D2.5 Asset methodology assessment in building complex level v2

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Asset methodology assessment in building complex level v2

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Authors List

Leading Author				
First Name		Last Name	Beneficiary	Contact e-mail
Ferrón		Leandro	UDEUSTO	l.ferron@deusto.es
Mugarra		Aitziber	UDEUSTO	aitziber.mugarra@deusto.es
Borges		Cruz	UDEUSTO	cruz.borges@deusto.es
Soimu		Oxana	UDEUSTO	o.soimu@deusto.es
Co-Author(s)				
#	First Name	Last Name	Beneficiary	Contact e-mail
1	Eciso Santocildes	Marta	UDEUSTO	marta.enciso@deusto.es

Reviewers List

Reviewers			
First Name	Last Name	Beneficiary	Contact e-mail
Pablo	Castells	GOI	pablo.castells@goiener.com
Tiberiu	Catalina	AIIR	tiberiu.catalina@gmail.com

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1.0	Leandro Ferrón (UDEUSTO)	10/06/2024	Final version ready for submission

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Executive Summary

This document presents the final asset indicators at the neighborhood level for the SmartLivingEPC project, aimed at developing a methodology to evaluate energy performance and sustainability at the neighborhood scale. This report is the continuation of deliverable 2.2 "Asset assessment methodology in omplex level v1".

Chapter 1 serves as an introduction, outlining the objectives and scope of the deliverable.

Chapter 2 details the methodology for selecting asset KPIs. It covers the refinement procedures, presents a final taxonomy of indicators for neighborhood asset assessment, and includes detailed descriptions for each KPI. Each indicator is defined with its calculation method and characteristics at both the energy and non-energy levels, with a focus on social implications. This section also validates the KPIs by detailing the unit normalization process and verifying implementation feasibility through identified data sources and the reliability of input information.

Chapter 3 explores the scoring of key asset indicators, proposing four different weighting methods. The first method involves generic weighting, assigning equal weight to each indicator to produce an unbiased score. The second method uses participatory action methodologies to tailor the score to the specific needs, culture, and aspirations of each neighborhood. The third method allows individual users to configure the weights of the SmartLivingEPC label to refine property searches based on specific requirements. The fourth method involves a large-scale survey to determine user preferences across Europe, resulting in a European Score that reflects these preferences. This chapter provides a robust framework for evaluating asset performance at the neighborhood level.

The document concludes with a summary of the main findings and contributions of the deliverable.

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List of Acronyms and Abbreviations

Term	Description
BEMS	Building and Energy Management System
EPC	Energy Performance Certificate
EV	Electric Vehicle
GEO	Geothermal
GHG	Greenhouse gas emissions
GIS	Geographic Information System
KPI	Key Performance Indicator
LCA	Life Cycle Analysis
LCC	Life Cycle Cost
PPA	Power Purchase Agreement
PV	Photovoltaic
RES	Renewable Energy System
SMI	Smart Metering Syestems Installes
SRI	Smart Readiness Indicator
STC	Solar Thermal Collector
UV Index	Ultraviolet Index
V2G	Vehicle-to-grid
VPPA	Virtual Power Purchase Agreement

1 Introduction

1.1 Task description

The objective of Task 2.5 is to develop a comprehensive methodology for evaluating the energy performance of building complexes at the neighborhood scale. It is proposed to establish a new rating scheme that integrates assessments of individual building units with additional parameters specific to building complexes. These parameters include energy infrastructure and services available at the neighborhood level, such as street lighting, grid services, smart grids, energy communities, and electric vehicles (EV). In version D2.2 these parameters and the interactions between buildings within a neighborhood were analyzed. This made it possible to provide information on the dynamics of energy consumption and efficiency in urban environments. This document presents the description of the key indicators for the evaluation of assets at the neighborhood scale, outlining the necessary conditions, the calculation data and the prescribed results for the construction of Energy Performance Certificates (EPC) at the urban scale.

1.2 Background and Objectives

The main objective of this deliverable is the development of a new rating scheme for neighborhood scale, based on the assessment of individual building units and additional building complex parameters.

The secondary objectives are:

- Determine the key performance indicators (KPI) of the SmartLivingEPC at neighborhood level,
- Verify the data availability and feasibility,
- Verify the data integrity,
- Creating the SmartLivingEPC neighborhood labeling/rating.
- Propose a specific methodology for the execution of the evaluation, based on participatory action methodologies in the KPI weighting and urban planning processes.

1.3 Scope of the deliverable

As advances in smart grids and energy communities foster interactive energy management between buildings, the need for a comprehensive neighborhood-scale energy rating system becomes increasingly relevant. The SmartLivingEPC project addresses this need by introducing a novel methodology for energy classification at the neighborhood level. This methodology takes advantage of two key aspects:

- Categorization of individual building units: Analyzes the energy performance of individual buildings within the neighborhood.
- District Scale: Adds layers of complexity to the SmartLivingEPC calculation, incorporating specific aspects of the district scale, such as urban energy infrastructure and services, the mobility and transportation dimension, quality of life and energy poverty within the district.

The deliverable presents the results of the certificate created within the framework of the SmartLivingEPC projects, which reflects energy, non-energy and social aspects. . This report continues from deliverable D2.2, titled "Asset Assessment Methodology in Complex Level v1". The project has demonstrated the effectiveness of this neighborhood certification scheme by applying it to a district within Leitza, Spain, made up of a group of six nearby buildings that are part of an energy community.

2 Asset Key Performance Indicators selection methodology

The indicators used to define the asset energy performance of a neighborhood are essential tools for policymakers to make decisions that lead to the design of more sustainable, comfortable, and energy-efficient urban areas aligned with the culture and needs of residents. As environmental regulations and market demand for more environmentally conscious technological solutions increase, the identification, definition, and conceptual construction of indicators become central in the urban environment.

These asset indicators are tangible metrics to quantify, analyze, and improve the energy efficiency, environmental impact, and environmental comfort of residents in different urban areas. Their definition requires a multidimensional vision that encompasses energy consumption, environmental impact, and the well-being of residents.

Energy performance indicators are vital for assessing how much energy a neighborhood consumes and the efficiency of its energy services and systems. The evaluation of energy consumption can drive specific strategies for optimizing systems or implementing energy-saving strategies. This not only reduces economic and energy costs but also minimizes the carbon footprint, aligning with global efforts to combat climate change.

Environmental indicators, such as greenhouse gas emissions or resource use, provide a measure of the impact that a neighborhood has on its environment. These indicators can highlight areas with opportunities for improvement, whether technical or strategic, so that policymakers can design policies or implement practices that reduce emissions, such as promoting the use of renewable energy sources, adapting public transport service routes, or improving neighborhood accessibility systems. The goal is to create spaces that are not only energy-efficient but also comfortable and healthy for residents and regular and occasional visitors.

Based on the preliminary taxonomy of indicators presented in Deliverable D2.2, this section describes the methodological operations used to optimize the number of indicators facing the construction of an efficient energy rating scheme at the neighborhood scale. The initial taxonomy was derived from an analysis of energy-consuming services at the urban level and a list of KPIs in-extenso extracted from infrastructures, services, and dynamics present at the neighborhood scale. To achieve the reduction of indicators, a three-step methodology was implemented:

Indicator refinement procedure:

- Proposal of an initial in-extenso set of indicators.
- Consultation to streamline the extensive set of indicators based on qualitative insights and practical considerations from experts and stakeholders.
- Contrast of the resulting KPIs against the most widely used indicators globally, in reference frameworks for assessing the sustainability of cities.

- Identification and elimination of highly correlated indicators and final KPI selection based on factors such as data availability, reliability, perceived usefulness, and simplicity of understanding.

The application of this methodology resulted in a refined set of indicators that are comprehensive and efficient, providing a solid foundation for the development of an accurate and viable neighborhood-scale energy rating scheme.

2.1 Asset Key Performance Indicators refinement procedure

The task of defining indicators began with the development and compilation of an extensive list of Key Performance Indicators (KPIs) at the urban scale. This initial list contained 810 indicators, covering urban assets, analyzed from the perspectives of Life Cycle Analysis (LCA), Life Cycle Costing (LCC), Energy Parameters, Non-Energy Aspects, Proximity Aspects and Social Perspective.

The initial list underwent a comprehensive optimization process in collaboration with project partners and stakeholders, carried out in three stages. In this initial step of the optimization process, the indicators were refined until the six analytical perspectives were obtained, on which a total number of 138 KPIs depended (See Table 1-Table 3).

Table 1: List in-extenso of SmartLivingEPC Asset Key Performance Indicators

DIMENSION	CATEGORY	INDICATOR
Residential infrastructures	Internal Comfort	Heating assets of Individual buildings (Thermal comfort)
		Cooling assets of Individual buildings (Thermal comfort)
		Ventilation assets of Individual buildings
		Air quality index (Internal)
		Illumination assets of Individual buildings
		Noise and acoustic quality
	Building Envelope	Reflectance of building opaque surfaces
		Absorptance of building materials
		Delimitation infrastructure
		Thermal mass of the building materials
	Common Infrastructures	Appliances assets
		Cooking assets
		Fences, walls, green fences, etc.
		Building parkings
		Elevators and escalator
	Energy and Services	Domestic drinking/hot water for Individual buildings

		Electricity connection for Individual buildings
		Gas connection for Individual buildings
		Renewable energy devices in buildings (PV, solar water heating)
		Community Renewable Energy
		Potential energy flexibility services (demand response, load shredding, etc.)
	Architecture	Passive solar design
		Green building materials
Neighborhood infrastructures	Uban Elements	Roads
		Highway
		Body of water
		Freeways
		Parking Lots
		Street furniture
		Playgrounds
		Bicycle paths
		Assigned areas for pets
		Urban corridor (don't understand)
		Wi-Fi access
		Electric recharging point
		Gasoline charging point
		Motorisation rate (number of personal automobiles per capita)
		Urban forest
	Public Services	Sewage network
		Black waters management system (urban infrastructure, buildings, etc)
		Rain water management
		Security Cameras
		Street Lighting
		Public drinking water
		Bills (Urban electricity, irrigation, sewers, etc)

	Community organization	Neighborhood participation bodies (energy communities, neighborhood associations, etc.)
		Smart grid (smart meters, tele operated transformers and substations, STATCONs and other FACTS devices, price signals, local markets, energy storage, etc.)
		Self-generated energy
	Social interest areas	Infrastructure that concentrates the main commercial activity
		Infrastructure that concentrates the main source of work
		Infrastructure that concentrates the main financial activities
		Infrastructure that concentrates the main of public administration activities
		Infrastructure that concentrate permanent/seasonal tourist attraction
		Infrastructure that concentrate students attending college (different levels)
		Infrastructure that concentrate regular/occasional cultural events (Sports, recitals, etc)
Mobility (Distance in minutes by walk, using personal mobility, using public transport, using shared vehicles or using private vehicles)	Education	Child care / primary
		Secondary
		Tertiary
	Health services	Primary care
		Social Care
		Hospitals
	Provisioning	Shoppings (clothes, hardware store, etc)
		Supermarkets (non-perishable food, cleaning products, etc.)
		Fresh ingredients (Food, vegetables, etc)
		Pharmacy
	Social Activities	Entertainment (Cinema, theatre, disco, museums, etc)
		Socialization (bars, cafes, pubs, etc.)
		Green zones (Squares, parks, etc.)
	Institutional services	Banks
		Public administration
		Train Station

	Medium and long-distance transport	Bus Station
		Ports
		Airport
Confort	Lighting	Daylight availability
		Light Pollution
		Glare (pedestrian, drivers)
	Thermal loads	Street Insulation (tree cover, building shadows, etc)
		Reflectance of surfaces (Asphalt, building facades, curtain wall, surface coatings, etc)
		Absorptance urban materials (Asphalt, building facades, green areas, urban furniture, etc)
		Heat Island Effect (an urban area that is significantly warmer than its surrounding rural areas due to human activities.)
		Sky View Factor (the ratio of sky hemisphere visible from the ground (not obstructed by buildings, terrain or trees))
	Air quality	Air quality index (external)
		Flow field in Urban Environment
		Allergens
		Particles (PM)
		CO_2 and other pollutants
	Noise	Acoustic barriers
		External noise
	Healt	Mental health (scenery, access to daylight)
		Landscape Views
		Accessibility (easiness to access people with disabilities to the different infrastructures)
		City health index
	Safety	Road conditions
		Criminality index
Land use	Purpose	Residential
		Commercial
		Industrial
		Green Zones

		Parking
		Energy generation capacity
		Energy storage capacity
	Surroundings	Industrial surroundings
		Farmland
		Night Life surroundings
		Rural surroundings
		Shantytown surroundings
		Highway surroundings
		Wildlife environment
		Solid Waste Landfills (Municipal or illegal)
		Infrastructures that produce unpleasant smells
		Graveyards
		Prison
	Urban features	Functional Diversity (Degree of homogeneity of the functions of buildings in an area.)
		Complexity of the urban fabric (Characteristics of the streets organization: orthogonal, non-regular, etc.)
		Commute distance to (primary, secondary or tertiary education, primary, social or childcare, hospitals, shoppings, green zones, public administration, etc.)
		Distance to nearest public transport
		Urban density (of the different land uses)
Natural Conditions	Weather	Temperature
		Humidity
		Wind
		UV index
	Location	Latitude, longitude, altitude
		Topography (landforms, elevations, water courses etc.)
		Heliophany
	Natural Disasters	Volcanic eruptions
		Earthquakes
		Tsunamis

		Floods
		Landslides
		Avalanches
		Tornados
		Extreme temperatures (hot or cold)
		Pest (Insects, rats, etc.)
		Ionizing radiation

Table 1 is composed of 135 indicators that were defined from 6 different perspectives: Life Cycle Analysis (LCA), Life Cost Cycle (LCC), Energy Parameters, Non-Energy Aspects, Proximity Aspects and Social Perspective. For reasons of visibility and readability, Table 1 just shows the names of the 135 KPIs. The complete version of the table contains, for each KPI, a tentative definition elaborated from each of the 6 perspectives mentioned above, resulting in an initial list of 810 indicators.

Table 2: List of SmartLivingEPC Asset Key Performance Indicators debugged with contributions from partners and stakeholders

DIMENSION	CATEGORY	INDICATOR
Building infrastructures	Building ratings	Individual assets ratings from buildings (heating, cooling, ventilation, illumination, appliances and cooking)
	Complex rating	Common infrastructures
Urban Design	Mobility (Distance in minutes by walk, using personal mobility, using public transport, using shared vehicles or using private vehicles)	Child care / primary education
		Secondary education
		Tertiary education
		Primary care
		Social Care
		Hospitals
		Shoppings
		Entertaiment
		Green zones
		Banks
		Public administration
Confort	Illumination	Natural Lighting
		Artificial Lighting
	Thermal loads	Insulation

		Solar passive gains (building interactions)
		Heat Island Effect
		Sky View Factor
		Natural based solutions
	Air quality	External air quality
		Internal air quality
		Natural ventilation
		Humidity
		Allergens
		Particles (PM)
		CO_2 and other pollutants
	Noise	Internal noise
		External noise
	Health	Fungus
		Ionizing radiation
		Dangerous wildlife
		Mental health (scenary, access to outdoor linght)
		Other chemicals
	Safety	Road
		Criminality
Spacial distribution	Land use	Generation capacity
		Storage capacity
		Diversity of land uses (Residential, Comercial, Industrial, Green zones, Parking, etc.)
		Complexity of the urban fabric
		Urban density (of the different land uses)
Urban infrastructures	Disponibility of public services	Electricity
		Water
		Waste
		Illumination
		Public transport
		Parking spaces
		Security forces
		Telecomunications

		Energy vectors (charging points / gas stations)

The Table 2 presents a list of 50 indicators analysed through six different perspectives: Life Cycle Analysis (LCA), Life Cycle Cost (LCC), Energy Parameters, Non-Energy Aspects, Proximity Aspects and Social Considerations. The table displays only the names of the indicators and does not include their tentative definitions. This methodological operation resulted in a list of 300 indicators. The criteria used to reduce the indicators from the first taxonomy focused on streamlining and condensing the future evaluation processes while ensuring comprehensive coverage of essential aspects. Factors considered included relevance to neighborhood evaluation and redundancy with other indicators. This selection process aimed to identify the most important dimensions while preserving the integrity and effectiveness of the evaluation process.

Table 3: List of SmartLivingEPC Asset Key Performance Indicators with Highly Redundant Indicators Removed

DIMENSION	CATEGORY	INDICATOR
Enviromental	Neighborhood Services	Urban Conditioning (District heating and cooling)
		Domestic Hot Water
		Lighting
		Water distribution
		Sewage
		Service Station (fuels)
		Electricity distribution
		Telecommunication services
		Solid waste management
	Urban Comfort	Heat Island
		Air quality
		Noise
	Energy	Energy Generation
		Energy Storage
Social	Urban mobility	Transport
		Accesibility
	Economics	Logistics
		Real-life conditions
Institutional	Urban Plannig	Urban fabric
		Urban Density
		Urban Diversity
	Green Areas	Urban green spaces / forests

		Urban forestry

Table 3 presents a list of 23 KPIs analysed from the same six perspectives: Life Cycle Assessment (LCA), Life Cycle Cost (LCC), Energy Parameters, Non-Energy Aspects, Proximity Aspects, and Social Aspects. The table displays only the names of the indicators and excludes their provisional definitions. This methodological operation resulted in a list of 138 indicators.

The next step was to benchmark the list of identified KPIs against those used in globally adopted urban sustainability indicator frameworks and neighborhood sustainability assessment tools. These assessment frameworks and tools consist of indicators that have been validated by the scientific community and through field testing. By comparing our KPIs with those of well-established urban sustainability indicator frameworks and neighborhood sustainability assessment tools [1], we were able to identify which indicators could feasibly be retained. Indicators that aligned with established frameworks were considered reliable, while those requiring further study and validation were designated for possible exclusion (Table 4). Further explanation of each SmartLivingEPC proposed indicator provided in Table 6.

Table 4: Contrast between SmartLivingEPC Asset Key Performance Indicators and global urban sustainability indicators

MOST FRECUENTS INDICATORS USED IN URBAN SUSTAINABILITY FRAMEWORKS	DIMENSION	CATEGORY	OUR PROPOSED INDICATOR
Municipal waste generated—in kg per capita	Environmental	Neigbourhood services	Waste Collection
Percentage distribution of average daily journeys: on foot, public transport, motorised private transport, and bicycles			Public Transport
Domestic water consumption (litres/capita/day/year)			Drinking Water
Share of population connected to a public sewerage system and wastewater treatment system (%)			Sewage
Green area within the city (forests, parks, gardens, etc.) per inhabitant (m2/inhabitant)			Green Space
Share of a city's total energy consumption that comes from renewable sources as a share of the city's total energy consumption (%)		Energy	Renewable Energy rate: Electricity
Total consumption of electricity in kWh per capita			Total Energy Consumption: electricity
Number of personal automobiles per capita			Total Energy Consuption: fuels
Number of times that the limit of pollutants the NO2, PM10, O3 is exceeded	Social	Quality of Life	Air quality
Number of times that the limit of Db is exceeded			Noise Levels
% of area affected by the heat island effect (excess of temperature)		Life conditions	Heat Island Effect
Percentage of population living within 500 m of basic public services (%)			Proximity

Connection to services—percentage of households are connected to piped water, sewerage, electricity, gas distribution network, and broadband internet (%)			Cost of Innaction
Equity: Income distribution (Gini Coefficient)			Burden of Poverty

An optimised taxonomy of 84 KPIs was developed through this operation (resulting from the multiplication of 14 main indicators by the 6 perspectives of analysis). The KPIs were classified into 4 categories and organised into 2 dimensions. By using existing global assessment frameworks and tools, this simplified taxonomy offers a comprehensive and concise framework to determine which aspects are of relevance in the evaluation of the SmartLivingEPC at the neighborhood scale.

2.2 Asset Key Performance Indicators Taxonomy

With the objective of providing solidity and reliability in practice to the set of proposed KPIs, work was done on the identification and elimination of highly correlated indicators and on the presentation of a final selection of KPIs based on factors such as data availability, reliability, usefulness perception and simplicity of understanding. This operation took the KPI refinement process to its final selection stage (Table 5).

These indicators cover a wide range of aspects that are crucial for evaluating the performance of a neighborhood. The indicators are classified into three main dimensions: Environmental, Infrastructure, and Social.

- The Environmental dimension includes indicators for calculating services at the neighborhood level, using renewable energy at the district scale, and implementing demand-side management as a strategy for controlling energy consumption. These metrics are crucial for comprehending the energy efficiency and environmental impact of the neighborhood. The calculation methodologies for these indicators involve analysing data from the city council, energy supply companies, and resident surveys.
- The infrastructure dimension focuses on indicators that evaluate aspects related to mobility and the inventory of buildings within the area to be evaluated. These parameters include the availability of EV charger services, the modal split of residents' trips, proximity, and the ratios of fuel-powered and electric cars. Calculation methodologies could involve data from resident surveys and cadastral databases, among others.
- Social indicators are essential to evaluate urban variables from the point of view of their possible impacts on the most vulnerable sectors. These indicators consider aspects related to environmental comfort, such as noise, air quality, and heat island, as well as quality of life factors, such as per capita income, debt ratio, and average energy consumption per household. They help to understand the long-term social implications of urban design. The calculation methodologies involve meteorological, physical, and economic data.

Table 5: Final Taxonomy of SmartLivingEPC Asset Key Performance Indicators

DIMENSION	CATEGORY	INDICATOR	EQUATION	UNIT
Environmental	Neighborhood services	Street Lighting and public area lighting	(Area illuminated / Total pedestrian area) *100	%

		Waste Generation	(Waste generated in the area/neighbor) * (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 neighborhood) *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	%
	Renewable Energies	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	%
		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 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 neighborhood) * 100	%
		BEMS ratio	(buildings that applied BEMS / total number of buildings in the neighborhood) * 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 kilometers 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 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 carry out one trip in some Car Sharing app / Total number of inhabitants) * 100	%
	Neighborhood 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	%
		SmartLivingEPC Asset Rating	Mean distribution of Asset Rating EPC score	%
		SmartLivingEPC SRI	Mean distribution of SRI score	%
		SmartLivingEPC LCA	Mean distribution of LCA score	%
		SmartLivingEPC Non Energy	Mean distribution energy and 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 [2M] / Total number of households) * 100	%
		Thermal comfort threshold	(Households that cannot reach the indoor thermal comfort threshold / Total households) * 100	%
	Quality of Life	Heat Island	(Local area temperature / Surrounding temperature) * 100	%

		Air Quality	(Annual average levels of each pollutant in the assessed area (NO_2, PM_{10}, $PM_{2.5}$) / annual average levels of each pollutant in the administrative area of belonging) * 100	%
		Noise	(average year noise level in the area/ average year noise level in the administrative area belonging) * 100	%

The final set of asset indicators is presented in Table 5 following the identification and elimination of highly correlated indicators and the final selection of KPIs based on various factors such as data availability, reliability, perceived usefulness, and ease of understanding. The taxonomy of KPIs is organized into three dimensions, eight categories, and thirty-seven indicators, each accompanied by an equation outlining the calculation methodology. This structured approach provides insights into the perspective from which each indicator is addressed. Additionally, the "Unit" column specifies the measurement unit for each indicator, reflecting efforts made towards unit normalization, enhancing the comparability and interpretability of the results across different contexts.

2.3 Asset Key Performance Indicators Description

The SmartLivingEPC neighborhood rating system places a strong emphasis on integrating environmental sustainability as a core principle. Its primary goal is to provide a comprehensive evaluation of a neighborhood's environmental impact, covering various indicators that assess energy, non-energy, environmental and social related issues, among others. These indicators have been meticulously designed to align with the framework of European methodologies used for assessing and disclosing the sustainability attributes of urban áreas. This section presents a detailed description of neighborhood-level asset indicators, in tabular format, facilitating an organized understanding of each metric. The table format lists the 'Indicator Name', 'Indicator Description' (including definition, calculation methodology and possible data sources) and 'Unit and Source' (showing the unit of measurement and the specific file path when accessing the Leitza pilot data source),(Table 6).

Table 6: SmartLivingEPC Asset Key Performance Indicators description

INDICATOR NAME	INDICATOR DESCRIPTION	UNITS AND SOURCE
Street Lighting	Street Lighting and the lighting of public areas refers to the availability of artificial night public lighting, road sign lighting and advertising elements. Lighting not only impacts aspects of energy consumption, but also extends to broader aspects, such as accessibility, the feeling of personal security, road safety and psychological comfort. This indicator denotes the percentage of neighborhood surface illuminated over the total pedestrian areas of the neighborhood, multiplied by 100. The data that make up this indicator come from municipal GIS maps.	**Unit** % **Source** geoLEITZA (navarra.es) **Path** - Capas Disponibles › Geo Leitza › Servicios y equipamiento › Alumbrado Público

Waste Generation	The "Waste Generation" indicator is the amount of waste generated per person in the urban populations of the evaluation area. In practical terms, the indicator shows the % of waste generated per person in the assessed area compared with the average amount of waste generated at country level. To determine this, you must take the total amount of waste generated in the area and divide it by the number of inhabitants. Then you normalize this value by the average waste generated at the country level and multiply by 100. Primary data can be obtained from municipal information and public observatories at national level. The social impacts of a high value for the "Waste Generation" indicator can be the accumulation of garbage in public spaces and residential areas, mainly affecting populations with fewer resources.	**Unit** % **Source** geoLEITZA (navarra.es) and http://www.navarra.es/home_es/Temas/Medio+Ambiente/Residuos/Inventarios+de+residuos.htm#header2 **Path** - Capas Disponibles › IDENA › Medio Ambiente › Residuos › Ubicaciones Potenciales › Compostaje y Fracción Resto.
Waste Recycling rate	The indicator "Waste Recycling Rate" evaluates the processing process of waste materials generated by the urban populations of the evaluation area. This KPI indicates the percentage of waste that is recycled within the evaluated area. To determine this, it is necessary to determine the total waste that is recycled and divide it by the total waste generated in the neighborhood and normalize the value by multiplying it by 100. Primary data can be obtained from municipal information or from the nearest public administration headquarters. The social impacts of a low value for the "Waste Recycling Rate" indicator can be the accumulation of garbage in public spaces and residential areas, the risk of transmission of diseases, pests, exposure to dangerous substances, air, soil and water, mainly affecting populations with fewer resources.	**Unit** % **Source** geoLEITZA (navarra.es) and http://www.navarra.es/home_es/Temas/Medio+Ambiente/Residuos/Inventarios+de+residuos.htm#header2 **Path** - Capas Disponibles › IDENA › Medio Ambiente › Residuos › Ubicaciones Potenciales › Compostaje y Fracción Resto.
Wastewater Processing rate	"Wastewater Processing rate" indicator refers to the availability of wastewater treatment services. Wastewater services have relevant positive environmental and social effects, but they could produce a significant impact by consuming energy, producing emissions, by-products, and waste to be disposed of. This indicator denotes the percentage of neighborhood surface covered by the wastewater system over the total area of the neighborhood, multiplying by 100. The data that make up this indicator come from municipal GIS maps.	**Unit** % **Source** geoLEITZA (navarra.es) **Path** - Capas Disponibles › IDENA › Servicios de Utilidad Ciudadana › Agua Abastecimiento
District Heating System	The District Heating System indicator refers to the amount of energy used by centralized systems that provide heat to multiple buildings or residences in a specific area or district. These systems typically generate heat using more efficient and environmentally friendly methods, optimizing energy efficiency, reducing greenhouse gas emissions and	**Unit** % **Source** Municipal GIS or by asking the EPC.

	moving towards a more sustainable and integrated approach to district heating. Since this is a buildable property, it is proposed to evaluate the indicator as the percentage of the Building area heated by a district heating system divided by the total building area, multiplied by 100. The information for its calculation can be obtained from the municipal GIS or by asking the SmartLivingEPC. From a social perspective, this indicator can be addressed through the concept of energy poverty, defined as a situation in which individuals or households cannot afford adequate levels of essential energy services, such as heating, cooling, lighting and the use of household appliances. This concept highlights the intersection of economic, social and environmental vulnerabilities. Energy poverty impacts living conditions, health problems and social exclusion. The approach to determine its weight is through the percentage of households with energy poverty. The data to define it can be obtained from public statistics or through surveys of pilots.	The indicator does not apply to the pilot
District Cooling System	The District Cooling System indicator refers to the amount of energy used by centralized systems that provide heat to multiple buildings or residences in a specific area or district. These systems typically generate cool air using more efficient and environmentally friendly methods, optimizing energy efficiency, reducing greenhouse gas emissions and moving towards a more sustainable and integrated approach to district cooling. Since this is a buildable property, it is proposed to evaluate the indicator as the percentage of the Building area cooled by a district cooling system divided on the total building area, multiplied by 100. The information for its calculation can be obtained from the municipal GIS or by asking the SmartLivingEPC. From a social perspective, this indicator can be addressed through the concept of energy poverty, defined as a situation in which individuals or households cannot afford adequate levels of essential energy services, such as heating, cooling, lighting and the use of household appliances. This concept highlights the intersection of economic, social and environmental vulnerabilities. Energy poverty impacts living conditions, health problems and social exclusion. The approach to determine its weight is through the percentage of households with energy poverty. The data to define it can be obtained from public statistics or through surveys of pilots.	**Unit** % **Source** Municipal GIS or by asking the EPC. The indicator does not apply to the pilot

District Heating Potential	The district heating potential indicator refers to the availability of waste energy generated by some industry or factory that could be used to provide heat to multiple buildings or residences in a specific area or district. It is proposed to evaluate the indicator as the thermal energy consumption that could be covered with residual heat over the total thermal energy consumption of the assessed area, multiplied by 100. The information for its calculation can be obtained by crossing the municipal GIS with data from the SmartLivingEPC.	**Unit** % **Source** geoLEITZA (navarra.es) **Path** - Capas Disponibles › IDENA › Industria y Energía › Polígonos Industriales Capas Disponibles › IDENA › Cartografía e Imágenes › Cartografía 1:1000 (SIUN) › Cartografia 1:1000. Construcciones › Edificio Singular
RES ratio	The “RES ratio” indicator evaluates the presence of renewable energy systems within the assessed district. In practical terms, the indicator shows the percentage of buildings within the evaluated area that have some RES installed. To determine this, it is necessary to determine the total number of RES installed, divide it by the total number of buildings in the evaluated neighborhood, and multiply by 100. Primary data must be obtained by asking on a house-by-household. The social impacts of a low value for the “RES ratio” indicator can be excessive consumption of energy from the grid, lack of energy autonomy and high payments for consumption, mainly affecting populations with fewer resources.	**Unit** % **Source** geoLEITZA (navarra.es) **Path** - Capas Disponibles › IDENA › Industria y Energía › Energía Solar Fotovoltaica › Plantas solares fotovoltaicas en servicio.
PV ratio	The “PV ratio” indicator evaluates the presence of Photovoltaic systems within the evaluation area. In practical terms, the indicator shows the percentage of buildings within the assessed area that have some PV system installed. To determine this, it is necessary to determine the total number of PV installed, divide it by the total number of buildings in the evaluated neighborhood, and multiply by 100. Primary data must be obtained by asking on a house-by-household. The social impacts of a low value for the “PV ratio” indicator can be excessive consumption of energy from the grid, lack of energy autonomy and high payments for consumption, mainly affecting populations with fewer resources.	**Unit** % **Source** geoLEITZA (navarra.es) https://transicion-energetica.navarra.es/pages/potencial **Path** - Capas Disponibles › IDENA › Industria y Energía › Energía Solar Fotovoltaica › Plantas solares fotovoltaicas en servicio.
STC ratio	The “STC ratio” indicator evaluates the presence of Solar Thermal Collectors systems within the neighborhood. In practical terms, the indicator shows the percentage of buildings within the assessed area that have some STC system installed. To determine this, it is necessary	**Unit** % **Source** geoLEITZA (navarra.es)

	to determine the total number of STC installed, divide it by the total number of buildings in the evaluated neighborhood, and multiply by 100. Primary data must be obtained by asking on a house-by-household. From a social view, a low value for the "STC ratio" indicator can be excessive consumption of energy from the grid, lack of energy autonomy and high payments for consumption, mainly affecting populations with fewer resources.	https://transicion-energetica.navarra.es/pages/potencial **Path** - Capas Disponibles › IDENA › Industria y Energía
GEO ratio	The "GEO ratio" indicator evaluates the presence of Geothermal systems within the neighborhood. In practical terms, the indicator shows the percentage of buildings within the assessed area that have some GEO system installed. To determine this, it is necessary to determine the total number of GEO installed, divide it by the total number of buildings in the evaluated neighborhood, and multiply by 100. Primary data must be obtained by asking on a house-by-household. From a social view, a low value for the "GEO ratio" indicator can be excessive consumption of energy from the grid, lack of energy autonomy and high payments for consumption, mainly affecting populations with fewer resources.	**Unit** % **Source** Municipal GIS or by asking the EPC. The indicator does not apply to the pilot
Potential RES ratio	The RES potential ratio indicator takes into account buildings with availability to connect to renewable energy systems at the district level in a specific area. It is proposed to evaluate by counting individual buildings that could be connected to RES at the district level divided by the total number of buildings in the evaluated area, multiplying by 100. The information for its calculation can be obtained from the municipal GIS or by asking the SmartLivingEPC.	**Unit** % **Source** geoLEITZA (navarra.es) **Path** - Capas Disponibles › IDENA › Administración del territorio › Foro Entidades Locales › Energías Renovables › Mapa Solar › Potencial energético de los edificios.
PPA and VPPA contracts	The "PPA and VPPA Contracts" indicator shows, from a Demand Side Management approach, the number of PPA and VPPA contracts available per building unit in a neighborhood. To calculate it, you must take the number of buildings that have active PPA and VPPA contracts divided by the total number of buildings in the neighborhood and multiplying by 100. Primary data can be obtained through surveys or by going to the records of energy companies or energy communities.	**Unit** % **Source** Surveys to neighbors or by going to the records of energy companies or energy communities.
SMI ratio	The "Smart Metering Installed ratio" indicator shows, from a Demand Side Management perspective, the number of buildings in a neighborhood that have smart metering systems. To calculate this, you need to take the number of buildings that have smart metering systems	**Unit** % **Source** Contadores inteligentes | i-DE - Grupo Iberdrola

	installed, divide it by the total number of buildings in the neighborhood, and multiply by 100. Primary data can be obtained through surveys or by going to the records of energy companies or energy communities.	
BEMS ratio	The "Building Energy Management System ratio" indicator shows, from a Demand Side Management approach, the number of buildings in a neighborhood that have Building Energy Management System. To calculate this, you need to take the number of buildings that applied BEMS divided by the total number of buildings in the neighborhood, and multiplying by 100. Primary data can be obtained through surveys or by going to the records of energy companies or energy communities.	**Unit** % **Source** Municipal GIS, by asking the EPC or records of energy companies or energy communities. The indicator does not apply to the pilot
EV charger service ratio	The "EV charger service rate" indicator shows, within a neighborhood, what percentage of cars (in the total fleet) could be powered thanks to the installed capacity of EV chargers. For example, if a neighborhood has an inventory of 1,000 electric cars and the installed capacity of electric vehicle chargers can deliver 500 full charges per day, the indicator will have a value of 0.5 (or 50%). Thus, its calculator method is proposed in two blocks. On the one hand, the nominal power of the charger fleet, and on the other, the demand of the vehicle fleet. Thus, the indicator is measured according to: ((Nominal power of the charger, multiplied by 24 hours, multiplied by an EV capacity factor), divided (15 kWh/100 km)) determined by the average number of kilometers that a driver usually travels the area in one day (in Spain it is 33 kilometers) The information for its calculation can be obtained from the municipal GIS or by asking the SmartLivingEPC.	**Unit** % **Source** geoLEITZA (navarra.es) **Path** - Capas Disponibles › IDENA › Transporte y Movilidad › Recarga de Vehículos Eléctricos › Puntos de Recarga de Vehículos Eléctricos.
V2G EV chargers ratio	The V2GEv chargers ratio indicator shows the quantity of EV with V2G capability in the total fleet of EV chargers. For its calculation it is necessary to take the number of V2GEv capable chargers within the assessed district, divide it by the total fleet of EV chargers, and multiply by 100.	**Unit** % **Source** geoLEITZA (navarra.es) **Path** - Capas Disponibles › IDENA › Transporte y Movilidad › Recarga de Vehículos Eléctricos › Puntos de Recarga de Vehículos Eléctricos.
EV chargers by building	The "EV chargers per building" indicator shows the number of EV chargers available per unit building in a neighborhood. To calculate it, you must take the number of electric vehicle chargers, divide it by the total number of buildings in the neighborhood, and multiply by 100.	**Unit** % **Source** It is necessary to ask in each building
Transport mode	The "Transport Mode" indicator reflects the means of transportation that residents of a neighborhood use and the frequency with which they	**Unit** % **Source**

	do so. For this, the indicator takes the "modal split" as a metric that reflects how residents choose to travel, whether by car, public transport, bicycle, walking or other means. The data for its determination can be obtained from the nearest available public administration or through surveys during the EPC analysis. For an accurate assessment from Energy, ACV and LCC perspectives, it would be necessary to develop specific EPCs for this type of urban assets.	geoLEITZA (navarra.es) **Path** - Capas Disponibles › IDENA › Transportes y Movilidad › MCP. Transporte
Fuel Cars ratio	The indicator "Fuel Cars Ratio" evaluates the presence and quantity of vehicles powered by fossil fuels per inhabitant within the evaluated district. In practical terms, the indicator is calculated by determining the total number of private vehicles powered by fossil fuels over the total number of inhabitants of the inhabited area, multiplying by 100. Primary data will be obtained by asking house by house.	**Unit** % **Source** It can be obtained through the circulation tax, managed by the city council.
EV Cars ratio	The indicator "EV Cars Ratio" evaluates the presence and quantity of vehicles powered by electricity per inhabitant within the assessed district. In practical terms, the indicator is calculated by determining the total number of private vehicles EV powered over the total number of inhabitants of the neighborhood area, multiplying by 100. Primary data will be obtained by asking house by house.	**Unit** % **Source** It can be obtained through the circulation tax, managed by the city council.
Bike lanes ratio	The indicator "Bike lanes ratio" shows the presence and quantity of bike lanes within the assessed district. In practical terms, the indicator is calculated by determining the total length of bike lanes divided by the total length of roads within the district, and multiplying by 100. Primary data will be obtained by municipal GIS data.	**Unit** % **Source** geoLEITZA (navarra.es) Path - Capas Disponibles › IDENA › Transporte y Movilidad › Movilidad ciclista
Proximity	This indicator refers to the strategic planning and design of urban environments to minimize physical and social distances between essential services, amenities and residential areas. This concept aims to create more efficient, accessible and interconnected urban spaces, where residents can easily access work, education, healthcare and recreational facilities, often by walking, cycling or using efficient public transport. Proximity improves urban liveability, reduces dependence on private vehicles and contributes to reducing carbon emissions, thus supporting broader goals of sustainability and environmental responsibility in urban development. This indicator denotes the percentage of population at walking distance (500 m) to different neighborhood services: Schools, Hospital, Public	**Unit** % **Source** geoLEITZA (navarra.es) **Paths** - Capas Disponibles › GeoLeitza › Servicios y equipamientos › Bibliotecas/Instalaciones deportivas/Oficinas de Correos/Atención Ciudadana/Oficinas Bancarias/Merenderos/Juegos infantiles/

	Administration, Banks, Shops, Sport Centre and Leisure Spaces, among others. To calculate it, the distance from each building to all places of interest in the neighborhood is calculated using different labels created on the OpenStreetMap platform (www.openstreetmap.org). Some of the proposed labels are: • building=commercial; • building=central office; • building=civic; • services=school; • services=university; • services=hospital; • services=bank; • leisure=park; Finally, the percentage of buildings that are within a 15-minute walk to the different sites of interest is calculated. From a social approach, Proximity expresses the percentage of neighborhood infrastructure that has adequate facilities for accessibility for people with motor disabilities. Building property (wheelchair = yes) can be used on the OSM platform. Finally, a sum of the number of buildings with this property must be made. Primary data will be obtained by municipal GIS data	Capas Disponibles › GeoLeitza › Guía Comercial Capas Disponibles › IDENA › Cultura, Turismo y Ocio › Turismo › Restaurantes/Ocio Capas Disponibles › IDENA › Direcciones y Callejero › Edificaciones/Zonas verdes urbanas › IDENA › Administración del Territorio › Foro Entidades Locales › *Varios*
Sharing Mobility	The indicator "Shared Mobility" is calculated determining the proportion of inhabitants who have utilized some Car Sharing application for at least one trip, divided by the total number of inhabitants within the specified area, multiplied by 100. This approach offers insight into the adoption and utilization of Car Sharing services within a community, providing a quantitative measure of the extent to which individuals engage with this mode of transportation. By considering the ratio of users to the total population, the calculation aims to gauge the prevalence and acceptance of Car Sharing as a viable transportation option within the studied context. Primary data will be obtained by asking the app company.	**Unit** % **Source** - Conduct surveys of city residents to inquire about their use of Car Sharing services. - Car Sharing companies data.
Age of the building stock	The “Age of the building stock” indicator shows the percentage of buildings in the neighborhood that are more than 30 years old. For this, the indicator is calculated as the number of Buildings over 30 years old divided by the total number of buildings, multiplying by 100. Primary data will be obtained by municipal GIS data.	**Unit** % **Source** geoLEITZA (navarra.es) **Path**

		- Capas Disponibles › IDENA › Direcciones y Callejero › Edificaciones
Renovated 30-year-old buildings	The indicator "30-year-old buildings rehabilitated" shows the percentage of buildings in the neighborhood that are more than 30 years old that have been rehabilitated. To do this, the indicator is calculated as the number of rehabilitated buildings over 30 years old divided by the total number of buildings over 30 years old (surround insulation) within the evaluated area, multiplying by 100. Primary data will be obtained by municipal GIS data.	**Unit** % **Source** It is necessary to ask in each building
SmartLiving EPC Asset Rating	The "SmartLiving EPC Asset Rating" indicator is a score that shows the level of efficiency in energy consumption of a building. This indicator is derived directly from the buildings located in the area to be evaluated. If information is not available on all the buildings in the neighborhood, we will seek to have at least one SmartLiving EPC Asset Rating for each type of building, based on its characteristics, its year of construction, etc.	**Unit** % **Source** It is necessary to ask in each building
SmartLiving EPC SRI	The "SmartLiving EPC SRI" indicator is a score that shows the building's ability to host smart-ready services. This indicator is derived directly from the buildings located in the area to be evaluated. If information is not available for all the buildings in the neighborhood, we will seek to have at least one SmartLiving EPC SRI for each type of building, depending on its characteristics, its year of construction, etc.	**Unit** % **Source** It is necessary to ask in each building
SmartLiving EPC LCA	The "SmartLiving EPC LCA" indicator is a score that condenses the inventory of materials and processes used throughout the life cycle of a building to obtain the overall environmental impacts of a building. This indicator is derived directly from the buildings located in the area to be evaluated. If information is not available on all the buildings in the neighborhood, we will seek to have at least one SmartLiving EPC LCA for each type of building, depending on its characteristics, its year of construction, etc.	**Unit** % **Source** It is necessary to ask in each building
SmartLiving EPC Non -Energy	The "SmartLiving EPC non Energy" indicator is a score that shows the impact of non-energy aspects on a building. This indicator is derived directly from the buildings located in the area to be evaluated. If information is not available on all the buildings in the neighborhood, we will seek to have at least one SmartLiving EPC nos Energy for each type of building, depending on its characteristics, its year of construction, etc.	**Unit** % **Source** It is necessary to ask in each building
Debt ratio	The "Debt Ratio" indicator is an economic indicator that shows the percentage of households that are late in paying utility bills. The indicator is calculated as the number of Households that have arrears in the payment of public services over the total households, multiplying by	**Unit** % **Source** informe-AROPE-2023-navarra.pdf (eapn.es)

	100. Primary data will be obtained by asking house by house or from the energy supply company.	
Low absolute energy expenditure	"Low absolute energy expenditure" is a percentage indicator that focuses on the proportion of homes within the evaluated neighborhood that have an absolute energy expenditure less than half of the national median. The indicator is calculated as the number of households whose absolute energy expenditure is less than half of the national median, divided by the total number of households in the neighborhood (M/2), multiplying by 100. Primary data will be obtained by asking house by house or from the energy supply company.	**Unit** % **Source** It is necessary to ask in each building
High share of energy expenditure in income	The "High share of energy expenditure in income" indicator is a percentage value that shows the proportion of households within the assessed neighborhood that have an energy expenditure that doubles the value of the national median. The indicator is calculated as the number of households whose proportion of energy expenditure in income is more than double the national median divided by the total number of households in the neighborhood (2M), multiplying by 100. Primary data will be obtained by asking house by house or from the energy supply company.	**Unit** % **Source** It is necessary to ask in each building
Thermal comfort threshold	The indicator "Thermal comfort threshold" shows the proportion of homes within the evaluated neighborhood that do not meet their thermal air conditioning needs. The indicator is calculated as the number of homes that do not reach the indoor thermal comfort threshold divided by the total number of homes in the neighborhood, multiplying by 100. Primary data will be obtained by asking house by house.	**Unit** % **Source** It is necessary to ask in each building
Heat Island	The "Heat Island" indicator shows the proportion in which the temperature increases locally in certain urban environments, with respect to peripheral areas. The indicator is a score and can be estimated using the concept of relative brightness temperature, proposed by Xu, Xie and Li (2013) as follows: $T_R = 100 * (T_I - T_A) / T_A$ where T_R is the relative surface temperature, T_I is the temperature (LST) observed within the city center and T_A represents the temperature (LST) in the peripheral region (Xu et al., 2013)	**Unit** % **Source** Urban heat island intensity for European cities from 2008 to 2017 derived from reanalysis (copernicus.eu) https://climate.copernicus.eu/demonstrating-heat-stress-european-cities

	A simpler method is to obtain primary data can be obtained from various sources, one of the most consulted being the EU Copernicus program.	
Air Quality	The air quality indicator refers to the condition of the air in and around urban areas, particularly in terms of how clean or polluted it is. Achieving good air quality involves taking actions to reduce pollutants from various sources, such as promoting public transport, using cleaner energy sources and increasing green spaces. Air quality monitoring and management directly impacts public health, environmental health, and overall quality of life in urban areas. This indicator expresses the percentage of the population affected by a low air quality index, in accordance with the parameters established by local or national regulations.	**Unit** % **Source** Datos e informes (navarra.es) and discomap.eea.europa.eu/map/fme/AirQualityExport.htm
Noise	Noise levels refer to the intensity and frequency of unwanted or disturbing sounds within urban environments. This concept is crucial as excessive noise can have significant implications for the health and quality of life of residents. It aims to manage and reduce noise pollution through various means, such as enforcing noise regulations, designing urban spaces that minimize sound transmission, incorporating green spaces that absorb sound, and promoting quiet areas. This indicator is expressed as the percentage of the population that is affected by high levels of noise, according to local/national regulations.	**Unit** % **Source** geoLEITZA (navarra.es) and Noise data reported under Environmental Noise Directive (END) (europa.eu) **Path** - Capas Disponibles › IDENA › Medio Ambiente › Ruido Ambiental › Zonificaciones Acústicas › Zonificación Acústica › Grandes Ejes Varios

Realize that the comprehensive description provides in central column goes beyond the KPI calculation methodology, to explore potential social implications. This includes an examination of how the indicator could impact various aspects of community well-being, social equity, and economic factors. By delving into these broader implications, the descriptions offer valuable insights into the complexity of urban sustainability assessment, highlighting the interconnectedness between environmental performance and social welfare. Considering the social dimensions of each indicator empowers stakeholders to make more informed decisions that prioritize enviromental respect alongside social justice and inclusivity. This holistic approach fosters an understanding of the urban environment dynamics, facilitating effective policy formulation and urban planning strategies aimed at building resilient, equitable, and sustainable communities.

3 Asset Key Performance Indicators Scoring

3.1 Generic Weighting of Asset Key Performance Indicators

The weighting methodology can assign an equal level to each indicator, with a uniform weight of 2.70 for each of the proposed KPIs. This has the advantage of giving equal importance to all aspects, but does not consider the specific requirements of the neighborhoods evaluated.

Table 7: Example of SmartLivingEPC neighborhood rating system indicators with default weighting

DIMENSION	CATEGORY	INDICATOR	UNIT	PROJECT VALUE	DEFAULT WEIGHTING
Environmental	Neighborhood services	Street Lighting and public area lighting	%	100	2,70%
		Waste Generation	%	68	2,70%
		Waste Recycling rate	%	30	2,70%
		Wastewater Processing rate	%	35	2,70%
		District Heating System	%	13	2,70%
		District Cooling System	%	0	2,70%
		District Heating Potential	%	54	2,70%
	Renewable Energies	RES ratio	%	12	2,70%
		PV ratio	%	15	2,70%
		STC ratio	%	0	2,70%
		GEO ratio	%	2	2,70%
		Potential RES ratio	%	70	2,70%
	Demand Side Management	PPA and VPPA contracts	%	0	2,70%
		SMI ratio	%	0	2,70%
		BEMS ratio	%	23	2,70%
Infrastructure	EV chargers	EV charger service ratio	%	21	2,70%
		V2G EV chargers ratio	%	0	2,70%
		EV chargers by building	%	28	2,70%
	Mobility and transport	Modal Split	%	39	2,70%
		Fuel Cars ratio	%	14	2,70%
		EV Cars ratio	%	62	2,70%
		Bike lanes ratio	%	70	2,70%
		Proximity	%	93	2,70%
		Shared Mobility	%	13	2,70%
	Neighborhood Building Inventory	Age of the building stock	%	17	2,70%
		Renovated 30-year-old buildings	%	35	2,70%
		SmartLivingEPC Asset Rating	%	67	2,70%
		SmartLivingEPC SRI	%	43	2,70%
		SmartLivingEPC LCA	%	43	2,70%
		SmartLivingEPC Non Energy	%	20	2,70%
Social	Energy poverty	Debt ratio	%	8	2,70%
		Low absolute energy expenditure	%	5	2,70%
		High share of energy expenditure in income	%	3	2,70%
		Thermal comfort threshold	%	5	2,70%
	Quality of Life	Heat Island	%	69	2,70%
		Air Quality	%	90	2,70%
		Noise	%	84	2,70%
					100

Table 7 presents a **hypothetical example**, for which arbitrary values were defined for each KPI (PROJECT VALUE column). In the example, the cross product of these values and the DEFAULT WEIGHT results in a **Score = 33.77**.

3.2 Weighting of Asset Key Performance Indicators through Participatory Action Methodology

In second place, the weighting of each indicator could be adjusted, allowing modifications to the value of 2.70 if deemed appropriate according to the specific needs or culture of neighborhood residents or policymakers. For this case, the use of participatory action methodologies involving all neighborhood stakeholders in the indicator weighting process is proposed. This weighting approach is the one that best suits the specific needs of neighborhood actors, reflecting aspects of their culture and aspirations. The advantages behind this approach are several:

1) When the certificate is used to identify improvement directors in a neighborhood, different communities will have the possibility to assign completely different importance to the aspects covered in the certificate, respecting the identity and needs of different neighborhoods, and allowing this to be reflected in the final result.
2) This alternative allows citizens who want to use the certificate to select a neighborhood to live in to also define their own set of weights, based on their interests and needs. This would be achieved by ensuring that the SLEPC technological platform allows any certificate user to modify this section.
3) The use of different weights gives policymakers a neighborhood score that does not allow direct comparisons between cities or neighborhoods, avoiding confrontations between neighborhoods and making the SLEPC an easy tool to assimilate and implement from a political and administrative point of view.

Table 8 presents a synthesis of steps to conduct a participatory action methodology that involves all parties in the KPI weighting process.

Table 8: Generic proposal of steps to carry out a participatory action methodology with the community

STAGE	STEP	DESCRIPTION
Stage 1: Scope Definition	Step 1: Defining the Evaluation Area	Identify the physical, administrative, natural, or cultural boundaries of the neighborhood. Consider aspects such as the homogeneity of the urban fabric, physical barriers, or the presence of distinctive elements. Document the boundaries on a map or sketch.
	Step 2: Stakeholder Identification	Develop a comprehensive list of stakeholders involved in the neighborhood, including: residents, owners, tenants, shops, health centers, educational institutions, among others. Representatives of the city council, construction companies, and consultants. Specialized urban evaluators. Other relevant actors, such as neighborhood associations, cultural entities, or business groups.
	Step 3: Awareness Campaign	Design a communication campaign to inform residents about the participatory urban evaluation project. Use diverse communication channels, such as posters, brochures, social networks, informative meetings, or gatherings in

Stage 2: Awareness and Call to Action		public spaces. Emphasize the importance of citizen participation and the impact of the SmartLivingEPC.
	Step 4: Call for Participatory Workshops	Define the dates, times, and places for participatory workshops. Consider accessibility for residents, including schedules compatible with different activities and adequate spaces for group meetings. Use established communication channels to disseminate the call.
Stage 3: Participatory Evaluation	Step 5: Urban Aspects Identification Workshop	Gather residents in a participatory workshop led by an expert facilitator. Present the SmartLivingEPC neighborhood rating scheme and its objectives. Facilitate a brainstorming session to raise awareness among residents regarding the different urban aspects with which they interact daily and their related indicators. Group ideas into the taxonomy categories: Neighborhood services, Renewable Energies, Demand Side Management, EV chargers, Mobility and transport, Neighborhood Building Inventory, Energy poverty and Quality of Life.
	Step 6: Prioritization and Weighting Workshop	Divide participants into small groups. Ask each group to analyze the identified KPIs and prioritize the most relevant ones for evaluation. Use voting or consensus techniques to establish a relative weighting for each indicator Share the results of each group and discuss the different weightings assigned. Reach a consensus on the final weighting of the SmartLivingEPC neighborhood indicators.
	Step 7: Qualitative and Quantitative Data Collection	Design data collection instruments adapted to each prioritized indicator. Instruments may include surveys, interviews, direct observations, or participatory mapping. Implement data collection with the active participation of residents.
Stage 4: Analysis and Conclusions	Step 8: Results Analysis	Analyze the qualitative and quantitative data collected in relation to the weighting established for each Indicator. Identify patterns, trends, and areas for improvement in each evaluated urban aspect. Synthesize the findings into a comprehensive report.
	Step 9: Recommendations Development	Based on the results of the participatory evaluation, formulate concrete recommendations to improve different aspects of the neighborhood, such as energy efficiency, quality of life, urban mobility, etc, Consider the different perspectives and needs expressed by residents during the participatory process. Prioritize recommendations based on their viability, impact, and feasibility. Present the recommendations to the relevant stakeholders.

It must be taken into account that this proposal arises from bibliographic analysis work and has not yet been implemented in the territory [1, 2, 3, 4, 5, 6].

Unlike generic indicator weighting, this participatory approach ensures that the weight of each indicator reflects the priorities and perspectives of community members, stakeholders, and policymakers [5, 6, 7, 8]. The transparency and inclusiveness of the methodology fosters agency and buy-in from all stakeholders, ultimately leading to a more robust and credible neighborhood rating system that effectively addresses community needs and aspirations.

Table 9 shows an example rating scale for stakeholders to assign weights to the indicators based on the relevance they deem appropriate. Each KPI is classified according to the level of relevance collaboratively given to it, ranging from "highly relevant" to "completely irrelevant" (5 to 1 respectively). The "Weighting" column indicates the weight or importance assigned to each rating category in the overall evaluation scheme. These weights assign higher weights to higher relevance ratings. For instance, indicators rated as “Highly Relevant” are assigned a weight of 0.5, signifying their significant importance in the evaluation process compared to indicators rated as “Completely Irrelevant,” which receive a weight of 0.06, indicating minimal importance. The total weighting for all rating categories adds up to 1, ensuring balanced consideration of KPIs.

Table 9: Tentative rating scale to collaboratively assign weights to Asset KPIs

RATING SCALE FOR STAKEHOLDERS	VALUE CODE	WEIGHTING
Highly Relevant	1	0.5
Relevant	2	0.25
Interesting to consider	3	0.12
Minimally Relevant	4	0.07
Completely Irrelevant	5	0.06
		1

Next, Table 10 presents the indicators proposed by the SmartLivingEPC neighborhood evaluation scheme. The "Project Value" column indicates the actual performance level of each indicator within the assessed neighborhood. The "Agreed scale values" column assigns a numerical scale value to each indicator obtained through the participatory process. Finally, the "Co-developed weighting" column represents the weight or importance assigned to each indicator in the overall evaluation scheme.

Table 10: Example of Co-developed SmartLivingEPC neighborhood rating system indicators applying participatory action methodologies with the community

DIMENSION	CATEGORY	INDICATOR	UNIT	PROJECT VALUE	AGREED SCALE VALUES	CO-DEVELOPED WEIGHTING
Environmental	Neighborhood services	Street Lighting and public area lighting	%	100	1	5,6%
		Waste Generation	%	68	2	2,5%
		Waste Recycling rate	%	30	2	2,5%
		Wastewater Processing rate	%	35	5	1,0%

		District Heating System	%	13	4	1,2%
		District Cooling System	%	0	3	2,0%
		District Heating Potential	%	54	3	2,0%
	Renewable Energies	RES ratio	%	12	5	1,0%
		PV ratio	%	15	4	1,2%
		STC ratio	%	0	1	5,6%
		GEO ratio	%	2	1	5,6%
		Potential RES ratio	%	70	2	2,5%
	Demand Side Management	PPA and VPPA contracts	%	0	1	5,6%
		SMI ratio	%	0	2	2,5%
		BEMS ratio	%	23	2	2,5%
Infrastructure	EV chargers	EV charger service ratio	%	21	5	1,0%
		V2G EV chargers ratio	%	0	4	1,2%
		EV chargers by building	%	28	3	2,0%
	Mobility and transport	Modal Split	%	39	3	2,0%
		Fuel Cars ratio	%	14	5	1,0%
		EV Cars ratio	%	62	4	1,2%
		Bike lanes ratio	%	70	1	5,6%
		Proximity	%	93	1	5,6%
		Shared Mobility	%	13	2	2,5%
	Neighborhood Building Inventory	Age of the building stock	%	17	1	6,3%
		Renovated 30-year-old buildings	%	35	2	2,5%
		SmartLivingEPC Asset Rating	%	67	2	2,5%
		SmartLivingEPC SRI	%	43	5	1,0%
		SmartLivingEPC LCA	%	43	4	1,2%
		SmartLivingEPC Non Energy	%	20	3	2,0%
Social	Energy poverty	Debt ratio	%	8	3	2,0%
		Low absolute energy expenditure	%	5	5	1,0%
		High share of energy expenditure in income	%	3	4	1,2%
		Thermal comfort threshold	%	5	1	5,6%
	Quality of Life	Heat Island	%	69	1	5,6%
		Air Quality	%	90	2	2,5%
		Noise	%	84	2	2,5%
						100,0%

The proposed collaborative approach ensures that the weightings reflect the needs, interests, and aspirations of the diverse neighborhood stakeholders, while respecting their unique values, social status, and culture. In this case, the same values assigned to the KPIs were maintained as in the previous example, but the CO-DEVELOPED WEIGHTING was altered with new, randomly assigned values, resulting in a **Score = 37.96.**

3.3 Weighting of Asset Key Performance Indicators for Individual Users

The following alternative involves the inherent flexibility of the SmartLivingEPC neighborhood rating scheme, allowing individual users to effectively adapt the weighting of the indicators according to their priorities.

Two clear examples of the usefulness of this feature of the SmartLivingEPC neighborhood rating system are the case of tenants looking for properties to buy and real estate investors. In the first case, tenants can seek to rent properties located in neighborhoods with particular characteristics, such as the proximity to specific buildings (schools, health centers, their workplaces, etc.), or features like walkability, connection to other areas via public transportation, or the availability of green spaces, among others. In the second case, for those looking to buy properties as an investment, the SmartLivingEPC neighborhood rating system can be useful in locating areas with specific characteristics, which they can identify by configuring the weighting of indicators adapted to their search.

Users will have access to an online platform that allows them to assign weights to the indicators based on their own criteria. Through a user-friendly interface, users will be able to adjust the importance of each indicator according to their specific preferences and priorities. The platform will offer a range of options for adjusting the weighting of indicators and will provide guidance and support to users throughout the entire weighting configuration process, ensuring that they can make informed decisions and achieve optimal results in their evaluations.

Overall, this feature will enhance the flexibility and usability of the SmartLivingEPC platform, allowing users to tailor the evaluation process to their specific needs and objectives.

3.4 Weighting of Asset Key Performance Indicators Based on European Users' Preferences.

The development of a ranking system that reflects the preferences of European residents was considered a useful parameter within the SmartLivingEPC labeling system. This ranking system aims to incorporate the diverse perspectives and priorities of countries across Europe, providing a comprehensive and user-centered evaluation framework. To achieve this, a massive survey was conducted, seeking representative participation from European countries to ensure that voices from various regions were equitably heard and integrated into the process.

In order to recognize the geographical, cultural, and socio-economic differences of European users, the countries in the region were grouped into four groups: North, South, East, and West. This grouping strategy was discussed to capture the nuances of the specific needs and preferences of each area, thereby enhancing the relevance and applicability of the SmartLivingEPC labels.

Table 11: Survey participation quota

COUNTRY	POOL SIZE	PERCENTAGE
United Kingdom	36,597	8%
Ireland	1,118	1%
Germany	3,643	8%
France	1,441	8%
Spain	1,23	7.0%
Austria	297	1%
Belgium	428	2%
Bulgaria	133	2%
Croatia	145	2%
Cyprus	32	0%
Czech Republic	276	2%
Denmark	224	1%
Estonia	297	2%
Finland	193	4%
Greece	1,058	3%
Hungary	705	2%
Italy	2,783	7.0%
Latvia	234	3%
Lithuania	122	3%
Luxembourg	<25	0%
Malta	<25	0%
Netherlands	1,596	3%
Norway	221	4%
Poland	3,426	7.0%
Portugal	3,619	3%
Romania	252	4%
Slovakia	106	4%
Slovenia	273	3%
Sweden	641	5%
Switzerland	29	1%

The quota assigned to each country as a result of the discussion is detailed in Table 11. This participatory approach at the regional level not only fosters greater engagement and ownership among stakeholders but also ensures that the developed ranking system is grounded in the real-world needs and aspirations of European residents.

Moreover, the SmartLivingEPC labeling system, with its Europe-centered rating, provides valuable insights for policymakers, urban planners, and residents alike. By reflecting the collective preferences of a diverse population, the ranking system can guide improvements in neighborhood development, enhance the quality of life for residents, and promote sustainable urban practices across Europe. This collaborative and inclusive approach to developing the rating system underscores the commitment of the SmartLivingEPC initiative to creating a more equitable and representative framework for evaluating neighborhood performance.

Next, the results of the semantic slider used in the survey were divided into 5 quintiles, for its analysis. In this case, the weighting of the indicators was carried out based on the median values acquired for each indicator.

Table 12: 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	1rt quintil	0.06
		1

To prioritize their importance, these medians were arranged in descending order, which led to the segmentation of indicators into: the first 8 KPIs as highly relevant, the second 8 KPIs as relevant, the third 7 as interesting to consider, the fourth 7 as minimally relevant and the fifth 7 as completely irrelevant (Table 12). This classification was intended to provide a nuanced understanding of the importance of each indicator within the framework of the study.

After this, a weighting was done, assigning the indicators with the highest medians the highest scores, and gradually decreasing their weight to those with the lowest medians. This stage allows attributing relative importance to each indicator based on its perceived relevance in the survey responses. By adopting this weighted approach, it can be ensured that indicators perceived as most critical by respondents receive greater consideration in the overall evaluation process.

Table 13: Example of the application of asset indicators from the SmartLivingEPC neighborhood rating system weighted according to the preferences of European Users

DIMENSION	CATEGORY	INDICATOR	UNIT	PROJECT VALUE	MEANS SURVEY RESULTS	EUROPE SCALE VALUES	EUROPEAN WEIGHTING
Environmental	Neighborhood services	Street Lighting and public area lighting	%	100	63,94	2	3,13%
		Waste Generation	%	68	59,87	3	1,71%
		Waste Recycling rate	%	30	62,32	2	3,13%
		Wastewater Processing rate	%	35	62,09	2	3,13%
		District Heating System	%	13	66,93	1	6,25%
		District Cooling System	%	0	63,11	2	3,13%
		District Heating Potential	%	54	68,02	1	6,25%
	Renewable Energies	RES ratio	%	12	67,39	1	6,25%
		PV ratio	%	15	60,19	3	1,71%
		STC ratio	%	0	64,71	2	3,13%
		GEO ratio	%	2	59,69	3	1,71%
		Potential RES ratio	%	70	67,38	1	6,25%
	Demand Side Management	PPA and VPPA contracts	%	0	61,55	3	1,71%
		SMI ratio	%	0	57,68	4	1,00%
		BEMS ratio	%	23	58,84	3	1,71%
Infrastructure	EV chargers	EV charger service ratio	%	21	56,31	4	1,00%
		V2G EV chargers ratio	%	0	51,79	5	0,86%

	EV chargers	EV chargers by building	%	28	54,83	4	1,00%
	Mobility and transport	Modal Split	%	39	55,57	4	1,00%
		Fuel Cars ratio	%	14	52,49	5	0,86%
		EV Cars ratio	%	62	52,23	5	0,86%
		Bike lanes ratio	%	70	54,76	5	0,86%
		Proximity	%	93	68,95	1	6,25%
		Shared Mobility	%	13	44,06	5	0,86%
	Neighborhood Building Inventory	Age of the building stock	%	17	65,47	1	6,25%
		Renovated 30-year-old buildings	%	35	64,93	2	3,13%
		SmartLivingEPC Asset Rating	%	67	75,88	1	6,25%
		SmartLivingEPC SRI	%	43	55,19	4	1,00%
		SmartLivingEPC LCA	%	43	64,65	2	3,13%
		SmartLivingEPC Non Energy	%	20	50,45	5	0,86%
Social	Energy poverty	Debt ratio	%	8	46,19	5	0,86%
		Low absolute energy expenditure	%	5	58,9	3	1,71%
		High share of energy expenditure in income	%	3	57,83	4	1,00%
		Thermal comfort threshold	%	5	62,51	2	3,13%
	Quality of Life	Heat Island	%	69	59,22	3	1,71%
		Air Quality	%	90	70,08	1	6,25%
		Noise	%	84	58,19	4	1,00%

Finally, an operation was performed to divide the value of the assigned weights by the number of indicators for each level. So that the results obtained are comparable with previous methodologies, in the PROJECT VALUE column the same values were used for each indicator. The difference is that, in this case, the EUROPEAN WEIGHTING column reflects the value of the medians of the responses for each KPI, collected through the survey. In other words, the **weights used effectively take into account the preferences of European users** for each indicator (Table 13), so these **values are statistically supported**. Continuing with the example, multiplying the value of each KPI by its corresponding weighting (EUROPEAN WEIGHTING) and subsequently adding all the results, a **Score = 40.65** is obtained.

4 Conclusions

Within the framework of the development of a methodology to evaluate the performance of various Assets at the neighborhood level, a refined set of indicators was established, which provides a solid basis for designing a comprehensive, accurate and feasible energy rating scheme for neighborhoods. This methodology involved a meticulous selection process, incorporating judgments from experts and stakeholders and aligning with current reference frameworks on the topic worldwide. The selected indicators cover a wide range of energy performance aspects, including energy consumption, waste generation, transportation and building characteristics, among others. Consequently, a taxonomy of urban indicators was developed to evaluate the performance of neighborhood assets. Key considerations included determining data sources, ensuring the integrity of input information, and normalizing units.

Additionally, three alternatives were proposed to weight the developed indicators, using precisely described mathematical procedures, considering the needs of the various actors involved in neighborhood evaluations. These weights allow a unique score to be derived for each case, expressed numerically on a percentage scale from 1 to 100, which reflects the rating obtained within the reference framework of the SmartLivingEPC methodology.

The first rating is a Generic Rating, where all indicators are assigned the same weight. The second is a Neighborhood Rating, which proposes the implementation of participatory action methodologies to actively define the weightings of the indicators by community members. The third is a European Rating, which reflects the preferences of European residents, collected through a massive opinion survey.

The versatility of the asset evaluation methodology at the neighborhood level allows it to adapt to various needs and realities. Clear examples include a group of neighbors demanding the evaluation of their neighborhood according to their criteria, respecting the unique culture of the neighborhood and making the analysis incomparable with other neighborhoods. Another example is an individual conducting a neighborhood search based on personal interests as a resident or investor. Furthermore, a municipality could attempt to understand defined or general aspects of two or more neighborhoods, analyzing them using uniformly weighted indicators to allow comparability between the results obtained.

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