PEDvolution

Interoperable solutions to streamline
PED evolution and cross-sectoral integration

Deliverable 4.1

PED Readiness Assessment methodology, calculation tool, and action plan for testing the PED Readiness Assessment

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[1] According to Project's Quality Assurance Process

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Glossary of terms and abbreviations used

ABBREVIATION / TERM	DESCRIPTION
API	Application Programming Interface
CIM	Common Information Model
DDSG	Dynamic Decision Support Guideline
DGNB	Deutsche Gesellschaft für Nachhaltiges Bauen (German Green Building Council)
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificate
EPC	Energy Performance Certificate
ICT	Information and Communication Technology
IEQ	Indoor Environmental Quality
IP	Interoperability platform
KPI	Key Performance Indicator
PED	Positive Energy District
RA	Readiness Assessment
SAIDI	System Average Interruption Duration Index
SDG	Sustainable Development Goals
SGNI	Schweizer Gesellschaft für Nachhaltige Immobilienwirtschaft (Swiss Green Building Council
SSHP	Shared Socioeconomic Pathways

1 EXECUTIVE SUMMARY

This deliverable presents the Positive Energy District (PED) Readiness Assessment framework, along with a dedicated calculation tool and an action plan for testing its implementation. The PED Readiness Assessment (PED RA) methodology provides a concise, high-level approach to evaluate how prepared a district is to achieve net-positive energy performance. It is a strategic instrument designed to align diverse stakeholders - from the public sector and city planners to industry leaders and technical developers - around the planning, deployment, and scaling of PED projects. By establishing a common framework and language for assessment, the PED RA helps ensure all parties work toward shared goals in developing sustainable, energy-positive communities.

The PED RA methodology adopts a systemic, lifecycle-based and cross-sectoral perspective. It is built around four core "genotype" dimensions - Technology, Market, Social, and Interoperability - which together capture the key factors underpinning a district's readiness. Evaluating these four dimensions ensures a holistic view: technical innovations and infrastructure, economic viability and business models, community engagement and social acceptance, and the seamless integration of systems. This genotype-based framework enables a comprehensive assessment of PED projects, covering both the full project lifecycle (from initial planning to operation) and cross-sectoral interactions (e.g. energy systems, mobility, buildings, and ICT). In doing so, the PED RA guides cities and stakeholders in identifying strengths and gaps, translating the current status of a district into clear development pathways aligned with broader sustainability goals (such as climate targets and the UN Sustainable Development Goals).

Development of the PED RA framework has been participatory and evidence-based. The methodology was co-developed through stakeholder workshops and expert engagement, ensuring it addresses practical needs across different contexts. It builds on consolidation of best practices and insights from related initiatives - including the European Smart Readiness Indicator and other sustainability assessment schemes - as well as on research in social innovation and energy community development. Through triangulation of multiple inputs (top-down literature and existing frameworks, bottom-up data from pilot PEDs, and stakeholder feedback), the project refined a robust set of Key Performance Indicators (KPIs) underpinning the assessment. This collaborative and iterative process has resulted in a framework that is both rigorous and grounded in real-world experience, increasing its relevance and acceptance among all stakeholder groups.

A central output of this work is the PED RA calculation tool, which operationalises the assessment framework into a practical scoring system. This tool provides a standardised, transparent means of evaluating a district's performance across the four genotype dimensions, yielding a comparable "readiness score" for each aspect. By applying common criteria and scoring rubrics, the tool enables objective benchmarking of PED readiness between different districts or different stages of a project's evolution. The standardised scoring not only ensures transparency in how readiness is measured, but also allows stakeholders to identify critical improvement areas at a glance. In practice, this empowers decision-makers with clear, data-driven insights - for example, highlighting whether a project's major strengths lie in technology deployment or community engagement, or where additional efforts (such as market innovation or interoperability improvements) are needed. Overall, the calculation tool adds strategic value by making PED readiness measurable and trackable over time, thereby informing planning decisions and facilitating communication among partners.

Finally, this deliverable outlines an action plan for testing and deploying the PED RA framework in real-world settings. In the next phase of the project, the methodology and tool will be rolled out in selected PED demonstration sites (as part of Work Package 9) to collect data and validate PED solutions under actual operating conditions. This pilot deployment and data collection will serve to verify the assessment framework's effectiveness and impact, while engaging local stakeholders in the evaluation process. The structured testing approach - aligned with the project's dynamic decision support guidelines - ensures that feedback from the field is captured systematically. Insights and results from this validation phase will be reported in Deliverable 9.2, feeding back into the framework's refinement and supporting its broader adoption. Through this iterative deployment and improvement cycle, the PED Readiness Assessment is positioned as a unifying and enabling tool for PED implementation: it helps coordinate stakeholder actions, guide policy and investment strategies, and ultimately accelerate the planning, implementation, and scaling-up of Positive Energy District projects across Europe.

2 INTRODUCTION

The objectives of this Deliverable are to provide the PED readiness assessment methodology (Chapter 3), the calculation tool (chapter 4) and an action plan for testing the PED Readiness Assessment calculation tool (Chapter 5). The calculation tool will be made available on a dedicated 'Tools' page on the PEDvolution website.

2.1 Mapping Project's Outputs

This section maps the PEDvolution grant agreement commitments, both within the formal deliverable and task description, and against the project's respective outputs and work performed as listed in Table 1.

Table 1: Adherence to Project's GA Deliverable & Tasks Descriptions.

PROJECT GA COMPONENT TITLE	PROJECT GA COMPONENT OUTLINE	RESPECTIVE DOCUMENT CHAPTER(S)	JUSTIFICATION
DELIVERABLE			
D4.1	PED readiness assessment methodology, calculation tool and action plan for testing the PED Readiness Assessment calculation tool.	Chapters 3, 4 and 5	Chapter 3 describes the methodology of the PED Readiness Assessment framework. Chapter 4 describes in detail the PED Readiness Assessment calculation tool. Chapter 5 describes the implementation plan for the PED Readiness Assessment tool.
TASKS			
T4.1 PED Readiness Assessment co-development	This task co-develops the methodology for the PED Readiness Assessment (PED RA) and builds on WP2, T2.2.	Chapter 3	The methodology is described and the co-development of the methodology is explained. The outputs of T2.2 form the foundation for the methodology (Phases 1-4).
	A comprehensive calculation tool and scoring will be created on consolidation exercises and builds on expertise from related initiatives such as the Smart Readiness Indicator (VITO), social innovation research in energy communities (SIN), Energy Master planning, social readiness levels, and other building assessment	Chapters 3 and 4	Chapter 3 describes the consolidation and triangulation of KPIs building on existing assessment schemes and expert inputs, while Chapter 4 delivers the resulting calculation tool and scoring system grounded in these consolidated frameworks and initiatives.

	schemes (e.g. DGNB, EPCs) (D4.1).		
	The focus will be put on the lifecycle approach of PEDs, the 4 genotype factors (social, technology, interoperability and market) and the cross-sectoral integration aspects of the PED Phenotype (amongst others energy system, mobility and industry). This will capture the status at a specific time and facilitate the translation to development pathways (in line with SDGs, decarbonisation plans and planetary boundaries).	Chapters 3 and 4	Chapter 3 defines the lifecycle-based methodology structured around the four PEDvolution genotype dimensions and cross-sectoral integration, while Chapter 4 operationalises this logic in the calculation tool to capture PED status at a given time and support development pathways aligned with SDGs and decarbonisation goals.
	This task directly links to T4.3 in the development of policy strategy roadmap.	Chapter 6	The calculation tool can be used as stand-alone or add-on solution tool to measure the performance of a PED. This plays an important role for T4.3 when planning exploitation of the framework and the duplication of PED on larger scale.
Task 4.2 Life cycle incorporation in PEDvolution Readiness Assessment	The PED RA methodology and calculation approach (T4.1) will incorporate different life cycle stadiums of PED evolution.	Chapter 3	Chapter 3 incorporates lifecycle stages of PED evolution by classifying KPIs and assessment phases across planning, implementation, and operation within the PED RA methodology.
	Here, the PED evolution monitoring (WP8) will be used to assure a PEDvolution development in line with the overall transformation goals from planning to implementation process.	Chapters 3 and 4	Chapters 3 and 4 enable repeated, lifecycle-based PED Readiness Assessments using consistent KPIs and scoring, allowing WP8 monitoring results to track PED evolution and ensure alignment with overall transformation goals from planning to implementation.
	This task will also develop an action plan for testing the PED RA in the PED demonstrators to ensure successful implementation and deployment, and this in alignment with the testing approach in T4.4.	Chapter 5	Chapter 5 defines the action plan for testing and deploying the PED Readiness Assessment in PED demonstrators, ensuring alignment with the testing and validation approach defined in Task 4.4.

2.2 Deliverable Overview and Report Structure

In Chapter 3 the methodology is described. It builds upon D2.2 (Understanding the PED Readiness Assessment framework) where the PED Readiness Assessment framework is outlined. This section includes the lifecycle dimensions and how the co-development was applied to identify the key performance indicators. The chapter outlines the purpose and scope of the work and sets out the key methodological principles underpinning the approach. It provides an overview of the overall methodological process and summarises the different implementation phases, including stakeholder workshops. The chapter further explains the triangulation approach, stakeholder voting and decision criteria, validation and final consolidation, and the application of SMART criteria with project-specific KPI operationalisation. It concludes by describing the PEDvolution governance approach.

Chapter 4 describes the content of the calculation tool. Furthermore, it outlines the different genes of the PEDvolution project and how they were aligned with the four dimensions of PED Readiness Assessment. The calculation tool is the main deliverable of T4.1: PED readiness co-development and can be used as stand-alone or add-on solution tool to measure the performance of a PED. This plays an important role for D4.3 (PED assessment policy strategy roadmap) when planning exploitation of the framework and the duplication of PED on larger scale.

In Chapter 5 the implementation plan of the PED Readiness Assessment is described. It outlines step by step how the PED Readiness Assessment framework will be implemented. It should be read in line with D4.4 (Dynamic Decision Support Guideline (DDSG) tool), which offers a tailored decision support to PED providers based on the local context via dynamic and interactive platform. The work uses the list of KPIs developed in this task.

Chapter 6 concludes with the main outcomes of the PED Readiness Assessment, emphasising policy alignment, comparability, stakeholder co-development, and scalability across PED pilot projects.

3 METHODOLOGY

This chapter describes the methodological foundation of the Calculation Tool, developed under *Task 4.1 - PED Readiness Assessment Co-development*, led by ZHAW with contributions from VITO, SIN, INLECOM. The aim of the task is to co-develop the PED Readiness Assessment (PED RA) methodology, building upon prior workshops with all stakeholders from the consortium and the work done within *WP2 Solution specification and concept design*, particularly under *T2.2 - Preliminary study on PED Readiness Assessment framework and its standardisation* and insights gained during the workshops with stakeholders in Task 4.1. The findings and the methodology for the PED RA calculation sheet (reported in chapter 4) are consolidated in this section.

3.1 Purpose and scope

This methodology describes how PEDvolution builds a set of Key Performance Indicators (KPIs) for the PED Readiness Assessment (PED RA) and for monitoring how PEDvolution solutions support the evolution of PEDs. It combines (i) evidence from existing PED assessment and certification schemes, (ii) KPI practice from prior PED projects, and (iii) the PEDvolution 'genotype' logic (Technology, Market, Social, Interoperability) into one integrated KPI system.

The methodological workflow is addressing two layers:

- A common 'core KPI set' used to compare PED readiness across demos and over time.
- A project- and site-specific KPI layer where KPIs are operationalised for specific tools, data pipelines and local constraints.

3.2 Methodological Key Principles

Developing a robust framework to assess Positive Energy Districts (PEDs) requires a clear and evidence-based methodology. In the PEDvolution project – which aims to create a PED Readiness Assessment (RA) tool – Key Performance Indicators (KPIs) serve as the backbone for measuring progress and guiding the transition toward PEDs. Ensuring these KPIs truly support PED development means introducing fundamental guiding principles throughout the methodology. By grounding the assessment in well-defined principles, the project establishes a consistent and credible approach that bridges technical qulaity with market relevance.

The methodology is therefore underpinned by six guiding principles:

- **Triangulation**. KPIs are only treated as 'core' when they are supported by three independent evidence streams (see Section 3.5). This reduces bias that comes from any single framework or project.
- **Top-down + bottom-up.** We start from established frameworks and project practice, then validate and prioritise KPIs with stakeholders.
- **Traceability.** Each KPI has a clear definition, unit, calculation logic, clear data source and spatial scale.
- **Lifecycle awareness.** KPIs are classified by when they can be evaluated (planning/design, implementation, operation) and how they evolve over time.

- **Project-fit.** SMART refinement and monitoring protocols are applied after KPI shortlisting/validation **S.M.A.R.T. Criteria** (Specific, Measurable, Attainable, Relevant, Time-bound)**.** We will make sure to apply the S.M.A.R.T. criteria to each potential KPI:
    - **Specific:** Clearly defined and unambiguous.
    - **Measurable:** Quantifiable and trackable.
    - **Attainable:** Realistic and achievable.
    - **Relevant:** Aligned with strategic goals.
    - **Time-bound:** Defined within a specific timeframe.
- **Iteration.** PED Pilot tests and stakeholder's workshops
  These were incorporated in T4.1 through a triangulation approach.
    - **Regular Review and Refinement of** KPIs ensures their continued relevance. This allows for adjustments based on changing circumstances and new data.
    - **Pilot Testing** of new KPIs before widespread implementation to identify any potential issues. This allows for fine tuning of the KPIs.

Together, these principles enable a systematic and adaptive assessment process. They ensure that the KPI framework draws on multiple evidence sources and stakeholder perspectives, maintains transparency and clarity in each metric, accounts for all phases of a PED's lifecycle, is tailored to local project contexts through SMART criteria, and continuously improves over time. In essence, these methodological principles safeguard the robustness of the PED RA framework, making sure it remains practical and aligned with the project's overall objectives of supporting PED readiness.

In addition, the following techniques have been considered:

- **Benchmarking techniques** compare performance against industry benchmarks or best practices. This can help to identify areas for improvement and establish realistic targets.
- **Stakeholder Feedback** gathers feedback from relevant stakeholders (customers, employees, etc.) to identify key performance indicators. This ensures that the KPIs reflect the priorities and concerns of those who are affected by the project or organisation. We incorporated this method in T2.2 through dedicated workshops.
- **Alignment with Strategic Objectives:**
    - Begin by clearly defining the overarching goals of the project or organisation.
    - Ensure that every KPI directly supports these strategic objectives.
    - This approach helps to avoid "vanity metrics" that don't contribute to meaningful progress.

3.3 Framework development process overview

The overall workflow is a structured multi-step process which took place over two years (the foundation is D2.2 Understanding the PED Readiness Assessment framework). The first four phases built the evidence base (desktop analysis + consolidation) and are detailed in D2.2. In this deliverable, the KPI pool is triangulated and refined through stakeholder processes, and finally pre-validated with PED Managers for real-world use. The overall methodological workflow is shown in Table 2.

Table 2: Overall workflow of the methodology (the outputs of the first four phases, represented in blue are part of internal Deliverable D2.2).

Phase	(Phase) name	Main inputs	Key activities	Outputs
1	**Foundation from D2.2 (desktop analysis)**	Existing PED frameworks, rating/certification schemes, PED project documentation; early stakeholder feedback	Desktop analysis of KPI frameworks and assessment approaches; inventory of KPIs; review of rating/certification schemes; consolidation into PED RA dimensions	Starting KPI inventory + baseline PED RA concept + first version of the 4 PEDvolution genotype dimensions
2	**Preliminary stakeholder ideation workshop (2024)**	Sustainability assesments; demo contexts; stakeholder needs role-play (PED managers, city reps, solution owners)	Ideation workshop (generate/refine concepts and missing KPIs)	Ideas RA Framework concepts
3	**Define initial KPI pool (Top-down)**	KPI sets from prior PED projects (e.g., ARV, ATELIER, CIVITAS, MakingCity, POCITYF, PROBONO, RESPONSE, SCIS, SPARCS, VITALISE)	Collect KPI catalogues; deduplicate; normalise naming; capture metadata (definition, unit, scale, theme)	Raw 'initial KPI pool' (broad list)
4	**Preliminary stakeholder evaluation workshop (2024) (Bottom-up)**	KPI shortlist; demo contexts; stakeholder needs (PED managers, solution owners)	Evaluation workshop (test in real contexts, check feasibility)	Refined shortlist + documented stakeholder reason + feasibility notes
5	**Triangulation**	A) District certification KPIs (DGNB/SGNI etc.) B) PED project KPI practice & PED assessment schemes C) PEDvolution genotypes + solution needs	Map each KPI to the three criteria; identify intersection (core) vs partial overlaps (extended); identify gaps and conflicts	KPI shortlist: core + extended
6	**Stakeholder voting (05/2025) - Bottom-up prioritisation**	Refined KPI shortlist; mapping to PEDvolution solutions/tools	Stakeholders vote on relevance for PEDs and relevance for PEDvolution solutions; classify priority (A/B); tag dimension (T/I/M/S) and spatial scale	Prioritised KPI set with classifications and tags

	(iteration with Phase 5)			
7	**Validation**	Prioritised KPI set; available data sources; calculation sheet requirements; interoperability constraints	3 rounds of review; expert check of definitions and calculation methods; data availability & interoperability check; final consolidation	Validated KPI set ready for PED RA calculation sheet
8	**Final Consolidation: SMART (iteration with phase 5)**	Validated KPI set + tool requirements + PEDs data needs	Apply SMART criteria per KPI where needed; define targets/thresholds and measurement frequency; assign responsibilities; integrate into tool workflows	Operational KPI handbook per demo and per PEDvolution tool

3.4 Phases 1 - 4 (Foundation from D2.2)

3.4.1 Phase 1: Desktop analysis

The main goal of this phase was to establish a foundation for KPI development by researching existing knowledge sources (literature, past projects, and frameworks).

Key activities involved:

- Conducted a thorough review of literature and previous PED assessment schemes to gather existing KPIs and best practices. This included compiling an initial pool of KPIs from multiple EU Positive Energy District projects.
- Examined relevant performance frameworks and standards (e.g. Balanced Scorecard perspectives, ISO 9001/14001) to ensure the KPI set covers all critical dimensions.
- Reviewed sustainability certification schemes at the district/community level (such as BREEAM and DGNB) to identify established KPI categories for environmental, economic, and social performance. Insights from this analysis helped reveal gaps (e.g. lack of district-wide energy synergy metrics) and informed the initial categorisation of KPIs.

3.4.2 Phase 2: Preliminary stakeholder ideation workshop (2024)

The main goal of this phase was to gather stakeholder input on needs and define preliminary KPI dimensions through collaborative brainstorming.

Key activities involved:

- Ran an ideation workshop (July 2024) to generate diverse ideas for the assessment framework, using structured, interactive methods to encourage creativity and ensure all stakeholder groups were heard.

- Engaged a broad mix of participants (from academia, industry, municipalities, etc.) to explore what needs and priorities the KPI framework should address. The workshop focused on identifying important performance areas and innovative concepts for measurement.
- Collected and documented stakeholder insights on KPI dimensions (e.g. technological, social, economic needs), which provided a creative foundation for the KPI development moving forward.

3.4.3 Phase 3: Define initial KPI pool (Top-down)

The main goal of this phase was to create a state-of-the-art KPI inventory from PED / PED-related projects to capture the key performance characteristics of PEDs and enable later categorisation into the PEDvolution "five Genotypes" as a basis for the PED Readiness Assessment scheme.

Key activities involved:

- Desk-based identification of relevant PED / PED-related projects and their KPI frameworks (survey of existing methodologies and assessment approaches).
- Compile KPIs from the selected projects into one consolidated inventory (created for analysis; stored as a complete list in Annex and project repository).
- Standardise the information captured per KPI (structured extraction fields):
  - project, framework
  - category, subcategory
  - KPI name, unit, definition
  - spatial scale of evaluation
- Quantify the inventory scope to understand coverage, as shown in Table 3. These catalogues were used as an evidence base (what other PED initiatives measure). Deduplication and harmonisation were performed.

Table 3: Phase 3 input - top-down KPI pool sources.

Project	KPI count in source catalogue
ARV	36
ATELIER	47
CIVITAS	31
MakingCity	20
POCITYF	63
PROBONO	20
RESPONSE	40
SCIS	36
SPARCS	30
VITALISE	20

- Quality check + synthesis of issues across the compiled KPIs, noting inconsistencies that affect comparability (e.g., absolute vs relative units, formatting variations, qualitative vs numerical scales, unit inconsistencies)

3.4.4 Phase 4: Stakeholder evaluation workshop (2024) (Bottom-up)

The main goal of this phase was to evaluate the draft KPIs in practical contexts and refine them for real-world applicability.

Key activities involved**:**

- Conducted an evaluation workshop (September 2024) to validate and refine the KPIs by applying the preliminary framework to real or simulated PED settings. This step ensured that the proposed indicators were grounded in practical reality and relevant to on-the-ground conditions.
- Involved key stakeholders from the PED pilot projects (around 12 participants) to trial the KPIs and provide feedback on their usability and relevance. Participants assessed whether the KPIs were adaptable, scalable, and aligned with actual project priorities, highlighting any issues or gaps.
- Used the feedback from this hands-on evaluation to adjust the KPI set. Less practical or unclear indicators were revised or dropped, and definitions were clarified, resulting in a more robust framework tailored to real setting needs.

3.5 Phase 5: Triangulation Phase 5

In PEDvolution, 'triangulation' is the method used to move from a long list of KPIs to a coherent, defensible core set. It explicitly combines three independent KPI "evidence streams":

A - District-level sustainability assessment (SGNI/DGNB).
District certification and sustainability assessment schemes provide KPI definitions, life-cycle perspective and proven evaluation structures. In PEDvolution, this stream is anchored in DGNB and its Swiss adaptation SGNI, extended to capture district-wide energy synergies relevant for PEDs.

B - PED assessment practice from major PED projects (top-down KPI pool).
PED-related EU projects and initiatives provide empirically tested KPI catalogues and reporting conventions. This stream ensures that KPIs reflect what cities and projects already measure and can realistically deliver.

C - PEDvolution genotypes (Technology, Market, Social, Interoperability).
The PEDvolution genotype logic ensures the KPI set reflects the four systemic domains that PEDvolution solutions target. A KPI is only 'core' if it can be clearly positioned in at least one genotype and is meaningful for PED readiness.

Triangulation outcome rules are:

- Core KPIs: KPIs that appear in all three streams (A ∩ B ∩ C).
- Extended KPIs: KPIs supported by two streams (e.g., A ∩ B) but still valuable for completeness.
- Additional KPIs: KPIs present in only one stream or emerging in workshops; kept for further investigation or iteration in 2026. Some of these KPIs may still be essential for specific demos or PEDvolution solutions.

The triangulation is graphically shown in Figure 1.Figure 1: KPI Triangulation.

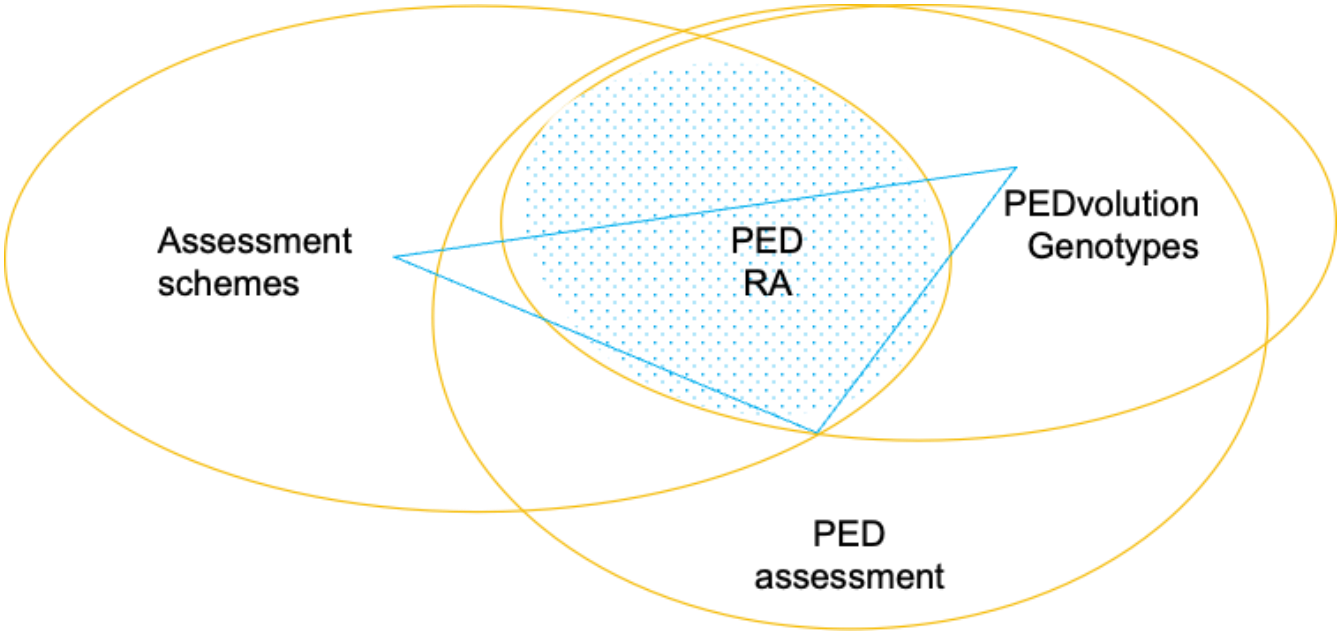

Figure 1: KPI Triangulation.

3.5.1 District/community assessment

As reviewed in D2.2, there exist several certification schemes. European sustainability targets are setting standardised criteria for environmental, social, and economic performance. It promotes resource efficiency, low emissions, and high liveability standards, helping districts meet EU goals for energy use, waste reduction, and carbon neutrality. By guiding planning, construction, and operational practices, certification ensures districts support the EU's sustainable development targets, enhancing resilience and quality of life in line with Europe's green agenda.

Certification in district development seeks alignment with these sustainability targets. DGNB is a sustainability certification system, which emphasises life-cycle assessment, economic viability, and occupant well-being [3]. It covers categories such as environmental quality, economic quality, and sociocultural and functional quality. For this, it applies KPIs that encompass environmental quality, economic efficiency, and sociocultural aspects. As found in T2.2 already, its holistic approach and life-cycle focus align well with PEDs, as DGNB-certified buildings are evaluated on their long-term energy contributions and adaptability to district energy-sharing models. In Switzerland, SGNI[2] has adapted the German DGNB system, with KPIs focused on socio-cultural, economic, and ecological impacts. SGNI applies KPIs that measure building life-cycle impacts, energy consumption, and economic viability, supporting Switzerland's sustainability initiatives and advancing the goals of PEDs through integrated energy and resource metrics. SGNI assesses buildings across multiple dimensions, including environmental quality, economic viability, sociocultural and functional quality, technical quality, and process quality. In this project, one prominent gap was identified which is in data integration for PEDs. Since PEDs aim to produce more energy than they consume, entire urban areas can benefit by reducing reliance on external energy sources. However, current certification systems often assess buildings

[2] https://www.sgni.ch/

individually and lack criteria to evaluate district-wide synergies that PEDs require. Thus, we co-generated a framework that measure shared energy production, storage, and distribution to support PEDs effectively. This was co-developed with a set of KPIs for SGNI certification and form the second corner of the triangulation. By addressing these gaps, the role of certification systems can enhance fostering climate-resilient, community-oriented energy solutions, particularly as cities seek sustainable growth models in line with the European Green Deal and the UN's Sustainable Development Goals.

3.5.2 PED assessment schemes

As reviewed in T2.2, existing PED assessment and certification approaches typically rely on KPI sets organised into thematic domains to reflect the multidimensional nature of Positive Energy Districts. These domains commonly include: (i) energy and environmental performance, (ii) economic performance, (iii) indoor environmental quality (IEQ), (iv) social performance, and (v) smartness and energy flexibility.

In PEDvolution, these established content areas are retained, but they are operationalised through the PED RA framework using the four PEDvolution "genes" (genotype dimensions): Technology, Market, Social, and Interoperability. This gene-based structuring provides a consistent taxonomy for KPI selection, scoring, and monitoring, while enabling transparent links to PED "phenotype" domains (e.g., energy systems, mobility, ICT, and other urban services) where cross-sector integration and real-world performance are realised.

The mapping can be summarised as follows:

- **Technology gene**: covers energy and environmental performance, building performance and IEQ, and the technical enablers of flexibility (e.g., RES integration, storage, control readiness, operational emissions, energy balance).
- **Market gene**: captures economic and financial feasibility across the lifecycle (CAPEX/OPEX, affordability, investment readiness, business model maturity and market incentives).
- **Social gene**: addresses community and governance readiness (participation, equity, acceptance, wellbeing, energy poverty and social innovation aspects).
- **Interoperability gene**: covers the digital and organisational interoperability needed for integrated operation and monitoring (data governance, standards-based interfaces, cross-sector data exchange, ICT-enabled flexibility and coordination).

3.5.3 From performance assessment to readiness and implementation analysis

A deeper review of existing PED Labs showed that KPI catalogues alone are not sufficient to explain *why* PED implementation succeeds (or stalls) in real places. For **PEDvolution**, assessment must therefore capture both:

- **Phenotype outcomes** (what performance is achieved, as measured by KPIs), and
- **Genotype readiness factors** (what systemic conditions enable implementation and replication, structured through the four PEDvolution genes).

The analysis framework follows the organisation suggested by WG2 “Technological & Non-Technological Tools”, Task 2.5 of the PED-EU-NET[3] network. While that work primarily focused on identifying tools [1], its logic is directly applicable to PEDvolution because tools, labs, and pilot districts are intrinsically linked: tools operationalise KPIs, and KPI evidence depends on how labs are instrumented, governed, and embedded in local decision processes. In this approach, KPIs remain central, because they determine which aspects tools must address and which data and governance conditions must be in place to evaluate PED readiness and evolution. This is illustrated in Figure 2.

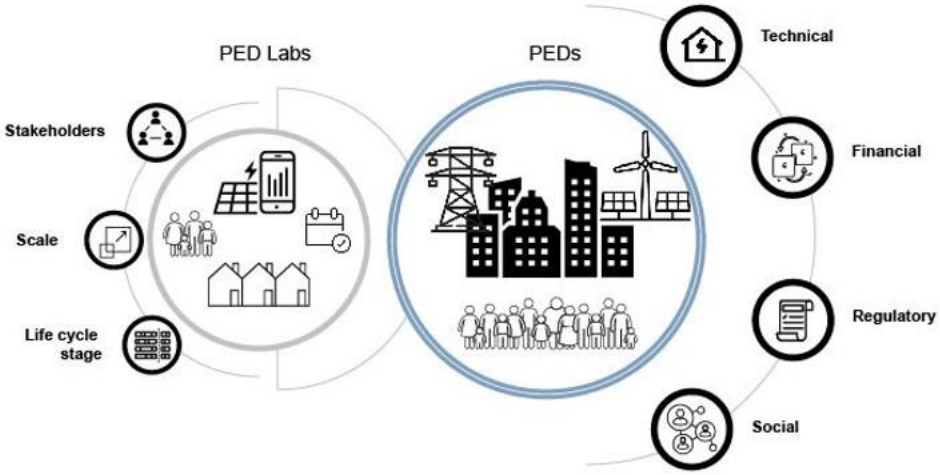

Figure 2: PED analysis Framework as suggested by Haase et al. [2]

The suggested framework integrates four enabling perspectives: technological, social, financial/market, and regulatory, and connects them to three cross-cutting dimensions: Stakeholders, Life-cycle phase, and Scale (as also illustrated in Figure 2). In PEDvolution, this aligns with the PED RA logic: gene-based KPI categories anchor assessment, while stakeholder mapping, lifecycle positioning (planning/design, implementation, operation), and spatial scale determine what can be assessed when, by whom, and for which decisions.

Through this approach, the PEDvolution methodology incorporates essential learnings from PED Labs into a framework that links (i) technological, social, market/financial and regulatory perspectives with (ii) stakeholder roles, lifecycle phases and scale, enabling a readiness-oriented understanding of PED implementation. While PED Labs are advancing sustainable urban development, several recurring gaps still hinder benchmarking and replication of Positive Energy Districts. PEDvolution addresses these gaps through its standardised KPI methodology, triangulation logic, lifecycle framing, and the PED RA toolchain. The identification of key gaps gave guidance for the PEDvolution RA development:

Standardised Methodologies and Metrics
There's a lack of standardised methodologies for assessing and comparing the performance of PEDs. This makes it difficult to benchmark progress and share best practices effectively.

[3] [3] https://pedeu.net/

- Thus, we developed a more comprehensive metrics that go beyond energy balance and consider other crucial aspects like environmental impact, social equity, and economic viability.

Long-Term Performance and Resilience
Most PEDs are relatively new, and there's limited data on their long-term performance, especially regarding energy efficiency, maintenance, and resilience to climate change.

- We thrived to better understand how PEDs can adapt to changing conditions, such as evolving energy technologies, climate patterns, and societal needs. These findings were incorporated into the T4.4 Dynamic Decision Support Guidelines Tool.

Integration and Scalability
Optimizing energy performance at the district level is complex, requiring sophisticated modelling and simulation tools that consider interactions between buildings, energy systems, and infrastructure.

- We did not fully address the scaling up PED initiatives from pilot projects to widespread implementation since it poses significant challenges, requiring innovative business models, financing mechanisms, and policy frameworks. It is thus reported more on in WP6 (Business model innovation and social innovation tool).

Social and Behavioral Aspects
Understanding user behavior and engaging residents in PED initiatives is crucial for their success. We need more research on how to promote energy awareness, encourage sustainable practices, and ensure social acceptance of new technologies.

- We realised that it is important to ensure that the benefits of PEDs are distributed equitably across all segments of society, including vulnerable populations. This was addressed in more detail in WP6 (Business model innovation and social innovation tool).

Technological Innovation and Integration
We need to keep abreast of emerging technologies in areas like renewable energy, energy storage, smart grids, and building automation and management, and explore how they can be integrated into PEDs.

- Integrating various technologies and systems at the district level requires advanced planning and coordination to ensure interoperability and optimise performance. This was addressed adequately in WP3 (PED planning tool).

Policy and Regulatory Frameworks
Supportive policies and regulations are essential to create an enabling environment for PED development.

- We tried to identify and address policy gaps and barriers that hinder the adoption of PEDs, avoiding misalignment between short-term plans and long-term targets (in T4.3 and D4.3 as mentioned above).

The suite of tools developed in PEDvolution will help streamlining planning and permitting processes for PED projects and can this reduce costs and accelerate implementation.

3.6 Phase 6: Stakeholder voting, decision criteria

The stakeholder voting phase translates the triangulated shortlist into an implementable set by prioritising what matters most for PEDvolution and its users. Voting captures both PED relevance and

solution relevance, while also enforcing consistent categorisation. Voting criteria (as applied in the project) are:

- Relevancy for PEDs: Is the KPI critical to monitor and assess PED performance? (yes/no)
- Relevancy for solutions: Does the KPI support measurement/monitoring of implemented PEDvolution solutions? (yes/no)
- Priority: Must-have (A) vs Good-to-have (B).
- Dimension tag: Technical (T), Interoperability (I), Market (M), Social (S).
- Spatial scale: Building / block / district / city / multi-district (as relevant).

A recommended consolidation rule is that a KPI is included in the final 'core KPI list' if it receives "yes" for PED relevance and is linked to at least one PEDvolution solution/tool; priority (A/B) controls whether it is mandatory for all demos or optional.

3.7 Phase 7: Validation

Validation ensures the KPI are feasible in real PEDs Pilot Demos. It is conducted through iterative review rounds and expert checks, focusing on three types of validity:

- Conceptual validity: the KPI really measures what it claims to measure for PED readiness.
- Computational validity: the calculation method is unambiguous, units are consistent, and inputs are available.
- Operational validity: data can be collected through PEDvolution data pipelines (including qualitative inputs where needed)

The final output of this phase is a KPI set ready for implementation in the PED RA calculation sheet, including minimum metadata for each KPI as described in chapter 4.

3.8 Phase 8: Final consolidation - SMART

SMART criteria (Specific, Measurable, Attainable, Relevant, Time-bound) are applied after validation, not before. This avoids prematurely filtering out KPIs that are strategically important but need project-specific refinement (e.g., targets, baselines, measurement frequency).

In PEDvolution, SMART application is done per demo site and per solution/tool, because data availability, governance, and lifecycle stage vary substantially across contexts.

Typical outputs of SMART operationalisation include:

- site-specific target values or performance bands
- measurement method (sensor, model output, survey, administrative data)
- reporting rythm (real-time, monthly, annual)
- responsible data owner and quality assurance process
- integration into the tool workflows

3.9 PEDvolution governance

PEDvolution structures PED readiness through four genotype dimensions. These dimensions are used as the primary taxonomy for KPI categorisation and later scoring. As a result of the analysis (and also initially discussed in D2.2) the final four main dimensions of PEDs are concerned with market, social, technology, and interoperability. These dimensions collectively contribute to the successful implementation and sustainability of PEDs, promoting a holistic approach to urban energy management. The PED RA framework is based on performance indicators (as described in chapter 4) which assess in these four dimensions the performance of the PED. By weighting the results and putting them in the lifecycle perspective the readiness can be assessed.

In order to consolidate PED governance we organised a workshop during the General Assembly meeting in Germany (22nd Oct. 2025 in Freising). The design of the workshop is shown Table 4.

Table 4: The design of the workshop at 3rd GA in Freising, Germany.

Time	Activity	Focus/Methodology	Output
00:00 - 00:05 (5min)	1. Welcome and Context Setting	Moderator introduces the strict 90-minute agenda and the key challenge: *Moving from a successful pilot to a replicable governance model.* Define "Governance" in the PED context (roles, rules, responsibilities, risk management).	Clear understanding of workshop goals and scope.
00:05 - 00:20 (15 min)	2. Activity 1: The 'Pilot Pain Points' Brainstorm	**Method:** Participants write down (anonymously or openly) 3 key governance challenges experienced in current/past energy projects (e.g., unclear ownership of data, delayed municipal approvals, funding gaps, conflicting stakeholder interests). Quick clustering by the moderator.	A prioritised list of 3-5 critical governance challenges to address in the next activity.
00:20 - 00:45 (25min)	3. Activity 2: Mapping the Core Governance Structure (Group Work)	**Method:** Divide into 3 small mixed-stakeholder groups. Each group uses a pre-printed template focused on a core governance area: **Group A: Asset & Data Ownership**, **Group B: Financial/Legal Risk**, **Group C: Operational Decision-Making**. They must define **Who** (Role), **What** (Responsibility), and **How** (Mechanism/Agreement).	Three completed Governance Component Templates (A, B, C) outlining proposed roles and rules.
00:45 - 01:05 (20min)	4. Group Presentations & Replication Filter	**Method:** Each group presents its 3 key findings (5 mins per group). After each presentation, the full group uses the "Replication Filter" question: *"Is this solution simple/standardised enough to be copied by a new city/developer?"*	Consensus on 3-5 **Standardisable Governance Elements** that are essential for future PED projects.
01:05 - 01:25 (20min)	5. Synthesis and Action Planning	**Method:** Full group discussion led by the moderator. Focus on the transition phase: *How do we legally lock in the standardised elements?* Define the **next three actions** (e.g., draft a Memorandum of Understanding, set up a Policy Working Group) and assign clear owners.	**Final Action Plan:** A list of 3 concrete, assigned next steps for policy or legal implementation.
01:25 - 01:30 (5min)	6. Q&A and Wrap-up	Final questions, feedback collection (e.g., via a quick poll), and thanking the participants.	Workshop closure.

The outcome of the workshop was posing several questions:

- Should there be a standardised or minimal governance structure required for all PEDs?
- How to measure governance quality (e.g., self-organisation, inclusiveness, adaptability)?
- Can governance be integrated into the PED Readiness Assessment (PED RA) as a measurable criterion?
- What happens after project funding ends, who maintains governance continuity and accountability?
- How to replicate governance models across different legal and regulatory frameworks?
- How can citizen engagement be sustained without creating decision fatigue?
- What mechanisms ensure financial resilience against energy market volatility or operator bankruptcy?
- How to align technical decision-making (best technical option) with democratic decision-making (majority vote)?
- Should governance models anticipate long-term transitions (e.g., energy source replacement, new partners)?

It was concluded that PED governance is a phenotype that is not a PED RA dimension but rather a site-specific aspect of PED and depends on other parameters as well. Thus, it was decided to include these in the scenarios of the Dynamic Decision Support Guideline Tool (DDSG). The Dynamic Decision Support Guideline applies the Shared Socioeconomic Pathways (SSPs), to represent long-term external conditions that influence the performance of strategies. SSPs provide the structure for Scenario Modulation translated into DDSG scenario multipliers that either relax or intensify the expected future conditions under which PEDs operate. This provides a more realistic basis for governance issues of PED as it includes global developments, technological, climatic, economic, institutional, and behavioural aspects of PEDs. The Dynamic Decision Support Guideline methodology and specifications are detailed in D4.3 Specifications and plan for testing and deployment of PEDvolution decision support guideline.

4 CALCULATION TOOL

This chapter describes the content of the Calculation Tool, developed under *Task 4.1 - PED Readiness Assessment Co-development*, led by ZHAW with contributions from VITO, SIN, INLECOM. The tool and the content of the tool is co-developed with the project partners during the project. The findings for the PED RA calculation tool are consolidated in this section.

The PED RA Calculation Tool consolidates the multi-dimensional assessment logic of PEDs through a harmonised, transparent, and comparable framework. It captures the status and maturity of PEDs at a specific point in time, supports the identification of development pathways, and aligns with broader European and international policy objectives, including the European Green Deal [4], Energy Performance of Buildings Directive (EPBD) [5], Renovation Wave [6], and Sustainable Development Goals (SDGs) [7].

The calculation tool is structured around four main categories, referred to as the **PEDvolution genes**: **technology, market, social, interoperability.** They are further described in Table 5.

These represent the *genotypes* that define the intrinsic readiness and systemic maturity of a PED. Each main category/gene includes specific Key Performance Indicators (KPIs) that together reflect the cross-sectoral integration of the PED *phenotype* - spanning energy systems, mobility, and industry - thereby ensuring a lifecycle-based and systemic approach.

Table 5: PED genes.

Gene	DESCRIPTION
Technology	The technology dimension addresses the technological innovations required for the effective functioning of PEDs. It measures the integration of smart energy systems, renewable energy technologies, energy storage solutions, and advanced grid management systems.
Market	The market dimension focuses on the economic viability and business models that support the development and operation of PEDs. It measures financing, investment, and revenue generation mechanisms, as well as market incentives that encourage the adoption of renewable energy sources and energy-efficient technologies.
Social	The social dimension emphasises community engagement and the social acceptance of PED initiatives. It measures (ensuring that) the benefits of energy efficiency and renewable energy are equitably distributed among residents, participation of local stakeholders in decision-making processes. Promoting social cohesion and enhancing the quality of life is crucial in this dimension.
Interoperability	The interoperability dimension involves the seamless integration of different systems and technologies within a PED. This measures communication between various energy sources, building management systems, transportation networks, and information and communication technologies (ICT).

The calculation tool is an excel sheet. It will be made available on a dedicated 'Tools' page on the PEDvolution website in the third year of the project (2026). An overview is provided in Annex V.

During the triangulation exercise carried out in WP4 (Phase 5), the KPI longlist developed in Task 2.2 (Preliminary study on the PED Readiness Assessment framework and its standardisation) provided the empirical and conceptual foundation for consolidating the final PED Readiness Assessment KPI set. The initial KPI pool, was systematically assessed using the PEDvolution triangulation approach, which combines district-level sustainability assessment schemes (SGNI/DGNB), KPI practices from major PED projects, and the PEDvolution genotype logic (Technology, Market, Social, and Interoperability).

Phases 1 to 4 were supported by two stakeholder workshops organised by the PEDvolution consortium under WP2 (Solution specification and concept design). An ideation workshop in July 2024 generated initial KPI concepts and assessment ideas, while an evaluation workshop in September 2024 tested and refined these concepts against real PED contexts to ensure their relevance and feasibility. The triangulated KPI shortlist was reviewed and refined through stakeholder workshops held in July and September 2024, corresponding to the preliminary stakeholder engagement and lifecycle evaluation. This was followed by stakeholder voting and prioritisation (Phase 6), applying agreed decision criteria on PED relevance, solution relevance, priority level, and dimensional classification.

This structured consolidation and prioritisation process resulted in a coherent and defensible KPI set organised across two category levels: (i) the PEDvolution genotypes, representing the core systemic domains of PED readiness, and (ii) KPI subcategories, ensuring consistent classification, comparability, and implementation within the PED RA calculation tool.

The PED Readiness Assessment tool includes a list of 342 KPIs that were narrowed down to around 80 KPIs, distinguishing between "must-haves" and "good-to-have" KPIs based on relevance, measurability, and alignment with EU policy objectives. The final list includes only the must-have KPIs and has 36 KPIs, with 11 technology KPIs, 6 market KPIs, 8 Social KPIs, and 11 interoperability KPIs.

A validation exercise (Phase 7) will be executed during the demonstration and performance assessment phase (WP9 PEDvolution demonstrators and performance assessment) to assess the conceptual, computational, and operational feasibility of the selected KPIs for real PED pilot demonstrations.

4.1 Design of the calculation tool

This section summarises how the PED Readiness Assessment (PED RA) Calculation Tool was designed and implemented within the project, during Phase 5 (Triangulation exercise) in section 3.5 and Phase 6 (Stakeholder voting) in section 3.6. The tool operationalises the assessment methodology developed in the project, which was explained in Section 3 and ensures consistent, transparent, and comparable evaluation of PED readiness across all participating districts. The tool allows the assessors to input the measurement or the calculation of the KPI, while automated backend logic provides the scoring through the values that the assessors inserted. However, at this stage, there is no formal definition of who the assessors are, nor does it specify the required skills, competencies, or organisational roles responsible for completing the calculation tool; while it is currently foreseen that this role may be assumed by PED managers or designated project experts, this definition represents a recognised limitation and will be addressed in future work, notably during WP9 (PEDvolution Demonstration and Performance Assessment), Task 9.3 (PEDs performance assessment, M22–M34).

This section further describes the underlying logic, KPI structure, and automated scoring processes.

The tool incorporates:

Unified KPI catalogue across four PEDvolution genes with predefined categories, units, and thresholds. The tool consolidates the KPI catalogue for all four PED readiness genes (technology, market, interoperability, and social) into one structure. Each KPI is presented with a fixed definition, assigned main category (genes) and subcategory, and a specified unit. The tool also includes predefined threshold/target values that are used to translate the entered KPI value into a score. This ensures that assessments across different PEDs follow the same KPI framing and scoring reference points.

Standardised KPI definitions, external calculation, and value input structure. The tool provides a harmonised KPI framework that defines, for each indicator, the KPI description, unit, assessment boundary, and reference calculation method (such as formula or equations). KPI values are not measured or calculated within the tool; instead, Assessors are responsible for deriving the final numeric values externally using appropriate data sources such as measurements, simulations, project reports, surveys, or official statistics. The tool then serves as a standardised entry interface where these externally produced values are reported in a consistent format, ensuring uniform interpretation and comparability across all assessments.

Automated scoring and uniform weighting based on predefined thresholds. Once the KPI value is entered, the tool automatically assigns a score by mapping the value to predefined threshold ranges using a transparent and uniform scoring scale. Scores are then aggregated using a consistent weighting structure across KPIs and categories, with equal weighting applied to KPIs within the same category to avoid bias between different domains. This automated scoring and weighting approach minimises assessor workload, eliminates subjective scoring decisions, and ensures consistency and comparability across all PED assessments and across the four assessment domains.

Conditional "N/A" logic, so irrelevant KPIs do not penalise the assessment. The tool allows assessors to mark KPIs as "Not Applicable" when an indicator genuinely does not apply to the assessed PED context. When N/A is selected, the KPI is excluded from the scoring aggregation so that the PED is not penalised for non-relevant indicators. The assessor can provide a short justification explaining why the KPI was excluded, supporting transparency and traceability of the assessment.

The tool is designed to be user-friendly for the Assessors and must enable the assessment of PED readiness through a consistent, evidence-based, and policy-aligned methodology that is both replicable and scalable across European contexts.

4.1.1 Metadata

The metadata below is processed during the tool's design phase and is not user-facing. Each KPI is designed to have a harmonised data and scoring structure, ensuring coherence across projects, cities, and national contexts:

- **Definition:** Clear articulation of KPI scope, boundaries, and normalisation scale (e.g., per m² TFA, per capita, or per energy vector).
- **Unit:** Measurement unit appropriate to the indicator (e.g., kWh/m², MWh, tCO_2, €).

- **Target Value and Source:** Defined benchmark values drawn from EU or international standards (ISO [8], CEN/CENELEC [9], ETSI[10]). When no official target exists, transparent assumptions and data sources are provided from credible sources such as peer-reviewed articles.
- **Scoring:** Four-point scale defining the range between minimum acceptable and optimal target values.
- **Weighting Factor of the scores:** KPIs within each category are uniform and assigned equal weights by default (uniform KPI-level weighting), unless a justified rationale is provided for adjusting individual KPI weights. Each of the four main categories contributes equally to the final overall score, ensuring a balanced category-level weighting. During testing (T.9), some weighting factors may be adjusted to emphasise certain key performance indicators (KPIs) if needed.
- **Calculation Formula and Methodology:** Specification of data inputs, measurement methods, mathematical formulations, and data acquisition sources.
- **Justification and Assumptions:** Explanation of data choices, normalisation methods, and any estimation procedures.
- **Normalisation Guidance:** Ensures comparability across PEDs by applying common rules for:
    - *Spatial boundary*: KPIs calculated within the PED's defined physical limits, listing included energy vectors (electricity, thermal, mobility).
    - *Temporal alignment*: Data referenced to the same reporting year, applying weather-corrected values where applicable.
    - *Absolute vs. intensity metrics*: Reporting of both absolute and normalised values to enable benchmarking.

4.1.2 Scoring the values

The calculation tool provides a percentage score indicating how 'PED-ready' a district or neighbourhood is. This score is derived from evaluating KPIs across four genes: technology, social, market, and interoperability. Alongside the aggregate score, the tool also presents separate scores for each category. The scoring of the KPIs is designed to carry equal weight within the same category. Scoring for each KPI is given as shown in Table 6.

Table 6: Scoring for each KPI.

Score	Performance Level	Description
4	Excellent	Meets or exceeds the target
3	Good	Close to the target
2	Moderate	Partially meets the target
1	Minimum	Significant improvement is needed

The target values and scoring for each KPI were based either on relevant standards, scientific articles, or expert experience.

4.2 Using the tool

KPIs that are not relevant to a particular PED context are excluded from the scoring process. This approach helps prevent bias and maintains the methodological integrity of the assessment, ensuring there is no undue penalty.

Assessors are responsible for gathering raw data -sourced from metering, documentation, surveys, or substantiated estimates- to support the necessary calculations. While the tool offers automated validation, such as checking unit consistency, input completeness, and calculation value ranges, it does not perform automatic KPI calculations. Instead, it facilitates automatic scoring.

Assessors should gather the measurement information or do the calculation based on the formula for each KPI, which varies depending on the KPI. The resulting value will be manually entered into the tool. The tool subsequently compares the entered values against predefined thresholds and automatically assigns a score (ranging from 1 to 4) according to the specified value bands.

The KPIs within the same category were built to have the same equal weighting factor during the design phase, reflecting their equivalent importance in determining overall readiness. This balance ensures that technological advances are assessed alongside social inclusivity, market maturity, and interoperability.

The tool employs a four-point scoring and an automatically attained equal weighting system:

The scoring and weighting methodology embedded within the calculation tool is developed to be user-friendly for Assessors. It enables the evaluation of PED readiness by employing a consistent, evidence-based, and policy-aligned framework that is replicable and scalable across diverse European contexts.

Only the metadata in Table 7 is considered essential for users to understand and complete the sheet; not all metadata will be visible to users.

Table 7: KPI information and data sources are visible to the users.

Section	Description
N/A Use Rule	Conditions where KPI can be set to “Not Applicable.” Indicates whether the KPI will be included in the total scoring.
What the KPI Measures	1–2 sentence plain-language explanation of what the KPI quantifies.
Data Required	List of inputs needed to calculate the KPI (values, surveys, invoices, metering data). For each category, the data sources may differ.
Unit	Most preferred units of the KPIs are: %, kWh/m²·year, MWh/year, €, tCO_2/year, etc.

Formula	The formula provided by the tool for Assessors to do the calculation. Assessors are encouraged to use the formula from the tool for overall accuracy and comparability reasons if data is not available from the measurements
Target Value	Target threshold and source (EU regulation, literature, expert assumption).
Boundary	Spatial/temporal boundaries that must be applied consistently.

In the Calculation Tool, assessors must indicate whether each KPI is included or N/A, providing a short explanation in the free-text box whenever a KPI is not applicable. For all included KPIs, assessors enter the value obtained from their calculations or data sources, after which the tool automatically generates the score based on predefined ranges. In the realm of this project, the 5 PED managers will download the sheet from the website, complete these required fields for each KPI, and return the filled-in file to the project team for assessment**.**

To summarise, the Assessors will only fill in this information:

- ***Included N/A: If this KPI is not relevant for the assessment, should be excluded for accuracy.***
- ***Value: The value represents the result of the calculation or measurement.***
- ***Score: Once the value is entered, the sheet will provide the score automatically.***

4.2.1 Total Scoring and Summary

The tool operationalises the project's assessment methodology within a semi-automated, repeatable environment. By integrating technology, market, social, and interoperability data, and applying consistent KPIs, formulas, and boundaries, it ensures comparable, reliable, and transparent evaluation across all PEDs. The calculation process reduces subjectivity through standardised rules and enables both quantitative and qualitative assessment of readiness.

The PED RA Calculation Tool (Annex V) consolidates category scores and delivers an overall readiness score through a results interface that flags incomplete or inconsistent data. This final score offers a comprehensive view of PED maturity, helping stakeholders to pinpoint development needs, prioritise resource allocation, benchmark progress across PEDs and countries, and ensure alignment with EU climate neutrality and decarbonisation goals.

Designed for clarity and auditability, the tool supports ongoing monitoring and verification during implementation and is adaptable for future use beyond the project's scope. Figure 3 Example page from the interface of the calculation toolrepresents the user interface of the calculation tool. Its user-friendly design and methodological consistency make it a robust solution for tracking PED readiness within Horizon Europe and subsequent initiatives.

PED name	TEST
Location	TEST

Category	Sub category	KPI	Unit	Calculation	Should there be a motivation needed for not including a KPI? Included	Value	Score	Score	Score %
Market	Economic	Total Investments	€/m²	$\frac{\text{Total Investment} - \text{Grants received}}{\text{total floor area of the system built/renovated}}$	Yes	50	1	1,6	40%
		Total Annual Costs	€/year/m²	$\frac{\text{OPEX}}{\text{total floor area of the system built/renovated}}$	Yes	10	1		
		Return on Investment (ROI)	%	$\frac{\text{Total Income}}{\text{Total Investment}}$	Yes	20	1		
		Economic value of savings	€/kWh	$\frac{\text{Total Investment}}{\text{Energy Saving}}$	No				
		Average CO2 abatement costs	%	$\frac{\text{Total Investment}}{\text{GHG Emission Saving}}$	Yes	20	2		
		Payback Period	Years	$\frac{\text{Total Investment}}{\text{Net annual cash flow}}$	No				
		Local energy resources traded locally	%	$\frac{\text{local RES traded}}{\text{local RES produced}}$	Yes	50	3		

Figure 3 Example page from the interface of the calculation tool.

4.3 The PED Genes

4.3.1 Technology

The technology gene evaluates the technical capacity, system integration, and innovation potential of PEDs. It captures readiness in renewable energy deployment, energy storage, smart grid interoperability, and building-level efficiency. The final list of the KPIs was selected after the triangulation exercise that explained in Section 3.5, and stakeholder voting in Section 3.6. Combining technical data, stakeholder expertise, and benchmarking against standards confirms that technological maturity is a primary enabler of PED progression toward energy positivity and decarbonisation. This category especially aligns with the Energy System Integration Strategy, ensuring policy coherence and technical interoperability.

The KPIs in this category are divided into three subcategories: energy, environmental, and architecture, and are described below. Relevant equations can be found in Annex I and the target values and scoring can be found in Annex VI

Architecture

Indoor air quality: CO2 concentration

Measures the CO_2 concentration in occupied indoor spaces as an indicator of ventilation performance and indoor air quality. Based on ISO 16798-1, assessed through measured or calculated average CO_2 levels

Units: ppm

Energy

% of households with EPC <300 kWh/m²·yr

Measures the share of households whose dwelling energy performance is better than the national average threshold of 300 kWh/m²·year. Intended to track energy efficiency and energy-poverty risk.

Units: %

Renewable Energy Ratio

Ratio of on-site renewable energy production to total energy demand within the PED, expressed as a percentage. Measures progress toward PED-level energy autonomy and decarbonisation.

Units: %

Self-Consumption Ratio

Share of locally produced energy that is consumed on-site. Indicates alignment between local RES generation and local load.

Units: %

Energy storage capacity installed

Measures the extent of installed storage capacity relative to local renewable generation capacity, indicating the district's ability to shift loads and balance supply and demand.

Units: %

Net Energy Balance

Measures whether the PED is net-positive or net-negative in terms of energy over a complete year, based on local production versus total energy consumed.

Units: %

Primary Energy Consumption

Primary energy demand of the district, weighted by national primary energy factors. Scored relative to improvements over national NZEB thresholds.

Units: kWh/m²·yr (scored by % improvement)

Self-Sufficiency Ratio

Percentage of hours in which local generation matches local load such that there is no net electricity import or export. Measures temporal independence of the PED energy system.

Units: %

Final energy consumption

Total final energy consumed (electricity, thermal, gas) normalised by floor area, excluding transport and public lighting. Indicates building-level total energy demand.

Units: kWh/m²·year

Environmental

Total operational GHG emission

Measures annual CO_2-equivalent emissions from delivered energy minus exported renewable energy, using standardised emission factors (IPCC or national databases).

Units: gCO2/kWh

GHG emissions compared to grid

Compares the PED's operational GHG intensity to the national grid average to assess decarbonisation performance relative to the surrounding energy system.

Units: %

4.3.2 Market

The Market gene assesses the enabling economic and financial ecosystem that underpins PED implementation. It considers business model maturity, financial instruments, and investment readiness within local and regional markets; therefore, it has subcategories: market, economic, and ICT Governance. The final list of the KPIs was selected after the triangulation exercise that is explained in Section 3.5, and stakeholder voting in Section 3.6 and yielded results demonstrating coherence between local investment conditions and EU-level financing instruments. KPIs in this category evaluate cost-efficiency, funding availability, market incentives, and public–private collaboration. These indicators reflect the need for lifecycle-based market mechanisms that support both initial deployment and long-term operation of PEDs.

The six market KPIs have two subcategories: economic and energy. Relevant equations can be found in Annex II and the target values and scoring can be found in Annex VI.

Economic

Total Investments on infrastructure

Total investments made in the PED infrastructure, corrected for grants and normalised by floor area or capacity. Tracks capital expenditure for PED development.

Units: %

Total Annual Costs

Annual operational costs per square metre, combining maintenance, required energy costs, operational costs, and other associated annual expenses.

Units: €/year/m²

Average CO_2 abatement costs

Cost per tonne of CO_2-equivalent avoided, calculated by dividing total investments by annual GHG emission savings.

Units: €/ton CO2-eq/year

Operational Cost of Energy

Average operational cost per kWh per year within the PED

Units: €/kWh/year

Electricity costs compared to country average

Compares household electricity costs within the PED to the national household electricity cost average to assess affordability relative to national standards.

Units: %

Energy

Electricity grid Delivered Factor

Percentage of total electricity used that is imported from the grid. Indicates dependency on external electricity supply.

Units: %

4.3.3 Social

The Social gene evaluates the social readiness, inclusivity, and behavioural dimensions that determine community engagement and acceptance of PEDs. It integrates insights from Deliverable D2.4 (Report on business models, social innovation, and engagement tools for PEDs) and uses them to define KPIs relevant to social innovation research in energy communities, as well as to social readiness level frameworks developed within SIN. The final list of the KPIs was selected after the triangulation exercise (explained in Section 3.5), and stakeholder voting (explained in Section 3.6), which highlights the central role of social participation in sustaining energy transitions. KPIs measure levels of citizen co-creation, accessibility of clean energy solutions, social equity, and awareness of PED benefits. These indicators align with SDG 11 (Sustainable Cities and Communities) and SDG 7 (Affordable and Clean Energy), reinforcing the social dimension of sustainability.

This category has subcategories: engagement, governance, and wellbeing, which specify the KPIs. Nine (9) of these KPI's are the result of a questionnaire to be held among inhabitants of the PEDs. Relevant equations, as well as questions for the questionnaire and how to assess the answers, can be found in Annex III and the target values and scoring can be found in Annex VI.

Governance

Existence of a formal governance structure

Assesses the maturity of governance through documentation quality, including the existence of a formal board, constitution, defined roles, decision-making procedures, and membership rules.

Units: 5-point scale

Engagement

Resident engagement rate

Percentage of unique households actively participating in PED-related activities such as workshops, living labs, energy programs, or community initiatives.

Units: %

Energy awareness and consciousness

Survey-based measure of residents' understanding of their energy consumption, efficiency opportunities, building performance, and motivation for sustainable behaviour.

Units: %

Acceptance Level

Composite acceptance index based on resident survey responses assessing technology acceptance, community acceptance, and sociopolitical acceptance of PED measures.

Units: Index (%)

Wellbeing

Social inclusion index

Survey-based index reflecting whether residents perceive diversity (age, income, background) as a strength and feel comfortable interacting across demographic groups.

Units: %

Social cohesion index

Measures how well residents know and trust their neighbours, perceive mutual support, participate in community events, and feel they have a voice in decisions affecting shared spaces.

Units: %

Target value: ≥ 80 %

Quality of life

Survey-based measure of physical health, mental wellbeing, social relationships, living environment quality, and overall life satisfaction among PED residents.

Units: %

Perceived safety and security

Survey-based assessment of residents' feelings of safety, fear of crime, and perceived general security when moving around the neighbourhood.

Units: %

Energy poverty rate

Percentage of households spending more than 10 percent of gross income on energy, identifying those at risk of energy poverty.

Units: %

Perceived Indoor Air Quality

Survey-based measure of occupants' perception of indoor air freshness, odours, ventilation, humidity comfort, and overall breathing comfort.

Units: %

Thermal Comfort Satisfaction Rate

Percentage of residents satisfied with thermal conditions in their dwellings across seasons, based on self-reported comfort levels.

Units: %

4.3.4 Interoperability

The Interoperability gene focuses on the digital, institutional, and governance linkages that enable integration across systems and sectors. It assesses data management, interoperability of digital tools, governance coordination, and compliance with European standards for digitalisation. It also includes mobility as a sub-category. The final list of the KPIs was selected after the triangulation exercise that explained in Section 3.5, and stakeholder voting in Section 3.6. The results confirmed that interoperability is critical for scaling and monitoring PED performance. The category builds on the Digital Building Logbook [11], Smart Readiness Indicator [12], Interoperable Europe Act [13], and emerging data space initiatives under the European Data Strategy, ensuring compatibility and openness of data exchange.

This category has subcategories: ICT and mobility, which specify the KPIs. Relevant equations can be found in Annex IV and the target values and scoring can be found in Annex VI.

ICT

Peak Load Reduction

Measures reduction in maximum electricity demand relative to a 5-year baseline. Indicates the effectiveness of load shifting and demand management.

Units: %

Increased System Flexibility (ICT-related)

Measures the share of peak demand that can be met through flexible resources including controllable loads and storage discharge capacity.

Units: %

Increased Reliability (ICT-related)

Measures improvement in system reliability through reduction in average interruption duration (SAIDI), comparing a 5-year baseline to post-intervention values.

Units: %

Increased Hosting Capacity for RES

Increase in the renewable generation capacity the distribution grid can host without violating voltage or thermal limits.

Units: %

Increased Power Quality (ICT-related)

Percentage of time the local grid voltage remains within ±5 percent of nominal, indicating stability and power quality improvements.

Units: %

Improved interoperability

Percentage of required data interfaces that expose open, standards-based APIs, measuring ICT interoperability and openness.

Units: %

Mobility

Share of EVs' energy demand covered by local RES

Measures the share of electric vehicle charging demand that is supplied directly by local renewable energy sources within the PED. Indicates the extent to which EV charging is decarbonised and integrated into the local energy system.

Units: %

Annual energy demand by charging infrastructure

Share of total PED energy demand used for EV charging, or alternatively energy per EV per year. Indicates EV penetration and infrastructure impact on the energy system.

Units: %

5 IMPLEMENTATION PLAN

The purpose of this section is to summarise how the PED RA has been implemented in the PED demos.

For each co-developer PED, (i) the current technical and infrastructural situation, (ii) the regulatory and organisational context, and (iii) the socio-economic conditions under which the PED operates is captured. It follows the four main KPI categories which are to be covered by the Monitoring and Verification Plan (in *Task 8.1- Monitoring and verification plan*), namely energy, environmental, economic and social. These four categories are embedded in the list of KPIs under the four dimensions Technology, Market, Social and Interoperability. Consequently, they form the basis for KPI definition and later verification (of the objectives of PEDvolution).

The implementation consists of the following elements:

- For each PED, the physical, functional and organisational boundaries are defined. This includes the spatial extent of the district, the assets relevant for local generation, storage, flexibility and consumption, and the relevant actors (municipal actors, DSOs, building owners, residents, operators). The boundary definition is necessary to ensure that monitoring of generation, consumption, emissions, socio-economic activity and stakeholder engagement is comparable over time and across sites. This system definition is consistent with the PEDvolution concept that PEDs are embedded in and interacting with local ecosystems (energy, mobility, ICT, industry) and continuously evolve under changing environmental, social and market conditions.
- For each PED, baseline KPI values are defined for the KPI set of four genotype dimensions: market, social, technology, and interoperability. These dimensions reflect PED maturity in terms of planning, implementation readiness, governance, and scalability. The baseline records the initial PED RA score per dimension and maps these to the energy, environmental, economic, and social pillars required in Task 8.1. This enables the quantification of the "readiness improvement per dimension" (project KPI: "Average PED readiness improvement, per dimension").
- The local situation KPIs document the current energy infrastructure and operational practices in each PED: on-site renewable generation and performance; flexibility assets and their control strategies (e.g. DERMOT, DRMS, AURORA, ANODE); building stock and renovation status; district heating and cooling where relevant; storage; and the current import/export balance.
- Socio-economic and governance characterisation. The baseline captures stakeholder structures, governance models, and business model configurations at each PED site (*WP6 - Business & Social Innovation tools*). It identifies (i) which actors hold operational, financial, or decision-making authority, (ii) which stakeholder engagement processes are in place, (iii) which business model patterns exist or are emerging, and (iv) the degree of community participation and social innovation. This forms the quantitative and qualitative baseline for the "economic" and "social" pillars of the PED RA.
- Data interoperability and traceability. The baseline uses the data pipelines, semantics, and interfaces defined in WP7 *(Data Exchange, Integration and Interoperability Platform*), including the Common Information Model (CIM) and the interoperability platform. This ensures that all baseline indicators are linked to defined sources, units, temporal resolutions, and spatial references, remain available during monitoring and verification, and are auditable in WP9 (*PEDvolution Demonstration and Performance Assessment*).

- Temporal reference point. The baseline is fixed at the point where the PEDvolution solutions are technically ready for deployment but before full operational rollout in the co-developer demonstrations. The data collection plan involves a decentralised data acquisition and coordinated exchange system. It addresses the collection and exchange mechanisms necessary for real-time, continuous, and interoperable monitoring across PED demonstration sites and solution components. Additionally, this plan operates within the framework of interoperability, technical standards, stakeholder engagement, and regulations.

Data collection of energy measurements will occur at the PEDs level through the deployment of edge devices and pre-existing or newly installed meters. Through these devices energy consumption and production at various intervals will be measured.

Once collected, the data will be temporarily stored on-site and then transmitted to centralised local repositories, where it will be retained in a structured format for further use. AURORA, as an EMS, will host energy-related data, managing primary storage and access to measurement data sets from the PEDs.

Data exchange will be facilitated by the Interoperability Platform (D7.1 Data exchange platform design). This platform does not function as a storage system but rather as an orchestrator of data exchange.

When PED RA requires access to specific data, a request will be sent to the Interoperability Platform. The platform will then identify the appropriate data host (number of hosts needed to be specified), retrieve the relevant information via established APIs, and deliver the data to the requesting tool without storing it internally. In this sense, the Interoperability Platform enables secure and targeted data sharing across the ecosystem while preserving the decentralised structure of data ownership and storage.

The system is designed to accommodate data flows of technical and quantitative data managed by automated measurement systems and consigned using the interoperability platform. Qualitative and semi-quantitative data that cannot be collected by sensors or automated protocols, including social and behavioural information, which will be collected directly by project partners through interviews, questionnaires, spatial mapping, and observational surveys. This type of data will be sent through the interoperability platform from the social innovation tool activities.

Energy data will be continuously gathered using smart power meters and heating meters measuring within relevant intervals and fed into the Energy Manager tool for real-time visualisation and analysis of energy flows, including the matching between on-site renewable production and local consumption. Environmental data will be collected through sensors installed in accordance with the EN 16798-1:2019 [14] standard, monitoring key parameters such as indoor air temperature, humidity, CO_2 concentration, and illuminance over a minimum period of one year to capture seasonal effects. Economic data will be collected through static assessments and dynamic monitoring, including CAPEX and OPEX as benchmarks. Real-time data on energy pricing, investment returns, and cost savings will be transmitted into the Interoperability Platform.

Social data collection will be carried out through locally managed engagement processes, including surveys, technical screenings, and participatory mapping exercises. The data collected will undergo quality assurance protocols.

The data exchange between the PED and the PED RA is coordinated by the Interoperability Platform (IP), establishing secure, decentralised communication between data providers and consumers. The PED

Readiness Assessment benchmarks the PED's level of advancement by analysing consolidated datasets received via the IP in the four dimensions.

The Interoperability Platform serves as the central mechanism for dataset access and exchange coordination. The platform does not store data internally.

The data for the PED RA are collected and exchanged, e.g. energy performance and calculations for balancing operations utilise real-time metering data, historical trends, and local generation forecasts, while flexibility forecasts are computed using load and generation data, weather predictions, user-defined preferences, and asset constraints. At the economic level, cost analyses depend on dynamic market data, including retail and wholesale electricity prices, as well as economic parameters for district heating and fuel inputs. Environmental indicators, such as GHG emissions, are determined using emission factors linked to each energy carrier and technology profile. Social and behavioural data are collected through stakeholder-oriented activities, such as surveys, interviews, and participatory mapping. These datasets are processed and structured using the Social Innovation Tool. The Interoperability Platform creates a communication link to technical datasets through shared metadata, enabling the dedicated PEDvolution solutions to offer a holistic approach and understanding of user behaviour, and community needs.

5.1 Description of planned deployment

The PED RA traces integration of PED solutions (WP2–WP7), and deployment and validation will be done in WP9. The alignment with demonstration preparation requires that the demonstration setup is refined in WP2–WP7 (scenarios, infrastructure mapping, regulatory constraints).

Operationally, the baseline approach functions as follows:

1. Collect site-specific technical, organisational, regulatory and socio-economic input for each PED, using WP7-compliant data structures.
2. Derive initial KPI values per PEDvolution 4 dimensions (market, social, technology, interoperability) and analyse these KPI values in relation to the PED readiness. This outcome includes expected improvements in PED integration into the wider energy system, flexibility and grid robustness, citizen participation in energy communities, and availability and uptake of interoperable PED planning and operation tools.
3. Document assumptions and data limitations (e.g. incomplete metering data, preliminary stakeholder engagement data still under collection) are to be recorded explicitly so that later changes can be attributed to actual intervention rather than to improved data availability.
4. Freeze these values, assumptions, and mappings as the baseline state to be used in WP8 monitoring and in WP9 validation.

6 CONCLUSIONS

This deliverable presents the PED Readiness Assessment (PED RA) methodology and its calculation tool. It is a strategic framework designed to guide Positive Energy District (PED) projects and align all key stakeholders - city planners, policymakers, technical developers, and funding bodies - around a common understanding of "PED readiness." By providing a harmonised assessment approach, the PED RA methodology supports shared vision, informed decision-making, and the scalable deployment of PED solutions in pilot projects.

The PED RA framework integrated insights from related initiatives such as the Smart Readiness Indicator, social innovation research in energy communities, energy master planning, and established building assessment frameworks such as Energy Performance Certificates (EPCs). This convergence ensures methodological robustness and compatibility with existing standards and policy instruments.

The PEDvolution genes emerged from a structured methodological process in *D2.2. Understanding the PED Readiness Assessment framework which* integrates evidence synthesis, comparative analysis, and iterative stakeholder engagement.

Holistic Framework Aligned with Policy Goals

The PED RA methodology introduces a harmonised, transparent, and comparable framework to evaluate a district's readiness for positive energy objectives. It captures the PED's status at a given point in time and identifies development pathways in line with broader European sustainability policies (including the EU Green Deal, the Energy Performance of Buildings Directive, and the UN Sustainable Development Goals). This strategic alignment ensures that PED projects are not only locally effective but also contribute to national and EU climate targets.

Lifecycle-Based, Cross-Sector Integration

The PED RA approach covers the entire project lifecycle – from planning and design through implementation to operation – so that readiness is assessed at each stage. Four PED "genotype" dimensions structure the assessment (Technology, Market, Social, Interoperability), reflecting a cross-sector integration of energy systems, mobility, and industry within the district. This ensures a systemic view of PED development, where technological innovation, market viability, community engagement, and platform interoperability are all factored into readiness. The four-category framework also underpins a Monitoring and Verification Plan, enabling ongoing tracking of progress and later verification of PED performance objectives.

Standardisation & Comparability through a Common Tool

The PED RA calculation tool provides a standardised set of Key Performance Indicators (KPIs) and scoring logic, enabling consistent measurement of PED performance across different projects and cities. This common KPI catalogue ensures that results are directly comparable, allowing stakeholders to benchmark one district against another and track improvement over time. The tool generates an overall "PED-readiness" score for each district, along with separate scores for each dimension (technical, market, social, interoperability), giving decision-makers a clear snapshot of strengths and gaps. By quantifying readiness in a uniform way, the tool brings clarity and objectivity to discussions among diverse stakeholders.

Stakeholder Co-Development & Evidence-Based Triangulation

The PED RA methodology was co-developed with extensive stakeholder engagement to ensure relevance and buy-in. Workshops with city officials, industry experts, researchers, and community representatives were conducted to ideate and test KPIs in real PED contexts. A robust triangulation approach was applied: KPIs were only deemed “core” if supported by multiple independent evidence streams (e.g. existing sustainability frameworks, prior PED project data, and the PEDvolution genotype logic), which minimises bias from any single source. This evidence-based consolidation yielded a defensible set of indicators that reflect best practices and on-the-ground insights. Finally, stakeholders participated in voting and prioritisation exercises, applying agreed criteria (PED relevance, solution relevance, priority level, etc.) to focus the assessment on the most critical and feasible KPIs. This inclusive, data-driven development process ensures the PED RA tool addresses what matters most for successful PED implementation.

Scaling Deployment Across PED Pilot Projects

The PED RA tool is designed for deployment in multiple pilot districts, serving as a common evaluation backbone for the PED program. It can be used as a stand-alone or add-on solution to consistently measure PED performance, which is crucial for scaling up and replicating PED solutions. This standardised monitoring backbone allows lessons from one pilot site to inform others, keeping all stakeholders aligned on performance targets and accelerating collective progress in PED development. It also enables stakeholders to benchmark progress across projects and ensures that PED initiatives stay on track with broader climate neutrality goals. In sum, the PED Readiness Assessment methodology and tool provide strategic clarity and comparability, helping to de-risk innovation and guide investments as cities and communities work toward sustainable, positive-energy districts.

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ANNEX I: FORMULAS FOR TECHNOLOGY KPIS

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ANNEX II: FORMULAS FOR MARKET KPIS

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ANNEX III: FORMULAS AND QUESTIONS FOR SOCIAL KPIS

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ANNEX IV: FORMULAS FOR INTEROPERABILITY KPIS

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ANNEX V: SCORING VALUES FOR KPIS

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