Empa
Materials Science and Technology

Urban Energy Systems Laboratory: Shaping sustainable cities through integrated energy systems research

"The challenges of the 21st century will be solved in an urban context for most of the world."— Prof. David Fisk, CISBAT Keynote, 2009

Urban areas are central to both the challenges and solutions of our time. On one hand, cities are responsible for around 70% of global energy use and greenhouse gas emissions. On the other, they are hubs of economic activity, generating over 80% of the world's GDP, and offer unique opportunities for collaboration, innovation, and systemic change. As more than half of the global population already lives in cities, the way we shape urban systems will significantly influence global sustainability outcomes.

At Empa's **Urban Energy Systems Laboratory**, **we study how cities can transition toward sustainable, resilient, and inclusive futures**. Technology plays a central role in enabling these transitions — from digital tools for optimizing energy flows to new materials, infrastructure systems, and building designs. Yet we also recognize that technical solutions alone are not enough. They must be embedded in real-world contexts, aligned with societal needs, and designed with those who are affected by them.

This is why we are committed to **developing strategies that combine technical excellence with social relevance**. We draw on systems thinking to understand cities as interconnected networks of technologies, institutions, behaviors, and policies. Our work connects engineering approaches with diverse perspectives to address fundamental questions: How can technological solutions respond to both environmental and social challenges, such as the tension between energy efficiency and housing affordability? What approaches might balance the needs of different urban stakeholders? How can we design transitions that distribute benefits equitably?

In this context, we do not see science as delivering one-way solutions to society. Instead, we are committed to collaborative processes that bring together different forms of knowledge — including those beyond our own disciplines. We believe that meaningful change in cities can only emerge through engagement, dialogue, and shared responsibility.

Research topics and projects

Our research spans multiple scales, ranging from individual technologies to buildings, urban districts, entire cities, and beyond (see Fig. 1). We investigate both the design and operation of urban energy systems, with a focus on long-term planning, integration of renewable energy, and the development of algorithms to improve flexibility, efficiency, and resilience. Digital tools such as simulation models and digital twins play a key role in this work.

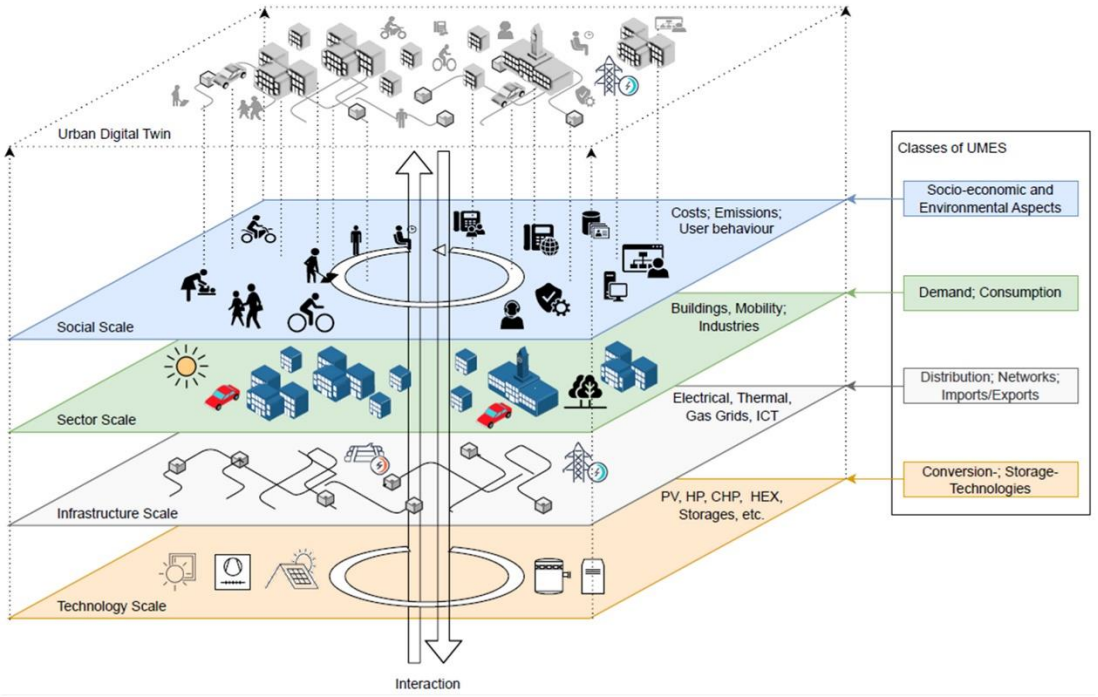

Figure 1. Research scales for Empa's Urban Energy Systems Laboratory.

We explore topics including renewable energy integration, circularity, energy efficiency, and sufficiency. Our main approach is the development of computational methods and techno-economic models to support decision-making in complex urban environments. At the same time, we actively test and demonstrate our ideas in real-world settings, including the NEST demonstrator building on the Empa campus.

Recent projects include:

- Neighbourhood-scale energy planning and visualization (e.g., Colouring Dübendorf), where we collaborate with local stakeholders to co-develop energy transition strategies for specific urban areas.
- Decentralized heating networks for residential areas (e.g., nanoverbund), focusing on innovative approaches to local energy distribution and management.
- Regional net-zero strategies (e.g., Netto-Null Rheintal), where we contribute to the development of comprehensive plans aiming for carbon neutrality at a regional scale.
- Data-driven urban energy modeling (e.g., Digicities), which involves creating digital infrastructures to facilitate energy planning and operation through advanced data architectures.

Across all these projects, we aim to combine analytical rigor with a practical understanding of urban systems, always considering the social and institutional contexts in which these systems operate.

Why are we interested in this collaboration?

We are drawn to cities not just because we study them, but because we live in them. Cities are where people build their lives — where they grow up, work, meet others, and experience the everyday. For us, they are not just technical systems or research subjects. They are living environments that matter to people in different ways. That's one of the reasons we're interested in working with an artist.

In our lab, we use data, models, and simulations to understand how cities can become more sustainable and inclusive. These tools help us work with complexity, but they don't capture everything. An artistic perspective could help us look at familiar topics from a different angle — not by simplifying them, but by asking new questions, or by helping us see things we might otherwise overlook.

We also see this as a chance to explore new ways of communicating what we do. Artists might translate complex systems into visual or spatial forms, create different kinds of stories around our work, or engage people who might not normally connect with scientific research. That's something we value.

Above all, we see this residency as a shared process of exploration. We do not expect predefined outcomes, but we are open to being surprised. We are curious to see what happens when scientific and artistic approaches meet — and how this exchange might expand the ways we imagine and engage with urban futures.

Residency environment

The artist will be welcomed as part of our interdisciplinary team at Empa, which includes engineers and researchers from various backgrounds. They will have access to lab meetings, ongoing discussions, and the opportunity to engage informally with different members of the Lab. While we do not expect a defined output from the residency, we encourage mutual curiosity and open exchange. Depending on interest, there may also be opportunities to visit real-world demonstrators such as NEST, Empa's modular research and innovation building, which serves as a testbed for sustainable building and energy technologies.

Selected publications and useful links

- Official laboratory website: https://www.empa.ch/web/s313/
- Laboratory LinkedIn page: https://www.linkedin.com/company/urban-energy-systems-laboratory/
- Urban Futures Symposium organized by our Laboratory: https://urban-futures.empa.ch/
- Relevant publications:
    - Koirala, B., Cai, H., Khayatian, F., Munoz, E., An, J. G., Mutschler, R., ... & Orehounig, K. (2024). Digitalization of urban multi-energy systems–advances in digital twin applications across life-cycle phases. *Advances in Applied Energy*, 100196. https://doi.org/10.1016/j.adapen.2024.100196
    - Upadhyay, A. (2025) Sector-coupled energy system models for clean energy policy. *Nature Reviews Clean Technology*. https://doi.org/10.1038/s44359-025-00060-2
    - Sulzer, M., Wetter, M., Mutschler, R., & Sangiovanni-Vincentelli, A. (2023). Platform-based design for energy systems. *Applied Energy*, *352*, 121955. https://doi.org/10.1016/j.apenergy.2023.121955
    - Lerbinger, A., Powell, S., & Mavromatidis, G. (2024). MANGOever: An optimization framework for the long-term planning and operations of integrated electric vehicle and building energy systems. *Advances in Applied Energy*, *16*, 100193. https://doi.org/10.1016/j.adapen.2024.100193

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The team of the Urban Energy Systems Laboratory