# Deep-dive #3: Digital Twins and decision-making tools for PED

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# 1 Introduction & Background

The Positive Energy Districts Transition Pathway (PED TP) is one of three thematic priorities of the Driving Urban Transitions Partnership (DUT) and builds on the PED Programme as a joint initiative between the SET Plan and JPI Urban Europe. In this context, five transnational calls have been launched so far[1], with 25 R&I projects working on the strategic and operational development of the PED concept. It is a central ambition of DUT to synthesise outcomes of the different projects, promote exchange and cooperation between them and stimulate the conceptual discourse in perspective of delivering substantial inputs for Europe's ambition of becoming climate-neutral (Green Deal, Cities Mission).

At the DUT projects meeting in Brussels in April 2024, many project partners clearly expressed a need for thematic exchange between PED. The **PED Thematic Deep-Dives** have been set up as a series of thematic exchanges between the JPI UE- and DUT-funded PED projects – they represent an excellent opportunity to share insights, collaborate with fellow professionals, and explore best practices in the field of sustainable urban development. Furthermore, the PED Deep-Dives shall serve as a starting point for synthesising approaches, achievements and learnings in different areas from the PED projects. The PED Deep-Dive event series has been initiated and organised by the PED Expert Support Facility (ESF)[2], and takes place between December 2024 and May 2025 within the ESF and will be integrated into the new Knowledge Hub-function across all 3 pathways within DUT, and serves as a build-up to the PED Conference in autumn 2025:

| # | Deep-dive thematic area | Date |
|---|---|---|
| 1 | How to operationalise the PED Framework[3] | 6 Dec 24, 13:30-16:00 |
| 2 | Stakeholder engagement and social aspects | 6 Feb 25, 13:30-16:00 |
| 3 | Digital Twins and Decisionmaking tools for PED | 6 Mar 25, 13:30-16:00 |
| 4 | Flexibility Services and Climate Impact Assessment | 8 May 25, 13:30- 16:00 |
| 5 | Financial instruments: Framework and Business models | TBD |

The focus of this deep-dive was on digital tooling to design PEDs, to predict and control the energy flows in a PED and to monitor PEDs and evaluate their effectiveness. The first part of the session gave an overview of digital twins and decisionmaking tools followed by three pitches explaining how digital tools have been applied in the respective projects. This was followed by a roundtable discussion on how projects could use digital tools in decision-making processes and the roles of a PED within a city. All this to accelerate PED development **in relation to the Mission of 100 climate-neutral and smart cities by 2030**.

The recording of Deep-Dive one is available here.

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[1] as of January 2025

[2] The PED ESF is a panel of experts from JPI UE PED Call II projects, aiming at promoting cooperation between the projects and developing joint outcomes. It is operating from 2022 to 2025.

[3] PED Framework 3.0: A Policy Guide to Advance Positive Energy Districts in Europe | dut

# 2  Introduction to the topic

Establishing a PED requires the practitioner to reflect on its relationship to the outside world. Within the PED you have energy production, energy consumption and the potential for both efficiency and flexibility. Achieveing net zero greenhouse gas emissions and playing an active role in the energy system for achieving overall climate neutrality, one has to consider both the energy balance within the PED and the (energy) transport capacity between the PED and the outside world.

Decision-making tools offer structured approaches for evaluating options and making informed choices, and in this case they are helpful in understanding a PED in detail. This includes a better understanding of demand patterns, local generation capacity and the spontaneous simultaneity between thoose two. Decision-making tools also great for well informed discussions on PED boundaries and the art of balance keeping with controllable production, demand response, storage and interconnection / external dependency on different time resolutions.

A digital twin (DT) is a common decision-making tool for a PED and can be used in two major ways. One area of usage for a PED DT is to mirror physical counterparts in real-time, connected to real-world data and you can use it to test, implement and optimize control strategies. Another area of usage is planning & strategizing on a longer time frame, simulating backcast-driven goal-oriented or forecast-driven development scenarios. Something that is being discussed is however if or how good the DT is at capturing human behavior.

# 3  Project pitches

Within the deep dive four projects were invited to share their thoughts on digital twins and decision-making tools and how they approached these concepts within their project. The projects were chosen to represent diverse generations of PED calls funded projects with a strong focus on the topic of this deep-dive.

## 1.1FLEXPOSTS

A major challenge in PEDs are understanding & communications between the stakeholders that needs to be involved. Within the FLEXPOST project we asked ourself how we better could support that process, to get everyone involved on the line from A to the mission of climate neutrality with a clear plan, preparation for setbacks and a monitoring process ready. Within FLEXPOSTS, we have developed The Energy Transition Roadmap Toolbox, a new approach for supporting decision makers and increasing collaboration between stakeholders. The toolbox is highly modular and integrateable, i.e. a simple game can constitute an important step unlocking insights on difficulties related to energy transition and thus creating increased awareness by fun elements with an educational context. Another example is the We-Energy tool, helping the stakeholders in a PED choose between technologies to lower grid congestion, effectively showing impact and consequences of decisions made by the tool users. From FLEXPOSTS perspective the future for PEDs combine the digital twin and the decision-making process, relying on easily accessible and interactive planning tools integrating serious gaming, energy system modeling, map interface and data collection (see figure X).



**FIGURE 1. THE VISION OF A COMBINED DIGITAL TWIN AND DECISION-MAKING PROCESS FROM FLEXPOSTS PROJECT.**

# 1.2 DigitalTwin4PEDs

The aim of the DigitalTwin4PEDs project is to develop a Digital Twin (DT) for pilot areas, to apply the DT to generate scenarios and investigate new technological solutions with upscaling potential, to explore the potential of the DT to support stakeholder dialogue, decision-making, and simplify collaboration, and finally, to build transferrable knowledge that can be applied in other neighborhoods aiming for PEDs or energy communities regarding climate neutrality and energy efficiency. The project defined DT use cases across three pilot areas and integrated the DT in real projects, targeting planning support, quality assurance, energy simulation, and circularity. A framework and a prototype for a Digital Twin Viewer has been developed in close relationship with stakeholders including simulation of renovation packages and renewable energy production and optimizations balancing energy, climate impact, and costs. Challenges relate to data accessibility, ownership, and interoperability. Future recommendations include early integration of DT in the process to ensure alignment with urban development and design phases, to clarify governance and ownership, to promote interdisciplinary teams for the DT development and assurance of institutional uptake beyond project duration.
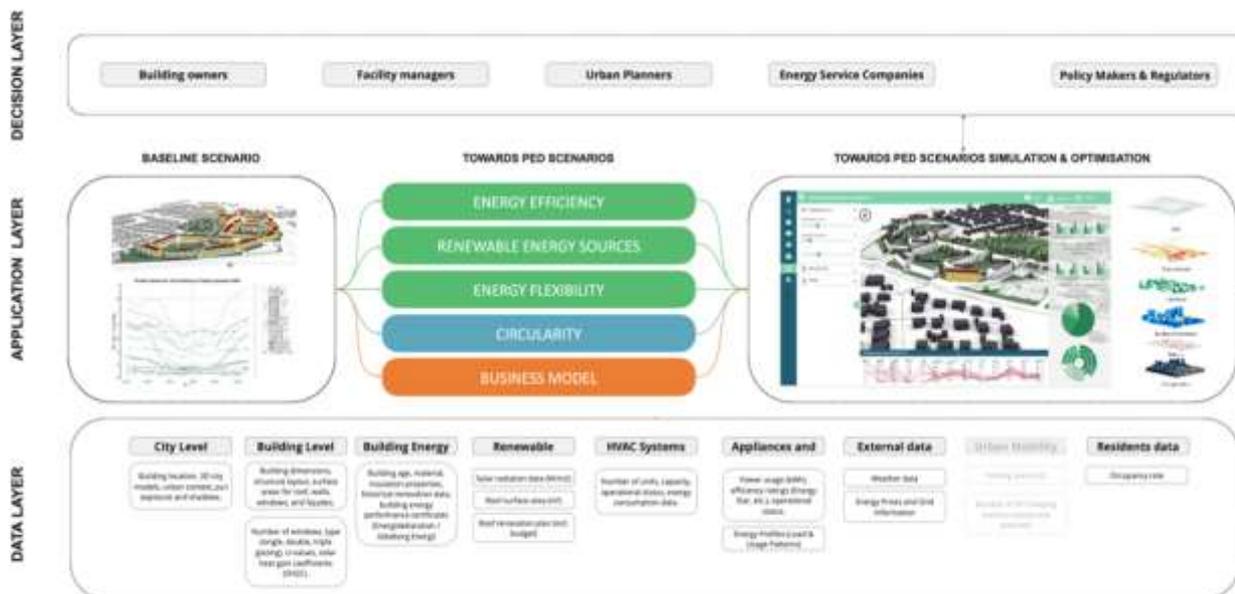


FIGURE 2. DIGITAL TWIN FRAMEWORK WITH THREE MAIN LAYERS: DATA LAYER, APPLICATION LAYER AND DECISION LAYER.

# 1.3 SynergyS

The SynergyS project's goal is to realize a marked-based control system for a *Smart Multi-Commodity Energy System*, tested in practice with physical assets with the motivation of increasing the share of intermittent renewable sources that requires better utilization of the flexibility in the energy system.

The SynergyS project successfully developed new local energy markets for electricity, hydrogen and heat – complementing existing wholesale markets. The markets has been developed with an agent-based design which was completely decoupled by using a centralized data platform. It was tested in practice using a combination of Digital Twins and physical assets. In the project two clusters were looked at, the first one

being an industrial area in Groningen Seaports and a residential area in Leeuwarden, individually first and then at potential synergies between the two areas. Unfortunately, both the areas showed to be a net producer and consumer of the same commodities, limiting the synergies in this specific real world example (see figure X).
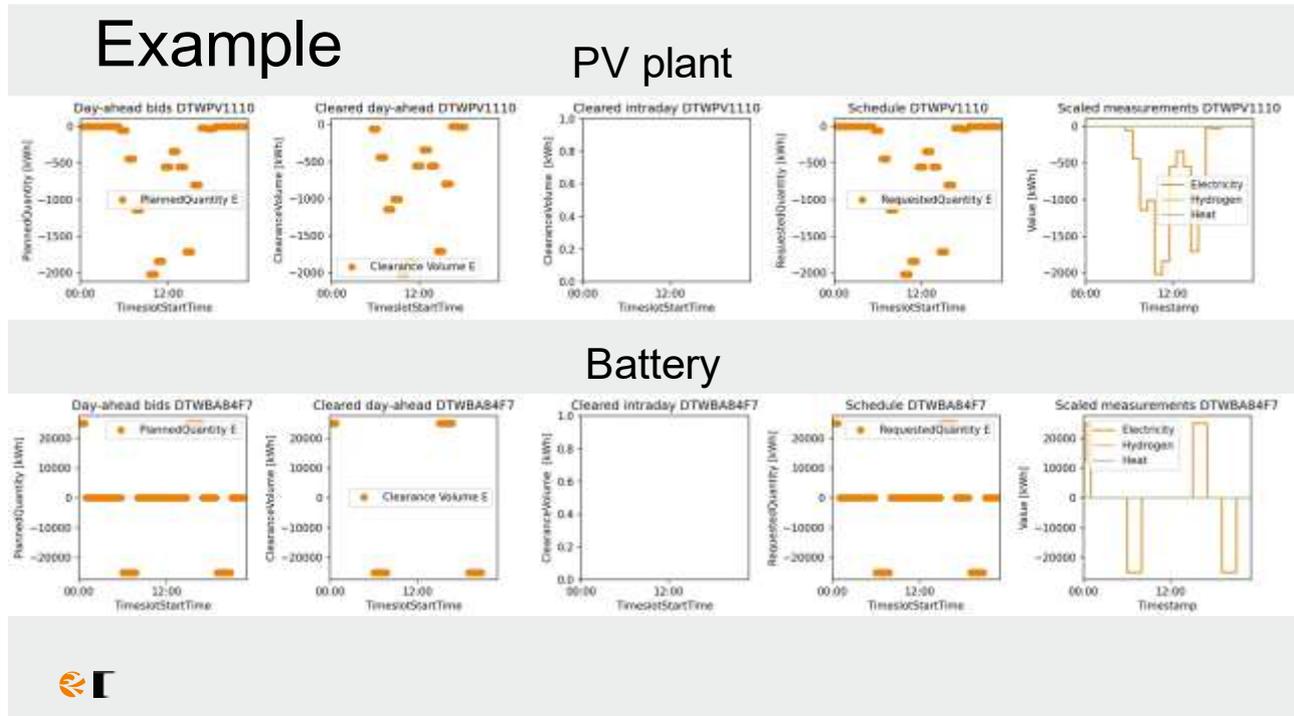


FIGURE 2. RESULTS ON POTENTIAL ENERGY RELATED SYNERGIES BETWEEN THE TWO CLUSTERS STUDIED IN THE SYNERGYS PROJECT.

# 1.4 DigiTwin4PEDs

In the DigiTwin4PEDs project, an urban digital twin platform to co-create PEDs with citizens is being developed. New data-driven methodologies to evaluate various energy flexibility scenarios based on user behaviour and assessing over energy balance has been developed, integrating the use of OGC-compliant components to ensure interoperability and standardization across energy simulation systems. The requirements for a UDT to support co-creation of PEDs is dependent on democratization of data access, including open data and easy to use tools. Interactive visualization of data is another central aspect being able to communicate and simulate different scenarios de-risking through foresight. A prototype for a DT has been developed for Stuttgart, integrating user scenario prototype (WIP), being able to test different load profile scenarios etc, identifying potential for efficiency and flexibility potential for different stakeholders and the synergies between them simultaneously.

**FIGURE 3.** INTERACTIVE VISUALIZATION OF DATA AND SCENARIOS FROM THE METHOD AND SOFTWARE DEVELOPED WITHIN THE DIGITTWIN4PEDS PROJECT.

# 4 Discussion

A central part of the DD#3 was the discussion in groups - breaking rooms – in which a set of three questions that have been facilitated to launch the dialogue with the participants.

- **Room #1 (Digital Twin as a Concept)**

  ***What are digital twins, and why are they relevant for Positive Energy Districts (PED)? What challenges arise in terms of data management?***

  *What is a DT in relation to PED?*

  *How can a DT support development and implementation of PEDs?*

  *Who owns the DT? Who provides the service of a DT? And who is responsible for data?*

- **Room #2 (Digital Twin as a Tool)**

  ***How can digital twins serve as effective tools for decision-making for the energy transition? What challenges and opportunities do they present for PEDs?***

  *What makes digital twins a successful tool for implementation of PEDs? Which use-cases are served by DT? What questions can it answer?*

  *To what extent should the DT model the real-world? What is the time-resolution and granularity*

  *How to validate a DT?*

- **Room #3 (Digital Twins for Decision Making Tools)**

  ***How can digital twins generate tools/innovation for decision-making for the energy transition?***

  *(How) Can DM tools support the decision-making process within the energy transition for municipalities and stakeholders?*

  *How to make the tools themselves useful?*

  *In which part of the decision-making process? In which way in the decision-making process?*

## 1. Break-out room: Digital Twin as a Concept

The discussion initially circled around the main usages and definitions of a digital twin and why they are relevant in relation to a PED. The conditions for PED differ greatly in a European perspective, e.g. PED is not as clearly a self-interest in Sweden given the conditions with District Heating and the overall energy mix already being 95% fossil free and PED is interpreted in a wider sense to also include climate impact. What was agreed upon as important was the need for a systematic work with the three pillars of energy efficiency, flexibility and renewable energy production within PED contribution to the overall climate neutrality.

A digital twin in relation to a PED is first and foremost an enabler to support, strengthen and accelerate important processes within the climate transition at a local scale aiding the stakeholders with more insightful decisions through optimization, monitoring, scenarios etc.

A large part of the discussion was connected to challenges in terms of data management in several dimensions, from data collection, management, interpretation to sharing of data. A specific challenge is related to temporal granularity of data coming from different sources. There is also a risk that challenges within the different dimensions persist or intensify depending on local preconditions or external factors such as the geopolitical situation.

# 2. Break-out room: Digital Twin as a Tool

Discussions in this breakout room explored the role of Digital Twins (DTs) as a tool for PED development: DTs can serve as powerful tools for decision-making in the energy transition by providing dynamic, data-driven representations of physical energy systems. For Positive Energy Districts (PEDs), they offer a way to integrate real-time and historical data, simulate scenarios, and perform what-if analyses that combine static system characteristics with dynamic operational data. This helps stakeholders understand the impacts of different design or operational choices, optimise asset performance, detect errors or inefficiencies, and address the operational complexity of coordinating multiple energy assets. Although developing DTs is time-consuming and standardisation is still limited, these challenges also create opportunities for harmonisation and scalable solutions across PEDs.

DTs support PED implementation across numerous use cases. They enable continuous monitoring and visualisation of energy flows, making it easier to assess decarbonisation measures in existing buildings and neighbourhoods. Their ability to represent realistic asset behaviour supports smart control and participation in flexibility markets. DTs can also increase transparency and improve communication among diverse stakeholder groups—including residents—thus fostering social acceptance. By capturing technical, social, and organisational insights, they contribute to shared learning and more informed decision-making. A key success factor is achieving the right balance between the cost and effort of DT development and the practical value it provides.

The degree to which a DT should mirror the real world depends on its purpose and users. Strategic studies generally require hourly time resolution, while operational control tasks may need second-level detail, especially for fast-responding assets in flexibility markets. Selecting relevant performance indicators and determining the appropriate level of detail is important to keep the model manageable and useful. DTs are especially valuable for systems that are planned or not yet built, as they allow stakeholders to explore alternatives before physical implementation.

Validating a DT requires comparing its outputs with real measurement data from the corresponding physical system. This involves collecting sensor data, testing the model in different environments, checking replicability, and adjusting the model based on practical evaluations. Whether the DT relies on detailed modelling or AI-driven approximations, grounding it in real data is essential to ensure reliability and accuracy.

# 3. Break-out room: Digital Twins for Decision Making Tools

This Break-out room focused on the main question on how digital twins can generate tools/innovation for decision-making for the energy transition? The topic was shortly introduced by framing how decision-making tools could be used to reach the objective of a 100 climate neutral cites by 2030. Attention needs to be put on the human centered process with digital tools and on how non-experts could use these tools. How can we make sure the information gets across?

The group discussion first focused on how the tools themselves can be useful. What is required from the model or process to support the decision maker, who does not necessarily understand the energy system as experts do? The overall answer was to keep it simple. But simple is not the same as understandable, energy is a complex topic, but we need to make sure people understand. Also: the tools are already there, but they are often very technical and difficult to use and understand. We need more user-friendly interfaces, to help decision makers. More focus should go to using the existing digital tools but making them useful for non-experts. This means differentiating between different types of users. A mayor for instance needs a different approach compared to someone living in a social housing block. As a last point the need for stable and reliable tools to create confidence of the users was raised.

The second discussion focused on when decision making tools could be used within a decision-making process. The group agreed that there is a need to use tools in every part of the decision-making process, but they need to focus on different aspects (goal setting, scenario planning, monitoring, ..). This could also be the same tool, using different modules. Using the same tool would also be easier for training and avoids confusion with non-experts.

# 5 Conclusions

- **A digital twin in relation to a PED** is first and foremost an enabler to support, strengthen and accelerate important processes within the climate transition at a local scale aiding the stakeholders with more insightful decisions through optimization, monitoring, scenarios etc.
- **Challenges in terms of data management** arises in several dimensions, from collection, management, interpretation to sharing of data and a specific challenge is often somehow related to granularity. There is also a risk that challenges within the different dimensions persist or intensifies depending on local preconditions or external factors such as the geopolitical situation.
- Attention needs to be put on the **human centered process** with digital tools and on how non-experts could use these tools, there is a need to further develop more user-friendly interfaces, to help decision makers.
- More focus should go to using the **existing digital tools** but making them useful for non-experts. This means differentiating between different types of users but also relates to increased stability of the tools and as following an increased reliability from the users.
- There is a need to use tools in **every part of the decision-making process**, but they need to focus on different aspects (goal setting, scenario planning, monitoring, ..). Ideally it could be the same tool, using different modules. Using the same tool would also be easier for training and avoid confusion with non-experts.