



Research Articles

From experts to citizens: Co-creating neighbourhood coziness metrics

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ABSTRACT

Current urban sustainability metrics often overlook local community preferences. The shortcomings of existing assessment tools stem not only from overarching frameworks but also from limitations in their key performance indicators. This study introduces a novel methodological approach integrating multidimensional indicators spanning environmental, social, and economic dimensions, culminating in the Community Coziness Rating. Structured expert discussions and a comprehensive survey across multiple European nations targeted non-expert residents to ensure a representative cross-section of perspectives. Survey participants evaluated indicators categorized and weighted for technical and community significance. Findings show building energy efficiency, air quality, and proximity to essential services were most critical, while technical metrics like smart energy management systems and advanced electric vehicle infrastructure ranked lower, highlighting a disconnect between expert prioritization and public perception. The proposed framework incorporates participatory action dynamics, enabling more nuanced, context-specific neighborhood evaluations that reflect localized needs and preferences.

Introduction

The growth of cities worldwide has positioned them as major energy consumers and one of the leading generators of greenhouse gases. It is estimated that, in 2020, urban areas hosted over 55 % of the global population, and this figure is projected to rise to 68 % by 2050 [1].

In response to this, the European Commission has developed various initiatives aimed at improving the sustainability of urban areas. One of these is the Energy Performance of Buildings Directive (EPBD), which aims to reduce energy consumption and greenhouse gas emissions by promoting energy-efficient technologies and practices in the construction sector. Considering that 85 % of the building stock in the EU was constructed before the year 2000, with 75 % of those buildings exhibiting poor energy performance, this directive is regarded as a fundamental policy framework for achieving the European Union's climate goals [2,3].

Similarly, the EU developed the European Green Deal, a framework aimed at achieving at least a 60 % reduction in emissions in the building sector by 2030 compared to 2015, and a fully decarbonized, zero-emission building stock by 2050. Through a series of measures to adapt the EU's climate, energy, transport, and fiscal policies, the European Green Deal seeks to ensure: 1) zero net greenhouse gas emissions

by 2050; 2) economic growth decoupled from resource use; 3) that no person and no place is left behind [4].

Recently, efforts have been made to connect the European Green Deal with daily life and living spaces through the New European Bauhaus (NEB) initiative. With a focus on research and innovation-driven solutions, NEB aims to transform neighborhoods across Europe, making them more beautiful, sustainable, and inclusive. The initiative is expected to encourage greater social acceptance of EU Green Deal policies, foster ownership of green solutions, and promote behavioral changes necessary to meet the Green Deal objectives [5]. As an example of the creative approach pursued by this initiative, Hu et al. analyze the potential of NEB to integrate traditional knowledge with advanced technologies to create sustainable and inclusive urban environments. The authors highlight the challenge of balancing cutting-edge technologies with context-specific traditional knowledge [6].

At this point, two main lines of research related to cities can be observed: on the one hand, studies focusing on sustainability and energy savings, and on the other, research centered on more "human" aspects, such as environmental comfort and livability. The complexity and multifaceted nature of the challenges faced by urban areas require multidisciplinary and integrated research approaches. In this context, neighborhoods, as core units of cities, play a crucial role in achieving

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broader sustainability goals.

In this context, the most widely used strategy to measure the effectiveness of policies aimed at energy savings and reducing the environmental impact of cities is the design and development of Key Performance Indicators (KPIs) to evaluate various aspects of urban spaces. Thus, understanding the role of indicators and developing a viable methodology that can be applied within a solid framework for assessing neighborhoods can provide valuable insights into their performance and guide targeted interventions across environmental, social, and economic dimensions [7,8]. The use of KPIs at the neighborhood scale can offer quantifiable data related to consumption and emissions, as well as qualitative information useful for urban planning and informed policymaking.

Following this line, several authors have contributed interesting work on the analysis of indicator sets at the urban scale. Among them, Boschetto et al. (2020) conducted a comparative review of neighbourhood sustainability assessment tools (NSATs), identifying key success factors such as stakeholder engagement, comprehensive coverage of sustainability dimensions, and adaptability to local contexts [9]. These factors coincide with the broader indicators identified by Adiyarta on the smart city environment. The author elaborated a systematic review of smart city indicators, detecting 43 indicators classified into eight categories: economy, environment, governance, mobility, people, life, information and communication technologies (ICT) and education [10]. This comprehensive classification highlights the multifaceted nature of urban sustainability and the importance of a holistic approach to evaluation. The researcher highlights the role of information and communication technologies in improving urban sustainability. This supports the findings of Huovila (2019), in which compares standardized indicators for sustainable smart cities and suggests that the choice of indicators should be context-specific and aligned with local priorities [11]. These works highlight the importance of a multidimensional and inclusive approach to sustainability assessment.

In the field of smart cities, various studies have identified and classified a wide range of indicators. For example, Bibri (2020) conducted a deep review of compact city planning and development strategies, emphasizing the integration in urban planning, which aligns with the broader understanding of smart city indicators. Bibri's work stresses the importance of integrating sustainability practices with smart city technologies to improve urban resilience and advocates the use of ICT to effectively monitor and manage urban resources, which can significantly contribute to the sustainability of neighbourhoods [12,13]. This perspective is consistent with the findings of Han (2020), who conducted a review of smart city research from an urban context perspective, identifying key performance indicators such as infrastructure, environment, economy, governance, mobility, and social factors [14]. Their work suggests that a multidimensional approach is needed for a holistic assessment of urban sustainability. In the same way, Homer (2020) supports this approach, who after developing a scale to measure perceptions about smart and sustainable cities emphasizes the role of social and human capital in urban development [15].

Another contribution comes from Butkiene et al. (2020), who conducted a literature review on energy poverty indicators, stressing the social dimension of sustainability in urban areas [16]. Their publication highlights the importance of considering socio-economic factors in neighbourhood assessments, which is crucial for addressing equity and inclusiveness in urban development. In addition, Sharifi and Murayama [17] provide an extensive review of neighbourhood sustainability assessment tools, classifying various indicators into dimensions such as environmental quality, social well-being, economic vitality and governance. This categorization underscores the importance of a multidimensional approach to assessing neighbourhood sustainability and suggests that effective neighbourhood sustainability assessment tools must integrate these various dimensions to provide a holistic assessment.

In a literature review of smart city assessment tools and indicator

sets, Sharifi [18] highlights the need for adaptability in assessment frameworks to address different urban contexts too. The author argues that while standardized indicators provide a basis for comparison, flexibility is essential to address unique local challenges and opportunities. This opinion is shared by Dai, who reviewed the transformation process of smart cities, showing the dynamic interaction between stakeholders and technology. Dai mark the importance of stakeholder participation in the development and implementation of sustainable urban strategies [19].

Joined the above-mentioned, two concepts are linked to the performance and evaluation of urban areas: zero-emission neighbourhoods and positive energy districts. These were reviewed by Brozovsky et al. [20], who illustrates the potential of neighbourhoods not only to achieve sustainability but also to contribute positively to the environment. Authors argue that integrating renewable energy sources, enhancing energy efficiency, and fostering community engagement are central components of such initiatives. These findings highlight the interconnectedness of environmental, social, and economic sustainability dimensions in neighbourhood assessments. Farther, in another study, Bosse et al. [21] discuss the role of indicators in formulating and measuring the Urban Sustainability Index (USI), emphasising that indicators must be adaptable to local contexts to effectively measure sustainability at the neighbourhood level, for ensuring that the indicators remain relevant and accurate across different urban settings.

Recent studies such as those by Mazzanti et al., and Balest et al. [22,23] discuss the importance of energy indicators in monitoring progress towards energy efficiency and sustainability goals. However, current discussions on indicators used to assess urban sustainability face several limitations, generally related to individual and collective well-being and preferences of human aspects. In this context, the concept of *Liveability* was introduced to help to understand the well-being that a community provides to its residents. Designing liveable communities involves promoting multidimensional aspects such as social cohesion, guaranteeing accessibility and promoting health, ultimately improving the quality of life of all neighbours. Liveability as a holistic concept takes into consideration aspects such as access to housing, medical care, educational opportunities, consumption and leisure, convenience of transportation, support facilities and social stability, reflecting the quality of the person-environment relationship, meeting the needs and expectations of residents through the built environment and available services [24–28].

Finally, the so-called Neighborhood Sustainability Assessment (NSA) tools, which include certifications such as LEED-ND, BREEAM Communities, CASBEE-UD, among others, present several methodological limitations that have been studied by various authors. One of the main criticisms concerns the limited and unbalanced coverage of sustainability dimensions. As Komeily and Srinivasan (2016) point out, many of these tools disproportionately focus on environmental aspects, while social, economic, and institutional dimensions receive marginal attention [29]. This results in evaluations that fail to address fundamental issues such as social cohesion, economic equity, or adequate governance. For instance, Holden (2013) emphasizes that indicators related to community inclusion, safety, and livability are conspicuously absent from current assessment frameworks [30]. This lack of balance is particularly concerning in Global South contexts, where socioeconomic inequalities are more pronounced [31].

Another significant limitation is linked to the predominantly top-down approach and the lack of transparency in the development of these tools. Indicator selection and weighting are often carried out by experts, excluding the perspectives and priorities of local stakeholders. Sharifi and Murayama (2013) criticize this practice, arguing that “the voices, concerns, and expectations of residents are not adequately integrated into the process” [32]. While tools such as HQE2R and Ecocity have attempted to include consultations with residents, these initiatives are more the exception than the rule, and most tools fail to consider specific local needs.

In addition, there is a lack of consideration for the specific contexts in which these tools are implemented. Standardized criteria and indicators often fail to reflect the socioeconomic, environmental, or cultural realities of particular regions. As example, applying tools like LEED-ND in Europe or Japan, where urban development patterns differ significantly from those in the United States, may result in inadequate evaluations [33]. While LEED-ND emphasizes connectivity and mixed-use design patterns, these characteristics are already inherent in many European cities, reducing the relevance of these indicators in such contexts.

The rigidity and prescriptiveness of design measures is another problematic aspect. Tools such as LEED-ND and BREEAM Communities tend to impose fixed designs and standards, limiting innovation and adaptability to local needs. Boeing et al. (2014) criticize this rigidity, stating that “traditional design principles, such as street connectivity, do not always lead to the expected outcomes in terms of sustainable behavior” [34]. This rigidity can also exclude innovative projects that do not meet the standard requirements of the tools, as seen in the case of the City to Lake project in Canberra, Australia, where innovative recreational facilities were ignored because they were not included in the predefined criteria [35].

Another challenge is the lack of measures to ensure compliance with minimum sustainability requirements. Many tools adopt credit-based systems where developments achieve certifications based on the total points accumulated. This can encourage a “credit-chasing” approach, leading to imbalances in the evaluated dimensions. Garde (2009) warns that this practice allows projects to be certified by meeting environmental indicators while neglecting essential aspects such as affordable housing or economic efficiency [36]. Although some tools have introduced mandatory indicators, these are not always sufficient to ensure balanced coverage of sustainability dimensions [32].

The lack of consensus among the evaluation methodologies used by different tools also presents significant challenges. Differences in indicators, weightings, and evaluation approaches make it difficult to compare neighborhoods assessed with tools such as LEED-ND, BREEAM Communities, and CASBEE-UD. Several authors point out that a neighborhood may receive different sustainability ratings depending on the tool used for its assessment, complicating benchmarking and potentially leading to the use of tools solely for marketing purposes [37].

At last, NSA tools often oversimplify the complex interactions between indicators and fail to adequately consider cross-boundary interactions. Sharifi (2020) highlights that “tools should inform stakeholders about potential synergies and trade-offs between efforts related to different indicators” [38]. Furthermore, these tools tend to evaluate neighborhoods as isolated entities, without taking into account their interactions with broader urban scales. Benites et al. (2020) underline that this disconnection limits the sustainability benefits of projects beyond their own geographic boundaries [39].

The literature and conceptual review conducted thus far reveals that, although a rich array of tools exists for assessing the sustainability of urban regeneration initiatives, significant knowledge gaps remain, particularly concerning the validation of the importance the general public attributes to used key performance indicators. While there is a growing body of research on smart city indicators, sustainability assessment tools, and livability issues, there is limited evidence on *how residents evaluate their own community* or how they weigh different aspects of their neighborhood. In response to this gap, and with the aim of establishing a new multidisciplinary and comprehensive approach, this work introduces the concept of *Coziness*, focusing on understanding what value residents place on both the urban materiality of the neighborhood and the social aspects of their community. Concretely, the novelty of this paper is to draw attention to the assessment of specific aspects of a neighbourhood from the consideration of the preferences of the inhabitants of that community [40]. For this, a Community Coziness Rating (CCR) is proposed based on a new Neighbourhood Indicators Framework (NIF). This framework aims to address the limitations of current KPIs, which are generally characterized by their inability to

Table 1
Profile and affiliation of the experts consulted.

Participant	Institution	Areas of Expertise	Sector	Country
Expert 1	Ethniko Kentro Erevnas Kai Technologikis Anaptyxis (CERTH)	Research and technological development in energy, environment, industry, transport, and information technologies	Public	Greece
Expert 2	Frederick Research Center (FRC)	Scientific research, technology transfer, sustainable built environments, energy-efficient technologies	Private	Cyprus
Expert 3	Federatie van Verenigingen voor Verwarming en Luchtbehandeling in Europa (REHVA)	Development and dissemination of economical, energy-efficient, safe, and healthy building mechanical services technology; knowledge exchange; support for EU policy development and implementation	Private	Belgium
Expert 4	Asociatia Inginerilor de Instalatii din Romania (AIIR) Filiala Valahia	Professional association for installation engineers, focusing on building services engineering and installations	Private	Romania
Expert 5	IES R&D (IESRD)	Research and development in building performance analysis, energy modeling, and sustainable building design	Private	Ireland
Expert 6	DEMO Consultants BV	Consultancy services in real estate development, project management, and sustainable building solutions	Private	Netherlands
Expert 7	R2M Energy SRL	Energy consultancy, sustainable building solutions, and innovation management	Private	Italy
Expert 8	Deusto University	Higher education and research in economics and social sciences.	Private	Spain
Expert 9	QUE Technologies Kefalaiouchiki Etaireia (QUE)	Technology solutions and services, focusing on innovation	Private	Greece

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Table 1 (continued)

Participant	Institution	Areas of Expertise	Sector	Country
Expert 10	Goiener Cooperative	and digital transformation Renewable energy cooperative, focusing on sustainable energy production and consumption	Private	Spain
Expert 11	Tallinna Tehnikailikool (TALTECH)	Engineering, technology, and innovation research and education	Public	Estonia
Expert 12	Austrian Standards International – Standardisierung und Innovation (ASI)	Development of standards, innovation in standardization processes	Private	Austria
Expert 13	Association Européenne pour la Coordination de la Représentation des Consommateurs pour la Normalisation (ANEC)	Representation of consumer interests in standardization and certification processes	Private	Belgium
Expert 14	Eunice Energy Technologies GmbH & Co. KG (EUNICE)	Renewable energy technologies, energy solutions	Private	Germany
Expert 15	Waide Strategic Efficiency Europe Limited (WSEE)	Energy efficiency consultancy, policy analysis, strategic advisory services	Private	Ireland

integrate technical values with social and environmental considerations, and, in particular, by their failure to account for the cultural specificities of the communities under evaluation. To overcome these shortcomings, the proposed framework incorporates a broader set of evaluation criteria driven by both experts and end-users. In light of these, the proposal of a ranking system that can be adjusted to the cultural, economic, and social particularities of a community will not only respect the individual and collective characteristics of its residents but also the urban and environmental identity of cities.

Methodology

This research employed a two-stage methodology aimed at addressing its core objectives. The process involved: (1) a series of expert discussion rounds focused on the definition of Key Performance Indicators and (2) a large-scale survey directed at the general audience residing in European countries to determine the degree of importance citizens assign to each KPI.

The research was structured around two fundamental questions:

- What are the most suitable dimensions, categories, and indicators for evaluating urban space?
- What is the most appropriate weighting of indicators to ensure that the evaluation of urban space meets sustainability requirements while also aligning with the values and aspirations of urban space residents?

In the first stage, the development of a novel neighborhood-scale evaluation framework and the construction of a taxonomy of indicators were achieved through structured discussions and analytical

Table 2

Platform’s parameters to define the General Audience profile.

Prolifics Parameters Configuration		
Demographics	Age Sex Current Country of Residence	18 and above Male 50 %, Female 50 % See Table 3
Geographic	Country Quota	See Table 3
Language	Fluent languages	English
Education	Highest education level completed	Secondary education (e.g. GED/GCSE)
Participation on Prolific	Device requirements Approval Rate	Mobile, Tablet, Desktop 95 %

Table 3

Countries included in the study and the participation quota for each one.

Demographic	Participants	Percentage
United Kingdom	40	8 %
Ireland	5	1 %
Germany	40	8 %
France	40	8 %
Spain	35	7.0 %
Austria	5	1 %
Belgium	10	2 %
Bulgaria	10	2 %
Croatia	10	2 %
Cyprus	0	0 %
Czech Republic	10	2 %
Denmark	5	1 %
Estonia	10	2 %
Finland	20	4 %
Greece	15	3 %
Hungary	10	2 %
Italy	35	7.0 %
Latvia	15	3 %
Lithuania	15	3 %
Luxembourg	0	0 %
Malta	0	0 %
Netherlands	15	3 %
Norway	20	4 %
Poland	35	7.0 %
Portugal	15	3 %
Romania	20	4 %
Slovakia	20	4 %
Slovenia	15	3 %
Sweden	25	5 %
Switzerland	5	1 %

sessions with experts. This collaborative process was carried out through 6 rounds of participation of 1:30 h each, held online, between the months of May and June 2023. This ensured that the classification developed has a solid technical perspective, addressing key aspects such as energy performance, environmental quality and user comfort. These sessions provided a robust foundation for the framework, integrating technical expertise with practical relevance. The profiles of the experts consulted are detailed in Table 1.

The second stage of the methodology involved conducting a large-scale survey to ascertain the importance that the general European public assigns to the developed indicators. To facilitate this, the survey was designed using SurveyMonkey.com [41], a leading online survey platform that enables users to create, distribute, and analyze surveys efficiently. The distribution of the survey was managed through Prolific.com [42], a platform that connects researchers with a diverse pool of over 200,000 actives, verified, and engaged participants, ensuring high-quality and reliable data collection. To gather insights from the general audience, the distribution platform’s parameters were setting as detailed in Table 2.

This setting ensured that the survey reached a diverse and representative sample of European residents, facilitating the collection of comprehensive data on the importance assigned to each indicator. The

Table 4
Proposed rating scale of KPI weights.

RATING SCALE FOR EUROPEAN USERS	VALUE CODE	WEIGHTING
Extremely relevant	5th quintil	0.5
Very relevant	4th quintil	0.25
Moderately relevant	3rd quintil	0.12
Slightly relevant	2nd quintil	0.07
Not relevant at all	1st quintil	0.06
		1

countries included in the study and the participation quota for each can be seen in Table 3.

The surveys participation quota ensures a representative number of respondents for each European country, aiming to guarantee that the voices of diverse regions were heard and equitably integrated into the process. Specifically, the distribution of respondents from each country was determined proportionally based on the size of their population and their relative percentage within the overall sample. For instance, the United Kingdom’s population constitutes 8 % of the total population across the countries where the survey was conducted. Consequently, the 40 respondents from the UK represent 8 % of the total survey participants, ensuring alignment between the population distribution and sample representation.

Once the participant pool was established, respondents were presented with the curated set of indicators. Each indicator was evaluated using a slider button, allowing for a nuanced and graduated expression of preferences and opinions. By focusing on the general public, the survey sought to enrich the understanding of societal views on the subject matter, ultimately contributing to a more comprehensive and democratic framework for analysis and decision-making. To start the survey, each respondent was provided with the following context:

“Imagine that you are an official in your country who has to face an important decision related to building energy policies (energy consumption levels, prohibition of inefficient materials or technologies, implementation of renewable energies, etc.) that could have a deep impact for the inhabitants of the neighborhoods (availability of energy services at the district level, rewards or penalties for energy performance, increase in the price of purchasing or renting homes, etc.). To inform yourself, you hope to find relevant data on the assessment of energy consumption of the neighborhood in the information contained in the innovative neighbourhood’s energy performance certificate.

In this context: What indicators do you think should be included in this certificate so that the information contained therein is relevant from the point of view of policymakers, building owners and tenants?”.

The general instruction asked respondents to use the slider to indicate whether they considered each indicator to be “not at all relevant” or “extremely relevant.” Respondents’ preferences were processed by taking the median value from 600 surveys. The indicators were then sorted and divided into 5 quintiles according to the following categories: the top 8 KPIs as highly relevant, the next 8 KPIs as relevant, the following 7 KPIs as interesting to consider, the next 7 KPIs as minimally relevant, and the final 7 KPIs as completely irrelevant (Table 4). This classification was intended to provide a nuanced understanding of the importance of each indicator within the study’s framework.

Subsequently, a weighting was conducted, assigning the indicators with higher medians the highest scores, and gradually decreasing their weight for those with lower medians. This stage allows for the relative importance of each indicator to be attributed based on its perceived relevance in the survey responses. By adopting this weighted approach, it ensures that the indicators perceived as most critical by the respondents receive greater consideration in the overall assessment process.

Finally, an operation was performed to divide the value of the assigned weights by the number of indicators for each level, reflecting the value of the medians of the responses for each KPI, collected through the survey.

Table 5
First round of indicator selection according to technical feasibility and clarity criteria.

TECHNICAL FEASIBILITY AND CLARITY CRITERIA	
Rule	Description
Measurability	Choose of indicators that can be quantitatively measured or assessed.
Data Availability	Selection of indicators for which reliable and up-to-date data are readily available.
Clarity	Choice of indicators are clearly defined and easily understood by all stakeholders.
Feasibility	Feasibility of collecting and analysing data for each indicator.
Timeliness	Identify indicators for which data can be collected and reported in a timely manner.
Non-overlapping	Eliminate indicators that are contained within or subsume other indicators.
Scalability	Indicators scalable and applicable to different sizes or types of urban areas.

Methodological limitations

The research carried out sought to develop and validate a set of indicators for the evaluation of neighbourhoods in the European territory. For this reason, all the experts consulted reside in European countries, so their vision is loaded with a geographical and cultural bias according to the context. This can be a limitation for the application of the proposed framework in other regions and countries, so studies at a local level are necessary. On the other hand, the survey to determine the importance of each KPI was structured in such a way that it reflects the perception of the general audience in Europe. This means that the quota strategy was designed not to capture the nuances of the specific needs and preferences of each country, but rather to capture the general vision of the non-specialist audience of the countries included in the study. As an example, we can mention that countries with participation rates of up to 3 % (defined by the ratio between their number of inhabitants and the total number of inhabitants of the countries included in the study) would be represented by the opinion of 15 respondents, which is not representative. To obtain results that reflect the social-economic-cultural differences of each country, it would be necessary to carry out specific surveys in each territory, considering demographic, behavioural, linguistic, educational parameters, among others.

Applications and results

Key performance indicators refinement procedure

The definition of indicators began with the development and compilation of an extensive list of KPIs at an urban scale, composed by 135 indicators, and crossed by six perspectives of Life Cycle Analysis

Table 6
Second round of indicator selection by relevance and impact criteria.

RELEVANCE AND IMPACT CRITERIA	
Rule	Description
Relevance	Each indicator is directly relevant to the specific goals and objectives of the evaluation.
Impactful	Significant impact on the overall assessment.
Comparability	Allow/prevent comparison between different urban areas or time periods.
Redundancy Elimination	Remove indicators that provide overlapping or duplicated information.
Validity	Ensure indicators accurately measure what they are intended to measure.
Reliability	Choose indicators that consistently produce similar results under the same conditions.
Actionability	Prioritize indicators that provide actionable insights for policy or decision-making.

Table 7
Second round of indicator selection by specific concepts and inclusivity.

CONCEPTUAL AND INCLUSIVITY	
Rule	Description
Specificity	Indicators that are specific rather than broad or vague.
Comprehensiveness	Balanced representation across all relevant dimensions
Sensitivity	Indicators sensitive to changes and can capture variations over time.
Stakeholder Relevance	Indicators that reflect the interests and concerns of key stakeholders.
Alignment with Standards	Indicators that align with recognized standards or frameworks.
Inclusivity	Focus on multiple aspects of urban life and the needs of different population groups.

(LCA) and Life Cycle Costs (LCC), Energy and Non-Energy Parameters. Aspects, Proximity Aspects and Social Approach, resulting in 810 potential initial KPIs.

The initial list of 810 indicators was subjected to a comprehensive three-stage optimization process, in collaboration with experts and stakeholders. During the first stage, the KPIs were refined based on the criteria expressed in Table 5.

As a result of the initial pre-selection of KPIs, a total of 50 indicators were obtained, analysed through the six perspectives mentioned above. This methodological operation resulted in a list of 300 indicators evaluated from their technical and formal aspects. In the second stage, the indicators were filtered based on their relevance and impact, ensuring they were appropriate for the granular urban scale intended for the assessment (Table 6). This step requires an analysis to prioritize indicators that would provide relevant and feasible data aimed at urban planning for coziness.

Third, criteria aligned with specific concepts were established to further refine the list of indicators (Table 7). As a result of this process, a list of 23 KPIs was obtained, analysed from the six perspectives already mentioned, culminating in a total of 138 indicators.

After the first indicator pre-selection operations, based on discussions with experts and stakeholders, the next step was to compare the identified KPIs with those used in globally validated urban sustainability indicator frameworks and neighbourhood sustainability assessment tools. For this, the work of Michalina was taken as a reference [29]. These established frameworks and tools comprise indicators that have been validated by the scientific community and tested in practical applications. When comparing the proposed KPIs with those of these frameworks, indicators that aligned with these established frameworks were considered reliable, while those that needed further investigation and validation were discarded (Annex 1).

The set of indicators reached covers a wide range of fundamental aspects to evaluate the coziness of a community. The proposed taxonomy is presented in Table 8.

The KPI taxonomy is organized into three dimensions, eight categories and thirty-seven indicators, each accompanied by the equation that describes its calculation. This structured approach provides information on the perspective from which each indicator is approached. In addition, the “Unit” column shows the unit of measurement of the indicators, normalized to a percentage to ensure comparability and interpretability of the results in different contexts. Annex 2 presents a table with the complete description of each indicator, including its calculation method, units and data sources.

Weighting of the coziness community rating indicators based on European users’ preferences

The methodological design of the indicator weighting system for the Community Coziness Rating can reflect the preferences of larger territories, potentially at local, national, or even regional scales. To test and demonstrate this feature for the regional scale, a large-scale was

Table 8
Final taxonomy of neighbourhood’s coziness key performance indicators.

DIMENSION	CATEGORY	INDICATOR	EQUATION	UNIT
Environmental	Neighbourhood services	Street Lighting and public area	(Area illuminated / Total pedestrian area) 100	%
		Waste Generation	(Waste generated in the area/ neighbour) (Waste generated at national level/ inhabitant) 100	%
		Waste Recycling rate	(Total waste recycled / Total waste generated) 100	%
		Wastewater Processing rate	(Total area covered by the wastewater system / Total area of the neighbourhood) 100	%
		District Heating System	(Building area heated by a district heating system / Total building area) 100	%
		District Cooling System	(Building area cooled by a district cooling system / Total building area) 100	%
		District Heating Potential	(Thermal energy consumption that could be fulfilled with renewable heat sources / Total thermal energy consumption) 100	%
		RES ratio	(Building units with RES installation / Total number of building units) 100	%
		PV ratio	(Building units with PV installation / Total number of building units) 100	%
		STC ratio	(Building units with Solar Thermal Collectors installation / Total number of building units) 100	%
Renewable Energies		GEO ratio	(Building units with geothermal installation / Total number of building units) 100	%
		Potential RES ratio	(Buildings units with the potential to connect to district level RES / Total number of	%

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Table 8 (continued)

DIMENSION	CATEGORY	INDICATOR	EQUATION	UNIT
			building units) 100	
	Demand Side Management	PPA and VPPA contracts	(building units with PPAs – VPPAs / total number of building units) 100	%
		SMI ratio	(buildings that have smart metering systems installed / total number of buildings in the neighbourhood) 100	%
		BEMS ratio	(buildings that applied BEMS / total number of buildings in the neighbourhood) 100	%
Infrastructure	EV chargers	EV charger service ratio	Percentage of cars EV charger could service ((Nominal charger power 24 EV capacity factor) / (15 kWh/100 km)) / average number of kilometres that a driver travels the area in a day.	%
		V2G EV chargers ratio	(V2G capable EV chargers/total number of EV chargers) 100	%
		EV chargers by building	(Buildings with EV charging facilities/total number of buildings) 100	%
	Mobility and transport	Modal Split	Number of daily journeys made by each transport means (on foot, public transport, motorized private transport, and bicycles) divided by the total number of daily journeys.	(table in) %
		Fuel Cars ratio	(Fossil fuel based private transport / Total Inhabitants) 100	%
		EV Cars ratio	(EV based private transport / Total Inhabitants) 100	%
		Bike lanes ratio	(Total length of bike lanes / Total length of roads within the district) 100	%
		Proximity	Assuming you have a table with the minimum distance (in minutes) from each building to each of the places of interest. For each place of interest, it is	%

Table 8 (continued)

DIMENSION	CATEGORY	INDICATOR	EQUATION	UNIT
			calculated the median value of the distance of all buildings. Then, these are divided by the expected time distance from a survey on the pilot or standardized values. Finally, the proximity indicator is the maximum of the relative values.	
		Shared Mobility	(Inhabitants that has at least carried out one trip in some Car Sharing app / Total number of inhabitants) 100	%
	Neighbourhood Building Inventory	Age of the building stock	(Buildings over 30 years old / Total buildings) 100	%
		Renovated 30-year-old buildings	(Rehabilitated buildings over 30 years old / Total buildings over 30 years old) 100	%
		Building EPC Rating	Mean Distribution of Building EPC score	%
		Building SRI	Mean Distribution of Building SRI score	%
		Building LCA	Mean Distribution of Building LCA score	%
		Building Non-Energy	Mean Distribution of Building non-energy resources analysis score	%
Social	Energy poverty	Debt ratio	(Households that have delays in the payment of utility bills / Total households) 100	%
		Low absolute energy expenditure	(Households whose absolute energy expenditure is below half of the national median [M/2] / Total number of households) 100	%
		High share of energy expenditure in income	(Households whose proportion of energy expenditure in income is more than double the national median [2 M] / Total number of households) 100	%
		Thermal comfort threshold	(Households that cannot reach the indoor thermal comfort threshold	%

(continued on next page)

Table 8 (continued)

DIMENSION	CATEGORY	INDICATOR	EQUATION	UNIT
	Quality of Life	Heat Island	$\frac{\text{Total households} - \text{Local area temperature}}{\text{Surrounding temperature}} \times 100$	%
		Air Quality	$\frac{\text{Annual average levels of each pollutant in the assessed area (NO}_2, \text{PM}_{10}, \text{PM}_{2.5})}{\text{annual average levels of each pollutant in the administrative area of belonging}} \times 100$	%
		Noise	$\frac{\text{average year noise level in the area} / \text{average year noise level in the administrative area belonging}}{100}$	%

conducted with the aim of providing a comprehensive assessment framework that incorporates the diverse perspectives and priorities of residents from across Europe. In the Table 9, the EUROPEAN

Table 9

Neighbourhoods rating system weighted according to the preferences of European Users.

DIMENSION	CATEGORY	INDICATOR	MEDIAN SURVEY RESULTS	EUROPE SCALE VALUES	EUROPEAN WEIGHTING
Environmental	Neighbourhood services	Street Lighting and public area lighting	63,94	2	3,13 %
		Waste Generation	59,87	3	1,71 %
		Waste Recycling rate	62,32	2	3,13 %
		Wastewater Processing rate	62,09	2	3,13 %
		District Heating System	66,93	1	6,25 %
		District Cooling System	63,11	2	3,13 %
		District Heating Potential	68,02	1	6,25 %
	Renewable Energies	RES ratio	67,39	1	6,25 %
		PV ratio	60,19	3	1,71 %
		STC ratio	64,71	2	3,13 %
		GEO ratio	59,69	3	1,71 %
		Potential RES ratio	67,38	1	6,25 %
	Demand Side Management	PPA and VPPA contracts	61,55	3	1,71 %
		SMI ratio	57,68	4	1,00 %
BEMS ratio		58,84	3	1,71 %	
Infrastructure	EV chargers	EV charger service ratio	56,31	4	1,00 %
		V2G EV chargers ratio	51,79	5	0,86 %
		EV chargers by building	54,83	4	1,00 %
	Mobility and transport	Modal Split	55,57	4	1,00 %
		Fuel Cars ratio	52,49	5	0,86 %
		EV Cars ratio	52,23	5	0,86 %
		Bike lanes ratio	54,76	5	0,86 %
		Proximity	68,95	1	6,25 %
	Neighbourhood Building Inventory	Shared Mobility	44,06	5	0,86 %
		Age of the building stock	65,47	1	6,25 %
Renovated 30-year-old buildings		64,93	2	3,13 %	
Building EPC Rating		75,88	1	6,25 %	
Building EPC SRI		55,19	4	1,00 %	
Building EPC LCA		64,65	2	3,13 %	
Building EPC Non Energy		50,45	5	0,86 %	
Social	Energy poverty	Debt ratio	46,19	5	0,86 %
		Low absolute energy expenditure	58,9	3	1,71 %
		High share of energy expenditure in income	57,83	4	1,00 %
		Thermal comfort threshold	62,51	2	3,13 %
	Quality of Life	Heat Island	59,22	3	1,71 %
		Air Quality	70,08	1	6,25 %
		Noise	58,19	4	1,00 %

WEIGHTING column reflects the median values of the responses for each KPI. In other words, the weightings used correspond to the preferences of European users for each indicator, with values statistically supported by the survey results. To assign weights to the indicators, respondents answered the following prompt: "The next section asks you to score the categories and indicators proposed for the assessment of neighbourhoods".

To analyse the impacts of the weights provided by European users, the results of the selected indicators in each quintile were explored separately. First of all, Table 10 reveals that among the KPIs evaluated as *Extremely relevant*, the best weighted aspect is the energy efficiency of buildings, supported by a high Building EPC Rating indicator. Secondly, the concern of the respondents is related to quality of life, represented by the air Quality Indicator. Next, the Proximity indicator stands out (from the Mobility and transport category), which refers to the distance in minutes from the home to various points of interest. Following this, there are four indicators with very similar scores, related to the use and potential of renewable energies and district heating systems. Finally, the last indicator identified as extremely relevant is the Age of the Building Stock, related to Building EPC Rating indicator and belonging to the same category (Neighbourhood Building Inventory).

The table also shows the PERCENTAGE OF REPRESENTATION BY CATEGORY, which indicates that the first quintile indicators belong mainly to the categories of Neighbourhood Services (25 %), Renewable Energy (25 %) and Neighbourhood Building Inventory (25 %), with additional representation from the Mobility and Transportation (12.5 %) and Quality of Life (12.5 %) categories. In particular, the categories such as energy poverty, demand management and electric vehicle

Table 10
First quintile, indicators weighted as extremely relevant.

INDICATOR	CATEGORY	DIMENSION	MEDIAN SURVEY RESULTS	PERCENTAGE OF REPRESENTATION BY CATEGORY
Building EPC Rating	Neighborhood Building Inventory	Infrastructure	75,88	
Air Quality	Quality of Life	Social	70,08	
Proximity	Mobility and Transport	Infrastructure	68,95	
District Heating Potential	Neighborhood Services	Environmental	68,02	
RES ratio	Renewable Energies	Environmental	67,39	
Potential RES ratio	Renewable Energies	Environmental	67,38	
District Heating System	Neighborhood Services	Environmental	66,93	
Age of the building stock	Neighborhood Building Inventory	Infrastructure	65,47	

Table 11
Second quintile, indicators weighted as very relevant.

INDICATOR	CATEGORY	DIMENSION	MEDIAN SURVEY RESULTS	PERCENTAGE OF REPRESENTATION BY CATEGORY
STC ratio	Renewable Energies	Environmental	64,71	12,5%
Building EPC LCA	Neighborhood Building Inventory	Infrastructure	64,65	12,5%
Street Lighting and public area lighting	Neighborhood Services	Environmental	63,94	50,0%
District Cooling System	Neighborhood Services	Environmental	63,11	
Waste Recycling rate	Neighborhood Services	Environmental	62,32	
Wastewater Processing rate	Neighborhood Services	Environmental	62,09	
Thermal comfort threshold	Energy Poverty	Social	62,51	12,5%

chargers are not represented among the indicators best valued by European users.

The analysis of the second quintile groups the indicators weighted as *Very important*. Table 11 reveals that indicators related to neighbourhood services predominate in this set, representing 50 % of the selected indicators. These include street and public area lighting, district cooling systems, waste recycling rates, and wastewater processing rates. The high weighting of these indicators reflects the importance that European users place on the management of resources and basic infrastructure in their neighbourhoods. In addition, the STC ratio (Solar Thermal Collectors) and the life cycle assessment of building EPCs represent a significant concern for renewable energies and energy efficiency in infrastructure. These indicators highlight the interest in integrating

sustainable technologies and improving energy efficiency in the urban environment.

Table also shows the presence of the Thermal Comfort Threshold indicator, classified under energy poverty. This indicates the relevance of well-being and living conditions in the assessment of liveability. This indicator emphasizes the need to ensure that buildings provide a comfortable environment, especially in terms of temperature, which is crucial for cozy environments.

In the third quintile (*Moderately relevant* weighting), it was found that the indicators related to energy demand management represent 25 % of the selected KPIs (Table 12). These include the PPA and VPPA contracts and the BEMS ratio. Indicators related to renewable energies also have a representation of 25 %, through the inclusion of the PV ratio

Table 12
Third quintile, indicators weighted as moderately relevant.

INDICATOR	CATEGORY	DIMENSION	MEDIAN SURVEY RESULTS	PERCENTAGE OF REPRESENTATION BY CATEGORY
PPA and VPPA contracts	Demand Side Management	Environmental	61,55	25%
PV ratio	Renewable Energies	Environmental	60,19	
Waste Generation	Neighborhood Services	Environmental	59,87	
GEO ratio	Renewable Energies	Environmental	59,69	
Heat Island	Quality of Life	Social	59,22	
Low absolute energy expenditure	Energy Poverty	Social	58,9	
BEMS ratio	Demand Side Management	Environmental	58,84	

Table 13
Fourth quintile, indicators weighted as slightly relevant.

INDICATOR	CATEGORY	DIMENSION	MEDIAN SURVEY RESULTS	PERCENTAGE OF REPRESENTATION BY CATEGORY
SMI ratio	Demand Side Management	Environmental	57,68	12,5%
EV charger service ratio	EV Chargers	Infrastructure	56,31	25,0%
EV chargers by building	EV Chargers	Infrastructure	54,83	
Modal Split	Mobility and Transport	Infrastructure	55,57	12,5%
Building EPC SRI	Neighborhood Building Inventory	Infrastructure	55,19	12,5%
Noise	Quality of Life	Social	58,19	12,5%
High share of energy expenditure in income	Energy Poverty	Social	57,83	12,5%

and the GEO ratio. Additionally, the Waste Generation indicator (Neighbourhood Services category); the Heat Island indicator (Quality of Life category); and the Low Absolute Energy Expenditure indicator (Energy Poverty category), are also represented among the KPIs to which European residents assign moderate importance as suitable indicators for neighbourhood evaluation.

The indicators weighted as *Moderately relevant* are closely linked to strategic perspectives and the incorporation of environmentally friendly technologies. The low weighting of the PPA and VPPA contracts, Low absolute energy expenditure, and Waste generation indicators demonstrate that this type of “long-term” thinking, with strategic approaches aimed at improving neighbourhood sustainability, is not prevalent among the general public.

Furthermore, the PV ratio, GEO ratio, BEMS ratio, and Heat Island indicators, which focus on technological and environmental aspects

contributing to sustainability, also did not receive high weightings. This outcome highlights the gap between the enthusiasm these technologies generate among urban planning professionals and the disinterest or lack of awareness of them among the general public. Although these indicators play an important role as innovative solutions to reduce energy consumption and improve energy autonomy, they currently seem not to have been embraced by residents and city dwellers.

The case of the fourth quintile showed that indicators within the EV chargers category represent 25 % of the selected KPIs (EV charger service ratio and EV chargers by building). This underscores the *Slight importance* that European users assign to the infrastructure for electric vehicle chargers. In this scenario, indicators related to infrastructure also represent 25 %. This group includes the Building EPC SRI and the Modal Split, reflecting a minimal concern for the smartness of buildings and the diversity and frequency of transport modes in urban areas

Table 14
Fifth quintile, indicators weighted as not relevant at all.

INDICATOR	CATEGORY	DIMENSION	MEDIAN SURVEY RESULTS	PERCENTAGE OF REPRESENTATION BY CATEGORY	
Bike lanes ratio	Mobility and Transport	Infrastructure	54,76	57%	
Fuel Cars ratio	Mobility and Transport	Infrastructure	52,49		
EV Cars ratio	Mobility and Transport	Infrastructure	52,23		
V2G EV chargers ratio	EV Chargers	Infrastructure	51,79		14,3%
Building EPC Non-Energy	Neighborhood Building Inventory	Infrastructure	50,45		14,3%
Debt ratio	Energy Poverty	Social	46,19		14,3%
Shared Mobility	Mobility and Transport	Infrastructure	44,06		

(Table 13).

The inclusion of the SMI Ratio (Smart Metering Infrastructure category) indicator indicates the low importance assigned to smart energy management and the monitoring of energy consumption at the neighbourhood level. Moreover, the indicators of noise, impacting the quality-of-life category, and energy expenditure relative to income, classified under energy poverty, indicate the low relevance that European users find in both indicators.

Finally, Table 14 presents the results obtained for the fifth quintile. Indicators related to mobility and transport infrastructure dominate the lowest quintile, representing 57% of the selected KPIs. These include the ratio of bike lanes, the ratio of fuel cars, the ratio of electric vehicles, and shared mobility. At first glance, this seems to contradict the fact that the Mobility and Transport category is among the best-weighted indicators of the first quintile. However, the difference lies in the specific indicators within this category. The well-weighted indicator in the first quintile is proximity, which refers to distances and accessibility to essential services, while the indicators in the lowest quintile pertain to the energy efficiency of various modes of transport and the availability of infrastructure or low-consumption mobility services. Apparently, users want to live close to places of interest, rather than have efficient transportation to those places.

The V2G EV charger’s ratio, representing 14.3% of the selected indicators, also shows a low priority assigned to advanced EV charging infrastructure. This finding suggests a lack of concern for bidirectional charging technologies, which allow electric vehicles to return energy to the grid.

The Building EPC Non-Energy, part of the neighbourhood building inventory, also appears among the indicators weighted as not relevant at all, almost in opposition to the extreme importance assigned to the Building EPC Energy as the highest-scoring indicator. Non-energy characteristics of buildings are perceived as an insignificant factor in the evaluation of neighbourhood liveability.

Discussion and conclusions

After addressing the challenges of traditional frameworks for energy efficiency, sustainability, and livability, as well as NAS methodologies for neighborhood assessment, we introduced the concept of Coziness as a measure of residents’ preferences on both the urban materiality of the neighborhood and the social aspects of their community. The key aspect

of this concept lies in the incorporation of participatory action methodologies to identify the specific priorities of each community. As a result, a Community Coziness Rating (CCR) and a Neighborhood Indicator Framework (NIF) were developed, based on indicators validated by urban development experts and weighted by non-expert neighborhood residents. These tools are capable of capturing the nuanced needs and aspirations of residents both at large scale, such as national or regional, and at a granular urban scale, even smaller than the neighborhood, ensuring that urban development strategies are aligned with local priorities.

In this regard, it is worth highlighting that the CCR methodological framework is closely aligned with the cluster of projects under the Next-Generation Energy Performance Certificates (EPC) initiative, funded by the Horizon 2020 and Horizon Europe research and innovation programs. These 13 projects¹ were launched in four successive generations, emphasizing co-creation processes over rapid isolated advances. This open approach enables decision-makers at both the EU and Member State levels, as well as stakeholders within the broader EPBD community, to swiftly leverage emerging results for the ongoing process of transposing, implementing, and monitoring the EPBD while ensuring meaningful integration with the policy package.

The CCR proposes a scalable methodology that allows for the analysis of aggregated data across multiple neighborhoods, making it a valuable resource for policymakers seeking to implement coordinated sustainability initiatives. For instance, regional authorities could use CCR-derived insights to identify common patterns and allocate resources to interventions aligned with shared priorities, such as improving energy efficiency or enhancing access to urban services.

Moreover, the indicator weighting methodology proposed by the CCR could complement the assessment frameworks of the Next-Generation EPC project cluster by providing insights into community preferences at the neighborhood level. This would enable municipal governments to align urban policies with both technical data and community priorities.

To validate this proposal, an indicator weighting large-scale survey was conducted among non-expert European users. The analysis of the

¹ 2019: QualDeEPC, U-CERT, and X-tendo2020: D²EPC, E-DYCE, ePANACEA, EPC RECAST2021: crossCert, EUB Super Hub, iBRoad2EPC, TIME-PAC2022: CHRONICLE, SmartLivingEPC.

weights assigned by European citizens to the indicators reveals that KPIs related to tangible assets, such as building energy consumption, the availability of urban services (e.g., district heating systems, public lighting, waste management), renewable energy use, air quality, thermal comfort, and proximity to points of interest within the neighborhood, are considered extremely relevant.

On the other hand, KPIs with medium and low weights seem to be linked to the degree of “abstraction” or technical complexity of the indicator. For example, indicators related to advanced technologies, such as demand management, the presence of electric vehicle chargers, the application of commercially less widespread renewable energy sources, or the readiness of buildings to become smart, received low scores. This suggests a potential lack of public awareness or a limited perception of the immediate benefits of these technologies. Furthermore, the low scores for social indicators, such as low absolute energy expenditure, a high share of energy expenditure in income, and debt ratio, as well as indicators related to mobility and transport, may reflect low public sensitivity to these social and quality-of-life concerns or the perception that other areas are more urgent.

Future research directions emerging from this work include the development of optimized participatory action methodologies to address the identification of stakeholders at the community level, the determination of preferences, and the design of policies adapted to the cultural differences of each neighborhood. Another avenue for exploration could involve conducting national- and local-scale surveys to identify citizens’ preferences, taking into account a finer filtering of cultural differences.

CRedit authorship contribution statement

Leandro Martín Ferrón: Writing – original draft, Investigation. **Cruz Borges:** Conceptualization. **Aitziber Mugarra Elorriaga:** Methodology, Conceptualization. **Oxana Soimu:** Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data will be made available on request.

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