Cities4PEDs

WORKPACKAGE 6

Monitoring Framework

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C4PED - Monitoring Framework

D.6.1 & 6.2

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1. Introduction

The transformation towards a Positive Energy District (PED) shifts the focus from the individual positive energy building and positive energy blocks towards neighbourhoods and thus a new level of impact on sustainable urban development and the energy transition process.

PEDs

Numerous measures will have to be taken, including technology, spatial, regulatory, financial, legal, social and economic measures, to reach climate targets while providing a good life for all. Ultimately, it requires interaction and integration between buildings, the users and the regional energy, mobility and ICT system. To keep track of all these measures and in order to measure progress, one needs a monitoring system in place to be able to steer towards a PED. It is of crucial importance that this monitoring system is in function of achieving the PED goal, otherwise monitoring just adds extra terabytes to the ever-growing pile of data.

Cities4PEDs is one of the four research projects from the first JPI Urban Europe Pilot Call focusing on PEDs. The consortium consists of municipalities, experts, research institutions and civil society organisations from Brussels, Stockholm and Vienna.

Monitoring

This document discusses the monitoring framework developed under Work Package 6 (Task 6.1 and 6.2). The objective of this work package is to develop a monitoring framework that captures the multi-faceted characteristics of a PED project to guide its next steps and allow for strategic steering. This will allow for mapping success factors of the local cases and distil learnings to develop a useful and step-by-step guide for future PED development.

This document is structured as follows:

1. Chapter 2 presents an overview of the monitoring framework.
2. Chapter 3 contains a catalogue of indicators resulting from desktop research and initial exchanges between the Cities4PEDs consortium.
3. Chapter 4 chapter contains the preliminary application of the monitoring framework for the three cities, highlighting how the monitoring framework and indicators could be applied in each local case.
4. Chapter 5 presents the conclusion and next steps

This working document is intended to be shared among public authorities, researchers and others involved in monitoring a PED, not just to give a success label, but to help steer the process and give guidance.

2. The monitoring framework

A monitoring framework typically adopts indicators, with baselines and targets, to measure progress against certain goals and objectives. Indicators help to outline goals in specific terms, monitor progress, and provide feedback to stakeholders. This could help capture the multi-faceted characteristics of PED projects to guide its next steps and allows for strategic steering. While monitoring could occur on various levels – EU-level, national level, regional level, city-level, and district level – this framework is designed to be used on the district level. This implies that all indicators will be collected on the district-level scale.

Link with the PED definition

As there is not yet an official definition of what a PED is at the moment of writing, this district-level monitoring framework goes beyond the pure definition, and in conversation with the three local cases – Vienna, Brussels and Stockholm – identifies what the district representatives find important towards achieving a PED. This in turn furthers the PED definition as it would need to resonate with the reality of the local cases and would need to be measurable according to the guiding principles below. The monitoring framework and the PED definition are thus in fact a two-way street.

Guiding principles

The Monitoring Framework is based on the following guiding principles:

- The Monitoring Framework must provide a comprehensive and transparent way of assessing the PED's strength and progress.
- The Monitoring Framework must help assess the progress of becoming a PED. It should allow to identify where there is more effort required, and where the PED is on track.
- The Monitoring Framework must be flexible enough to allow adaptation to the unique context of a particular project.
- The Monitoring Framework must be manageable. The number of indicators monitored simultaneously must be limited and the volume of data being reported should be kept to the necessary minimum.
- The Monitoring Framework must utilize feasible reporting frequencies. Ensuring the frequency of reporting is relevant in terms of the availability of data and the temporal scale of project intervention implementation.
- The Monitoring Framework must accurately describe project impacts. Accurately defining what each indicator needs to be measuring.
- The Monitoring Framework must utilize defined calculation methods. Refinement and acceptance of proposed calculations to ensure each stakeholder has the ability to measure interventions in their respective project areas.

With the ambition being to have a monitoring framework that monitors the progress and evolution of districts to become PEDs, the Cities4PEDs consortium chose to adopt a process-oriented approach to monitoring and evaluation. This means that for each indicator a score can be calculated, without it being necessary to reach the full score on all indicators to be labelled as a full-fledged PED. The objective is rather to help districts in transition to understand on which aspects they still have to work towards becoming a PED. This way the monitoring framework can be seen as a step-by-step guidance tool for local cases. Our proposed indicators help to outline goals in specific terms, monitor progress, and provide feedback to stakeholders.

Monitoring categories

The indicators have been developed within three monitoring categories striking a balance between quantitative and qualitative indicators:

Table 1 - Monitoring Categories

Monitoring Category	Description	Example indicators
Technical	Energy performance focuses mainly on the interventions facilitating the energy transition.	Energy demand and consumption; RES generation ratio; Peak load reduction
	Environmental performance is increasingly important for smart cities striving to identify environmental risks and factors that are essential for humans and natural resources and special for smart city planning and operation.	CO_2 emissions reduction; Air quality, Noise pollution
Social & organisational	Social performance is crucial to estimate the extent to which the project and its designed collaborative action model facilitate the involvement of citizens and social actors in the planning, decision-making and implementation activities through social citizen-driven innovation mechanisms.	Citizen participation in co-creation processes and (online) decision making; ; Affordability; Degree of users' satisfaction; Quality of life
	Governance performance refers to the city governance from the side of the municipality administration, planning and evaluation mainly, but also includes aspects of the legal domain regarding the regulatory framework and its compatibility with the proposed solutions and implemented policies at project or city level.	City Instruments; Involvement of the city administration; Legal framework compatibility; New rules/regulations due to the project
Economic	Economic performance refers to the business efficiency and cost of each application and usage scenario from a market perspective	Average cost of energy consumption; Cost savings; Return on investment

Indicator fiches

Indicator fiches contain the description and the basic calculation and assessment method that will be utilized for each indicator. The defined calculation and assessment methodologies of each indicator are to be applied throughout the project lifecycle to ensure that data is monitored consistently and accurately, which enables the evaluation of datasets to determine the success and replicability of the interventions.

Table 2 - Indicator Fiche

Parameter	Description
Monitoring category	Here it is determined to which monitoring category the indicator belongs; Technical, Social and organisational or Economic
Definition	This definition defines the specific indicator to be measured
Description	Here more detail on the rationale behind the indicator as well as its relevance is described.
Calculation/assessment	Here the calculation (technical/economic) or assessment methodology for the indicator is described.
Expected availability	Here the expected availability of the data required for the calculation, or the assessment of the indicator is defined.
Expected reliability	Here the expected reliability of the data required for the calculation or assessment of the indicator is defined.
Considerations	General points to be considered in the calculation of the indicator are mentioned here.
Scoring and/or Target	The expected value/number/unit that the indicator is aiming to achieve is described here.
Unit of measurement	The unit of measurement of the indicator to be reported is referred to here.

Scoring system

The following scoring system aims to combine the three monitoring categories at the same time while avoiding the trap of the monitoring framework to become a static checklist that would merely put a PED-label or not on the district. Therefore, a radar diagram can be used that visualises on which aspects the district scores well and on which aspects there is still work to be done. Each indicator can be accredited a score on a scale of 1 to 10. For the technical and economic indicators, this is based on the 'target' to be achieved, which is to be developed by each local case. For the social and organisational indicators, a Likert scale is most often used.

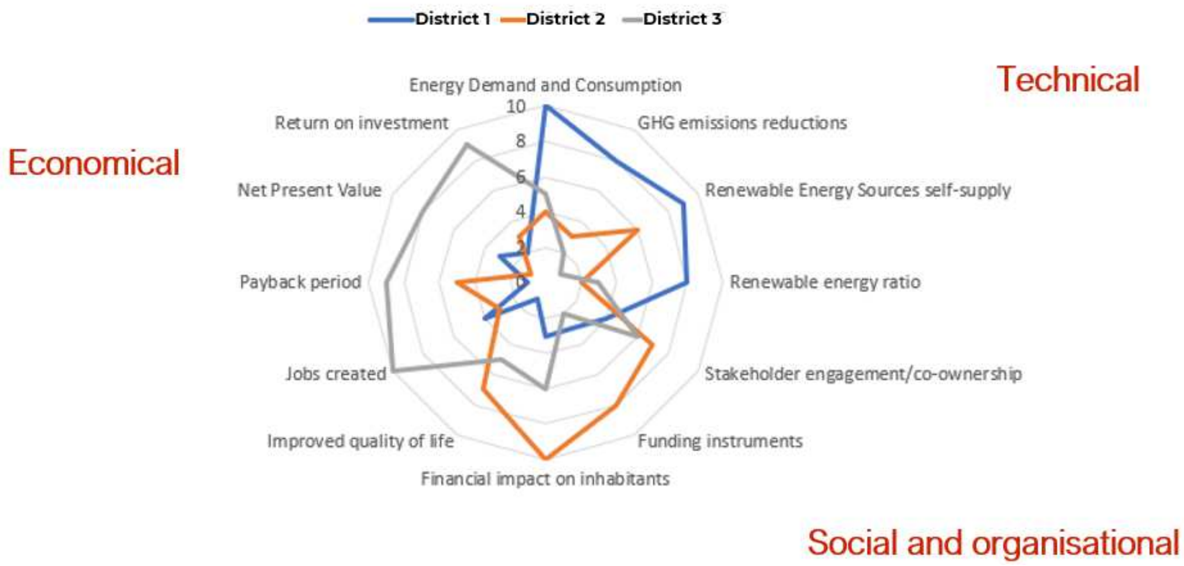

Figure 1: Scoring system

3. The catalogue of indicators

For each monitoring category, an initial set of indicators was presented to the whole consortium. These were based on both general literature on zero-energy districts[1], sustainable city monitoring and evaluation systems[2] and specific literature such as Smartcities Information System (SCIS), CITYkeys, Syn.ikia, REPLICATE, MatchUp, SmartEnCity, MySMARTLife, SHARING CITIES, TRIANGULUM, GrowSmarter, +CityxChange, STARDUST and Angelakoglou et al. (2019)[3].

Based on the guiding principles and subsequent discussions with the participating cities, a selection was made of ten indicators divided into three monitoring categories:

- Technical indicators:
  Final energy consumption, Local production of renewable energy sources & $CO_{2,eq}$ emissions
- Economic indicators:
  Internal rate of return (IRR), Payback time for PED investments & New jobs created
- Social & organisational indicators:
  Stakeholder engagement, City instruments, Improved quality of life & Affordability

The indicators were assessed and further developed by each local case (see Chapter 4), to adjust the monitoring framework to their respective district requirements. The objective is not that every indicator should necessarily be applied to each local case, and not that each local case should have a perfect score on each indicator to be regarded as a PED. The framework rather supports as an evaluation tool on its process of becoming a PED.

3.1. Technical indicators

These indicators address overall energy and environmental performance. They focus mainly on the interventions facilitating the energy transition. They are quantitative in nature and can thus be assessed using various calculation methods.

The crux does not really lie in the indicator definition or the calculation method (as there were found to be relatively common among the three districts under

1 Saheb, Y., Shnapp, S. and Paci, D., From nearly-zero energy buildings to net-zero energy districts, EUR 29734 EN, Publications Office of the European Union, Luxembourg, 2019.

2 Vandevyvere, Han. (2013). Evaluating the sustainable performance of an urban district: Measured score or reflexive governance?. International Journal of Sustainable Development and Planning. 8. 36-58. / Economist Intelligence Unit. 2011. Asian Green City Index,

3 SCICS Essential Monitoring Guides. Smartcities Information System / Bosch, Peter & Jongeneel, Sophie & Rovers, Vera & Neumann, Hans-Martin & Airaksinen, Miimu & Huovila, Aapo. (2017). CITYkeys indicators for smart city projects and smart cities. / Syn.ikia - Sustainable Plus Energy Neighbourhoods – Methodology framework for Plus Energy Buildings and Neighbourhoods / REPLICATE – D10.2 Report on Indicators for Monitoring at City Level. / MatchUp-D1.1: Indicators Tools and Methods for Advanced City Modelling and Diagnosis. / SmartEnCity-D7.2: Monitoring and Evaluation: KPIs Definition. / MySMARTLife: D5.1-Integrated Evaluation Procedure. / SHARING CITIES-D8.1: Common Monitoring and Evaluation Framework. / TRIANGULUM-D2.1: Common Monitoring and Impact Assessment Framework. / GrowSmarter: Publications-D5.1: Evaluation Plan. / +CityxChange, D7.1-Approach and Methodology for Monitoring and Evaluation. / STARDUST-D7.3: Business Models and KPIs Analysis and Validation for Lighthouse Cities Interventions. / Giourka, Paraskevi & Kourtzanidis, Konstantinos & Apostolopoulos, Vasilis. (2020). From a Comprehensive Pool to a Project-Specific List of Key Performance Indicators for Monitoring the Positive Energy Transition of Smart Cities—An Experience-Based Approach. Smart Cities. 3. 705-735..

study), but rather in the data availability. Existing districts might have more difficulties in gathering data since historically, no structures or relationships have been set up to collect and share such data. Additionally, existing developments generally don't yet have many smart meters, making granular data unattainable. Furthermore, districts also differ in ownership structure, where a district with a high share of private ownerships might make it more strenuous to gain access to data, compared to a district with large building blocks owned by project developers with extensive data access.

Therefore, a '**Tier-based approach to monitoring**' is developed, where the most appropriate tier depends on the local context of the district.

Tier-based monitoring

In general, a tier-system refers to a series of rows or layers or a level or grade in the hierarchy of an organization or system. A tier structure describes a system with distinct levels or layers. In the arrangement of a tier system, one level must be completed or accomplished before another commences. Each level must be undertaken separately from the other[4].

The different tiers for collecting data on technical indicators are:

- **Tier 1:** Data is transferred by the DSO or district heating operator to the project team periodically, such as (bi-)yearly.
  This occurs on a relatively course spatial level, since GDPR regulations do not allow to share data that can be traced back to individuals.
  Furthermore, no distinction can be made between energy end uses.
- **Tier 2:** Data is transferred by the developer or building owner(s) to the project team periodically, such as monthly or trimestral.
  This can occur on a finer spatial level but requires building owners to give their permission to share their data (in an anonymised way).
  Furthermore, depending on the hardware lay-out of the electrical and heating system, a distinction could be made between energy end uses.
- **Tier 3:** Data is transferred via a data-platform and smart meters to the project team periodically, such as hourly or daily.
  This can occur on a finer level spatial level but requires each data sharing participant to agree to share their data (in an anonymised way).
  Furthermore, a finer distinction can be made between energy end uses.

Several things quickly become clear when analysing the different tiers. First, lower tiers will mostly correspond existing districts as 'smart' data is not easily collected there. However, even for new developments with many smart meters, partnerships and agreements need to be set up in time in order to facilitate a Tier 3 district monitoring, as gathering the necessary data or setting up the required bodies might become more difficult once the district is fully populated. The Making City report[5] gives guidelines on how to perform Tier 3 monitoring. Additionally, as granular data access might be difficult for lower tiers, a proposed solution is to simulate the energy flows.

Simulation-assisted monitoring

If a Tier 3 monitoring can be achieved, all data can be collected on a fine temporal and spatial granularity, possibly including a distinction between energy end uses.

[4] https://thebusinessprofessor.com/en_US/mgmt-operations/tier-structure-definition

[5] Making City: D5.6 – Guidelines for definition of Monitoring Programmes. Available online at: https://makingcity.eu/wp-content/uploads/2021/12/MakingCity_D5_6_Guidelines_for_Definition_of_Monitoring_Programmes_Final.pdf

However, this is not the case for lower tiers and while the collected data might be sufficient to derive energy consumption for the district as a whole on a yearly basis, it hardly allows for strategic steering due to the coarse nature of the data. In these cases, collected data could be combined with a simulation model.

Such simulation model accounts for the district's physical parameters, the meteorological conditions, a typical user behaviour, the current energy systems and the renovation standards to model the energy consumption. The model can be calibrated using the collected data, with finer data leading to a more accurate model. The model allows to transform coarse data (temporal, spatial and usage) into granular insights, revealing where and what bottlenecks need to be resolved first to steer towards a PED. Furthermore, in contrast to only collecting data, the simulation model allows to create different scenarios, illustrating the effects of various choices. The Brussels local case has created a simulation model for the Northern Quarter using the open-source software "City Energy Analyst" (see Section 4.1).

Baseline-monitoring

Besides monitoring the situation how it currently is, it also interesting to understand the starting point, also referred to as the baseline. Baseline assessment refers to the procedure to assess the actual situation before the intervention takes place and can be used to compare the effect of an intervention. Baseline calculations differ whether performing them for existing districts or for newly developed districts.

When considering an existing district, the baseline refers to the actual situation before the refurbishment. This situation must be monitored for all energy performance metrics before any renovation actions are made (either through actual measurements or through the use of simulation tools).

When considering newly built districts, there are no existing data to serve as a comparison. Therefore, the baseline refers to the business-as-usual practice, which can be derived e.g., from building regulations or by utilizing measured data from same type of buildings.

Methodologies such as IPMVP[6] can also be directly applied. This is a best practice methodology commonly used for measuring, computing and reporting savings achieved by energy efficiency projects. This protocol establishes how to perform the evaluation of energy savings by comparing measured consumption before and after implementation of energy actions making suitable adjustment for changes in conditions. The comparison of the baseline period and reporting period is carried out by the following equation:

$$Savings = Baseline\ period\ energy - Reporting\ period\ energy\ +/- \ Adjustments$$

The adjustment term shown in the equation should be computed from identifiable physical facts and in this case, proceed to perform an adjusted of the baseline energy.

[6] Efficiency Valuation Organization (2012). EVO 10000 – 1:2012 International Performance Measurement and Verification Protocol. Concepts and Options for Determining Energy and Water Savings Volume 1.

Primary energy consumption

Table 3 - Indicator: Primary energy consumption

Monitoring category	Technical
Definition	Primary energy consumption
Description	This indicator assesses the primary energy consumption of the district for all forms of energy (i.e. electricity & thermal). The exact formulation of what to include in the energy consumption is up to the district representatives to choose. This is linked to a bigger question revolving around system boundaries[7] (functional/spatial/etc.). The Cities4PEDs consortium has decided to include the building operation (space heating, cooling demands, etc.) and user demand (plug loads and domestic / office appliances) except for uses that provide services beyond the district (hospitals, schools, transportation, industries through their products).
Calculation / assessment	The calculation method depends largely on the data availability and the subsequent tier achieved. **Tier 1-2:** Make use of the simulation model in combination with the available data, as specified above. **Tier 3:** All data can be collected on a fine temporal and spatial granularity, possibly including a distinction between energy end uses.
Expected availability	**Tier 1:** High, as the majority of energy flows of any district are monitored by the local DSO or district heating operator (except for fuel oil, wood pellets and so forth, but these should be phased out in the hopes of becoming a PED). However, in order to increase the value of coarse tier 1 data, it should be supplemented with a simulation model. The input data for this simulation model (renovation standards, energy systems, etc.) might be difficult to assess. This is specially the case for existing districts while these are the type of districts that most likely will have to rely on tier 1 data. **Tier 2:** High for new developments, as these data sharing requirements can be part of the tender for a successful project developer. Existing districts might incur more issues, especially when the majority of dwellings is owned by private people. **Tier 3:** Low, requires up-front and strong interaction between the relevant parties involved in order to set up the necessary data infrastructure.
Expected reliability	Data relating to direct energy flows can be expected to be highly reliable. Data relating to the simulation model will pose more issues. For example, there can always be a discrepancy between the design of the building and how it is actually operated.
Considerations	/
Scoring and/or Target	Sufficiently low to be offset by local production and context factors
Unit of measurement	$kWh/(m^2_{NFA}.year)$
Source	Depends on the data tier and the local context
References	SCIS; REPLICATE; Angelakoglou et al. (2019)

[7] Schneider, S.; Zelger, T.; Sengl, D.; Baptista, J. A Quantitative Positive Energy District Definition with Contextual Targets. Buildings 2023, 13, 1210. https://doi.org/10.3390/buildings13051210

Renewable energy sources, local production

Table 4 - Indicator: Renewable Energy Sources local production

Monitoring category	Technical
Definition	The total Renewable Energy Sources (RES) from local production
Description	This indicator calculates the total local production of renewable energy. This includes the on-site electricity production and the on-site renewable heat & cold generation. The exact formulation of what to include in the local renewable energy production is up to the district representatives to choose. For example, in Sweden, waste heat from industrial processes is seen as a commodity rather than a renewable waste product. Alternatively, for the Vienna local case, discussions are ongoing to include off-site RE production that would otherwise NOT be utilized or exploited if the district wasn't there.
Calculation / assessment	The production of large-scale or collective systems (e.g., wind turbines or district heating) is measured by the DSO or the district heating operator. Monitoring the production of small-scale, individual systems (solar PV, heat pumps, etc.) depends on the tier of the district: **Tier 3** monitoring allows to directly monitor the production of these systems. **Tier 1-2** monitoring requires the same simulation model as for the energy consumption can be used.
Expected availability	The expected availability is high as these production systems are registered by the local authority.
Expected reliability	**Tier 3** Data relating to direct energy measurements can be expected to be highly reliable. **Tier 1-2** Data relating to the simulation model can pose more issues. For example, the production units can be less efficient than designed, experience more unavailability, shading losses and so forth. However, when considering enough production units, the simulated behaviour is expected to be in line with the actual utilization.
Considerations	/
Scoring and/or Target	Sufficiently high to offset by local consumption, taking into account context factors
Unit of measurement	kWh/ (m^2_{NFA}.year)
Source	Depends on the data tier and the local context
References	SCIS; +CityxChange

CO_2-equivalent emissions

Table 5 - Indicator: CO2-equivalent emissions

Monitoring category	Technical
Definition	CO_2-equivalen emissions
Description	This indicator assesses the GHG emissions (converted in CO_2-eq.) generated over a calendar year by the same activities included in the primary energy consumption indicator inside the PED boundaries (as defined by the district representatives). The indicator should express the difference of situation before and after the development of the project or, in case of new developments, to a state-of-the-art or business-as-usual option
Calculation /Assessment	The CO_{2eq} emissions are calculated by using emission factors for each energy source, based on the total energy mix. The choice of emission factors is up to the district representatives to choose but are usually set on the national level or perhaps regional level. If emission factors are not available, the factors from the Covenant of Mayors[8] can be used. **Tier 2-3.** When considering grid electricity as a source, variable emission factors could be used if electricity consumption is known on a fine temporal level. These emission factors vary throughout the year, ranging from every x months up to a variable factor for every hour to accurately reflect the reality of the grid electricity mix. When considering greenfield developments, the district representatives can choose to only include operational emissions (emissions during the operational life) or include the embodied emissions (emissions related to the creation of the building material and the actual construction). This is linked to a bigger question revolving around system boundaries[7].
Expected availability	High, immediately available to be calculated from the energy consumption using emission factors.
Expected reliability	High
Considerations	/
Scoring and/or Target	Sufficiently low to reach zero emission taking into account context factors
Unit of measurement	CO_{2eq}/ (m^2_{NFA}.year)
Source	Project owner, energy utility or provider in case these are involved in the project
References	CITYkeys

[8] Electricity: https://www.covenantofmayors.eu/index.php?option=com_attachments&task=download&id=326

Fuel combustion: https://www.covenantofmayors.eu/index.php?option=com_attachments&task=download&id=326

3.2. Economic indicators

Economic indicators assess the business efficiency and cost of each application and usage scenario from a market perspective.

Internal Rate of Return

Table 6 - Indicator: Internal Rate of Return

Monitoring category	Economic
Definition	The interest rate at which the net present value of the investment is zero
Description	The internal rate of return (IRR) is a widely used investment performance measure in commercial real estate. It allows investors to know whether a project will be lucrative and gives them a means to compare alternative investments based on their yield.
Calculation/assessment	The calculation is based on the cost of developing the project, including possible additional costs because of higher building standards of a PED, and on the sale or rental price of project. These are converted to yearly cash flows and lead to the internal rate of return based on the best practices of corporate finance in the local case.
Expected availability	As this will often go to the core of why a project is being executed, it is expected that this information will be available
Expected reliability	High, as this goes hand in hand with the financial performance of the project developer.
Considerations	In fact, the internal rate of return is only one metric real estate investors can use to assess the profitability. Others include the payback period or the Net Present Value, but these can all be derived from the same financial analysis. For example, in Stockholm, the rental price is capped based on location, so the further from the centre, the less likely investors will want to invest in efficient buildings since they can barely ask a premium for the increased efficiency.
Scoring and/or Target	The scoring depends on the expected internal rate of return of project developers in each local case. In any case, a rating system can be imagined where above average returns would constitute a favourable score while below average returns constitute an unfavourable one.
Unit of measurement	%
Source	Project documentation and/or interviews with the project leader or other actors involved.
References	SCIS; CITYkeys

Payback time for additional PED investments

Table 7 - Indicator: Payback time for additional PED investments

Monitoring category	Economic
Definition	The time it takes before a project developer can earn back the additional investment it made to achieve PED standards. This can occur by savings in the operational costs or by asking a premium for the sale/rental.
Description	Constructing buildings which adhere to PED standards (and are thus even above the required legal standards) often times requires additional investments above "business as usual". However, higher standard buildings lead to a lower energy bill, compensating the higher up-front cost. In the Swedish case where they have a "warm rent" – a rent which includes the heating of the dwelling – this lower energy bill is felt by the project developer, which brings them lower operational costs to provide the heating required in the warm rent. In the Brussels and Viennese case, the lower energy bill is felt by tenants, which allows the dwelling to be sold/rented out at a premium since the lower energy bill compensates the higher up-front cost. The knowledge on the payback period to achieve this compensation could convince project developers to go above and beyond the purely legal standards and strive towards PED standards.
Calculation/assessment	This requires knowing two main pieces of information: • One, the additional cost due to aspiring towards PED standards instead of business as usual. This includes the cost of better insulation, building materials, more efficient energy systems, etc. While this is unknown for new developments, surrounding high-standard building projects and other relevant references can give a first indication of the additional cost. • Second, the benefits a project developer receives for a PED standard construction. This is linked to the local context, as it depends on the target group of the buildings (e.g., housing for the less affluent), as well as local regulations. In Vienna and Brussels, this benefit can be expressed as a price premium for delivering a more energy efficient building. In Stockholm, this benefit is expressed as savings in the operational costs for providing heating, included in the warm rent.
Expected availability	This data cannot directly be measured as they depend on projections or relevant references.
Expected reliability	While this calculation will depend on several estimates (local premium, extra cost of PED-standard, etc.), having a rough figure might help in the conversations with project developers.
Considerations	Payback period is usually considered as an additional criterion to assess the investment, especially to assess the risks. Also, payback in general ignores all costs and savings that occur after payback has been reached. Payback period doesn't take into consideration the time value of money and therefore may not present the true picture when it comes to evaluating cash flows of a project. This is why sometimes decisions that are based on payback periods are not optimal and it is recommended to also consult other indicators
Scoring and/or Target	At this moment there is not standard appreciation of the distribution of values for the payback period in built environment projects, where renovation projects may have very long payback periods. A preliminary normalisation formula in the CITYkeys project is:

Normalisation	
Payback period	Score

	>30 years	1
	25-30 years	2
	21-25 years	3
	18-21 years	4
	15-18 years	5
	12-15 years	6
	9-12 years	7
	6-9 years	8
	3-6 years	9
	0-3 years	10
Unit of measurement	Years	
Source	Project documentation or interviews with project leader.	
References	SCIS, CITYkeys	

New Jobs Created

Table 8 - Indicator: New Jobs created

Monitoring category	Economic
Definition	Number of new jobs created
Description	Activities of the local cases are expected to trigger the creation of new jobs directly with the solution providers and partners involved in the project, as well as indirectly through association with the project and induced. These indirect and induced employment opportunities are based on the “multiplier effect” and can be potentially achieved in areas such as engineering, construction, maintenance, consultancy, sales, etc. which will benefit from the impacts of the project and potential subsequent investment.
Calculation/assessment	The actual number of new full-time equivalent employment positions created directly and indirectly as a result of project activities, including additional investments, new replication or spin- out projects, new businesses created etc. Each project partner will provide the number of (direct) new employment opportunities created internally as a result of project activities. Where possible, partners will report indirect jobs, by applying a best-practice multiplier to the number of direct employment opportunities created. Applied research will be undertaken to determine appropriate multipliers for the project and/or individual interventions or countries.
Expected availability	High availability for partners providing the number of direct employment opportunities created. Unclear reliability for outside, indirect, and induced jobs.
Expected reliability	Limited reliability, as job creation has an induced component and is not directly derivative from investment.
Considerations	Local legislation/project partner specific criteria for FTE criteria
Scoring and/or Target	Collection of data from partners on the absolute value of number of new jobs created. The following types of jobs should be included: new contracts (both temporary and long-term) related to the project and/or needed to ensure the implementation of

project actions (e.g., for the construction & retrofitting works). However, it should be considered that, while the scoring depends on the number of jobs created, the size of the project and the district should be considered. A large project will naturally lead to more new jobs created, simply due its size, and not because of additional effort to source labour locally. Therefore, the scoring depends on the number of jobs created per total cost of investment. The latter would be data underpinning the other economic indicators. The below theoretical scoring table should thus be downscaled or upscaled according to the size of the project and district, at the beginning of the project to allow for an objective and accurate monitoring.

# of jobs created	Score
< 0	1
1-3	2
3-5	3
5-7	4
7-10	5
10-30	6
30-50	7
50-70	8
70-100	9
>100	10

Unit of measurement	Number
Source	Project documentation or interviews with the project leader.
References	SCIS, CITYkeys,

3.3. Social and organisational indicators

These indicators address the aspects of equity, community and people. The social performance indicators assess the extent to which the project and its designed collaborative action model facilitate the involvement of citizens and social actors in the planning, decision-making and implementation activities through social citizen-driven innovation mechanisms. The organisational indicators asses the governance from the side of the local authorities. They are qualitative in nature and can thus not be assessed in the same manner as the technical and economic indicators.

Data collection

There are different ways to collect qualitative data[9]. One "traditional" way of collecting data are surveys, which enable standardized data collection, ensuring that the same data is collected from each respondent. Surveys can be roughly divided into two categories: questionnaires and interviews.

- **Questionnaires:** Questionnaires provide an efficient way to collect information from multiple stakeholders quickly. They can force users to

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select from choices, rate something or have open ended questions allowing free-form responses.

- **Interviews or consultations**: There are three types of interviews - unstructured, structured, and semi-structured. In structured interviews, the analyst uses a predetermined set of questions. In unstructured interview there is no agenda or list of questions. Semi-structured interview is a combination of the structured and unstructured.

Different kind of survey must be prepared for each type of stakeholder. In the case of the residents, the questionnaire format is most likely to be chosen because a high number of responses is desired. However, if only few stakeholders are involved as for example with city decision makers, interviews may be the more appropriate choice.

However, outreach should not be limited to these "traditional" forms of public participation. A multitude of techniques exist that can lead to an interaction between stakeholders, local authorities and citizens. Examples are neighbourhood festivities, games/apps (cf. Stockholm), digital platforms (cf. Brussels) citizens' summit, discussions in public space, educational programmes. Furthermore, outreach does not have to be very elaborate either, but can also happen in an informal way, e.g., citizen mobilisation can happen through interactions in everyday settings like the market, or around a coffee table[10].

Important to note as well is that outreach does not just happen at the beginning of a project but is a long-term process. It should be clear from the beginning, when you will come back and how the gathered input will be used. Finally, extra care should be taken so that everyone is represented, even marginalised groups (e.g., women, elderly). One method for this is mapping existing persona and their networks since this helps identify how certain groups can best be reached.

Data evaluation

Contrary to the technical and economic indicators which have defined calculation methods and thus exact outcomes, social and organisational indicators are more subjective in their assessment. This begs the question as to who assesses these indicators as this might influence their outcome.

A first attempt to answer this question was the introduction of a **Quality Chamber**. 'A quality chamber would be an independent body that takes various social facets of a district into account and makes a judgment call on whether it meets the requirement for being a PED on a social level. Besides making a judgement, its other function is to guide the district or a specific project within the district towards becoming a PED. The social and organisational indicators below provide an assessment framework that can be used by this quality chamber. While the exact governance of such a quality chamber is yet to be determined, for Brussels this role could possibly be fulfilled by the Coordination Platform.

[10] Architecture Workroom Brussels (2022). Cities4PEDs. VERLINDEN, Chloé & DUBOIS, Orson. Towards co-ownership and inclusive PED development.

Stakeholder engagement

Table 9 - Indicator: Stakeholder engagement

Monitoring category	Social and organisational
Definition	The extent to which stakeholders in the neighbourhood have been involved in the planning process and/or in the implementation process
Description	The need for timely and effective public involvement has been identified for successful smart city projects as user behaviour is an essential component of the project's performance in the use phase[11]. As residents' beliefs, needs, preferences and expectations towards sustainable living environments have a strong influence on project performance, public involvement during the development stage is essential to provide developers with input to ensure that the project will perform as intended[12]. An active involvement of residents in the development process is therefore beneficial to the necessary awareness and long-term support for smart city projects. The role of community participation events in the local cases is to create awareness and inform the local inhabitants of the city, and within the project area, about PED development and enable participation. The events are designed to suit each city's local context and interventions. Events can include open-door events, community meetings, co-design workshops and consultation processes and design processes as well as digital tools such as debating forums, voting and participatory budgeting platforms that enable citizens to co-create the solution with the relevant stakeholders, project partners and the local authority.
Calculation/assessment	The Likert scale is based on the ladder of citizen participation of Arnstein (1969)[13]: No involvement – 1 — 2 — 3 — 4 — 5 — High involvement 1. **Not at all:** No community involvement. 2. **Inform & consult:** The more or less completed project plan is announced to the community either for information only, or for receiving community views. The consultation, however, is mainly seeking community acceptance of the plan. 3. **Advise:** During planning: the project plan is drafted by a project team and then presented to community actors, who are invited to ask questions, provide feedback and give advice. Based on this input the planners may alter the project plan. During implementation: the project implementation is done by a project team. Community actors are invited to ask questions, provide feedback and give advice. Based on this input the planners may alter the project. 4. **Partnership:** community actors are asked by the project planners to participate in the planning and/or the implementation process by prioritizing issues and planning actions. The local community is able to influence the planning process and or the implementation process. 5. **Community self-development:** During planning: the project planners have empowered community actors to outline their needs and to make action plans. During implementation: the project planners have empowered community actors to manage the project implementation and evaluate the results.

[11] Abdalla, G. Sustainable Residential Districts: The residents' role in project success. Eindhoven: University of Technology, 2012. https://pure.tue.nl/ws/files/3450528/734057.pdf

[12] Williams, J. "Regulative, facilitative and strategic contributions of planning to achieving low carbon development." Planning theory & Practice (Routledge) 13, no. 1 (2012): 131-144.

[13] Arnstein, S. (1969) A Ladder of Community Participation. Journal of the American Institute of Planners, 35, 216-224 - https://doi.org/10.1080/01944366908977225

Expected availability	The mentioned sources should easily be able to provide insight in the role of the local community in the planning process.
Expected reliability	Because of the subjectivity that cannot be excluded, this indicator is not 100% reliable.
Considerations	This indicator determines the actual result in citizen participation efforts and allows benchmarking with other cities. Although it is tried to make scoring the indicator as objectively as possible, a certain amount of subjectivity is present. Without guidance and supervision by experts and local authorities, community self-development can lead to unwanted results.
Scoring and/or Target	Likert scale
Unit of measurement	Number
Source	To be derived from project documentation and/or interviews with project leader and others involved in the project
References	CITYkeys

City instruments

Table 10 - Indicator: City instruments

Monitoring category	Social and organisational
Definition	The extent to which the project has benefitted from city instruments
Description	Smart city projects often rely to some extent on city instruments, which can take a variety of forms (see PED atlas[14]). This indicator analyses whether city instruments are available and, in this way, facilitates smart city developments.
Calculation/assessment	The indicator provides a qualitative measure and is rated on a Likert scale: Not at all – 1 – 2 – 3 – 4 – 5 – Very much 1. **Very much hampered:** Project development has been hampered by an absence of a city instruments. 2. **Somewhat hampered:** The (lack of) city instruments have, to some extent, hampered the development of the project or the achievement of its ambitions. 3. **Neutral**: The city instruments have had no significant, positive or negative, effect on the project's development or in achieving its ambitions. 4. **Somewhat benefitted**: The city instruments have to some extent benefitted the project in the development of the project or in achieving its ambitions. 5. **Very much benefitted**: the city instruments have benefitted the project to a great extent in the development of the project or in achieving its ambitions.
Expected availability	Expected to be easily available
Expected reliability	Because of the subjectivity that cannot be excluded, this indicator is not 100% reliable.
Considerations	Although it is tried to make scoring the indicator as objectively as possible, a certain amount of subjectivity is present
Scoring and/or Target	Likert scale
Unit of measurement	Number

[14] Cicchianni, C., Desmet, L., Lindorfer, A., Mangelschots, H., Schofmann, P. (2021). Atlas: From 7 case interviews to recurring strategies and PED relevant aspects. Energy-cities. https://energy-cities.eu/wp-content/uploads/2021/11/Cities4PEDs-Atlas-Nov.-2021.pdf.pdf

Source	To be derived from project documentation and/or interviews with project leader and other team members
References	CITYkeys

Improved quality of life

Table 11 - Indicator: Improved quality of life

Monitoring category	Social and organisational
Definition	The extent to which the project offers clear advantages for end users
Description	Smart city projects should preferably offer a clear advantage to a majority of end-users. End-users are conceptualised as those individuals who will be using/working with the solution. The advantage can take many forms, for instance improved thermal quality and increased comfort. It is presumed that solutions which have a higher level of advantages to end users will be more likely to be adopted than solutions which have negative or no advantages.
Calculation/assessment	The indicator provides a qualitative measure and is rated on a Likert scale: No advantage– 1 — 2 — 3 — 4 — 5 — Very high advantage 1. **No advantage:** The project does not offer clear advantages for end users. The technologies or principles applied in the project are not at all beneficial to end users. 2. **Little advantage:** The project offers truly little advantage to end users. The vast majority of the technologies/principles offer an indirect and insignificant advantage to end users. 3. **Some advantage:** The project offers some advantage to end users who to a certain extent experience direct benefits from the technologies/principles applied in the project. 4. **High advantage:** The project offers a high advantage to end users who benefit mostly from the applied technologies or principles as the applied technologies/principles have a direct and high positive effect on end users. 5. **Very high advantage:** The project offers a very high advantage to end users as the applied technologies/principles have a direct and an extremely positive effect on end users (e.g., increased thermal comfort, increased quality of the living environment etc.).
Expected availability	The required information will be easily available with the below mentioned resources
Expected reliability	Because of the subjectivity that cannot be excluded, this indicator is not 100% reliable.
Considerations	The indicator allows the evaluation and comparability of a wide range of project types and (still to-be-developed) solutions. Although it is tried to make scoring the indicator as objectively as possible, a certain amount of subjectivity is present.
Scoring and/or Target	Likert scale
Unit of measurement	Number
Source	To be derived from project documentation, and/or interviews with project leader or end-users, and based on expert judgement
References	CITYkeys

Affordability

Table 12 - Indicator: Affordability

Monitoring category	Social and organisational
Definition	The total cost for the combination of housing and energy. This indicator is only relevant when the inhabitants can directly feel the effect of energy-efficiency measures, as is the case in Vienna and Brussels. However, in the Stockholm case where there is a "warm rent" – a rent which includes heating – inhabitants will not feel this benefit as both the costs and benefits are attributed to the building owner.
Description	Achieving a PED will decrease the monthly energy bill for its inhabitants but demands initial investments or other costs that eventually will be transferred to them in full or at least partly, due to more expensive rent and/or housing. The combination of rent/housing (including the amortization of the investments) and energy costs must be monitored and compared to the baseline. This allows to understand whether the project generates cost savings for the end-users. Financial benefit can be an important trigger for user acceptance and market uptake of smart city solutions. Cost savings can be generated, for example, through a reduction in energy use, the generation of renewable energy on site, or reduction in housing costs. In the end, the total cost of energy and housing should be compared to the household's income as high-cost savings for a household that spends only a small share of income on energy is not equal to high-cost savings for a household that spends a large share of their income on energy.
Calculation/assessment	Different methods can be used, depending on the context. <u>Surveys</u>: a yearly survey taken from the inhabitants on the impact of the project on their energy costs. <u>Calculation</u>: Energy consumption before the project compared to the energy consumption after the project, linked to the average cost of energy and the population in the neighbourhood. The local case of Vienna has worked out this method further in section 4.3.
Expected availability	<u>Survey:</u> the availability of data will depend on the organisation of the survey and the uptake of participation by the inhabitants <u>Calculation:</u> The effect of energy related interventions of a project is usually well-known.
Expected reliability	Many aspects influence the costs and different calculations methods exist to calculate the costs (and revenues), which make the indicator not 100% reliable. With regards to energy cost savings, there is limited reliability of the energy demand calculations due to user behaviour.
Considerations	As far as energy-related cost savings are concerned, significant deviations between demand calculations and the actual consumption data are a well-known phenomenon.
Scoring and/or Target	If a <u>survey</u> is used, a Likert scale assessment can be used: No advantage– 1 — 2 — 3 — 4 — 5 — Very high advantage 1. **No cost-savings:** The project does not offer clear cost-savings for end users. The technologies or principles applied in the project are not at all beneficial to end users. 2. **Little cost-savings:** The project offers truly little cost-savings to end users. The vast majority of the technologies/principles offer an indirect and insignificant cost-saving to end users.

	3. **Some cost-savings:** The project offers some cost-savings to end users who to a certain extent experience direct benefits from the technologies/principles applied in the project. 4. **High cost-savings:** The project offers a high cost-saving to end users who benefit mostly from the applied technologies or principles as the applied technologies/principles have a direct and high positive cost-savings on end users. 5. **Very high cost-savings:** The project offers a very high cost-saving to end users as the applied technologies/principles have a direct and an extremely positive cost-saving on end users (e.g., increased thermal comfort, increased quality of the living environment etc.). If the abstract calculation has been used, a scoring ladder in monetary values – in line with the objectives of the project – should be created. The lowest score would be accorded to little or no cost savings per (energy bill per) end-user. The highest score would be accorded to high and very high-cost savings.
Unit of measurement	Number
Source	Project documentation, interviews with project leader and/or with end-users.
References	CITYkeys

4. Operationalization of local cases

This section specifies how each local case has assessed how these indicators, or other indicators, can be applied to their district. Concretely, each district has filled in the indicator fiche for all indicators in the catalogue that they deem important for the proper monitoring of a PED. This includes the exact definition for each indicator, determining the data source, the feasible time interval of measuring, and so forth. On top of this, they have added additional indicators, not present in the catalogue, based on prior research performed in each local case. After discussing each local case separately, the commonalities are further discussed.

4.1. Brussels

The City of Brussels has the ambition to create the first Positive Energy District (PED) on its territory. To this end, the Quartier Nord has been identified as an experimental site. The perimeter of the North District DEP (in red on the map) is delimited by the Masui and Mabru districts to the north and aligned with the perimeter of the North Territory to the east/west and the inner ring road (Boulevard du Jardin Botanique/Baudouin Boulevard) to the south.

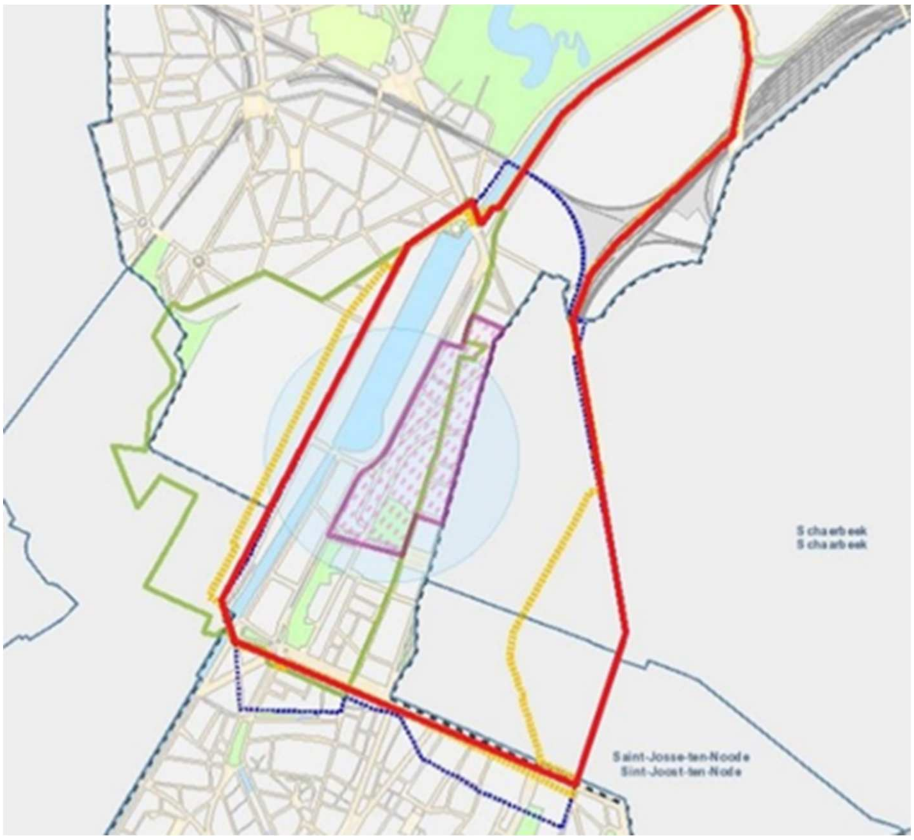

Figure 2: Map of the northern quarter

The Northern Quarter was chosen because of the dynamics underway in this area. In particular, there is a certain overlap with the perimeters of the Maximilien-Vergote PAD, the Citroën-Vergote CRU and the Héliport-Anvers CQD. In addition, the City owns a number of properties within the perimeter.

The Northern Quarter has historically been the site of profound urban changes and is composed of contrasting realities such as numerous office towers, residential areas, commercial and semi-industrial areas. It is a brownfield development with many existing structures and can also be described as a Tier 1 district (see Section 3.1).

During the Brussels Deep-Dive in January, consecutive focus meetings with the Brussels Partners afterwards, and during the Stockholm Deep-Dive in June, the Monitoring Framework for the Brussels local case has continually been developed. These occurred in parallel with the City of Brussels working on a Vision note[15] which delineates the scope of the PED and provides a general timeline and guidelines for the realisation on the PED. It is the vision of the city of Brussels to work on 3 strategic action areas:

1. Renovation of residential and commercial buildings
2. Renewable energy production
3. Changes in consumption and mobility behaviour

This culminated in several indicators that were brought forward. For the Energy-Technical indicators it was decided to further develop the following indicators:

1. Local Renewable Energy Production
2. Energy Consumption
3. Energy Efficiency
4. CO2-equivalent emissions
5. Transportation

For the social and organisational indicators, the following ones were raised:

1. Citizen Involvement
2. Supporting Framework
3. Quality of Life

Furthermore, 3E has integrated the inputs from the various meetings and complemented it with research to suggest concrete targets for the indicators. The latter is done by taking the targets for the whole of the Brussels Region as baseline – the minimum target - and increasing in a ‘progressive’ and ‘ambitious’ target’. Additionally, 3E has contacted different organisations in order to obtain data that could feed in into the indicators and to identify data gaps.

The Brussels simulation model

The Brussels simulation model makes use of the City Energy Analyst software. This is an urban building simulation platform and one of the first open-source initiatives of computation tools for the design of low-carbon and highly efficient cities. It combines knowledge of urban planning and energy systems engineering in an integrated simulation platform. This allows to study of the effects, trade-offs, and synergies of urban design options and energy infrastructure plans.

The simulation model was used to better understand the baseline energy consumption, and to test different scenarios to give a first view on what policy actions would be required in order to become a PED. A brief description of the set-up, the various scenarios and the results are discussed below. A complete

[15] Not yet published at the time of writing

description can be found in the dissertation of two master students from the Technicum[16].

The simulated area

The North District as a whole has a surface area of 1.318 km^2 (including streets and public, not building related, places). The net floor area of the whole area is 2.934 km^2, while the gross floor[17] area is 3.668 km^2, resulting in a floor space index of about 2.8. Most of the floor area consists of office buildings (68%), followed by living space (26%) while education and retail space represent each about 3% of the floor area.

To get viable results, only a part of the North District was modelled as modelling all buildings would greatly overstrain CEA. The subarea that was modelled can be seen in Figure 3. this subarea was chosen because it provides a good mix between accurately representing the district and computing limits. It represents the district quite well as it contains part of the Masui district, part of Manhattan, part of Maximilien and the entire Foyer Laekenois. The choice of this subarea thus combines family row houses with large apartment complexes, as well as large office towers. The mix of usage is now focusing more on living space compared to the entire district as its floor area now takes up 53%, followed by office space (38%) and education and retail space each about 5%. The subarea has a surface area of 0.055 km^2 (ca. 5% of total), a net floor area of 0.307 km^2 and a gross floor area of 0.383 km^2 (ca. 10% of the total). This results in a floor space index of 6.9, which is higher than 2.8 floor space index of the whole district. This shows that the subarea is quite a bit denser than the whole district, mostly due to the office towers and apartment buildings.

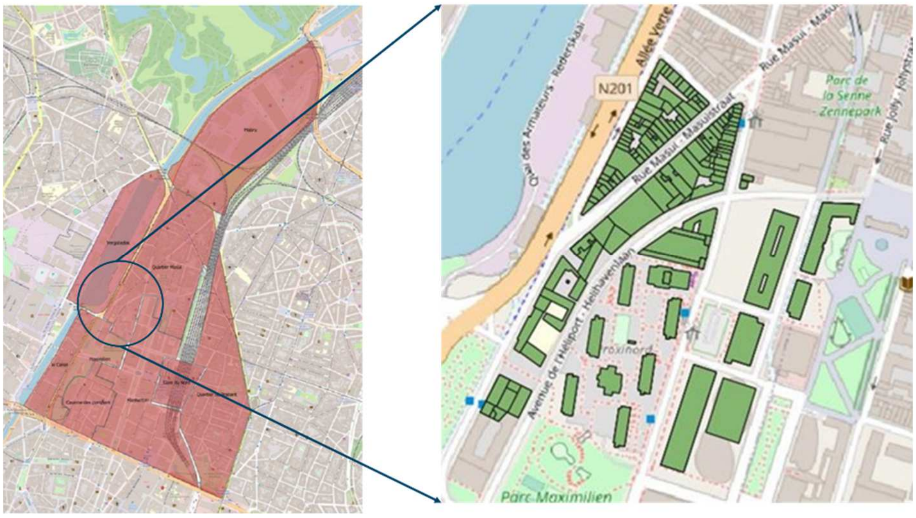

Figure 3: illustration of the simulated subarea

[16] Czarnecki, P., Dennermaier J. (2022) Cities4PEDs - Brussels North Modelling, Simulation and Comparison of Scenarios. [Bachelor dissertation] FH Technikum Wien.

[17] Using a conversion factor of 0.8

The scenarios

Seven different scenarios were created to test the impact of various policy choices on the energy balance in 2050. These scenarios are displayed in Table 13.

Each scenario has parameters (or policy choices) on three categories: “renovation, Renewable Energy production, and behavioural change”.

- For renovation, two choices can be made.
    - The renovation rate: the share of the total building stock that is renovated each year where the least performing buildings are assumed to be renovated first.
    - The U-values: the insulation standard that is achieved when renovating.
- For RE production, two choices can be made.
    - The heating system: the type of heating system
    - The PV rate: the share of the total roof area on which PV is installed each year where the best performing roofs are given priority.
- For behavioural change, two choices can be made.
    - Desired comfort: the target indoor temperature during winter
    - DHW reduction: the reduction of Domestic Hot Water consumption

The first scenario is the baseline scenario. This corresponds to the current situation and serves to calibrate the model with the data received from the DSO. It is assumed that all heating systems are operated with natural gas and utilize high temperature radiators. The current number of PV installations was estimated based on GIS data and all panels are assumed to have a tilt angle 30°. The PV roof coverage is assumed to be 0.7.

The second scenario is the generic policy scenario. This scenario assumes that no significant policy changes are made and that currently existing trends persist, also referred to as “business as usual”. The renovation rate per year is 1%, leading to 28% of all buildings being renovated by 2050. All renovated apartments have its heating system (gas in combination with high temperature radiators) replaced by a heat pump in combination with floor heating. Annually, PV is installed on 0.8% of all roofs, resulting in a PV coverage of 22.5% by 2050. No behavioural change is assumed, so the desired comfort stays at 21 °C, while the domestic hot water consumption is lowered by 5 %.

The third scenario is the ambitious individual – floor heating scenario. The renovation rate per year is 3%, leading to 84% of all buildings being renovated by 2050. All renovated apartments have its heating system (gas in combination with high temperature radiators), including domestic hot water supply, replaced by a low-temperature heat pump in combination with floor heating. Annually, PV is installed on 1.43% of all roofs, resulting in a PV coverage of 40% by 2050. Behavioural change is assumed, so the desired comfort is lowered to 19° C and the domestic hot water consumption is lowered by 15%.

The fourth scenario is the ambitious individual – radiator heating scenario. This scenario is similar to the third scenario, with the sole differences that renovated buildings now use high-temperature heat pumps in combination with radiator heating.

The fifth scenario is the ambitious collective – behavioural change scenario. In this scenario, both collective and individual measures are investigated, including behavioural change. Collective measures relate to (1) collective renovation to increase the total number of renovated buildings and (2) collective heating via a district heating system. It assumes that 10% of the entire building stock is renovated every two years until 50% of all buildings are renovated. All affected apartments have its heating system, including domestic hot water supply, replaced by district heating from an incinerator. The other buildings are renovated at a renovation rate of 1.5%/year and have its heating system, including domestic hot water supply, replaced by a heat pump in combination with floor heating. Both collective and individual renovation measures together lead to 92% of all buildings being renovated by 2050. During the collective renovation, 70 % of all roof area will be used for new PV installations, resulting in an increase of 35 % by 2050. Additionally, 0.9 % of individual PV-systems are installed annually on the roofs, resulting in an increase of 25 % by 2050. PV on both collectively and individually renovated buildings lead to a PV coverage of 60% by 2050. Lastly, as this scenario assumes behavioural change, the desired comfort is lowered to 19° C, and the domestic hot water consumption is lowered by 15%.

The sixth scenario is the ambitious collective – no behavioural change scenario. This scenario is similar to the fifth scenario, with the sole differences that no behavioural change is assumed. The desired comfort thus stays at 21° C, and the domestic hot water consumption only lowers by 5%, as was the case in the generic policy scenario.

The seventh and last scenario is the excellence scenario. This scenario brings all parameters to the theoretical maximum, even beyond what is practically feasible in order to see what would be needed to achieve full climate neutrality. The renovation rate per year is 3.7%, leading to 100% of all buildings being renovated by 2050. All renovated apartments have its heating system, including domestic hot water supply, replaced by a low-temperature heat pump in combination with floor heating. Annually, PV is installed on 2.85% of all roofs, resulting in a PV coverage of 80% by 2050, which is about the highest possible taking into account heritage and other constraints. Behavioural change is assumed, so the desired comfort is lowered to 19° C and the domestic hot water consumption is lowered by 15%.

Table 13: Simulated scenarios

		Renovation		RE production		Behavioural change	
#	Scenarios	Renovation rate	U-values	Heating	PV rate	Desired comfort	DHW reduction
1	Baseline	0%	Based on Tabula research[18]	Gas heating	Currently installed	21°C	0%
2	Generic policy	1%/year	roof/walls/floors = 0.24 windows = 1.5 glazing = 1.1 doors = 2	Heat pumps (SH)	0.8%/year (22.5% in 2050)	21°C	5%
3	Ambitious individual – floor heating	3%/year	"	Low temperature heat pumps (SH & DHW)	1.43%/year (40% in 2050)	19°C	15%

[18] Van Holm et al. (2011), Belgische woningtypologie: Nationale brochure over de TABULA woningtypologie, https://episcope.eu/fileadmin/tabula/public/docs/brochure_until2012/BE_TABULA_TypologyBrochure_VITO_2011.pdf

4	Ambitious individual – radiator heating	3%/year	"	High temperature heat pumps (SH & DHW)	1.43%/year (40% in 2050)	19°C	15%
5	Ambitious collective – behavioural change	10%/2 years until 50% 1.5%/year	"	District heating High temperature heat pumps (SH & DHW)	70% per step (35% in 2050) 0.9%/year (25% in 2050)	19°C	15%
6	Ambitious collective – no behavioural change	10%/2 years until 50% 1.5%/year	"	District heating High temperature heat pumps (SH & DHW)	70% per step (35% in 2050) 0.9%/year (25% in 2050)	21°C	5%
7	Excellence	3.7%	"	Low temperature heat pumps (SH & DHW)	2.85 %/year (80% in 2050)	19°C	25%

SP = Space Heating, DHW = Domestic Hot Water

The results

The results of each scenario are shown in Figure WX. Each scenario on the x-axis contains two bars. The left bar relates to the specific energy consumption, while the right bar shows the specific local consumption (solely represented by PV in this case). Additionally, the right bar also has a part of which only the borders are visible. This relates to the density context factor and is explained more below. If both bars have the same height, the subdistrict is energy neutral. Once the right bar becomes larger than the left bar, the subdistrict is energy positive. Several conclusions can be drawn from these results:

1. Generic policy measures are clearly not enough to reach a positive energy balance as they offer hardly any advantage over the baseline scenarios. This is exemplified by the fact that the specific energy consumption of the baseline and generic policy scenario are similar.

2. Ambitious policies (be it individual or collective measures) do achieve in reaching a specific energy consumption of around 50 kWh/m², which is almost a third of the baseline scenario.

3. The addition of district heating slightly increases the total energy demand. However, depending on the source of district heating, emissions can still go down. This would for example the case if district heating comes from renewable sources, meaning that its corresponding emissions would be zero.

4. Behavioural change leads to a total energy reduction of 8%. This does represent some easy won gains but must be accompanied by structural policy measures.

5. Reaching a positive energy balance in the pure sense is impossible for the North district. This is however not surprising and is the reason why context factors have been brought forward. While the exact formulation of these context factors in the Brussels is not yet clear, the preliminary formulation of density context factor from the Viennese Zukunftsquartier can give a first indication. The context factor is displayed via the bar on the right which only has a border. Using this formulation, the ambitious individual and ambitious collective scenarios (depending on the source) can in fact achieve a positive energy balance.

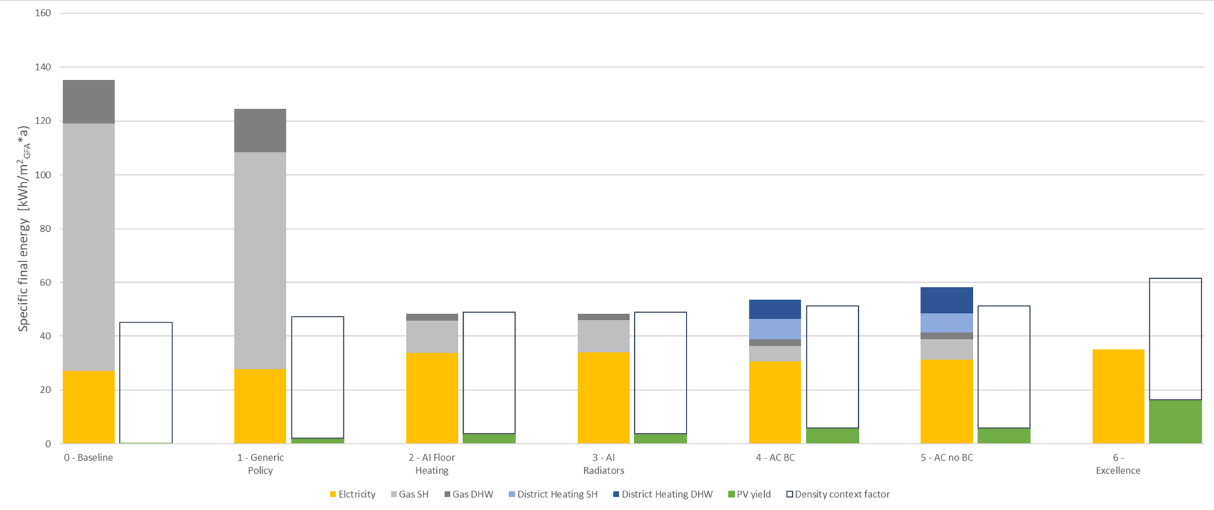

Figure 4: Results of the Brussels scenario simulation

Technical

Primary energy consumption

Table 14 - Brussels indicator: Primary energy consumption

Monitoring category	Technical
Definition	Primary energy consumption
Description	This indicator assesses the primary energy consumption of the district. This includes the building operation (including space heating, cooling demands, etc.) and user demand (plug loads and domestic / office appliances) except for uses that provide services beyond the district (hospitals, schools, industries through their products). Energy consumption as a consequence of transportation is not directly included in the calculation, rather several proxy indicators are utilized as specified below.
Calculation/assessment	As the Northern District can be categorized as a Tier 1 district, the energy consumption will be based on calculated (e.g., simulated) figures, validated by the gas and electricity measurements of the DSO. As the majority of all energy consumption is delivered by the DSO – the use of wood pellets, fuel oil, etc. is low – the measurements by the DSO should provide sufficient accuracy for the validation.
Expected availability	High, the data for the model is quite readily available

Expected reliability	Medium, the calibration of the model has been finalized and while it gives decent results on the district scale, it quickly loses accuracy when evaluating specific building blocks.
Considerations	/
Scoring and/or Target	The target is based on the primary total energy balance, this is: *primary energy saldo (export-import) + credit due to context factors > 0* Context factors can refer to urban density, heritage, mobility, regional/national energy system and context, and so forth. There is thus no individual target for energy consumption, only a combined target for both consumption and local renewable production.
Unit of measurement	GWh/year or kWh/m^2_{GFA}*year
Source	For electricity and gas consumption, the Brussels DSO (Sibelga) can provide aggregated data. Another useful source can be the report from 'Teritorium Noord' and more specifically their 'Diagnostic et dynamiques actuelles'
References	SCIS; REPLICATE; Angelakoglou et al. (2019)
Baseline	North District: 557.81 GWh/year or 152.1 kWh/m^2_{GFA}*year Simulated area: 51.68 GWh/year or 135.3 kWh/m^2_{GFA}*year

Renewable Energy Sources local production

Table 15 - Brussels indicator: Renewable Energy Sources local production

Monitoring category	Technical
Definition	The total Renewable Energy Sources local production
Description	For the Northern District, this includes the production from PV panels, solar collectors, and the waste incinerator.
Calculation/assessment	The amount of locally produced thermal/electrical energy is calculated in two ways. 1) The production of electricity (solar PV, waste incinerator) is measured by the DSO and the incinerator plant. 2) The production of small-scale, individual heating systems (solar collectors) cannot be measured directly but can be modelled using the simulation model.
Expected availability	Actual PV production is available as each installation owner needs to send their meter readings to the DSO (Sibelga) in order to receive Green Certificates. However, due to differences and inconsistencies in the timing each owner sends through production data, it is difficult to find the actual production per year. Therefore, solar PV production will most likely also be determined through modelling. Installed capacity of all other energy units (solar collectors, etc.) is available as these production systems are registered by the relevant local authority, in this case Brussels Environment. However, they only offer a generic overview per municipality, which makes determining the impact on the district level more difficult. Averages will have to suffice here

Expected reliability	The simulated behaviour of these production units is in line with the average utilization when considering enough production units
Considerations	In a later stage, there will also be differentiation between different neighbourhoods in the Brussels Northern district
Scoring and/or Target	The target is based on the primary total energy balance, this is: *primary energy saldo (export-import) + credit due to context factors > 0* Context factors can refer to urban density, heritage, mobility, regional/national energy system and context, and so forth. There is thus no individual target for energy consumption, only a combined target for both consumption and local renewable production.
Unit of measurement	GWh/year or kWh/m^2_{GFA}*year
Source	The data on solar PV will be collected via Sibelga. This will either be via direct knowledge on the actual aggregated production, or knowledge on the total installed capacity supplemented with the simulation model. The data on heat pumps and solar collectors will be collected via Brussels Environment. This will be data on the total installed capacity supplemented with the simulation model to determine the yearly production.
References	SCIS; +CityxChange
Baseline	North District: 20.89 GWh/year or 5.69 kWh/m^2_{GFA}*year Simulated area: 0.27 GWh/year or 0.07 kWh/m^2_{GFA}*year[19]

CO_2-equivalent emissions

Table 16 - Brussels Indicator: CO2-equivalent emissions

Monitoring category	Technical
Definition	CO_2-equivalen emissions
Description	Same as in the catalogue of indicators
Calculation /Assessment	The CO_{2eq} emissions are calculated by using emission factors for each energy source, based on the Covenant of Mayors[20]. Additionally, when considering grid electricity as a source, variable emission factors[21] will be used
Expected availability	High
Expected reliability	High
Considerations	/

[19] The difference between the North District and the simulated area is quite large since 95% of the PV installed in the North District comes from one industrial location, the Mabru subdistrict.

[20] Electricity: https://www.covenantofmayors.eu/index.php?option=com_attachments&task=download&id=326

Fuel combustion : https://www.covenantofmayors.eu/index.php?option=com_attachments&task=download&id=326

[21] https://www.mdpi.com/1996-1073/14/8/2165

Scoring and/or Target	The target is not yet defined but will be based on the vision note and the simulation model, as described above.
Unit of measurement	Ton CO_{2eq}/year or kg CO_{2eq}/ m^2_{GFA}*year
Source	Can be derived from previous estimations with specific emission factors.
References	CITYkeys
Baseline	North District: 163 325 ton CO_{2eq}/year or 44.53 kg CO_{2eq}/ m^2_{GFA}*year Simulated area: 19 636 ton CO_{2eq}/year or 51.4 kg CO_{2eq}/ m^2_{GFA}*year

Energy efficiency

Table 17 - Brussels Indicator: Energy Efficiency

Monitoring category	Technical
Definition	Energy efficiency
Description	This indicator assesses the energy efficiency of the district's building stock. This relates to the insulation rate of the building, expressed in its U-value or thermal transmittance. This can later be used in the simulation model.
Calculation/assessment	An average of the district or the subregion will be based on the EPB certificates, mandatory for every residential dwelling (>18 m²) or office building (>500 m²) that will be sold or rented. This certificate on the Energy Performance of Buildings has been translated from EU legislation into the Brussels context, and contains, among others, the insulation value of the building. While not every building has such an EPB certificate, there should be sufficiently available to have an estimate of the average insulation value of the district.
Expected availability	Brussels Environment has delivered EPB information, albeit in a redacted fashion in order to guarantee privacy. The average value for all buildings with EPB certificates is known per subdistrict (with subdistricts relating to e.g., Masui, Manhattan). Values in this context relates to e.g., thermal insulation, thermal shell volumes and surface areas as well the average energy score.
Expected reliability	The Northern district is quite heterogenous, so sufficient EPB certificates in each subdistrict will be required to have a holistic image (even though sufficient isn't yet defined). Furthermore, the buildings with EPB certificates will generally be in better quality, so this should be accounted for when converting the EPB values to a subregion average.
Considerations	Relevant for collective renovation projects Not all buildings have an EPB value Maybe to be considered as part of local RE production
Scoring and/or Target	The target is not yet defined but will be based on the vision note and the simulation model, as described above.
Unit of measurement	% of building stock renovated per year
Source	Brussels Environnement – Leefmilieu Brussels is the public service for environment and energy of the Brussels-Capital Region. Perspective Brussels operate the database 'Monitoring des quartier – Wijkmonitoring'. The objective of the Monitoring is to provide a selection of indicators characterising the dynamics and territorial disparities within the Brussels-Capital Region. Maps, tables and graphs illustrate the state of the neighbourhoods according to different themes: population, labour market, housing.

	It can be a useful tool but, it should be noted that despite their definition of Brussels Northen District being quite close, is not exactly the same as the one within the Cities4PEDS project. In the Indicator Category 'Buildings and facilities' information about the type of buildings in the district could be found. Another useful source can be the report from 'Territorium Noord' and more specifically their 'Diagnostic et dynamiques actuelles'
References	/
Baseline	1%

Mobility

After several discussion between the Brussels partners, it was clear that it would be interesting to include indicators that represent mobility within the district. However, unlike the previous technical parameters (energy consumption, etc.), expressing this in terms of actual consumed energy proved to be tricky. This because there is no central governing body that keeps track of energy consumed for transport or kilometres travelled, which is the case for electricity and gas, namely the DSO. A pilot project has been set-up by the Aspern Mobil Lab22 where inhabitants could download an application on their smartphone that would track their movement, allowing to among others, track the average number of kilometres driven in the district. While these solutions are technically possible, they take up many resources. If part of a bigger research towards the movement of inhabitants, this might be justified, but if only trying to determine energy consumption, this method does not provide enough added value.

Therefore, the Brussels partners have decided to use proxy indicators. These types of indicators do not attempt to measure energy consumption by transport in absolute terms, but rather determine whether the built environment and services are designed in such a way that facilitate and incentivize transportation modes with low carbon emissions. Preliminary ideas for these indicators were: "Access to public transport, access to vehicle sharing solutions, number of registered cars, number of parking spaces, and so forth". These discussions were not yet finished but can provide an interesting starting point for future conversations.

Social and organisational

Stakeholder engagement

Table 18 - Brussels indicator: Stakeholder engagement

Monitoring category	Social and organisational
Definition	The extent to which residents/users have been involved in the planning process and/or in the implementation process
Description	The description of what would be seen as 'stakeholder engagement' or 'citizen involvement' is being studied in Work Package 4. No concrete description for the Brussels case exists at this point.
Calculation/assessment	Option 1: Survey

[22] https://www.mobillab.wien/en/panel-en/

	A (yearly) survey taken from the inhabitants. This could be done as part of the ongoing project 'Territorium Noord'. **Option 2: Evaluation by Quality Chamber** Regular assessment by a 'Quality Chamber' which for Brussels can be fulfilled by the Coordination Platform. A quality chamber is an independent body that takes various social facets of a district into account and makes a judgment call on whether it meets the requirement for being a PED on a social level. This can then for example be done using a Likert scale. This scale is based on the ladder of citizen participation of Arnstein (1969)[23] as specified in the catalogue of indicators. **Option 3: Inventory of PED actions** On a regular basis, the actions performed in the PED (citizen activation, co-creation projects, coordination platform) are inventoried. Each action then is given a score on how well it meets the stakeholder engagement criteria. A combination of these options will be tested by the City of Brussels by, one the one hand, doing a self-evaluation (including the Brussels partners) and by, on the other hand, inclusion of these indicators in the yearly survey of Territorium Noord.
Expected availability	**Option 1: Survey** The availability of data will depend on the organisation of the survey and on the uptake of participation by the inhabitants. **Option 2: Evaluation by Quality Chamber** The below mentioned sources should easily be able to provide insight in the role of the local community in the planning process.
Expected reliability	**Option 1: Survey** The reliability is highly dependent on the participation rate. **Option 2: Evaluation by Quality Chamber** Because of the subjectivity that cannot be excluded, this indicator is not 100% reliable. Positive self-assessment biases must be considered. To overcome this, it might be required to also interview citizen representatives / field workers, who have a quite good view on what happens on a social level.
Considerations	This indicator determines the actual result in citizen participation efforts and allows benchmarking with other cities. Although it is tried to make scoring the indicator as objectively as possible, a certain amount of subjectivity is present. Without guidance and supervision by experts and local authorities, community self-development can lead to unwanted results.
Scoring and/or Target	/
Unit of measurement	/
Source	To be derived from project documentation and/or interviews with project leader and others involved in the project
References	CITYkeys

City instruments

Table 19 - Brussels indicator: City instruments

Monitoring category	Social and organisational

[23] Arnstein, S. (1969) A Ladder of Community Participation. Journal of the American Institute of Planners, 35, 216-224. Available online: https://doi.org/10.1080/01944366908977225

Definition	The extent to which the PED has benefitted from city instruments
Description	This indicator analyses whether city instruments are available and, in this way, facilitates urban energy developments.
Calculation/assessment	The indicator provides a qualitative measure and is rated on a Likert scale: Not at all – 1 – 2 – 3 – 4 – 5 – Very much 1. Very much hampered: Project development has been hampered by an absence of a city instruments. 2. Somewhat hampered: The (lack of) city instruments have, to some extent, hampered the development of the project or the achievement of its ambitions. 3. Neutral: The city instruments have had no significant, positive or negative, effect on the project's development or in achieving its ambitions. 4. Somewhat benefitted: The city instruments have to some extent benefitted the project in the development of the project or in achieving its ambitions. 5. Very much benefitted: the city instruments have benefitted the project to a great extent in the development of the project or in achieving its ambitions.
Expected availability	Expected to be easily available
Expected reliability	Because of the subjectivity that cannot be excluded, this indicator is not 100% reliable. Positive self-assessment biases must be considered. To overcome this, it might be required to also interview citizen representatives / field workers, who have a quite good view on what happens on a social level. Data to be gathered by surveys (on affordability, quality of life) as mentioned might lead to a sampling bias (e.g., consultation surveys are mostly filled in by very specific parts of the population (usually well educated, affluent, etc.)
Considerations	Both city instruments and regional instruments are considered Although it is tried to make the indicator as objective as possible, a certain amount of subjectivity is present
Scoring and/or Target	Multiply Likert scale value by 2
Unit of measurement	Number
Source	To be derived from project documentation and/or interviews with project leader and other team members
References	CITYkeys

Improved quality of life

Table 20 - Brussels indicator: Improved quality of life

Monitoring category	Social and organisational
Definition	The extent to which the PED offers clear advantages for end users
Description	Improved quality of life can be characterized by many forms: "improved thermal quality, increased indoor comfort, qualitative public space, access to facilities, and so forth". However, there is not yet a consensus on what form it would take in the Brussels case.
Calculation/assessment	The indicator provides a qualitative measure and is rated on a Likert scale: No advantage– 1 — 2 — 3 — 4 — 5 — Very high advantage

	1. No advantage: The project does not offer clear advantages for end users. The technologies or principles applied in the project are not at all beneficial to end users. 2. Little advantage: The project offers truly little advantage to end users. The vast majority of the technologies/principles offer an indirect and insignificant advantage to end users. 3. Some advantage: The project offers some advantage to end users who to a certain extent experience direct benefits from the technologies/principles applied in the project. 4. High advantage: The project offers a high advantage to end users who benefit mostly from the applied technologies or principles as the applied technologies/principles have a direct and high positive effect on end users. 5. Very high advantage: The project offers a very high advantage to end users as the applied technologies/principles have a direct and an extremely positive effect on end users
Expected availability	The required information will be easily available with the below mentioned resources
Expected reliability	Because of the subjectivity that cannot be excluded, this indicator is not 100% reliable.
Considerations	The indicator allows the evaluation and comparability of a wide range of project types and (still to-be-developed) solutions. Although it is tried to make the indicator as objectively as possible, a certain amount of subjectivity is present. Positive self-assessment biases must be considered. To overcome this, it might be required to also interview citizen representatives / field workers, who have a quite good view on what happens on a social level.
Scoring and/or Target	Multiply Likert scale value by 2
Unit of measurement	Number
Source	The inputs for this indicator could be gathered via a survey in the district as part of the project 'Perspective Brussels – Territorium Noord'. Within this framework, two surveys have already been executed. The survey reached almost 1000 participants. When assessing the topics this survey dealt with - Housing and Urban Renewal, Parks and Public Space, Mobility, Public Amenities and Social Cohesion, Economy and Employment, Inclusion, Sustainable Development and Climate Change, Cultural heritage – Energy in general and Quality of Life specifically can be integrated within this survey.
References	CITYkeys

4.2. Stockholm

The Stockholm Pilot will be implemented in a sub-district of Stockholm Royal Seaport[24] – Loudden. The area that previously was an oil depo and container terminal is being transformed into a vibrant new district with some 4,000 new apartments and 150,000 sqm of commercial space and amenities such as sports facilities and a school. As it is part of SRS the same preconditions, i.e., any developer will be subjected to follow the stringent sustainability requirements and follow-up process as for the rest of the SRS development. Since Loudden already monitors[25] certain indicators since 2015, it was deemed not necessary for the Loudden district to adopt the monitoring approach developed under this work package, but rather to analyse how the selected indicators are monitored in SRS.

Technical

Final energy consumption

Table 21 – Stockholm indicator: Final energy consumption

Monitoring category	Technical
Definition	Final energy consumption
Description	This indicator assesses the final energy consumption of the district, including electricity, heating, and hot water.
Calculation/assessment	As the District can be categorized as a Tier 2 district, the energy consumption will be reported by the developer on an annual basis (6x over 5 years). This self-declaration will be audited by 3rd party.
Expected availability	High, data is directly collected from smart meters
Expected reliability	High, check has been incorporated
Considerations	/
Scoring and/or Target	Hot water, heating, and building electricity: 50 kWh/m².yr (for offices: 45 kWh/m².yr) Plug-loads: 20 kWh/m².yr
Unit of measurement	kWh/m².yr
Source	Project developers
Baseline	Heating: 60 kWh/m² Baseload electricity: 10 kWh/m² Plug-loads: 18-24 kWh/m²

[24] https://vaxer.stockholm/omraden/norra-djurgardsstaden/in-english/

[25] https://vaxer.stockholm/globalassets/omraden/-stadsutvecklingsomraden/ostermalm-norra-djurgardsstaden/royal-seaport/a-sustainable-urban-district/results-2020/sustainability-report-stockholm-royal-seaport_2020.pdf

Local renewable generation

Table 22 – Stockholm indicator: Local renewable generation

Monitoring category	Technical
Definition	Local renewable generation
Description	This indicator assesses the local renewable generation from PV, RES electricity and RES heating
Calculation/assessment	As the District can be categorized as a Tier 2 district, the energy consumption will be reported by the developer on an annual basis (6x over 5 years). This self-declaration will be audited by 3rd party.
Expected availability	High, data is directly collected from smart meters
Expected reliability	High, check has been incorporated
Considerations	/
Scoring and/or Target	PV on 80% of the buildings RES-Electricity: 2 kWh/m² or RES-heating: 6 kWh/m² (for economic reasons) Compensation is allowed with new RES offsite
Unit of measurement	kWh/m².year
Source	Project developers
Baseline	PV on 50% of the buildings RES Electricity: 2 kWh/m² RES-heating: 6 kWh/m²

CO_2 emission reduction

Table 23 – Stockholm indicator: CO_2 emission reduction

Monitoring category	Technical
Definition	CO_2 emission reduction
Description	This indicator assesses the CO_2 emissions. The objective is to be fossil free by 2030
Calculation/assessment	The energy consumption will be converted to emissions based on standard emission factors for energy use in the area. A distinction is made between the energy end use (electricity for heat pumps or districts heating, etc.) The Nordic electricity mix will be used for calculations.
Expected availability	High, conversion factors are easily obtainable and energy consumption can be easily collected as it is a Tier 2 district.
Expected reliability	High
Considerations	/
Scoring and/or Target	0 tCO2/capita, scope 1 and 2

Unit of measurement	$CO_{2,eq}$/kWh or $CO_{2,eq}$/capita*year
Source	Project developers
Baseline	Electricity: 50 g $CO_{2,eq}$/kWh Heating: 80 g $CO_{2,eq}$/kWh

Social and organisational

For Stockholm, regarding the **District Organisation Indicators** the following has been discussed:

- For the parameter 'involvement of future inhabitants in the decision making' it is important to note that 50% of the buildings will be privately owned and 50% will be rented. The homeowners will, like in the other districts most likely organise them in home-owners associations and via these have their say in district matters. The tenants in the existing districts are in some way also involved (via tenant groups). Stockholm will think about this parameter.
- For the parameter 'Supporting framework For CityDevAdmin & City Planning' there is an overarching policy for city development that is ratified by the city council, which guides the whole development process. The city council set the overall goals and specific project management teams work towards those goals. There is also the policy for sustainable development of the SRS, which is politically ratified; so, there is **strong political support**. It is also recognized as a testbed for innovation. There is also **operational support** from the district administration that helps at every stage. Overall, there is an overall vision and target for the area, which is broken down in different targets and action and there is dedicated support in all phases. This can be turned in an indicator as shown in the white paper.

For Stockholm, regarding the **Social Indicators** the following has been discussed:

- In existing districts, a 'socio-economic analysis' has been carried out. This will also happen for the new district of Loudden. This is not something that will be monitored. It is rather a one-time analysis to feed in into decision making for future projects.

Economic

For Stockholm, regarding the **Economic Indicators** the following has been discussed:

- For 'job creation', it was said that it would be impossible (or senseless) to try to monitor this. It would not be possible to say 'this number of jobs' is created due to the project.
- For 'energy cost' it was made clear that this will not be monitored in Stockholm, as the cost of energy is included in the rent.

4.3. Vienna

The local case in Vienna will be implemented in Aspern Seestadt. In 2007, a Masterplan was created, including detailed guidelines for the design of public space, quality criteria for mobility, buildings, usage, diversity, climate adaptation and protection. Today, the district development area consists of several quarters such as "Seeparkquartier", "Pionierquartier" etc. with different focuses. Their borders are either temporally (building phases) or spatially defined (one quarter as a "functional unity"). Aspern Seestadt is developed in four phases. The aim is not only to develop a new residential area, but to create a functional new district which affects beyond its borders and provides a central function for the 22nd city district. The *Smart City Wien Rahmenstrategie* (Smart City Wien framework strategy, 2014) was a great impulse and resource efficiency (material and emissions) became central for the development plans and for project marketing.

Technical

Primary energy consumption

Table 24 - Vienna indicator: Primary energy consumption

Monitoring category	Technical
Definition	Primary energy consumption
Description	This indicator assesses the primary energy consumption of the district. What to include within this district depends on the chosen system boundaries. The preliminary Viennese research delineates three options: "Alpha, Beta, and Omega"[7]. Alpha includes the building operation (including space heating, cooling demands, etc.) and user demand (plug loads and domestic / office appliances) except for uses that provide services beyond the district (hospitals, schools, industries through their products). Beta also includes consumption as a consequence of mobility. Lastly, Omega also includes embodied emissions as a consequence of the actual construction.
Calculation/assessment	As the district can be categorized as a Tier 2 district, and heating occurs mostly via heat pumps, all necessary data will be collected via smart meters. Converting this final energy consumption to primary energy will occur via weighing factors (monthly conversion factors from OIB RL 2019[26])
Expected availability	High, the data will be available via smart meters
Expected reliability	High, the data will correspond to exact measurements at an hourly timescale. The spatial granularity is not yet clear (and might have to be made somewhat more course due to GDPR constraints), but most likely will be at the level of one urban block, sufficiently detailed for any analysis.
Considerations	/
Scoring and/or Target	The target is based on the primary total energy balance, this is: *primary energy saldo (export-import) + credit due to context factors > 0* Context factors can refer to urban density, heritage, mobility, regional/national energy system and context, and so forth.

[26] https://www.oib.or.at/sites/default/files/erlaeuternde_bemerkungen_richtlinie_6_12.04.19_0.pdf

	There is thus no individual target for energy consumption, only a combined target for both consumption and local renewable production.
Unit of measurement	kWh_{PE_total}/m^2_{NFA}*year
Source	Data will come from smart meters in all buildings. These data are aggregated by the DSO and can be collected from them.
Baseline	All buildings should adhere to the new zero-energy building standard[27]. Furthermore, in specific areas, new constructions must not have a fossil heating system according to the Viennese heat plans[28].

Local renewable energy production

Table 25 - Vienna indicator: Local renewable energy production

Monitoring category	Technical
Definition	Local renewable energy production
Description	This indicator assesses the local renewable energy production within the district. What to include within this district depends on the chosen system boundaries. The preliminary Viennese research delineates three options: "Alpha, Beta, and Omega[7]". Alpha includes the building operation (including space heating, cooling demands, etc.) and user demand (plug loads and domestic / office appliances) except for uses that provide services beyond the district (hospitals, schools, industries through their products). Beta also includes consumption as a consequence of mobility. Lastly, Omega also includes embodied emissions as a consequence of the actual construction.
Calculation/assessment	As the district can be categorized as a Tier 2 district, all necessary data can be collected via smart meters.
Expected availability	High, the data will be available via smart meters
Expected reliability	High, the data will correspond to exact measurements at an hourly timescale. The spatial granularity is not yet clear (and might have to be made somewhat more course due to GDPR constraints), but most likely will be at the level of one urban block, sufficiently detailed for any analysis.
Considerations	/
Scoring and/or Target	The target is based on the primary total energy balance, this is: *primary energy saldo (export-import) + credit due to context factors > 0* Context factors can refer to urban density, heritage, mobility, regional/national energy system and context, and so forth. There is thus no individual target for energy consumption, only a combined target for both consumption and local renewable production.
Unit of measurement	kWh/year
Source	Data will come from smart meters in all buildings. These data are aggregated by the DSO and can be collected from them.

[27] https://www.oib.or.at/sites/default/files/nationaler_plan_20.02.18_1.pdf

[28] https://www.wien.gv.at/stadtentwicklung/energie/erp/aktuell.html

Baseline	All buildings should adhere to the solar obligation in the building code of the City of Vienna: • Residential: min. 1 kWp / 300 m² GFA • office: min. 1 kWp/ 100 m² GFA

CO_2 emissions

Table 26 - Vienna indicator: CO_2 emissions

Monitoring category	Technical
Definition	CO_2 emissions
Description	This indicator assesses the CO_2 emissions within the district. What to include within this district depends on the chosen system boundaries. The preliminary Viennese research delineates three options: "Alpha, Beta, and Omega[7]". Alpha includes the building operation (including space heating, cooling demands, etc.) and user demand (plug loads and domestic / office appliances) except for uses that provide services beyond the district (hospitals, schools, industries through their products). Beta also includes consumption as a consequence of mobility. Lastly, Omega also includes embodied emissions as a consequence of the actual construction.
Calculation/assessment	The calculation will be based on the primary energy consumption within the district. This will be converted into CO_2 emissions via monthly conversion factors for $CO_{2,equivalent}$ (OIB RL6 2019[27]) Regarding embodied emissions, these will be based on a material catalogue and the impact factor of primary energy per kg (kg CO_{2eq}/$kg_{material}$)
Expected availability	High, the base data (energy consumption) will be available via smart meters
Expected reliability	High
Considerations	/
Scoring and/or Target	The target is based on the emissions balance, this is: *GHG credits – GHG emissions > 0* GHG credits are calculated as: $GHG_{person}(800 \text{ kg CO}_{2,eq}/\text{person} \cdot \text{year})$ GHG emissions are calculated as : $Consumption \cdot f_{CO2,eq,} - production \cdot f_{CO2,eq}$
Unit of measurement	kg CO_{2_eq}/kWh or kg CO_{2_eq}/ m^2_{NFA}*year
Source	Data will come from smart meters in all buildings. These data are aggregated by the DSO and can be collected from them.
Baseline	No compulsory standard in place

Economic

Affordability of living: Rent and energy spending

Table 27 - Vienna indicator: Affordability of living

Monitoring category	Economic
Definition	Affordability of living: Rent and energy spending
Description	This indicator aims to find out the cost of living for an average household within the district. The cost of living is based on both the rent and the cost of energy. PED projects will have energy bills that are lower than standard buildings but require a higher initial investment. It is this combination of rent/housing (including the amortization of the investments) and energy costs that will be monitored and compared to the baseline. This allows to understand whether the project generates cost savings for the end-users.
Calculation/assessment	The calculation will be based on comparing the PED project with the baseline project. The baseline project includes (1) the rent price and (2) the energy costs considering a "regular" energy system. In Vienna, heating would traditionally be delivered via the district heating systems or gas, while electricity comes from the grid. The PED project includes (1) the rent price (incl. amortising rate of investment costs for renewable energy system) and (2) the (assumed) energy costs with a renewable energy system
Expected availability	Relatively low, data is available through various research and pilot projects, but these are not yet exhaustive. However, the availability is expected to increase in the upcoming years because of a more standardized and consistent execution of surveys.
Expected reliability	Medium, no fine spatial or temporal granularity can be reached as gathering data requires surveys that can only be done every so often for a limited number of people. Furthermore, energy and construction prices differ in time and are difficult to predicted for the upcoming years.
Considerations	/
Scoring and/or Target	The goal is for the affordability of a PED project to be cost-neutral or lower than the baseline scenario
Unit of measurement	€/ m^2_{NFA}*year
Source	Two phases can be distinguished: Planning a PED project: • The average rent can be collected from SILC[29] • The average energy tariff can be collected from the energy providers For monitoring a PED project: • The average rent and electricity bills can be collected from the building owner

[29] https://www.statistik.at/ueber-uns/erhebungen/personen-und-haushaltserhebungen/eu-silc-einkommen-und-lebensbedingungen

Baseline	The Austrian Rental Law (MRG) states that • for subsidized new buildings, there is a defined max rent for apartments (Vienna: 5,81 €/m2) • for privately financed new buildings, only exorbitantly high rents are not allowed.

Additional spending to achieve a PED: the investment costs compared to energy spendings over lifetime

Table 28 - Vienna indicator: Additional spending to achieve a PED

Monitoring category	Economic
Definition	Additional spending for the building developer to achieve a PED: the investment costs compared to energy spendings over lifetime
Description	In order to convince developers to install renewable energy systems & build a high thermal quality of the buildings envelope it is important to know if an investment into local renewable energy will be returned over time, especially as non-profit developers have a limit on rent price.
Calculation/assessment	The calculation will be based on comparing the PED project with the baseline project with a 25–30-year amortization timeframe. For the payback of investment costs by tenants of **PV systems**, which are installed on the building, there are the following options: • Only the commonly used electricity (elevator, light in the staircase, etc.) is covered and the rest is fed into the grid. • The PV system becomes a "§16a community system" and tenants are only charged for the electricity which is consumed just-in-time. The rest is fed into the grid. • Energy communities: the electricity that is consumed just-in-time is charged to the tenants. The system is also integrated into the grid. For the payback of investment costs by tenants of **heat pump** systems, installed in the building, there are following options: • The consumed electricity for the heat pump will be paid by the tenants. If the electricity is produced by an on-site PV system, the above-mentioned options are applicable. • Contracting: The system installer guarantees the heat supply for a certain time period (e.g., 20 years). In this time, the tenants pay a previously agreed price per month for the heat supply. Planning, financing, implementation, operation, maintenance and billing are the responsibility of the installer (contractor
Expected availability	Medium
Expected reliability	Medium
Considerations	/
Scoring and/or Target	Payback period should be within certain timeframe
Unit of measurement	€/ m^2_{NFA}*year
Source	Two phases can be distinguished: Planning a PED project: • Cost simulation

	For monitoring a PED project: • The electricity bills and the final investment costs, to be collected from the building owner
Baseline	Can be collected from building owners or project developers if prior PEDs have already been established.

4.4. Discussion on the local cases

During the Stockholm Deep-dive in July 2022, the C4PEDS consortium finished the cities application and looked ahead on which indicators contain commonalities. Although it became clear that every city has a different approach as to what it wants to monitor and how it wants to monitor, some commonalities could be extracted. These are shortly discussed here.

Technical

For several of the technical indicators it is clear the three local cases have a similar understanding of the scope of the indicator, but the method of monitoring – what we have called 'tier' above – and the targets are differentiated. For example, for the indicator Local Renewable Energy Production, the local cases agree on what to measure but data is transferred either by the DSO/urban heating operator or by the developer or building owner. For the indicator Energy Consumption, the definition of the indicator is quite similar across the local cases, but the time and scale of the monitoring may differentiate.

While mobility as such has not explicitly been put forward as an indicator, all local cases consider mobility as an important aspect of a PED. For Greenfield PEDs (VIE & STO) this indicator can be monitored during the planning phase by following-up on the developer.

- In Stockholm developers need to perform studies on how to design buildings that encourage walking, cycling and the use of public transport. Infrastructure is valued important (automatic doors, elevator that can take a bike). The city gives scores and recommendations during this design process and is currently developing a 'mobility index' to making this scoring easier. There are also electrification targets – charging infrastructure – that the developers have to comply with.
- In Vienna, contrary to Stockholm, no liberty to choose from different measures is given to the developer. Instead, mandatory criteria are imposed, such as for example a fixed amount of parking spots, a certain type of elevator that can transport a bicycle. Both for Greenfield PEDs (VIE & STO) and Brownfield PEDs (BXL) mobility can also be monitored during operationalization. Via digital tools it could be monitored who takes which type of transport for how lang and to cover which distance. This allows to assess the real impact of the measures. However, the three cities are still exploring how this can best be done.
- Currently the SRS monitoring platform already provides a view on the number of bicycles (data gathered via a three-yearly survey) and the aim is to include the mobility index in this platform

Social

While Brussels aims to monitor several specific social and organisational indicators as port of its PED project, Stockholm and Vienna do not intend to develop such indicators for their respective PED project since the social and organisational aspects are already (being) monitored as part of city-wide or district-wide one-time or recurring analysis.

Economic

Due to different contexts and visions, Vienna is the only of the local cases that has elaborated on economic indicators. A comparison is thus not possible.

5. Conclusion and next steps

The purpose of this document is to provide guidelines and the methodology for defining the monitoring framework. This framework captures the multi-faceted characteristics of a PED and allows for strategic steering. Its guiding principles are comprehensiveness, transparency, flexibility, manageability, feasibility, accuracy and most importantly, process oriented. The objective of the framework is to help districts in transition to understand on which aspects they still have to work towards becoming a PED and can thus be seen as a step-by-step guidance tool.

A catalogue of energy-technical, social-organisational, and economic indicators was developed, both quantitative and qualitative in nature. Each of these indicators is represented by a fiche, which details the exact definition, the calculation method, the data source, the scoring method, and so forth. Each of the local cases (Brussels, Vienna and Stockholm) used the framework and its indicators on their local case.

While there is largely a consensus on which energy-technical indicators to monitor, it became apparent that there are differentiating views on the specificities of these indicators as well as the method of monitoring them. This has led to the development of a tier-based monitoring system for the energy-technical indicators, where the most appropriate tier depends on the local context of the district. This tier-based system could be further developed in the PED guide as a progressive approach for monitoring. It represents the different steps in monitoring its progress a PED project can take.

Regarding the economic and social-organisational indicators, the local cases have different views and timelines regarding their implementation. They are therefore still based on a more theoretical outline but can already be put forward as part of the other building blocks of the PED guide.

ANNEX A Table of tables

ANNEX B Abbreviations and acronyms

Abbreviation or Acronym	Description
BXL	The City of Brussels
CO_2	Carbon dioxide
DSO	Distribution System Operator
GHG	Greenhouse Gas
kWh	Kilowatt hour
MWh	Megawatt hour
PED	Positive Energy District
STO	The City of Stockholm
VIE	The City of Vienna

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