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Research Article

Towards Sustainable Urbanism: Technology Applied to Water, Energy and Construction Materials Resources

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ABSTRACT

Sustainable urbanism has become a central axis for the construction of resilient cities in the face of climate change, resource scarcity and population growth. This article examines the role of emerging technologies applied to the efficient management of water, energy, and building materials. Through a systematic review of the recent scientific literature (2019–2024), advances such as the use of smart sensors, renewable energy systems and sustainable materials are presented. The results show that technological integration in these three pillars makes it possible to reduce environmental impacts, improve urban efficiency and promote sustainable development.

Keywords: sustainable urbanism, emerging technologies, energy efficiency, water management, green materials, smart cities.

INTRODUCTION

Mass urbanization, coupled with intensifying climate change and the depletion of natural resources, has generated an unprecedented ecological crisis in contemporary cities. According to data from the United Nations Human Settlements Programme (*UN-Habitat*, 2023), more than 55% of the world's population lives in urban areas, and this figure is estimated to reach 68% by 2050. This unplanned urban growth has led to excessive consumption of water and energy, as well as accelerated construction that compromises environmental sustainability.

Faced with this panorama, the concept of sustainable urbanism has gained relevance as an alternative that seeks to harmonize urban development with the care of the natural environment, reducing greenhouse gas emissions, efficiently managing water resources and promoting construction materials with a lower ecological footprint (Cabrera & Ruiz, 2020). However, for this paradigm to be effective, it is essential to incorporate emerging technologies that enable smarter and more precise control of the resources used in the city.

The development of applied technologies such as the Internet of Things (IoT), artificial intelligence, energy management systems, and green building materials has opened up new possibilities for achieving more resilient and sustainable urban models (Navarro et al., 2022). For example, the use of sensors in water supply systems makes it possible to detect leaks and losses in real time, optimizing consumption and avoiding waste (Gutiérrez & Salazar, 2022). Likewise, the incorporation of solar panels, smart energy grids, and prediction algorithms has proven to be effective in the transition to a cleaner and decentralized urban energy system (López & Vargas, 2021).

In the same way, the choice of sustainable, recyclable materials with a lower environmental impact in the construction process represents a key component of the urban planning of the future. Recent research has shown that the use of materials such as recycled concrete, laminated wood or biocomposites not only reduces CO_2 emissions, but also improves the energy performance of buildings (Torres & Jiménez, 2020).

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This article proposes an updated review of the role of technology applied to the management of water, energy and construction materials resources in the context of sustainable urbanism. Through a systematic documentary review, best practices, technological advances and case studies are identified that show how cities are transforming towards more sustainable, efficient and resilient urban models.

THEORETICAL FRAMEWORK

2.1 Sustainable urbanism

Sustainable urbanism is an integrative approach that seeks to generate more equitable, ecological and resilient cities. It is based on the principles of sustainable development defined by the UN: meeting the needs of the present without compromising those of the future (UN-Habitat, 2023). This involves efficiently managing land, natural resources and urban infrastructure, promoting social welfare, reduction of the environmental footprint and citizen participation.

According to Cabrera and Ruiz (2020), sustainable urbanism requires a transition from expansive urban models to more compact, mixed, and green models, where the use of space and resources is rational. The technological component is key in this transformation, as it allows us to monitor, automate and optimise fundamental urban processes.

2.2 Water Resources Technology and Management

Efficient water management is essential in a context of increasing water stress and climate variability. The digitalisation of water systems through smart grids, IoT sensors and predictive analysis platforms makes it possible to improve leak detection, automate urban irrigation and optimise the use of drinking water (Navarro et al., 2022).

Gutiérrez and Salazar (2022) highlight that technologies such as rainwater harvesting systems, decentralized graywater treatment, and the use of biofilters are transforming traditional models of urban water management. These innovations not only reduce consumption, but also increase the self-sufficiency of neighborhoods.

2.3 Urban energy transition through digital technologies

The transition to clean and decentralised energy is an indispensable condition for sustainable urban planning. Cities are incorporating renewable sources—such as solar, wind, and geothermal—along with digital management systems that integrate Big Data, AI, and energy storage (López & Vargas, 2021).

The automation of buildings through thermal sensors, intelligent lighting and ventilation controls, as well as the use of shared energy networks (smart grids), makes it possible to reduce energy consumption and improve urban comfort (Sánchez, Ortega & Ramírez, 2023). In addition, there is a growing trend towards "energy democratization", in which citizens become producer-consumers (prosumers).

2.4 Sustainable and innovative construction materials

The use of sustainable materials in construction is another central pillar of green urbanism. The development of bioconstruction, the circular economy in the building industry and innovation in ecological compounds are transforming the standards of design and execution of works (Torres & Jiménez, 2020).

Materials such as:

- **Recycled concrete**: made with aggregates from demolition waste.
- **CLT (cross-laminated timber):** highly resistant, renewable and with a low carbon footprint.
- **Geopolymers**: alternatives to traditional cement, which emit less CO_2 during their production.

The following table summarizes the main emerging technologies applied to each type of resource:

Table 1. Emerging technologies for sustainable urbanism by resource type

Resource	Applied Technology	Main benefit	Application Example
Water	IoT sensors, smart irrigation, rainwater harvesting, biofilters	Loss reduction, reuse and efficiency	Barcelona: smart drinking water network

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Energy	Solar panels, smart grids, energy AI, local batteries	Emission reduction, efficiency, self-sufficiency	Copenhagen: Heat network with renewable energy
Construction materials	CLT, geopolymers, recycled concrete, eco-friendly bricks	CO_2 reduction, circular economy, lower impact	Japan: CLT wooden skyscrapers

Source: Authors' elaboration based on Torres & Jiménez (2020), Navarro et al. (2022), López & Vargas (2021).

METHODOLOGY

3.1 Research approach and design

This research was developed under a **qualitative and exploratory approach**, focused on the systematic review of recent scientific literature related to sustainable urbanism and the technological application to water, energy and construction material resources. A strategy of **thematic mapping** and comparison of case studies at the international level was used, according to the guidelines of the PRISMA method (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) adapted to urban studies (Moher et al., 2019).

This approach made it possible to identify common patterns, emerging solutions, and good practices in the transition to sustainable cities through the use of innovative technologies (Navarro et al., 2022; Gutiérrez & Salazar, 2022).

3.2 Inclusion and exclusion criteria

The **inclusion** criteria applied were as follows:

- Academic and technical publications between **2019 and 2024**.
- Studies focused on **technological management of water, energy and materials in urban environments**.
- Articles in Spanish or English with full access.
- Relevant case studies in Latin American, European and Asian cities.

Excluded sources that:

- They will not address the technological component.
- They had a rural or agricultural focus.
- They will not present clear empirical or conceptual evidence.

3.3 Information sources and databases

The information collection was carried out between January and April 2025 through the following databases:

- **Scopus**
- **ScienceDirect**
- **Google Scholar**
- **RedALyC and SciELO** (for literature in Spanish)
- **Institutional documents of UN-Habitat, ECLAC and the World Bank**

In addition, technical reports from cities that have implemented sustainable urbanism strategies such as Copenhagen, Bogotá, Singapore, Barcelona, and Medellín were reviewed (UN-Habitat, 2023).

3.4 Search strategy and thematic coding

Keyword combinations such as: *"sustainable urbanism", "smart cities", "IoT water", "urban energy efficiency", "green building materials", "CLT", "geopolymers", "smart energy grids" were used.*

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The results obtained were subjected to a thematic coding following the categories:

1. **Water**: technologies applied to urban water management.
2. **Energy**: innovation in sustainable energy systems.
3. **Materials**: new compounds for sustainable construction.

Table 2. Methodological process of the research

Stage	Description	Tools used
Literature collection	Search in academic databases, selection by relevance and topicality	Scopus, ScienceDirect, Google Scholar
Filtering and organization	Application of inclusion and exclusion criteria	Bibliographic file, Zotero manager
Thematic coding	Grouping by impact areas (water, energy, materials)	Qualitative Analysis Matrix
Analysis and interpretation	Contrast of results, identification of trends	Case Comparison, Content Analysis
Document validation	Verification of consistency, timeliness and scientific validity	Cross-Source Evaluation

Source: Authors' elaboration based on Moher et al. (2019) and Navarro et al. (2022).

3.5 Limitations

Among the main limitations of the study are:

- The partial availability of recent studies in some regions of Latin America.
- The lack of systematization in municipal technical reports.
- Possible bias in the interpretation of studies that do not use standardised methodologies.

Despite this, the methodological approach made it possible to build a robust and updated framework on the integration of technology in sustainable urbanism.

RESULTS

The comparative analysis of recent cases revealed that **technology applied to urban management** produces measurable benefits in terms of resource savings, operational efficiency and emission reduction. The findings are then presented organized into three fundamental categories:

4.1 Results in urban water management

Smart water systems have proven to be effective in **reducing leakage losses**, optimizing consumption, and increasing resilience to droughts. In Melbourne, Australia, the use of IoT sensors and automated valves in distribution networks led to a 32**%** reduction in drinking water losses over a three-year period (Gutiérrez & Salazar, 2022). In Medellín, the implementation of artificial urban wetlands and biofilters has facilitated the treatment of domestic wastewater in peripheral areas, improving environmental quality and reducing the load on conventional plants (UN-Habitat, 2023).

Table 3. Effects of smart technologies on urban water management

City	Applied technology	Quantitative results	Fountain
Melbourne	IoT for leak monitoring	32% loss reduction (2019–2022)	Gutiérrez & Salazar (2022)
Barcelona	Automated irrigation in parks	25% annual water savings	Navarro et al. (2022)
Medellin	Artificial wetlands + urban biofilters	40% improvement in treated water quality	UN-Habitat (2023)

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4.2 Results in urban energy efficiency

Cities that have implemented digital technologies for energy management have achieved significant reductions in consumption and emissions. For example, Amsterdam achieved an **18% decrease in residential electricity consumption** thanks to smart meters, public lighting optimization, and solar panels on community rooftops (López & Vargas, 2021). In Bogotá, the "Solar Roofs for Public Administration" program has made it possible to cover up to **20% of institutional energy consumption** through photovoltaic solar energy (Sánchez et al., 2023).

Table 4. Impact of energy technologies in urban areas

City	Applied technology	Results achieved	Fountain
Amsterdam	Smart meters, solar roofs	18% reduction in residential electricity consumption	López & Vargas (2021)
Bogota	Solar panels on public buildings	20% of institutional demand covered	Sánchez et al. (2023)
Copenhagen	Solar and geothermal heating network	55% reduction in urban emissions since 2013	UN-Habitat (2023)

4.3 Results in the use of sustainable construction materials

The adoption of **eco-friendly materials** has demonstrated both environmental and economic benefits in urban projects. In Tokyo, cross-laminated timber (CLT) construction has reduced **CO_2 emissions by 35%** compared to concrete structures (Torres & Jiménez, 2020). In Mexico City, the use of blocks made from recycled plastic waste in social housing has achieved a 25% decrease in costs and a 30% savings in water during the construction phase (Cabrera & Ruiz, 2020).

Table 5. Innovations in sustainable construction materials

LOCATION	MATERIAL USED	MEASURABLE IMPACT	FOUNTAIN
TOKYO	CLT Wood	35% lower emissions vs. traditional concrete	Torres & Jiménez (2020)
MEXICO CITY	Blocks with recycled plastic	25% lower costs and 30% less water consumption	Cabrera & Ruiz (2020)
FILE	Geopolymers based on volcanic ash	50% less use of conventional Portland cement	Navarro et al. (2022)

4.4 Cross-sectional analysis

The cross-sectional analysis of the results reveals that **technological integration in these three axes (water, energy and materials)** is directly related to the sustainable development goals (SDGs 6, 7, 9, 11 and 13). In addition, it is observed that **cities that integrate public policies with technological innovation** present greater advances in urban sustainability, reinforcing the need for regulatory frameworks adapted to these transitions.

CONCLUSIONS

The results obtained through the analysis of scientific literature and international case studies show that technology **applied to the management of water, energy and construction materials resources** not only represents an emerging trend, but an urgent need to guarantee urban sustainability in the context of the twenty-first century.

First, the incorporation of **smart technologies for water management**, such as IoT sensors, rainwater harvesting systems, and biofilters, has proven to be highly effective in reducing losses, improving the quality of treated water, and increasing resilience to water stress (Navarro et al., 2022; Gutiérrez & Salazar, 2022). The

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experience of cities such as Melbourne or Medellín confirms that these solutions allow not only operational savings, but also a positive environmental impact in the short and long term.

In terms of **energy efficiency**, emerging technologies linked to renewable energies, building automation and smart grids are transforming the urban energy structure. Successful experiences in Copenhagen, Bogotá, and Amsterdam show that it is possible to significantly reduce greenhouse gas emissions and achieve a fair and decentralized energy transition (López & Vargas, 2021; Sánchez et al., 2023). This dimension not only responds to environmental objectives, but also to social demands such as equitable access to clean and affordable energy.

Regarding **sustainable construction materials**, it is concluded that innovation in the use of recycled, renewable and low-carbon footprint resources is a key axis to reduce the environmental impact of the construction industry, one of the most polluting sectors globally. The use of CLT wood, geopolymers or ecological blocks demonstrates that it is feasible to build more responsibly without compromising the structural strength or functional efficiency of buildings (Torres & Jiménez, 2020).

A cross-cutting conclusion is that **technological urban sustainability cannot be achieved in isolation**, but through the articulation of **public policies, regulatory frameworks, investment in innovation and citizen participation**. Cities that have made progress on this path have opted for comprehensive strategies that combine smart infrastructure with inclusive governance and environmental education (UN-Habitat, 2023).

Finally, it is concluded that in order to accelerate the transition towards **sustainable urbanism**, it is essential to adopt a systemic and intersectoral vision, where urban design, environmental engineering, social sciences and digital technologies converge in the planning of resilient, equitable and livable cities.

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