International Building Physics Conference

IABP – International Association of Building Physics

25-26-27 July, 2024

Toronto, Ontario, Canada

Influence of urban microclimate on the energy performance of buildings of complex shapes in different district layouts and climates

Authors: Borelli G[1], Battini F[1], Pernigotto G[1], Gasparella A[1]

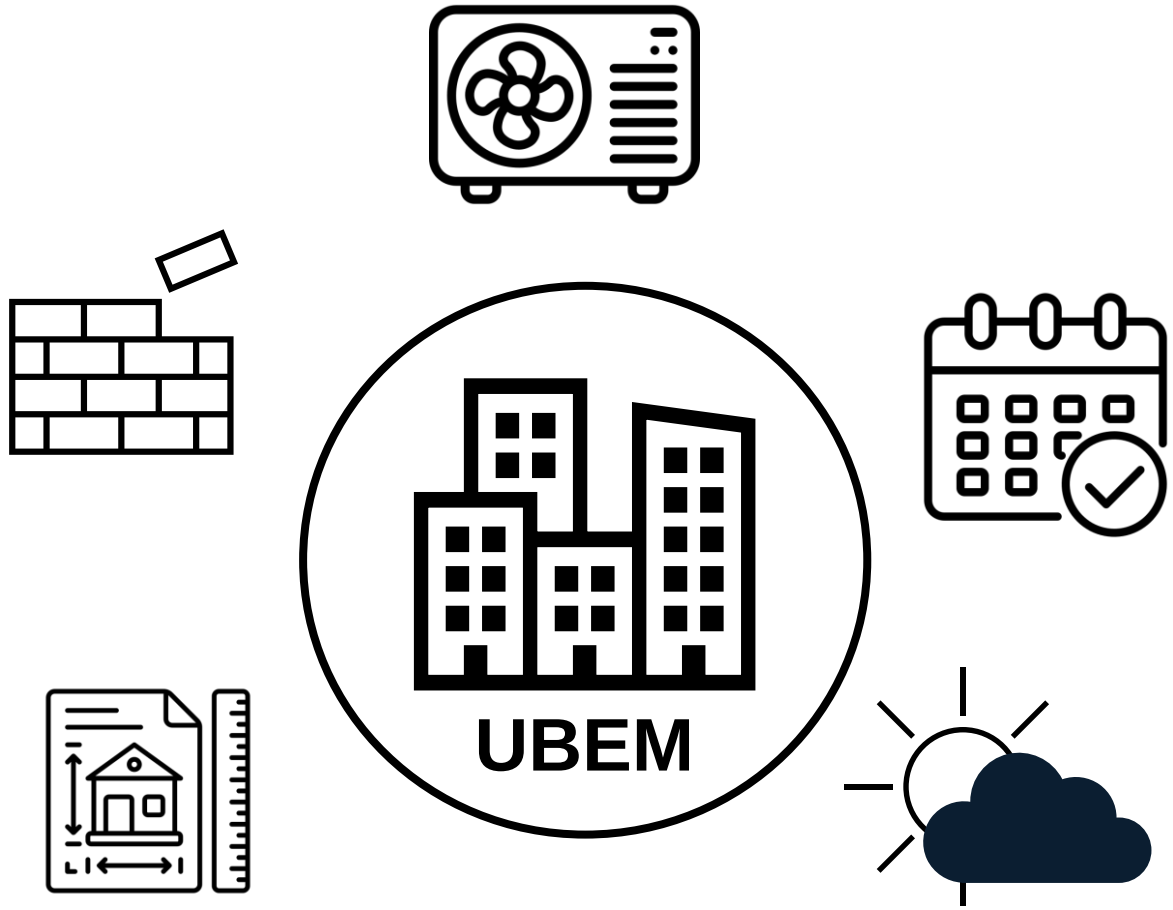
Free University of Bozen-Bolzano
Bolzano
Italy

CONTEXT

UBEM require several input data:

- *Difficult to retrieve*
- Affected by *big uncertainty*
- With *high spatial variability*

It is then important to characterize both quality and impact of the used inputs



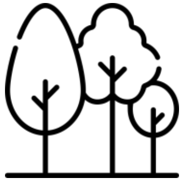
CONTEXT

Climate conditions change inside the cities, affecting:

- *Building energy needs and final uses*
- *Outdoor comfort* and *indoor comfort* in natural ventilated building

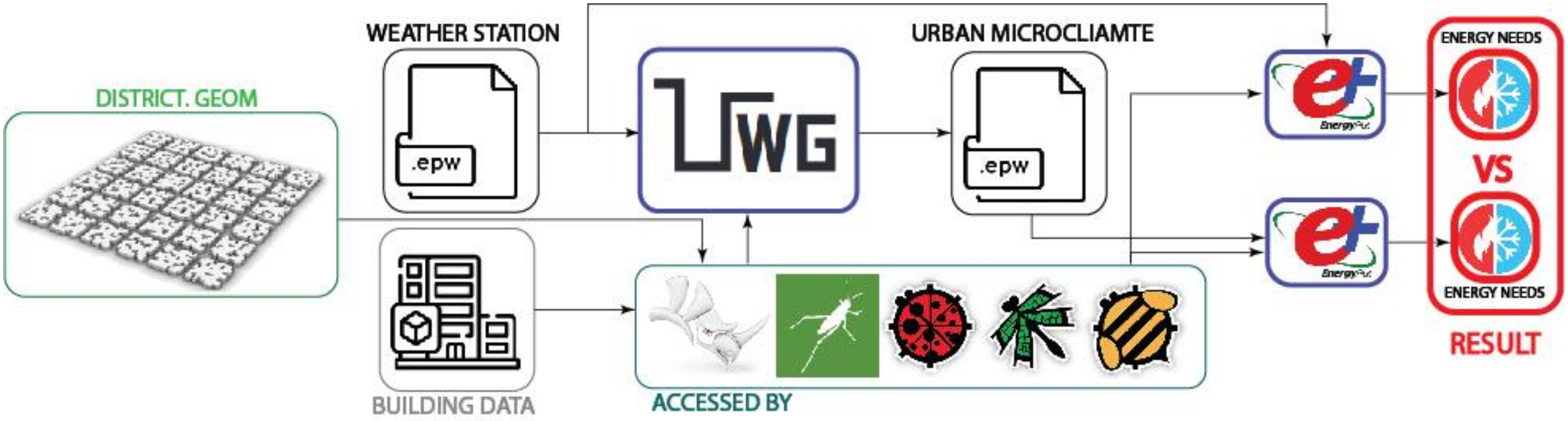
Different **influence factors**:

- ***Morphology***
- *Vegetation*
- *Anthropic heat*



AIM AND METHODS

This study focused on assessing **the impact of urban climate** on the simulated energy needs for urban districts compared to **rural climate condition**

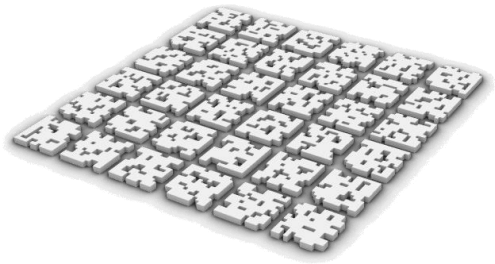


METHODS: LOCATIONS

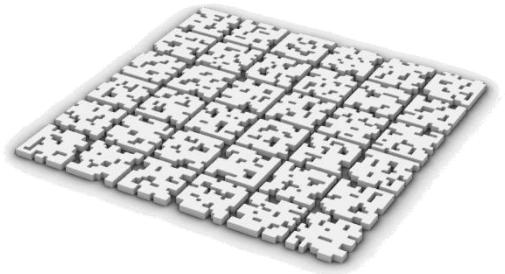
Two different Italian locations:

- Heating-dominated location (Bolzano)
  - HDD_{18} : 2178 K d
  - CDD_{18} : 504 K d
  - Avg Temp: 13.4 °C
- Cooling-dominated location (Palermo)
  - HDD_{18} : 803 K d
  - CDD_{18} : 1089 K d
  - Avg Temp: 18.8 °C

METHODS: GEOMETRIES



5 fictitious district from a previously-studied dataset of 64 complex districts, selected according *median*, *min*, and *max values* of Surface Coverage (**SC**), Volume Area Ratio (**VAR**), and Floor Area Ratio (**FAR**).



- 324 buildings of complex shape in each district
- Buildings arranged in a 6x6 grid

District	FAR [-]	SC [-]	VAR [m]	Vth [-]
Street10_Scale1_Floor2	1.09	0.54	3.27	0.81
Street10_Scale2_Floor4	2.54	0.63	7.62	0.95
Street20_Scale2_Floor2	1.09	0.54	3.27	0.41
Street40_Scale1_Floor1	0.26	0.26	0.78	0.2
Street40_Scale1_Floor4	1.04	0.26	3.13	0.78

Vth – Vertical to horizontal ratio

METHODS: BUILDING DATA

Building envelope: two **glazing ratios** (20 % and 30 %) and two **insulation levels**

OPAQUE ENVELOPE			
Bld. Type	**Layer**	**Thickness [m]**	**U-value [W m^{-2} K^{-1}]**
INSULATED	Clay Block	0.20	0.19
	XPS	0.15	
UNINSULATED	Clay Block	0.20	1.05
FENESTRATION			
Bld. Type	**Type**	**U-value [W m^{-2} K^{-1}]**	**SHGC [-]**
INSULATED	Low-E Triple Glazing	1.53	0.472
UNINSULATED	Double Glazing	2.72	0.764

METHODS: SIMULATION

MICROCLIMATE

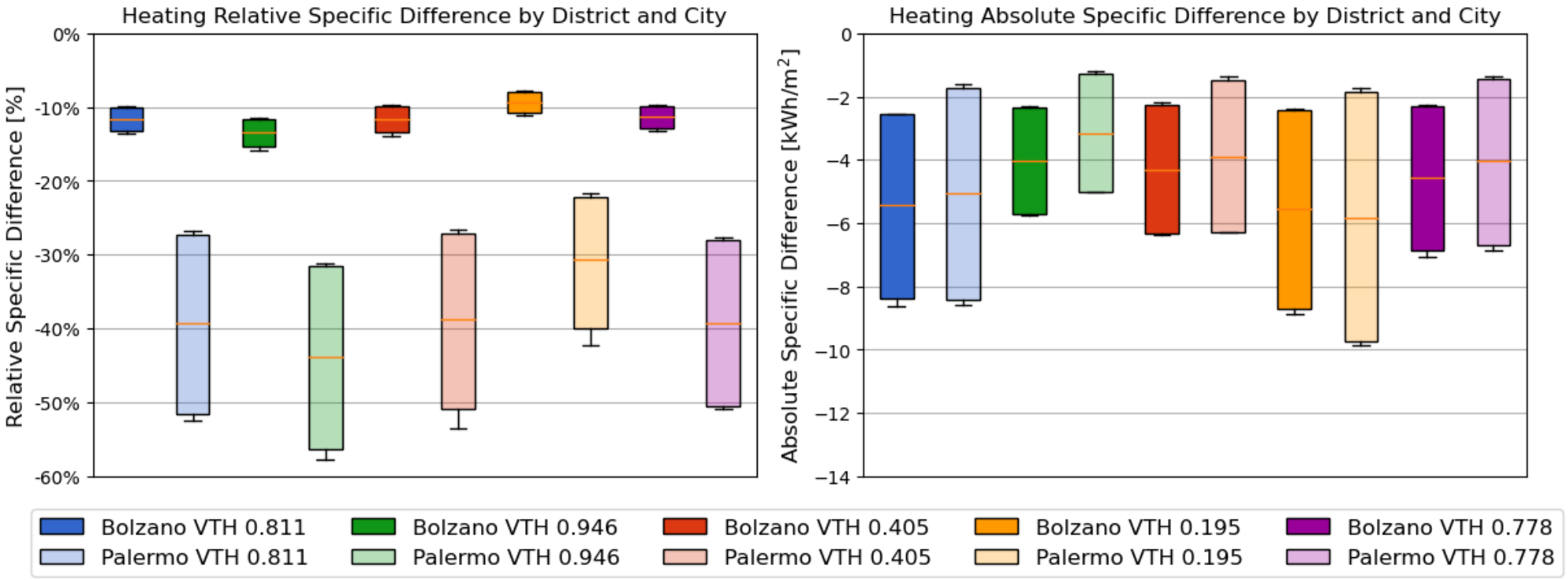
The urban microclimate is calculated using the **urban weather generator by MIT**. Default values are assumed for the other parameters not mentioned before (e.g., anthropic heat, vegetation), since the main focus of this research is the urban morphology.

ENERGYPLUS SIMULATIONS

- Context area considered: half of total district length
- Heating and cooling setpoints: 20°C and 26°C
- Ventilation rate: 0.5 ACH
- Internal gains of 4 W/m^2

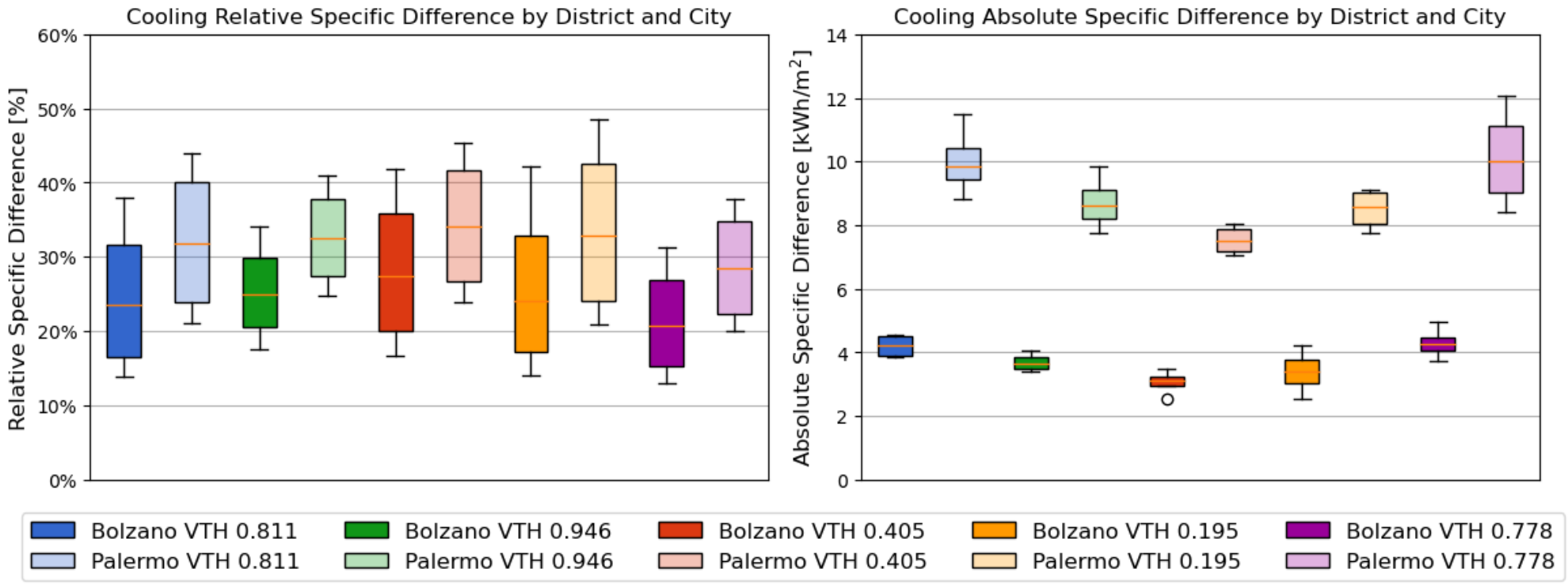
RESULTS: Space Heating

- **Similar absolute deviations** across different locations and districts: **from -1.9 to -9.7 kWh m^{-2} a^{-1}**
- **Urban morphology** is the parameter most affecting the variability of deviations.



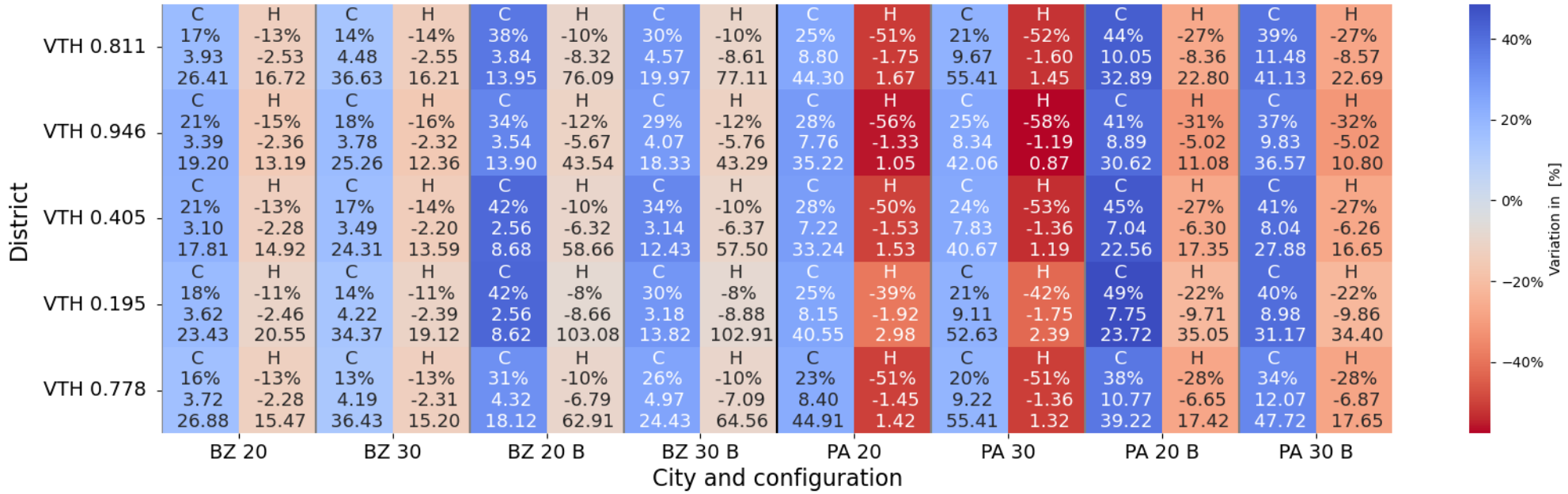
RESULTS: Space Cooling

- **Marked difference of absolute deviation** between the two climate, but **similar relative deviations**.
- Again, urban morphology is the parameter most affecting the variability of deviations.



RESULTS: Building Features

- **Glazing ratio** increases the cooling demand
- **Insulation** reduces the impact of microclimate on heating needs
- **Peak load** deviation almost negligible in Bolzano but relevant in Palermo



	BZ 20		BZ 30		BZ 20 B		BZ 30 B		PA 20		PA 30		PA 20 B		PA 30 B	
	C	H	C	H	C	H	C	H	C	H	C	H	C	H	C	H
VTH 0.811	17%	-13%	14%	-14%	38%	-10%	30%	-10%	25%	-51%	21%	-52%	44%	-27%	39%	-27%
	3.93	-2.53	4.48	-2.55	3.84	-8.32	4.57	-8.61	8.80	-1.75	9.67	-1.60	10.05	-8.36	11.48	-8.57
	26.41	16.72	36.63	16.21	13.95	76.09	19.97	77.11	44.30	1.67	55.41	1.45	32.89	22.80	41.13	22.69
	C	H	C	H	C	H	C	H	C	H	C	H	C	H	C	H
VTH 0.946	21%	-15%	18%	-16%	34%	-12%	29%	-12%	28%	-56%	25%	-58%	41%	-31%	37%	-32%
	3.39	-2.36	3.78	-2.32	3.54	-5.67	4.07	-5.76	7.76	-1.33	8.34	-1.19	8.89	-5.02	9.83	-5.02
	19.20	13.19	25.26	12.36	13.90	43.54	18.33	43.29	35.22	1.05	42.06	0.87	30.62	11.08	36.57	10.80
	C	H	C	H	C	H	C	H	C	H	C	H	C	H	C	H
VTH 0.405	21%	-13%	17%	-14%	42%	-10%	34%	-10%	28%	-50%	24%	-53%	45%	-27%	41%	-27%
	3.10	-2.28	3.49	-2.20	2.56	-6.32	3.14	-6.37	7.22	-1.53	7.83	-1.36	7.04	-6.30	8.04	-6.26
	17.81	14.92	24.31	13.59	8.68	58.66	12.43	57.50	33.24	1.53	40.67	1.19	22.56	17.35	27.88	16.65
	C	H	C	H	C	H	C	H	C	H	C	H	C	H	C	H
VTH 0.195	18%	-11%	14%	-11%	42%	-8%	30%	-8%	25%	-39%	21%	-42%	49%	-22%	40%	-22%
	3.62	-2.46	4.22	-2.39	2.56	-8.66	3.18	-8.88	8.15	-1.92	9.11	-1.75	7.75	-9.71	8.98	-9.86
	23.43	20.55	34.37	19.12	8.62	103.08	13.82	102.91	40.55	2.98	52.63	2.39	23.72	35.05	31.17	34.40
	C	H	C	H	C	H	C	H	C	H	C	H	C	H	C	H
VTH 0.778	16%	-13%	13%	-13%	31%	-10%	26%	-10%	23%	-51%	20%	-51%	38%	-28%	34%	-28%
	3.72	-2.28	4.19	-2.31	4.32	-6.79	4.97	-7.09	8.40	-1.45	9.22	-1.36	10.77	-6.65	12.07	-6.87
	26.88	15.47	36.43	15.20	18.12	62.91	24.43	64.56	44.91	1.42	55.41	1.32	39.22	17.42	47.72	17.65

The second value corresponds to the absolute differnce in kWh/m^2 and the third to case specific demand in kWh/m^2

CONCLUSION

- Results show significant deviation between the energy performance simulated with urban microclimate and those simulated with the rural one for all the considered cases:
  - **Space Heating deviations**
    - -11% in the heating-dominated climate (Bolzano)
    - -38 % in the cooling dominated one (Palermo)
  - **Space Cooling deviations**
    - +25 % in the heating-dominated climate (Bolzano)
    - +32 %in the cooling dominated one (Palermo)
- Urban condition has significant influence on the simulated urban energy performance.
- Findings underlined **the importance of adopting representative urban climates in urban-scale simulations** to improve the representativeness of their outputs and their accuracy.

LIMITATIONS AND FUTURE STEPS

Limitations

- Focus only on morphology, vegetation albedos and anthropic heat not investigated in the current research
- UWG does not consider wind speed variation

Future steps

- Integration of other parameters
- Wider rage of urban layout
- Different envelope composition (urban building archetypes)

Thanks for the attention

Author's contacts: gregorio.borelli@student.unibz.it

This study has been developed in the framework of the PhD Research Scholarship "Development of urban building energy models to support the definition of energy policies by municipalities and local public administrations" (DM 118/2023) and of the «Climate Resilient Strategies by Archetype-based Urban Energy Modelling (CRiStAll)» project – funded by European Union – Next Generation EU within the PRIN 2022 PNRR program (D.D.1409 del 14/09/2022 Ministero dell'Università e della Ricerca), M4C2, I 1.1.

Authors: Borelli G, Battini F, Pernigotto G, Gasparella A

Finanziato dall'Unione europea NextGenerationEU
Ministero dell'Università e della Ricerca
Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA
unibz Freie Universität Bozen Libera Università di Bolzano Università Liedia de Bulsan