TRANSFORMING CITIES THROUGH POSITIVE ENERGY DISTRICTS

# SUCCESS FACTORS AND CHALLENGES OF POSITIVE ENERGY DISTRICTS IN EUROPE

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May 2023

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# ABSTRACT

Positive Energy Districts (PEDs) are emerging as an important European policy tool to upgrade energy systems, achieve decarbonisation goals, reduce costs, and strengthen communities. PEDs are bounded spaces of innovation with aims of energy efficiency, energy generation, and energy flexibility. Achieving these technological aims requires the strategic alignment of context-specific stakeholder processes. The aim of this paper is to identify the success factors and challenges of current PEDs and to characterise how PED stakeholders achieve their goals. The findings reveal three types of PEDs – technical, social, and socio-technical – that interpret, integrate, and enact PED principles in different ways. These findings provide a starting point for further development of the PED concept in practice.



# KEYWORDS

Positive Energy Districts, Cluster Analysis, Success Factors, Challenges, Typology

# INTRODUCTION

Positive Energy Districts (PEDs) are emerging as an important European policy tool (SET-Plan 2018, Turci et al. 2021). PEDs are bounded spaces of innovation that achieve a combination of energy efficiency, energy generation, and energy flexibility through new configurations of energy technologies, regulations, and practices. The purpose of PEDs is manifold. They have the potential to decarbonise energy production, transmission, and use while also reducing costs and fostering social cohesion. PEDs are often located in urban areas and are closely integrated with urban development dynamics and processes of change (Brozovsky et al. 2021). Moreover, PEDs are customised to specific contexts and include multiple stakeholders that own, design, build, manage, and use the energy services. This results in a wide variation of how PEDs are conceived, negotiated, designed, and implemented in practice.

This report complements and extends previous reviews of PED development (Brozovsky et al. 2021, Turci et al. 2021, Zhang et al. 2021, Magnusson and Rohracher 2022) by identifying the success factors and challenges of current PEDs. While PEDs tend to have unique characteristics that are specific to their particular geographic, political, and social contexts, they also share many similar attributes. To identify these similar attributes, we conducted a cluster analysis of an existing dataset of 61 self-identified PED projects across Europe. The analysis reveals three distinct approaches to PEDs that emphasise technological innovation, social innovation, and socio-technical innovation. The findings serve as a starting point to develop a knowledge base on the opportunities and pitfalls of situated energy innovation and to support future research agendas on the development and adoption of PEDs.

# DEVELOPING A PED TYPOLOGY OF SUCCESS FACTORS AND CHALLENGES

In 2020, JPI Urban Europe published a study titled *Europe towards Positive Energy Districts* that includes descriptions of 61 PEDs in the implementation or planning stage as well as their specific strategies to achieve net zero emissions (JPI Urban Europe 2020). Each description includes general information about a specific PED as well as a summary of the goals, indicators, overall strategies, and stakeholders that influence its development. In this analysis, we examined the success factors and challenges identified by the authors of each description. Examples of success factors and challenges of three PEDs are provided in **Table 1**.

| PED | Success factors | Challenges |
|---|---|---|
| +CityxChange (Trondheim) | – Full anchoring and ownership at top level adm and political level; CEO formal project owner<br>– Solid anchoring at all key departments within municipality<br>– Highly skilled personnel also within municipality, on core topics such as project coordination/management, energy, business development, ICT, citizen involvement<br>– Pro-active and innovative external partners that covers all crucial topics to realise PEBs/PEDs. DSO level totally necessary to have on board<br>– The possibility of setting up local regulatory sandboxes with several dispensations from national regulator<br>– Open, local trade of energy, effect, flexibility, frequency etc.<br>– Viable business, investment, and risk sharing models that focuses on improved/adequate ROI for the private stakeholders involved | – Obtaining the "correct"/necessary dispensations from national energy/grid/concession legislation<br>– Deregulation of monopolies, possibilities for P2P trading<br>– Willingness from building/asset owners to invest<br>– Local stakeholder engagement and involvement – including both citizens, businesses, NGOs etc.<br>– Impact of innovative interventions difficult to quantify; scarce historic data and track records for PEB/PED cases<br>– Uncertainty as to whether new business concepts and models will float. Lack of clarity on how to get to commercially viable models on shorter term |
| Barrio La Pinada | – Involvement of citizens and local authorities in the development of a new district<br>– Open innovation lab (La Pinada Lab, http://lapinadalab.com) focused on urban sustainability where we collaborate with companies, startups, universities, research and technological institutes and citizens to tackle challenges in cities; Barrio La Pinada serves as a real-world testbed of new, innovative urban solutions | – Gaining international recognition so our solutions and learning can be scaled up and we can achieve a greater impact.<br>– Establishment of an international network of collaborators to learn from other positive energy districts, projects and initiatives<br>– Mobilizing finance for sustainable urban developments |
| Santa Chiara Open Lab | – Involvement of main public and private stakeholders as project partners<br>– High reduction of heat demand in existing buildings (- 77%)<br>– Refurbishment of existing buildings and shift from 0 to 100% in the use of renewable sources<br>– Construction of new highly efficient buildings 100% powered by renewable sources<br>– High production of renewable electrical (291 MWh/year) and thermal energy (734 MWh/year heat + 1100 MWh/year coolth)<br>– Use of seasonal underground thermal energy storage (seasonal UTES)<br>– Optimal integration of multiple renewable sources and waste heat (power to heat; low temperature DHC)<br>– Inclusion of the study area in the Province of Trento characterized by renewable electricity production (mainly hydroelectric) greater than consumption (in an annual balance)<br>– Introduction of advanced monitoring and control systems at building and at DHC level | – Involvement of all citizens living in the Santa Chiara Urban District<br>– The Santa Chiara Urban District is a mixed-property area (Public-Private): share technical solutions, subdivision of costs and incentives<br>– High financial commitment<br>– Intervention on existing buildings<br>– Optimal integration of multiple renewable sources and waste heat<br>– Introduction of advanced monitoring and control systems at building and at DHC level |

Table 1: Examples of success factors and challenges identified in the +CityxChange, Barrio La Pinada, and Santa Chiara Open Lab PEDs (JPI Urban Europe 2020)

To analyse the dataset, we employed a grounded approach that uses the concept of attribute space (Kluge 2000). This involves identifying all attributes and their dimensions relevant for analysis, grouping similar attributes, and analysing the constructed types. The combination of attributes within a type must not only correlate but have meaningful relations; internal homogeneity and external heterogeneity are the criteria that determine the quality of the overall typology. The process can be repeated until the final characterisation of constructed types is achieved.

To develop the PED typology, we identified the success factors and challenges in each PED description and organised them into general categories to make them comparable. We then created a binary coding of each success factor and challenge for all of the PED descriptions to create a data matrix. To identify the commonalities across the PEDs, we analysed the data matrix using statistical cluster analysis, specifically hierarchical agglomerative clustering as described in Märzinger et al. (2021). The resulting groups were then reviewed and analysed internally to construct meaningful types.

It is important to note that the selected dataset has several limitations. The PED descriptions in the JPI study are based on self-assessment and it is likely that the PED stakeholders presented their projects in a positive light. In addition, the descriptions of each PED follow a similar structure but the level of detail varies greatly from one PED to the next. While some descriptions are based on rigorous analysis, others are simply cursory overviews. There is no standard evaluation criteria for PEDs and this makes comparison difficult. Despite these limitations, the dataset serves as a useful snapshot of the current state of PED development across Europe and the analysis described in this report provides multiple insights on how PEDs are navigating a wide range of success factors and challenges related to PEDs.

# ANALYSING PED SUCCESS FACTORS AND CHALLENGES

We analysed the success factors and challenges in the 61 PED descriptions and sorted them into categories as summarised in **Table 2**. The success factors and challenges noted by the PED stakeholders include a range of issues related to administrative and governance issues, financial and economic considerations, technologies and expertise, and aligning with context-specific characteristics.

| Success Factors | Challenges |
|---|---|
| S1 Support from administrative institutions | C1 Getting enough financial resources |
| S2 Involvement of different stakeholders | C2 Legislation and regulation barriers |
| S3 Committed local population | C3 Making innovations economical |
| S4 Favourable preconditions | C4 Building competences in urban energy planning |
| S5 Data collection | C5 Collaboration between many stakeholders |
| S6 Professional personnel involved | C6 Conflicting goals among stakeholders |
| S7 Adequate investment models | C7 Conflicts regarding ownership of land or properties |
| S8 Supportive regulations | C8 Time pressure |
| S9 Integrated planning | C9 Long-term commitment |
| | C10 Need for specific forms of government |
| | C11 Upscaling the project |
| | C12 Making innovations adaptable |
| | C13 Involvement of local citizens |
| | C14 Acceptance among citizens |
| | C15 Data and knowledge management |
| | C16 Complexity of urban energy systems |
| | C17 Technical difficulties |

Table 2: Categories of success factors and challenges derived from the 61 PED project descriptions

We then conducted a cluster analysis on the 61 PEDs as they relate to these success factors and challenges. We created a data vector for each PED by assigning a value to represent the presence (1) or absence (0) of a success factor or challenge. In the next step, we used the hamming distance (x-axis) to determine the pairwise distance between the individual data vectors. In **Figure 1**, the PEDs are arranged over this hamming distance with the highest distance to the left and the shortest distance to the right. The coloured branches in the dendrogram indicate the affiliations between clusters. We used the Calinski-Harabasz criterion (or variance ratio criterion) to determine the 'optimal' number of clusters.

The cluster with the largest pairwise distance (indicated in red) includes 6 PEDs and is strongly influenced by C13 (Involvement of local citizens) and C16 (Complexity of urban energy systems) with weaker influence by C7 (Conflicts regarding ownership of land or properties), C8 (Time pressure) and C9 (Long-term commitment). Those PEDs that do not address C13 tend to focus on C9 (Long-term commitment) due to an emphasis on present and future populations. Further analysis is needed to determine how C7 and C8 are related to the other challenges in this cluster. The cluster with the second highest pairwise distance (indicated in green) includes 53 PEDs and is strongly influenced by S1 (Support from administrative institutions) and C2 (Legislation and regulation barriers). The cluster with the third highest pairwise distance (indicated in blue) includes 2 PEDs and is strongly influenced by C7 (Conflicts regarding ownership of land or properties), C8 (Time pressure), and C15 (Data and knowledge management).

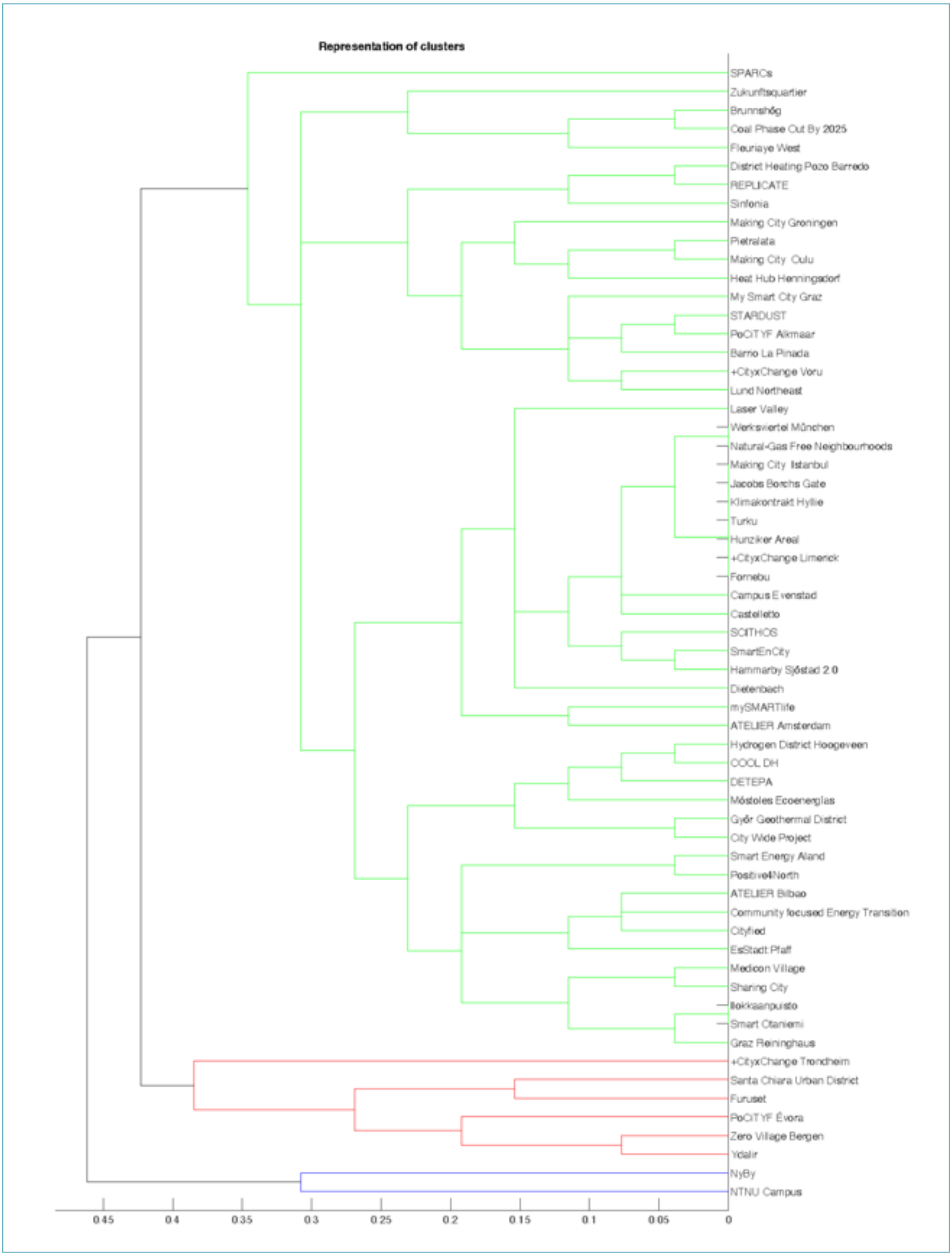


Figure 1: Dendrogram of the Level 1 cluster analysis

We then conducted a deeper cluster analysis of the Level 2 cluster (indicated in green in **Figure 1**). This deeper cluster analysis is presented as a dendrogram in **Figure 2** and includes eight clusters. Five of these clusters only included one or two PEDs and were discarded due to the small sample size. The three remaining clusters included 10 PEDs (indicated in purple), 11 PEDs (yellow), and 25 PEDs (red) and were grouped together in the data matrix and analysed to identify commonalities. The first two clusters did not exhibit sufficient commonalities or plausible connections to be considered as actual types. In other words, internal homogeneity of the success factors and challenges was not fulfilled. However, the third group was characterised by a combination of C1 (Getting enough financial resources) and C2 (Legislation and regulation barriers), as well as S2 (Involvement of different stakeholder). The PEDs in this group share common challenges related to bureaucratic structures, funding issues, and regulatory barriers while also stressing the importance of stakeholder engagement. In other words, these PEDs tend to be more ‘bottom-up’ while the PEDs in the second cluster (yellow) tend to be more ‘top-down’.

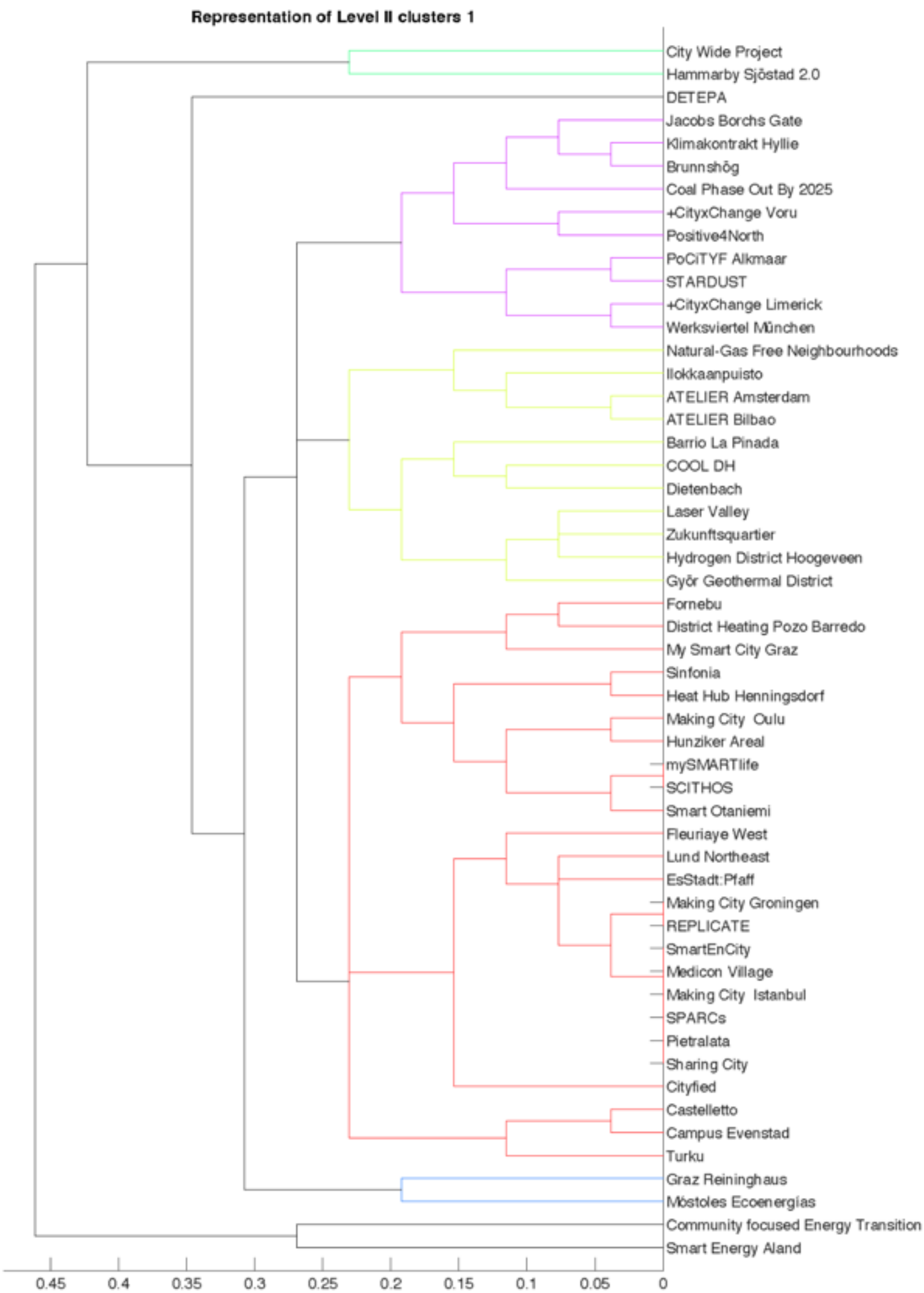


Figure 2: Dendrogram of the Level 2 cluster analysis

We then conducted further analysis of the yellow Level 3 cluster (11 PEDs) in **Figure 2**. We removed some of the success factors and challenges because they were not relevant to the PEDs in this cluster. This resulted in a simplified dendrogram (see **Figure 3**). The first cluster (indicated in green) includes COOL DH and ATELIER Amsterdam where the most prominent success factors and challenges include S2 (Involvement of different stakeholders), S4 (Favourable preconditions), and C17 (Technical difficulties). The second cluster (indicated in purple) includes Laser Valley and Dietenbach where the dominant success factors and challenges include S1 (Support from administrative institutions), S2 (Involvement of different stakeholders), C10 (Need for specific forms of government), and C14 (Acceptance among citizens). The third cluster (indicated in teal) includes Natural Gas Free Neighbourhoods, Ilokkaanpuisto, Barrio La Pinada, and Zukunftsquartier where success factors and challenges include S1 (Support from administrative institutions), C1 (Getting enough financial resources), C3 (Making innovations economical), C11 (Upscaling the project), and C12 (Making innovations adaptable). The final cluster (indicated in red) includes Györ Geothermal District, Hydrogen District Hoogeveen, and Atelier Bilbao where success factors and challenges include S2 (Involvement of different stakeholders), S8 (Supportive regulations), and C5 (Collaboration between many stakeholders).

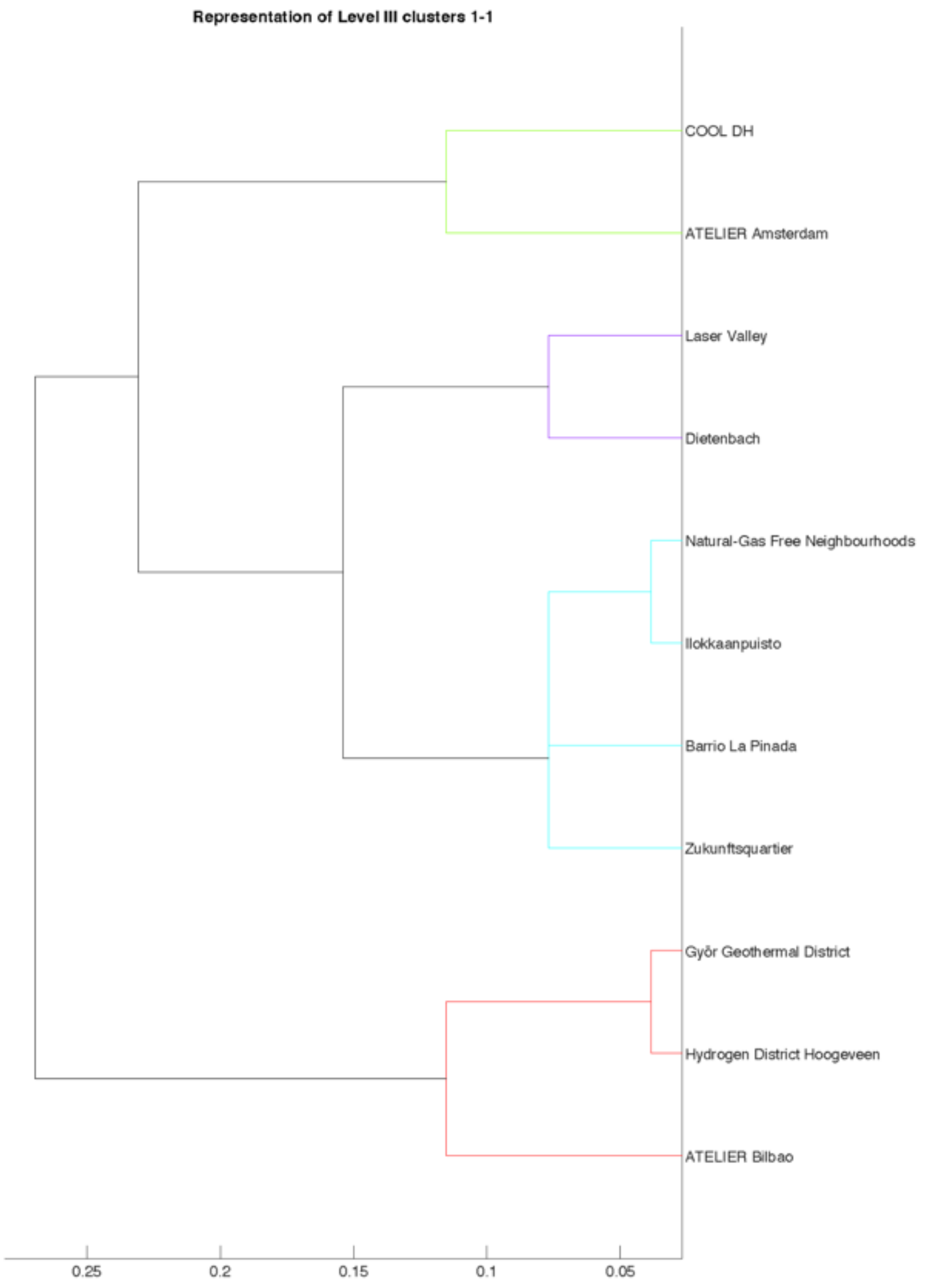


Figure 3: Dendrogram of the Level 3 cluster analysis

# TECHNICAL, SOCIAL, AND SOCIO-TECHNICAL PEDS

The cluster analysis described above reveals three general types of PEDs. The first type focuses on the numerous technical aspects of achieving ambitious energy transformations and the complexity of aligning urban energy system innovation with urban planning dynamics. A second type focuses on community development and the social processes that are implicated in changing energy services (Verkade and Höffken 2019, Baer et al. 2021). Here, there is an emphasis on involving a wide range of stakeholders and addressing financial and regulatory issues. And a third type of PED places emphasis on both technical and social aspects. We can understand such integrated PEDs as embracing a socio-technical approach. Examples of all three types are listed in **Table 3**.

| PED Type | Examples | Success factors | Challenges |
|---|---|---|---|
| **Technical** | Ydalir<br>PoCityf Évora<br>Furuset<br>+City xChange Trondheim<br>Zero Village Bergen<br>Santa Chiara Urban District | [No typical factors] | – Conflicts regarding ownership of land or properties<br>– Time pressure<br>– Complexity of energy systems and urban planning |
| **Social** | Fleuriaye West<br>Making City Groningen<br>Lund Northeast<br>Making City Oulu<br>Pietralata<br>Smart Otaniemi<br>District Heating Pozo Barredo<br>Sharing City<br>Sinfonia<br>REPLICATE<br>My Smart City Graz<br>Heat Hub Henningsdorf<br>EsStadt Pfaff<br>Medicon Village | – Involvement of different stakeholders | – Getting enough financial resources<br>– Legislation and regulation barriers |
| **Socio-technical** | Smart Energy Aland<br>DETEPTA<br>City Wide Project<br>Hammarby Sjöstad 2.0<br>ATELIER Amsterdam | – Involvement of different stakeholders<br>– Support from administrative institutions | [No typical factors] |

Table 3: Examples of technical, social, and socio-technical PEDs

The identification of technical, social, and socio-technical PEDs has several implications. First and foremost, they further emphasise that PEDs are processes rather than end goals (Magnusson and Rohracher 2022). Stakeholders interpret situated energy innovation processes in different ways and emphasise technical aspects, social aspects, or in a few cases, a combination of technical and social aspects. The exemplars of each type listed in **Table 3** can provide valuable insights to other PEDs who are attempting to develop specific technical, social, or socio-technical capacities. The list also highlights potential deficiencies and opportunities for further development in the identified PEDs. From this, clear intervention strategies can be developed by PED stakeholders to build up competence in deficient areas. Technology-focused PEDs and socially-focused PEDs can learn a lot from one another and it would be helpful to group PEDs from all three types into learning clusters. External intervention strategies to improve the work in each PED could then be aligned with the three basic types of PEDs. Support schemes and training sessions could be tailored to address social and technical issues and how the different processes can be linked together more effectively.

The findings also point to the need for a more robust dataset to develop more meaningful insights on PED characteristics. The analysis conducted in this study should be seen as an initial foray into a more standardised and detailed survey of success factors and challenges to situated energy innovation processes. Future studies should have more opportunities to analyse an expanded palette of success factors and challenges to provide a richer and more nuanced interpretation of PED development processes.

# CONCLUSION

PED development is closely tied to physical, social, and political contexts and it can be difficult to identify general insights that can be applied to other PEDs. The purpose of this report was to compare and contrast the achievements of the 61 PEDs described in the 2020 JPI study. We analysed the PED descriptions and identified 9 success factors and 17 challenges. We then applied a cluster analysis methodology to identify commonalities between the PEDs. The analysis revealed that PEDs can be characterised as technological, social, or socio-technical depending upon the dominant success factors and challenges. These findings can be used to inform existing and future PEDs.

For future research, the cluster analysis methodology could be used to identify further commonalities between existing PEDs and also be expanded to include new PEDs. However, this will require a more robust PED database to identify more accurate clusters with an increased number of similarities and differences. The overarching aim of this work is to provide insights on the dynamics of situated energy innovation and to support energy transitions. This journey is only just beginning and the coming decades will be a critical period for PED development.

TRANS PED

# REFERENCES


Baer, D., Loewen, B., Cheng, C., Thomsen, J., Wyckmans, A., Temeljotov-Salaj, A., & Ahlers, D. (2021). Approaches to social innovation in Positive Energy Districts (PEDs) – A comparison of Norwegian projects. *Sustainability, 13*(13), 7362.

Brozovsky, J., Gustavsen, A., & Gaitani, N. (2021). Zero emission neighbourhoods and positive energy districts – A state-of-the-art review. *Sustainable Cities and Society, 72,* 103013.

JPI Urban Europe. (2020). *Europe Towards Positive Energy Districts; First Update.* https://jpi-urbaneurope.eu/wp-content/uploads/2020/06/PED-Booklet-Update-Feb-2020_2.pdf, last accessed 22 November 2022.

Kluge, S. (2000). Empirically grounded construction of types and typologies in qualitative social research, *Forum Qualitative Social Research 1*(1), 1124.

Magnusson, D. & Rohracher, H. (2022). *A Typology Framework for Positive Energy Districts.* www.trans-ped.eu, last accessed 10 March 2023.

Märzinger, T., Kotík, J., & Pfeifer, C. (2021). Application of hierarchical agglomerative clustering (Hac) for systemic classification of pop-up housing (puh) environments. *Applied Sciences, 11*(23), 11122.

SET-Plan Working Group 3.2. (2018). *Europe to Become a Global Role Model in Integrated, Innovative Solutions for the Planning, Deployment, and Replication of Positive Energy Districts.* https://jpi-urbaneurope.eu/wp-content/ uploads/2021/10/setplan_smartcities_implementationplan-2.pdf, last accessed 10 March 2023.

Turci, G., Alpagut, B., Civiero, P., Kuzmic, M., Pagliula, S., Massa, G., Albert-Seifried, V., Seco, O., & Soutullo, S. (2021). A comprehensive PED-database for mapping and comparing Positive Energy Districts experiences at European level. *Sustainability, 14*(1), 427.

Verkade, N. & Höffken, J. (2019). Collective energy practices: A practice-based approach to civic energy communities and the energy system. *Sustainability, 11*(11), 3230.

Zhang,X., Penaka,S.R., Giriraj, S., Sánchez, M.N., Civiero, P., & Vandevyvere, H. (2021) Characterizing Positive Energy District (PED) through a preliminary review of 60 existing projects in Europe. *Buildings 11*, 318.w


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