# Chapter 1
# Introduction: Anthropocene or Urbanocene?

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## 1.1 Anthropocene or Urbanocene?

We live in times of great changes. Global warming is altering the planetary thermal equilibrium, causing deep changes in our lifestyles. Economic transformations are also pushing the society toward new organisational structures, able to respond to the characters of a deeply globalised world. The human activity has an impact on the ecological system that had never been seen before. As a result, we are exposed to new risks, including extreme climatological events, pandemic diseases and massive migrations. For this reason, many specialists in different fields, geologists in particular, are proposing the term "Anthropocene" for the geological epoch in which we are living (Crutzen and Stoemer 2000; Zalasiewics et al. 2018). This epoch could have started with the great acceleration in economic growth of the 1950s, or with the industrial revolution or with the trip of Columbus to America and its ecological consequences; it could even coincide with the entire Holocene. One of the fundamental characteristics of the "Anthropocene", especially starting from the industrial revolution, is the urban living. Cities have expanded into large metropolitan areas and megacities and are still expanding at a very fast pace, especially in Asia and Africa. The urban population passed from 33.6% to 55.7% of the total population between 1960 and 2019 (United Nations Population Division 2018) and it is expected to be 70% by the middle of the century. The London School of Economics and the Alfred Herrhausen Gesellschaft have extensively analysed the deep economical, societal and environmental consequences of these urban transformations, defining this epoch as the "Urban Age" (Burdett and Rode 2018; Burdett

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and Sudjic 2007, 2011). Some scientists proposed the term "Urbanocene" (West 2017) to describe this new epoch, arguing that even the stratigraphic signal of a "golden spike" could be found in urban geomorphology (Certini and Scalenghe 2011; Elias 2018).

As a matter of fact, the world is increasingly populated and urbanised. Cities are the places where we live and use almost 80% of the final energy, with associated dissipation of heat to the environment. For this reason, many scientists from different fields highlighted the need of studying the urban metabolism, to understand the fluxes of materials, energy, food, water and information across our cities. The urban metabolism is directly associated to entropy production, whose most visible effect is the generation of local microclimates in cities (Palme et al. 2017). The existence of these microclimates is often neglected when studying global warming. For a matter of scale and computational efficiency, the IPCC scenarios and the global climate models do not explicitly consider the presence of cities and their different thermal behaviours compared to non-urbanised areas in their predictions. However, even though cities occupy a negligible percentage of the earth surface, they concentrate 75% of global $CO_2$ emissions (Burdett and Sudjic 2007) and are warmer than their surroundings (Stone 2012). This could lead to underestimate of the pace of warming of cities that is higher than that of rural environment.

## 1.2 Cities' Metabolism and Urban Climate

The concept of urban metabolism was firstly proposed by Wolman (1965) and today it is an increasing field of study (Kennedy et al. 2007; Princetl et al. 2012; Zhang et al. 2015; Cui 2018; Dijst et al. 2018), whose purpose is to understand the physical processes taking place in a city, by analogy with living structures. It grounds on seminal contributions by Schrodinger (1944) regarding the quintessence of life, Prigogine and Stengers (1984) regarding far-from-equilibrium thermodynamics and Odum (1988) and Allen (1994) regarding complex systems dynamics. Allen (1998) and Pumain (1998) were among the first to apply these concepts to urban systems.

The study of urban climate should be considered as one of the most important areas in this field of research today. Starting from the pioneering study by Howard on the climate of London (1888), urban climatology has turned into an established academic discipline. The energetic basis of the urban heat island effect and other urban microclimatic phenomena has been deeply studied and described in influential books such as "Boundary Layer Climates" (Oke 1987) and "Urban Climates" (Oke et al. 2017). Urban climate can be seen as the resulting modification introduced in the environment by urban structure and activities taking place in cities. Anthropogenic heat generation, changes in land cover and land use and building density contribute to the generation of new climatic patterns that modify the environment in which cities are placed. The modified urban climate has a deep impact on both building energy performance and comfort of inhabitants. Santamouris (2014) showed that the increase in cooling needs due to urban warming could rise up to 500% by the middle of the century. Many studies carried out in different cities of the world confirmed that the urban heat island causes an energy penalty on urban buildings, increasing their annual energy demand (Santamouris 2020).

## 1.3 Integrating Urban Climate Knowledge in Urban Policies, Planning and Design: What Went Wrong?

The growing concern for the risks posed by climate change to the liveability of cities has certainly also contributed to increase in the awareness on the impact of the built environment on urban microclimate. Nevertheless, the attempts to integrate climate principles in the planning, design and renovation of cities and buildings are still scarce, or not effective.

Oke advocated the need for a greater consideration of climate principles in urban planning yet in the 1980s (Oke 1984), encouraging urban climatologists to translate their knowledge into practical applications and guidelines for the design of street canyon geometry (Arnfield 1990; Oke 1988). Since then, the body of knowledge in urban climatology has grown, as well as the computation capabilities to carry out more advanced modelling studies (Chen et al. 2011; Grimmond et al. 2011). Other attempts to disseminate this knowledge to a wider audience have been done (Grimmond et al. 2010; Oke et al. 2017). Today, a wide and multidisciplinary research community recognises the importance of interactions among buildings in the urban environment to assess urban sustainability and energy performance (Emmanuel and Steemers 2018). However, it is still rare to find good applications of climate principles in urban planning and architectural practice. The basic concepts of urban climatology are often unknown also to building energy modellers that normally carry out energy performance simulations just neglecting any urban effect.

The poor importance given to urban climate in planning and design is partially due to the absence of microclimate regulations. As a matter of fact, the introduction of regulations on the energy efficiency has improved the thermal performance of buildings, making architects and engineers accountable for the energy consequences of their choices. However, as shown by Futcher et al. (2017), the energy impact of new buildings, especially tall ones, can go far beyond their envelope, modifying the solar access, wind speed and air quality of surrounding areas and consequently the energy use of other buildings. As Futcher and Mills rightly point out (Futcher and Mills 2015), no one is accountable for the microclimate and energy impact of new buildings beyond their envelope and this should be better regulated to achieve sustainable urban development.

Other motivations behind this persistent gap between urban climatology and planning are still those enumerated by Oke: “the inherent complexity of the subject, its interdisciplinary nature and lack of meaningful dialogue between planners and the climatological research community” (Oke 1984).

The communication gap between climatologists and designers, including planners, architects and building engineers, is basically due to the lack of a common ground in terms of vocabulary, educational background and scale of analysis. The designers do not have any background on climatology and urban physics, while climatologists know very little about architectural design and planning processes. Architects and planners are more prone to think about buildings and cities in relation to the users' practical needs, while climatologists tend to abstract the urban context into surface properties (i.e. roughness, albedo) and heat fluxes. Designers and climatologists also associate different meanings to key properties of the built environment such as urban morphology, compactness or density. Ultimately, they are interested in the same things, buildings and cities, but they use different languages and, as a result, they struggle to understand each other's.

This communication issue has also led to some misinterpretations of the concept of urban heat island (UHI) by architects, planners and engineers. The most common misunderstanding is the consideration of the UHI intensity as a constant phenomenon in time and space. Therefore, the first myth to debunk is that there is no single UHI effect in a city, but different types of urban climate modifications that influence thermal comfort and building energy performance (Salvati et al. 2020).

Another difficulty is given by the multiple scale of urban climate phenomena and the interconnections between meso-climate, local climate and microclimate. For instance, to assess the impact of urban microclimate on the energy performance of buildings in a certain street, a multiscale approach including at least three steps is needed: (1) an analysis of the geographic and topographic features of the city and its surroundings, (2) an analysis of the urban fabric characteristics in terms of local climate zones (Palme et al. 2018; Salvati et al. 2019; Stewart and Oke 2012) and (3) an analysis of the three-dimensional shape and arrangement of buildings in the street canyon, the thermal and optical properties of urban and building materials and the thermal performance and function of buildings (Futcher et al. 2018; Salvati and Kolokotroni 2019). Due to this complexity, it is not possible to draw easy-to-apply and universally valid climate guidelines, because every city is different, and so are the districts, streets and buildings across a city.

Another aspect to consider is that urban climate modifications may have favourable or negative impact depending on the season and the objective of the analysis, which can be thermal comfort and air quality in the outdoors or energy efficiency and environmental quality indoors. For this reason, it is crucial to understand the net impact of architectural and planning choices on the environmental performance of cities, including urban microclimate, building energy performance, air quality, noise and daylight access at least.

In light of these issues, more has to be done to bridge urban climatology to planning, architectural design and building energy simulations. This entails an effort from both disciplines. Architects, planners and engineers need to expand their understanding of the microclimate impact of design choices and the impact of urban context on the building performance. Urban climatologists and geographers need to understand the complexity of the planning and design processes and work with architects and planners to develop more design-oriented tools.

## 1.4 The Book Structure

This book provides the state of the art of applied modelling and simulation of cities' thermodynamics, including contributions by some of the most influencing experts and emergent researchers in the field. Information is organised in three parts. In the first part, the general topic of the city as a complex adaptive system is presented, putting in evidence of the relation between the city metabolism and the resulting microclimate, as well as the implications for comfort and energy consumption. The second part includes a range of studies on modelling methodologies and available tools for urban climate simulation. The third part is a compendium of planning and design applications applying the described methodologies to improve cities' resilience and sustainability.

### *1.4.1 Urban Climate and Sustainability: Energy Performance and Thermal Comfort in Cities*

In the first part, Butera and Palme (Chap. 2) introduce the city as a complex thermodynamic system. Mills, Futcher and Stewart (Chap. 3) discuss the energetic basis of the urban heat island and Nicolopoulou (Chap. 4) introduces the concept of outdoor thermal comfort.

The chapters from 5 to 8 are focused on specific issues in different climate regions. Kolokotroni and Salvati (Chap. 5) explore the energy implications of urban microclimates in high-latitude cities, Coch and Salvati (Chap. 6) focus on comfort and energy performance of Mediterranean cities, Gooroochurn and Renganathan (Chap. 7) describe how to enhance energy performance in tropical climates, while Marincic and Ochoa (Chap. 8) explore thermal comfort in arid climates. The first section is concluded by a position paper by Mills and Futcher (Chap. 9), making an argument for a redefinition of the "urban canopy layer" to include both the indoor and outdoor space in a single domain of investigation, namely the zone of human occupation. Perhaps, this could be an effective attempt to overcome the current lack of integration between complementary disciplines that study this space in a fragmented way and a step forward for the management of urban climate and energy issues under the same context, scale and regulation framework.

### *1.4.2 Urban Climate Modelling and Simulation: Physics and Tools*

The second part of the book is dedicated to modelling studies. Di Bernardino et al. (Chap. 10) review the topic of air circulation in urban environments. Jandaghian and Berardi (Chap. 11) show how to couple weather forecasting models and urban canopy models to obtain data for building performance simulation. Mao and Norford (Chap. 12) present the last-released version of the Urban Weather Generator tool, while Musy et al. (Chap. 13) present the SOLENE-microclimat model. Pacifici and Nieto-Tolosa (Chap. 14) compare ENVI-met and Grasshopper modelling strategies to assess local climate and urban heat island. Rodler et al. (Chap. 15) review the most significant urban microclimate and building energy simulation coupling techniques. Matzarakis et al. (Chap. 16) present RayMan and SkyHelios models, while Ganem and Barea (Chap. 17) present a methodology to assess the impact of climate change on energy performance of buildings.

### *1.4.3 Applying Urban Climate Modelling in Policy, Planning and Design: Case Studies*

In the third part, Morganti (Chap. 18) presents spatial metrics to investigate the impact of urban morphology on microclimate and energy performance of buildings. De la Barrera and Reyes (Chap. 19) explore the possibility to mitigate extreme temperatures by using green infrastructure, while Privitera et al. (Chap. 23) present the capability of green infrastructure to reduce energy needs of a city. Correa et al. (Chap. 20) discuss urban morphology as a mitigation strategy for urban warming, Santos-Nouri and Matzarakis (Chap. 21) present human biometeorological studies in Lisbon and Ganem et al. discuss the impact of urban climate on building energy performance in the city of Mendoza (Chap. 22). Finally, Fabiani and Pisello (Chap. 24) review the importance of cool materials for passive cooling of buildings.

## 1.5 Conclusion

The Anthropocene-Urbanocene epoch is pushing humanity beyond the planetary limits. Many processes involved in the maintenance of our economic system and social structure have been found already out of control, while others are facing the limits of the planet resources (Rockstrom et al. 2009; Steffen et al. 2015). At least two of these processes are directly related to urban living (land use and climate change), and all the others are strictly connected (nitrogen and phosphorus cycles, biodiversity loss, ocean acidifications, etcetera). To maintain our living standards (and to permit the same rights to all the world population) and to stay in the so-called Safe Operating Space, we should deeply change our vision of prosperity and society (O'Neil et al. 2018). Urban climate and building operation are key factors in both defining new standards of acceptable prosperity and achieving the challenge of staying in the aforementioned limits.

As a final note, this book has been mostly written and edited over the 2020 COVID-19 pandemic, which has definitely made clear to all of us how it is important to have healthy, liveable and comfortable houses and cities for our physical and mental well-being. We hope this further lesson will foster all the stakeholders involved with the study and management of cities and buildings, including architects, engineers, planners, physicists, geographers, climatologists and economists, to effectively collaborate to achieve more resilient, sustainable and liveable cities.

## References


Allen, P. (1994). Evolutionary complex systems: Models of technology change. In *Evolutionary Economics and Chaos Theory*. London: Pinter Ed.

Allen, P. (1998). Cities as self-organizing complex systems. In *The city and its sciences*. Heidelberg: Physica-Verlag.

Arnfield, A. J. (1990). Street design and urban canyon solar access. *Energy and Buildings, 14*, 117–131. https://doi.org/10.1016/0378-7788(90)90031-D.

Burdett, R., & Rode, P. (Eds.). (2018). *Shaping cities in an urban age*. London: Phaidon Press.

Burdett, R., & Sudjic, D. (2007). *The endless city—Urban age project*. London: Phaidon Press.

Burdett, R., & Sudjic, D. (Eds.). (2011). *Living in the endless city*. London: Phaidon Press.

Certini, G., & Scalenghe, R. (2011). Anthropogenic soils are the golden spikes for the Anthropocene. *The Holocene, 21*(8), 1269–1274.

Chen, F., Kusaka, H., Bornstein, R., Ching, J., Grimmond, C. S. B., Grossman-Clarke, S., et al. (2011). The integrated WRF/urban modelling system: Development, evaluation, and applications to urban environmental problems. *International Journal of Climatology, 31*(2), 273–288. https://doi.org/10.1002/joc.2158.

Crutzen, P. J., & Stoermer, E. (2000). The Anthropocene. *Global Change Newsletter, 41*, 17.

Cui, X. (2018). How can cities support sustainability: A bibliometric analysis of urban metabolism. *Ecological Indicators, 93*, 704–717.

Dijst, M., Worrel, E., Bocker, L., Brunner, P., Davoudi, S., Geertman, S., Narmsen, R., Helbich, M., Holtslag, A. A. M., Kwan, M. P., et al. (2018). Exploring urban metabolism—Towards an interdisciplinary perspective. *Resources, Conservation and Recycling, 132*, 190–203.

Elias, S. A. (2018). *Finding a "golden spike" to mark the Anthropocene. Encyclopedia of the Anthropocene*. Amsterdam: Elsevier.

Emmanuel, R., & Steemers, K. (2018). Connecting the realms of urban form, density and microclimate. *Building Research and Information, 46*, 804–808. https://doi.org/10.1080/09613218.2018.1507078.

Futcher, J., & Mills, G. (2015, April). Pushing the envelope. *CIBSE Journal*, 13–27. Retrieved from http://portfolio.cpl.co.uk/portfolio/CIBSE/201504/opinion-futcher/.

Futcher, J., Mills, G., Emmanuel, R., & Korolija, I. (2017). Creating sustainable cities one building at a time: Towards an integrated urban design framework. *Cities, 66*, 63–71. https://doi.org/10.1016/j.cities.2017.03.009.

Futcher, J., Mills, G., & Emmanuel, R. (2018). Interdependent energy relationships between buildings at the street scale. *Building Research and Information, 46*, 829–844. https://doi.org/10.1080/09613218.2018.1499995.

Grimmond, C. S. B., Roth, M., Oke, T. R., Au, Y. C., Best, M., Betts, R., & Carmichael, G. (2010). Climate and more sustainable cities: Climate information for improved planning and management of cities (producers/capabilities perspective). *Procedia Environmental Sciences, 1*, 247–274. https://doi.org/10.1016/j.proenv.2010.09.016.

Grimmond, C. S. B., Blackett, M., Best, M. J., Baik, J.-J., Belcher, S. E., et al. (2011). Initial results from Phase 2 of the international urban energy balance model comparison. *International Journal of Climatology, 31*, 244–272. https://doi.org/10.1002/joc.2227.

Kennedy, C., Cuddiby, J., & Engel-Yan, J. (2007). The changing metabolism of cities. *Journal of Industrial Ecology, 11*, 43–59.

O'Neil, D., Fanning, A., Lamb, W., & Steinberger, J. (2018). A good life for all within planetary boundaries. *Nature Sustainability, 1*, 88–95.

Odum, H. T. (1988). Self-organization, transformity and information. *Science, 242*, 1132–1139.

Oke, T. R. (1984). Towards a prescription for the greater use of climatic principles in settlement planning. *Energy and Buildings, 7*(1), 1–10. https://doi.org/10.1016/0378-7788(84)90040-9.

Oke, T. R. (1987). *Boundary layer climates (2nd edition)*. London: Taylor & Francis.

Oke, T. R. (1988). Street design and urban canopy layer climate. *Energy and Buildings, 11*, 103–113. https://doi.org/10.1016/0378-7788(88)90026-6.

Oke, T. R., Mills, G., Christen, A., & Voogt, J. A. (2017). *Urban climates*. Cambridge: Cambridge University Press. https://doi.org/10.1017/9781139016476.

Palme, M., Inostroza, L., Villacreses, G., Lobato, A., & Carrasco, C. (2017). From urban climate to energy consumption. Enhancing building performance simulation by including the urban heat island effect. *Energy and Buildings, 145*, 107–120.

Palme, M., Inostroza, L., & Salvati, A. (2018). Technomass and cooling demand in South America: A superlinear relationship? *Building Research and Information, 46*(8), 864–880. https://doi.org/10.1080/09613218.2018.1483868.

Prigogine, I., & Stegers, I. (1984). *Order out of chaos*. New York: Bantam Ed.

Princetl, S., Bunie, P., & Holmes, T. (2012). An expanded urban metabolism method: Toward a system approach for assessing urban energy processes and causes. *Landscape and Urban Planning, 107*, 193–202.

Pumain, D. (1998). Urban research and complexity. In *The city and its sciences*. Berlin: Springer Verlag ed.

Rockstrom, J., Steffen, W., Noone, K., et al. (2009). Planetary boundaries: Exploring the safe operating space for humanity. *Ecology and Society, 14*(2), 32.

Salvati, A., & Kolokotroni, M. (2019). Microclimate data for building energy modelling: Study on ENVI-met forcing data. In V. Corrado & A. Gasparella (Eds.), *Proceedings of the 16th IBPSA conference* (pp. 3361–3368). Rome, Italy: IBPSA.

Salvati, A., Monti, P., Coch Roura, H., & Cecere, C. (2019). Climatic performance of urban textures: Analysis tools for a Mediterranean urban context. *Energy and Buildings, 185*, 162–179. https://doi.org/10.1016/j.enbuild.2018.12.024.

Salvati, A., Palme, M., Chiesa, G., & Kolokotroni, M. (2020). Built form, urban climate and building energy modelling: case-studies in Rome and Antofagasta. *Journal of Building Performance Simulation, 13*(2), 209–225. https://doi.org/10.1080/19401493.2019.1707876.

Santamouris, M. (2014). On the energy impact of urban heat island and global warming on buildings. *Energy and Buildings, 82*, 100–113.

Santamouris, M. (2020). Recent progress on urban overheating and heat island research. Integrated assessment of the energy, environmental, vulnerability and health impact. Synergies with the global climate change. *Energy and Buildings, 207*, https://doi.org/10.1016/j.enbuild.2019.109482

Schrodinger, E. (1944). *What is life?* Cambridge: Cambridge University Press.

Steffen, W., Richardson, K., & Rockstrom, J. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science, 347*(6223), 1259855.

Stewart, I. D., & Oke, T. R. (2012). Local climate zones for urban temperature studies. *Bulletin of the American Meteorological Society, 93*(12), 1879–1900. https://doi.org/10.1175/BAMS-D-11-00019.1.

Stone, B. (2012). *The city and the coming climate. Climate change in the places we live*. Cambridge: Cambridge University Press.

United Nations Population Division. (2018). World urbanization prospects: 2018 Revision. Retrieved 26 August, 2020, from https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS?end=2019&start=1960&view=chart.

West, G. (2017). *Scale*. London: Penguin Books.

Wolman, A. (1965). The metabolism of cities. *Scientific American, 213*(3), 178–190.

Zalasiewics, J., Waters, C., Summerhayes, C., & Williams, M. (2018). The Anthropocene. *Geology Today, 34*(5), 162–200.

Zhang, Y., Yang, Z., Yu, X. (2015). Urban metabolism: A review of current knowledge and directions for future study. *Environmental Science and Technology, 49*(19). https://doi.org/10.1021/acs.est.5b03060