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5-E Levers: A New Conceptual Model for Achieving Carbon Neutrality in Cities

Jordi Mazon [1,2]

[1] Department of Physics, Universitat Politècnica de Catalunya—BarcelonaTECH, 08060 Castelldefels, Barcelona, Spain; jordi.mazon@upc.edu; Tel.: +34-650-720-380
[2] UNESCO Chair on Sustainability, Universitat Politècnica de Catalunya—BarcelonaTECH, 08222 Terrassa, Barcelona, Spain

Abstract: This article proposes a conceptual model for integrating and categorizing urban projects aimed at achieving carbon neutrality. This model comprises five interconnected levers: energy efficiency, renewable energy production and consumption, electrification of end use, circular economy, and CO_2 ensnaring (capture). Each lever encompasses projects and initiatives capable of directly or indirectly capturing urban CO_2 and accelerating the reduction of greenhouse gas emissions. These levers are interlinked, providing a road map for constructing a coherent and sustainable municipal model. Referred to as the "5-E levers", this conceptual framework derives its name from the fact that all levers begin with the letter "E", facilitating memorization and dissemination among policymakers.

Keywords: efficiency; renewable energy; electrification; CO_2 ensnaring; circular economy; levers; carbon-neutral cities

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1. Introduction

Climate change poses the greatest challenge currently confronting humanity, which is why the global imperative to reduce greenhouse gas emissions and curb CO_2 concentration in the atmosphere has become entrenched in the agendas of policymakers worldwide. On the European continent, achieving carbon neutrality by 2050 delineates an ambitious trajectory for EU countries' policies. Scientific consensus solidly affirms the origins and repercussions of climate change, predominantly stemming from the accumulation of carbon emissions resulting from fossil fuel combustion [1]. Extensive research underscores the repercussions of surpassing the global temperature thresholds stipulated in the Paris Agreement [2].

Presently, addressing climate change has become inherently political, requiring robust decision-making processes and clear governance frameworks to guide targeted actions aimed at reducing CO_2 emissions. In recent years, numerous frameworks have emerged to tackle this challenge. One such framework is the 2030 Agenda, ratified by the United Nations General Assembly in September 2015. This agenda outlines an ambitious overhaul, aiming to foster a more sustainable world across environmental, social, and economic spheres by 2030. Central to the 2030 Agenda are 17 overarching sustainable development goals (SDGs), which serve as political instruments for integrating transformative projects. At the environmental level, these goals are indispensable for fulfilling the objectives outlined in the Paris Agreement, specifically for limiting the rise in global temperatures to 1.5 °C.

The declaration of a climate emergency has emerged as a potent symbol of concerted climate action. Originating in the media in 2016, the term has swiftly garnered traction, leading to a proliferation of governmental and non-governmental organizations issuing such declarations worldwide. Governments and scientists globally have thrown their support behind climate emergency declarations, underscoring the urgency of addressing the climate crisis across various countries and regions.

According to the IPCC report published in 2022 [3], global warming is accelerating, and the impacts of climate change are projected to intensify more rapidly and severely over the next two decades. Model forecasts suggest that the target of limiting global temperature rise to 1.5 °C, originally set for 2040, should be advanced to 2030. However, despite widespread declarations of a climate emergency, official efforts have failed to curb CO_2 emissions, which have continued to escalate [4,5], indicating a lack of substantive action despite stated intentions. The latest IPCC report, published in 2022 [2], emphasizes the imperative for emissions to peak before 2025 and then rapidly decline over the subsequent three decades, approaching near elimination by the latter half of the century to avert catastrophic climate outcomes. Confronting the ineffectiveness of measures under the climate emergency framework, the authors of ref. [6] have advocated for a more stringent approach, declaring a climate alarm, and advocating for regulatory measures to curtail emissions, ensuring adherence to the limits defined by the Paris Agreement.

Nonetheless, plans formulated by countries and cities to effectuate these changes often suffer from vagueness, lack of focus, and a low likelihood of full implementation. This is partly attributable to the absence of a clear framework to articulate a coherent policy narrative for reducing emissions and capturing carbon, thus hindering progress toward carbon neutrality objectives. Ref. [7] underscored the necessity for a more comprehensive acknowledgment of these complexities to discern feasible mitigation actions, cautioning against overly generalized and optimistic assumptions.

The goal of this article is to propose a framework that is more streamlined and concise than the more commonplace SDGs. Our 5-E levers is a conceptual model intended to serve as a tool to assist cities and municipalities in developing a road map towards carbon neutrality in the upcoming years. Cities and municipalities are the primary focus of this framework due to their pivotal role in the decarbonization of our society. According to UN-Habitat, cities consume 78% of the world's energy and produce over 60% of greenhouse gas emissions, despite occupying only 2% of the Earth's surface. With an estimated 85% of EU citizens projected to reside in urban areas in the coming decades, addressing CO_2 emissions reduction and capture in urban settings is imperative. This commitment to action is internationally endorsed and spearheaded by the EU, which has set a target of a 55% reduction in emissions by 2030 and aims for a carbon-neutral continent by 2050. To realize this objective, the EU has initiated mission projects, including the "Smart Carbon Neutral Cities" mission, which endeavors to establish 100 carbon-neutral pilot cities by 2030. The proposed framework seeks to support cities worldwide in their pursuit of this ambitious goal.

The novelty of this article lies in our development of a conceptual model for facilitating the ecological transition towards carbon neutrality in cities, achieved through the integration and interaction of distinct levers. The 5-E levers proposed here serve as an integrated framework that offers a comprehensive perspective and organizational structure for aligning a city's emission reduction and carbon capture projects. Each lever is underpinned by scientific rationale, providing a holistic approach to urban decarbonization. Notably, existing approaches typically address isolated levers without a cohesive, interconnected view, resulting in fragmented strategies lacking synergy. Our innovative framework fills a gap in the current landscape, offering a structured methodology that simultaneously satisfies multiple levers while accelerating Europe's achievement of reaching the goal of carbon neutrality.

2. Materials and Methods

The methodology employed to develop the conceptual framework of the 5-E levers outlined in this article consisted of two phases. The first phase involved a systematic review of the literature aimed at analyzing actions contributing to a reduction in CO_2 emissions in urban areas. This review synthesized findings from the scientific literature to build a theoretical framework for organizing actions that cities can take to achieve carbon neutrality. At the time of this review, the literature contained thousands of articles and scientific knowledge related to climate change and the quantification of CO_2 emissions.

The systematic review of scientific literature plays a fundamental role in evidence-based decision-making. By scouring and analyzing scientific literature on various topics such as efficiency, energy production, and electrification, researchers gain comprehensive insights into each specific area. These insights are then integrated into a holistic conceptual model, such as the framework of the 5-E levers presented here.

The proposed levers are predicated on the principle of dual-action for achieving carbon neutrality: minimizing emissions to the fullest extent possible and maximizing carbon capture. With this premise in mind, we have identified five levers that are either directly or indirectly associated with these actions. Some of these levers align with initiatives outlined in the European Green Deal, such as electrification, while others correspond to SDGs, such as clean energy. Each lever will be substantiated through a review of pertinent scientific literature, elucidating why it is imperative to regard them as pivotal components within the conceptual framework of the 5-E levers.

The second stage involved applying the proposed 5-E levers framework to a real case study. The municipality of Viladecans, a medium-sized city with approximately 67,000 inhabitants, situated 15 km south of Barcelona on the northeastern Iberian Peninsula in Spain, served as the subject of this implementation. The city has demonstrated a strong environmental commitment, with a transition to green practices forming a core aspect of its political agenda. In recent years, Viladecans has formulated its 2030 urban strategy with a firm pledge to achieve carbon neutrality by 2030 and carbon negativity by 2050, aligning with the 4-helix methodology advocated by the EU's mission [7–9].

This methodology emphasizes equal involvement from politicians, businesses, academia, and civil society in addressing common challenges, such as attaining carbon neutrality by 2030. Since 2023, Viladecans has acted as a testing ground for the 5-E levers framework. Implementing the 5-E levers as a city-wide framework provides a road map for realizing the carbon neutral mission by 2030, encompassing ongoing city projects and future endeavors designed in accordance with this framework.

The foundation for defining and implementing the 5-E levers conceptual model proposed in this article establishes the necessary coherence within the city's trajectory and policies aimed at combating climate change. This journey commenced in 2016 with the initiation of the European project Vilawatt, an Urban Innovative Action sponsored by the EU. Vilawatt aimed to explore novel approaches to energy management in urban settings and foster citizen engagement in energy matters. Central to the project was the promotion of energy-efficient rehabilitation of residential and public buildings, aimed at reducing energy consumption and emissions.

However, the focus of energy rehabilitation should extend beyond individual buildings, houses, and flats, and it should instead encompass the entire public space, advocating for the alignment and promotion of energy-saving practices across residential, commercial, and public domains as a whole. The conceptual framework of the 5-E levers emerged in 2022 as a product of this pursuit of coherence and political action, seeking to fulfill the city's overarching objective of achieving carbon neutrality by 2030.

As exemplified by the 5-E levers framework, the essential collaboration between science and policymakers is underscored by the need to implement a comprehensive strategy rooted in scientific research within a political action to address challenges like achieving carbon neutrality by 2030. This approach highlights the importance of ensuring scientists are not excluded from active involvement in politics and decision-making.

3. Results

Figure 1 depicts the conceptual scheme of the 5-E levers, as derived from the analysis conducted in the previous section. The proposed name for this scheme is the "5-E Levers Pentagon".

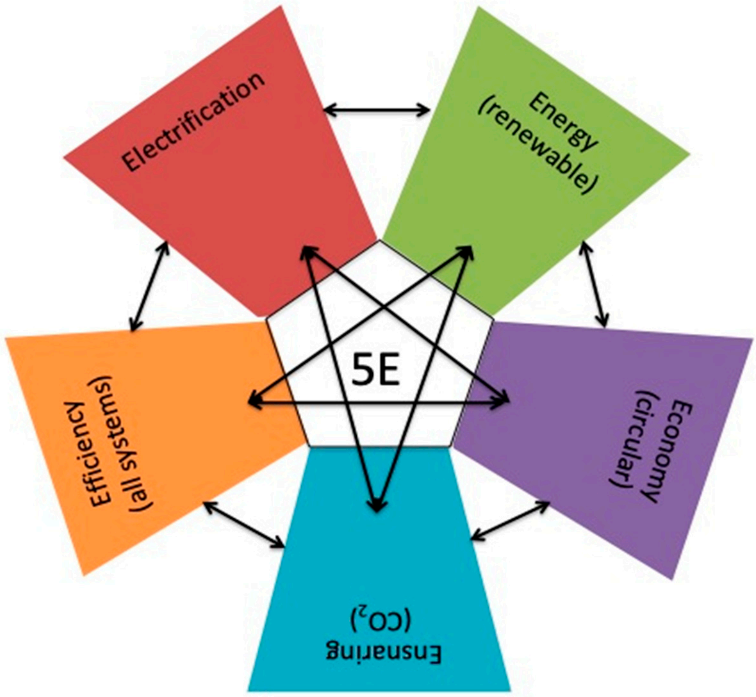

Figure 1. Conceptual scheme of the 5-E levers (The 5-E Levers Pentagon).

In contrast to the 17 goals outlined in the UN 2030 Agenda, which encompass sustainability across environmental, social, and economic dimensions, the five levers presented here offer more specific and direct responses to the primary drivers of CO_2 emissions: energy production and consumption, efficiency, and carbon capture from the atmosphere. With only five levers, all beginning with the letter "E", they are designed for ease of recall, dissemination among policymakers, integration into municipal policies, and subsequent implementation. These levers include: energy (generation and consumption of renewable energies), electrification of end-user consumption (across all energy systems), efficiency of all systems (not limited to electrical ones), economy (circularity), and CO_2 ensnaring (encapsulating). Each city project and action can align with one or more E-levers, as they are interconnected.

Presently, all city projects pertaining to the mission of achieving carbon neutrality, along with the 2030 city strategy, have been systematically integrated into the 5-E levers framework. The city's objective to attain carbon neutrality by 2030 is structured around the aforementioned 5-E levers framework.

In October 2023, the city of Viladecans submitted its plan outlining its environmental commitment and its endeavor to achieve carbon neutrality to the EU Green Leaf Award. Consequently, Viladecans has succeeded in holding the distinction of becoming the European Green Leaf Capital in 2025, making the city the European Green Capital for cities of less than 100,000 inhabitants. According to the jury's assessment, the multi-tiered approach embodied by the 5-E levers framework stood out as a key factor in their decision. Additionally, the comprehensive strategy and engagement of all stakeholders were highlighted. Viladecans has embraced its environmental commitment through a multi-faceted approach with enthusiasm, focusing its overarching strategy during its tenure as the European Green Leaf winner on two primary pillars: ecological transition and promotion of a healthy lifestyle. The jury commended the city's inclusive approach and the active participation of all citizens and stakeholders in fostering the city's green transition. Notable areas of emphasis for the Spanish city include renewable energy and energy efficiency. Viladecans' proactive stance toward sustainability challenges serves as a beacon of hope and inspiration, encouraging collective action in the global effort toward sustainability.

The city is presently implementing and structuring its projects within the framework of these 5E levers, which delineate the conceptual model proposed in this article. However, despite the qualitative outcomes mentioned earlier, there is currently a lack of objective data to quantitatively evaluate whether the 5E levers model accelerates CO_2 reduction and effectively progresses toward CO_2 neutrality in the foreseeable future.

4. Discussion

Five levers have been proposed for reducing and capturing CO_2 in urban areas: efficiency, electrification, energy, circular economy, and ensnaring CO_2. According to findings in the scientific literature, the combination of levers, as illustrated in Figure 1, holds promise for achieving carbon neutrality in urban environments.

4.1. Efficiency

Efficiency entails the avoidance of waste when undertaking a specific task, whether that waste pertains to materials, energy, effort, money, or time. Within urban contexts, efficiency encompasses all endeavors aimed at reducing waste and greenhouse gas emissions associated with energy consumption in residential areas, institutional buildings, transportation, and the generation of solid urban waste. Figure 2 illustrates a conceptual framework depicting the essence of efficiency as a lever.

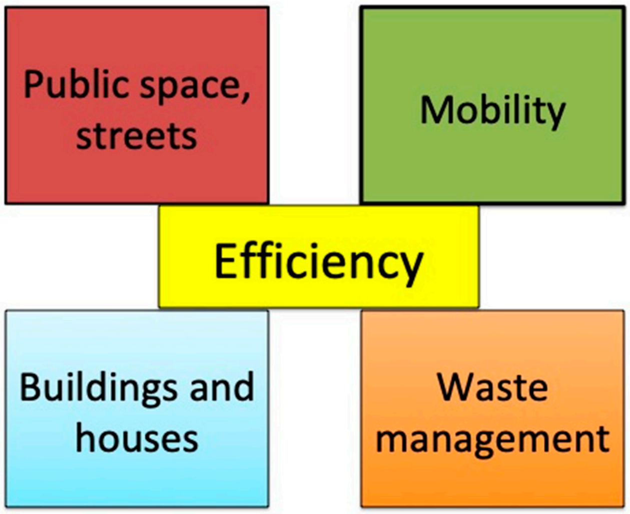

Figure 2. Conceptual scheme illustrating the efficiency lever.

4.1.1. Efficiency in Urban Public Spaces

Efficiency in energy consumption is not a novel concept. It has historically been employed as a means of conserving energy, mitigating climate change, reducing CO_2 emissions associated with energy production, and fostering sustainable development. It is also a key component of the European Green Deal, which aims to achieve carbon neutrality by 2050 (2030 in 100 pilot cities). However, efficiency should not solely target direct energy consumption systems but also extend to public spaces, where enhancing efficiency can indirectly promote energy savings and emissions reductions.

The urban heat island phenomenon prevalent in many cities contributes to increased energy expenditures for cooling buildings. The research in [10] suggests potential energy savings ranging between 300 kWh and 1700 kWh for every 92 m^2 of naturalized surface compared to traditional pavement and asphalt. This estimation underscores the potential for mitigating the heat island effect by reducing air temperatures through strategies such as tree shading, reflective pavement, urban vegetation, and other natural systems. Furthermore, studies such as [11] indicate that the intense heat island effect leads to a 19% increase in energy consumption for cooling homes, with variations between cities ranging from 10% to 120%. Conversely, a decrease of between 3% and 45% is found in heating consumption.

The naturalization of cities fosters more efficient public spaces, leading to a reduction in energy usage for cooling interior spaces situated in naturalized environments, thereby lowering emissions and waste from energy production. Several studies demonstrate a decrease in energy usage for air conditioning in buildings located on streets shaded by trees (e.g., [12–14]). Moreover, ref. [15] quantifies the impact of urban tree cover on the cooling of buildings and commercial premises, determining that trees can reduce summer cooling costs by 26% to 47%. Numerical simulations conducted by [16] indicate that a 30% increase in street vegetation coverage can enhance albedo by up to 20%, resulting in a 10% to 20% reduction in building heating costs and a further 30% to 100% reduction in cooling costs during the summer. Additionally, these findings suggest that trees have the capacity to cool streets and urban public spaces, with the authors determining that for every 1 °C increase in maximum daily temperature, peak electricity demand rises between 2% and 4%. Urban areas, according to these authors, are typically between 0.5 °C and 3 °C warmer than their rural counterparts.

Ref. [17] estimates a 10% energy savings in buildings due to urban trees, translating to an annual savings of nearly 800 million dollars in energy consumption and greenhouse gas emissions. Ref. [18] investigated the effect of tree shade on summer electricity usage and found that trees reduce summer electricity consumption by 185 kWh (equivalent to a 5.2% reduction). Additionally, their results indicate that a single adult street tree can reduce carbon emissions associated with summer electricity use by an average of 31% over 100 years. Research by [19] reveals that urban parks contribute to an average daily cooling effect of around 0.94 °C, with variations determined primarily by park size [20,21] and composition (trees or grass). Additionally, ref. [22] highlights that temperatures under trees are consistently cooler than the ambient temperature during the day, with differences of up to 10 °C.

4.1.2. Efficiency in Transportation

The primary sources of CO_2 emissions in urban areas are associated with transportation. Transportation efficiency in urban environments is being enhanced by strategies such as transitioning from combustion engine vehicles to hybrid and electric engines, promoting bicycle usage, and optimizing public transport systems. These efforts, aimed at reducing CO_2 emissions and pollutants, are integral to cities striving for sustainability and are thus often incorporated into local sustainable urban mobility plans [23]. Research by [24] evaluates which alternative sustainable mobility measures should be prioritized in Greek cities, using the Sustainable Mobility Efficiency Index (SMEI). Additionally, ref. [25] evaluates multimodal mobility to enhance public transport efficiency and intermodality, representing another measure aimed at reducing emissions in the city by improving urban travel times.

Transportation stands as one of the world's foremost energy consumers and the largest contributor to CO_2 emissions. Enhancing the energy efficiency of transportation is imperative for sustainable development and the realization of CO_2 neutrality objectives in the coming years. Efficient management of transportation is paramount in this endeavor. Research conducted by [26] delves into the constraints of energy management within railways, stemming from the prevailing market regulation model. Through critical analysis, documentary research, and the case study of a Polish railway company, the authors conclude that the European regulatory framework introduces more complexities in energy management compared to other global regions where railways hold similar economic importance. Despite advancements in transport energy efficiency, these improvements primarily result from organizational rather than technological measures, contrary to previous research expectations. According to the authors, efficient mobility management stands as a linchpin in achieving efficiency.

4.1.3. Efficiency in the Residential Sector

Following transportation, the residential and tertiary sectors constitute the primary segments of energy consumption and emissions. Implementing efficiency measures is crucial for reducing consumption and fostering the development of sustainable residences. Various studies have assessed the energy installation potential and economic implications of various energy efficiency measures for buildings (e.g., [27–31]). These studies indicate that residences with insulation can decrease electricity consumption by 35% to 43%. The European Commission's 2030 framework for climate and energy policy underscores that the construction sector harbors the largest share of the energy potential within the European Union.

Ref. [32] analyzes the adoption of connected thermostats and home energy-management system solutions as effective strategies for addressing the residential energy footprint. The authors investigate the impact on the Italian real estate stock at a regional level, demonstrating that all adoption scenarios dramatically reduce residential energy consumption, surpassing the EU targets for Italy by 2030.

According to the European Environment Agency and the European Commission, buildings account for approximately 40% of total final energy consumption and 36% of CO_2 emissions in the EU.

4.1.4. Efficiency in Urban Waste Management

Conceptually, waste represents energy that has been converted but not utilized in the production of a relevant value [33]. By reducing waste generation, energy expenditure is reduced, while an increase occurs in the energy efficiency of manufacturing processes. Recycling serves to diminish wasted energy within the system [34] while also reducing CO_2 emissions into the atmosphere [35]. Thus, recycling emerges as a means for improving the efficiency of urban waste generation. Material recycling efficiently reduces net carbon emissions, augments carbon sequestration in soil and forests, and acts as a catalyst for balancing energy loss to entropy [36]. Conversely, landfill disposal entails a loss of the economic value of waste [37] and leads to substantial carbon and methane emissions [38]. Research by [39] elucidates the interconnectedness between energy efficiency and carbon emissions, energy efficiency and economic growth, and economic growth and carbon emissions. As companies innovate and make technical progress in implementing new practices, processes, and products, they inevitably promote recycling and energy conservation, which in turn contributes to reducing not only emissions but also atmospheric and environmental pollution [40–43].

4.2. Electrification

Electrification, as the ultimate stage of consumption for all systems, is imperative for breaking dependence on fossil fuels for energy procurement. For instance, domestic, industrial, and municipal gas boilers typically rely solely on fossil fuels for heat generation, whereas electric boilers offer the flexibility to derive electricity from either fossil or renewable sources. Electrification affords the opportunity to opt for renewable sources over fossil fuels. With this principle in mind, the electrification of final consumption stands as a key objective of the EU Green Deal [44].

4.3. Energy

Fossil fuels serve as the primary source of energy worldwide, owing to their high energy density. However, the combustion of fossil fuels and the resulting greenhouse gas emissions are direct contributors to climate change. Approximately 35% of greenhouse gases are emitted by existing power plants [45]. Energy derived from fossil fuels is responsible for over 75% of global greenhouse gas emissions and approximately 90% of all carbon dioxide emissions, as noted by [46]. The utilization of fossil fuels significantly contributes to global warming [47]. Decarbonization of the energy sector entails a shift towards renewable energy sources. Renewable energy refers to energy obtained from naturally replenished resources. Achieving carbon neutrality objectives involves a widespread increase in the utilization of these renewable energy sources. Ref. [48] estimate that a 74% increase in renewable energy use by 2050 necessitates an eight-fold annual increase. Moreover, ref. [49] projects a 56% increase in energy demand by 2040, which, to prevent an increase in emissions, must be generated with renewable energies. Combatting climate change requires stringent control of CO_2 emissions from energy production as well as consumption. Attaining the desired carbon neutrality state demands rapid, immediate, and sustained innovation, along with the effective utilization of renewable energy across all sectors [50].

According to the International Renewable Energy Agency [51], approximately 80% of the world's population resides in countries that are net importers of fossil fuels. Conversely, renewable energy sources are accessible in all nations, yet their full potential remains largely untapped. Projections suggest that by 2050, it is feasible and imperative for 90% of the world's energy to originate from renewable sources [52].

In urban areas, energy communities focused on renewable energy production and consumption play a vital role in the Energy Transition. Participants within a renewable energy community not only consume the energy they generate but also have the opportunity to share any surpluses they generate with other members of the community. These renewable energy communities serve as a means to empower citizens regarding energy matters while simultaneously promoting the production of renewable energy [53].

According to the EU commission, local energy communities can serve as an effective means for managing energy at a community level. These communities consume the electricity they generate directly for power or (district) heating and cooling, whether or not they are connected to distribution systems [54]. Defined as legal entities controlled by natural persons, local authorities (including municipalities), or small enterprises and micro-enterprises, these communities operate based on voluntary and open participation. Their primary objective is to provide environmental, economic, or social community benefits rather than financial profit. These entities are engaged in energy management and involved in the generation, storage, and distribution of energy at a local level, with the additional possibility of accessing organized energy markets.

4.4. Ensnaring CO_2

The capacity of trees and vegetation to absorb and sequester CO_2 from the atmosphere is widely acknowledged. They are pivotal in combating climate change and advancing carbon neutrality goals. Numerous studies have quantified the CO_2 absorption potential of vegetation using various methodologies (e.g., [55–59]).

Urban trees, also known as urban forests, serve as reservoirs of CO_2, which can be reintroduced into the atmosphere upon the tree's demise if no intervention is taken. During their growth, urban trees actively sequester CO_2, thereby impacting urban air temperatures and the energy consumption of buildings, as detailed in preceding sections. Urban trees and urban greening initiatives are integral to carbon capture and sequestration efforts in the pursuit of carbon neutrality. However, the amount of CO_2 captured by urban trees varies significantly, contingent upon the species of trees and heavily influenced by weather and climate conditions. Various authors have reported values ranging from 2 to 80 tons of CO_2 per year per hectare of urban forest (e.g., [60–62]). Furthermore, ref. [63] conducted direct measurements of CO_2 fixation in street trees in Helsinki, yielding a range between 3.5 kg CO_2/year and 13.44 kg CO_2/year.

In addition to urban vegetation, particularly urban trees, future efficient and sustainable carbon capture systems (CCS) should be incorporated into this lever to expedite the removal of CO_2 from the atmosphere.

4.5. Economy

The circular economy aims to curtail resource consumption and waste generation by maximizing the efficiency of finite resources, harnessing renewable resources more effectively, reclaiming materials at the end of their cycle, and fostering regenerative natural systems. All of these are key aspects in achieving a circular economy aligned with decarbonization. As asserted by [64], the true circularity of the economy necessitates, among other measures, the integration of renewable energies, increased efficiency, waste reduction, and the valorization of resources. The 5-E levers proposed here are closely aligned with these principles, which embody the essence of the circular economy—an economic paradigm focused on minimizing, sharing, reusing, repairing, and recycling resources to the greatest degree possible in order to generate added value. Consequently, product lifecycles are extended, promoting efficiency, low energy consumption, and reduced CO_2 emissions. In practical terms, this entails waste and energy minimization. For instance, within the domain of urban solid waste management, the adoption of circular economy waste practices serves as a vehicle for sustainable development. Ref. [65] introduced a circular design framework founded on the principles of the 9Rs, categorizing various production chains according to Refuse, Rethink, Reduce, Reuse, Repair, Renew, Remanufacture, Reuse, Recycle, and Recover. These principles are inherently congruent with the objectives underpinning the 5-E levers.

5. Final Remarks and Conclusions

Based on a scientific review, a conceptual model has been constructed around five interrelated levers: the production and consumption of renewable energies, the efficiency of all city systems and spaces, the electrification of consumption endpoints, the implementation of circular economy practices, and carbon capture. These interconnected levers serve as a framework for delineating city projects, with each project aligning with one or more of these levers. The 5E conceptual model provides a comprehensive and holistic perspective on the projects required for a city to achieve carbon neutrality in the foreseeable future.

For this research, an extensive review of the scientific literature has been conducted for each of the 5E levers in order to demonstrate their direct or indirect effects on carbon reduction. By integrating these individual levers into the overarching 5E conceptual model, cities can develop a strategic vision for decarbonization and naturalization projects. This integrated approach enables cities to refine project definitions by ensuring they are aligned with the maximum number of levers, thereby optimizing their impact on carbon reduction and environmental sustainability.

Scientific knowledge, represented by a subset documented in the bibliography, serves as the rationale for selecting each of the five levers in the proposed model. While existing research has outlined actions necessary for reducing CO_2 emissions, these have often been addressed in isolation rather than as an integrated approach. The conceptual model presented here aims to streamline and enhance the definition of projects by considering multiple levers simultaneously, providing a more cohesive perspective.

Numerous studies have indicated that the greatest contribution to CO_2 emissions in cities stems from the residential and transportation sectors (e.g., [66–68]). To mitigate emissions associated with the residential sector, one focus of the 5E levers is on optimizing building energy efficiency and reducing consumption. In the realm of urban mobility, transitioning to more efficient public transportation modes and utilizing clean energy sources devoid of CO_2 emissions are crucial for city decarbonization efforts. Consequently, efficiency is proposed here as one of the five levers for cities striving to achieve CO_2 neutrality in the forthcoming decades. The emphasis on efficiency extends beyond buildings to encompass all aspects of urban life, including mobility, waste management, and public spaces, all of which should align with energy-efficient building practices.

Clean renewable energy sources and the electrification of both power generation and end-consumption represent two more levers proposed herein. These are essential for bolstering the efficiency lever and curtailing emissions. The circular economy has demonstrated its efficacy in waste and energy minimization, thus warranting its inclusion as the fourth lever. These four levers collectively aim to reduce consumption and CO_2 emissions.

The fifth lever revolves around CO_2 capture (ensnaring), whether through biological systems or future technological advancements that align with the preceding levers. Carbon capture is imperative for reducing CO_2 concentrations in urban atmospheres, and by extension, on a planetary scale, given that an estimated 70% of total emissions originate from cities, according to the UN.

The presented model is constrained by the absence of data necessary to evaluate its effectiveness in achieving the ultimate goal of reducing emissions and increasing the capture of a city's CO_2. The Viladecans case example mentioned in this article adopted the model in mid-2023, with the objective of becoming a CO_2-neutral city by 2030. Due to the recent adoption, objective data for assessing the model's efficacy are currently unavailable. This limitation underscores the need for future research aimed at promoting the model's application in urban settings and acquiring objective data associated with each lever comprising the model. Such data would facilitate the evaluation of decarbonization and carbon capture efforts.

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