D4.3 Evaluation Action Plan and Reports (update 1)

The monitoring and evaluation framework for the project.

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List of Abbreviations/Glossary

Abbreviation	Definition
AEF	Activity Evaluation Form
AI	Artificial Intelligence
API	Application Programming Interface
BEF	BIPED Evaluation Forum
BEST	Building Estimate Specification Table
BIPED	Building Intelligent Positive Energy Districts
BMS	Building Management Systems
CAPEX	Capital expenditures
CEA	Cost Effectiveness Analysis
CBA	Cost Benefit Analysis
DMI	Danish Meteorological Institute
DMP	Data Management Plan
DT	Digital Twin
ESG	Economic Social Governance
FAIR	Findable, Accessible, Interoperable and Re-usable
FoA	Field of Action
GA	Grant Agreement
GDPR	General Data Protection Regulation
GHG	Greenhouse Gas
KPI	Key Performance Indicator(s)
LDT	Local Digital Twin
MCA	Multi Criteria Analysis
M&E	Monitoring and Evaluation
NWPs	Numerical Weather Predictions
OD	Origin Destination

OPEX	Operational Costs
PED	Positive Energy District(s)
RES	Renewable Energy Sources
SCIS	Smart Cities Information System
SCBA	Social Cost Benefit Analysis
SCM	Smart Cities Marketplace
SDG	Sustainable Development Goals
SMART	Specific, Measurable, Achievable, Relevant, Time-bound
SRT	Self Reporting Tool
TRL	Technology Readiness Levels
WP	Work Package

Executive summary

This report presents ***Deliverable 4.3 - Evaluation Action Plan and Reports: Update*** of Work Package (WP) 4 of the Building Intelligent Positive Energy Districts (BIPED) project. This deliverable reports on Task 4.1, which focuses on the creation of a methodology plan to cover testing cycles and project validation. The framework is expanded upon in this deliverable to include the methodology, tools and scenarios to be tested from the solution developed. In addition to the stakeholder/end-user activities in WP4, the key stakeholders, end-users, and broader data space communities identified in WP2 and WP3 were engaged in the Monitoring and Evaluation (M&E) actions through questionnaires, workshops and focus group discussions, as prescribed through the framework.

Since D4.1, the BIPED project has seen significant advancements in the development of its Monitoring & Evaluation (M&E) framework. Key updates included in Deliverable 4.3 are the hosting of an in-person KPI workshop, a BIPED modelling and technical workshop, and the development of a multi-criteria analysis for project KPIs. These efforts have culminated in the finalisation of KPIs, assignment of KPI ownership, and determination of data collection ownership and methodology.

D4.3 outlines the development of a comprehensive M&E framework tailored for BIPED as previously outlined in D4.1. The framework integrates both qualitative and quantitative data collection methodologies to ensure a holistic understanding of project performance and impact. Central to the M&E framework will be monthly workshops and forums designed to gather both qualitative and quantitative data by engaging members of the project consortium and Key Performance Indicator (KPI) owners. Quantitative data will be documented using KPI Sheets, offering a structured approach to measuring project metrics and performance indicators. These sheets provide a clear overview of project progress and enable data assessment and evaluation.

The in-person KPI workshop and BIPED modelling workshop highlighted that the current TRL levels of the data models were insufficient to support certain KPIs at this stage of the project. Consequently, the KPIs and their themes were adjusted to align with the current TRL levels of data models. As a result, the KPIs now focus on the themes of Community Engagement, Energy & Mobility, and Digital Solutions. This collaborative approach has ensured that KPIs are realistic and achievable, considering the existing capabilities of the models (Section 4).

A significant advancement was the development of a multi-criteria analysis (MCA) approach (Section 5) for weighting the KPIs, presented at the KPI workshop in Copenhagen. This structured framework prioritises and evaluates KPIs to emphasise the most critical aspects of the project. The MCA approach will be informed by project use cases, to be confirmed in the second year of the project, ensuring KPI weighting aligns with practical applications and expected outcomes.

The systematic approach established by the M&E framework (Section 2) aims to continuously assess project effectiveness, identify areas for improvement, and ensure alignment with BIPED's overarching goals and objectives. By leveraging a comprehensive evaluation strategy combining qualitative and quantitative methods, the framework supports informed decision-making and effective project management. This dual approach also facilitates the accurate and consistent collection of KPI data, contributing to the Smart City Information System's Self Reporting Tool throughout the project's duration.

This M&E framework provides the scope and direction for the assessment framework. The Assessment Framework will implement a series of testing cycles, which will occur every six months. The identification of both local and external stakeholders and end users allows for the solution to be tested in different environments and ensure the compliance and alignment with BIPED's KPIs. The testing cycles will be developed with partners within the consortium and follow best practice in the M&E and assessment procedures.

1. Introduction

This deliverable describes the significant advancements in the development of its Monitoring & Evaluation (M&E) framework. Key updates included in Deliverable 4.3 are the hosting of an in-person KPI workshop, a BIPED modelling and technical workshop, and the development of a multi-criteria analysis for project KPIs. These efforts have culminated in the finalisation of KPIs, assignment of KPI ownership, and determination of data collection ownership and methodology.

Within the deliverable, the structure of the report lays out the role of M&E and the need for this within the document and the impact of the overall BIPED M&E framework. The Framework's approach in terms of the quantitative and qualitative methodology is described, and how this approach incorporates multiple mechanisms to conduct the framework. This is followed by the description of the project KPIs and how these were developed as part of the overall co-creation approach. This is supported by a summarization of the Multi-Criteria Analysis approach in Section 5. The deliverable report concludes with the initial evaluation of the current models within the project and the challenges foreseen and encountered up to the end of this M&E phase.

1.1 SMART Cities, Horizon Europe and Monitoring & Evaluation

As part of the BIPED project, the M&E framework will ensure the project outcomes remain relevant and impactful to the identified relevant stakeholders and the wider smart city development in Europe. A set of KPIs are employed to monitor the project's progress and success. Through the continuous assessment of performance, action will be taken to ensure resources are optimised, risks are managed, and necessary adaptations are implemented to promote the overall success of the digital twin city initiative as part of the BIPED project.

Positive Energy Districts (PEDs) are a key building block in the future energy paradigm for carbon-neutral cities and communities. With the rise of modern technology, PED development is evolving towards a more agile arrangement in which decisions are first tested and fine-tuned in virtual environments before they are deployed on the ground. A key enabler of this virtual prototyping is the Local Digital Twin (LDT) technology. Traditionally, LDTs create digital representations of a functional territory by combining low- and high-velocity data with dynamic models of energy, traffic, buildings and natural environment.

However, focusing narrowly on these domains means that digital twins of PEDs can lack representation of other elements that make up the urban fabric. LDTs that omit social, economic and cultural properties will only provide a partial representation of an area they are designed to model.

This shortcoming in LDT-PED modelling, which can be caused by limited data availability and siloed systems design, can lead to suboptimal decisions, impacting negatively ambitious efforts of sustainable development in cities and communities.

BIPED's ambition is to unlock a spectrum of data-driven decision making, covering both short-term city operations and long-term policy planning, to guide AI-supported optimisation of PED development. Funded under the Horizon Europe scheme (Grant ID: 101139060), the BIPED project strives to further efforts towards achieving Sustainable Development Goals (SDG) through the promotion of digital twin models. The strategy of deploying digital twin models relates to using modern technology to develop digital representations of a specific functional territory through the collection and various data forms[1]. In this way, BIPED works to recognise the role digital twin models can play to overcome the complexities associated with PED development as well as providing information for the adoption and optimisation of existing systems[2].

The central focus of the BIPED project is to further establish the effective role of digital twin models in the development of PEDs in cities across Europe. This will be aided by an M&E framework which acts as an essential feedback loop to guide the project's trajectory.

1.2 Importance of M&E in BIPED

In the context of the leading technological developments comprising the BIPED project, M&E acts as a comprehensive framework crucial for the assessment of the initiative's performance against the predetermined project objectives and KPIs. In this way, stakeholders are equipped with relevant information cultivated through the continuous monitoring of real-time progress. This places stakeholders in the advantaged position of being able to make informed decisions and implement timely interventions. Additionally, M&E works as a vital mechanism in the assessment of risk which ensures a project's success is adequately safeguarded against unforeseen challenges. This highlights the role of M&E in navigating the inherently complex nature of urban development and ensures the resilience of the BIPED project and its associated digital twin models.

In order to further emphasise the importance of M&E to the BIPED Project's success, the beneficial roll such frameworks played in past EU funded projects will be outlined:

"Enable the impacts of the project to become relevant to the wider policy and innovation community" [3].

Monitoring and evaluation of data in BIPED will be vital in ensuring its success and continued effectiveness during and beyond the end of the project. By continually monitoring data, the BIPED consortium can identify trends, patterns and potential challenges allowing for adjustments of project KPIs, interventions and allow for a collaborative decision making process. BIPED's M&E will provide valuable insights into the project's performance against its objectives, helping stakeholders understand what worked well and what needs improvement. The monitoring and evaluation will ensure the outcomes can be employed

1 (BIPED Proposal, 2023)

2 (European Commission, 2022)

3 (European Commission, 2019)

within and beyond the context of the project so as to work towards cultivating sustainable cities across Europe.

The BIPED Project presents a prime opportunity to explore and develop the most efficient manner to roll-out digital twin models across European cities. In order to ensure this opportunity is capitalised on to maximum efficiency, WP4 provides an M&E framework that works towards providing an overarching and iterative process that showcases the learning and lessons from the project, both for the project during its runtime and future development. BIPED will allow space for stakeholders to explore and adapt the digital twin initiative to ensure knowledge is efficiently circulated so as to assist with the creation of sustainable smart urban areas.

1.3 Principles for the Development of a M&E Framework

A robust M&E framework requires a distinct understanding among stakeholders regarding the purpose and objectives of the project at hand. It is paramount to the project's success that all key actors hold a clear understanding of the goals they wish to achieve throughout the course of the project. Such goals should be clear, defined and measurable whilst also in alignment with the central vision of the project. In this way, communication with stakeholders should be a priority during the framework's development phase.

The M&E framework should maintain a form that allows for flexibility and adaptability to accommodate contextual changes that may arise throughout the project's lifespan. In this way, M&E is seen to facilitate the continuous improvement and refinement of the project whilst also showing a commitment to an approach characterised by integrity. The following sections outline the M&E approach for the BIPED Project, including an overview of KPIs.

2. Overall Framework

2.1 What is a Framework?

A M&E Framework is both a planning process and a written product designed to provide guidance on the conduct of monitoring and evaluation functions over the life span of a program or other initiative (Markiewicz, 2016)[4]. A framework acts as a tool which informs the project consortium decision-making processes, such as definition of KPIs, timing of interventions, data collection methodology and analysis, and reporting of data. This is to further understand the impact, successes, and challenges faced, and what insights, guidelines, and recommendations can be drawn from the evaluation of activities that would improve future application and replication of such activities. The development of a framework for evaluation provides a guideline that project partners can reference and follow in order to efficiently and effectively report on data related to their project activities. The reporting of data will, in turn, inform the creation of other guidelines for the implementation and replication of interventions.

2.2 Rationale

A data-driven M&E framework serves as the backbone for effective decision-making, performance assessment, and optimisation of products and/or services for a smart city and digital twin development project . At its core, this framework defines the systematic process of collecting, analysing, and interpreting data generated by various tools embedded within the city of Aarhus' infrastructure. It encompasses a structured approach to monitoring the project's performance across different domains such as transportation, energy, and environment.

BIPED's M&E framework acts as a plan for undertaking M&E throughout the project and will provide project partners with a guide on how to apply M&E to its own interventions and initiatives. The BIPED project explores the possibilities associated with building intelligent PEDs to assist cities with the decarbonisation efforts. In this way, the establishment of a standardised M&E approach acts as a means through which each intervention can be monitored and evaluated against other EU and world projects, to maximise efficiency and translate the project to other EU cities and contexts.

Such a framework entails establishing clear objectives and targets aligned with the overarching goals of the BIPED project. It involves selecting relevant metrics and indicators that reflect the desired outcomes, alongside defining data collection methodologies, frequency, and sources. Furthermore, the framework outlines mechanisms for data aggregation, processing, and visualisation to derive replicable recommendations and actions for stakeholders. Continuous evaluation and feedback loops are integral, allowing for adjustments and improvements in KPI interventions based on real-time or near-real-time data analysis.This framework serves as a vital instrument in fostering sustainability, resilience, and replicability within BIPED and externally.

4 (Markiewicz & Patrick, Developing Monitoring and Evaluation Frameworks, 2015)

2.3 Co-Creation Principles of the BIPED M&E framework

Co-creation is the joint, collaborative, concurrent, peer-like process of producing new value, both materially and symbolically[5] (Galvagno, 2014). At the heart of the BIPED co-creation principles which underpin the framework is the recognition that effective solutions emerge from the multiple and varied perspectives of the project consortium and the stakeholders involved across the wider project. In the landscape of smart city and digital twin development, the principles of co-creation stand as pillars of collaborative innovation and stakeholder engagement. In developing the M&E framework, WP4 has worked extensively with WP2 and WP3 to develop documents and methodologies which will be at the core of M&E, KPI data collection and stakeholder engagement. The creation of the KPI data collection sheets, which was created in a collaborative and iterative process with WP2, is shown in full form in Annex 3. To complement the KPI data collection sheet, WP4 has developed Activity Evaluation Forms (AEFs) in collaboration with WP2 and is shown in full in Annex 1. This will be used to evaluate project interventions and activities in future deliverables.

Central to BIPED's co-creation principles are planned periodic meetings, where stakeholders convene to discuss and analyse both qualitative and quantitative data collected through project interventions. These meetings will serve as focal points for dialogue, reflection, and joint decision-making, fostering transparency and accountability within the framework. By intertwining data-driven insights with participatory processes, the co-creation principles ensure that the resulting urban interventions are not only technologically robust but also socially and environmentally sustainable, resonating with the needs and aspirations of the communities they serve.

As part of the evaluation process, partners will provide feedback on project interventions applied in Aarhus such as, how the activity/intervention has performed and the key lessons learnt. The reporting on interventions can be viewed in conjunction with the quantitative data captured via the data collection sheets as the captured data validates the results reported on. Through a structured process of periodic engagement, partners will be requested to provide feedback on the various types of interventions implemented according to the aims of the project. Through long-term monitoring and evaluation of the project's interventions, partners and the public will be able to view the impact that BIPED and related projects have had on Aarhus. The analysis of project data and inputs from partners will therefore be used in conjunction to inform decision making and planning of future upscaling and replication of the project's initiatives in other cities and countries.

2.4 Identification of the District

Each of the interventions implemented in Aarhus will have an impact on a predefined spatial location. The following subsections define the spatial scale and discuss the identification of the district and PED within Aarhus.

[5] (Galvagno, 2014, Theory of value co-creation: a systematic literature review)

As defined in BIPED's project vision, PEDs are defined as:

..a key building block in the future energy paradigm for carbon-neutral cities and communities. With the rise of modern technology, local digital twins – the digital representations of a functional territory combining low- and high-velocity data with dynamic models enabling advanced analytics and artificial intelligence (AI) – play a significant role in PED development and the scaling of it, supporting decision makers, planners and communities in taking informed decisions towards a sustainable future[6].

Identification of the district and PED within Aarhus is crucial to the M&E framework as it allows BIPED to define the system border, map local existing Renewable Energy Sources (RES). By mapping the local existing RES, the project consortium can map, analyse and decide on viable energy efficiency measures to be implemented. By defining the district, BIPED can map and analyse current digital infrastructures within Aarhus and decide on additional interventions required. This identification of the district will allow BIPED to create strategies to achieve sustainable and resilient urban communities that optimise the use of renewable energy sources and minimise greenhouse gas emissions.

2.4.1 City Level

The city level is the highest level of intervention scale and analyses the impact of interventions on the city of Aarhus. The city level designation will take interventions which play a significant role in development of the Digital Twin and scaling of it, supporting decision makers and planners and key project stakeholders in being able to make informed decisions towards implementing the Digital Twin solution in Aarhus. These interventions in support of the Digital Twin will also support aspects such as social, economic, and environmental properties which lack representation.

2.4.2 Sub-City District Level

A sub city district level refers to an area within Aarhus which will be the smallest project area showing main streets, city neighbourhoods, a single or multiple city districts. Within the sub city district level there is three areas of priority for the BIPED project which are:

Table 1: Sub City District Level Demonstrations

Demonstration Site	The site level will be defined as a building or street level where interventions are conducted.
Demonstration Area	Contains several sites where interventions are carried out.
Demonstration District	The demonstration district can contain multiple demonstration areas depending on the scope of interventions.

[6] A Vision for Braband: Marching forward with confidence toward climate-neutrality

2.4.3 Identification of the Positive Energy District (PED) in BIPED

An essential milestone in the BIPED project was the identification of the PED. All project partners were engaged in a collaborative process and four key questions were posed:

1. **Building Selection:** Which buildings should be part of the district?
2. **Connectivity:** Should the district be interconnected, or can it consist of fragmented parts within Brabrand?
3. **Size Considerations:** Is there a limit to the district's size?
4. **Additional Comments:** Partners were invited to share any further insights.

Each partner contributed with valuable feedback. Consensus emerged on several points:

- **Diverse Buildings:** The PED should include a wide variety of building types, reflecting different uses and architectural features.
- **Connectivity:** The district needed to be interconnected.
- **Scale Matters:** A larger district was preferable overall.

Based on these discussions and feedback led by Aarhus Kommune (AAKS), the positive energy district in BIPED was defined as the entire Brabrand area, identified by the postcode, 8220:

Figure 1: The Positive Energy District (PED) in BIPED

In the process of identifying the PED in BIPED, two significant advances emerged; which will be key to the overall project and be discussed in more detail in subsequent and aligned deliverables.

1) Identifying the district served as the starting point for the Stakeholder Mapping and Community Engagement. It kick-started the process of creating the stakeholder list within Aarhus.

2) Gaining clarity on the specific areas from which we needed to obtain data also kick-started the Data Acquisition from both a city and project perspective.

3. Quantitative & Qualitative Methodology

The BIPED project and the overall Framework is founded on the alignment and integration of the qualitative and quantitative aspects of M&E. To this point, both approaches are key as part of the convergent parallel design, where both components are compared and aligned as a single resource, rather than explaining or proving the other component. The qualitative dimension of the evaluation process involves a comprehensive review of all engagement with partners and stakeholders regarding the evaluation of project activities and interventions. The quantitative dimension utilises a group of measurable interventions, described as KPIs, to compare the performance and progress of the project consortium's interventions in achieving project goals over the lifespan of the project. More details on this is described in the preceding deliverable in this series, D4.1.

3.1 Role of Qualitative Evaluation in the Project

The qualitative dimension of the evaluation process will involve a comprehensive review of all engagement with partners and stakeholders regarding the evaluation of project activities and interventions, alongside insights derived from quantitative data. This encompasses the evaluation of activities and interventions as reported by partners, gathered through various channels such as feedback forms, interviews, informal discussions, and group workshops. Additionally, relevant project documentation including deliverables and meeting notes will be scrutinised. The ongoing collaboration within the BIPED Evaluation Forum (BEF) will further enhance the planning and execution of the evaluation process, ensuring its continuous refinement and application across the project. This is described in more detail in the previous deliverable, D4.1.

3.2 Monitoring & Evaluation Themes

As numerous interventions will be implemented across the BIPED Work Packages the project consortium has divided the project interventions into three core themes. These themes have been adjusted since the initial iteration of this deliverable D4.1. This adjustment was conducted following the BIPED Consortium Meeting in Aarhus in October 2024 and further developments in the available datasets via the KPI workshops conducted as co-creation developments. The current themes will remain in this format until the completion of the project, however new themes focused on areas such as soft data and cross-sectorial data may be added as the technological and technical work packages develop throughout the project. Any addition will be included in future iterations of the deliverable series as part of the evolving M&E framework approach.

Changing the thematic title from 'Energy Consumption' to 'Energy & Mobility' was decided upon at the BIPED General Assembly in Copenhagen in October 2024. The rationale for this change was related to the fact that 'Energy Consumption' didn't fully reflect the type of data being captured by the BIPED models being developed by DTU, AIT, RT and UWB.

The third theme originally titled ICT Digital Solutions has been shortened to Digital Solutions in order to avoid an overcomplication of the title.

The 'Social and Economic Value' has been removed from the explicit themes and the KPIs from this theme have been merged into the other themes. This was conducted as it was decided that the theme's KPIs and use cases were all underpinning characteristics and these would be better allocated to the other three themes and the social and economic aspects be incorporated across all three to show their utility.

Table 2: M&E Themes

Community Engagement
The KPIs which fall under the community engagement theme are focused on the long term impact of the interventions and the extent to which key stakeholders and citizens are made aware of the activities within the BIPED project and the wider potential of Digital Twin technologies being utilised on a micro and macro scale within their cities and day to day lives.
Energy & Mobility
Energy & Mobility KPIs will provide insights into the contribution of project interventions to energy efficiency and sustainability goals. These KPIs serve as benchmarks to make informed decisions to optimise energy usage within Aarhus.
Digital Solutions
Digital Solutions KPIs for a project will offer essential insights into the effectiveness and impact of digital technologies deployed. Analysing KPIs such as user engagement metrics, system uptime, response times, and adoption rates provides a comprehensive view of the project's digital performance.

3.3 Defining Key Performance Indicators

KPIs are a group of measurable interventions that the BIPED project will use to compare the performance and progress of the project consortium's interventions in achieving project goals over the lifespan of the project. The Central European Research Infrastructure Consortium describes KPIs as representing standard measuring values that help institutions assess their performance in a consistent and periodic way[7]. KPIs within the BIPED project will follow the SMART (Specific, Measurable, Achievable, Relevant, Time-bound) criteria model which is an internationally recognised standard for developing indicators and measures.

3.4 Data Requirements and Typologies

Data will be collected and provided by KPI leads and supporters as defined in the KPI framework. The following definitions will provide a guide as to the roles and responsibilities of the KPI and KPI technical experts and supporters. By having a clear distinction between the KPI Owner and KPI Technical Experts this will allow the project to define the responsibilities for the owner of the titles and where KPI owner may refer to KPI Technical Experts in regards to the implementation of project interventions.

[7] ERIC Forum Toolkit, Key Performance Indicators

3.4.1 KPI Owner

The KPI owner takes the lead in the implementation, testing and monitoring of the project interventions. The KPI owners use the KPI framework created for the BIPED project to ensure that interventions are recorded and made available for analysis. The KPI owner will agree to the definition, description and calculation method of the KPIs, in cooperation with WP4. For further reading on KPI Owners refer to the original iteration of this deliverable D4.1.

3.4.2 KPI Technical Experts

KPI technical experts are parties that act as complementary partners to KPI owners. KPI technical experts are specialists in their area/sector and provide technical support, tools and data to KPI owners which will assist in implementing project interventions. This support will contribute to the achievement of the KPI as well as providing trusted information which allows KPI owners to monitor and report on the data. For further reading on KPI Technical Experts refer to the original iteration of this deliverable D4.1.

3.4.3 KPI & KPI Metadata Collection Sheet

Metadata which is defined as data relating to data, provides a summary of information about certain datasets[8]. Metadata acts as a reference to simplify searching in, working with and reutilisation of datasets. Having the relevant metadata for the project KPIs is vital to stakeholders having a full understanding of the aspects of the KPIs. Knowledge of how the KPIs have been developed will ensure solution providers and stakeholders involved to measure and record data from project interventions. The table in Annex 3 showcases an overview of the metadata which will be collected for the project KPIs during the data capturing process.

3.4.4 Timeframes and Reporting Periods

Each intervention within the projects will involve a degree of adaptation in a number of sectors and organisations across the three M&E themes and these changes will be monitored individually or as a group depending on whether the intervention is a one-off intervention or part of a group of interventions taking place across the city of Aarhus. Reporting intervals are either monthly, quarterly, bi-annually or annually.

The reporting frequency of each KPI determines when the measured performance of each intervention will be assessed, however, the data collection process will occur monthly via the BIPED Evaluation Forum. KPIs with a reporting frequency of bi-annually will collect six months of data to be reviewed. The date of reporting of this data will depend on when the intervention commenced.

8 (Computer Security Research Center, 2015)

3.5 Setting Baselines and Targets

For certain KPIs, particularly those within the Energy and Mobility domains, it is crucial to establish baseline data to effectively measure progress throughout the project's duration. Some KPIs, such as the number of events or workshops, begin with a baseline of zero and increase as related activities occur over the course of the project. For other KPIs, the baseline will be a fixed reference point used to measure and compare the performance of project interventions over time. Specifically, it is the initial set of data points collected before any new interventions are implemented. These data points serve as a benchmark to assess the impact of the interventions by allowing for a "before and after" comparison. The target values, identified as part of the Co-Creation approach, refer to a specific goal or objective that the project aims to achieve. Reaching the target set will provide a basis to measure the success of the interventions taken in the project.

In terms of baselines for the project KPIs, all soft data KPIs (e.g. community engagement and events) start with a baseline of zero. In terms of the energy & mobility KPIs, the original TRL levels for the individual models have been indicated in section 6 and their end TRL level has been set as a target in the KPI Outlines Section 4.5.

3.6 WP3 & WP4 Stakeholder/End User Engagement

Overview of Stakeholder and End User Engagement in Aarhus / WP3
The stakeholder and end user engagement is a critical component for the M&E of the project. In placing co-creation at the forefront of the framework we have ensured that stakeholders and end users feedback have and will continue to be reflected in the engagement approach and integrated into the project KPIs. This integration of stakeholder and end user feedback highlights the connection and alignment between WP3 and WP4.

In the reporting period of D4.3, a series of engagement activities with stakeholders and end users has taken place in WP3 in Aarhus. These activities build on the foundation created in D3.1 BIPED Community, aiming to foster collaboration, gather valuable insights, and address the community's needs and challenges. This period marks the transition from a theoretical framework to the actual creation of a community of local stakeholders in Aarhus. The engagements from M7 to M12 include meetings, presentations, and a stakeholder questionnaire developed in the D3.2 BIPED Training program to gain insight and understanding of the PED community being built in Brabrand.

Engagement Activities

Throughout the reporting period, various engagement activities were conducted with stakeholders and end users, including:

- **Meetings with Local Stakeholders:** Focused on both informing about BIPED and understanding the concerns and stakes of various stakeholder groups.
- **Presentations at Events:** Such as the Wicked Tech Festival in Aarhus and Sol over Brabrand, aimed at showcasing the project's value and the BIPED digital twin, while gathering feedback.

- **Community Insights Questionnaire:** Distributed to local stakeholders to understand their training needs and gather insights.

Key Findings and lessons learned

- **Diverse Participation:** Engagements included a wide range of stakeholders, highlighting broad interest in the project.
- **Collaboration Needs:** Emphasis on the importance of collaboration and coordination among stakeholders to deliver a holistic solution.
- **Training Needs:** Significant demand for training on the technical aspects of digital twin technology, with a preference for varied learning methods.
- **Challenges:** Common challenges included resource constraints, technical difficulties, and the need for clear communication. Additionally, understanding the value of BIPED from a local stakeholder perspective was crucial.

Overview of Stakeholder and End User Engagement in WP4

The stakeholder engagement aspect embedded in WP4 is Task 4.4, which aims to establish and facilitate an end-user forum. In contrast to the other activities related to stakeholder engagement in BIPED, namely T2.5, which focuses on engagement with data space communities, and WP3, which primarily targets stakeholders at the pilot level, T4.4 complements the scope of stakeholder engagement in two key aspects. Firstly, T4.4 brings a more specific focus on end-users who are directly connected to the BIPED DT solution and/or whose opinions are crucial for its development. Secondly, T4.4 goes beyond the pilot level. Specifically, for the later stage of replication exploration, T4.4 provides the platform to engage with non-pilot potential end-users to explore the replicability and flexibility of the BIPED Digital Twin design. In general, this end-user linkage between pilot and non-pilot levels is mutually beneficial. While pilot end-users can benefit from the insights of non-pilot experts, non-pilot end-users can also be encouraged by experiencing the development journey with pilot end-users, which may lead to their support for the project.

A more detailed plan of the stakeholder engagement strategy for T4.4 is provided in D4.2 (M12). In general, the Forum facilitation will continue to seek synergies with other WP activities and the project work plan in order to increase efficiency and avoid unnecessary duplication. Following a rough 3 phase plan of the project, the first year, M1-M12, has been on further refining the design thinking of the project plan, during which a more detailed conceptual and operational strategy for T4.4 has been developed (D4.2). Stage 2 will focus on further design and validation, where T4.4 will not only support the identification of end-users at pilot level to improve the functionality and usability of the BIPED DT. It will also support the involvement of external end-users, both for additional expert input and in preparation for the later replication phase in Phase 3. As mentioned above, a more detailed plan is included in D4.2, below (Table 3) is a table summarising the transition of the key focus points of T4.4 during the project period.

Table 3. The Forum's (T4.4) Support Angle Roadmap

Text	Year 1 (M1-M12) 2024	Year 2 (M12-M24) 2025	Year 3 (M24-M36) 2026
Phase (Original Text from the Proposal)	Development (Knowledge Baselining and Design Thinking)	Implementation (PED Design and Validation)	Replication (Scaling and Sustainability)
Target Stakeholder Groups for Engagement	Primarily Aarhus-focused for the initial design and development of the LDT solution	Aarhus-focused for usability second half: non-Aarhus stakeholder feedback (development focused)	Broader stakeholder/end-user engagement outside of the pilot
Forum's Support Angle	1. Support WP3 to raise awareness of the project 2. Provide needed support for the initial LDT development	1. Improve usability of the solution in the pilot setting 2. Raising awareness beyond Aarhus 3. Feedback for LDT development beyond the pilot-specific focus	1. Scalability 2. Replicability

3.7 Self Reporting Tool (SRT) submission and BEST Tables

3.7.1 What is the Self Reporting Tool?

The Self Reporting Tool has been developed by the Smart City Information System which was merged into the Smart Cities Marketplace and the objective of this development is to provide a tool for project coordinators to report on projects' outputs and information and populate the SCM database. The Self Reporting Tool is the link between the information and outputs from the projects within the scope of SCM and the stakeholders. The users of the SRT use this tool to upload the relevant information on the different interventions carried out in projects. The information reported will provide the stakeholders with information that is monitored in real time, allowing them to obtain first hand information with the aim of fostering replication[9].

[9] https://smart-cities-marketplace.ec.europa.eu/insights/publications/self-reporting-tool-srt-guide

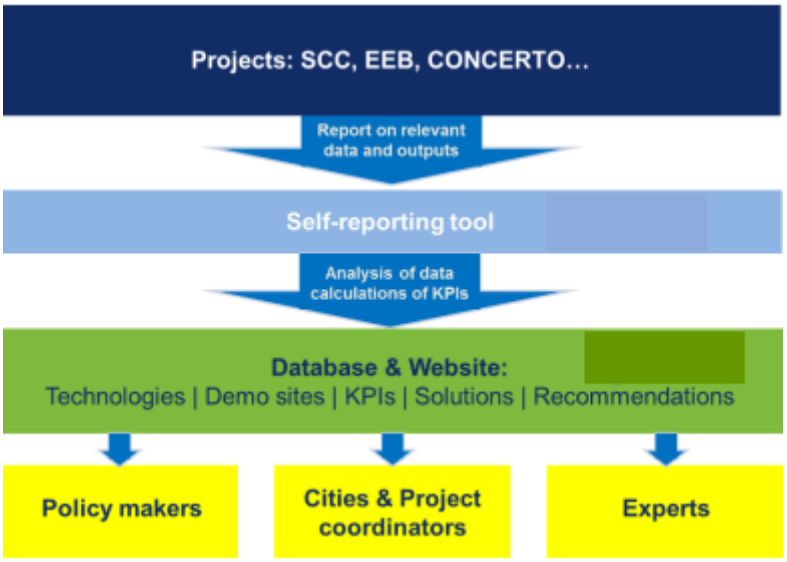

Figure 2: Stakeholder Map of SCM-SRT[10]

The approved approach from the European Commission is to submit data to the SRT on a PED level using BEST Tables as the approach aligns with data collection and submission approaches established across EU projects. The BEST Tables/PED approach set out also helps in reduction of the amount of reporting across projects significantly due to the variety of data across projects which report on a KPI-by-KPI basis. If all projects reported as per their own monitoring and evaluation mechanisms, they would not be comparable with other projects and hence not usable or reportable. This is the main role of the SRT as a comparison tool.

3.7.2 How the SRT fits into the BIPED M&E Framework

The role of the SRT and the BEST tables is to provide a quantitative record of the data developed as part of the BIPED project. The consistent formatting and alignment with a European standardised format is a key element in the project's results being comparable and contrastable to other European projects in the area, and as part of the long term exploitation of the benefits of the platform in other cities. BIPED still retains its own Framework and M&E approach to ensure that the more specialised elements of the project are reported upon and that lessons from the approach taken are identifiable and measurable during and post the project's lifespan.

3.7.3 Status Update on Submitting Data to the SRT

Further detail on the submission of data to the SRT will follow in later versions of this deliverable series. At this stage of the process, WP4 has engaged with the SCM and BIPED is now included as one of the included projects on the SCM-SRT.

Data submission to the SCM-SRT will commence in Year Two of the project.

[10] https://smart-cities-marketplace.ec.europa.eu/insights/publications/self-reporting-tool-srt-guide

3.8 Alignment with T2.6

Within the Energy and Mobility theme, the development of KPIs is conducted in collaboration with the WP2 leads (AIT) and as part of Task 2.6. A significant aspect of the monitoring and evaluation of the PED framework is the collaboration between these two tasks, which will be further examined in the subsequent iteration of this series of deliverables.

At this stage of the process, multiple models and structures within the BIPED twin have been outlined and are under development. The key KPIs in the monitoring phase are currently related to the development of the Technology Readiness Levels (TRLs) of these models and the overall framework. The aim is to meet the project's objectives of achieving a replicable and interoperable digital twin that can be utilised in other municipalities and cities across Europe.

At present, the TRL development of the models and their application are the key KPIs which will be measured as part of the overall M&E Framework. Within each of the models (described in Section 6), the modelling experts have developed internal KPIs that will be updated within WP2 as the models develop and further integrated into the Digital Twin Solution.

3.9 KPI Amendments

The following amendments have been made to KPIs:

Table 4: KPI Amendments

KPI Name	Original (Title Target, Description, Reporting Frequency etc.)	Changelog
Number of Co-Creation & Training Workshops	**Target:** 3	**Target:** 10.
Networks/Associations Targeted	**Reporting Frequency:** Quarterly	**Reporting Frequency:** Bi-Annual.
EU Cities Engaged	**Description:** BIPED will showcase the digital solution and engage with 100 cities via the Net Zero Cities project supporting the EU's Mission of "100 Climate-Neutral and Smart Cities by 2030" newly-launched as part of the Horizon Europe programme. The project works as a service-oriented platform supported by world-class practitioners. It helps European cities by providing them with the support and solutions they need to achieve their Net Zero goals.	**Description:** BIPED will showcase the digital solution and engage with 100 cities via the Net Zero Cities project supporting the EU's Mission of "100 Climate-Neutral and Smart Cities by 2030" newly-launched as part of the Horizon Europe programme. The project works as a service-oriented platform supported by world-class practitioners. It helps European cities by providing them with the support and solutions they need to achieve their Net Zero goals. ***BIPED will also broaden this to general engagement with EU cities, which does not necessarily have to go through the NZC mission network.***
Media Coverage (News Articles, News Videos) of BIPED Project	**Reporting Frequency:** Bi-Annual	**Reporting Frequency:** Quarterly.

Usability of the Digital Twin Solution for End Users	**Target:** TBD **Reporting Frequency:** Bi-Annual/Annual **Description:** The extent to which the solution is perceived as difficult to understand and use for potential end-users. It is presumed that a smart city solution that is easy to use and understand will be more likely adopted than a difficult solution.	**Target:** 3 (Out of 5) (Likert Scale) **Reporting Frequency:** Annual. Description: The extent to which the solution is perceived as difficult to understand and use for potential end-users. It is presumed that a smart city solution that is easy to use and understand will be more likely adopted than a difficult solution. *Usability of the digital twin will refer to how effectively, efficiently, and satisfactorily a user can interact with and achieve specific goals using a digital twin system. The definition will include the following items:* ***Ease of Use:*** *The system's interface should be intuitive, allowing users to navigate and interact with the twin without extensive training or prior experience.* ***Efficiency:*** *Users should be able to complete tasks quickly and accurately. This often means that the digital twin should allow users to find and manipulate data seamlessly, optimising workflows.* ***Accessibility:*** *The digital twin should be accessible to all intended users, considering factors like cross-platform functionality, compatibility, and adaptive design for varied user needs.* ***Reliability and Responsiveness:*** *The system should reliably represent real-time or near-real-time data of the physical asset, with minimal delay or disruption. This is especially critical in environments where digital twins monitor ongoing operations, like industrial machinery or transportation networks.*

		Interpretability: *Users should find it easy to interpret the visual and data representations within the digital twin. Effective data visualisation and relevant, clear metrics help make complex information understandable, which enhances decision-making.* ***Feedback and Error Tolerance:*** *The system should provide feedback to users, helping them understand the consequences of their actions and recover from errors if they occur.*
Number of stakeholders/buildings/assets utilising the Digital Twin Solution	**Title:** Number of stakeholders/buildings/assets utilising the Digital Twin Solution **Target:** TBD	**Title:** Number of ***buildings/assets*** utilising the Digital Twin Solution **Target:** 20
Improved Interoperability of the Digital Twin Solution	**Target:** TBD **Description:** Interoperability is the ability of a system (or product) to work with other systems by providing services to and accepting services from other systems and to use the services so exchanged to enable them to operate together (ISO/TS 37151). The indicator assesses the improvement in interoperability in a qualitative manner. **Theme:** Energy Consumption	**Target:** Level 3 **Description:** Interoperability is the ability of a system (or product) to work with other systems by providing services to and accepting services from other systems and to use the services so exchanged to enable them to operate together (ISO/TS 37151). The indicator assesses the improvement in interoperability in a qualitative manner. *Levels of Interoperability:* *IMTs define five levels of interoperability maturity:* ***Ad hoc (level 1):*** *Poor interoperability – the digital public service cannot be considered interoperable* ***Opportunistic (level 2):*** *Fair interoperability – the digital public service implements some elements of interoperability best practices*

		Essential (level 3): *Essential interoperability – the digital public service implements the essential best practices for interoperability* ***Sustainable (level 4):*** *Good interoperability – all relevant interoperability best practices are implemented by the digital public service* ***Seamless (level 5):*** *Interoperability leading practice – the digital public service is a leading interoperability practice example for others*[11] **Theme:** Digital Solutions
Demonstrations of the Digital Twin Solution	**Target:** TBD **Reporting Frequency:** Quarterly	**Target:** 10. **Reporting Frequency:** Bi-Annual.
Usage of Open Source Software	**Title:** Usage of Open Source Software **Target:** TBD **Reporting Frequency:** Quarterly	**Title:** Usage of Open Source Software **and Solutions** **Target:** 75%. **Reporting Frequency:** Bi-Annual.
Quality of Open Data	**Target:** TBD **Reporting Frequency:** Quarterly	**Target:** 75% **Reporting Frequency:** Bi-Annual.
Soft Datasets Integrated	**Target:** TBD **Reporting Frequency:** Quarterly	**Target:** 20 **Reporting Frequency:** Bi-Annual

[11] Interoperability Maturity Models

The following KPIs have been newly developed following consultation with project partners in Technical Workshops which are described in Section 4.4:

Table 5: Newly Developed KPIs

No.	Name	Description	Data Collection Methodology & Data Collection Execution	KPI Group	Measurement Type	Target	Reporting Frequency
12	**Energy Model TRL Development**	We will describe a new energy systems modelling tool that will be able to take advantage of short-term flexibility in long-term energy planning. This tool will take advantage of the additional flexibility unlocked by sector coupling and data-driven methods on all relevant scales, but here with a focus on PEDs to smart cities.	DTU	Energy & Mobility	TRL Level	8	Annual
13	**Mobility Model TRL Development**	Creates a traffic model of selected areas. Portrays hourly changes in traffic flows in the area. Allows recalculating traffic flows in reaction on added events or changes in the road network topology and/or traffic demand	RT	Energy & Mobility	TRL Level	9	Annual
14	**Traffic Enviro Impact Analyst TRL Development**	Traffic Enviro Impact Analyst is software designed to help assess traffic's environmental impact on air and noise pollution. The software	DKSR	Energy & Mobility	TRL Level	7	Annual

		uses traffic flows as input and applies emission factors and dispersion models to calculate the level of air pollution generated by vehicles, as well as a noise model to estimate the amount of noise pollution.					
15	**DKSR Open Urban Platform TRL Development**	Open Source real-time platform for cross-domain data integration and match-making. Real-time sensor data platform that follows the vision of Open Urban Platforms [OUP] as expressed by the European Innovation Partnership Smart Cities and Communities and defined in DIN SPEC 91357. The OUP enables small and large cities and businesses to efficiently integrate new and existing data sources, process and analyse data in near real-time, and ultimately share the data with various stakeholders. Unlike many other platforms, it is cloud agnostic and can run in the cloud, in container environments Kubernetes or in the local data centre. Depending on the requirements, cloud-based services or open source technologies can be used for these purposes.	DKSR	Digital Solutions	TRL Level	9	Annual

The following KPIs from D4.1 have been removed:

Table 6: Removed KPIs

Name	Description
Tonnes of CO_2-equivalent emissions reduction per year via utilisation of the Digital Twin solution	The indicator measures the reduction in CO_2-equivalent emissions as a result of the use of the Digital Twin Solution developed by the BIPED project. The reduction is based on the CO_2-equivalent emission baseline compared to the reduced emission through the Digital Twin. The reduction is based on the CO_2-equivalent emissions calculated through measurements and models for the different constituent components as detailed in the BEST tables.
Progress towards development of a PED	In collaboration with WP2, KPMG will develop a methodology for measuring the progress towards development of a PED. This KPI will be updated in the next iteration of this deliverable
Energy Savings for Key Stakeholders via Implementation/Uptake of the Digital Twin Solution	The reduction of the energy consumption to reach the same services (e.g., comfort levels) after the implementation/uptake of the Digital Twin solution, taking into consideration the energy consumption from a reference period
Increase in Local Renewable Energy Generation via implementation of the Digital Twin Solution	The share of Renewable Energy production in itself gives an idea of the rate of self-consumption of locally produced energy, which is an indicator of the flexibility potential of the local energy system. The indicator accounts for the increase of renewable energy generation due to the intervention.

These KPIs were removed after further discussion with the project consortium at the BIPED GA in Copenhagen. The data currently available to the models in BIPED was not sufficient in order to meet these KPIs and thus it was suggested they were removed. However, as the models develop throughout the lifespan of the project they will be revisited for inclusion in later iterations.

4. Project KPIs

4.1 Developing the Project KPIs

The BIPED KPIs were developed by WP4 in collaboration with subject experts and Work Package leads. In relation to the Community Engagement themed KPIs, these KPIs were developed predominantly in collaboration with WP3 (AAKS). For the Digital Solutions and Energy & Mobility KPIs, these KPIs were developed predominantly in collaboration with WP2, specifically the pending outputs of T2.6 and related T2.2-T2.4. The KPIs have been developed in order to identify the extent of and responsibility of individual task responsibilities within the BIPED project and Work Packages.

4.2 KPI Data Management

Strong dissemination of results, sharing of data, communication, and utilisation of the ecosystem are key success markers in making the project results more accessible, attractive, evaluable, and credible for a broad set of stakeholders including practitioners, researchers and policymakers. The project aims to make research data findable, accessible, interoperable and re-usable (FAIR) in line with the Horizon Europe Guidelines on FAIR Data Management. The FAIR principle asserts that research data is 'findable, accessible, interoperable and reusable', as it can help the ongoing project and/or other researchers in the domain and it does not contain personal or other sensitive data. Processing of personal data will respect the Data Protection Principles as set out: Lawfulness, fairness, and transparency; Purpose limitation; Data minimisation; Accuracy; Storage limitation; Integrity and confidentiality; accountability

The BIPED project aims to fulfil all ethical requirements and acknowledges that compliance with ethical principles is of utmost importance within Horizon Europe, including those that involve citizens and other actors, especially regarding human participants and processing of personal data. As such, the beneficiaries will carry out the action in compliance with ethical principles (including the highest standards of research integrity); and applicable international, EU and national law. The project will ensure respect for people and for human dignity and fair distribution of the benefits and the burden of research, and will protect the values, rights, and interests of the participants. The project will respect the privacy of all stakeholders and citizens and will seek free and fully informed consent where personal identifiable data is collected and processed. In case the project requires processing of personal data, this is done in strict compliance with the General Data Protection Regulation.

Data provided by the project will support a range of goals, such as improving dissemination and exploitation of data and results; improving access and reuse of research data; and knowledge sharing with citizens, the wider public, interested stakeholders, and the scientific community. Documentation and research data repositories will follow the Horizon Europe best practice, with a focus on open access, peer-reviewed journal articles, conference papers, and datasets of various types.

Data minimisation is a fundamental principle of the General Data Protection Regulation (GDPR) and is particularly relevant for projects like BIPED. It involves ensuring that only the

necessary and relevant data is collected for the specific purpose of the project. This includes data such as names, contact information, place of work or other identifiers. It's also important to consider the frequency and volume of data collection, ensuring that data is not collected more often or in greater quantities than necessary. Additionally, data minimisation extends to the storage of data, meaning that personal data should not be retained for longer than needed.

The BIPED consortium is aware of potential issues arising from data aggregation from different sources, scales, flows, and devices, including possible ethical implications for stakeholders. Data collected in the project will thus be anonymised and aggregated as close to the source as possible (privacy by design and by default). In certain cases, personal data avoidance and minimisation can eliminate and/or reduce identifiability. The BIPED consortium is guided on privacy and ethical issues by a dedicated partner via deliverables (including data management plan and ethics implementation manual) and takes informed decisions on this basis.

Further details on the Data Management and Privacy and Ethical LDT Implementation (Completion December 2024) work in the project is described in D1.3 and D1.4 respectively.

4.3 Development of KPI Data Collection & Ownership

In further developing the M&E framework, KPMG has incorporated a ***Data Collection Methodology Creation & Execution*** as a new column in the M&E framework for BIPED. KPMG decided upon this as it is essential for ensuring accurate, reliable, and actionable insights. By addressing the creation and execution of data collection strategies, the M&E framework can ensure that the right types of data are captured from appropriate sources using well-defined protocols, thereby minimising errors and inconsistencies. Additionally, this inclusion supports transparency and repeatability in data gathering processes and enables continuous improvement through iterative refinement.

4.4 KPI Co-Creation Activities

Section 4.4.1 KPI Workshop (GA Copenhagen)

The in-person KPI workshop held in Copenhagen was a critical step in refining the project's KPIs. This workshop built upon the outcomes of previous sessions since the finalisation of D4.1 that had established a preliminary set of KPIs under the three thematic areas. The main objectives of the workshop were to validate these KPIs for inclusion in Deliverable 4.3 (D4.3), identify areas where new KPIs could be introduced, and streamline the existing set by removing KPIs constrained by current data or modelling limitations. The interactive format enabled stakeholders to provide insights, ensuring the KPIs aligned with the project's technical objectives and practical constraints. As part of the KPI Workshop in Copenhagen, KPMG also outlined the MCA approach which will be adopted for the weighting of the project KPIs. The MCA is further outlined in Section 5.

Section 4.4.2 BIPED KPI Workshop (Online)

Following the in-person KPI workshop at the GA in Copenhagen, an online session was conducted via Teams, involving project partners. This follow-up workshop revisited the outcomes of the Copenhagen session, allowing for further refinement and discussion of the KPIs. It served as a preparatory step for the upcoming Modelling/Technical Workshop by consolidating inputs from partners. This virtual engagement was instrumental in ensuring alignment across the project team, providing a forum to address emerging challenges and solidifying the framework for finalising the KPIs in alignment with technical and modelling requirements.

Section 4.4.3 BIPED Modelling/Technical Workshop (Online)

The Modelling/Technical Workshop conducted online was a pivotal milestone in the project, aimed at aligning the technical modelling efforts with the overall project objectives, particularly the refinement and validation of KPIs. This session was attended by partners and focused on ensuring that the modelling framework and associated KPIs addressed key aspects of the Positive Energy District (PED) demo site in Aarhus. Below is a detailed breakdown of the workshop agenda and presentations.

The workshop agenda was carefully structured to provide a comprehensive understanding of the modelling framework, the current data available to the models as well as the data constraints, the current and future TRL levels of the models and understanding how the KPIs aligned with the models. The outputs of the technical workshop and the models presented are covered further in Section 6.

Table 7: BIPED Modelling/Technical Workshop Agenda

Title	Description
Introduction and Workshop Objectives/Agenda	Led by KPMG, this segment outlined the objectives of the workshop and its importance in the broader context of the project. It emphasised the goal of integrating individual models into a cohesive framework while ensuring the KPIs reflected real-world data and outcomes.
Intersection of Individual Models and Overall Model Framework	DTU delivered this session, focusing on the integration of individual models into the overall modelling framework. Key aspects included the dependencies between energy mobility, and cross-sectorial models and their implications for KPI design.
Energy Models	Presented by DTU, this segment delved into the modelling framework for energy systems, highlighting data availability, current progress, and challenges. The following models were presented: ● District Heating Load Forecasting ● District Heating Testbed Model

Mobility Models	Delivered by RT and UWB, this session explored mobility model descriptions, available data, and use cases, with a focus on their alignment with project KPIs.The following models were presented: ● Traffic Enviro Analyst - Emissions ● Traffic Enviro Analyst - Energy
Cross Sectoral Model	A presentation by DTU outlined the cross-sectorial modelling approach, addressing overlaps between energy and mobility systems. The session continued with a presentation by AIT on the Building Occupancy Model. The following models were presented: ● Climate Risk (DTU) ● Indoor Climate Model (DTU) ● Building Occupancy Model (AIT)

In terms of looking ahead to co-creation activities for the project, the BIPED Evaluation Forum will proceed in year two of the project as application of the models begin to take place in Brabrand and data can begin to be gathered and analysed. The qualitative workshops with internal project stakeholders will serve as a vital source for consolidating perspectives and insights gathered throughout the lifespan of the project. By engaging internal project stakeholders in the qualitative data review process, WP4 will ensure a comprehensive understanding of the project's successes, challenges and areas for improvement. This collaborative approach will enhance buy-in and alignment towards the project's objectives and KPIs.

4.5 KPI Outlines

Table 8: Key Performance Indicators

No.	KPI Name	Description	Methodology & Data Collection Execution Owner	KPI Group	Measurement Type	Reporting Frequency	Target
1	Number of community participation events organised/coordinated	The role of community participation events is to enable local communities to have a greater understanding of the Digital Twin solution. Community participation events refer to events such as learning workshops, joint exhibitions or event participation and other events promoting the project and its outcomes. By tracking the community participation events and evaluating their outcomes, you can gauge the level of community engagement within the project and make informed decisions to enhance participation and collaboration.	AAKS	Community Engagement	Number	Quarterly	10

2	Number of Co-Creation & Training Workshops	BIPED will conduct a number of co-creation & training workshops which will involve key stakeholders identified by AAKS. The co-creation workshops Co-will focus on collaborating with key stakeholders to guide the design process of the Digital Twin solution and other BIPED interventions. The training workshops will be commenced upon completion of the Digital Twin solution and will involve the same key stakeholders and train them in the use of the Digital Twin solution.	AAKS, DTU	Community Engagement	Number	Bi-Annual	10
3	Workshop participants	By systematically measuring stakeholder engagement through workshops and evaluating participation levels, engagement, and outcomes, you can assess the effectiveness of your engagement efforts and ensure that stakeholder perspectives are considered in project decision-making and implementation.	AAKS, DTU	Community Engagement	Number	Quarterly	400

4	Networks/Associations Targeted	Through engagement with smart city networks such as SCC1 Monitoring & Evaluation Task Group, BIPED can engage with networks and associations focusing on smart city and digital twin projects which share common goals and objectives. Engaging with these networks/associations will give BIPED expertise into digital twin/smart city experiences which will help the project navigate potential challenges	AAKS, DTU, OASC	Community Engagement	Number	Bi-Annual	30
5	EU Cities Engaged	BIPED will showcase the digital solution and engage with 100 cities via the Net Zero Cities project supporting the EU's Mission of "100 Climate-Neutral and Smart Cities by 2030" newly-launched as part of the Horizon Europe programme. The project works as a service-oriented platform supported by world-class practitioners. It helps European cities by providing	AAKS, DTU, OASC	Community Engagement	Number	Bi-Annual	100

		them with the support and solutions they need to achieve their Net Zero goals. BIPED will also broaden this to general engagement with EU cities, which does not necessarily have to go through the NZC mission network.					
6	Joint Actions with 'Sister Projects'	Through participation in smart city networks, BIPED can engage with 'sister projects' and 'PED projects' in the digital twin/smart city sphere. Through this network, BIPED can carry out joint actions with 'sister projects' for the digital twin solution By systematically measuring joint actions with other projects, BIPED can evaluate collaboration in terms of alignment, impact, benefits, challenges, and lessons learned when implementing a digital twin solution across different environments/settings.	All (Leads AAKS, DTU, KPMG, OASC, DRI,AIT)	Community Engagement	Number	Bi-Annual	3

7	Increased Citizen Understanding and Awareness of the potential of Digital Twin projects	This KPI aims to measure the initial citizen awareness of digital twins and the nature of how they operate. Through the lifecycle of the project, BIPED will aim to raise this awareness through bi-annual workshops, focus groups and questionnaires with citizens and track the potential increase in awareness via BIPED's efforts and the wider digital twin landscape and awareness of the potential socio-economic impacts of the digital twin solution.	AAKS, KPMG	Community Engagement	Five-point Like scale/Questionnaire	Annual	3 (On Likert Scale 1-5)
8	Media Coverage (News Articles, News Videos) of BIPED Project	This KPI assesses the frequency and breadth of media attention, reflecting the project's visibility and public awareness, vital for garnering support and replicability of the Digital Twin solution.	DRI	Community Engagement	Number	Quarterly	10
9	Usability of the Digital Twin Solution for End Users	The extent to which the solution is perceived as difficult to understand and use for potential end-users. It is presumed that a smart city solution that is easy to	DKSR, AAKS	Community Engagement	Likert Scale	Annual	3 (Out of 5) (Likert Scale)

		use and understand will be more likely adopted than a difficult solution. Usability of the digital twin will refer to how effectively, efficiently, and satisfactorily a user can interact with and achieve specific goals using a digital twin system. The definition will include the following components: **Ease of Use:** The system's interface should be intuitive, allowing users to navigate and interact with the twin without extensive training or prior experience. **Efficiency:** Users should be able to complete tasks quickly and accurately. This often means that the digital twin should allow users to find and manipulate data seamlessly, optimising workflows. **Accessibility:** The digital twin should be accessible to all intended users,					

		considering factors like cross-platform functionality, compatibility, and adaptive design for varied user needs. **Reliability and Responsiveness:** The system should reliably represent real-time or near-real-time data of the physical asset, with minimal delay or disruption. This is especially critical in environments where digital twins monitor ongoing operations, like industrial machinery or transportation networks. **Interpretability:** Users should find it easy to interpret the visual and data representations within the digital twin. Effective data visualization and relevant, clear metrics help make complex information understandable, which enhances decision-making. **Feedback and Error Tolerance:** The system					

		should provide feedback to users, helping them understand the consequences of their actions and recover from errors if they occur.					
10	Peer Reviewed Publications	This KPI measures the number of research papers or articles published by BIPED partners in journals, conference proceedings, magazines, or other outlets. Peer-reviewed publications refer to scholarly work that has undergone review by subject matter experts before being accepted for publication. These publications are typically considered credible and authoritative in the academic and research community.	All	Community Engagement	Number	Annual	10
11	Number of buildings/assets utilising the Digital Twin Solution	This KPI tracks the uptake of the market by the number of buildings/assets which are able and technically equipped to adopt the digital twin solution.	DTU, AAKS, DKSR, VCS	Energy & Mobility	Number	Bi-Annual	20

12	Energy Model TRL Development	We will describe a new energy systems modelling tool that will be able to take advantage of short-term flexibility in long-term energy planning. This tool will take advantage of the additional flexibility unlocked by sector coupling and data-driven methods on all relevant scales, but here with a focus on PEDs to smart cities.	DTU	Energy & Mobility	TRL Level	Annual	8
13	Mobility Model TRL Development	Creates a traffic model of selected areas. Portrays hourly changes in traffic flows in the area. Allows recalculating traffic flows in reaction on added events or changes in the road network topology and/or traffic demand	RT	Energy & Mobility	TRL Level	Annual	9
14	Traffic Enviro Impact Analyst TRL Development	Traffic Enviro Impact Analyst is software designed to help assess traffic's environmental impact on air and noise pollution. The software uses traffic flows as input and applies emission factors and dispersion models to	DKSR	Energy & Mobility	TRL Level	Annual	7

		calculate the level of air pollution generated by vehicles, as well as a noise model to estimate the amount of noise pollution.					
15	DKSR Open Urban Platform TRL Development	Open Source real-time platform for cross-domain data integration and match-making. Real-time sensor data platform that follows the vision of Open Urban Platforms [OUP] as expressed by the European Innovation Partnership Smart Cities and Communities and defined in DIN SPEC 91357. The OUP enables small and large cities and businesses to efficiently integrate new and existing data sources, process and analyse data in near real-time, and ultimately share the data with various stakeholders. Unlike many other platforms, it is cloud agnostic and can run in the cloud, in container environments Kubernetes or in the local data centre. Depending on the	DKSR	Digital Solutions	TRL Level	Annual	9

		requirements, cloud-based services or open source technologies can be used for these purposes.					
16	Demonstrations of the Digital Twin Solution/Platform	By systematically measuring demonstrations held of the Digital Twin and evaluating feedback and impact, you can assess the effectiveness of the solution and refine the solution to ensure an interoperable solution.	All (Leads: AIT, DTU, AAKS, DRI)	Digital Solutions	Number	Bi-Annual	10
17	Datasets Published	Publication of open datasets for use by third parties.	All (Leads: AIT, DTU, UWB, RT)	Digital Solutions	Number	Bi-Annual	5
18	Models Linked to PED Published	Publication of models for use by third parties.	AIT, DTU, UWB, RT	Digital Solutions	Number	Bi-Annual	3
19	Usage of Open Source Software and Solutions	The use of open source software and solutions means less possibilities of vendor lock-in and more space for communities to develop smart city solutions. It also lowers the software costs.	AIT, DKSR, DTU	Digital Solutions	Percentage	Bi-Annual	75%
20	Quality of Open Data	Percentage of data that uses DCAT standards. The quality of open data is better if standardised. Processes get	CDK, DKSR, INNO, DTU	Digital Solutions	Percentage	Bi-Annual	75%

		easier when data standards are applied. The DCAT standard allows municipal employees to produce data in a standardised way.					
21	Soft Datasets Integrated	Capture and integrate soft (intangible) data into the BIPED Digital Twin platform which goes beyond tangible energy and mobility sources to better understand how spaces and policies affect people's behaviours etc.	AIT, DKSR, DTU	Digital Solutions	Number	Bi-Annual	20
22	Website Visits	Number of visits to the BIPED website.	DRI	Digital Solutions	Number	Bi-Annual	10,000
23	Social Media Followers	Across different channels e.g. LinkedIn, X (formerly Twitter), YouTube	DRI	Digital Solutions	Number	Bi-Annual	1,000

24	Number of Aarhus City Council Staff Trained to use the Digital Twin	This KPI tracks the training of the developed digital twin through the number of city council staff that have received training for the tool. The staff trained will be able to operate the digital twin and its functions to assist with analysis of and reporting on project implementation, baseline development feasibility studies and general use.	DTU, AAKS	Digital Solutions	Number	Bi-Annual	20
25	Interoperability of the Digital Twin Solution	Interoperability is the ability of a system (or product) to work with other systems by providing services to and accepting services from other systems and to use the services so exchanged to enable them to operate together (ISO/TS 37151). The indicator assesses the improvement in interoperability in a qualitative manner. Levels of Interoperability:	OASC, AAKS, DTU, AIT, DKSR	Digital Solutions	Inter-operability Maturity Model[13]	Bi-Annual	Level 3

[13] Interoperability Maturity Model

		IMTs define five levels of interoperability maturity: **Ad hoc (level 1):** Poor interoperability – the digital public service cannot be considered interoperable. **Opportunistic (level 2):** Fair interoperability – the digital public service implements some elements of interoperability best practices. **Essential (level 3):** Essential interoperability – the digital public service implements the essential best practices for interoperability. **Sustainable (level 4):** Good interoperability – all relevant interoperability best practices are implemented by the digital public service. **Seamless (level 5):** Interoperability leading practice – the digital public service is a leading interoperability practice example for others[12].					

[12] Interoperability Maturity Models

4.6 KPI Data Collation and Reporting

KPMG, working in collaboration with KPI owners and KPI technical experts will determine which deliverables can be reviewed to gather qualitative and quantitative information in regards to the KPIs and lessons learned and evaluated activities. WP4 will also engage on a monthly basis with partners via the data collection meeting on the development and improvement of the M&E framework and methodology which will lead to a greater collation and evaluation process based on the co-creation principles of the M&E framework. The insights gained from the review of deliverables will be presented to partners in the data collection meeting and wider management meeting to allow partners to discuss the process behind the interventions, the lessons learned and challenges experienced in greater detail.

The qualitative data evaluation process will commence with the beginning of the first project interventions and activities related to KPIs, which will provide an initial outlook on qualitative data sourcing and collation. Further refinement will continue throughout the lifetime of the project. Paired with the quantitative data, qualitative insights from the M&E process will be reviewed to provide insight and recommendations from interventions within BIPED.

5. Use Cases and Multi-Criteria Analysis

To ensure that BIPED effectively meets its objectives, a structured approach to M&E has been implemented. This process is designed to assess the progress and impact of the project across its various themes—Energy and Mobility, Community Engagement, and Digital Solutions—through the development and evaluation of the project KPIs. KPMG has structured the process into three main phases: ***Context, Multi-Criteria Analysis,*** and ***Assessment***. Each phase comprises specific stages, which together enable a comprehensive and balanced approach to evaluation. The figure below gives a high level view of the phases and stages of the KPI Assessment Process.

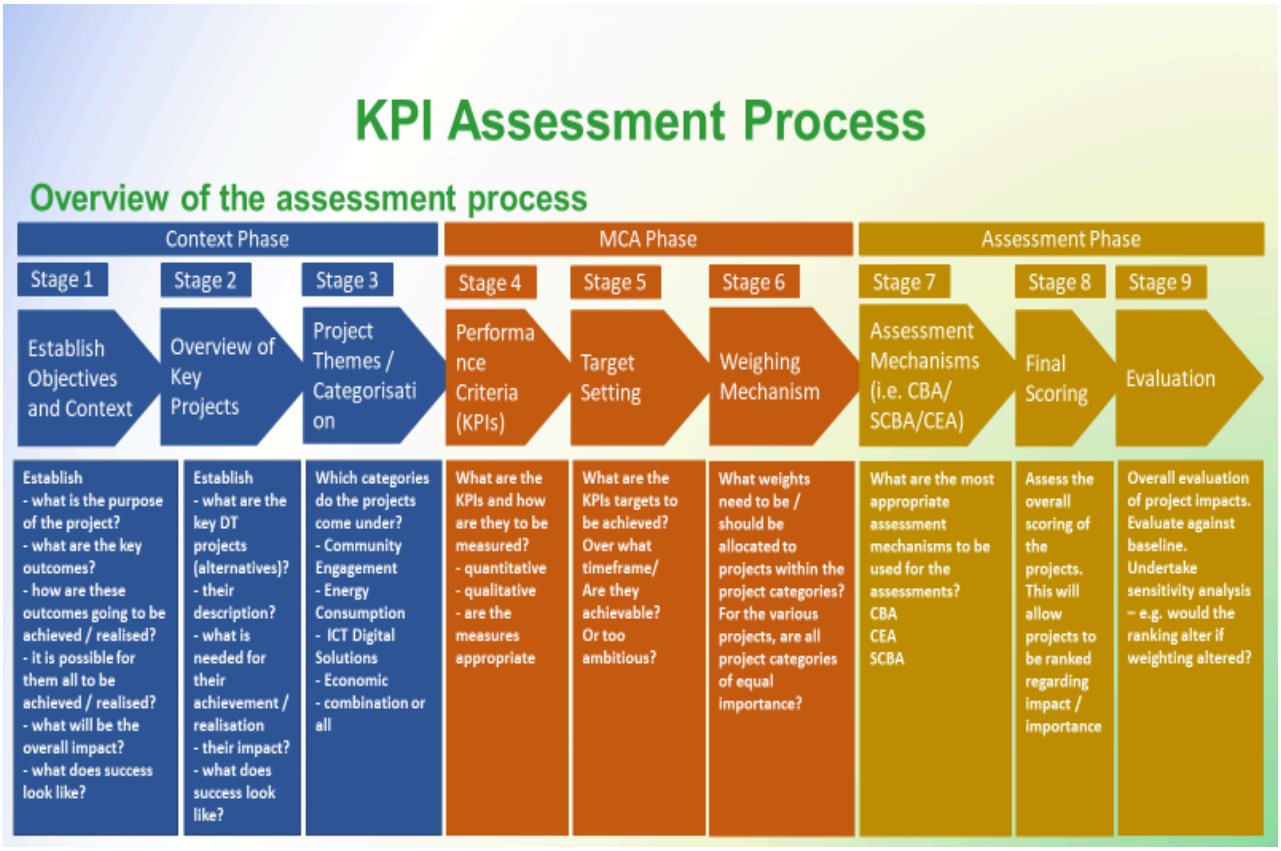

Figure 3: Overview of KPI Assessment Process

Phase 1: Context

In the Context phase, the foundation for the KPIs is established by defining project objectives, understanding existing initiatives, and organising KPIs into relevant themes. This phase ensures that the KPIs developed are relevant, actionable, and aligned with the broader goals of the smart city project.

1. **Establish Objectives and Context**:
    - This initial stage involves identifying the key goals of the Digital Twin project, such as enhancing urban efficiency, sustainability, and liveability. The M&E

team aligns these project goals with the overarching objectives of the smart city initiative, creating a clear framework that directs the KPI selection process.
    - The context analysis considers external factors, such as regulatory requirements, technological advancements, and community needs. This comprehensive understanding of the project environment helps in setting KPIs that are responsive to both internal and external influences on the project.
2. **Overview of Key Projects**:
    - In this stage, the KPMG maps out specific sub-projects and initiatives that support the Digital Twin. This overview includes identifying both ongoing and planned initiatives within the broader smart city program that relate to the Digital Twin's development.
    - By understanding the landscape of related projects, the team can identify synergies and potential overlaps, allowing for more efficient allocation of resources. This overview also helps pinpoint focal areas for KPI development, ensuring that they reflect both the current state and future ambitions of the Digital Twin.
3. **Project Themes and Categorisation**:
    - The final stage in the Context phase categorises KPIs under the key themes of *Energy and Mobility*, *Community Engagement*, and *Digital Solutions*. Each theme represents a critical domain where the Digital Twin project can drive value and impact.
    - Grouping KPIs by theme ensures that they are tailored to the specific characteristics and goals of each area, facilitating a more focused assessment. For example, *Energy and Mobility* focuses on sustainability metrics like energy savings, while *Community Engagement* emphasises social metrics, and *Digital Solutions* tracks technological performance and user adoption.

Phase 2: Multi-Criteria Analysis

The Multi-Criteria Analysis phase sets up the evaluation framework by defining criteria for performance, setting targets, and assigning weights. This phase ensures that KPIs are both measurable and aligned with strategic priorities.

4. **Performance Criteria**:
    - Here, the M&E team establishes performance metrics for each KPI theme. Performance criteria are selected to capture critical aspects relevant to the project's success in each domain.
    - For *Energy and Mobility*, criteria include metrics like energy efficiency, emissions reduction, and public transportation optimization. For *Community Engagement*, criteria might include metrics such as engagement rates. For *Digital Solutions*, criteria focus on data integration levels and the rate of adoption of digital services.
5. **Target Setting**:
    - Once performance criteria are defined, specific, measurable targets are set for each KPI. These targets represent quantifiable goals that allow for

progress tracking and ensure that each KPI has a clear benchmark for success.
    - The targets are designed to be ambitious yet achievable, reflecting the Digital Twin's potential to impact Aarhus.
6. **Weighting Mechanism**:
    - A weighting mechanism is implemented to prioritise KPIs based on their strategic relevance and anticipated impact. Each KPI is assigned a weight based on factors such as alignment with core objectives, potential for positive outcomes, and contribution to the overall value of the Digital Twin.
    - This weighting ensures that KPIs with a higher potential to drive success receive greater focus on the evaluation.

Phase 3: Assessment

The Assessment phase evaluates the KPIs through specific analysis methods, scoring mechanisms, and a final synthesis to gauge project impact. This phase combines economic, social, and performance-based analyses for a well-rounded evaluation.

7. **Assessment Mechanisms**:
    - This stage involves applying three distinct analytical frameworks—Cost Benefit Analysis (CBA), Cost Effectiveness Analysis (CEA), and Social Cost Benefit Analysis (SCBA)—to evaluate each KPI theme.
        - **Cost Benefit Analysis (CBA)**: For *Energy and Mobility*, CBA quantifies financial and environmental benefits, allowing the project to evaluate potential returns on investment. For instance, reductions in energy consumption and transportation costs are assessed against implementation expenses, helping justify the economic viability of these projects.
        - **Cost Effectiveness Analysis (CEA)**: CEA is applied to *Digital Solutions* to determine the most efficient use of resources in achieving digital transformation objectives. For example, CEA might compare various digital solutions by measuring their costs relative to achieved improvements in system integration and data utilisation.
        - **Social Cost Benefit Analysis (SCBA)**: SCBA is particularly relevant for *Community Engagement*, where benefits like social cohesion and improved public trust are difficult to monetise. SCBA assesses these social benefits, considering both tangible and intangible impacts on community well-being, which are central to the project's success.
8. **Final Scoring**:
    - After conducting the analyses, a final score is assigned to each initiative within the project based on its overall performance across the KPIs. The scoring integrates the weights established in the Multi-Criteria Analysis phase, ensuring that higher-priority KPIs contribute more substantially to the final score.
    - This scoring system facilitates a balanced comparison of initiatives across the three themes, allowing KPMG to easily identify high-performing areas and highlight areas needing improvement. The final scores help prioritise future investments and project adjustments.

9. **Evaluation**:
    - The final evaluation synthesises insights from the assessment phase, providing a comprehensive view of the Digital Twin project's overall performance and impact. This stage includes summarising achievements, identifying challenges, and drawing actionable recommendations.
    - The evaluation also reflects on the effectiveness of the assessment framework itself, noting any adjustments that could further improve the M&E process. The insights generated here are intended to inform decision-making, offering a roadmap for future phases of the Digital Twin project and its integration into the wider smart city program.

By following this structured, multi-stage approach, KPMG has developed a thorough and adaptable assessment framework. This approach ensures that each KPI is carefully developed, monitored, and evaluated, providing a reliable basis for continuous improvement, and maximising the Digital Twin's contribution to Aarhus and ensuring replicability and interoperability.

The absence of identified use cases and developed KPIs in relation to the use cases can primarily be attributed to the current TRL of the data models. At lower TRLs, the models are experimental phases, where their capabilities are still being assessed. This lack of maturity makes it challenging to align the models with practical, operational scenarios or to define measurable outcomes. Furthermore, early-stage models often require iterative development and validation before their utility in specific contexts can be established.

At the end of year one, the three themes have progressed significantly. Within the Community Engagement theme, multiple community partition events have been organised, BIPED has engaged significantly with the various smart city networks and started engagement activities with the sister projects (xPEDite and Tips4PED), and has had strong media coverage on the commencement and developments of the project. Within the Digital Solutions theme, significant work on the LDT has led to the development of an initial prototype and there is currently amalgamation on the various models into the LDT, which is on target at this stage of the project. The progress in the development of the LDT links directly with the third theme of Energy and Mobility. This theme and the relevant project interventions will progress significantly in Year 2 and 3; but is reliant on the development of the Digital Twin over the past year to move forward the use cases.

In the second year of the project, Work Package 4 (WP4) will intensify its collaboration with model and local digital twin developers to advance the development of use cases and implement the MCA approach. In anticipation of this phase, we have identified several potential use cases for the models. Detailed descriptions of these use cases, categorised by each model, are provided in Section 6.

6. Modelling Data Collection & Challenges

A key element of the LDT development is the integration of the various models and data typologies present within the digital footprint of Aarhus. This section of the deliverable describes each of the models that are currently being included as part of the LDT solution and describes the current status of the model, data availability, potential use cases, outlines the current and expected TRL level and some of the anticipated and experienced challenges in gathering data for this model. This section will be updated in subsequent versions of these deliverables to identify lessons learned and feedback on the model's development as components of the LDT solution.

6.1 Energy Data Models

6.1.1 District Heating Load Forecasting Model

Description

The DTU Load Forecasting model provides point forecasts for district heating loads with a pre-specified set of time horizons. The model relies on heat load data, numerical weather forecasts and optionally weather observations to forecast heat loads. Forecast reconciliation across time horizons will be used to improve model accuracy and improve existing forecast capabilities.

To enable forecasting, input data should include building meter data for heat loads at the finest available temporal solution up to 15 minutes or an hour. Numerical weather predictions are important regressors for the model and should be included. Existing historical forecasts provided by district heating operators are important for use in forecast reconciliation and model validation.

Available Data and State of the Model Currently

A prototype model has been developed and is ready for data integration. It is implemented as a Python package based on the onlineforecast framework (Bacher et al., 2023), which supports features such as regressor transformations, RLS fitting, and hyperparameter optimization. Ongoing discussions with CDK aim to retrieve necessary data, including an extended historical dataset and load forecasts from Kredsløb, which will be combined with historical Numerical Weather Predictions (NWPs). Further development is planned, including the implementation of temporal hierarchy models as proposed in the literature (e.g., Bergsteinsson et al., 2021), alongside exploring additional methods under consideration.

The currently available data includes district heating metre data from Kredsløb and information from 28 public buildings. However, additional data is required to enhance the analysis, including a significantly extended historical dataset and historical NWPs.

Further development and testing are expected to take approximately three months following data acquisition.

Potential Use Cases
The model aims to improve forecast accuracy, facilitate lower supply temperatures in district heating systems, enhance overall energy efficiency, and contribute to reducing greenhouse gas emissions.

We aim to implement the model for use by Kredsløb, potentially through the development of an API and hosting by CDK. The model may be useful for other district heating suppliers.

Current TRL and Expected TRL Timeline (High level)
The prototype enhances overall energy efficiency, and contributes to reducing greenhouse gas emissions. It is currently at a prototype stage (TRL 3) and the targeted TRL is 8.

Challenges in gathering data
The currently available data is prohibitively restricted in its historical extent, significantly reducing its useability. Furthermore, historical heat load forecasts may not be available from Kredsløb which would limit the use of forecast reconciliation in temporal hierarchies. Discussions with AAKS, CDK and Kredsløb are in progress, to retrieve data for additional buildings, and by request for the load forecasting model, extended history and if possible historical forecasts.

6.1.2 District Heating Testbed Model

Description
The DTU model is a digital twin of a neighbourhood with buildings and a district heating network. It can be used as a virtual testbed for virtual experiments to develop e.g., optimal retrofitting strategies, control strategies, scenario analysis, etc. The model can be used to optimise the operation of heating consumption in buildings and the operation of the district heating system in the Aarhus pilot site, e.g., to reduce flow temperature, reduce heat consumption, and peak demand reduction.

Available Data and State of the Model Currently
The data required for our analysis includes heating consumption data (specifically flow and temperature), building floor area, number of residents, building construction year, and detailed district heating network data (including length, flow, and temperature). We have recently initiated discussions around this model within the BIPED project team and are now in the preparatory phase of formally requesting this data from the relevant stakeholders. Acquiring this data is critical for refining the model and ensuring that our evaluations and simulations align with real-world conditions.

Potential Use Cases
The data can optimise heating consumption in buildings and enhance the operation of the district heating system at the Aarhus pilot site, benefiting utilities, building owners, and residents. By analysing parameters such as flow and temperature, and building characteristics, the model can drive key improvements, including reducing flow temperature, minimizing heat consumption, and managing peak demand. This enables utilities to improve efficiency, building owners to reduce operational costs, and residents to enjoy more sustainable and cost-effective heating solutions.

The model can also be used for real-time control in collaboration with heat substation managers.

Current TRL and Expected TRL Timeline (High level)
Model has already been tested in other pilots with TRL 4. The targeted TRL is 8.

Challenges in gathering data
As we have recently initiated discussions on data gathering for this specific model, no data challenges have been identified at this stage.

6.1.3 Model for Energy Analysis of Positive Energy Districts

Description
The MAPED (Model for Energy Analysis of Positive Energy Districts) is a bottom-up rapid energy assessment tool designed to model the annual energy demand and supply of urban districts. It evaluates a district's potential to achieve a positive energy balance by considering local renewable energy sources (RES) and its interaction with the regional energy system. Using an end-use approach, the model calculates the final energy demand of a district based on demographic, social, and technological data, making it a valuable tool for planning and optimising energy systems in urban areas.

Available Data and State of the Model Currently
The model application starts with the description of a base year district energy demand and supply, e.g., 2024. For that a set of district specific data are needed covering: demographic, current energy balance by sector and fuel, building specification (household and service), local RE potential, Demographic and social data, Technological data (e.g., energy efficiencies, fuel penetration rates). Detailed descriptions of the needed data are provided in an Energy Data Template as agreed in WP2. The status of data availability is being checked with the owners of the demo sites. Some data can be collected from the open statistics of the city (demographical, social, economics). Other technical data including the current energy balance needs direct contribution from the local stakeholders.

Potential Use Cases
One use case for each demo site consists of base year reconstruction and developing a district transformation pathway (clean energy transition scenario) to transform the district towards PED with positive annual energy balance. The scenarios are crafted in co-creation with the local stakeholders.

Current TRL and Expected TRL Timeline (High level)
Current TRL: 6, expected TRL: 7-8 in 2026.

Challenges in gathering data
- Data related to real district energy balance by sector (building and mobility) and fuel type is not readily available and needs support from local stakeholders (energy supplier, energy bill,...) and citizens (privacy concern).
- Social and technical data needs official references which are only available at city scale.
- Data related to scenario assumptions (socio-economic and technical drivers) needs several runs and discussion with the key stakeholder to justify them and ensure consistency and plausibility.

6.2 Mobility Data Models

6.2.1 RT Traffic Model

Description

The Traffic Model provides a macroscopic (city wide) simulation of traffic patterns within the city and supports the creation of "what-if" scenarios to model the impact of changes such as road closures or reduced traffic in specific areas. It relies on calibration data, a precise origin-destination (OD) matrix, and demographic information for accuracy. The model is under development, with Version 1 complete, a more detailed Version 2 expected in April, and Version 2.1—featuring full calibration—dependent on acquiring the necessary data from Innoconnect. In conjunction with the Enviroanalyst tool, the model can estimate emissions and energy consumption caused by traffic, linking these calculations to proposed scenarios. Additionally, it is capable of providing detailed and precise analyses for specific areas of interest, enhancing its value for urban planning and environmental assessments.

Available Data and State of the Model Currently

The traffic model was developed using a variety of data sources. The foundational traffic network was derived from OpenStreetMap, a publicly available dataset. However, significant modifications were necessary to make the network functional for the traffic model. These adjustments included incorporating features such as one-way streets and motorway on-ramps. Since the extracted network primarily consisted of main streets, additional streets had to be manually added to enhance the network. Despite these efforts, the final network remains less dense than desired. Plans are already in place to develop a second version with increased density, particularly in the area of Brabrand region.

The second data source used for the traffic model was the Origin-Destination (OD) matrix, obtained through the TomTom platform. While this platform is not free, the City of Aarhus has access to it. The OD matrix was generated directly within the TomTom platform, using hexagonal zones as the basis for the analysis. The data is derived from SIM cards embedded in vehicles by default, as well as records from transportation companies like Amazon. However, the TomTom platform's overall data coverage ranges between 15-25%, limiting the accuracy of the data.

Currently, the traffic model is fully operational and can be used to simulate traffic scenarios. Nevertheless, plans are underway to develop a more refined version of the model with increased density. Future steps also include calibration of the model, though the availability of suitable data for this process remains a challenge. To address this, ongoing discussions are taking place among RoadTwin, Innoconnect, and the City of Aarhus to identify and secure the necessary data.

Potential Use Cases

As mentioned earlier, the traffic model can be used to simulate "what-if" scenarios, allowing users to explore various traffic conditions. These scenarios can be customised by the user and typically involve closures of specific segments, restrictions on certain road sections or junctions (e.g., turn prohibitions), or modifications to traffic sources and targets. For instance, reducing or increasing traffic generation in specific areas can simulate local traffic changes. While these adjustments are usually localized, they often have broader impacts on surrounding areas or even the entire city.

Additionally, when integrated with the Enviroanalyst tool, the model can calculate emissions and energy consumption for the entire scenario, providing insights into environmental and energy implications of the proposed traffic changes.

Current TRL and Expected TRL Timeline (High level)
Current TRL: 8
Expected TRL: 9

Challenges in gathering data
Initially, the plan for the traffic model was to leverage the existing model owned by the City of Aarhus. This model is built on a more comprehensive and precise dataset and is typically calibrated, resulting in significantly more accurate outcomes. During the early stages of development, efforts were made to acquire access to this model. However, it was discovered that the city does not directly own the model and it is owned by the company that developed it. As a result, the city was unable to provide access, necessitating the creation of an entirely new model based on the available data sources, as previously described.

Data-related challenges persist, particularly due to the need for calibration data. While the City of Aarhus operates sensors capable of measuring vehicle flow using Bluetooth technology, these sensors are currently not providing any usable data, further complicating the calibration process.

6.2.2 Traffic Enviro Analyst - Energy & Emissions

Description
The Traffic Enviro Analyst - Energy model calculates the energy consumption of traffic using data from a macroscopic traffic model provided by RoadTwin. It analyses traffic flows on road segments and considers the share of different propulsion types, such as electric, hybrid, and conventional vehicles. It enables energy consumption assessments for specific areas of interest, contributing to defining the energy positivity of a district. Designed for city planners, the model is intended for integration with RoadTwin software and can be hosted on UWB or RT development servers. Its operation depends on the macroscopic traffic model produced by RoadTwin, ensuring robust and comprehensive energy analysis for urban mobility systems.

Available Data and State of the Model Currently
The model is in the prototype phase (v 1.0) by the end of the year 2024, when this deliverable is due. It means it calculates overall traffic energy consumption of a selected traffic scenario calculated by the RoadTwin Traffic model.

The data needed is:

- Macroscopic traffic model (provided RT)
- Share of propulsion types (provided by AAKS)

Potential Use Cases
The model can provide support for potential use cases defined upon user requirements described in D2.1:

- UR-1.1DM: As a Decision Maker, I want to know what influence a considered measure will have on the traffic itself, on traffic energy consumption and on the traffic environmental impact so that I can consider alternative measures and select the optimal one.
- UR-5.1CE: As a Community Engagement Officer, I need a visualisation tool that I can use in participatory processes with citizens to clarify planning measures, e.g. compare designs.

Current TRL and Expected TRL Timeline (High level)

The future development plan is as follows:

- Traffic Enviro Analyst v 1.1; due 2025/01:
  - Integration with main development branch of RoadTwin SW
  - RoadTwin SW API enriched by overall Energy Consumption attribute
- Traffic Enviro Analyst v 1.2; due 2025/04:
  - Implementation of Energy Consumption calculation per propulsion type
  - RoadTwin SW API enriched by Energy Consumption per propulsion type attributes
- Next foreseen development lies in supporting particularly defined User scenarios - potential lies in calculation of traffic pollution or in calculation of energy consumption/traffic pollution in a specified area(s).

The model is currently under development, with TRL 3 achieved ~ prototype, TRL 4 expected by January 2025, and further advancements to TRL 6-7 planned by the end of the project.

Challenges in gathering data

Same as for the underlying traffic model (see corresponding paragraph in section 6.2.1) - data for proper calibration is needed to produce relevant outputs.

6.3 Cross Sectoral Data Model

6.3.1 Indoor Climate Model

Description

The DTU Indoor Climate Model is designed to provide both live and long-term evaluations of indoor environments, offering quality labels based on data analysis. By integrating time-series readings of indoor environmental data and user feedback, the model aims to assess for secure transmission of model results must be developed ad hoc, which can be executed quickly within one month from the "go."

This model supports key objectives such as human-in-the-loop building control, adapting to dynamic energy prices, and evaluating sustainability aspects in PEDs. It is intended for use by various stakeholders, including citizens, developers, architects, and city planners, and can integrate with partners' platforms and sensors for a more comprehensive evaluation.

Available Data and State of the Model Currently

Currently, the model utilises indoor environmental data points collected through sensors, along with user feedback as a key input. However, the API required for transmitting the model results securely has not yet been implemented, though its development is

straightforward and can be completed rapidly once initiated. The deployment of sensors and partner platform integration are critical components of the current setup.

Potential Use Cases
The indoor climate model has significant potential applications, including enabling and improving the indoor climate effectively. To facilitate real-time applications, an API human-in-the-loop building control for optimised comfort and energy use, responding dynamically to fluctuating energy prices, and assessing sustainability aspects in PEDs. These functionalities can aid various stakeholders, such as city planners in urban development, architects in designing energy-efficient buildings, and citizens seeking improved indoor climate conditions.

Current TRL and Expected TRL Timeline (High level)
The current TRL of the Comfort model is 5, and the expected TRL is 7-8.

Challenges in gathering data
There is a challenge in gathering indoor climate data due to being part of Building Management Systems (BMS) which is not available to the outside usually, and additional sensors are required to collect this sort of data.

The other challenge is getting continuous feedback from users, as there is willingness to share feedback at the beginning, but over time, users refuse to provide further input.

6.3.2 Building Occupancy Model

Description
The Building Occupancy Model aims to compute occupancy rates in buildings based on the demographic and economic characteristics of households, as well as land use patterns within a given area. Depending on data at hand and its level of granularity, the model aims to generate occupancy rates for different times of the day, days of the week (including distinctions between weekdays and weekends), and months (accounting for public holidays). These occupancy rates are correlated with energy consumption peaks, providing insights into usage patterns and demand fluctuations.

Available Data and State of the Model Currently
Based on our BIPED data sheet, initial data sets have been selected based on interest in the model as suggested by relevant literature and on suspected ease of accessibility. In doing so following data sets have been discussed and are currently in preparation from Aarhus municipality.

Demographic data:
- Age
- Gender
- Citizenship
- EU/non-EU
- Western/Non-Western
- Address cell coordinates

Housing distribution data :

- Municipality rented housing

- Private rented housing
- Privately own housing
- Other type housing

Currently under development, the model is planned for completion as part of Deliverable 2.3 by the end of 2025.

Potential Use Cases
The model aims to detect and potentially predict energy demand peaks in different areas and at different times within Brabrand. Such information is useful to the energy provider to take informed action.

Current TRL and Expected TRL Timeline (High level)
Currently under development, and discussing highly exploratory properties that have not been involved in past and ongoing PED discussions, the model is on TRL2 and aims to reach TRL 6-7 by the end of the project.

Challenges in gathering data
Accessing data constitutes a significant challenge for the occupancy model:

- The model includes data from different domains coming from various sources and hence, in a municipality, including different departments. Finding the right contacts that can help in providing access to the data has been time consuming in the beginning.
- As the model includes properties from social, economic and environmental domains, such as demographics and education levels, preparatory steps need to be taken not to harm any GDPR guidelines. Hence, data needs to be preprocessed first and aggregated so no privacy issues will result from the established model.

6.3.3 Climate Risk Model

Description
The DTU Climate Risk model provides climate risk assessments for critical infrastructure, focusing on roads and bridges at this stage. It supports strategic asset maintenance and operational budget planning for asset owners and maintainers by identifying risks linked to climate impacts. The model uses road segment data, historical and current road condition information, road properties, budget plans for maintenance, and climate data. A first version has been developed, and it can be iteratively enhanced by incorporating additional road property data and map referencing. This cross-sectoral use case aligns with Task 2.4 and can eventually be expanded to include other critical infrastructure. Acting as a monitoring tool, the model introduces a new categorisation of asset conditions, enabling prioritised maintenance and cost savings for asset managers. It can be hosted independently and integrated with external platforms. The model depends on data from Aarhus's road department and includes a potential "human-in-the-loop" concept, allowing it to evolve through practitioner feedback on road defects and the impact of weather and other factors.

Available Data and State of the Model Currently
The Climate Risk model requires a variety of data sources. Climate data, hydrological and road data are those that need to be added in order to make this solution work.

Climate data forms a fundamental input for the Climate Risk model, providing essential environmental parameters that influence infrastructure resilience. This data can be obtained from the Danish Meteorological Institute (DMI) through an open Application Programming Interface (API), listed below.

Climate data:

- Precipitation
- Temperature
- Frost days

Similarly, the hydrological data play a crucial role for our integration of the model with below needed data.

hydrological data:

- Sea-level rise
- Flood mapping
- Extreme precipitation

In order to have a use case, Road data is necessary for the Climate Risk model, as it directly relates to the physical infrastructure under analysis. This dataset must be provided by relevant municipal authorities or road owners and include below data.

Road data:

- Road attributes
- Road mapping (segments, Ids,..)
- Road and Hazard Condition

Currently, the model operates at an initial operational level, demonstrating the capability to generate predictions based on the provided climate and hydrological data, alongside with dummy road condition data. While the model offers a framework for assessing road deterioration, its accuracy and predictive power can be significantly enhanced through the incorporation of comprehensive historical datasets.

Specifically, integrating extensive historical data from both climate and road condition records will allow the model to establish more accurate correlations between road deterioration patterns and preventive maintenance strategies. This maturation process is critical to refining the model's predictive capabilities and ensuring its effectiveness in supporting infrastructure.

Potential Use Cases

There are three use cases on cost saving, reduction of carbon emission, and increase of asset lifespan via climate risk model listed below:

UR-2.4.1CR: As a Municipality Planner, I want to compare historical road repair data with predictive maintenance outcomes so that I can highlight cost savings from proactive maintenance versus reactive repairs and recommend cost-effective strategies.

UR-2.4.2CR: As an Environmental Manager, I want to assess the impact of targeted maintenance actions on carbon emissions so that I can promote sustainability initiatives and reduce the environmental footprint of road operations.

UR-2.4.3CR: As an Infrastructure Manager, I want to quantify the potential increase in road lifespan by analysing historical data, so that I can allocate maintenance resources efficiently and improve the durability of road infrastructure.

Current TRL and Expected TRL Timeline (High level)

The current TRL level is 5 with a ready Minimum Viable Product (MVP), and a ready model, and it is aimed for TRL level 8.

Challenges in gathering data

As previously noted, there are several challenges associated with data gathering, particularly concerning critical aspects of road data. To ensure the model's effectiveness, it is essential to have access to both live and historical data regarding road conditions. This includes detailed information on road segments and map-referencing attributes.

Additionally, historical budget planning data specific to the road segments must be collected. This information is crucial for evaluating the accuracy and efficiency of past maintenance activities, thereby supporting the optimisation of future planning efforts.

The inclusion of data on material usage and costs is equally important, as these factors play a significant role in both environmental considerations and achieving cost-saving objectives. Understanding how materials are utilised and their associated costs can inform sustainable and economically efficient maintenance practices.

Finally, for future enhancements, it is recommended to incorporate environmental data related to the maintenance process. This includes metrics such as carbon emissions and the environmental impact of specific maintenance actions. Such data will not only support sustainability goals but also provide a more comprehensive understanding of the broader implications of maintenance strategies.

7. Conclusion

Since Deliverable 4.1, significant progress has been made in the Monitoring & Evaluation (M&E) framework development for the BIPED project. Key developments incorporated in Deliverable 4.3 include the hosting of an in-person KPI workshop, the BIPED modelling and technical workshop, and the development of a multi-criteria analysis for project KPIs. These advancements have led to the finalisation of KPIs and the assignment of KPI ownership, as well as the determination of data collection ownership and data collection methodology ownership.

The systematic approach established by the M&E framework is designed to continuously assess project effectiveness, identify areas for improvement, and ensure that project activities remain aligned with the overarching goals and objectives of BIPED. By leveraging a comprehensive evaluation strategy that combines both qualitative and quantitative methods, the framework supports informed decision-making and effective project management. This dual approach also facilitates the population of the Smart City Information System's Self Reporting Tool, ensuring accurate and consistent collection of KPI data throughout the project's duration.

A significant advancement presented at the KPI workshop in Copenhagen was the development of a multi-criteria analysis (MCA) approach for weighting the KPIs. This methodology provides a structured framework for prioritising and evaluating KPIs, ensuring that the most critical aspects of the project are given appropriate emphasis. The MCA approach will be informed by the project use cases, which will be confirmed in the second year of the project. This ensures that the KPI weighting is directly aligned with the practical applications and outcomes expected from the project, thereby enhancing the relevance and impact of the M&E framework.

The insights gathered during the in-person KPI workshop and the BIPED modelling and technical workshop highlighted that the data models were not at the requisite level to commit to certain KPIs. As a result, the KPIs and their themes were adjusted to better reflect the current state of data models and their development needs. Building on this deliverable in M12 of the project, D4.3 showcases the development of the M&E Framework and KPIs in establishing a number of metrics and parameters that need to be monitored under the theme of Community Engagement, Energy & Mobility, and Digital Solutions. This collaborative approach ensured that the BIPED team could refine the KPIs to be more achievable, given the existing data capabilities and the requirements for further model development. As a result of the ongoing development of the BIPED data models, the BIPED Evaluation Forum will proceed in year two of the project as application of the models begin to take place in Brabrand and data can begin to be gathered and analysed.

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9. Annex

Annex 1: Activity Evaluation Form (AEF)

Number	Topic	Item	Answer
Title & Abstract			
S1	Project Activity Title	Name of Activity	
S2	Activity Description	Brief Description of the Project Activity	
S3	Motivation and Rationale	Purpose of the intervention, issues addressed by the intervention	
S4	Project partners and WP involved	List of all partners involved in the activity	
S5	Relevant KPI	KPI Number	
S6	Attendance Numbers (if applicable)		
Methods			
S7	Data Collection	Description of instruments (e.g. interview guides questionnaires, minutes)	
S8	Quantitative Data Collection	Any data captured for KPI or monitoring purposes and provide link if available	
S9	Qualitative Data Collection	Any descriptive data/information captured with regards to the project activity - challenges, solutions, experience etc. (Provide link if available)	

S10	Data Processing	Methods for processing data prior to and during analysis, including transcription, data entry, data management - where is the data captured/stored? How can it be accessed for M&E purposes?	
S11	Opportunities (Methods)	Did any method or practise you employed led to a better outcome, or caused any difficulties?	
Results/Findings			
S12	Challenges Faced	Brief description of challenges / stumbling blocks / unforeseen issues	
S13	Solutions developed (or under development)	Brief description of how the above mentioned were addressed	
Discussion			
S14	Key insights highlighted	Summarised (qualitative) evaluation of the activity/event. What were the key insights highlighted? Key questions/issues raised? Key solutions developed?	
S15	Key recommendations for replication of activity	How can things be improved for future activities of the same kind? Apart from this activity, how can other activities under the same theme benefit	

		from the key insights highlighted?	
S16	Next Steps	What still needs to be addressed, and how would it contribute to the success of the activity/intervention?	
S17	Relevant documentation / deliverable	Has this project been explained/described in a document/deliverable?	
S18	Sustainability	Is this activity something you are planning to continue after BIPED finishes? And why?	

Annex 2: Original KPIs from D4.1

KPI No.	Name	Description	KPI Group	Target	Reporting Frequency
1	Number of community participation events organised/coordinated	The role of community participation events is to enable local communities to have a greater understanding of the Digital Twin solution. Community participation events refer to events such as learning workshops, joint exhibitions or event participation and other events promoting the project and its outcomes. By tracking the community participation events and evaluating their outcomes, you can gauge the level of community engagement within the project and make informed decisions to enhance participation and collaboration.	Community Engagement	10	Quarterly
2	Number of Co-Creation & Training Workshops	BIPED will conduct a number of co-creation & training workshops which will involve key stakeholders identified by AAKS. The co-creation workshops Co-will focus on collaborating with key stakeholders to guide the design process of the Digital Twin solution and other BIPED interventions. The training workshops will be commenced upon completion of the Digital Twin solution and will involve the same key stakeholders and train them in the use of the Digital Twin solution.	Community Engagement	3	Bi-Annual
3	Workshop participants	By systematically measuring stakeholder engagement through workshops and evaluating participation levels, engagement, and outcomes, you can assess the effectiveness of your engagement efforts and ensure that stakeholder perspectives are considered in project decision-making and implementation.	Community Engagement	400	Quarterly

4	Networks/Associations Targeted	Through engagement with smart city networks such as SCC1 Monitoring & Evaluation Task Group, BIPED can engage with networks and associations focusing on smart city and digital twin projects which share common goals and objectives. Engaging with these networks/associations will give BIPED expertise into digital twin/smart city experiences which will help the project navigate potential challenges.	Community Engagement	30	Quarterly
5	EU Cities Engaged	BIPED will showcase the digital solution and engage with 100 cities via the Net Zero Cities project supporting the EU's Mission of "100 Climate-Neutral and Smart Cities by 2030" newly-launched as part of the Horizon Europe programme. The project works as a service-oriented platform supported by world-class practitioners. It helps European cities by providing them with the support and solutions they need to achieve their Net Zero goals.	Community Engagement	100	Bi-Annual
6	Joint Actions with 'Sister Projects'	Through participation in smart city networks such as SCC1 Monitoring & Evaluation Task Group, BIPED can engage with 'sister projects' in the digital twin/smart city sphere. Through this network, BIPED can carry out joint actions with 'sister projects' for the digital twin solution By systematically measuring joint actions with other projects, BIPED can evaluate collaboration in terms of alignment, impact, benefits, challenges, and lessons learned when implementing a digital twin solution across different environments/settings.	Community Engagement	3	Bi-Annual
7	Increased Citizen Understanding and Awareness of the potential of Digital Twin projects	This KPI aims to measure the initial citizen awareness of digital twins and the nature of how they operate. Through the lifecycle of the project, BIPED will aim to raise this awareness through bi-annual workshops, focus	Community Engagement	3 (On Likert Scale 1-5)	Bi-Annual

		groups and questionnaires with citizens and track the potential increase in awareness via BIPED's efforts and the wider digital twin landscape and awareness of the potential socio-economic impacts of the digital twin solution.			
8	Policy Results Downloads	This will involve monitoring the volume of downloads of policy documents and project deliverables which are accessible to the public from the BIPED website.	Community Engagement	500	Bi-Annual
9	Media Coverage (News Articles, News Videos) of BIPED Project	KPI Nine assesses the frequency and breadth of media attention, reflecting the project's visibility and public awareness, vital for garnering support and replicability of the Digital Twin solution	Community Engagement	10	Bi-Annual
10	Usability of the Digital Twin Solution for End Users	The extent to which the solution is perceived as difficult to understand and use for potential end-users. It is presumed that a smart city solution that is easy to use and understand will be more likely adopted than a difficult solution.	Policy Context	TBD	Bi-Annual /Annual
11	Changes in Planning	Measure and analyse the effectiveness of the AI BIPED platform for defining the energy profile of a city and for making data-supported decisions and make improvements to AI and other modules	Policy Context	300	Annual
12	Number of Aarhus City Council Staff Trained to use the Digital Twin	This KPI tracks the training of the developed digital twin through the number of city council staff that have received training for the tool. The staff trained will be able to operate the digital twin and its functions to assist with analysis of and reporting on project implementation, baseline development feasibility studies and general use.	Energy Consumption	40	Annual

13	Tonnes of CO_2-equivalent emissions reduction per year via utilisation of the Digital Twin solution	The indicator measures the reduction in CO_2-equivalent emissions as a result of the use of the Digital Twin Solution developed by the BIPED project. The reduction is based on the CO_2-equivalent emission baseline compared to the reduced emission through the Digital Twin. The reduction is based on the CO_2-equivalent emissions calculated through measurements and models for the different constituent components as detailed in the BEST tables.	Energy Consumption	TBD	Annual
14	Number of stakeholders/buildings/assets utilising the Digital Twin Solution	This KPI tracks the uptake of the market by the number of stakeholders/buildings which are able and technically equipped to adopt the digital twin solution.	Energy Consumption	TBD	Bi-Annual
15	Progress towards development of a PED	In collaboration with WP2, KPMG will develop a methodology for measuring the progress towards development of a PED. This KPI will be updated in the next iteration of this deliverable.	Energy Consumption	TBD	Annual
16	Energy Savings for Key Stakeholders via Implementation/Uptake of the Digital Twin Solution	The reduction of the energy consumption to reach the same services (e.g., comfort levels) after the implementation/uptake of the Digital Twin solution, taking into consideration the energy consumption from a reference period.	Energy Consumption	TBD	Bi-Annual
17	Improved Interoperability of the Digital Twin Solution	Interoperability is the ability of a system (or product) to work with other systems by providing services to and accepting services from other systems and to use the services so exchanged to enable them to operate together (ISO/TS 37151). The indicator assesses the improvement in interoperability in a qualitative manner.	Energy Consumption	TBD	Bi-Annual
18	Increase in Local Renewable Energy Generation via implementation of the Digital Twin Solution	The share of Renewable Energy production in itself gives an idea of the rate of self-consumption of locally produced energy, which is an indicator of the flexibility potential of the local energy system. The indicator accounts	Energy Consumption	TBD	Monthly

		for the increase of renewable energy generation due to the intervention.			
19	Demonstrations of the Digital Twin Solution/Platform	By systematically measuring demonstrations held of the Digital Twin and evaluating feedback and impact, you can assess the effectiveness of the solution and refine the solution to ensure an interoperable solution.	ICT Digital Solutions	TBD	Monthly
20	Datasets Published	Publication of open datasets for use by third parties.	ICT Digital Solutions	5	Bi-Annual
21	Models Linked to PED Published	Publication of models for use by third parties.	ICT Digital Solutions	3	Bi-Annual
22	Usage of Open Source Software and Solutions	The use of open source software and solutions means less possibilities of vendor lock-in and more space for communities to develop smart city solutions. It also lowers the software costs.	ICT Digital Solutions	TBD	Monthly
23	Quality of Open Data	Percentage of data that uses DCAT standards. The quality of open data is better if standardised. Processes get easier when data standards are applied. The DCAT standard allows municipal employees to produce data in a standardised way.	ICT Digital Solutions	TBD	Monthly
24	Soft Datasets Integrated	Capture and integrate soft (intangible) data into the BIPED Digital Twin platform which goes beyond tangible energy and mobility sources to better understand how spaces and policies affect people's behaviours etc.	ICT Digital Solutions	TBD	Monthly

Annex 3: KPI Data Collection Sheet

Classification & KPI Information	Example Input Fields
Theme	
KPI Number	
Definition	
KPI Owner	
KPI technical expert	
Data Type and Format	
Data Source/Provenance	Existing data - third party provided / Existing data owned by BIPED partner / New data to be collected by a BIPED partner
Unit of Measurement	
Scope	
Year of Data	
Considerations	
Expected Impact / Target	
KPI Share	
Size	
Data utility outside BIPED	
Quality and Validity	
Statistics Data	
ISO Applied	
Lineage	
Disclosure Control Methods (e.g. GDPR)	
Quality Issues	
KPI Owner / Organisation	
Organisation Name	
Email Address	

Responsible Party Role	
Telephone Number	
Resource Locator	
KPI Owner Approval	
Data Owner / Organisation	
Organisation Name	
Email Address	
Responsible Party Role	
Telephone Number	
Resource Locator	
Where stored	
Additional Solutions Providers / KPI technical experts	
Organisation Name	
Email Address	
Responsible Party Role	
Telephone Number	
Resource Locator	
Temporal	
Temporal Extent	
Frequency of Update	
Frequency of SCIS Update	
Dataset Reference Date	
Planned Date of Implementation	
Actual Date of Implementation	
Monitoring Start Date	
Geographic	
Geography / Spatial Scale	

Spatial Reference System	
Location	
Data Provider and Constraints	
Limitations on Public Access	
Use Constraints	
Licence Type	
Data Provider Name	
Email Address	
Telephone Number	
Resource Locator	
Where stored	
Conformity	
Conformity	
Metadata	
Metadata Date	
Metadata Language	
Metadata Point of Contact	
Unique Resource Identifier	
Resource Type	
Dataset Language	
Search Keywords	
Interoperability Best Practice	
Vocabularies / Ontologies	
GDPR	
Personal Data	Yes/No
Special categories of personal data	(personal data revealing racial or ethnic origin, political opinions, religious or philosophical beliefs, or trade union membership, and the processing of genetic data, biometric data for the purpose of uniquely identifying a natural person, data concerning health or data concerning a natural person's sex life or sexual orientation)

Mixed data	(personal and non-personal data in one dataset)
Anonymisation/ pseudonymisation	(personal and non-personal data in one dataset)
Artificial Intelligence	
AI elements in the model/tool	yes/no, describe
Data used to train a model	yes/no, describe
Ethical	
Ethical considerations/limitations	
Envisaged combination with other data/sets/models	

Annex 4: KPI Data Dictionary

Term	Definition
Scope	The extent of the area or subject matter that something deals with.
Theme	The relevant project theme
KPI Number	A unique identifier for a specific Key Performance Indicator (KPI).
Definition	A clear and precise description of the KPI.
KPI Owner	The KPI owner takes the lead in the implementation, testing and monitoring of the project interventions. The KPI owners use the KPI framework created for the BIPED project to ensure that interventions are recorded and made available for analysis. The KPI owner will agree to the definition, description and calculation method of the KPIs, in cooperation with WP4. The KPI owner is responsible for implementing measures which will enable data to be captured, and providing this data in a suitable and agreed upon format, for example the M&E quantitative and qualitative data collection sheets, for reporting within the WP4 deliverables/updates and overall project reporting KPI owners are responsible for the completion of the data collection sheets according to the agreed upon reporting frequencies for each KPI and the partner responsible for the management and update of the SRT. Throughout the BIPED project the KPI owners will review the accuracy of data recorded and issue recommendations to the project consortium for adjusting the KPI definition and KPI calculations.
KPI technical experts	KPI technical experts are parties that act as complementary partners to KPI owners. KPI technical experts are specialists in their area/sector and provide technical support, tools and data to KPI owners which will assist in implementing project interventions. This support will contribute to the achievement of the KPI as well as providing trusted information which allows KPI owners to monitor and report on the data. KPI technical experts are responsible for the management of data from project interventions. KPI technical experts have the responsibility to handle data according to the Data Management Plan (DMP) and ensure that the handling of data adheres to best practice in data governance in accordance with protocols from Horizon Europe.

Data Type and Format	the data type (e.g. number, percentage etc) and how the data is presented in a certain format (e.g. CSV)
Data Source/Provenance	The origin of the data or where it was obtained.
Unit of Measurement	The standard unit in which the KPI is measured.
Associated Demonstration Project	A project/event that demonstrates the KPI in action.
Year of Data	The year in which the data was collected
Considerations	Factors or aspects that should be taken into account.
Expected Impact / Target	The anticipated impact of the KPI and the target to be reached.
KPI Share	The portion or percentage of the KPI that is shared across KPI owners.
Size	The magnitude or extent of the KPI or data.
Data Utility Outside BIPED	The usefulness or applicability of the data beyond the BIPED framework.
Quality and Validity	The degree to which the data is accurate, reliable, and valid.
Statistics Data	Data that has been collected for statistical analysis.
ISO Applied	Whether or not International Standards Organization (ISO) standards have been applied.
Lineage	The history or lifecycle of the data, including where it originated and how it has been altered over time.

Disclosure Control Methods (e.g. GDPR)	Methods used to control the disclosure of data, such as those outlined in the General Data Protection Regulation (GDPR).
Quality Issues	Any problems or issues related to the quality of the data.
KPI Owner / Organisation	The organisation that the KPI owner belongs to.
Organisation Name	The name of the organisation.
Email Address	The email address of the contact person in the organisation.
Responsible Party Role	The role of the person responsible for the data or KPI.
Telephone Number	The contact telephone number of the responsible party.
Resource Locator	The location where the resource can be found, often a URL.
KPI Owner Approval	Whether or not the KPI owner has approved the data or KPI.
Data Owner / Organisation	The organisation that the data owner belongs to.
Where Stored	The location where the data is stored.
Additional Solutions Providers	Any additional organisations providing solutions related to the data or KPI.
Temporal	Pertaining to time-related aspects of the data or KPI.
Temporal Extent	The time period that the data covers.
Frequency of	How often the data is updated.

Update	
Frequency of SCIS Update	How often the Smart Cities Information System (SCIS) is updated.
Dataset Reference Date	The date that the dataset refers to.
Planned Date of Implementation	The date when the implementation of the KPI or data usage is planned.
Actual Date of Implementation	The date when the implementation of the KPI or data usage actually occurred.
Monitoring Start Date	The date when monitoring of the KPI or data began.
Geographic	Pertaining to geographical aspects of the data or KPI.
Geography / Spatial Scale	The geographical area that the data covers.
Spatial Reference System	The coordinate system used to define geographical data.
Constraints	Any limitations or restrictions on the data or KPI.
Limitations on Public Access	Any restrictions on the public's access to the data.
Use Constraints	Any restrictions on how the data can be used.
Licence Type	The type of licence that governs the use of the data.
Conformity	Whether the data conforms to certain standards or expectations.
Metadata	Data that provides information about other data.
Metadata Date	The date when the metadata was created or last updated.

Metadata Language	The language in which the metadata is written.
Metadata Point of Contact	The person or organisation to contact for more information about the metadata.
Unique Resource Identifier	A unique identifier for the resource, often a URL.
Resource Type	The type of resource, such as a dataset, image, document, etc.
Dataset Language	The language in which the dataset is written.
Search Keywords	Keywords used to search for the data or resource.
Interoperability Best Practice	Best practices for ensuring that systems can work together (interoperate).
Vocabularies / Ontologies	Standardised vocabularies or ontologies used in the data.
GDPR	Pertaining to the General Data Protection Regulation, a regulation in EU law on data protection and privacy.
Personal Data	Data that relates to an identifiable individual.
Special Categories of Personal Data	Categories of personal data that are considered sensitive under the GDPR or similar.
Mixed Data	Data that includes a mix of different types of data.
Anonymisation/Pseudonymisation	The process of making data anonymous or pseudonymous to protect privacy.
Artificial Intelligence	The use of artificial intelligence in relation to the data or KPI.

AI Elements in the Model/Tool	Specific elements of artificial intelligence used in the model or tool.
Data Used to Train a Model	The data used to train a machine learning model.
Ethical	Pertaining to ethical considerations in relation to the data or KPI.
Ethical Considerations / Limitations	Any ethical considerations or limitations related to the data or KPI.
Envisaged Combination with Other Data/Sets/Models	Any plans to combine the data with other datasets or models.