Driving Urban Transitions

EUROPEAN PARTNERSHIP

Deep-dive #4: PED Flexibility services and Climate impact assessment

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Driving Urban Transitions to a sustainable future

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Content

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**	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	**Energy balance, Flexibility Services and Climate Impact Assessment**	8 May 25, 13:30- 16:00
5	**Financial instruments: Framework and Business models**	TBD

Focus of the fourth deep-dive is on **Flexibility Services and Climate Impact Assessment for PED's**. Better understanding Positive and Clean Energy Districts (PCEDs) - a relatively novel term encompassing not only an energy but also emissions (neutrality) based taxonomy - requires the definition of clearly delienated boundaries and standardized definitions, to accurately measure their environmental and socio-economic effects. Evaluating the impact of PCEDs requires assessing the net energy surplus, reduction in carbon emissions as well as other environmental impacts and changes in energy consumption patterns resulting from renewable integration and efficiency measures. Establishing consistent metrics and methodologies is crucial for comparable impact assessments across different PCED projects and regions, ensuring effective policy development and resource allocation. Regarding the best techniques to tackle territorial emissions, the scale-up from districts to city and/or scale-down from city to districts (data

[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.

availability constraints) are presently tackled by several PED projects which will be presenting in this Deep Dive.

Flexibility is crucial in an energy system centered around variable renewable energy (VRE) sources. It ensures a continuous balance between energy demand and supply across all time scales. Additionally, flexibility helps address constraints in the energy transport and distribution infrastructure. Flexibility can be derived from various sources, including demand response, controllable generation, storage, and interconnections. In systems with multiple energy vectors, flexibility can also be achieved by converting energy from one vector to another. This makes flexibility a key concept in establishing a Positive Energy District (PED). To unlock flexibility, regulatory support is essential. This includes standardized products, standardized contracts, and market design.

But how do flexibility services impact climate emissions from a PED and can we structure flexibility incentives that also relate to the mission of 100 climate neutral and smart cities? That is something we want to focus on in the discussion and finally, we will wrap up the session with a discussion and investigate the role of research & innovation to speed up the applicability of climate impact assessment & flexibility services.

The recording of Deep-Dive one is available here.

1. Introduction to the topic

1. Flexibility services

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. This in turn leads us to energy flexibility services which can be used for balancekeeping and the constrains you have in the energy transport. There are four ways to enable flexility; beeing controllable production, demand respone, storage and interconnection (energy transport). Within demand respone you can either change behaviour, use flexibility in production processes or apply flexibility assets. Within controllable production, sun and wind are downwards adjustable (curtailment) with a low marginal cost while a generator is adjustable in both directions but comes with a high marginal cost (fuel). How to actually unlock flexibility there are two main ways of doing that, either implicitly (self-usage within given contract) or explicitly (bundled and offered to the market as a service). Interviening in flexibility markets there are 3 archetypes; spotmarkets that are typically energy markets selling high and buying low using flexibility asset as arbitrage, balancing markets aiding with system stability and quality /i.e. FCR, aFRR, mFRR, RR) and helping with transport constrains through rediscpatch markets. Other acronyms used for implicit & explicit flexibility are demand-side flexibility, demand-response or distributed flexibility.

2. Climate impact assessment

The terminology for district energy concepts has been developing over time going from buildings to blocks to districts and it's taking some time to get consensus and standardize on what matters. The latest addition to Positive Energy Districts is the introduction of the Clean concept in Horizon calls from 2021 and onward. In previous PED definitions, carbon or climate neutrality has not always been present and even with the updated DUT PED Framework definition 3.0[3] aligning PEDs more clearly to the mission for climate neutral and smart cities still leaves a lot of room for interpretation by the practitioners. Conceptually then, many PEDs aligned with the mission within a city actually constitutes one large PED in itself (sometimes the term super-PED is used here). Aligning a PED with climate neutrality one has to consider greenhouse gas emissions and system boundaries which for cities have been standardized by the Covenant of Mayors through the GHG protocol with the 3 scopes. PEDs and PCEDs within a scope-based lense, one can think of them as a city in miniature and then the same logic and concept applies for the area as for a whole city for energy related emissions. Another way of looking at emissions is to take consumption-based emissions into account, expanding the system boundaries and showing consequences of actions by participants within a system giving a more realistic picture between consumer cities and producing cities. The Clean concept within a PCED does not only imply climate neutrality, but other aspects as well. These aspets include water quality, air quality, waste production, land surface temperature, carbon storage potential among other things. There is still no standardized take on this, and many ongoing projects are developing concepts for standardization so there most likely will be a process on what is feasible and measureable going forward finding best practice and definitions for a PCED.

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

2. Project Pitches

Here a bit of intro about why we selected these projects.

- *Projects represent diverse generations of PED calls funded projects*
- *Strong focus on PED processes*
- *Strong focus on Stakeholders involvement as final objective on social justice?*

1. FLEdge

The FLEdge project, presented by Prof. Stelios Krinidis, coordinator of the project, during the DUT PED Deep-dive, introduces a novel hierarchical flexibility management ecosystem that operates across both building and city levels to support the transition towards Positive Energy Districts (PED). The presentation started with an overview of the consortium partners.

The project arises from the urgent problem and need to reduce carbon emissions, adapt to the increasing integration of renewable energy sources, and address the challenges of modern electricity markets, which demand flexibility, decentralization, and active consumer participation.

FLEdge's core vision involves creating user-friendly digital twins for smarter building management, enabling energy flexibility, and implementing demand-response (D/R) strategies across multiple scales. The system allows hierarchical communication between EEM devices, which manage local operations, and Energy Management Nodes (EMaN), which are responsible for neighborhood and city-wide coordination.

FLEdge supports the transformation of urban areas into Positive Energy Districts (PED), aiming for a significant reduction in greenhouse gas emissions (~40%) and increased renewable energy share (~27%). The project also promotes the integration of smart grid technologies, fostering grid stability, zero-net emissions, and enhanced occupant well-being.

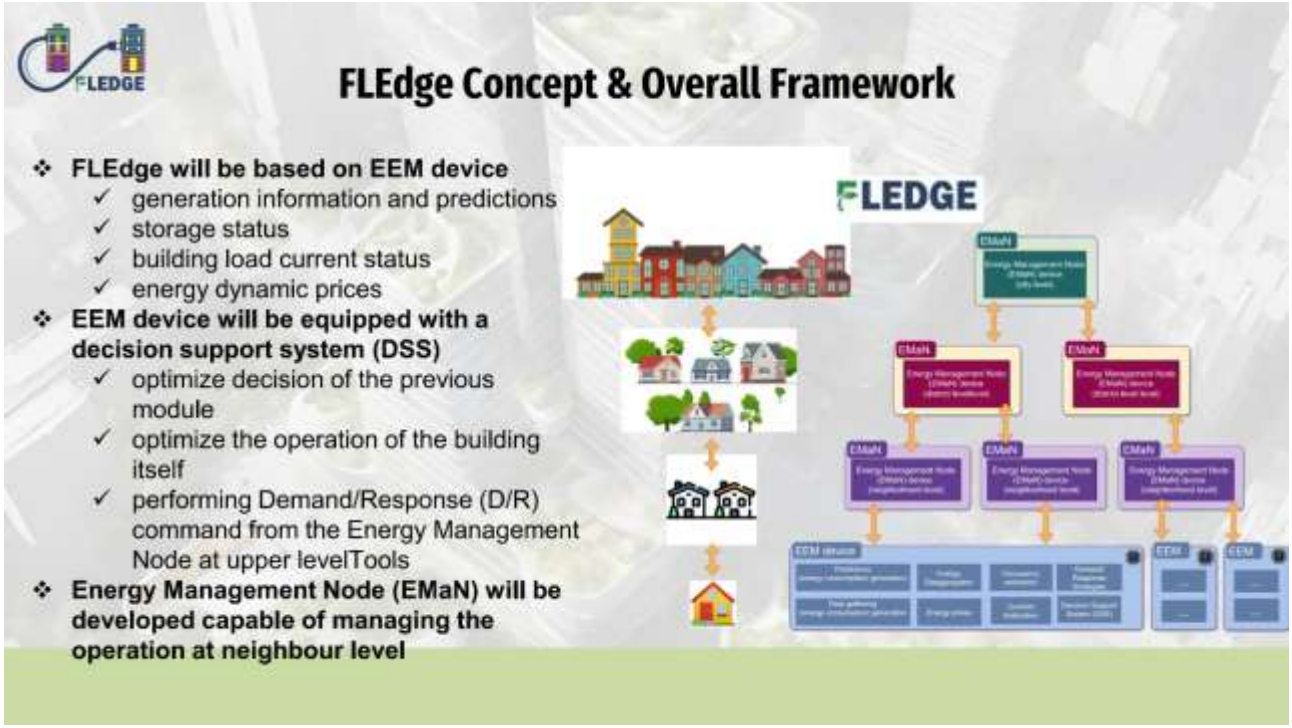

FIGURE 1. OVERALL CONCEPT AND FRAMEWORK OF FLEDGE PROJECT.

2. ASCEND & DigiTwins4PED

Positive Clean Energy Districts (PCEDs): A Next-Generation Urban Model

The Positive Clean Energy District (PCED) represents an evolution of the Positive Energy District (PED) concept. While PEDs focus primarily on achieving an energy surplus, PCEDs broaden this vision to encompass climate neutrality, sustainability, and citizen well-being.

The "clean" dimension highlights the use of renewable energy sources, while fostering environmental sustainability and improving citizens' quality of life. PCEDs involve the replacement of fossil fuel–based systems with renewables to create self-sufficient, decarbonised districts, while simultaneously delivering multiple co-benefits for citizens. This transformation brings cleaner air, lower noise, healthier lifestyles, stronger resilience to climate change, and greater social inclusion.

Whereas PEDs have already been studied extensively, PCEDs remain a novel approach under development within the EU Mission Cities projects ASCEND and its sister project NEUTRALPATH. Within ASCEND, the design, implementation, and performance assessment of PCED concepts across diverse urban contexts—Lyon, Munich, Porto, Prague, Budapest, Alba Iulia, and Charleroi—constitutes the project's core mission.

PCED concepts in ASCEND are structured around five interconnected solution areas: Zero-carbon buildings with on-site renewable energy sources, Smart energy grids, Mobility and decarbonised public spaces, Digital tools and Active citizenship; coordinated through an urban orchestrator. Each ASCEND city is deploying tailored solution packages, including:

Energy-efficient buildings: New constructions and refurbishments with systems based on renewable energy (PV, district heating, CHP), complemented by smart energy management, storage systems, and ICT/digital tools to optimise district energy performance.

Redesigning public spaces: Introducing greenery, pedestrianising areas, and adapting lighting levels to actual patterns of use.

Sustainable mobility for passengers and freight: Electro- and micro-mobility solutions, including e-cars with smart charging and V2X integration, e-bikes and cargo bikes, reorganisation of last-mile delivery, development of decarbonised logistics hubs, and repurposing underground spaces for mobility.

Circular economy practices: Rainwater harvesting, advanced waste management, recycling of construction materials, and reuse of organic matter for local soil fertilisation.

The project is currently advancing with the deployment of PCED concepts in the seven cities. Their effectiveness will be assessed through an evaluation framework, designed to measure energy balance and emission reductions, alonside economic and social performance, including social acceptance and quality of life outcomes.

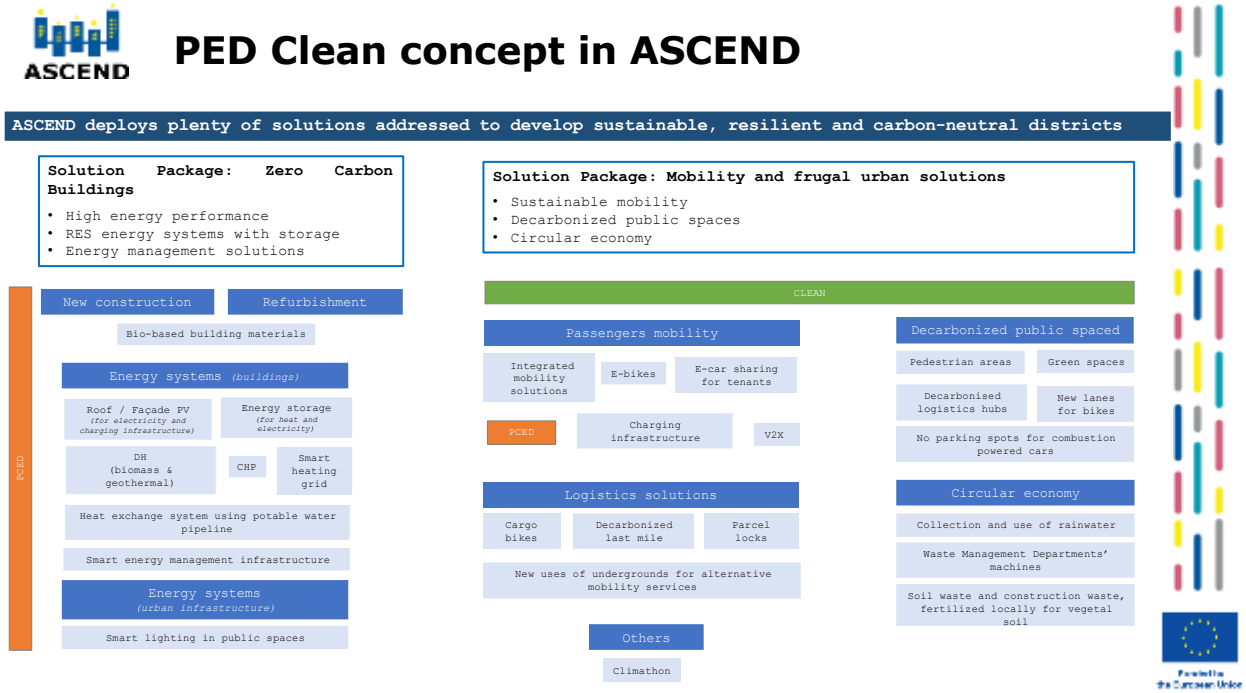

FIGURE 2. SOLUTION PACKAGES OF ZERO CARBON BUILDINGS AND MOBILITY AND FRUGAL URBAN SOLUTIONS FROM THE ASCEND PROJECT.

3. GARDEN

The focus of GARDEN lies on developing flexibility business models for Positive Energy Districts (PEDs) with grid-awareness as a central objective. The short key note started by comparing explicit (front-of-the-meter) and implicit (behind-the-meter) flexibility options, highlighting market mechanisms such as spot trading, balancing energy, redispatch, and dynamic pricing. All of them are generally interesting use cases for PEDs, however, their applicability strongly depends on national market design. The Austrian context, for instance, shows strong growth in energy communities but a lack of local flexibility markets and grid-aware incentives for small prosumers. The project's case study in Gleisdorf models district-level electrification, PV deployment, e-mobility, and collective self-consumption to assess the flexibility potential of PEDs and underline the importance district energy management as a tool to leverage distributed flexibilities.

FIGURE 3. CHALLENGES, OBJECTIVES AND METHODS OF THE DUT GARDEN PROJECT.

4. NEUTRALPATH

NEUTRALPATH aims at demonstrating that PCEDs designed under participative and human-centre principles are cost-effective and feasible solutions to contribute significantly to the cities' transformation towards climate-neutrality, allowing to speed up the process to achieve significant emissions reduction in 2030. The 25 NEUTRALPATH partners are working to co-design positive and clean energy districts (PCEDs) within the five cities and implement the defined measures in the two lighthouse cities. The objectives of the project is to establish innovative governance strategies to enable the transformation of cities towards climate neutrality, define metrics for the evaluation of PCED, the annual energy and CO2 balance, promote upscaling and replication through PCEDs and to promote city networks to build on existing knowledge, technology and funding, and in turn provide a factual contribution toward the climate targets. In the Evaluation Framework developed, the GHG Scope approach and a Life Cycle Assessment perspective is applied to the PCED concept stating that carbon positivity regarding the district lifecycle includes materials, energy installations during manufacturing, installation, use, maintenance and demolition – thus ensuring life cycle energy and climate impact balance comprehensive with the PCED concept.

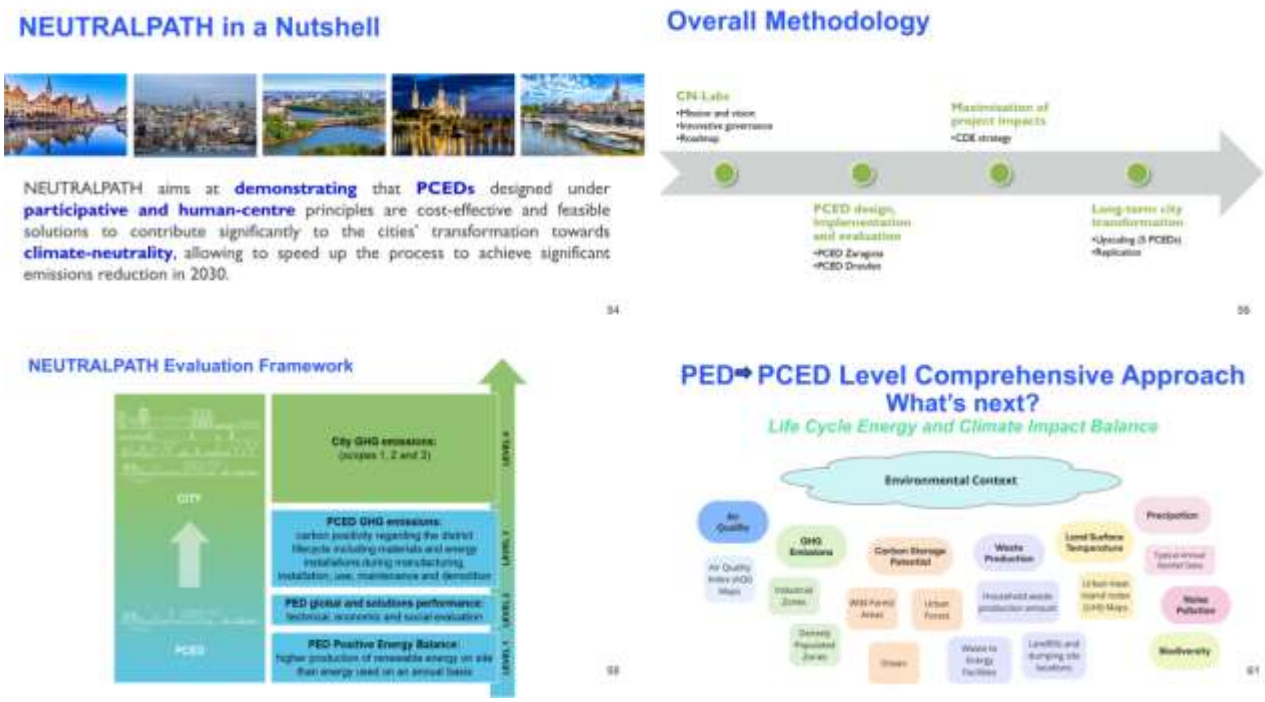

FIGURE 4. CHALLENGES, OBJECTIVES AND METHODS OF THE NEUTRALPATH PROJECT.

2 Discussion

A central part of the DD#4 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 (Flexibility services)**

  How can flexibility in the energy system support the development of PEDs?

  What are optimal flexibility sources for PEDs?

  What is the earning potential for flexibility in PEDs?

  What are the main challenges in providing flexibility services for PEDs?

- **Room #2 (Flexibility & Climate impact)**

  Making PED Flexibility result in a much improved PED climate impact

  Current state-of-play in business cases for storage options at different scales, vis a vis 'flexibility'

  Can 'Flexibility' incentives be structured to give stronger Climate Impact outcomes

  PED to Grid market transactions to benefit Climate Impact

- **Room #3 (Climate impact assessment)**: *Question 3: How might we ensure that PEDs promote a just transition where nobody is left behind?*

1. Break-out room: Flexibility services

PED Flexibility Services and Resources can include a wide array of measures: While often technical solutions to balance energy production and consumption are prioritized, Flexibility Services and Resources can also comprise measures directed to behavioural change. In fact, several of the discussants indicate that as many PED projects focus on residential functions, sources for energy flexibility are limited (in contrast to, for example, residual energy from industrial activities). Moreover, also the scale of a PED is often too small to install powerful large energy flexibility technologies. Hence, initiatives to change the energy consumption behaviour (and to a lesser extent, the energy production behaviour) of individuals that live and/or work in a PED, can have an important impact in achieving a positive energy balance. Yet, next to aligning energy production and consumption, such initiatives can also help diminishing the energy consumption altogether.

A main advantage of the PED concept is that it can facilitate 'collective self-consumption', next to 'individual self-consumption'. Sustainable energy that is generated locally is also consumed in the neighbourhood; By providing collective arrangements, the individual user that generates the energy can differ from the one that consumes it. This significantly increases the opportunities to maintain a positive energy balance. Flexibility can also be sought higher up in the electricity grid. However, discussants remark that the vast majority of typical PED stakeholders is not 'grid-aware', making it difficult to harness this potential. Their local, small-scale setup also entails that (financial) earning capacities of flexibility arrangements remain marginal.

Many energy flexibility measures introduce new rules, practices and constraints to households and other consumers. In the experience of the discussants, the complexity these add should be minimized in order to increase the success of the energy flexibility measures. Some of these changes can be facilitated by automatization. This, however, potentially raises distrust in the system as consumers might perceive this as giving away control over everyday practices to 'machines' or anonymous grid operators. If it proves impossible to actively engage PED users in energy flexibility schemes, discussants point out the possibility

to manage some of these schemes on the level of the PED or the energy community as this is a small-scale and familiar environment with identifiable actors.

2. Break-out room: Flexibility & Climate impact

This Break-out room focused on the main question on how PED flexibility could result in a much-improved PED climate impact.

The group discussion firstly focused on the current state of play in business cases for storage options at different scales, vis a vis flexibility. The first important insight focused on the fact that storage options are not only focussing on storage for electricity, but also on heat storage. This type of storage has an annual perspective instead of focussing on a shorter time frame. Heat can be stored in the subsurface, also facilitating the recovery of the soil. Moreover, the heat and cold stored in the soil could be seen as an energy common, shared by a neighbourhood. However, legislation is important when looking at using the available heat in the soil, to make sure there is enough for everybody, not overexploiting the resource. When looking at future developments, we can see that power and heat are getting more and more coupled, also having a spatial dimension on the district or neighbourhood level, because heat and electricity have different scale levels on which they operate. The district level is where they come together. However, some solutions are only possible at certain scale levels, using economies of scale. To conclude the link between PEDs and their potential to be part of the solution for grid congestion was also explored. By making better use of local renewables, combined with local storage, the more flexible your area becomes. The larger markets will be mainly electricity driven, because they function on larger territories, while heat is a more local energy source.

The discussion continued to look at how flexibility incentives can be structured to give stronger climate impact outcomes. The emphasis was made that it revolves around synergies between the two goals. Linking them is on the one side a very technical story, but on the other side also has a lot to do with behaviour. A changed behaviour, reducing energy needs and shifting the use of energy in time, becoming more flexible has a big impact. Change in behaviour is very much dependent on incentives and investments are needed. However, the incentives need to be well chosen to avoid adverse effects like people using battery storge as a way to make profits. Here there is an important role for energy communities, they can operate at a lower scale level, supporting local communities, and building communities around local energy sources.

3. Break-out room: Climate impact assessment

This Break-out room focused solely on the topic of climate impact assessment.

Considering different scales of impact in the climate transition, the group discussed mechanisms for amplification from district to City Scale. Some of the key scaling mechanisms the group found viable were:

- Making sure to connect between areas in the city, in a multi-level perspective, i.e. including social aspects and lifecycle assessment of mobility.
- Tailored Business Models / Stakeholders engagement
- Incorporating PCED projects and PCED strategy into overarching city level strategy
- The potential of the “Urban orchestrator”
- The importance of aligning district-level assessments with city-wide sustainability goals
- Co-creation processes engaging citizens and main stakeholders
- Best practices and learning lessons from previous experiences

- City tools for estimations based on real impacts previously measured + forecast from macroeconomic data

Following that, the group discussed another key question: what are the main benefits, challenges and limitations in their (own or general) climate impact assessment approach. The key limitations & challenges that was brought up were the following:

- Data & Digitalization
  - Data and data quality: big effort
  - Digital twins / massive calculation / data alignment
  - Data inconsistencies across districts prevent standardized data collection and replicability
  - Tools in district and city scale
- Indicators & strategy
  - Many aspects to consider making sure the lifecycle is considered on city-level
  - Policy integration across administrative levels
  - Selecting appropriate indicators and scope at the urban level
  - Indicators at district scale might not translate well into city level
  - Limitation also the non-existing monitoring as the project not being implemented
  - Monitoring stops once project ends
  - Indicators for resilience

The main benefits that were brought up in the discussion was that a CIA helps decision makers to prioritize measures to implement to buildings/disctrict/city level. And with an LCA-approach real impact is measured, not ony operation phase as it also includes construction and transport.

Finally, a short discussion focused on specific approaches towards CIA were discussed where one project shared its ambition in covering Environment impact (air quality, GHG emissions, resource uses +noise, congestion) as well as Co-benefits for citizens (quality of life, inclusiveness).

3. Conclusions

- **Behavioural and social engagement** are as vital as technical innovation for effective demand side flexibility.
- **Sector coupling and system integration** approach in relation to flexibility has an untapped potential allowing for optimized and coupled solutions strengthening energy resilience on multiple scales while mitigating climate impact.
- **Community-scale approaches**, i.e. energy communities, can enhance participation, efficiency, and fairness.
- **Well-targeted incentives** can link flexibility to climate goals and prevent profit-driven or counterproductive actions.
- **Data accessibility, standardized protocols & ontologies** are key success factors realizing the untapped flexibility potential going forward.
- District-level assessments should align with city-wide sustainability strategies through **multi-level governance**.
- **Data consistency, tools** and **indicators** for monitoring are crucial for credible impact measurement.
- **Robust, standardized CIA frameworks** can guide replicable, measurable, and equitable urban climate transitions.
- Linking PED and PCED insights to **city-level policy** ensures scalability toward Europe's climate-neutral goals.