



Deliverable 2.1

PED morphology parameters

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1. Purpose and scope

Deliverable D2.1 establishes the theoretical, methodological and analytical framework for identifying urban morphological parameters relevant to the transition towards Positive Energy Districts (PEDs). Developed within WP2 – *PED Morphologies for Urban Regeneration and Refurbishment*, the deliverable investigates the relationships between urban form, energy demand, renewable energy potential and climate adaptation, with particular attention to university campuses and their surrounding urban districts.

The underlying premise is that urban morphology is not merely a physical background condition, but an active factor influencing the energy and environmental performance of urban areas. Building geometry, urban density, street configurations, open-space systems and land-use patterns affect solar exposure, ventilation, thermal exchanges, renewable energy generation potential and local microclimatic conditions. Understanding these relationships is therefore essential for developing effective PED-oriented regeneration strategies.

The work positions educational campuses as strategic components of urban transformation. Their building stock, open spaces and infrastructural systems offer opportunities to test energy-efficiency measures, renewable energy integration and climate-adaptation strategies, while their institutional role enables connections with surrounding neighbourhoods.

D2.1 has two complementary objectives:

- **Analytical and interpretative:** to establish a common morphological framework for describing and comparing university campuses and surrounding districts, identifying spatial conditions that influence energy performance.
- **Operational and transferable:** to define a structured set of PED morphological parameters that can support the assessment of existing conditions and guide future refurbishment and urban regeneration scenarios.

The deliverable provides the methodological foundation for Task 2.2, which will translate morphological analysis into practical strategies and guidelines for PED transitions.

2. Theoretical and methodological framework

The research adopts a multi-scalar approach grounded in the theoretical traditions of urban morphology. Drawing on the contributions of Conzen, Muratori, Caniggia, Moudon, Kropf and other scholars, the study understands urban form as a structured system composed of buildings, plots, streets and open spaces, whose relationships develop and transform over time.

This theoretical perspective is complemented by research investigating the connections between urban morphology and environmental performance. Particular attention is given to the effects of building density, compactness, orientation, street-canyon geometry, vegetation and land-use distribution on energy consumption, solar accessibility, ventilation and urban microclimate.

The methodology follows a progressive sequence linking theoretical analysis, morphological documentation, comparative interpretation and parameter identification.

A central component is the distinction between morphological variables, parameters and indices. Variables represent measurable quantities describing physical characteristics; parameters express relationships between morphological characteristics and their potential environmental or energy implications; indices provide aggregated or specialised numerical measures that can support comparison and evaluation.

The framework is organised around four complementary analytical dimensions:

- **Boundary:** spatial limits, enclosure relationships and the definition of morphological units.
- **Use:** functional distribution, land-use diversity and occupation patterns.
- **Urban scale:** urban fabrics, block configurations, density, street networks and open-space systems.
- **Building scale:** building typologies, geometry, orientation, envelope configuration and construction characteristics.

This organisation enables the analysis of morphological conditions across different spatial scales while maintaining a consistent relationship between urban form and energy-oriented assessment.

3. Data collection and morphological analysis

D2.1 establishes a shared framework for collecting, documenting and comparing morphological information across the five EDUPED Living Labs.

The data collection strategy combines cartographic documentation, spatial datasets, building information and morphological interpretation. A common documentation template was developed to ensure methodological consistency among the project partners and facilitate comparisons between different geographical and urban contexts.

The analysis considers both the university campus and its surrounding district. This distinction is fundamental because the morphological characteristics of institutional buildings and open spaces may differ substantially from those of the surrounding urban fabric.

The adopted approach therefore examines how campuses are spatially embedded within, connected to or separated from their neighbourhoods, and how these relationships may influence opportunities for PED-oriented transformation.

The resulting morphological documentation provides a baseline for interpreting existing conditions and identifying spatial characteristics that may facilitate or constrain energy-efficiency improvements, renewable energy integration and climate adaptation.

4. Comparative analysis of the five Living Labs

The methodological framework was applied to five university campus-based Living Labs representing different European urban contexts:

The Hague University of Applied Sciences (THUAS), The Netherlands. The campus is located within a large-scale waterfront redevelopment characterised by coarse-grained urban blocks, residential towers and canal-related open spaces. Its morphology is organised around linear building volumes and infrastructural alignments, creating a distinct relationship between institutional spaces, transport networks and the surrounding mixed-use district.

Technische Universität Graz (TUG), Austria. The Living Lab is embedded in a mixed suburban and peri-urban fabric comprising single-family and multi-family housing. The campus consists primarily of linear and pavilion-like buildings arranged around

shared open spaces, with a relatively porous configuration and significant green-space continuity.

Universitat Politècnica de Catalunya (UPC), Spain. The Living Lab is situated within a dense and consolidated urban fabric characterised by continuous street fronts and courtyard blocks. The campus combines different building configurations within a compact district structure, where density, enclosure, solar accessibility and limited open-space availability represent important considerations for future transformation.

Politecnico di Torino (POLITO), Italy. The surrounding district is characterised by historic closed courtyard blocks, fine-grained urban structures and continuous street frontages. In contrast, the campus comprises connected pavilion buildings embedded within the Valentino Park landscape, establishing a distinctive relationship between institutional buildings, green spaces and the surrounding historic urban fabric.

Technical University of Cluj-Napoca (UTCN), Romania. The Living Lab is located within a residential urban fabric characterised by compact terraced houses and mid-rise buildings. The campus consists of linear and slab-type buildings organised along internal open spaces, creating opportunities to investigate relationships between building aggregation, open-space configuration and the surrounding neighbourhood. The comparative analysis reveals substantial differences in building typologies, urban density, block configurations, porosity, open-space distribution and campus–district relationships.

Three recurring morphological dimensions emerge as particularly relevant for PED transition strategies:

1. **Building typologies and aggregation patterns**, which determine enclosure, compactness, solar accessibility and the relationships between built and unbuilt spaces.
2. **Green-blue infrastructure and open-space configuration**, which influence microclimatic conditions, environmental quality and opportunities for climate-adaptive regeneration.
3. **Campus–district interfaces and spatial connectivity**, which condition the integration of institutional buildings, public spaces and shared infrastructures within broader urban systems.

These findings highlight that PED strategies cannot be defined independently of the existing morphological context. Different urban fabrics offer different opportunities

and constraints, requiring context-sensitive approaches rather than uniform design solutions.

5. Identification and classification of PED morphological parameters

Building on the theoretical framework and the comparative analysis of the five Living Labs, D2.1 develops a structured methodology for identifying morphological parameters with potential relevance to Positive Energy Districts.

The process comprises three main phases: **identification, classification and validation**.

The identification phase consists of a targeted literature review aimed at collecting measurable morphological descriptors associated with urban form, energy demand, solar accessibility, ventilation, urban microclimate and building thermal performance. The classification phase organises these descriptors according to their morphological meaning, spatial scale and energy-related implications. This process enables the distinction between parameters describing functional diversity, urban geometry, density, vegetation and building configuration.

The validation phase cross-references morphological descriptors with energy-oriented studies to identify parameters supported by documented relationships with energy or environmental performance.

The resulting framework identifies **19 PED morphological parameters**, organised into three main categories: **Use, Urban Scale and Building**.

5.1 Use

1. Land-use mix / Shannon H' Diversity Index

Measures the diversity of land uses within a defined area. Functional diversity is relevant to PED development because different activities and building uses generate distinct energy-demand profiles, potentially supporting more effective district-scale energy management and energy sharing.

5.2 Urban Scale

2. Height-to-Width Ratio (H/W)

Describes the relationship between average building height and street width. It characterises street-canyon geometry and influences solar accessibility, shading, ventilation and local microclimatic conditions.

3. Length-to-Width Ratio (L/W)

Expresses the proportion between street length and width. It is used to characterise street-canyon geometry and investigate its relationship with urban airflow and ventilation patterns.

4. Length-to-Height Ratio (L/H)

Describes the relationship between street length and building height. Together with H/W and L/W, it supports the analysis of street-canyon proportions and their potential influence on wind circulation.

5. Site Coverage (SC), also called Site Coverage Ratio (SCR)

Measures the relationship between building footprint area and total site area. It provides an indicator of the proportion of land occupied by buildings and is relevant to the analysis of urban compactness and the distribution of built and open surfaces.

6. Building Coverage Ratio (BCR)

Describes the proportion of land covered by buildings. It supports the assessment of building concentration and the relationship between built density and environmental conditions.

7. Facade-to-Site Ratio (F/S)

Expresses the ratio between the total vertical façade surface and the site area. It is relevant to the assessment of urban thermal behaviour, particularly the relationship between façade exposure and Urban Heat Island intensity.

8. Volume Area Ratio (VAR)

Measures the total built volume relative to the site area. It provides a three-dimensional descriptor of urban density and is relevant to the relationship between building concentration, urban microclimate and energy demand.

9. Plot Area Ratio (PAR)

Expresses the relationship between total building floor area and site area. It characterises development intensity and supports the comparison of different urban configurations and their potential energy implications.

10. Green Coverage Ratio (GrCR)

Also referred to as Urban Greenery Plot Ratio (UGPR), Vegetation Fraction (VF) or Green Space Density (GSD), this parameter measures the proportion of urban surface occupied by vegetation. It is relevant to climate adaptation, urban cooling and the mitigation of heat-related environmental impacts.

11. Tree Coverage Ratio (TCR)

Measures the proportion of land covered by the horizontal projection of tree foliage. It supports the assessment of tree-canopy coverage and its potential influence on shading, solar exposure and local air temperature.

12. Grass Coverage Ratio (GCR)

Measures the proportion of land occupied by grass-covered surfaces. It contributes to the characterisation of urban vegetation and its relationship with surface and air temperatures.

13. Shrub Coverage Ratio (SCR)

Measures the proportion of land occupied by shrub vegetation. It complements other green-coverage indicators in describing vegetation composition and potential microclimatic effects.

5.3 Building

14. Plan Depth (PD)

Describes the depth of a building in relation to solar penetration and daylight accessibility. It is relevant to the provision of natural light and the resulting energy requirements for lighting and thermal conditioning.

15. Absolute Orientation (AO)

Expresses the predominant orientation of building façades relative to true north or south. Building orientation influences solar exposure, passive solar gains and the potential reduction of heating demand.

16. Glazed Wall Orientation (GWO)

Describes the orientation of glazed building surfaces and their exposure to solar radiation. It is relevant to the assessment of solar heat gains, daylight availability and building thermal performance.

17. Surface-to-Volume Ratio (StoV/SVR)

Expresses the relationship between the exposed building envelope and the enclosed volume. It is a key indicator of building compactness and influences heat exchange between indoor and outdoor environments.

18. Perimeter-to-Section Area Ratio (PSAR)

Describes the relationship between the exposed building perimeter and its sectional area. It can support preliminary comparative assessments of building geometry and energy-related design measures.

19. Compactness Index (CI)

Expresses the relationship between conditioned building volume and exposed envelope area, representing the inverse of the Surface-to-Volume Ratio. It is relevant to the assessment of building compactness and its potential influence on heating-energy demand.

5.4 Relevance for PED transition strategies

The 19 parameters establish a shared morphological vocabulary for interpreting the relationships between urban form and energy performance across different spatial scales.

At the **Use scale**, land-use diversity provides information on the functional organisation of districts and the potential complementarity of energy-demand patterns.

At the **Urban Scale**, parameters describing street geometry, built density and vegetation coverage support the assessment of urban microclimate, solar accessibility, ventilation and the distribution of built and open surfaces.

At the **Building scale**, parameters describing orientation, envelope exposure, plan geometry and compactness contribute to the evaluation of building thermal behaviour and energy-efficiency potential.

The parameters are not intended to establish universally optimal morphological configurations. Their energy implications depend on climatic conditions, building characteristics, spatial relationships and interactions between different morphological variables.

The framework instead provides a consistent basis for identifying existing spatial conditions, comparing urban configurations and evaluating how morphological transformations may influence PED-related performance.

In the subsequent phase of EDUPED, these parameters will support the development of regeneration scenarios and the assessment of changes between existing and proposed morphological configurations, in coordination with energy and climate-performance analyses undertaken in the other work packages.

6. Main findings and implications for PED transitions

The principal contribution of D2.1 is the development of a replicable morphological framework that enables urban form to be interpreted as a relevant component of PED transition strategies.

The analysis demonstrates that the relationship between morphology and energy must be considered across multiple spatial scales. Building-level characteristics such as envelope geometry and compactness interact with district-scale conditions such as density, street configuration, shading, ventilation and green-space distribution.

The five Living Labs also demonstrate that campuses cannot be assessed independently of their surrounding urban environments. Their spatial relationships with neighbourhoods, infrastructures and public spaces influence the opportunities for integrating refurbishment measures into wider PED regeneration strategies.

The comparative analysis suggests that morphology can play several complementary roles in PED development.

First, **morphology constitutes an existing condition to be assessed**. Urban density, building typologies, land-use distribution and open-space configurations establish the physical context within which energy interventions must operate.

Second, **morphology represents a potential design variable**. Building form, coverage, compactness, vegetation and spatial organisation can be modified through refurbishment and regeneration strategies, potentially influencing energy demand and environmental performance.

Third, **morphology provides a framework for integrating interventions across scales**. The relationships between buildings, campuses and districts are essential for coordinating energy-efficiency measures, climate-adaptation solutions and renewable-energy infrastructures.

The deliverable also identifies the importance of distinguishing between morphological characteristics that can be modified through design interventions and those that constitute relatively stable constraints inherited from the existing urban fabric.

The resulting parameters are intended to support subsequent scenario development and performance assessment. They should therefore be understood as analytical and operational tools, rather than as direct evidence of energy savings independently of simulation or empirical validation.

7. Conclusions and next steps

Deliverable D2.1 establishes the theoretical and methodological foundations for integrating urban morphology into PED-oriented urban regeneration and refurbishment.

Through the development of a shared analytical framework and the comparative study of five university campus-based Living Labs, the research identifies morphological characteristics that may influence energy demand, renewable-energy potential and climate responsiveness.

The resulting PED morphological parameters provide a structured basis for describing existing conditions, comparing different urban configurations and identifying opportunities for spatial transformation.

The next phase of WP2, developed through **Task 2.2 – PED Morphology-Based Urban Regeneration Strategies in Living Labs**, will move from morphological identification towards the formulation and assessment of design scenarios.

The work will focus on the application of the identified parameters to the existing Living Labs, investigating how building refurbishment, open-space redesign and other spatial interventions can modify morphological conditions and contribute to PED transition objectives.

This process will be developed in coordination with the other EDUPED work packages, particularly those addressing energy-efficiency measures, climate adaptation, renewable-energy integration and stakeholder engagement.

The expected outcome is **Deliverable D2.2 – Practical Guidelines for PED Urban Refurbishment and Regeneration**, which will translate the morphological knowledge developed in D2.1 into spatial and architectural recommendations applicable to the Living Labs and potentially transferable to other European urban contexts.

Overall, D2.1 positions urban morphology as an essential analytical bridge between the existing physical structure of cities and the development of evidence-based PED transformation strategies. Its contribution lies in establishing a common framework through which spatial characteristics can be described, compared and subsequently assessed in relation to energy and environmental performance.

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