

Defining a common set of Key Performance Indicators for Positive Energy Districts

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ABSTRACT:

The concept of Positive Energy Districts (PEDs) is one of the central pillars for driving the urban energy transition, but a common definition has not been established yet. PED Key Performance Indicators (KPIs) are not yet consolidated either and cover a diverse field of sustainability aspects. The investigation of PED definitions can support the establishment of a common set of KPIs for projects with PED ambitions. The definitions of five prominent EU programmes and six PED-relevant projects across Europe were investigated to determine their commonalities. The results showed that only Energy related aspects were considered at least in 7 of the 11 definitions (Energy generation, Energy balance, Energy efficiency, and Active management). Additionally, five definitions also consider GHG emissions and Energy flexibility aspects and 4 of them include Participatory approaches. The associated KPIs of these aspects form the common KPI list of the investigated definitions, which can support the further development of a base PED definition and also to establish a common ground for performance assessment for projects with PED ambitions.

KEYWORDS: Positive Energy Districts; Key Performance Indicators; neighbourhood sustainability

1. INTRODUCTION

The concept of Positive Energy Districts (PEDs), one of the central pillars for driving the urban energy transition, has been developed through EU initiatives and research programmes, but a common definition has not been established yet [1]. Mayor organisations, programmes, research projects and individual PED projects have their own interpretation of how energy balance is calculated, what are the scale and boundaries of projects and what key concepts are needed to be covered by a PED [2]. It is clear the PED concept originates from the energy balance assessment, but the existing PED definitions show that the scope of PEDs go beyond the energy aspect and cover challenges related to social, economic or environmental sustainability as well.

Indicators are needed to measure the performance of PED projects, which have also started to be developed in relation to individual PED projects [3] and EU H2020 projects with pilot cases [1, 4, 5, 6, 7, 8]. These build upon widely researched building and neighbourhood level sustainability indicators developed for research, governmental or commercial purposes [9] and smart city indicators [6].

Systemic reviews of PED related KPIs collect indicator sets based on sustainable neighbourhood concept definitions [10] and state that their methodological approaches are based on KPIs supported by decision making criteria analyses, Life Cycle Thinking methods or their mixture [11] and that

PED KPIs mainly categorised by and cover the three pillars, i.e., environmental, economic, and social of sustainability [12].

Similarly to the PED definition, Key Performance Indicators (KPIs) are not yet consolidated either and cover a diverse field of sustainability aspects [12]. This means that projects with PED ambitions can get lost in the wide vision of the different initiatives and the related target metrics is not supporting to determine where to focus their efforts. Therefore, a standard set of PED KPIs could help on one hand to develop a base PED definition [10] and also to establish a common ground for performance assessment.

The aim of the research is to define a common indicator set for PEDs by assessing the commonalities in existing PED definitions.

2. METHODOLOGY

To define a common set of PED indicators, first the different PED definitions were collected from literature focusing on prominent EU programmes and PED-relevant projects across Europe. The SET-Plan Action 3.2 [13], Horizon 2020 Framework Programme – Smart Cities and Communities calls [14], EC Joint Research Centre, JPI UE [15] and the European Energy Research Alliance [16] programmes and initiatives establish the EU level decarbonisation goals and research areas for Positive Energy Districts, while ATELIER [4], MAKING-CITY [5], POCITYF [6], SPARCS

[7], +CityxChange [17] and syn.ikia [1] are lighthouse projects of the H2020 programme with their own interpretation of PEDs.

The definitions from the above listed sources are collected and detailed in [2], which were then extracted and reviewed for this research. All sources were also assessed based on their availability of developed KPI sets (no EU initiatives defined KPIs, all H2020 projects developed KPI sets), which were then collected along with additional sources from literature to establish a pool of indicators used on this field.

To determine the commonalities in potential indicators based on the PED definitions, the following steps were taken:

1. the text of the definitions was split according to which part of the PED performance characteristic/attribute each sentence part relates to;
2. the main sustainability categories and sub-categories a definition section relates to were identified;
3. the KPIs that can measure the performance of PEDs for each category and sub-category were identified and selected from the collected pool of indicators;
4. the following characteristics of the identified common indicators were analysed: dimension of sustainability coverage, assessed life-cycle, assessment scale, relevant stakeholders, type of the calculation;
5. the results of the deconstruction of definitions and related KPI assignments were compared, the cutoff point between Core and Optional indicators was defined to establish the most common PED themes and KPIs.

For example: the syn.ikia definition can be dissected (Step 1) to seven statements, one of them is “90% Renewable energy generation off-site”, which can be categorized (Step 2) into the Energy topic and Energy generation subtopic. From the indicator pool, the renewable or non-renewable thermal or electrical energy generation on- or off-site KPIs can be identified (Step 3) to measure the success of complying with the definition section. These indicators are in the Environmental sustainability domain, relate to the Design and Operation life-cycle of the project and can be measured on building and neighbourhood scale (Step 4). Compared to the others, energy generation indicators can be considered as Core KPIs in PED developments (Step 5).

3. RESULTS OF DEFINITION INVESTIGATION AND CORE KPI SET ESTABLISHMENT

The categories and sub-categories of the indicators are defined based on common neighbourhood sustainability topics (Buildings, Community, Ecology, Economy, Energy, Infrastructure, Location, Resources, Mobility [19]) and the categorisation of newer PED indicators (additional topics: ICT, Governance, Residents). After the review and combination of the topics in the different sources, the list of categories was defined to be used in this research: Energy, Environmental Performance, Economic performance, Society and Residents, Mobility, Materials and Resources and Governance (Table 1).

Table 1: KPI Categories and Subcategories considered in at least one of the PED definitions

Main category	Subcategory
Energy	Energy generation
	Usage factors
	Energy balance
	Energy efficiency
	Energy savings
	Active management
	Flexibility
Environmental Performance	Emission
	Emission reduction
	Resilience
Economic performance	Cost
	Cost reduction
Society and Residents	Participatory approach
	Life quality of users
	Inclusiveness
	Affordability
Mobility	Mobility
Materials and Resources	Materials
Governance	Scalability
	Local context

3.1 Energy

The Energy category is represented in all the investigated definitions with clear performance targets (Table 2). The results also show that the energy KPIs cover the three most important functions of districts in the context of their urban energy system [18]: all of the eleven definitions consider energy production and seven of them consider energy efficiency and energy flexibility topics. Additionally, seven consider active energy management which includes the use of integrated Building Management Systems, peak-load reduction strategies and smart metering and 5 definitions mention the flexibility topic.

3.2 Environmental Performance

The results show that emissions reduction is a quantified target of seven of the definitions, but they

differ in their considered emissions type. The syn.ikia and JPI UE definitions consider the overall greenhouse gas emissions of the district and target their 100% reduction, while the SET-Plan Action 3.2, EERA JPSC, ATELIER, SPARCS and +CityxChange definitions target net zero CO₂ emissions.

The deeper investigation of the available indicators of the considered initiatives shows that both CO₂ and GHG emissions only take into account the operational energy related emissions and embodied carbon emissions is not considered yet.

From other environmental indicators only JPI UE mentions Resilience aspect, focused on the resilience of the energy supply.

Table 2: Energy targets of the 11 investigated PED definitions

	Energy efficiency	Energy generation	Energy balance
SET Plan Action 3.2.	-	local surplus RES	net zero import
Horizon 2020	-	-	+
JPI UE	-	local surplus RES	+
EC Joint Research Centre	near zero energy demand	demand covered to a very significant extent by RES	+
EERA JPSC	-	local surplus RES	+
ATELIER	-	surplus RES	+
MAKING-CITY	-	-	+
POCITYF	-	-	+
SPARCS	-	local surplus RES	+
syn.ikia	-	90% RES generation	+
+CityxChange	-	local surplus RES	net zero import

-: no target defined; +: positive energy balance

3.3 Economic performance

Only the syn.ikia project mentions in its PED definition that PEDs should target “10% life cycle costs reduction compared to the level of 2020 nearly zero-energy buildings”. As operation energy costs clearly connected to the energy reduction targets, all other definitions imply a certain degree of cost reduction by complying with PED requirements.

When considering the available indicator pool for economic performance all PED Horizon projects define the Payback Period KPI and three of them (syn.ikia, POCITYF and ATELIER) also considers Investment cost and Operation Cost indicators. Other financial indicators that are mentioned in the KPI pool: Debt Service Coverage Ratio, Economic Value Added, Local Job Creation, Energy Poverty, Average CO₂ abatement costs etc.

3.4 Society and Residents

The category Society and Residents includes both the aspects related to participation and engagement and the social impact of PED developments as well.

As the participation of all stakeholders in the PED development process can improve the predictability of project outcomes, ensure more just and knowledgeable operations, facilitate community cohesion and improve communications to bring a system-wide energy transformation through collective action [20], some of the PED definitions (4 of 11) target the use of Participatory approaches in their definition as well. EC Joint Research Centre indicates the open and voluntary qualifications for the participation requirement.

The indicator pool from the investigated projects also includes metrics to measure the quality (e.g.: Degree of satisfaction, Degree of local community involvement in the implementation and planning phase) and quantity (e.g.: Percentage of citizens’ participation in online decision-making) of participatory actions.

Different aspects of the social impact of PED developments are mentioned by 1-1 PED definition:

- Life quality of users (JPI UE)
- Inclusiveness (JPI UE)
- Affordability: (SET-Plan Action 3.2.)

3.5 Mobility, Materials and Resources and Governance

There is a discrepancy in the mention of mobility targets in the PED definitions and the number of developed project mobility related KPIs: only JPI UE mentions mobility in its definition, but SPARCS, POCITYF, MAKING-CITY and ATELIER projects all define several relevant KPIs.

Only the Horizon 2020 and POCITYF definitions mention materials and resource management, highlighting on circularity principles. Also, these consider governance related aspects such as the scalability of the PED development (to encourage better replication of the innovative concept), specific requirements of ICT technologies and the consideration of the local context.

3.6 Missing topics

The investigation of the relevant PED aspects coverage by the PED definitions compared with the available indicator pool shows that all main categories are covered by at least one definition.

This definition-based approach for KPI development ignores some aspects commonly considered in sustainability projects, such as: water, indoor and outdoor comfort, safety, investment-related indicators. This may be a result of several definitions only mentioning that PED projects should be in line with environmental, economic and social

sustainability principles without specifying any particularities.

3.7 Core KPI list and optional indicators

The results of the PED definition assessment shows that only the Energy generation, Energy balance, Energy efficiency, and Active management aspects were considered at least in 7 of the 11 definitions. Additionally, five definitions also consider GHG emissions and Energy flexibility aspects and 4 of them Participatory approaches. All the other PED aspects only included in one definition. Based on these results the cutoff point for Core indicators is at least 4 mentions. Table 3 shows the Core categories and the associated KPIs that can measure the PED performance of the requirement.

Table 3: Common KPIs identified by assessing the selected definitions

Category	KPI
Energy generation	Renewable thermal energy generation off-site
	Renewable electrical energy generation off-site
	Non-renewable thermal energy generation off-site
	Non-renewable electric energy generation off-site
	Renewable thermal energy generation on-site
	Renewable electrical energy generation on-site
	Non-renewable thermal energy generation on-site
Energy balance	Ratio of generated renewable energy used within the PED boundaries
	Energy imported from outside the PED
	Energy exported from the PED
	Renewable energy imported from outside PED
Energy efficiency	Renewable energy exported from the PED
	Total primary energy demand
Active management	Total annual saved primary energy
	Integrated Building Management Systems
	Percentage of systems with smart energy meters, Percentage of peak load reduction
Flexibility	Flexibility index
	Energy storage capacity installed
GHG emissions	CO2 emission
	non-CO2 GHG emission
	GHG emission
	CO2 emission reduction
	non-CO2 GHG emission reduction
Participatory approaches	GHG emission reduction
	Local community involvement in the implementation and planning phase
	Energy citizenship

The common indicator set mainly consist of energy related KPIs, from the non-energy aspects of sustainability only indicators measuring GHG emissions are commonly considered. This means that currently only the Environmental dimension of sustainability is covered in the common indicator set and Social and Economic dimensions are ignored.

In addition to the common indicators, other, less frequently appearing KPIs were identified as well covering the rest of environmental (Resilience, Mobility, Materials and Resources, Local context) and the economic (Cost reduction, Scalability), and social (Life quality of users, Inclusiveness, Affordability) dimensions of sustainability. These indicators can be considered as optional indicators, where their usage could depend on the individual ambition of PED developments.

District characteristics are also established in the definitions. They focus on defining the geographical boundaries (mainly as districts with several connected buildings within a defined area), usage type (mixed use), building type (new or renovation) and included components (buildings and energy systems). These characteristics are quantifiable but differ from the indicators as they are not related to the performance of a PED district. However, they are useful for outlining the scope of the PED concept, as in establishing what kind of districts can target PED ambitions and use the developed concepts and methodologies.

Table 4: Number of PED aspects considered in the different definitions

	Number of aspects
SET Plan Action 3.2.	10
Horizon 2020	10
JPI UE	13
EC Joint Research Centre	7
EERA JPSC	6
ATELIER	11
MAKING-CITY	8
POCITYF	10
SPARCS	3
syn.ikia	6
+CityxChange	11

4. CONCLUSION

The study investigated five prominent EU programmes and six PED-relevant projects across Europe to determine the commonalities between their PED definitions. The research demonstrates that energy, carbon emissions and participatory approaches can be considered as the core targets for any PED project.

Additionally, there are several optional aspects that individual projects can target, but are not clearly mentioned and quantified in the existing PED definitions. As theoretical research on the Positive Energy District concept is still ongoing, new PED definitions (or updates of the existing ones) can emerge. With the application of the methodology outlined in this paper on them can result in adding new entries to the common aspect list.

Currently less research is available on non-energy ambitions of PEDs [10] which is reflected in the

existing PED definitions. However, the identification of what is needed on the non-energy related aspects should be considered as integral parts of PEDs. Therefore, without creating overly broad scope that can risk diluting the core ambitions of PEDs, it is necessary to improve existing PED definitions to better reflect all PED ambitions.

After establishing the core PED aspects, relevant indicators were selected to establish a Core PED KPI set. This common indicator set to evaluate PED performance is needed to bridge the gap between the wide-ranging PED research in academia and the practice where projects with PED ambitions need clear targets to achieve.

The comparison of the common KPI list with the indicators developed within some of the assessed projects or initiatives also shows that the initiatives consider more sustainability aspects or categories than what can be identified from their definitions. For example, the POCITYF project developed 8 of its 63 KPIs to cover the topic of Mobility, however the goal of providing sustainable transport modes and infrastructure for electric vehicles does not appear in the PED definition of the project (adopted from the Horizon 2020 Framework Programme) [6].

Finally, the core KPIs can also be used to finetune current PED definitions to establish new ones with defining the focus areas where they intend to measure the performance of districts. This research can provide the following recommendations:

- PED scope: a PED definition should clearly set what kind of boundaries, functions, components PED districts should include
- New definitions should at least include quantified goals for energy efficiency, flexibility and production and GHG emissions
- It is recommended to adapt life-cycle thinking in setting targets for carbon emissions to also consider the embodied carbon impacts
- The targets for mobility within a Positive Energy District is recommended to be included in the definition
- It is recommended to add targets for social and economic sustainability
- PED definitions could define the recommended range of topics for customization, to provide space for individual circumstances and ambitions

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