62	0.57	0.83	1.15	0.32	0.24	0.37
Compact	0.59	0.55	0.79	1.09	0.30	0.22	0.33
Mod. compact	0.56	0.52	0.77	1.05	0.29	0.22	0.33

- Few differences: Initial case > Compact > Moderately Compact scenarios
- Seasonality UHI well reproduced