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# Editorial: Cleaner production and circular economy as boosters for sustainable cities

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Editorial on the Research Topic
Cleaner production and circular economy as boosters for sustainable cities

## 1 Introduction to this Research Topic

Building sustainable cities relies on the principles of circular economy and cleaner production, which together can boost resource efficiency and environmental resilience. Redesigning and properly monitoring resource use with a focus on minimizing environmental, social and economic impacts are fundamental factors. As emphasized by Goal #11 of the 2030 Agenda (UN-SDGs, 2019), a sustainable city strives to meet the real needs of its present and future inhabitants while minimizing its impact on the environment, ensuring participatory governance processes to find effective solutions, and preserving resources for future generations. Although receiving some criticism (e.g., Giannetti et al., 2020), the SDGs are considered an important and practical guide for global governance, at various scales, to implement and monitor actions aimed at achieving sustainability. While it is recognized that each city may have its own unique needs and challenges (Zucaro et al., 2022), and that the concept of sustainability continues to evolve as new technologies and best practices emerge, there are some key characteristics and principles that can make cities more sustainable, including: a strong reliance on renewable energy, an efficient transportation system, participatory urban planning with community engagement, effective waste management, consideration of the life cycle in urban projects, water conservation strategies, availability of biodiversity and green spaces, shared economy strategies, quality education at all levels, safety and inclusiveness for diverse social classes and races, and resilience to global changes and their impacts.

The classic definition of sustainability provided in the United Nations Brundtland Report (1987) allows for distinct interpretations and the development of various conceptual models. While some models place greater emphasis on economic aspects, others indicate that social and environmental aspects are equally or even more important when discussing sustainability. There are models referred to as weak, medium, and strong (e.g., Costanza et al., 1991; Daly, 1995; Ekins et al., 2003), as well as those that consider the system under study as an open system, exchanging flows between economic, social, and environmental capitals (Pulselli et al., 2015; Giannetti et al., 2019). Additionally, the model by Rockström et al. (2009) is worth mentioning, which considers a biophysical approach but relates to the impacts that humans have on the biosphere. In general, the Urban Resources Management section of Frontiers in Sustainable Cities focuses on the biophysical relationships among urbanized centers and their surrounding environment (Figure 1). This conceptual model is the same one used by Odum and Odum (2008) and Wackernagel and Rees (1996) when discussing sustainability from a biophysical perspective, commonly referred to as strong sustainability.

Figure 1 illustrates the existence of an exchange of materials (food, water, minerals, wood, etc.), energy (fossil or non-fossil), information, and know-how between different levels of urbanization, where more rural areas provide primary resources that sustain more urbanized centers, while also receiving concentrated waste for dilution. At the same time, the more urbanized centers serve as hubs for generating and providing information, know-how and high-tech equipment that support and govern less urbanized areas. As always, the challenge lies in finding the limits of growth for urbanized centers while respecting the biophysical carrying capacity of the surrounding environment. Identifying these limits, often referred to as sustainability, is a complex issue that can be assessed and discussed from various perspectives (methods and indicators) and scales, connecting like pieces of a large puzzle to achieve the ultimate goal of sustainability. Specifically for this Research Topic (RT), the papers focused on the following subjects (Figure 1): sustainability & smart cities; circular economy in urban systems; GHG emissions from households; waste-to-energy; and urban design for environmental services. The main ideas behind each of the published papers are briefly presented in the following section.

## 2 Analysis of the contents

This RT consists of seven publications based on the subjects shown in Figure 1. The following paragraphs present the general ideas of papers, however it is strongly recommended to refer to the full papers for a better understanding of the details presented and discussed by the authors.

The first article discusses the challenges of urbanization, focusing on how models based on sustainability and smart city principles are being proposed. Despite their importance, these models are often misunderstood or misapplied due to a lack of proper conceptualization and are sometimes seen as interchangeable. In the study of Pierucci et al., authors aimed to verify if a correlation exists between sustainability and smartness indicators in cities. Although the Five-Sector Sustainability Model (5SenSu) proved to be a robust method for quantifying urban sustainability—offering diagnostics, rankings, and benchmarks to support decision-making—there is only a moderate correlation between sustainability and smart city, with Pearson and Spearman coefficients of −0.61 and −0.59, respectively. Therefore, the authors concluded that a smart city is not necessarily sustainable. This study enhances the understanding and measurement of sustainable and smart cities, informing policies aimed at fostering more sustainable urban environments.

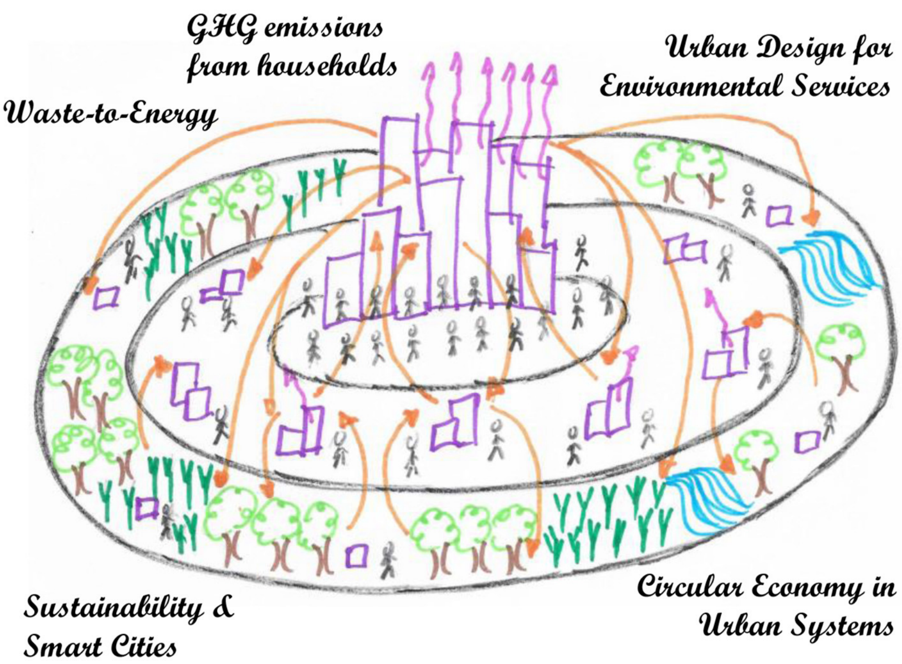


FIGURE 1
The relationship between highly urbanized centers and their surrounding less urbanized buffer regions acting as carrying capacity. There is a hierarchy of energy transformations, and exchanges of material, energy, information, know-how, and concentrated by-products. The subjects in the figure are discussed in this Research Topic (RT).

Innella, Ansanelli et al. highlighted the importance of the circular economy (CE) for the European Union as a key strategy to achieve climate neutrality by 2050, address the biodiversity crisis, and ensure sustainable growth in line with the Agenda 2030 goals. Stakeholder engagement is essential for implementing suitable innovation patterns according to the CE strategy, particularly in urban areas, where public institutions, researchers, businesses, and citizens need to work together. The authors argue that Urban Living Labs (ULLs) serve as an effective tool for stakeholder involvement, though a clear step-by-step method for implementing ULLs in CE projects is lacking. To address this, a framework for ULLs focused on co-designing CE activities is proposed, structured into four phases: (i) context analysis, (ii) exploration, (iii) participation, and (iv) execution. A detailed explanation of each phase and examples of initial applications are provided.

After presenting the ULL and its application steps, Innella, Barberio et al. in other study applied the proposed ULL in four Italian urban areas (Anguillara Sabazia, Bologna, Taranto, and Venosa) to demonstrate its effectiveness in fostering stakeholder engagement and co-design for the CE transition. The results show that, despite differing geographical and socio-economic contexts, the ULL successfully activated engagement and co-design processes in urban areas. The co-design process led to the creation of CE project proposals tailored to each territory, which is essential for their implementation. The authors concluded that the ULL is a promising approach for stimulating cultural growth and strengthening community ties by promoting skill exchange, collaboration, and increased collective awareness.

Also focusing on the Circular Economy (CE) strategy, Ceddia et al. emphasized that studies often highlight technical and economic aspects, but recent research has started to explore the social dimensions. The authors conducted a systematic literature review on the connection between CE and communities, examining different experiences. The analysis uses established frameworks, such as the R (reuse, reduce, recycle, and others) hierarchy, societal challenges from the EU CICERONE project, and the participation spectrum from the International Association for Public Participation, community types, tools, methodologies, and goals are analyzed in relation to participatory dynamics. The article discusses CE's social aspects and critically evaluates stakeholder engagement practices. The authors concluded by identifying the most common R strategies, community types, societal challenges, and participatory dynamics, while also emphasizing the need for further studies on the CE-community nexus.

Sustainability and circularity are two important macro-level concepts, with greenhouse gas (GHG) emissions representing a critical specific aspect of sustainability. Understanding the spatial heterogeneity of GHG emissions from household consumption is essential for advancing low-carbon cities, Yan et al. evaluated GHG emissions across districts in Xiamen, China, focusing on household energy, food, transportation, housing, waste, and wastewater treatment. Results indicated the total GHG emissions in Xiamen to be 8.39 Mt $CO_{2e}$/yr, with average household and per capita emissions at 8.11 and 2.72 $tCO_{2e}$/yr, respectively. Emissions varied significantly across districts, ranging from 0.41 to 2.45 $MtCO_{2e}$/yr, and across sectors, from 0.16 to 3.39 $MtCO_{2e}$/yr. These results indicate that higher population density is associated with greater total emissions but lower household emissions. Additionally, no clear relationship was found between emissions and population or income levels, although household energy use was identified as the largest GHG emitter.

In the broader context of waste-to-energy, Mor et al. studied the dual benefits of landfill gas utilization: reducing greenhouse gas emissions and generating renewable energy. The analyzed case study focuses on the methane emissions from Solid Waste Disposal Sites (SWDS) in Chandigarh, India, and evaluates the potential for electricity generation from captured landfill $CH_4$ gas. The findings indicated that Chandigarh generates approximately 350 tons of waste per day, with organic material accounting for over 50%. From this volume, the estimated $CH_4$ production is 0.34 Gg/yr, which can yield between 0.27 MW and 0.77 MW of electric power. Extrapolated nationally, India could potentially generate approximately 36% of its electricity demand from its SWDS, resulting in annual financial gains of $4.7 to $13 billion, emphasizing the need for integrated waste management strategies.

Another important topic related to the sustainability of cities is the design of urban infrastructure for environmental services. The implementation of Green and Blue Infrastructures (GBI) has emerged as a sustainable urban planning approach, consisting of a network of natural and semi-natural spaces designed to provide ecosystem services and improve ecological conditions, thereby enhancing citizens' wellbeing and quality of life. In this context, Shah et al. assessed the costs, benefits, and impacts associated with incorporating GBI in urban environments using eMergy accounting as a method. They proposed a novel integrated valuation framework that includes construction and maintenance costs, ecosystem services, and impacts on human health and biodiversity. The authors found that green roofs provide significant ecosystem benefits but incur higher initial costs and dis-services. In contrast, street trees have lower costs and impacts while generating greater benefits.

Despite the complexity of urban sustainability, the seven papers published in this RT cover diverse and significant aspects that support the transition toward fairer, more inclusive, equitable, and genuinely sustainable cities. It is widely recognized that "sustainable cities" are fundamental to addressing a key part of the broader challenge of pursuing of a more sustainable world. As covered by several Sustainable Development Goals of the 2030 Agenda, specifically Goal #11, the Urban Resource Management section will continue to play its important role as a vehicle supporting high-quality scientific papers for discussions on how to achieve more sustainable cities from a biophysical perspective. You are welcome to join us in this journey.

## Author contributions

FA: Conceptualization, Writing – original draft, Writing – review & editing. ID: Writing – review & editing. BG: Writing – review & editing. CA: Writing – review & editing. AZ: Writing – original draft, Writing – review & editing.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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