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NEW CHALLENGES FOR XXI CENTURY CITIES

Multilevel scientific approach to impacts of global warming on urban areas, energy transition, optimisation of land use and emergency scenario

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TeMA Journal was established with the primary objective of fostering and strengthening the integration between urban transformation studies and those focused on mobility governance, in all their aspects, with a view to environmental sustainability. The three issues of the 2025 volume of TeMA Journal propose articles that deal with the effects of Global warming, reduction of energy consumption, immigration flows, optimization of land use, analysis and evaluation of civil protection plans in areas especially vulnerable to natural disasters and multilevel governance approach to adaptation.

TeMA is the Journal of Land Use, Mobility and Environment and offers papers with a unified approach to planning, mobility and environmental sustainability. With ANVUR resolution of April 2020, TeMA journal and the articles published from 2016 are included in the A category of scientific journals. The articles are included in main scientific database as Scopus (from 2023), Web of Science (from 2015) and the Directory of Open Access Journals (DOAJ). It is included in Sparc Europe Seal of Open Access Journals, and the Directory of Open Access Journals.

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Editorial correspondence
Laboratory of Land Use, Mobility and Environment
DICEA - Department of Civil, Building and Environmental Engineering
University of Naples "Federico II"
Piazzale Tecchio, 80
80125 Naples (Italy)

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The cover image shows a composition of two photos of the Temple of Serapis in Pozzuoli (Italy). Giuseppe Mazzeo took them in January 2009 and March 2025. At the top, the 2009 image shows the temple flooded, with the pavement not visible. In the down, the 2025 image shows the temple’s pavement dry and exposed. The Temple of Serapis is one of the leading visual indicators of the bradyseism phenomenon in the Phlegraean Fields. The bradyseism phase, highlighted by comparison, started in the first years of this century, as shown by the data published by the National Institute of Geophysics and Volcanology (INGV) on the website dedicated to the phenomena (https://www.ov.ingv.it/index.php/il-bradisismo).

TeMA - Journal of Land Use, Mobility and Environment offers researches, applications and contributions with a unified approach to planning and mobility and publishes original inter-disciplinary papers on the interaction of transport, land use and environment. Domains include: engineering, planning, modeling, behavior, economics, geography, regional science, sociology, architecture and design, network science and complex systems.
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REVIEW NOTES
International regulation and legislation for the energy transition

Urban energy transition between regulatory evolution and scientific production: a bibliometric analysis

Valerio Martinelli

Department of Civil, Building and Environmental Engineering
University of Naples Federico II, Naples, Italy
e-mail: valerio.martinelli@unina.it
ORCID: https://orcid.org/0009-0007-8703-6573

Abstract
Starting from the relationship between urban planning and mobility management, TeMA has gradually expanded the view of the covered topics, always remaining in the groove of rigorous scientific in-depth analysis. This section of the Journal, Review Notes, is the expression of continuously updating emerging topics concerning relationships between urban planning, mobility and environment, through a collection of short scientific papers written by young researchers. The Review Notes are made of four parts. Each section examines a specific aspect of the broader information storage within the main interests of TeMA Journal. This section, International Regulations and Legislation for the Energy Transition, explores the challenges and opportunities in the urban context to understand the evolving landscape of the global energy transition. The contribution explores how scientific research on urban energy transition has evolved alongside European climate policies. It highlights the role of urban governance and planning in supporting decarbonisation through tools like Positive Energy Districts and Renewable Energy Communities. These models integrate innovation with citizen engagement and local energy autonomy. The analysis also reveals how regulatory developments have shaped research priorities. Finally, it underscores the need for stronger coordination to overcome implementation gaps.

Keywords
Energy transition; Urban planning; Regulations; Bibliometric analysis.

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1. Introduction

The energy transition is one of the central challenges for contemporary cities in a context of increasing urbanisation and the pressing need to reduce greenhouse gas emissions. Urban areas, responsible for more than 70 % of global CO_2 emissions (EC, 2024), play a key role in the adoption of strategies for decarbonisation and integration of renewable energy. However, the urban energy transition is not only a technological issue, but also a social, economic and governance issue, requiring solutions that combine technical innovation with integrated planning and active citizen participation (Cruz et al., 2023). Over the last two decades, European energy-climate policies have provided a strong impetus for the development of energy transition in cities, triggering a parallel evolution in academic research. Each new policy framework - from the 20-20-20 targets for 2020 to the European Green Deal - has set ambitious goals that have stimulated studies aimed at supporting their achievement (ISPI, 2022). At the same time, scientific interest in urban sustainability has grown exponentially, especially after 2015, with a spike in publications in recent years correlated with the rise of urban decarbonisation targets. Initiatives such as the Green Deal (2019), the Fit for 55 package (2021) and the REPowerEU plan (2022) have stimulated research on energy communities, positive energy neighbourhoods, urban electrification and energy resilience. Considering this co-evolution between policy and science, the aim of this study is to analyse the evolution of scientific production on urban energy transition in relation to European regulatory developments. By means of a bibliometric analysis of the literature (2004-2024), we intend to highlight how changes in energy policies have influenced academic research trends and, reciprocally, how scientific evidence has helped guide strategies and interventions for energy transition in cities. Ultimately, the review highlights the dialogue between policy and academia and the implications for cities' future challenges towards climate neutrality.

2. Bibliometric analysis methodology

The bibliometric analysis was designed to offer a representative overview of the scientific literature on the energy transition in urban areas, following a multi-step structured approach:

1. Data collection - source and coverage: Scopus was chosen as the reference database for the bibliographic search, given its broad subject coverage and the possibility of exporting metadata in formats compatible with analysis software. This choice also allows integration with software tools such as VOSviewer and Bibliometrix, useful for subsequent data processing phases.

2. Search strategy: a specific query string was defined to intercept the relevant literature. In particular, the query used is TITLE-ABS-KEY (energy transition' AND 'urban'), applied to the title, abstract and keyword fields. The search initially covered a broad time span (1973-2024), excluding 2025 to avoid distortions due to incomplete data. To ensure an international perspective of scientific production, the analysis was limited to English-language papers.

3. Filters and selection criteria: in order to focus the analysis on the studies most relevant to our field of research, targeted filters were applied to the initial dataset:

- Time range: limited to the last 20 years (2004-2024), as the topic was previously only treated sporadically;
- Type of documents: inclusion of scientific articles, conference proceedings and books, excluding less relevant types to ensure the reliability of the results;
- Disciplinary areas: restricted selection to the fields of Energy, Environmental Science, Engineering and Social Sciences, i.e. the areas most closely related to the urban energy transition. Attention was also paid to Open Access documents to facilitate their consultation and dissemination.

The application of these criteria produced a final dataset consisting of 1,276 relevant documents, which was subsequently exported in CSV format for quantitative analysis.

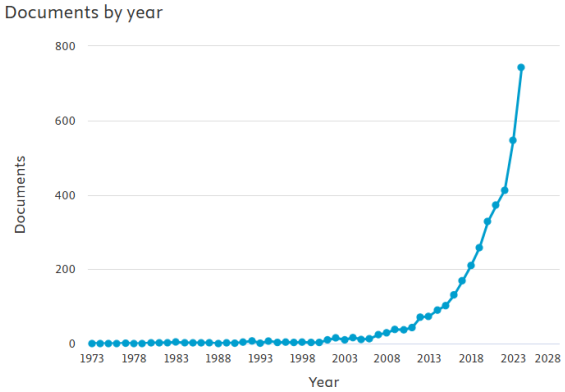
4. Bibliometric analysis and tools: the data collected were analysed using two main tools:

- VOSviewer used to construct the co-occurrence network of keywords and identify thematic clusters. All keywords associated with the articles were considered and, to focus on the most significant terms, a minimum threshold of 5 occurrences was set. This reduced the set from over 9,000 terms to approximately 688 relevant keywords. In addition, to obtain a clearer map, keywords directly derived from the main query (i.e. urban, energy, transition) were excluded from the network in order to better highlight links between specific topics. VOSviewer provided both a Network Visualisation (map of thematic clusters) and an Overlay Visualisation to observe the temporal evolution of the search topics;
- Bibliometrix (in R, via the Biblioshiny interface) - used to analyse general bibliometric metrics and the evolution of topic trends over time. In particular, the frequency of occurrence of the main keywords and topic trends per year were examined, as well as the word cloud of the most recurrent words.

Thanks to this articulated methodological approach, it was possible to obtain a clear view of the evolution of academic research on the subject, highlighting the main scientific trends and their relationship with the normative milestones.

3. Bibliometric analysis results

The literature analysis (period 2004-2024) shows a significant growth of academic interest in urban energy transition (Fig.1). The total number of publications identified is 1,276 papers, distributed across 378 academic sources, with a compound annual growth rate of 30.95%. This increase indicates that the field of study has gained increasing relevance in recent years. A strong international component is noticeable: more than 32% of the publications are the result of collaborations between several countries, confirming that the urban energy transition is a global challenge tackled with shared approaches. The degree of collaboration between authors is also high (an average of 3.91 co-authors per article), reflecting the interdisciplinary nature of the topic that requires contributions from experts in energy, urban planning, environmental policy, economics and engineering. Scientific production is not geographically homogeneous (Fig.2). Some countries emerge as predominant research poles on the topic, leading the scientific debate: the United Kingdom is the leading research centre on the urban energy transition (Brummer, 2018), followed by Italy, which has seen significant growth thanks to experiments on Renewable Energy Communities (RECs) (Musolino et al., 2023). China stands out for the volume of studies related to the environmental challenges of urbanisation (Quin, 2024). The Netherlands and Germany emerge for applied research on Positive Energy Districts and innovative models of urban energy governance (Mahzouni, 2017; Derkenbaeva et al., 2024).



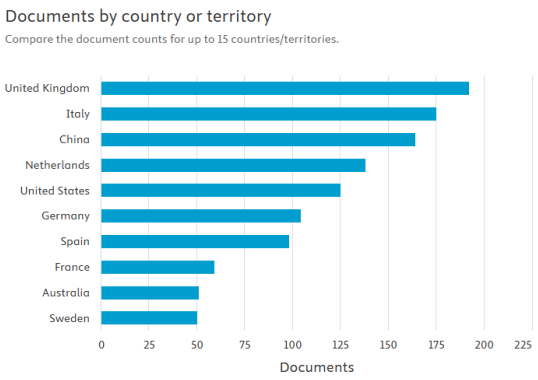


Fig.1 Documents by year; Fig.2 Documents by country or territory

The bibliometric network built on the co-occurrences of keywords offers a map of the main themes that have characterised research on urban energy transition (Fig.3). Analysis with VOSviewer reveals four predominant thematic clusters, each identified by a colour and a set of related key terms:

- Energy Transition & Smart Cities (red cluster): includes terms such as energy utilisation, renewable energies, energy efficiency, smart grid and positive energy districts (PEDs). This cluster reflects the focus on the integration of renewable energy sources and energy efficiency in smart cities, also highlighting the growing interest in positive energy districts and, in general, the active role of cities in producing more energy than they consume;
- Urban Planning & Sustainability (Green Cluster): links energy transition to spatial governance and planning processes. Key terms include urban area, sustainability, governance approach, urban transformation and socio-technical transition. The cluster emphasises how energy strategies are increasingly interlinked with urban planning and local sustainability, indicating the importance of integrated policies;
- Low Emission Mobility & Transport (Blue Cluster): highlights the relevance of the transport sector in the urban energy transition. Terms such as electric vehicle, hydrogen, charging infrastructure and fleet operations indicate a focus on sustainable mobility, from the electrification of transport (electric vehicles and charging infrastructure) to the use of hydrogen as an energy carrier to reduce emissions in public and private transport;
- Pollution & Environmental Impacts (Orange/Purple Cluster): represents the link between urban energy transition and local pollution mitigation. It includes keywords such as air pollution, carbon emissions, environmental policy and public health. This cluster draws attention to the fact that the decarbonisation of cities is also motivated by improving air quality and public health, in addition to combating climate change.

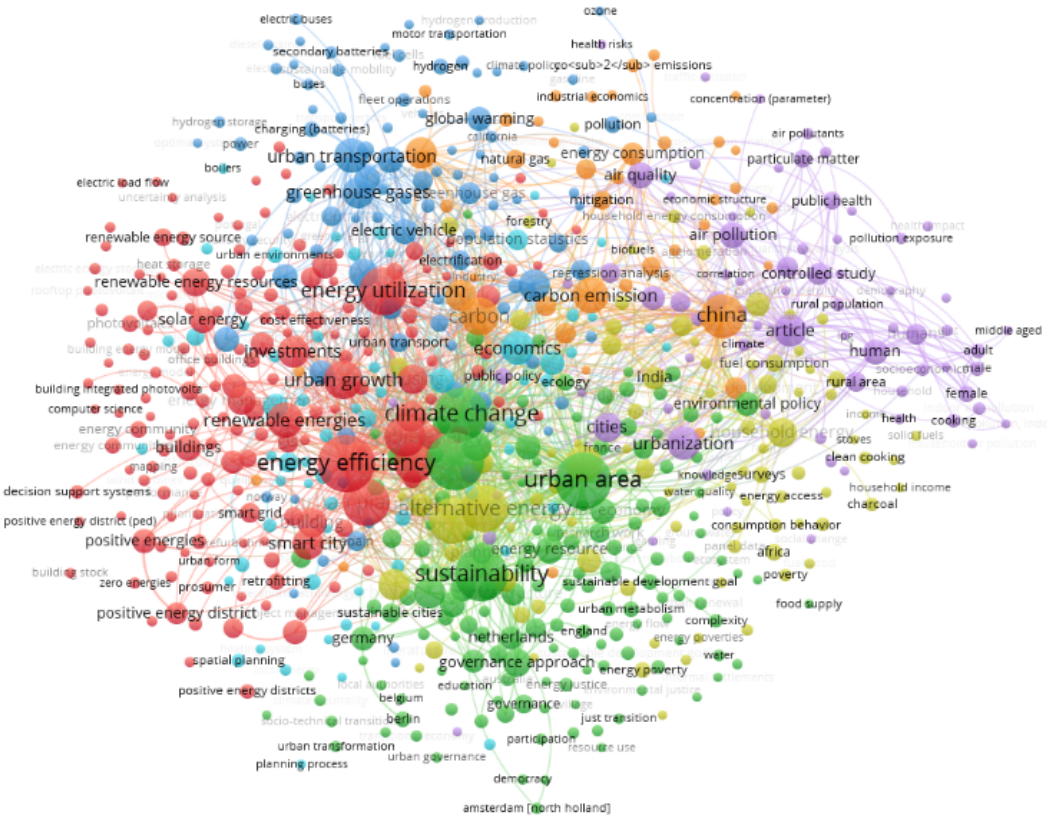


Fig.3 Network Visualisation of keywords

The time map (Overlay Visualization) of the keyword network clearly shows how research topics have evolved over time, following - and often anticipating - energy policy directions (Fig.4). As can be seen from the map marked in blue/purple in the visualisation, until 2018, studies focused on the core concepts of energy

efficiency, climate change and sustainable development, in line with the EU's early climate goals (e.g. Kyoto Protocol 2005). Words such as energy efficiency, climate change and sustainable development recurred frequently, highlighting the priority given to reducing emissions and optimising consumption. In contrast, in the more recent period from 2020 onwards - highlighted in yellow/light green - new and more advanced terms such as energy communities, prosumers, positive energy districts, smart grids and hydrogen mobility emerge. This reflects a shift in focus towards integrated models of urban decarbonisation, consistent with the entry into force of second-generation European policies (e.g. Clean Energy Packages) and the growing interest in innovative technologies in the urban context. The appearance of these concepts in the scientific lexicon marks the broadening of the research scope to include socio-technical and participatory dimensions of the energy transition, underlining the transition from a pioneering phase, focused mainly on energy efficiency and climate mitigation, to a more recent phase oriented towards complex strategies integrating governance, urban planning and sustainable mobility (Mazzeo & Polverino, 2023).

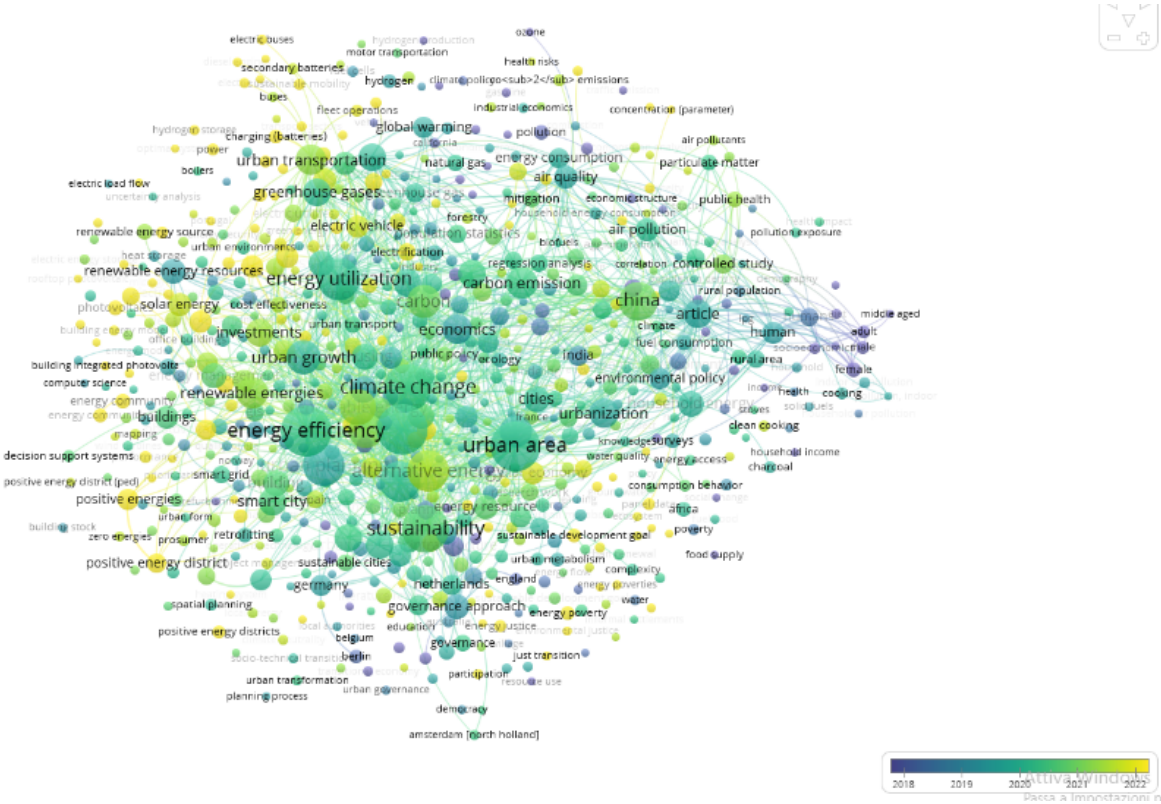


Fig.4 Overlay Visualization of keywords

In parallel, the analysis of keyword frequencies and temporal trends carried out in Biblioshiny (Fig.s 5, 6 and 7) provides further insights (Carpentieri et al., 2023). The most recurrent keywords over the entire period (e.g. energy efficiency, sustainable development, urban area) confirm the constant focus on sustainability and emissions, while the presence of terms such as climate change and energy policy underline the link between energy transition and climate mitigation strategies. As of 2018, a marked increase in publications on decarbonisation, renewable energy and sustainable urban planning can be observed, with a further acceleration after 2020 in terms such as clean energy and urban politics, in line with the launch of the European Green Deal and the Fit for 55 packages. At the same time, new terms are emerging with greater emphasis: words such as decision making, governance approach and alternative energy indicate the growing interest in participatory decision-making processes and alternative energy solutions, in addition to the already established strands.

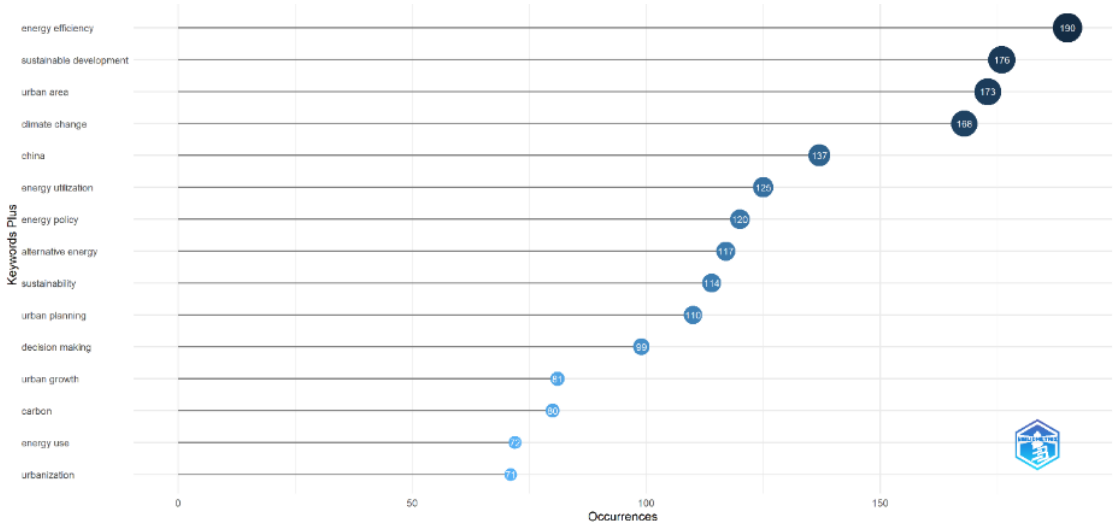


Fig.5 Most Relevant Words

Fig.6 Wordcloud of most relevant keywords

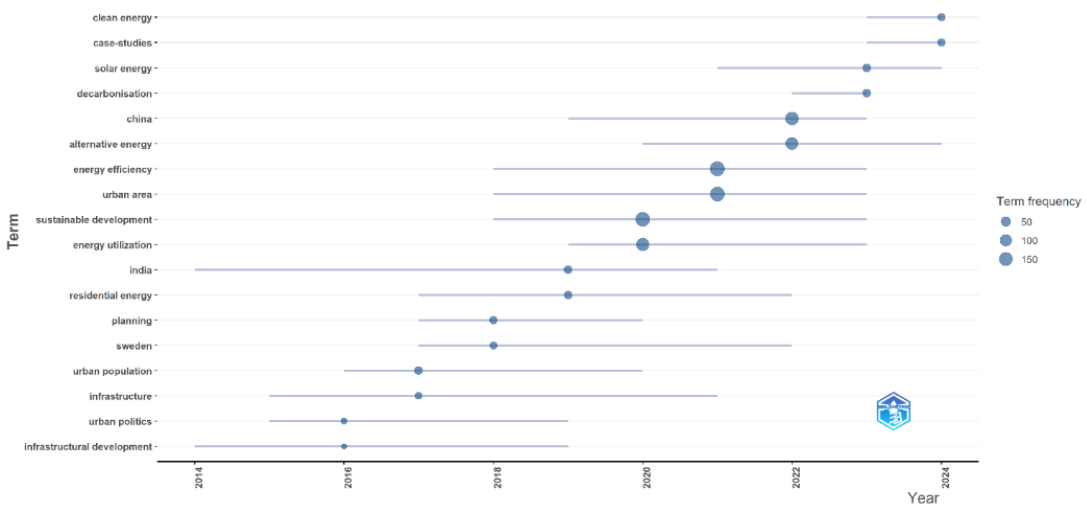


Fig.7 Trend Topics of the most frequent keywords over the years

In summary, the bibliometric results confirm that urban energy transition is a rapidly expanding and constantly evolving field of research. Over the last two decades, the horizon of studies has progressively broadened: from the classical themes of environmental sustainability, it has moved on to embrace aspects of governance, involvement of local actors and socio-technical innovation. The influence of European policies is evident in the spread of innovative concepts (think of the surge of studies on energy communities after 2018), while research is increasingly oriented towards integrated and holistic strategies, aimed at the goal of climate neutrality by 2050. This framework provides the context for understanding in detail, in the following section, how regulatory developments have marked and driven the main trends in scientific production.

4. Regulatory evolution and scientific production

Overall, the quantitative analysis suggests a close correlation between regulatory developments and scientific output. Spikes and accelerations in the number of publications often coincide with the adoption of new energy policy packages at the European level, signalling that the academic community actively responds to stimuli from policy makers. This link indicates the key role of research in supporting the development of strategies for urban energy transition. At the same time, there are signs of a time lag between theory and practice: the rapid development of knowledge and innovative solutions is not always immediately followed by an equally rapid implementation in cities, due to regulatory, institutional or financial obstacles (Good, 2017; Sæle et al., 2023; Martinelli, 2024). European and international energy-climate policies in recent decades have marked milestones that are reflected in the evolving scientific literature on urban energy transition. Below we retrace the salient phases of the dialogue between legislation and academic research, highlighting for each period the essential connections between the policy initiatives and the thematic trends that emerged.

- Until 2015 the European Union lays the foundations of its climate and energy strategy. With Directive 2001/77/EC and above all with Directive 2009/28/EC (Renewable Energy Directive - RED I), the ambitious 20-20-20 objectives for 2020 are introduced (20% emissions reduction, 20% renewable share, 20% more efficiency). These first regulations, aimed at promoting renewable sources and energy efficiency, immediately stimulated research on wind and solar technologies, on the efficiency of buildings and on the integration of sustainable energy in urban contexts (Newton & Newman, 2013). Key terms such as renewable energy, sustainable urban development and energy efficiency appear in the literature of the early 2000s, indicating the focus on local sustainability and efficient use of energy. The first concepts of local energy planning and intelligent networks (smart grids) also appear, a sign of a nascent attention to the advanced management of urban networks (Balta-Ozkan, 2015). An important impulse comes from the Covenant of Mayors initiative (2008), through which hundreds of European cities begin to develop Sustainable Energy Action Plans (SEAPs) sanctioning the active role of local communities in the transition (Grafakos, 2015). At the same time, the EU adopts measures aimed at sustainable mobility - Directive 2014/94/EU on alternative fuels dates back to 2014 - which lead to the development of studies on charging infrastructures for electric vehicles, on vehicle-to-grid integration and, in general, on the role of transport in the urban energy transition (Moore, 2015). A further impetus comes from the Paris Agreement (2015), which by setting global decarbonisation objectives shifts attention towards resilient and low-emission urban energy models. As a result, terms such as urban resilience and climate planning enter the scientific literature, and studies on the reduction of emissions in transport and on the potential of cities in contributing to global climate objectives are consolidated. It is also the period in which the awareness matures that urban governance and citizen participation are indispensable levers for implementing energy policies in the territory: research begins to explore participatory approaches and new models of multilevel governance for energy in the city (Berghi, 2016).
- In the second half of the 2010s there was an exponential growth in scientific production corresponding to the launch of the Clean Energy for All Europeans Package (2018). This package of directives and regulations which includes, among other things, RED II (Directive 2018/2001/EU) and Directive 2019/944 on the electricity

market for the first time officially recognizes and strengthens the active role of citizens and communities in the energy transition (Grignani et al., 2021). In fact, the concepts of renewables self-consumer and renewable energy community are formally introduced, guaranteeing prosumers and local communities new rights to produce, self-consume, share and sell renewable energy. The transposition of these rules has an immediate impact on research: after 2018 there is a boom in publications on topics such as energy communities, peer-to-peer energy trading, sharing economy models applied to energy and forms of collective involvement in distributed generation (Fichera et al., 2021). Terms that until a few years earlier were niche - prosumer, energy community - become mainstream in the scientific lexicon, often associated with studies on microgrids, digital platforms for energy exchange and new local energy business models (Martinelli, 2023). In parallel, the EU strengthens the integration between energy and territorial planning: cities are explicitly mentioned in post-2018 energy strategies, recognizing that objectives such as 32% renewables by 2030 (established by RED II) must also be pursued through bottom-up local initiatives. Consequently, attention for multilevel governance and integrated planning is spreading in scientific journals: numerous studies explore tools for coordinating urban policies and energy (Hunag et al., 2018; Oguz & Tanyas, 2024).

With the European Green Deal (end 2019) the EU adopts an all-encompassing strategy to achieve climate neutrality by 2050, integrating energy, climate and urban planning into a single synergistic framework. This new political horizon stimulates further changes of focus in academic research. The vision of "climate-neutral cities" promoted by the Green Deal encourages studies on local decarbonisation strategies, on the development of Urban Energy and Climate Plans and on the design of zero or positive emissions neighborhoods (Cumo et al., 2022). In particular, the concept of Positive Energy District (PED) - i.e. the positive energy urban neighborhood - receives great attention: supported by the European SET-Plan program, which envisages 100 of them by 2025, it becomes a central theme that requires integrated design approaches (Sassenou et al., 2023). At the same time, interest is growing in nearly zero-emission buildings (NZEB) and the energy requalification of existing building stock, in line with medium-long term objectives (Koutra, 2022). The Fit for 55 package (2021) further raises the bar to 2030 (requiring -55% of emissions compared to 1990) and emphasizes the principle of "energy efficiency first": this translates into an increase in studies on deep renovation of buildings, heat pumps, green district heating networks and on the electrification of heat consumption and transport (Margaritopoulos & Xenidis, 2023). In the same period, the theme of "just transition" forcefully enters the academic debate: key words such as just transition, energy justice and energy poverty signal a growing awareness of the socio-economic aspects of decarbonisation, reflecting the commitment of the Green Deal to "leave no one behind" (Knox et al., 2021). Finally, the REPowerEU plan (2022) - response to the energy crisis triggered by geopolitical shocks - gives a further direction to research, placing the emphasis on energy independence and diversification of sources. The need to reduce dependence on imported gas drives new studies on the hydrogen economy and green hydrogen, on the scalability of storage systems and on the network infrastructures necessary to integrate massive shares of intermittent renewables. In the urban context, this translates into research on distributed storage systems through neighborhood batteries and on the resilience of cities in the face of energy shocks (Proedrou, 2023).

Overall, the most recent European policies push the literature towards increasingly systemic and integrated approaches: the conceptual networks of academic studies today show a strong interconnection between technological, planning and social terms, reflecting the holistic nature of initiatives such as Fit for 55 and REPowerEU. This trend reflects the current orientation of EU policies, in which energy and territorial governance are now inseparable in designing the ecological transition of cities (Segales et al., 2023).

5. Conclusions

From the analysis carried out, it clearly emerges how regulatory evolution has had a decisive impact on academic research trends in the field of urban energy transition. Each major European directive or international

agreement has introduced new objectives and concepts which, in the space of a few years, have been assimilated by the scientific lexicon and explored in depth in numerous studies. We have moved from a pioneering phase, focused on renewables and energy efficiency (in the wake of the 2020 targets), to an era of strong interest for prosumers and energy communities (after the 2018 Clean Energy Package), up to more recent approaches that embrace the systemic dimension of urban decarbonisation (e.g. positive energy districts, sector integration, green hydrogen) in line with the Green Deal and post-2020 strategies. This process outlines a profound co-evolution: on the one hand, policies have oriented research towards areas considered priorities, on the other, scientific evidence has often provided bases and tools for the policies themselves, in a virtuous circle of mutual influence. Cities have emerged as absolute protagonists of the energy transition and are increasingly configured as innovation laboratories in which to experiment with advanced solutions. In fact, urban environments concentrate both the major critical issues (high energy consumption, polluting emissions, socio-environmental vulnerabilities) and the potential to intervene in an integrated way on energy, transport and territorial planning (Mauree et al., 2019). Numerous initiatives confirm the role of cities as "bridgeheads" of the transition: for example, the EU 100 Climate-Neutral Cities Mission (which aims for 100 climate-neutral cities by 2030) and the European Smart Cities & Communities projects finance pilot cities to act as examples and spread good practices (Natanian et al., 2024). Such experiences underline the importance of closely integrating energy policies with urban planning and local development strategies to ensure a sustainable and equitable transition. A truly holistic approach is fundamental: urban decarbonisation does not just concern systems and technologies, but involves the regeneration of neighbourhoods, mobility, waste management, the protection of vulnerable groups and the creation of new "green" employment opportunities (Gaglione & Ayiine-Etigo). Only through this multilevel integration, in which energy solutions are linked to land use, housing, social inclusion and economic development policies, will the energy transition be able to advance in a fair and sustainable way, maximizing collective benefits and minimizing social costs (Derkenbaeva et al., 2022; Fistola & La Rocca, 2024). Only through a balance between innovation, administrative capacity and social inclusion will it be possible to achieve a just, equitable and lasting urban energy transition, transforming cities into sustainable and resilient models (Martinelli, 2024).

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Author's profile

Valerio Martinelli

He is an engineer, with a master's degree in Building Engineering-Architecture at the Department of Civil, Building and Environmental Engineering of the University of Naples Federico II. He is currently a first year Ph.D. student in Civil Systems Engineering at the same department. His research activity focuses on the study of Renewable Energy Communities.