simply positive

D5.3 Updated Framework definition status and Methodology description for SIMPLY POSITIVE

November 2024


(Picture: Positive Energy District according to DaVinci AI)

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Dissemination Level

PU	Public	X
CO	Confidential	

History

Version	Description	Lead author	Date
V1	Table of Content	UASTW	June 2024
V2	First Draft	UASTW	July 2024
V3	Collection of partner input	UASTW	September 2024
V4	Review	SON	September 2024
V5	Discussion of stakeholder feedback	ALL	October 2024
V6	Final Template	UASTW	October 2024
V7	Internal review and approval	UASTW	November 2024
V8	Final Review and approval	SON	November 2024

Disclaimer

This project has been developed in the framework of the PED Program, which is implemented by the Joint Programming Initiative Urban Europe and SET Plan Action 3.2. *The Austrian part is supported by the Austrian Ministry of Climate Action, Environment, Energy, Mobility, Innovation, and Technology (BMK); the Romanian part is supported by a grant of the Ministry of Research, Innovation and Digitization CNCS/CCCDI – UEFISCDI, project number PED-JPI-SIMPLY POSITIVE, contracts number 325/2022 and 326/2022, within PNCDI III; the Dutch part is supported by the RVO (the Netherlands Enterprise Agency), reference number ERANETPED-02767306; and the Italian part is supported by a grant of the Ministry of Education and Merit - Department for Higher Education and Research, project number PED_00042, from the Fund for Investment in Scientific and Technological Research (FIRST/FAR) and/or Special Accounting Account no. 5944.*

Executive Summary

Based on the analysis of the four focus districts conducted within the framework of this research project, a comprehensive interdisciplinary approach to the early stages of PED identification was developed, based on considering PED as an object or system. Taking into account the available methods of energy balance analysis and the available data for its implementation, within the framework of this research project the focus districts were considered as objects.

The analysis of feedback from key stakeholders involved in the focus area evaluation helped identify critical areas for enhancing the energy balance calculation methodology and improving the interpretation of results in the context of their applicability to PED implementation.

Based on the results of the analysis of the focus districts, potential ways to improve the methodology for calculating the energy balance were identified, consisting in adapting the methods for calculating the context factor. Using the new context factors, Primary Energy Supply and Primary Energy Demand calculations were performed, showing the path and potential for achieving a positive energy balance in each of the focus districts.

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List of Abbreviations and Acronyms

BOB	building operation balance
BUB	building use balance
CF	context factor
CFD	context factor for density
CFR	context factor for renovation
DHW	domestic hot water
DSM	demand side management
EPBD	Energy Performance of Buildings directive
EU	European Union
FAR	Floor Area Ratio
FD	focus district
GHG	greenhouse gas
HVAC	heating, ventilation, and air-conditioning
ICT	Information and communications technology
IEA	International Energy Agency
JPI	Joint Programming Initiative
KPI	key performance indicator
PED	Positive energy district
PEN	Positive energy neighborhood
PV	Photovoltaics
REC	Renewable Energy Community
RES	Renewable Energy Sources
RRS	Realistic renovation scenario
SCR	Site Coverage Ratio
TRS	Technical renovation scenario
TMS	Technical maximum scenario
WP	work package

Table of Contents

1 Introduction

1.1 Purpose of the document

The purpose of the document is to provide a comprehensive analytical overview of the results of the PED energy balance calculation methodology and highlighting the possible ways of its improvement.

Provided suggestions are developed on the base of results analysis of the four focus districts and could be considered as a framework for the next global development and implementation of the Positive Energy Districts.

1.2 Relation to other project activities

The document is connected to project activities in the following way:

Activity / deliverable	Relation
D1.1. Report on operation scenarios, technical characterization and identified stakeholders of Focus Districts	Existing data for the Energy Balance Calculation.
D1.2. Key performance indicators for PED/PEN implementation assessment	KPIs related to the Energy Balance Calculation.
D3.1. Framework definition status and Methodology description	Methodology description and required data for its usage.
D3.2. Gap analysis of Energy Balance Calculation Data	Gaps and how to close them
D3.3. Assessment report on Focus District	Results of FDs assessment

2 PED as an object and methodology for its analysis in the SIMPLYPositive project

In modeling Positive Energy Districts (PEDs), researchers often lack a generalized characterization and a unified approach to identifying PEDs. For example, in [4], a straightforward approach is used to generalize already implemented PEDs based on the technological solutions applied. At the same time, a comprehensive level of consideration is not identified, and it remains unclear which specific aspects of PEDs should be considered in subsequent analysis and implementation. Another common approach involves identifying PEDs based on a set of performance criteria, which are subsequently used in monitoring [5]. Despite the effectiveness and relative simplicity of this approach, it does not resolve the issue of globally defining the boundaries of PEDs and the level of detail required in analysis. It also introduces additional challenges in analysis and monitoring if the PED evaluation criteria change.

Despite a fairly large number of review studies on PED topics and methods of analysis and identification [6], there are no definitive recommendations on the level of PED consideration, nor is there a systematic and unified approach. This situation calls for the development of a fundamentally new perspective on the aforementioned problem.

2.1 Is PED an “object” or a “system”?

When analyzing PED, the key aspect is its identification in a broad sense, which includes not only defining the district boundaries and the flows (typically energy flows) that cross them [2], but also a well-reasoned classification of PED as an object or a system, which is subsequently important for analysis.

According to several scientific sources [7], [8], etc., the concept of an object can be defined as follows. An object is a distinct entity with clearly defined boundaries, possessing unique identity, state (properties), and behavior (methods). At the same time, a system is a set of interconnected and interacting components that work together to achieve a common goal or perform a specific function [9], [10]. A comparative analysis of the concepts of an object and a system is presented in Table 1.

Table 1 – Characteristic features of “object” and “system”

Attribute	Object	System
Definition	A distinct entity with unique identity, state, and behavior	A set of interrelated components working together to achieve a common goal
Identity	Unique in itself	Identity is determined by the interaction of components (objects)
Purpose	May have its own goals	Always aimed at achieving a common goal or performing a function
State	Described through properties	Described through the state of all its components and their interaction

Behavior	Described through methods or actions	Described through the functions and processes performed by components

When considering a Positive Energy District (PED) as a complex entity, we can analyze its identity, purpose, state, and behavior in terms of system theory and object-oriented approaches in terms of urban energy management. Table 2 provides a comparative description of the object and system attributes.

Table 2 – Comparison of attribute concepts for object and system

Attribute	Object	System
Identity	defined by its physical characteristics and components	characterized by the interactions and relationships among its various components, including buildings, energy generation units, residents, and governance structures
Purpose	to function as a physical space that generates more energy than it consumes.	dynamic and multifaceted, aiming for sustainability, energy efficiency, and resilience
State	refers to its current physical and energy-related characteristics.	a dynamic measure of its overall performance and operational status.
Behavior	involves changes in its physical state over time.	encompasses the dynamic processes and interactions within the district

Based on the above definitions of the attributes of an object and a system in the context of PED, the following examples of each of them can be given (Table 3).

The system view focuses on energy flows and their management, while the object view focuses on the characteristics and behavior of the region as a single energy entity.

In the SimplyPositive project, it is advisable to consider all Focus Districts as objects for the following reasons:

– the analysis of FDs within the project is carried out in the context of the goals formulated by district representatives, which, in turn, are specific (own) for each FD (see the definition of the goal in Table 1);

– the selected methodology [2], [3] for the PED analysis is based on the normative approach to calculating energy balances and does not allow for the consideration and characterization of individual components of the system simultaneously with their interaction (see the concept of identity in Table 1);

– the impossibility of determining and generalizing the state and behavior of individual components of each FD with a subsequent description of their interaction (see the definition of the concepts “state” and “behavior”, Table 1).

Here and after we will consider PED as an object.

Table 3 – Examples of attributes for object and system

Attribute	Object	System
Identity	The unique layout of the district includes specific buildings, solar panels, wind turbines, and other infrastructure. This could include the geographical boundaries of the district and its specific renewable energy installations.	The integrated operation of smart grids, energy storage systems, and community engagement initiatives collectively define the district's functionality and sustainability goals.
Purpose	The district aims to achieve a net positive energy balance, showcasing practical implementation of renewable energy solutions to reduce dependence on non-renewable sources.	To create a sustainable living environment that continuously adapts and improves, reducing environmental impact and providing economic benefits while ensuring a high quality of life for residents.
State	Metrics such as total energy generation capacity, current energy consumption levels, efficiency of installed renewable energy systems, and the condition of the infrastructure.	Real-time data on energy production and consumption, operational status of smart grid technologies, and effectiveness of community initiatives in energy conservation.
Behavior	The installation of new solar panels or wind turbines, retrofitting buildings for better insulation, and other modifications aimed at improving energy efficiency and increasing renewable energy output.	Patterns of energy generation and consumption, responses to environmental changes, management of energy storage and distribution, and community engagement in energy-saving practices.

3 Stakeholders Feedback

This chapter consolidates feedback and insights from Project participants' feedback, focusing on challenges and recommendations in both the PED Framework Definition and Energy Balance Assessment phases. Since the Project involved a limited group of stakeholders and focused, in a large part, on the analysis of the applicability of the methodologies for identifying PEDs and calculating the energy balance of focus districts, feedback from PED representatives and the scientific team directly carrying out the calculations was analyzed. The feedback was requested on three main topics: PED Definition Framework, data preparation for Energy Balance Simulation, and Results of Energy Balance Simulation.

3.1 PED Framework Definition

The PED Framework (Positive Energy District Framework) serves as a strategic tool to guide municipalities and other stakeholders in planning and creating districts that achieve a positive energy balance (PED – Positive Energy Districts). The main goal of this phase is to define clear boundaries, objectives, and approaches for achieving energy-positive performance within a specific district. However, feedback from participants highlights practical challenges that need to be addressed to improve the framework and implementation methods.

Understanding of the PED Framework boundaries

Feedback indicates that most participants have a general understanding of the PED Framework, but issues arise when defining the functional system boundaries of a PED, especially in cases where municipalities face data gaps. This is often due to the absence of clear guidelines for data collection and interpretation and, as a result, difficulties in defining the type of focus district (e.g. PED Alpha or PED Beta, which also includes mobility).

For example, one report mentions difficulties with integrating daily private mobility into the PED assessment due to unclear data collection methods and issues in identifying who owns the relevant data. In another district, there were challenges in defining the boundaries from the perspective of a mobility model, which complicated the overall understanding of the PED Framework.

Defining the type and boundaries of focus districts

Most municipalities did not encounter difficulties in defining the type and physical boundaries of their district, especially when buildings shared similar characteristics. However, as previously noted, adding mobility considerations to the energy balance created uncertainties and complications in determining the district's overall boundaries.

Setting goals

Setting goals for PED districts was a challenging task for many participants. Several reports pointed out that existing municipal strategies and plans were not always aligned with PED objectives, making it difficult to adjust and set new goals. Additionally, some municipalities required approval at various levels of governance, which further delayed the goal-setting process.

3.2 Data Collection for Energy Balance Assessment

The Energy Balance Assessment is a critical phase of the Positive Energy District (PED) project, aimed at evaluating the energy performance and potential of the district. This phase requires detailed data on the district's physical, energy, and geometrical characteristics, which are essential for accurate simulations of achieving PED status. Feedback from various municipalities has highlighted several challenges related to data collection, particularly regarding delays, data accuracy, and the availability of relevant data.

The data collection process for the Energy Balance Assessment encountered significant hurdles, particularly in areas such as general characteristics of buildings, energy data, physical parameters, and geometrical dimensions [1]. These challenges stemmed from a combination of organizational, technical, and practical issues. The next are provided the main issues for each identified data group [1].

General Characteristics

General characteristics refer to basic data about the district, such as the number of inhabitants, building types, and the year of construction. The next issues were recognized:

- **Data availability:** multiple municipalities faced delays in gathering even basic information about their districts, such as the size and population of the area. The key challenge reported was the absence of pre-defined structures within municipalities for gathering and sharing data. In many cases, ownership of the required information was not established at the beginning of the project.
- **Responsibility and coordination:** the lack of clear responsibility for data collection within municipal structures often led to delays. Without dedicated personnel or departments responsible for this task, many municipalities struggled to meet the project's timelines. This problem was exacerbated by the need to interact with multiple municipal departments or external bodies to obtain the necessary information.

Energy Characteristics

Energy characteristics include information about energy supply, energy demand, photovoltaic (PV) installations, heating, ventilation, and air conditioning (HVAC) systems, among others. At the data collection the next issues were identified:

- **Access to energy data:** a major challenge in data collection was accessing accurate energy data, especially for older or privately owned buildings. In several cases, the energy data was only available through energy performance certificates (APEs), which were often outdated. Many buildings had not undergone recent updates, meaning that critical energy data was either unavailable or outdated.
- **Building ownership issues:** in districts where buildings were privately owned, gathering energy-related data proved particularly difficult. Municipalities lacked a single point of contact to collect consistent information across multiple private

buildings. Additionally, there was a lack of mandatory reporting from building owners, further complicating the collection of relevant energy data.

- **Old building stock:** in some municipalities, the buildings were constructed many decades ago, and their original design data (including energy characteristics) was often either unavailable or no longer reflective of the current state of the buildings due to renovations or other changes.

Physical Characteristics

Physical characteristics refer to the technical details of buildings, such as U-values (thermal transmittance), building materials, window types, and construction details [1]. The next issues were found:

- **Data gaps**: there were widespread gaps in the availability of physical characteristics, especially in older buildings where comprehensive technical documentation was missing. Municipalities often found it difficult to gather U-values and other relevant parameters (e.g. G-value for windows, etc.), leading to significant challenges in energy modeling or the necessity to use generalized data from scientific literature sources.
- **Inconsistency in data**: in some cases, while original design documents were available, they were no longer accurate due to undetectable changes made to the buildings over time. This inconsistency complicated efforts to gather precise data for energy simulations.

Geometrical Characteristics

Geometrical characteristics include floor plans, areas of thermal envelopes, net and gross areas, etc., all of which are crucial for accurate energy balance simulations [1].

Many municipalities lacked up-to-date floor plans or accurate measurements of building dimensions. In several cases, municipalities had to resort to manual measurements using tools like Google Maps to estimate building areas and thermal envelopes. This approach led to inaccuracies and must be considered insufficient for precise modeling.

For some districts, especially those with older building stock, obtaining geometrical data was particularly challenging. In some instances, the original design plans were outdated or incomplete, and modern updates or renovations to buildings had not been reflected in any documents.

3.3 Energy Balance Simulation Results

The results of energy balance simulation serve as a foundation for setting future goals and action plans for PED development. The following generalized feedback from participants reflects diverse expectations and experiences with the simulation results, highlighting both strengths and areas for improvement in different aspects.

Expectations for Energy Balance Simulation

Participants had varying expectations regarding the outcomes of the energy balance simulation, depending on the characteristics of their district and the stage of development within the PED project. There are two main directions in expectations from the results of energy balance modeling:

1. Guidance for future goals and action plans. Many stakeholders viewed the energy balance simulation as a starting point for defining future targets, action plans, and specific steps that their districts should take to achieve PED status. They anticipated that the simulation results would provide detailed benchmarks or recommendations on how to optimize energy supply and reduce energy demand within the district. For example, concrete recommendations, such as how much photovoltaic (PV) capacity would need to be installed to meet PED targets, and whether the available roofs area was sufficient for such installations.
2. PED Feasibility Assessment. In certain districts, particularly those with older building stocks or unique architectural constraints, participants expected the simulation to reveal challenges in achieving PED status. At the same time these stakeholders would like to understand whether the district's infrastructure could support renewable energy generation to the extent necessary for achieving energy-positive status, or if significant upgrades would be required.

Generally, stakeholders expected the simulation to offer clear, actionable insights into how their districts could transition toward energy-positive status.

Satisfaction with simulation results

The level of satisfaction with the energy balance simulation results varied across the districts, with some participants expressing satisfaction with the comprehensiveness of the analysis, while others highlighted areas where more detail or actionable insights were needed.

In cases where the simulation confirmed the district's ability to achieve PED status respondents reported that the PED analysis provided in the simulation was complete and satisfactory. In the regions where initially, difficulties were met (at the stage of FD identification or data collection) stakeholders, however, felt that the results lacked sufficient detail, particularly in providing concrete recommendations for achieving PED targets.

In some cases, the simulation results were based on estimated data rather than measured data, which participants felt limited the precision and impact of the results.

Preferred Format for Results Presentation

The format in which the simulation results were presented was another area where stakeholders had diverse preferences. Most respondents agreed that a combination of tables, graphs, and text was the most effective way to present the findings, as this approach provided both detailed data and a narrative explanation.

The graphs were particularly appreciated by many stakeholders because they provided a clear and easy-to-understand visual representation of the district’s energy balance. In cases where there were complex data sets—such as comparisons between energy supply and demand, or different scenarios for renewable energy generation—graphs helped stakeholders quickly grasp the key insights.

Tables were useful for those stakeholders who wanted to see the exact figures behind the simulation. Detailed numbers on energy consumption, renewable generation potential, and building characteristics were valued for their precision and usefulness in strategic planning.

While data and graphs were important, many stakeholders emphasized the need for accompanying interpretative text that explained the implications of the results. Participants wanted to understand what the numbers meant in practical terms, such as what actions should be prioritized or what the potential challenges might be. Without this interpretative layer, the data alone was seen as insufficient to drive informed decision-making.

3.4 Ways to improve FD's characterization and assessment

PED definition

There are a few directions in PED definition to improve overall process, which were suggested by stakeholders:

- **Clearer data collection guidelines:** to provide more specific instructions at the beginning of the project on what data to collect and which authorities are responsible for it. Structured sessions with municipal leadership were suggested to identify data owners and clarify the responsibilities within the organization.
- **Multi-tiered data collection system:** to implement a two-layered data collection system: minimum requirements and optional extended data. This approach would allow flexibility for municipalities at different levels of readiness to participate in the PED project. digital open-source tools should also be encouraged where data can be extrapolated or estimated.
- **Integration of professional data collection tools:** to use more professional tools for gathering geometrical data of buildings and their characteristics. This would replace less accurate methods that are currently used.

Energy balance simulations

The Energy Balance Simulation phase is crucial for assessing the feasibility of achieving PED status and setting future goals. Based on the feedback, several key recommendations emerged for improving the results of future energy balance simulations:

- **Use measured data where possible:** to enhance the accuracy and credibility of the simulations, future assessments should prioritize the use of measured data over estimated data. When estimations are necessary, the assumptions and methodologies used should be clearly documented to provide context for interpreting the results.
- **Balance supply and demand solutions: s**imulations should focus not only on increasing renewable energy supply but also on reducing energy demand. Detailed suggestions for energy-saving measures and retrofits could help districts lower their energy consumption and achieve PED status more easily.

Results interpretation

Despite the overall satisfaction with the energy balance simulation, several key areas for improvement were highlighted.

Stakeholders expressed the need for more detailed recommendations on how to implement PED strategies. For example, they wanted to know the exact steps required to increase renewable energy generation or reduce energy demand in their districts. This included specific guidance on:

- PV capacity needed (in numbers) to meet PED targets.
- Space utilization (e.g., how to use rooftops, green areas, or other surfaces for renewable energy installations).
- Energy efficiency measures or building retrofits to lower energy demand.

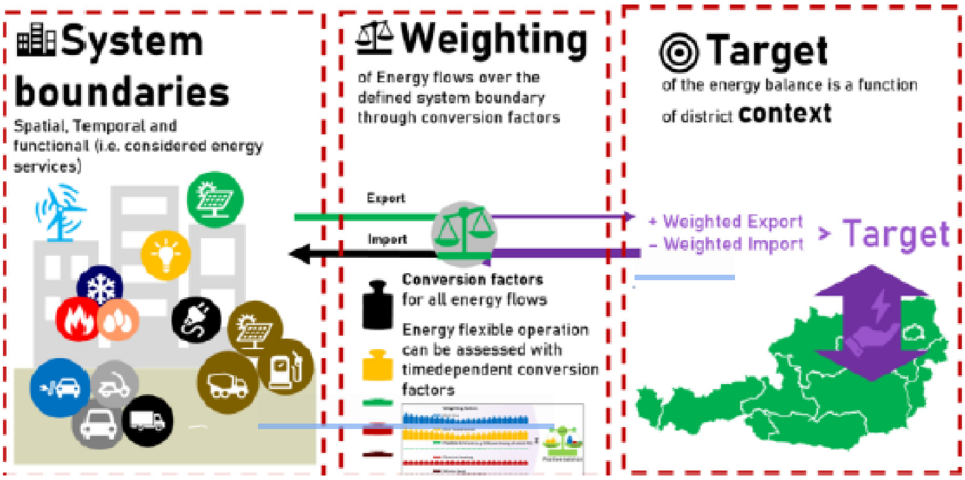
The absence of these specific recommendations was seen as a gap in the simulation results, which otherwise provided useful but somewhat generic insights.

For the improvement of stakeholder engagement, future results should continue using a combination of tables, graphs, and narrative explanations. Visuals such as graphs help communicate complex data effectively, while interpretative text provides valuable context and guidance.

4 Updates in Methodology Description for SIMPLY POSITIVE

The PED assessment concept in general is summarized in Figure 1 [2]. Methodology is mainly based on the district energy balance simulation and assessment framework [2], [17], which considers both demand-side and supply-side measures to achieve a positive energy balance.

Figure 1. PED assessment concept



The PED energy balance analysis, in general, involves the following key steps:

1. Focus district characterization.
2. Dataset forming.
3. Energy balance assessment.

On the first stage "district characterization" the boundaries of district are defined. It means that energy flows, geographic boundaries, district development goals, key performance indicators etc. should be defined [11]. This process is quite well described in [2]. It should be noted that the focus district characterization depends on computer technologies and the whole digitalization level requires mostly analytical work from experts with stakeholders' support.

The second stage "Dataset forming" is the least formalized and practically not described in the open literature. However, it is the quality of preparation of the initial data set that will directly affect the quality of the results obtained on the third stage (e.g. [12]).

Thus, there is a need to formalize the process of preparing initial data for calculating the energy balance, and, as a result, improve the quality and efficiency of the calculation process.

The process of dataset forming starts after focus district characterization and requires description of district boundaries [2]. This information is analyzed and requires information is taken from outer databases (climate/weather (e.g. [13]), energy monitoring/statistical (e.g. [14]), building documentations databases (e.g. [15]) and GIS systems (e.g. [16])). District representatives are involved remotely only if required data could not be approached directly by experts. In case data could not be obtained assumptions are made. Before forming the final dataset, all collected information is interpreted to the required format with purpose than to be transferred to the next task of energy balance calculation.

The high involvement of digital databases is typical for highly digitalized countries, where the most information is stored on digital sources and available for usage. In case if region is on the stage of middle level of digitalization, which means only part of required data is available in digital format, the role of district representatives is increased (Figure 2).

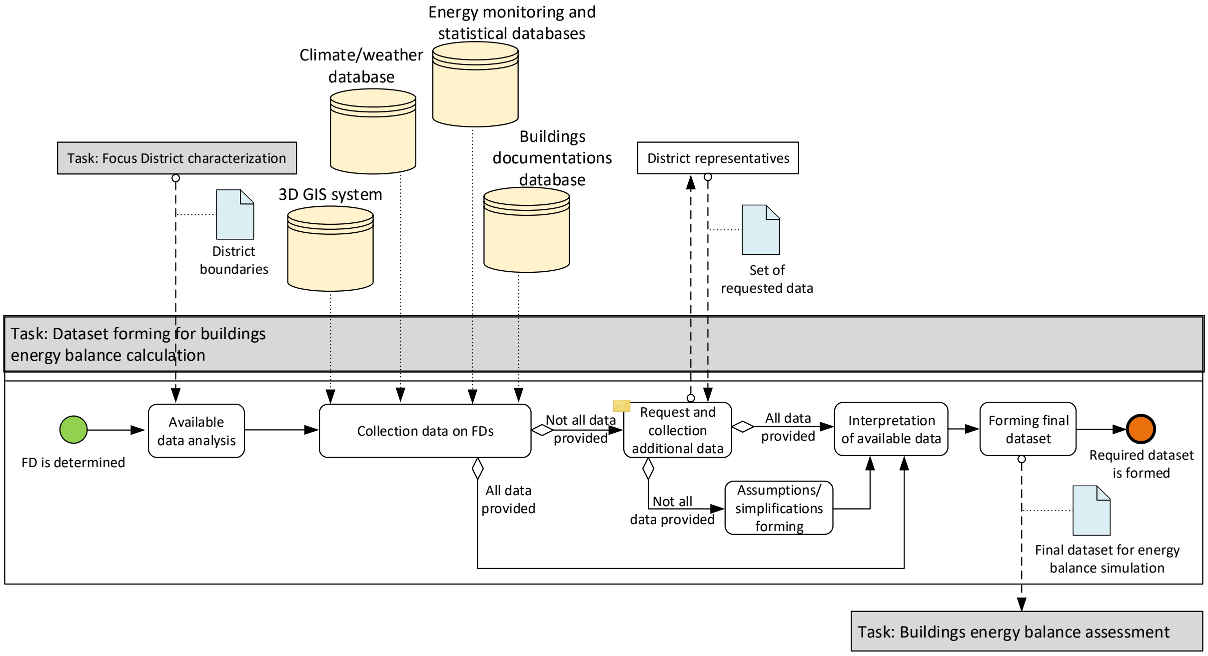


Figure 2. Adapted process flow for dataset forming

District characterization

Each district is characterized based on its physical and energy infrastructure, climatic conditions, and urban fabric. This includes the identification of building typologies, energy usage patterns, and renewable energy potentials and is summarized in Table 4.

Scenario Development and assessment

Scenario development is an important step at PED characterization and assessment. For each district, multiple retrofitting scenarios are developed. These scenarios include various combinations of building insulation, window replacement, roof insulation, and the installation of PV panels. Additionally, the potential for integrating flexible grid usage and renewable energy technologies is assessed. All districts are investigated by several different scenarios that each add measures and features compared to the previous one:

- Baseline represents the status-quo without any additional measures.
- Initial local renewable energy scenario is formed by including roof-mounted PV (+X%PV), where X denotes the share of roof areas covered by PV modules.

Table 4 – Comparison of Focus District characterization

Parameter	Unit	IT, Settimo Torinese	AT, Großschönau	NL, Amsterdam	RO, Resita
District Area	ha	19.0	705.0	3.0	47.0
Gross Floor Area	m^2 GFA	213 937	40 161	98 941	130 700
District Buildable Plot Area	m^2 PA	146 000	391 000	30 035	420 859
Floor Area Ratio (FAR)	-	1.47	0.15	3.29	0.31
Site coverage Ratio (SCR)	%	26	7	78	18
Net to Gross Floor Area Ratio	%	80	70	80	80
Building storeys (avg)		5.6	1.5	4.2	4.9
Residential usage	%	98.5	82.2	19.1	70.0
Commercial usage	%	0.2	11.7	29	3.9
Primary School Usage	%	0.0	5.0	0.0	0.0
Secondary School Usage	%	0.0	0.0	0.0	9.8
Others (Retail) Usage	%	1.4	1.1	51.9	9.8
Heating setpoint	°C	22	22	22	22
Heating COP Heat pump (Flex)	-	3.5 (4.5)	3.5 (4.5)	3.5 (4.5)	3.5 (4.5)
Heating degree days	°Cd	4786.0	3483.1	3917.9	3877.8
Cooling Setpoint	°C	26	26	26	26
Cooling COP Heat pump (Flex)	-	2.5 (5.0)	2.5 (5.0)	2.5 (5.0)	2.5 (5.0)
Cooling degree days	°Cd	0.4	6.9	1.1	16.4
Primary Energy Conversion factors	Source	[18]	[19]	[20]	[21], [22]

- **Realistic renovation scenario (RRS)** implements thermal renovation measures feasible to local practitioners. This is typically followed by another PV scenario.
- Measures representing the maximum technical potential for thermal energy savings within the **technical renovation scenario (TRS)**.
- **Flexibility measures (Flex)** are considered according to the specifications in Table 4.

- Final scenario measures are grouped into a Realistic scenario and a **Technical maximum scenario (TMS)**.

The energy balance for each scenario is calculated according to [2] by comparing the total energy demand of the district with the energy generated from renewable sources. The simulation accounts for seasonal variations in energy demand and generation, as well as the efficiency of the implemented technologies. System Boundaries for energy balance calculations include energy demands for building operation and user plug-loads and renewable energy produced within the district.

During the PED energy balance calculations, the correct consideration of context factor is the key issue. The results are analyzed in the context of each district's specific characteristics, including climatic conditions, building density, and energy infrastructure. This analysis provides insights into the effectiveness of different retrofitting strategies in achieving a positive energy balance. The realistic and TMS scenarios were subsequently analyzed with the following Energy balances and contexts:

- **Building use balance (BUB)** includes operation and plug-loads. It is the default balancing boundary and typically the most negative.
- **Building operation balance (BOB)** excludes user plug-loads, making it easier to achieve a positive balance.
- Including a **context factor for density (CFD)** as a virtual balance component as a function of the floor area ratio (FAR):

$$CFD = MIN\left(\left(\left(\frac{61.94}{FAR\_0.15}\right) - 53.79\right), 125\right)$$

- **CFD*2**: The initial contextualization is suitable for high density urban districts but leads to unrealistically high expectations for local renewable energy supply in low density neighborhoods. Here, it must be assumed that only parts of the plot area can be used for energy generation. This is operationalized by introducing an additional factor of “RES plot utilization”, that is bound by two times the Site Cover Ratio (SCR) up to 100% of the available plot.

$$CFD^{*}2 = MIN\left(\left(2SCR\left(\frac{61.94}{FAR\_0.15}\right) - 53.79\right), 125\right)$$

- **CFD*3**: Works the same as CFD*2, except with a higher factor of site cover utilization of three. This is a compromise between assuming the underlying RES potential to correlate with plot area and roof area respectively.

$$CFD^{*}3 = MIN\left(\left(3SCR\left(\frac{61.94}{FAR\_0.15}\right) - 53.79\right), 125\right)$$

- **context factor for renovation (CFR)**: Finally, a simpler approach was analyzed by adding a flat 15 kWhPE/m²NFA discount to the energy balance.

Based on the results of modeling [23], the main changes that can be implemented in the methodology for calculating the energy balance lie in changing the method for calculating the context factor.

The results illustrate that meaningful decarbonization targets must quantifiably include district density. Notably, achievability of a positive energy balance depends more on district density than on the amount of heating and cooling days determined by climate. Differences in PV yields due to different climate have an effect, but also to a much lesser degree. This is highlighted by the fact that the district with the coldest climate and most heating degree days, AT, Großschönau, achieves the best, almost positive energy balance, even though the PV roof utilization rate of 58% is similar if not lower when compared to the other districts (Figure 3).

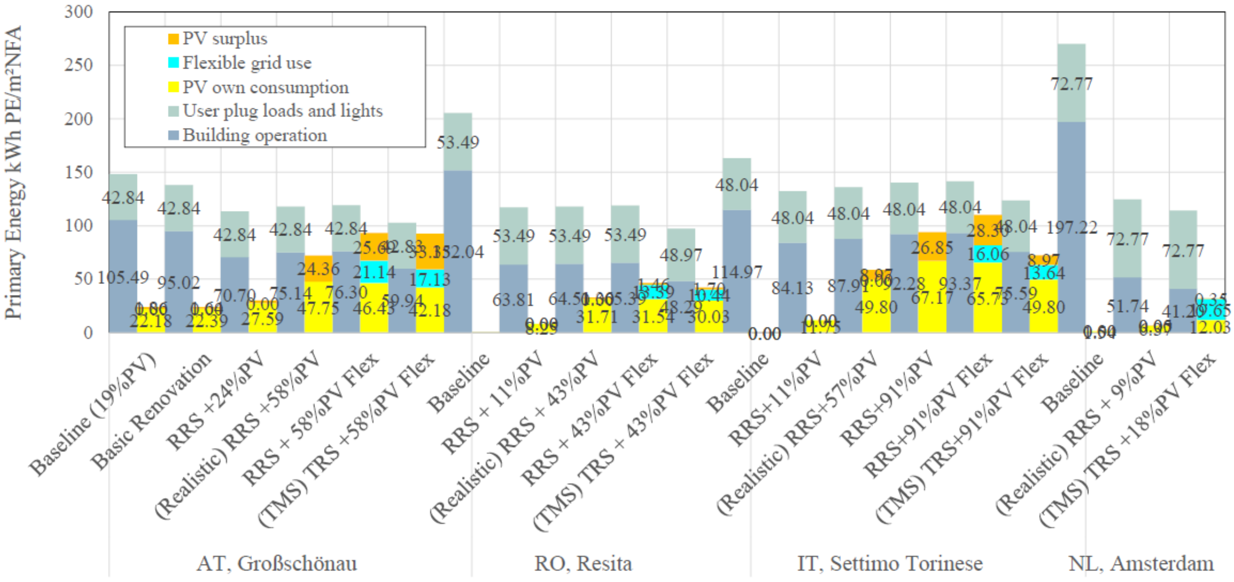


Figure 3. Primary Energy balance of investigated scenarios, grouped by district (Sections), demand (left columns) and supply (right columns)

The set of calculations was done with the new context factors (Figure 4). In Figure 4 are consecutive measures represented by solid arrows indicating energy savings (dark blue), additional PV installation (orange) and flexible HVAC operation (cyan). The 45° lines indicate the energy balance of the realistic (black) and technical maximum scenario (TMS, green) respectively. The TMS balance point (green x) is origin to the contextual balance components BOB (light blue), CFD (crimson), CFD*2 (lighter red), CFD*3 (light red) and CFR (teal)

Use of the already established context factor density (CFD) [2] can compensate for dense urban context's low potential, but is not feasible for rural retrofitting, as can be seen by the overwhelmingly negative balance shift for AT, Großschönau with FAR=0.1 and the negligible to moderate effects for the districts of medium density, RO, Resita (FAR=0.9) and IT, Settimo Torinese (FAR=1.5).

Instead, a combined density context factor including the site coverage ratio (SCR) as employed with CFD*2 and CFD*3 can maintain a density offsetting effect for urban areas while prevent unreasonably high requirements of PV installation for low density districts by decoupling it from the plot area as sole variable. With CFD*2, restricting the potential PV area to twice the roof area significantly dampens the balance target for all densities so that the initial effort sharing effect between high and low densities diminishes.

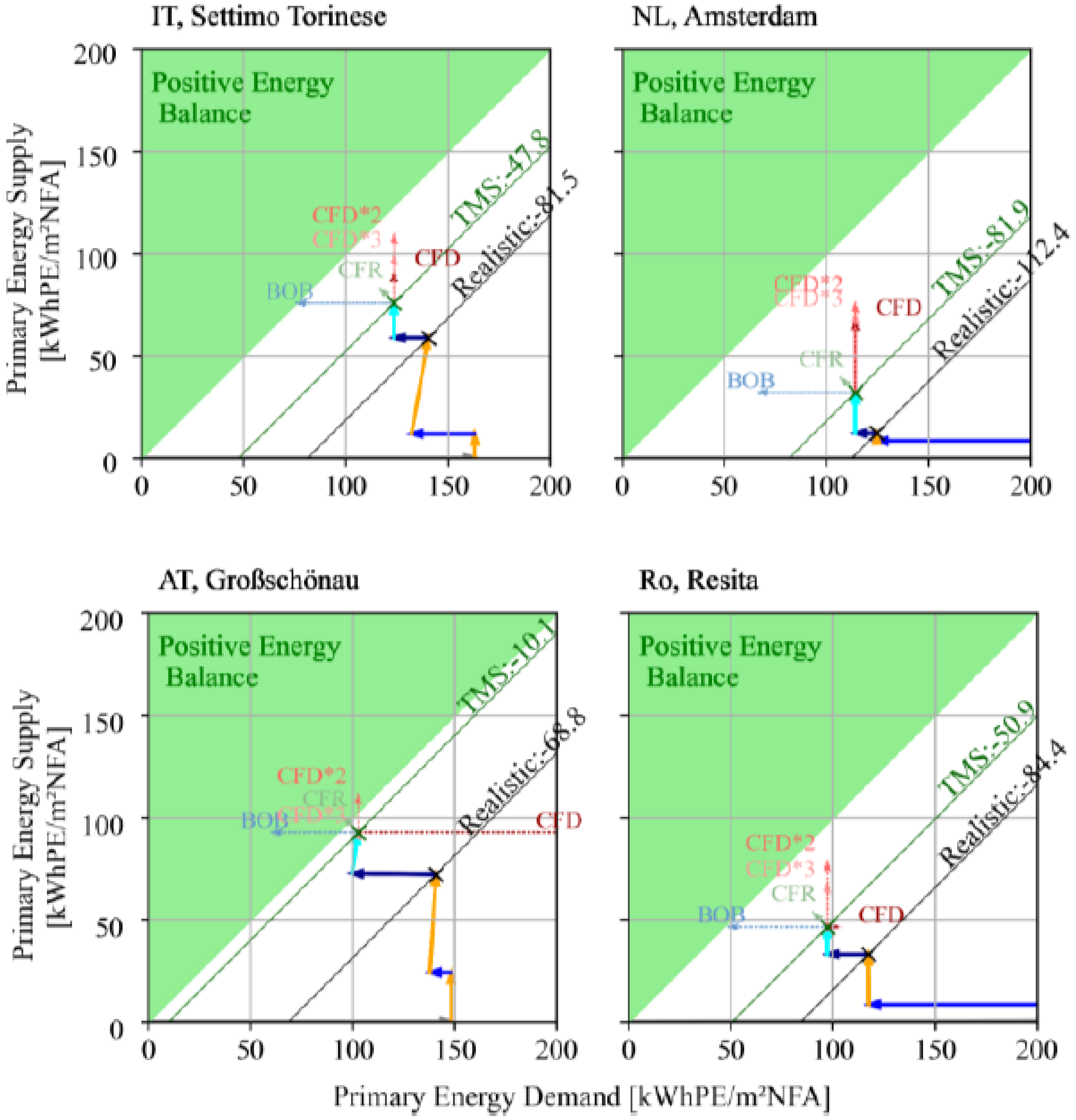


Figure 4. Primary Energy supply against demand with the different context factors

When combined with a small context factor for renovation (CFR), the application of CFD*3 is sufficient to ensure PED feasibility for all densities while retaining a strong density offsetting effect.

Nevertheless, heritage protected buildings pose additional challenges to a positive energy balance that cannot and, due to their nature as significant buildings, should not be handled by the application of standardized virtual balance components.

The case studies highlight the variability in the potential for urban retrofitting to achieve a positive energy balance across different European contexts. The results emphasize the importance of tailored retrofitting strategies that consider the specific climatic, urban, and regulatory conditions of each district. In colder climates like Großschönau, insulation and heating efficiency are critical, while in sunnier regions like Settimo Torinese, PV installations play a more significant role. In historical districts like Amsterdam, regulatory constraints necessitate innovative approaches to retrofitting.

5 Conclusions

This report proposes a fundamentally new interdisciplinary approach to identifying and considering PEDs as either an object or a system, depending on the required level of detail. In this context, key criteria for considering PEDs at both the object and system levels are presented, which have also been applied to the four focus districts examined in this research project.

Stakeholder feedback was analyzed across three main areas: characterization of FD, corresponding to the initial stages of FD assessment; evaluation of FD's energy balance, including the preparation of baseline data; and analysis and interpretation of calculation results in the context of PED implementation feasibility. Stakeholders experienced the most difficulties during the data preparation stage, and there were also significant differences in the expectations of the results obtained. Key recommendations for applying PED characterization methodologies and energy balance calculations include: increasing the level of FD digitalization, which will significantly simplify the application of modern energy balance calculation methods in the future; involving stakeholders more extensively in the early stages of PED implementation, which will help reduce communication issues and more effectively allocate roles in the overall PED implementation process; and expanding methods for presenting energy balance calculation results by adding visualized interpretations of the data obtained.

Urban retrofitting can significantly contribute to achieving a positive energy balance in European districts, but its success depends on a combination of factors, including climatic conditions, building characteristics, and regulatory frameworks. The case studies of Settimo Torinese, Großschönau, Amsterdam, and Resita demonstrate that while PEDs are attainable, they require aggressive retrofitting measures, the integration of renewable energy sources, and advanced energy management systems. The findings provide valuable insights for policymakers and urban planners aiming to promote sustainable urban development through retrofitting.

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