simply positive

D3.1 Framework definition status and Methodology description for ***SimplyPositive***

December 2023

(Picture: Positive Energy District according to GPT4)

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Disclaimer

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Executive Summary

The aim of the deliverable is to

- give district developers an overview of the current state of Positive Energy District (PED) definition frameworks.
- discuss their strengths and weaknesses.
- present the definition methodology used in the SimplyPositive Project.

A SimplyPositive Focus District is a “Positive Energy District” if its total primary energy balance is positive for a year of operation.

PED Definitions can be classified in two categories. This can be achieved for two system boundaries, of which only the first is mandatory:

1. PED Alpha: Including building operation and use.
2. PED Beta: Also including everyday mobility.

The energy balance includes virtual positions called “context factors” to contextualize the district potential and calibrate its balance target. These are:

1. Density Context factor, lowering the target for denser and increasing it for lower density districts.
2. Mobility system context factor depending on external resources for sustainable mobility.
3. Not yet developed: Heritage context factor

Other balance offsetting mechanisms such as crediting of external sources are not permissible.

The primary energy is assessed with time dependent conversion factors, where flexible grid supporting behavior has beneficial conversion factors.

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List of Abbreviations and Acronyms

CF	context factor
DHW	domestic hot water
DSM	demand side management
EPBD	Energy Performance of Buildings directive
EU	European Union
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
UASTW	University of Applied Sciences Technikum Wien
WP	work package

Table of Contents

1 Introduction

1.1 Purpose of the document

The aim of the deliverable is to

- give district developers an overview of the current state of PED Definition frameworks,
- discuss their strengths and weaknesses,
- present the definition methodology used in the Simply Positive Project, and
- discuss how the Definition can be operationalized.

The following sections two and three are dedicated to each of these goals.

This deliverable will act the initial PED definition framework for the SimplyPositive project and will be updated based on the project work and feedback before the project end.

1.2 Relation to other project activities

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

Activity / deliverable	Relation
Task 3.1 Common language and understanding	Common language workshop: understanding and definition FDs' goals
Deliverable 3.2 Gap analysis of Energy Balance Calculation Data	The definition gives one part of the input: the expected results
Deliverable 3.3 Assessment report on Focus Districts	Assessments are carried out in accordance with the described methodology of Energy Balance Calculation
Deliverable 5.3 Updated Framework definition status and Methodology description for SimplyPositive	An update of this document based on the findings and feedback throughout the project work.

2 Overview: current PED Definition frameworks – strengths & weaknesses

The necessity to establish a clear definition for Positive Energy Districts (PEDs) arises at both the European Union (EU) level and within individual projects. At the EU level, it is crucial to have a standardized PED definition to assess the progress of the strategic SET Plan mission, which aims to initiate a hundred PEDs by 2025 [1]. Simultaneously, individual projects require specific criteria that can be met for their recognition and potential certification as PEDs. Consequently, extensive discussions have taken place regarding the definition of PEDs, and while there is widespread acknowledgment of the need for a common definition, a consensus has not yet been reached [2-4]. Numerous approaches have been proposed [e.g., 5, 6, 7, etc.], some of which do not rely solely on a quantitative assessment scheme. Nonetheless, many researchers, practitioners and other stakeholders concur that a PED's definition should ultimately involve the evaluation of its energy balance, which must demonstrate a positive outcome.

In PED Definition frameworks could be highlighted three main types of approaches:

- "Official" framework definition by JPI Urban Europe.
- Process-oriented approaches.
- Normative Approaches.

Accordingly, to the definition of JPI Urban Europe framework definition for PED is as follows: "*Positive Energy Districts are energy-efficient and energy-flexible urban areas or groups of connected buildings which produce net zero greenhouse gas emissions and actively manage an annual local or regional surplus production of renewable energy. They require integration of different systems and infrastructures and interaction between buildings, the users and the regional energy, mobility, and ICT systems, while securing the energy supply and a good life for all in line with social, economic, and environmental sustainability*".

A process-oriented approach in Positive Energy Districts (PEDs) planning and implementation could be defined as a methodology that places a strong emphasis on the entire lifecycle of a PED development, from conception to implementation and ongoing operation (some examples could be found in [8, 9, etc.]). This approach recognizes that creating a successful PED involves not only defining the end-state, where the district generates more energy than it consumes but also the journey and processes that lead to this outcome.

A normative (methodological) approach in Positive Energy Districts (PEDs) development involves setting clear and enforceable norms, standards, and regulations to guide the development of districts that aim to generate more energy than they consume while adhering to sustainability principles. It provides a structured framework for addressing the complex challenges of PED projects.

Despite differences in conceptual definition of the PED all existing approaches uses "positive energy balance" as a key parameter.

The distinctions among existing definitions that use a positive energy balance as a sufficiency criterion can be delineated in several ways. Firstly, there are energy services, which should be considered at PED evaluation. Various approaches exist for this, but most tend to focus on the minimum requirements for operating the district's heating, ventilation, and air-conditioning (HVAC) systems, and occasionally, user electricity such as plug loads [e.g., 10]. In contrast, aspects like mobility and embodied energy are less frequently considered, either due to their potential negative impact on achieving a positive energy balance or due to the absence of suitable assessment methodologies. Some alternative approaches forego a universally quantifiable definition, leaving this determination as a project-specific process [e.g., 11].

The second difference lies in the choice of balance metric or key performance indicators (KPIs). Options include energy end-use or flexibility KPIs, total or non-renewable primary energy, greenhouse gas (GHG) emissions, or a combination of these and other factors [12, 13, etc.]. In the most recent review of the International Energy Agency (IEA) Annex 83, a primary energy indicator is predominantly used, with some exceptions. However, it should be noted, that disparities in primary energy conversion methods can lead to significantly different balance assessments.

Thirdly, variations arise in terms of the system boundaries within which the balance is evaluated. While the majority of Positive Energy Districts in Europe adhere to the dynamic-PED concept with geographical boundaries, this can be further complicated by the fact that many projects struggle to achieve a positive balance without some form of "offsite subsidies" [3]. These subsidies may take the form of renewable energy source credits or the direct inclusion of these resources within the PED boundary [e.g., 11]. However, clear guidelines for such inclusions are not always defined. From a time-related point of view, the most PEDs adopt an annual balancing period of an operational year [14]. Although, it is not a rule and evaluated period could be defined based on other factors especially considering "offsite subsidies" and energy credits mentioned above.

One aspect that is often not thoroughly explored is the purpose and extent of the PED definition. Under PED definition its purpose should be considered based on various climate zones, different population densities, will it be implemented on the new or already existed districts, what level of ambition should be set to attain the status of a "PED", etc. Much like other European standardization processes, such as the Energy Performance of Buildings directive (EPBD) [15], it might be advantageous to delineate what constitutes a PED at different regional levels, ranging from the European and national scales down to municipal and project-specific levels. However, in practice, most definitions are formulated within the context of international or national projects but are primarily employed by the districts participating in those projects. This complicates the issue of which definitions can and should be applied to specific PED projects and, more importantly, why they are chosen [4].

For SimplyPositive project the framework definition of the districts as PED will be done together with project partners based on existing priorities for each considered region and existing information regarding energy profiles. However, the main approach that finally should be applied for all focus districts will be "methodological" as the most quantitative and will allow compare focus districts in some kind.

3 Positive Energy District Definition

3.1 Goals of the Definition

The crucial element of the PED definition lies in the rationale behind its specific design, and it must provide a clear and well-articulated explanation of the objectives it seeks to achieve. This design approach [4] begins with defining the goals and subsequently derives the criteria and their operationalization from these objectives.

What is the purpose of the PED Definition for the SimplyPositive Project? It should allow to unambiguously answer the following questions:

1. Which of the Focus District (FD) development scenarios can be considered a “PED”?
2. What data is required to answer the above question?

In SimplyPositive, the PED definition was preceded by a Common Language Workshop. The goal of that activity was to develop common understanding of the main terms and to help in defining goals for each focus district. The Workshop was conducted 8 March 2023 by UASTW with active involvement of all partners. Through the discussions the main terminology was defined, such as “Focus District” (FD), “Key Performance Indicators” (KPI), “PED boundaries”, “Operation scenario” etc. This workshop helped partners to identify their focus districts and their goals.

Based on the results from Report of D1.1 “Report on operation scenarios, technical characterization and identified stakeholders of Focus Districts (FD) the next goals for the four focus districts were identified:

FD “Settimo Torinese” (Italy), goals:

- raising the energy and bio-architectural efficiency of the building entities.
- creation of a Renewable Energy Community (REC).
- implementation of the Energy management service.

FD “Lunca Pomostului” (Romania), goal:

- 20% CO_2 Emission Reduction compared to 1990.

FD “Amsterdam” (Netherlands), goals:

- to obtain 550 MW on roofs till 2030.
- all buildings natural gas free till 2040.

FD “Großschönau” (Austria), goal:

- self-sufficient on a yearly energy balance level regarding electricity by 2025.

The PED definition is inherently linked to these objectives and real-world implications. The overarching goal of the provided definition is to strike a balance—it should be attainable while still being suitably ambitious to be applicable to various urban and rural district types in alignment with the Paris 2050 goals. This aligns with the EU Commission's assertion that PEDs should "exceed the requirements of the Energy Performance of Buildings Directive" [17] and addresses the sufficiency aspect. The development of the definition should therefore adhere to these guiding principles [4]:

1. The PED definition is achievable for different types of usage mixes with comparable ambition, not just for uses with low energy demand or good temporal alignment between supply and demand.
2. The PED definition's achievability is not dependent on the incidental but uncommon availability of local renewables such as local (industrial) waste heat, hydro, or wind power.
3. The PED definition is compatible with the definition developed at the European level by the Alignment Taskforce JPI UE Framework Definition [1].
4. The PED definition should connect to the focus district's individual goals.
5. The PED definition should contain meaningful targets for the energy balance of brown field and renovation developments with respect to their individual development goals and should take their specific context quantitatively into account.
6. The PED definition should be replicable and assessable in monitoring.

3.2 Definition components

The first question, whether a configuration can be considered "PED" requires a concrete sufficiency criterion of a positive energy balance. Following the definition's goals, the concrete elements of a PED definition were recognized as a quantitative balance evaluation, which can be categorized into three primary components (in accordance with [16]), as shown in figure 1 below:

(1) the district's system or balance boundaries,

(2) a weighting system for the balance, and

(3) balance objectives.

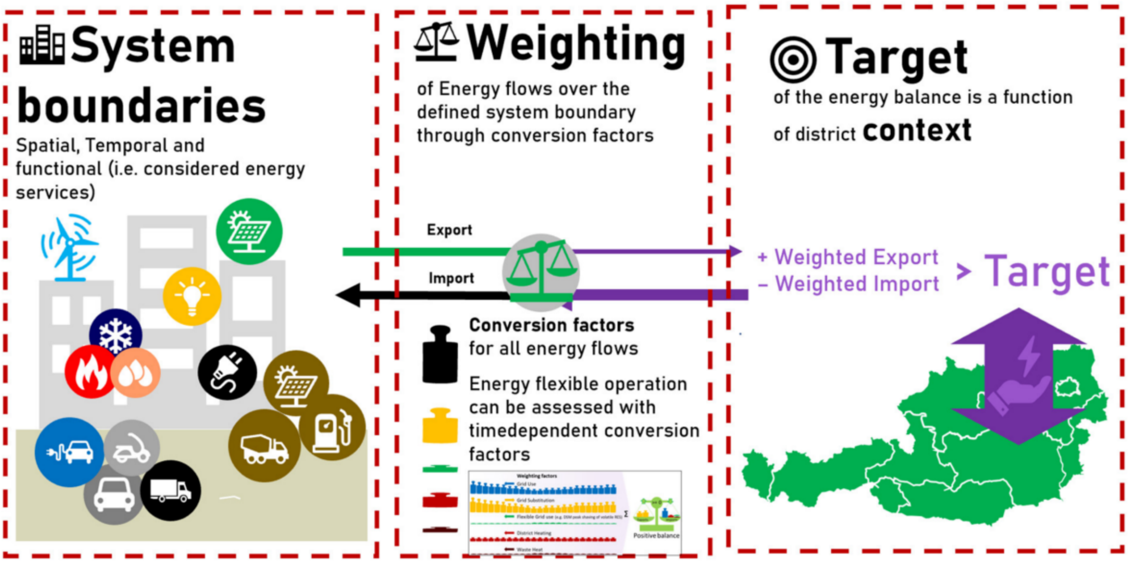

Figure 1. The three parts of a PED definition via an energy balance assessment.

These three aspects—defining the district system boundary, assigning weight to the system balance, and establishing the balance objective—collectively represent the core aspects that a quantitative PED definition using an energy balance needs to address as part of the definition's design problem. Initially, the balance objective doesn't necessarily have to be exclusively positive or zero; it can theoretically be a function of any relevant set of parameters. Therefore, the definition of an energy balance target can encompass both project-specific and external factors. This presents an added challenge but simultaneously offers an opportunity: it allows for dynamic external requirements to be associated with project-specific proposed solutions.

3.2.1 Key Performance Indicators

An important part of the PED definition contains the stage of weighting. Weighting KPIs, which could be applied for FDs, can be done by different methods. Under SimplyPositive project the survey was done, and participants evaluated the most important groups of the KPIs. All participants ranked the group of energy related KPIs as very important (Figure 2).

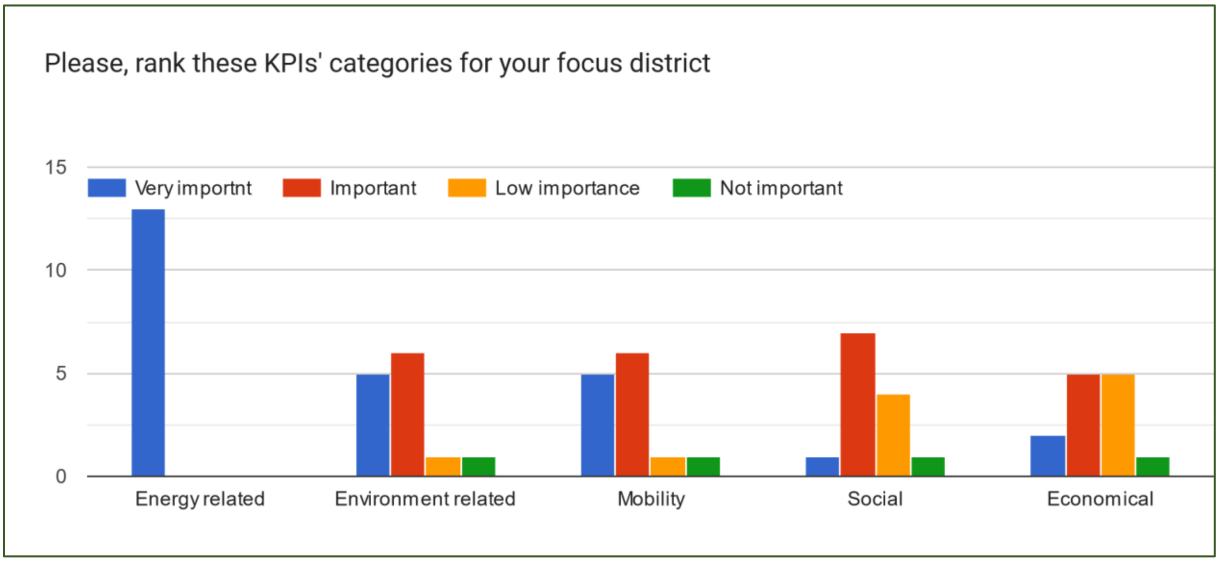

Figure 2. Results of the KPIs categories ranking under SimplyPositive project.

Inside the group of energy related KPIs the most important is final energy consumption according to the opinion of the project partners (**Figure 3**). This result coincides with basic definition of the PED Alpha (see also chapter 3.2.2).

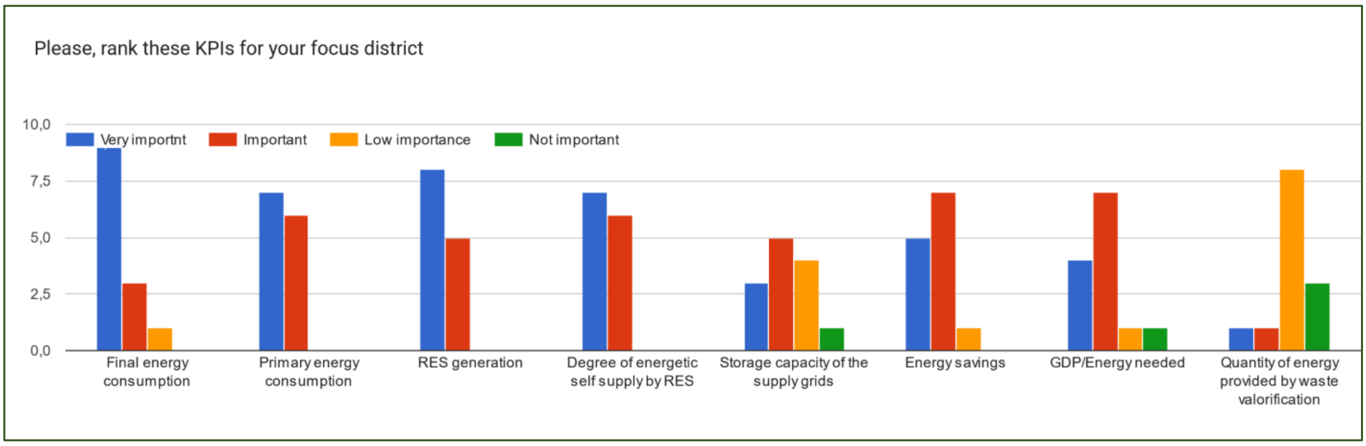

Figure 3. Results of the criteria ranking in category of energy related KPIs

Using a paradigm of three levels of PEDs, a quantitative PED definition can be designed with a balance target.

The inclusion of these virtual factors in the balance could be designed in an arbitrary number of ways. Given the relative importance of the KPIs based on the survey, the following KPIs were selected for PED assessment:

- Final Energy consumption
- Primary Energy Import-Export Balance
- RES Generation and ratio of self-supply

3.2.2 System boundaries

System boundaries are approached from spatial, temporal, and functional perspectives, following the principles outlined in the fundamentals of PED energy modeling as detailed in [14]:

1. **Spatial** means an actual physical boundary of included energy services and supplies.

2. **Temporal** system boundaries can be interpreted as the balancing period and are typically set to one operational year.

3. **Functional** system boundaries are used to identify specific energy functions, uses, or demands to be included or excluded according to function, rather than spatial proximity.

The functional system boundaries, along with the encompassed energy services, can be roughly categorized into three groups: (1) involving operational energy and user electricity, (2) addressing mobility aspects, and (3) accounting for embodied energy and emissions. This approach defines three distinct variants or layers, represented as

- **PED Alpha** at the innermost level, focusing solely on operational energy, then expanding to
- **PED Beta**, which incorporates private daily mobility, and extending further to
- **PED Omega** at the outermost layer. In PED Omega, considerations encompass the embodied energy associated with district construction, maintenance, repair, and mobility.

Each layer entails increasing complexity and introduces greater uncertainty compared to the previous one. Simultaneously, having suitable data is crucial for simulation and verification purposes. The system boundaries are visually depicted in Figure 4 below.

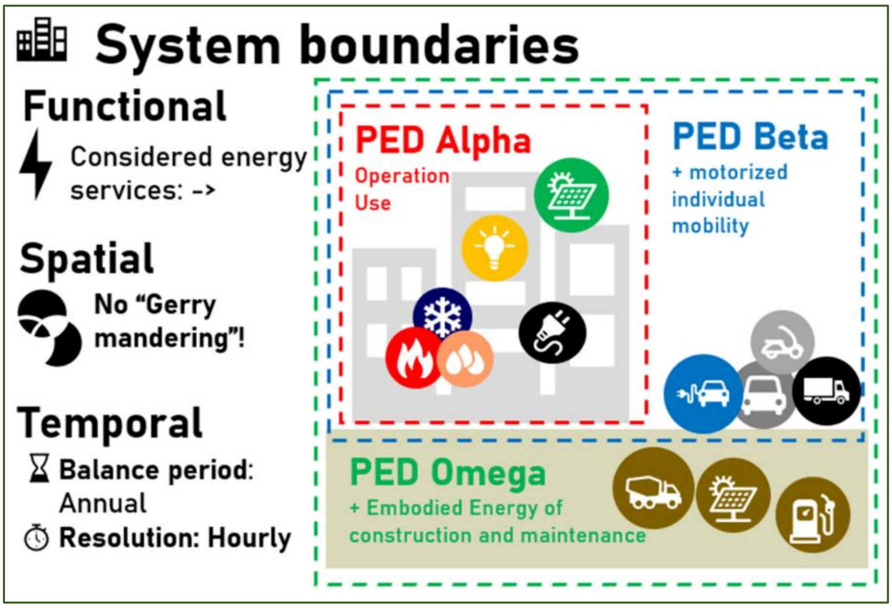

Figure 4. Types and extent of defined system boundaries.

Based on the provided information regarding PEDs definition under SimplyPositive project the first step was definition of the type of each focus district together with system boundaries.

Spatial boundaries for FDs are coincide with geographical borders of the selected regions. FDs sizes vary from large city Amsterdam till small village Großschönau. However, almost all goals of districts include "energy" KPIs. For FD “Lunca Pomostului” goal to reduce CO_2 Emission Reduction could be reformulated as "increasing part of renewable energy", which will lead to the decreasing CO_2 emission. It will made Romanian focus district on the same level as other districts. Two of three goals of Italian FD are devoted to social aspects, they are difficult to quantify, so, could be considered as supportive goals.

Temporal system boundaries would be set as one operational year due to absence of the additional local or project-specified requirements.

Type of considered focus district could be considered as functional system boundaries. All FDs used as living districts with small percentage of the social buildings (e.g., schools, offices etc.).

3.2.3 Considered energy services

The energy demand for room conditioning (heating and cooling), domestic hot water, lighting and building services as well as the energy demand for living, working and services (e.g., appliances, computers) are considered in the PED definition.

Table 1 Considered energy services in different boundary definition with related assessment. The energy balance calculations are carried out in hourly steps.

	Energy services	Alpha	Beta	Omega	Implicit*
Building operation	Heating	✓	✓	✓	-
	Cooling	✓	✓	✓	-
	Humidification and dehumidification	✓	✓	✓	-
	Ventilation	✓	✓	✓	-
	Auxiliary power of the building services system	✓	✓	✓	-
	General power and lift	✓	✓	✓	-
	Lighting	✓	✓	✓	-
District operation	Power requirements of users (plug loads)	✓	✓	✓	-
	Operating power (office, retail, school)	✓	✓	✓	-
Industry, agriculture	Process heat	-	-	-	✓

	Process cooling	-	-	-	✓
	Electricity demand for industrial production processes	-	-	-	✓
	Electricity demand for general use (incl. services)	✓	✓	✓	-
Mobility	Motorized private transport	-	✓	✓	-
	Public transport	-	-	-	✓
	Other mobility	-	-	-	-
Embodied energy	Components of national energy certificates	-	-	✓	-
	Accessory components (cellars, underground parking, garages, carports, bicycle storage areas, balconies and terraces, other outbuildings)	-	-	✓	-
	Building and energy equipment	-	-	✓	-
	Vehicles and infrastructure for mobility	-	-	✓	-
	Public transport	-	-	-	✓

(✓) Included in system boundary, (-) not included in system boundary.

* **Implicit**: Not included in any system boundary but instead part of the district context of the surrounding energy scenario that in turn influences the balance target as context factors.

3.2.4 Weighting system

The definition of Positive Energy Districts needs to include a coherent and transparent system for weighting and evaluation of its energy flows. This definition approach is following [4] in assessing a district's contribution to the national energy system's climate neutrality is prioritized over emphasizing the district's physical self-sufficiency. The specific weighting objectives include:

1. **Linking to Planning Practice and Existing Literature:** Utilizing total primary energy and greenhouse gas (GHG) emissions with conversion factors from the current building code or county-specific regulations for district heating.
2. **Mapping of Seasonal Differences:** Applying monthly conversion factors based on Austrian building codes to account for variations in renewable feed-in during summer and grid import in winter, considering their different grid support and substitution alternatives.

3. **Evaluation of Energy Flexible, Grid-Serving Actions:** Assigning a zero-conversion factor to otherwise unavailable energy in the surrounding system, emphasizing the importance of time-sensitive grid use and feed-in.
4. **Biomass Use Approach:** Allowing for biomass use without implicit preference, using an average of total and non-renewable primary energy. This approach balances the feasibility of biomass systems, avoiding biases that could arise from considering only one aspect.

These goals can be achieved by using time-dependent weighting factors as visualized in the following figure 5. The calculation of the Energy balance entails the aggregation of all incoming and outgoing energy streams within the district, incorporating specific weighting factors that vary with time and energy type.

These weights are chosen to mirror the relative significance and accessibility (or scarcity) of each energy source within the surrounding energy system, considering various aspects such as economic value, ecological impact, exergy content, and other relevant factors.

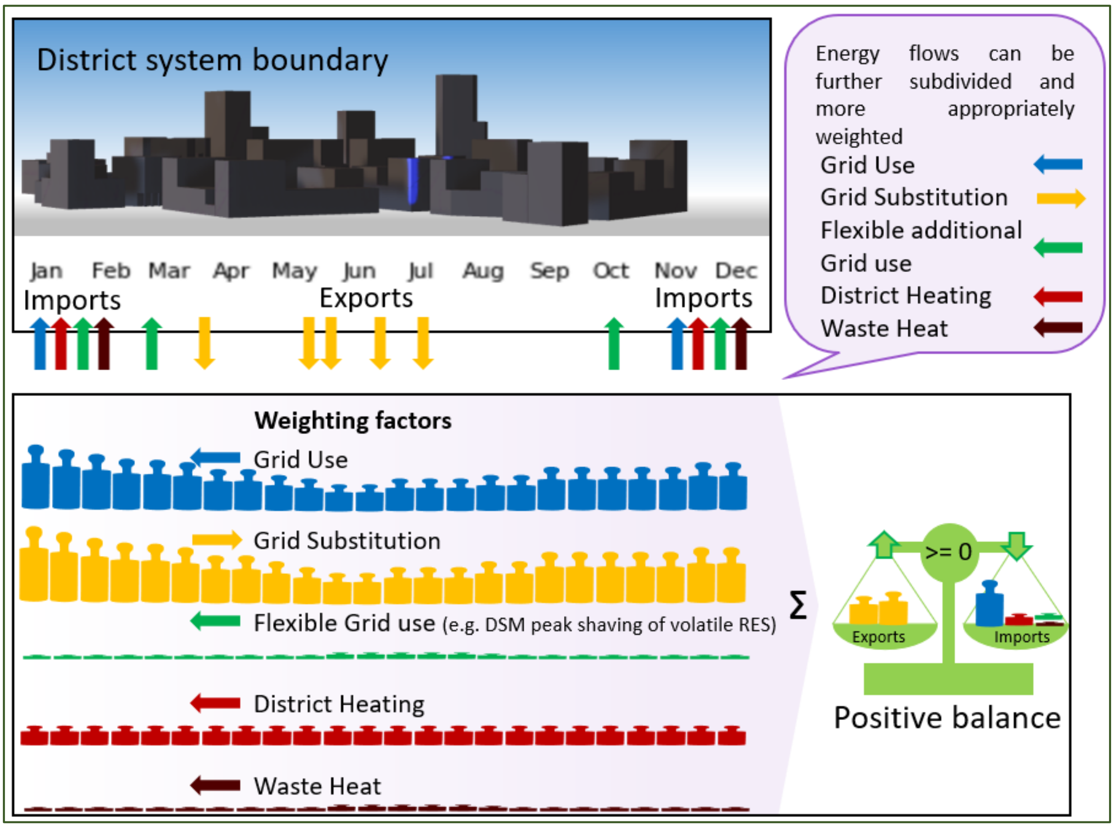

Figure 5. Example of time-dependent weighting factors of energy flows

In the context of the Positive Energy District framework and its core principle of achieving a positive energy balance, there exists an opportunity to incorporate an evaluation of energy flexibility. This entails a straightforward concept: By employing suitably designed weighting factors, the energy imports and exports of the district are assessed in conjunction with a finely grained temporal resolution, typically on an hourly basis. These temporal weighting factors are designed to capture the utility of energy importation or exportation to the external grid at any given moment. This however requires a temporal model of the PED surrounding, signifying its flexibility demands. The specific weighting factors are presented in the following table and correspond with the balance target KPI specified in section 3.2.5.

Table 2. Weighting factors for energy flows over the defined system boundaries.

Energy flow	PED Alpha, Beta Operation, Use, Mobility	Ped Omega Construction and Maintenance	Source
Uncontrolled grid uses and feed-in	Total Primary energy Monthly conversion feed-in sign-inversed	CO2-equiv. Monthly conversion feed-in sign-inversed	Nationally accepted conversion factors (e.g., from building code)
Energy-flexible grid use (DSM)	Zero	Zero	Project Externally (e.g., from scientific literature, etc.)
Biomass	100% renewable + 50% non-renewable primary energy	CO2-equiv.	Nationally accepted conversion factors (e.g., from building code)
Other energy carriers	Total primary energy	CO2-equiv.	Nationally accepted conversion factors (e.g., from building code)

3.2.5 Balance Targets

Using this paradigm, a quantitative PED definition can be designed with a positive balance target using the context factors for the appropriate system boundaries depicted in Table 3. The inclusion of these ultimately virtual factors in the balance could be designed in an arbitrary number of ways. Their use must be rooted in its comprehensibility and link to the definition goals, which are examined in the following subsections, that can be quantified.

Table 3. Balance targets.

System Boundary	Scope	Balance	Context Factors	Target	KPI
Alpha	Operation, use	Primary Energy Exports–Imports*	$\pm$ CF** Density	> 0	kWh PE tot./m²NFA/a
Beta	Operation, use, individual motorized mobility	Primary Energy Exports–Imports*	$\pm$ CF Density $\pm$ CF Mobility	> 0	kWh PE tot./m²NFA/a

Omega	Operation, mobility, and embodied emissions	GHG Emission Imports – Exports*	$-$CF Emissions	≤ 0	kg CO2eq./m²NFA/a

* Energy flows into the district are counted negatively (e.g., grid electricity purchases and district heating) and energy exports across the system boundary are accounted for positively (e.g., PV surpluses). The emission balance must be negative, the local and imported emissions are offset by export (external emission prevention) and a CF Emission, which represents an emission budget per reference area.
** CF—context factor.

3.3 Energy Balance Calculation

Energy balance calculation, as was mentioned above, is an important part of the PED assessment. UASTW developed a method for the simulation of the energy balance for PEDs and it features these main design goals:

- Transient Simulation of energy flows including e-mobility (at least hourly)
- Hourly load balancing with appropriate weighting factors
- Inclusion of energy flexible control schemes and DSM to increase utilization of volatile RES and increase PED target score
- Inclusion of building thermal storage potential to increase utilization of volatile RES and increase PED target score

The energy simulation revolves around four fundamental energy supply options (Table 4): natural gas (included solely as a reference variant), district heating, and two distinct heat pump variations. These variants diverge primarily in their final assessment regarding primary energy, driven by variations in the associated primary energy factors. Additionally, the variants vary in terms of their provisions for both heating and cooling.

Table 4. Variants of the energy systems in the operationalization tool

<table>
<tr><th>Name</th><th>Heating</th><th>Cooling</th><th>Domestic hot water</th><th>Primary energy factor</th></tr>
<tr><td>Natural gas</td><td>Combi boiler</td><td>VCR</td><td rowspan="4">Heat pump</td><td rowspan="4">per energy form and resource</td></tr>
<tr><td>District heating</td><td>District heating station</td><td>VCR</td></tr>
<tr><td>Heat pump without DSM</td><td>Heat pump</td><td>Heat pump</td></tr>
<tr><td>Heat pump with DSM</td><td>Heat pump</td><td>Heat pump</td></tr>
</table>

Additional biomass variations can be created by modifying the district heating option, adjusting factors like conversion efficiencies, auxiliary power requirements, and conversion factors.

The simulation is based on a straightforward model of a single thermal zone building. Electrical power requirements are met by the PV-System. Any surplus PV-generated energy can be directed either to the domestic hot water for additional Demand Side Management (DSM) operations or fed back into the grid to offset grid consumption in the energy balance. Unmet energy demands can be satisfied through specific grid-supporting sources, including wind peak shaving from nearby wind farms or ultimately from the power grid.

The thermal energy demand is determined by the desired temperature settings for the heating, cooling, and domestic hot water (DHW) systems. This demand can be met through electrical means, such as heat pumps, or through two built-in options: district heating and natural gas boilers. Each system utilizes corresponding primary energy conversion factors that can be sourced from various references, including national or regional standards, measurement data, and potential future energy system scenarios. Any surplus energy resulting from demand-side management can be stored in the building's thermal mass, reducing peak load curves, particularly during winter nights.

Schematically, the simulation method is shown on Figure 6.

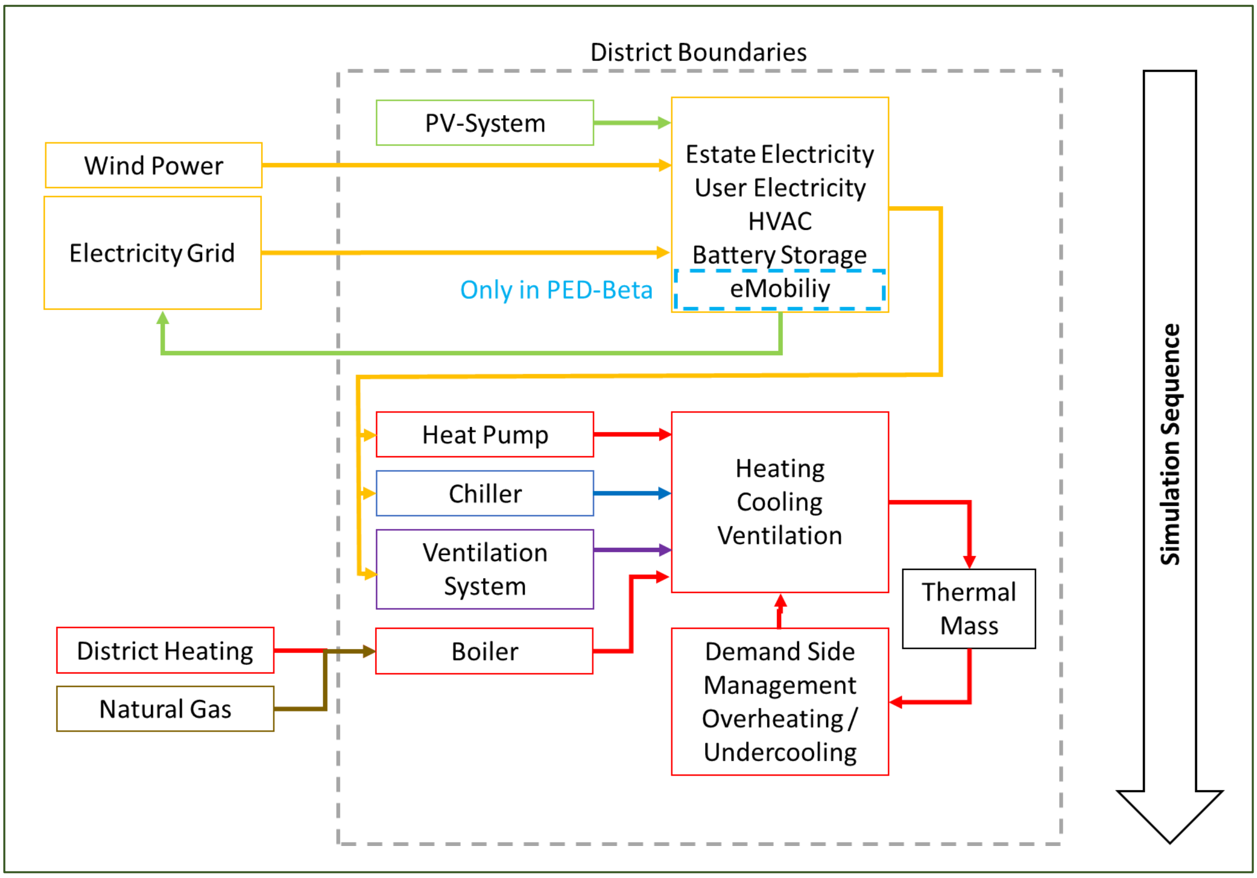

Figure 6. Simulation Components of the PED operationalization

4 Conclusion

Within this deliverable we connect the PED framework definition to the situation of the individual focus districts, their contexts, and their targets.

Three stages are relevant during the PED definition via an energy balance assessment: system boundaries, context factors, and the target.

Considering the functional, spatial, and temporal system boundaries, we distinguish between PED Alpha, PED Beta, and PED Omega.

With a density related context factor and a mobility related context factor different situational contexts are balanced within a country to align different districts and neighborhoods into national climate and energy targets.

Finally, we show the current schematic process of the operationalization of the PED energy balance simulation, which is intended to be optimized and refined throughout the SimplyPositive project work.

All updates and additions will be published within deliverable 5.3. Updated Framework definition status and Methodology description for SimplyPositive.

Sources

[1] JPI Urban Europe/SET Plan Action 3.2. White Paper on PED Reference Framework for Positive Energy Districts and Neighbourhood; JPI Urban Europe: Vienna, Austria, 2020.

[2] Casamassima, L., Bottecchia, L., Bruck, A., Kranzl, L., & Haas, R. (2022). Economic, social, and environmental aspects of Positive Energy Districts—A review. *Wiley Interdisciplinary Reviews: Energy and Environment*, *11*(6), e452.

[3] Hedman, Å., Rehman, H. U., Gabaldón, A., Bisello, A., Albert-Seifried, V., Zhang, X., ... & Reda, F. (2021). IEA EBC Annex83 positive energy districts. *Buildings*, *11*(3), 130.

[4] Schneider, S., Zelger, T., Sengl, D., & Baptista, J. (2023). A Quantitative Positive Energy District Definition with Contextual Targets. *Buildings*, *13*(5), 1210

[5] Brozovsky, J., Gustavsen, A., & Gaitani, N. (2021). Zero emission neighbourhoods and positive energy districts–A state-of-the-art review. *Sustainable Cities and Society*, *72*, 103013.

[6] Gabaldón Moreno, A., Vélez, F., Alpagut, B., Hernández, P., & Sanz Montalvillo, C. (2021). How to achieve positive energy districts for sustainable cities: A proposed calculation methodology. *Sustainability*, *13*(2), 710.

[7] Nguyen, M. T., & Batel, S. (2021). A critical framework to develop human-centric Positive Energy Districts: Towards justice, inclusion, and well-being. *Frontiers in Sustainable Cities*, *3*, 691236.

[8] Sibilla, M. (2021). Developing a process-oriented approach towards Positive Energy Blocks: the wind-analysis contribution. *City, Territory and Architecture*, *8*(1), 11.

[9] Koutra, S., Zubiaga, J. T., Bouillard, P., & Becue, V. (2022). 'Decarbonizing Europe'A Critical Review on Positive Energy Districts Approaches. *Sustainable Cities and Society*, 104356.

[10] Salom, J.; Tamm, M. D3.1 Methodology Framework For Plus Energy Buildings And Neighbourhoods, WP3 Technology Integration in Smart Managed Plus Energy Buildings and Neighbourhoods; EU Research and Innovation Programme: Brussels, Belgium, 2020.

[11] Shnapp, S.; Paci, D.; Bertoldi, P. Enabling Positive Energy Districts across Europe: Energy Efficiency Couples Renewable Energy; Publication Office of the European Union: Luxembourg, 2020.

[12] Nyffenegger, U. Positive Energy District Guide (German: Leitfaden Plusenergie-Quartier); Hauptstadtregion Schweiz: Bern, Switzerland, 2018.

[13] Schöfmann, P.; Zelger, T.; Bartlmä, N.; Schneider, S.; Leibold, J.; Bell, D. Future District—Path to Positive Energy Districts in Vienna; Berichte aus Energie- und Umweltforschung; Austrian Research Promotion Agency: Vienna, Austria, 2020; p. 203.

[14] Albert-Seifried, V.; Murauskaite, L.; Massa, G.; Aelenei, L.; Baer, D.; Krangsås, S.G.; Alpagut, B.; Mutule, A.; Pokorny, N.; Vandevyvere, H. Definitions of Positive Energy Districts: A Review of the Status Quo and Challenges. In Proceedings of the Sustainability in Energy and Buildings 2021, Split, Croatia, 14–16 September 2022; Springer Nature: Singapore, 2022; pp. 493–506.

[15] Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the Energy Performance of Buildings (Recast); 2010; Vol. 153. Available online: http://data.europa.eu/eli/dir/2010/31/oj/eng (accessed on 30 October 2023).

[16] Sartori, I.; Napolitano, A.; Voss, K. Net Zero Energy Buildings: A Consistent Definition Framework. Energy Build. 2012, 48, 220–232.

[17] European Commission FAQ-Work Programme 2018 for Horizon 2020—Smart Cities and Communities—Lighthouse Projects. Available online: https://ec.europa.eu/info/funding-tenders/opportunities/docs/cap/h2020/lc-sc3-scc-1-2018-2019-2020/1872640-faq_scc01_(updated)_v10_en.pdf (accessed on 30 October 2023).

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