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Approaches to Social Innovation in Positive Energy Districts (PEDs)—A Comparison of Norwegian Projects

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Abstract: The Positive Energy District (PED) concept is a localized city and district level response to the challenges of greenhouse gas emission reduction and energy transition. With the Strategic Energy Transition (SET) Plan aiming to establish 100 PEDs by 2025 in Europe, a number of PED projects are emerging in the EU member states. While the energy transition is mainly focusing on technical innovations, social innovation is crucial to guarantee the uptake and deployment of PEDs in the built environment. We set the spotlight on Norway, which, to date, has three PED projects encompassing 12 PED demo sites in planning and early implementation stages, from which we extract approaches for social innovations and discuss how these learnings can contribute to further PED planning and implementation. We describe the respective approaches and learnings for social innovation of the three PED projects, ZEN, +CityxChange and syn.ikia, in a multiple case study approach. Through the comparison of these projects, we start to identify social innovation approaches with different scopes regarding citizen involvement, stakeholder interaction and capacity building. These insights are also expected to contribute to further planning and design of PED projects within local and regional networks (PEDs in Nordic countries) and contribute to international PED concept development.

Keywords: social innovation; positive energy districts; PED; energy transition; smart cities; zero emission neighborhoods; sustainable positive energy neighborhoods; positive energy blocks; Norway



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1. Introduction

Reaching the climate gas reduction goals of the Paris Agreement is a challenge for stakeholders on all geographical and governance levels, from nations, regions, cities and districts. Cities and, especially, the district level, are pointed out as one of the important areas for change because cities consume approximately 80% of the total energy and are accountable for approximately 75% of global greenhouse gas (GHG) emissions [1]. Significant energy savings, emission reduction, the realization of economies of scale and increased energy security can be realized by considering holistic solutions on the district level. From a governance perspective, districts offer the appropriate arena for collaboration between different sectors and stakeholders in order to enable a holistic and inter-sectoral approach to energy planning as an integrative part of sustainable urban development [2,3]. The Positive Energy District (PED) concept is a localized response on the district level to the challenges of emission reduction and the European energy transition. It integrates local energy generation, plus-buildings and infrastructure with wider strategic and stakeholder approaches to anchor energy efficiency and renewable energy sources at the district level.

The PED approach is formulated on the European level through European initiatives, such as the Strategic Energy Transition (SET) Plan and is mainly based on technological innovations in the field of energy efficiency, renewable energy production and energy flexibility. However, we turn attention to the role of the social dimension, in particular the generation of social innovation in the planning, implementation and achievement of PEDs at the local level. A social innovation is defined as a new idea that aims at meeting social goals [4]. Thus, the role of social innovation within PED development is to enable the improvement of well-being for citizens and civil society in general.

Sustainability transition studies argue for a prominent role of citizens in the achievement of successful transitions, namely giving them a prominent role within the quadruple helix model (industry, government, academia and civil society) and emphasizing the citizen-oriented innovation approach [5–7]. The role of citizens is especially relevant in the Nordic model of sustainable development, which focuses heavily on social inclusion to promote the energy transition amongst other sustainability-related practices and behaviors [8,9]. The involvement of citizens in the development of PEDs can be seen as one means to foster social innovation in PED development.

As the PED concept, and the development of the first PED projects in Europe, is at an early stage, we examine the practical approach towards social innovation in Norwegian projects. We ask: *What is the variety of social innovation approaches in planning and early implementation of PED projects in Norway and what are the learnings to guide future PED developments in social innovations?* To answer these questions, we focus on the early planning and implementation stage of PEDs, according to the status of Norwegian PED projects. The objective of this paper is to give practitioners and researchers guidance on the future planning and design of PED projects regarding social innovation activities. Thus, the value of the research is to identify and map social innovation approaches in Norwegian PED projects and synthesize practical guidance for future PED projects.

This paper proceeds to introduce the PED concept and definition under development, as well as the concept of social innovation within the PED approach in Section 2. Section 3 will introduce the methodology applied to investigate the social innovation approaches and the context of PED development in Norway. We will introduce the three case studies and present the identified approaches in Section 4, discuss implications for social innovation in Section 5 and conclude with how these findings can contribute to the further development of the PED concept.

2. Background: PED Concept and Social Innovation

2.1. PED Definitions

We take, as a point of departure, the body of work generated by European initiatives to define PEDs and shape frameworks and strategies for PED development and future implementation. PED concept development has been acknowledged as a work-in-progress [10], while the primary sources for definitions indicate a general consensus on its basic elements. The European Commission defines Positive Energy Blocks/Districts as “several buildings [. . .] that actively manage their energy consumption and the energy flow between them and the wider energy system”. They have “an annual positive energy balance”, “are designed to be an integral part of the district/city energy system” and are “intrinsically scalable and [. . .] well embedded in the spatial, economic, technical, environmental and social context of the project site” [1]. Similarly, the Joint Programming Initiative on Urban Europe (JPI UE) defines PEDs as “energy-efficient and energy-flexible urban areas or groups of connected buildings which produce net zero greenhouse gas emissions and actively manage an annual local or regional surplus production of renewable energy. They require integration of different systems and infrastructures and interaction between buildings, the users and the regional energy, mobility and ICT systems, while securing the energy supply and a good life for all in line with social, economic and environmental sustainability” [10].

An operational definition of PEDs is evolving based on input from the eighth European framework program for Research and Innovation Horizon 2020 (H2020) Light-

house projects, the calls for which were designed to be in accordance with the SET Plan. The operational definition highlights the transitional aspects of PEDs and defines pathways of multiple ambition levels, ranging from importing clean energy from outside, up to fully self-sufficient and autonomous operation. Initial results of these PED definition workshops are summarized in [11], including the transitional approach identifying several possibilities for PED configuration. This underlines the ambition of PEDs as a process of growth and transition. Recent work has also initially analyzed overall PED implementation approaches in Europe and discusses their operational focus areas [12]. Technical definitions are also made available by related projects (e.g., <https://cityxchange.eu/knowledge-base/positive-energy-districts-ped/>) (accessed on 19 May 2021).

2.2. SET Plan Approach

The SET Plan aims to establish 100 PEDs by 2025 under Action 3.2 [13]. The delicate balance between technological and societal dimensions of PEDs is reflected in the set of eight challenges and requirements of the plan. On the one hand, integrated technological innovations play a key role. They do so by tackling the innovation need across building, energy, mobility and ICT sectors, including integrated urban energy system operation and planning and the digital planning of cities. They also maximize the use of renewable energy resources and designing flexibility options across different building types within the district in interaction with the wider energy system of the surrounding neighborhood. Technological innovations, supported by regulatory mechanisms to enable these processes, are indispensable to realize PEDs. On the other hand, social innovations are also imperative for transition. The eventual aim is to ensure that PEDs will be affordable for the majority of citizens and to generate wide public acceptance. Therefore, eventual realization calls for consumer-driven innovation in new energy markets. In particular, the transition from the passive consumer to the active prosumer role needs to be supported. In addition, a plethora of actors from technical experts to public administration and regulatory authorities will need to be activated and trained to establish the knowledge base for and supporting the whole process of developing and deploying PEDs. Urban authorities will have to take on a strong leadership and facilitator role to ensure that citizens and businesses as well as the wider community know, understand and participate in PED development.

2.3. Social Innovation Approaches

In the early 1960s, a theoretical differentiation between technical and social innovations was already described [14], but the concept of technological innovation gained stronger attention than social innovation in the literature [15]. In recent decades, however, social innovation has risen in prominence in the policy sphere, including on the EU level, as there developed a shared expectation towards the empowering potentials of social innovations and as the process of innovation is understood as a social action that mobilizes civic creativity and problem-solving capacity [16]. Social innovation is often seen from a perspective of empowerment, as a means for realizing development with citizens and other stakeholders as self-reliant actors who take change and development into their own hands, especially under pressing social, economic and environmental challenges [17]. Focusing on social innovation in PED development aids in orienting the technical innovation aspect towards the improved quality of life of citizens and civil society [18].

Referring again to the eight key challenges and requirements for PED development identified in the SET Plan, three relate to the domain of social innovation: stakeholder interaction, citizen participation and capacity building [13]. *Stakeholder interaction* is one crucial element for enabling social innovation within the quadruple helix model of cooperation involving stakeholders from the public and private sectors, academia and civil society [19]. A strong emphasis is placed on citizens and their needs, introducing an element of democratization in the innovation process. One of the current arguments around sustainable development is that it should be attained within the framework drawn up by

a democratic society [20]. The challenges of PEDs address the difference between socio-technical disciplines and segregation of their strategies, interests and perspectives, and challenges of governance in which citizens can contribute to the co-creation of solutions within this context. This calls for an intermediary which encompasses both perspectives, to create a counterbalance and engender consensus over important decisions [21,22]. The public sector represents an intermediary of social innovation in the urban environment [23]. Broad stakeholder interaction is supported for PED implementation in the view of the EU Smart Cities Information System (SCIS) and ongoing Horizon 2020 PED Lighthouse projects [24].

The closely related field of smart cities applies social innovation to socio-technical systems with citizens as end-users [25], directing attention to *citizen participation* in technical innovation processes. In recent years, smart city initiatives have fallen short of their objectives to meet user needs due to a lack of participation and public value creation [26]. According to Hollands (2008), smart cities should begin with people and human capital, and technical systems should support their vision of the city [27]. This indicates a bottom-up approach that, in relation to grand societal challenges, must meet top-down initiatives related to the decarbonization of cities. Building on Arnstein's (1963) ladder of participation [28], Cardullo and Kitchin (2019) developed the scaffold of smart citizen participation, showing levels of power to influence the outcome of participation processes from 'non-participation'—e.g., in a way to convince the end-user to apply technology in a desired way—to 'inclusive', with citizens as co-creators in innovation processes and outcomes [29]. While research on citizen participation methods remains relatively scant, a recent review specifies roles of citizens as democratic participants, co-creators and ICT users in a multi-stakeholder ecosystem comprised of public servants, political representatives and ICT managers [30]. Expanding these lists for PEDs, we can also consider the roles of citizens as energy producers and consumers, adding representatives from energy, engineering and utility companies, the real estate, building and construction sector, and financial intermediaries to the multi-stakeholder ecosystem. Attempts to open smart city solutions to citizen participation can be seen in the Nordic context, for example, through sustainable refurbishments [31].

To enable social innovation, the ability of stakeholders to co-create is crucial. One aspect of that can be described by the term *capacity building*. Capacity building is defined as activities that strengthen the abilities, knowledge, skills and behavior of individuals (individual capacity building) or organizations (organizational capacity building) [32,33]. Capacity building is thereby understood as both a process for improving the capacities of individuals and, at the same time, as an outcome of that process [34]. In relation to citizen participation, capacity building can be understood as local actors (including government institutions) aiming to enable citizens to participate or to build up human capital in the form of skills, experiences and knowledge [35,36].

For the PED concept to be realized in a sustainable way, the PED community of practitioners and researchers not only faces a multitude of technological requirements and challenges, but also has to address a host of social innovation aspects with regard to the planning and early implementation of PEDs. Yet social aspects are the least researched amongst the topics addressed in the PED literature [37]. From this review and based on the SET Plan framework [13], we select the most described and case-relevant approaches to enabling social innovation within PED deployment as: citizen involvement, stakeholder interaction and capacity building (see Figure 1).

Given the diverse social, economic and political contexts of localities implementing PEDs, there will probably be no simultaneous universal and detailed strategy that can be applied to achieve low-carbon urban development through PED approaches. Rather, those involved in urban development are challenged to identify and adapt suitable strategies within their geographical city, operational towards PED implementation [38]. Sustainable transition of the built environment and successful implementation of the PEDs within the

respective urban districts therefore asks for a balanced approach towards innovation that is combining technological and social dimensions [39].



Figure 1. Social innovation approaches relevant for PED development, own figure based on [13].

In the remainder of the paper, we set the spotlight to Norway to analyze existing approaches towards social innovation as a complementary part to technological innovations in PED development and to take into consideration its diverse local contexts. Norway currently has one of the largest numbers of PED projects in development [37,40,41]. The aim is to extract learnings from a multitude of approaches towards social innovation in diverse localities that will contribute to PED concept development and help other PED projects in planning and designing their approaches. We therefore ask: *What is the variety of social innovation approaches in planning and early implementation of PED projects in Norway and what are the learnings to guide future PED developments in social innovations?*

3. Methodology

3.1. Research Approach

This research adopted a qualitative comparative case study method, which is useful for highlighting similarities and differences between cases through the study of phenomena in various contexts [42]. We paid particular attention to conceptual and procedural differences in PED projects to enable a dialogue between theory and evidence [43]. The comparative method is used in the social sciences where laboratory conditions are often not possible. With a small number of cases, we used the ‘found experiment’ cases for within- and cross-case analysis of PEDs in different real-world contexts. The cases were limited to Norway, providing for a common political-institutional, social and economic environment and allowing us to focus on the planning, process, and technical differences between the cases through a ‘method of difference’ approach for concept development and early-stage implementation. A qualitative approach was also chosen due to limited data availability of quantitative indicators from the projects at their early stage of development.

The approach enabled a comparison of three PED projects in Norway—ZEN, +Cityx-Change and syn.ikia—from which we drew insights on the challenges from the early stages and relevant dimensions for enriching the PED concept. More specifically, the analysis provided an understanding of the different foundations of PED projects in Norway, the different approaches to social innovation within the PED concept and characteristics of specific projects, and learnings from early-stage PED planning and implementation. This comparison was done in 2020.

3.2. Context of Developing PEDs in Norway

Before expanding upon the potential for social innovation in PEDs, it is relevant to set the particular context of sustainable development in Nordic countries and Norway. Norway is in a unique position regarding PED developments to investigate early-stage implementation of PEDs. Not only is Norway’s power system based on renewable energy with the electricity production based mainly on hydropower, but the initiative for PED

development and the PED concept is supported and fits within Norway's high-level energy strategies and policies, thereby positioning Norway in a prominent role towards decarbonization of the electricity system. The initiative for PED development, with the focus on local energy generation, is supported and fits within high-level strategies and national policies. Norway aligns with the Nordic approach to sustainable development, which includes a common strategy for implementing Agenda 2030 and the Sustainable Development Goals (SDGs) [44] and has the tendency to preference social aspects of sustainability [8,9]. Thus, the Nordic setting presents favorable conditions for exploiting highly technical solutions for energy transition such as PEDs, in a way that emphasizes social dimensions. Social innovation within the Nordic model relates to activities that are social in both needs and ends, such as collaborations between multiple stakeholders in a community that initiate and drive developments to meet new challenges of the future [45,46].

In 2008, the Norwegian Parliament had decided that Norway should become carbon neutral by 2050 and, recently, Norway enhanced its nationally determined contribution under the Paris Agreement to reduce emissions by at least 50%, and towards 55% compared to 1990 levels, by 2030 [47]. While there is no specific regulation for PEDs, the policy framework consists of different laws and regulations, guiding principles, white papers and standards which influence the implementation of PEDs. Prominent amongst these are EU directives with relevance to the EEA (including Norway): The Energy Performance of Buildings Directive (EPBD) and Energy Efficiency Directive (EED). Through these, which have yet to be completely transposed and adopted in Norway, progressively stricter efficiency requirements are being put into force. For the energy sector, the national energy laws (Act on the production, transformation, transfer, turnover, distribution and use of energy, Energy Act, (Norwegian: Energiloven; LOV-1990-06-29-50 (<https://lovdata.no/dokument/NL/lov/1990-06-29-50>)) (accessed on 19 May 2021), require the development of energy and climate plans on the municipal level. Furthermore, in the Norwegian context, energy efficient solutions should become the preferred choice for consumers in the future [48]. The National Water and Energy Directorate (NVE) introduced the plus-customer arrangement to enable the rise of prosumers in Norway. The country's clean and renewable energy resources for national demands, technological readiness and orientation of sustainable development towards social objectives encourages the deeper analysis of the social dimension in PED development.

Citizen involvement in urban development is guaranteed by the Planning and Building Act (LOV-2008-06-27-71 (<https://lovdata.no/dokument/NL/lov/2008-06-27-71>) (accessed on 19 May 2021), which has the aim of promoting sustainable development in the best interests of individuals, society and future generations. According to the Act, planning should facilitate coherence between multiple sectors, functions and interests of society. Public participation is the responsibility of municipalities and regional authorities. According to a study of 16 Norwegian municipalities, the number of participation measures does not affect the level of citizen participation but does affect citizens' perceptions of being heard [49]. The actual approaches and quality of citizen participation are described as varied. We can see that early participation more often leads to long-term citizen engagement, while late participation has advantages and disadvantages for the citizen. On the one hand, the issues at stake become more specific and concrete, but on the other, the citizens' real influence on the decision becomes more limited.

4. Results

4.1. Case Analysis

Case 1: ZEN Centre. The Research Centre on Zero Emission Neighbourhoods in Smart Cities (ZEN Centre) (<https://fmezen.no/>) (accessed on 19 May 2021) will last eight years (2017–2024), and the budget is approximately 48 million EUR, funded by the RCN, the research partners NTNU and SINTEF, and the user partners from the private and public sector in Norway. NTNU is the host and leads the Centre together with SINTEF. The goal is to develop solutions for future buildings and neighborhoods with zero life-

cycle greenhouse gas emissions and thereby contribute to a low carbon society. The ZEN approach is building primarily on reduction of embodied emissions and energy demand and is aligned with compensation of emissions by renewable energy production [50]. The ZEN Centre, as a follow-up center to the Centre for Zero Emission Buildings, has 11 public partners, including Trondheim municipality, 21 industry partners and 2 research partners (NTNU and SINTEF). The partners of FME ZEN cover the entire value chain of built environment development on a neighborhood scale in the framework of smart cities and include representatives from municipal and regional governments, property owners, developers, consultants and architects, contractors, energy companies, manufacturers of materials and products, and governmental organizations.

The ZEN Centre will contribute to and manage a series of neighborhood-scale demo sites, which will act as innovation hubs and as testing grounds for the solutions developed in the ZEN Centre [51]. They are geographically limited, primarily urban areas in Norway, in which the Centre's researchers, together with the user partners, test the ZEN indicators under development and new solutions for the construction, operation and use of neighborhoods. This is in order to study how to reduce the greenhouse gas emissions on a neighborhood scale towards zero.

Case 2: +CityxChange. The aim of +CityxChange (<https://cityxchange.eu/>) (accessed on 19 May 2021) is to develop and deploy Positive Energy Blocks (PEBs) and Districts (PEDs) to achieve sustainable urban ecosystems that generate a surplus of local renewable energy by co-producing more energy than is consumed, integrating eMobility and energy trading, connecting energy and urban planning, involving citizens and stakeholders, improving quality of life and exchanging experiences with other cities across Europe. Co-creation of positive energy blocks and districts (PEB/PED) will be fulfilled through strategic alignment with city ambitions, citizen and stakeholder engagement and involvement, integrated planning, common energy markets, the use of digital services in an ICT ecosystem framework [31], regulatory sandboxes, integrated eMobility and sustainable business models. The expected outcomes include operational and scalable PED prototypes, an increase of local renewables and self-consumption, GHG emission reduction, meaningful stakeholder engagement and recommendations for policy intervention, market (de)regulation and business models that deliver positive energy communities. The project is structured around 11 topical and domain-specific demonstration projects that together form a holistic approach to PED development. These are developed in its two Lighthouse Cities and will be replicated in its five Follower Cities and beyond. +CityxChange is an EU H2020 Innovation Action project from the Smart City and Communities program and one of, to date, 18 high-level Lighthouse projects working on secure, affordable and clean energy in European Smart Cities (<https://smartcities-infosystem.eu/scc-lighthouse-projects>) (accessed on 19 May 2021). Direct funding is 20 million EUR, with an overall volume around 35 million EUR, running from 2018 to 2023. The consortium for +CityxChange consists of 32 partners: the 7 involved municipalities, 2 universities, 9 large enterprises, 2 distribution network operators, 9 SMEs, and 3 non-profit organizations. The Norwegian University of Science and Technology (NTNU) is coordinating the project with the two Lighthouse Cities of Trondheim, Norway and Limerick, Ireland, and five Follower Cities of Alba Iulia, Písek, Sestao, Smolyan, and Vöru.

Case 3: Syn.ikia. Syn.ikia (<https://synikia.eu/>) (accessed on 19 May 2021) is an EU H2020 Innovation Action project that started in 2020 and will run until 2024. Syn.ikia puts forth the concept of SPEN (Sustainable Plus Energy Neighbourhood) where the geographical boundary is expanded from the building level to the entire site of the neighborhood development, including local storage units and energy supply units [52]. The mission in syn.ikia is to increase the proportion of SPENs with surplus renewable energy in different contexts, climates and markets in Europe. The project aims to achieve more than 100% energy savings, 90% renewable energy generation triggered, 100% GHG emission reduction, and 10% life-cycle costs reduction, all compared to the 2020 nearly zero energy buildings. Syn.ikia will actively speed up the development of technologies for energy

efficiency, renewable energy sources, storage, flexibility, and exploitation (replication, market upscale, risk reduction) to all relevant market actors via four real-life demonstration cases in four climatic zones. One of the demonstration cases will be in Oslo, representing a sub-arctic climate.

An overview of the three cases is presented in Table 1.

Table 1. Overview of the cases.

Category	ZEN	+CityxChange	syn.ikia
A. Program and Call Information			
Timeframe	8 years (2017–2024)	5 years (2018–2023)	4.5 years (2020–2024)
Project Context	Follower project of FME ZEB on Zero Emission Buildings	Project based on NTNU Smart Cities and Communities approaches and city ambitions	Internationalization of FME ZEN to participate in international fora to exchange knowledge and experience
Main Funding Agency	Research Council of Norway	European Commission-Horizon 2020	European Commission-Horizon 2020
Project Type	Research Centre	Innovation Action	Innovation Action H2020-EU
Program	FME—Research Centre for Environmentally Friendly Energy	H2020-EU 3.3.1.3.—Foster European Smart cities and Communities	2.1.5.2.—Technologies enabling energy-efficient systems and energy-efficient buildings with low environmental impact
Topic of Call	N/A	EU H2020-LC-SC3-1-2018-2019-2020: Smart Cities and Communities	EU H2020-LC-EEB-03-2019: New developments in plus-energy houses
Budget	48 million Euro	35 million Euro	6.9 million Euro
B. Management and Partners			
Coordinator	NTNU: research institute; with SINTEF as main research partner	NTNU: research institute; cities for city demo site coordination	NTNU: research institute with SINTEF as part of consortium
Partners	32 Norwegian partners	11 Norwegian and 21 international partners	3 Norwegian and 10 international partners
Background of Partners	Partners from whole value chain within construction sector, plus-energy sector and municipalities, research	Research, public sector, energy, digital technology, engagement and outreach, planning, real estate, mobility	Property developers, urban design consultancies, energy forecasting and optimization solutions, real estate/facility management, research
Role of Partners	Active; but partners are not obligated to fulfil activities; Steering Committee led by partners	Active; partners are jointly working on specific tasks for project objectives	Active; partners are jointly working on specific tasks for project objectives
C. Project Goals and Approach			
Project Goal	Framework and methodology for Zero Emission Neighbourhoods	Design, deployment, testing, replication of PEBs/PEDs and PEB-enabling innovations	Replication and upscaling of SPENS; 10% market uptake of plus energy houses by 2030
Focus	Emission reduction in the built environment, energy systems and energy flexibility, introduction of new technology solutions to marked	Urban transitions, emission reduction, energy transition, local energy systems, Open Innovation, co-creation, sustainable business models, regulatory mechanisms	Development of new designs, tools, methods, and processes which will enable large deployment of sustainable plus energy buildings and neighborhoods
Greenhouse Gas (GHG) Emissions	Assessed in all life-cycle phases	Assessed in operational phase of the demo sites	Total GHG is part of its environmental performance indicators in the overall SPEN evaluation framework

Table 1. Cont.

Category	ZEN	+CityxChange	syn.ikia
D. Implementation			
Demo Sites	9 demo sites in 8 Norwegian Cities	2 PEB demo sites in Trondheim, Norway; 6 international demo sites	1 demo site in Oslo, Norway and 3 international demo sites
Coordinator of Demo Sites	(Mainly) public steered demo sites	Public and private steered demo sites	Private steered demo site

Presentation of the Demo Sites for PED Implementation in Norway

The three cases include twelve demo sites in Norway (Figure 2). Each demo site constitutes a unit of analysis and is presented in detail in Table 2 below.

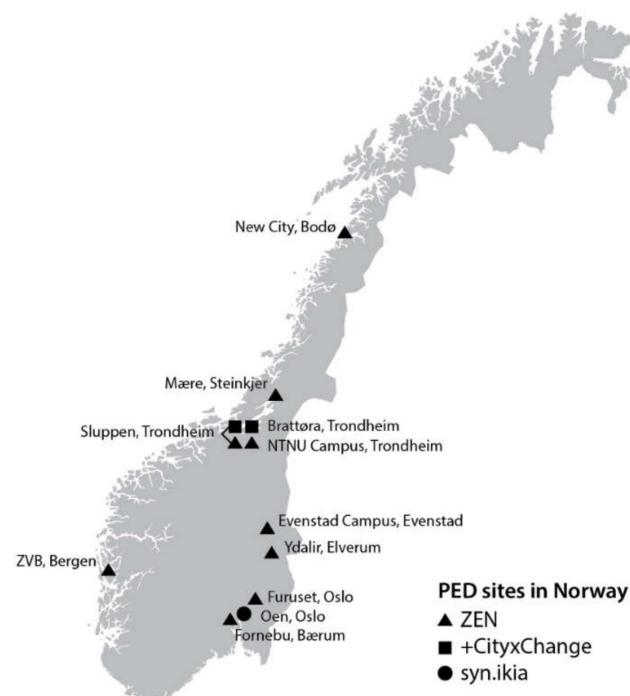


Figure 2. Units of analysis: 12 PED sites in Norway (source: authors' own, with open map files from Kartverket).

While all PED projects in the respective demo sites are aiming to become positive energy, either on an annual basis or over their lifetime, for each of the demo sites, an individual approach towards the PED concept, in general, and the energy system, specifically, is chosen, building on, e.g., reducing energy demand, energy flexibility and renewable energy production [53]. As the majority of demo sites are in the planning and construction phase, and several have been interrupted or altered since the beginning of the COVID-19 pandemic, it is not possible to report actual or estimates of energy consumption for all demo sites in a meaningful way for comparison.

As an initial estimate, the two +CityxChange demo sites are expected to have around a 3.2 GWh per year consumption that should be covered by renewables. Detailed numbers will be published in future Deliverables. Within ZEN, the yearly energy consumption is estimated for Ydalir with around 8 GWh, Fornebu with 4 GWh.

Table 2. Overview of the 12 Norwegian PED demo sites across the 3 cases (ZEN, +CityxChange and syn.ikia).

Demo Site	Project	Type of Area before PED Development	Area Size (m ²)	Project Owner	Planned Construction
Ydalir, Elverum	ZEN	Brownfield	430,000	Public	Residential area with a school and kindergarten
Furuset, Oslo	ZEN	Mixed-use neighborhood with local center	870,000	Public	Retrofitting/upgrading and new construction: 1700–2300 dwellings and 2000–3400 workplaces (up to 160,000 m ²)
Zero Village Bergen (ZVB), Bergen	ZEN	Greenfield	378,000	Private	Residential area with 720 dwellings (92,000 m ²), a kindergarten and additional service functions
NTNU Campus, Trondheim	ZEN	University Campus	339,031	Public	Retrofitting and new construction (ca. 136,000 m ²)
Sluppen, Trondheim	ZEN, +CxC	Mixed use area, mainly commercial	275,000	Private (+CxC), Public (ZEN)	Multifunctional local center with a mobility hub, residential area, offices, warehouses; incl. retrofitting and new construction
Brattøra, Trondheim	+CxC	Former harbor, mainly commercial and offices	450,000	Private (for site)/ Public (for neighborhood level)	Powerhouse office building completed, further (re) development upcoming, mobility hub with future e-ferris
Evenstad Campus	ZEN	University Campus	61,000	Public	Optimization of energy system
New City-New Airport, Bodø	ZEN	Former airport	3,400,000	Public	Multifunctional city quarter with residential and business areas; 2800 dwellings in first construction stage
Fornebu, Bærum	ZEN	Former airport	3,400,000	Public	Multifunctional city quarter, ca. 265,000 m ² existing building stock, ca. 3700 new dwellings
Mære, Steinkjer	ZEN	Agricultural school	18,000 (Gross building area)	Public	Optimization of energy system and control
Oen, Oslo	syn.ikia	Residential building	12,750 (Gross building area)	Private	New residential building with 146 housing units with sharing of community spaces, RES, local energy storage, peak shaving, flexibility and self-consumption

To summarize the review of demo sites (Table 2), great variation was found between the types of projects, size and planned construction covering both existing areas and new buildings with multiple functions. The areas for PED development range from 12,750 square meters of a residential site to 3,400,000 square meters of multi-functional city quarters. Moreover, approximately two-thirds of the projects, primarily from ZEN, are owned by public sector partners, and one-third, including +CityxChange and syn.ikia,

by the private sector. The demos are highly shaped by project aims and their respective funding programs from 2017 to 2024 (Table 1), giving opportunity to learn from early experiences and deepen approaches to social innovation.

4.2. Approaches towards Social Innovation

The social innovation and participation dimensions concern the integration of citizens in innovation and urban transformation processes spurring PED development. The approaches to such integration differed across the three projects in their orientations to citizen involvement, stakeholder interaction and capacity building, education and learning. These three areas were selected based on the results in Section 2. We present the findings of our multiple case study on social innovation in this section. The key results of the comparison between the three PED approaches on social innovation are highlighted in Table 3 and are described in detail in the subsections that follow.

Table 3. Social innovation approaches within the three cases of PEDs in Norway.

Dimension	ZEN	+CityxChange	syn.ikia
Citizen Involvement	Focus on technical innovation, bottom-up approach for social innovation in demo sites, citizen participation facilitated by project partners	Focus on technical and social innovation, citizen participation facilitated through the project	Focus on demonstrating innovations and savings going from a building level to a neighborhood scale to encourage a new level of citizens' participation and awareness via neighborhood scale user engagement systems, user journey assessments and surveys
Stakeholder Interaction	Open innovation driven by consortium partners and local stakeholders related to each demo site. Prominent role of public sector as main demo site project owner (8 of 9 demo sites are public owned)	Open innovation activities are driven by multiple stakeholders (public, research, private incl. SMEs, people)	Open innovation driven by consortium partners, local stakeholders related to each demo site and the development of a wider online stakeholder community to engage partners in different parts of the value chain
Capacity Building, Education and Learning	Professional capacity building	Community capacity building, professional capacity building through intra-project exchanges, education through universities	Capacity building is directed towards, not just end users, but actors in the combined value chain, hence extending to a diverse audience of experts, professionals and policy makers, such as investors, developers, municipalities, grid operators and utilities, and building owners

4.2.1. Citizen Involvement

The ZEN Centre is oriented to assisting partners in overcoming the traditional problems of citizen involvement. Social innovation is facilitated in living labs for experimentation with end-users and citizens [54]. There is, in general, a strong focus on technical innovation (e.g., across sectors) rather than social innovation. Nevertheless, the variety of ZEN demo sites across Norway present opportunities for social innovation, as they give insights on transformation processes and different stakeholder configurations in various regional contexts.

An example for realizing social innovation across sectors of energy and urban planning was given by the demo site of Ydalir. The construction of the subsurface pipe system for district heating in the neighborhood was combined with the construction of a walking

pathway above surface, connecting the demo site to the nearby city center in a shorter and more attractive way. This was an example for effective and early stakeholder collaboration between energy and urban planning actors. The collaboration was achieved through the facilitation of a series of workshops at the beginning of the planning phase of the project [55].

In +CityxChange, social innovation and citizen participation have taken a central place in the design of the project. PEDs are co-created with stakeholders and are intended to be open to social innovations that may shape their development, to the extent possible within the framework of a H2020 program. There is a dedicated work package on co-creation and community participation, which develops frameworks and tools for community-oriented activities. Amongst others, learning frameworks, playbooks, innovation playgrounds and living labs are included [56,57]. The participating cities use these to adapt and test new approaches.

In syn.ikia, the citizens are more occupants, residents and end-users. End-user involvement is planned in the development of a neighborhood scale user engagement system to facilitate the utilization of ‘energy plus’ systems from the building level to the neighborhood level focusing on the end-users in the value chain (i.e., households). This is anticipated to encourage a new level of citizens’ participation and awareness. In addition, a planned initiative is to conduct a post occupancy evaluation at the neighborhood scale, and a user journey assessment will also be prioritized to enhance user involvement and satisfaction. Surveys will be undertaken targeting the demo case residents to get insights on all aspects relating to energy and their behavior, feelings and actions in making the transition from a consumer to a prosumer.

4.2.2. Stakeholder Interaction

This dimension looks at co-creation and open innovation, particularly from the public sector perspective. The SET Plan foresees a need for a structured, integrated and innovative approach embedded in the city’s overall vision, which depends on the involvement of all relevant stakeholders. Public authorities are typically the gatekeepers and coordinators of the approach, due to their legal powers over land use, planning and infrastructure. Recognizing a need for open innovation pipelines to support PEDs from research to market and society, leadership in the public sector is essential. This can be achieved through co-creation and participatory processes, public sector innovation and procurement practices that encourage stakeholder participation and innovation. We compared the approaches to innovation and role of the public sector across the three projects.

The ZEN Centre is characterized by open innovation driven by mainly the public sector within the demo sites and following an experimental approach to PED deployment. Besides the demo sites, the project uses living labs as an additional method for involving stakeholders. Eight of nine demo sites are publicly owned and coordinated by public sector at this early stage of development. Being the earliest of the three PED projects, this has led to early learnings for stakeholder involvement and co-creation in the Norwegian context. Following these early processes, it was observed that integration between different governmental levels and its stakeholders, e.g., municipal and regional public bodies, is crucial. For example, a missing awareness of existing governance structures and the need for collaboration between different hierarchical policy structures held the Zero Village Bergen project on hold for many years [22]. In the specific local contexts of the demos, the roles and responsibilities of coordinating actors were not always clear to all involved stakeholders, and it was necessary to ‘muddle through’ to find the right cross-sectoral and administrative points for cooperation. A variety of approaches towards coordination of PED projects in the demo sites was found, such as the local land development agency in Ydalir, and the creation of a municipal inter-departmental working group for PED development in the demo site in Bodø. Different background, experiences and responsibilities of project coordinators led to diverse approaches towards stakeholder involvement in the PED project development. A specific challenge was identified in multi-owned demo sites, where a

multitude of stakeholders are involved and need to be orchestrated towards successful PED development. The ZEN Centre focuses on technical aspects of PEDs and dedicates some resources to the development and deployment of co-creation methodologies. Specifically, the definition for ZEN under development is incorporating more aspects towards process design and stakeholder involvement, including citizen participation.

+CityxChange demonstrates open innovation driven by multiple stakeholders [58,59] including co-creation with the public and private sector (e.g., energy providers, industry partners, SMEs) and strong citizen engagement. Innovation is deliberate in as much as the impacts of a H2020 project must be foreseen, but it is also left open via the strategy of co-creation adopted by the project. The project adopts a Bold City Vision (BCV) strategic alignment approach that integrates PED related principles and energy goals into the city's urban development plans and processes and vice versa. For example, through the BCV implementation, the municipality of Trondheim aims to link and scale learnings up to city processes [59].

Co-creation also entails significant citizen engagement and education to increase awareness and acceptance of PEDs, which is deemed necessary for replication. Living Labs are deployed as sites for community interaction and urban prototyping to foster open innovation. In Trondheim, four City Labs make the urban living lab approach tangible, under the concept of city-wide innovation playgrounds, open to the public and managed by the municipality and private partners. +CityxChange PEDs are developed in existing areas, requiring stakeholder constellations of cooperation. Co-creation is adopted as a strategy to support the process.

As a H2020 Innovation Action project, syn.ikia operates on an open innovation principle. Stakeholders are identified on different levels such as consortium level, local demo site level and a wider online stakeholder community (SPEN community) level. On a consortium level, the stakeholder interaction is addressed via a dedicated work package on innovation management and exploitation to track key exploitable results generated by consortium partners systematically. On a local demo site level, the Norwegian demo site, like syn.ikia's other three demo sites in Spain, Netherlands and Austria, serves as a co-creation hub for developing and testing of novel systems, technologies and processes for achieving sustainable plus energy houses at the neighborhood scale in the sub-arctic climatic type in Europe. This involves the local value chain actors in which the demo site is embedded. As for the wider online stakeholder community level that will comprise PED experts and practitioners, it is envisaged that the SPEN community will be instrumental in providing exposure and promoting the innovations coming from syn.ikia.

4.2.3. Capacity Building, Education and Training

While the three cases try to reach out to enhance capacities through knowledge transfer, experience, education, and training among a broad number of stakeholders, we identified a main target group within the three specific projects where most of the efforts were allocated.

The ZEN Centre focuses on capacity building among professional stakeholders, both individual and organizational, in Norway along the construction value chain, including relevant sectors of energy. Through partner meetings and both academic and popular-science presentations at professional meetings, e.g., the Norwegian annual meeting of building physics or the two-annual ZEN conference, knowledge from the ZEN Centre is spread to its partners and abroad. Some partners involved are associations, such as the Norwegian District and Heating Association, who represents a broad number of industry partners within district heating, and who use their respective information channel to inform and build up competencies. In addition, knowledge is published through relevant publication channels, such as SINTEF Building Research Design Guides, to reach out to a broad number of construction companies including SMEs. Some publications and meetings are dedicated to ZEN partners and are not open to the public. Experiences from early-stage implementation have shown that despite the broad channels to communicate and educate on ZEN, project partners in the demo sites report missing capacities and skills

to implement PED ambitions and technologies [51,60]. In the pilot project of Ydalir, this challenge was addressed by a guiding booklet for the implementation of district heating system technologies and technical installations in the buildings. At the time of writing, the booklet was still under development by the utility company and project partners.

Activities of the ZEN Centre itself are not primarily aiming at citizen or end-user capacity building. Experiences from the former demo site of Steinkjer, the kindergarten of Lø, show that a missing understanding of the ZEN concept, and knowledge from that, can put a project, or at least its higher ambitions towards climate neutrality, on hold [61]. In Steinkjer, two kindergartens should be relocated in an existing building, which should be retrofitted following the ambitions for climate neutrality within the ZEN Centre. The future users of the kindergarten, employees and parents perceived the ZEN ambition as an extra burden with regard to time and resources and intervened towards the political steering of Steinkjer, which put the project on hold. In the end, the relocation of the two kindergartens will take place in a new building without ZEN ambitions, and, due to that occurrence, this project is no longer part of the ZEN Centre.

In some cases, the ZEN Centre also provides training to respective users of tools developed within it. Training of a Geographic Information System (GIS)-based tool to evaluate spatial qualities was provided to employees of the urban planning departments in the municipalities of Bodø and Trondheim.

Living labs are facilitated as non-permanent (urban) experiments within demo sites, exploring end-user and citizen perspectives in relation to diverse ZEN aspects (future living, energy saving technology acceptance). Living labs are, therefore, designed to inform, consult, involve and educate end-users and other relevant stakeholders in ZEN. As the ZEN Centre is hosted by NTNU, and a broad number of teaching staff is part of the ZEN Centre, several student courses are dedicated to specific ZEN aspects, for instance, life-cycle assessment (LCA) or sustainability design with low emissions and using ZEN demo sites as case studies during courses and master theses across different fields.

The focus of ZEN on the planning and design phase reflects the status of several of the demo sites, which are covering planning and design for PEDs, as well as early-stage implementation, both in building and infrastructure areas. This broad range of demo sites in different phases of development as well as different contexts, from urban to rural or project size, offers the possibility for a broad comparison and learning between different PED developments. Experience sharing and knowledge transfer between demo sites is facilitated through annual meetings of the demo sites partners.

+CityxChange is reaching out to foster community competencies and to educate the next generation of smart citizens, with learning activities targeted to elemental and higher education. Information and engagement of citizens is facilitated through engagement and participation tools, such as the citizen engagement playbooks, innovation playgrounds and labs, next generation of smart citizens activities and learning frameworks. Four physical City Labs are established in different neighborhoods of Trondheim for connecting the municipality (and other stakeholders) with the community, to include local innovation ecosystems and to make the City-as-a-living-lab approach tangible. +CityxChange furthermore organizes regular learning sessions for its partners, as well as storytelling workshops with external stakeholders and decision makers. These serve as a form of capacity building and exchange of experiences between partners, and some are also open to the wider public, especially to related H2020 projects. Topics of +CityxChange and the project as a case study are also part of education activities of the participating universities. +CityxChange will also become a pilot for better integration between innovation, research and education on the UN Sustainable Development Goal 11 (Sustainable cities and communities) in a new Erasmus+-funded project ENHANCE (<https://enhanceuniversity.eu/>) (accessed on 19 May 2021).

In syn.ikia, capacity building is planned for at least two target groups: occupants and end-users, as well as actors in the combined value chain of the built environment and that of the residential energy. It is planned to implement training for occupants and end-users so

that they are able to use the new technologies efficiently. Furthermore, there will be regular monitoring of usage patterns and user comfort in the in-use phase. Beyond end-users, syn.ikia will disseminate SPEN concepts, technologies and solutions to the actors in the combined value chain via the demo site and via the online SPEN community. In this way, capacity building is directed towards a diverse audience of experts, professionals and policy makers, such as, investors, developers, municipalities, grid operators and utilities and building owners.

5. Discussion

In order to explore social innovation in PED projects and learning from the Norwegian experiences, we discuss the findings in terms of the two research questions.

What is the variety of social innovation approaches in planning and early implementation of PED projects in Norway?

All three projects are driving social innovations, albeit with different scope and extent. Comparison showed that +CityxChange, as a smart cities project, has a wide scope for urban transformation and societal transition incorporating social innovation. This leaves room for significant co-creation activities with citizens amongst other stakeholder groups. As the main focus of the ZEN Centre lays on technical innovations within the whole value chain of the construction industry in alignment with the energy sector, social innovation and involvement of citizens and users is mainly facilitated by the project partners in the demo sites.

Syn.ikia balances technological innovation with social innovation by focusing on occupants, residents and end-users (using tools such as co-design, neighborhood scale user engagement system, post occupancy evaluation at the neighborhood scale, user journey assessment and surveys) and by combining the perspectives of existing and emerging actors in the combined value chain of the built environment and that of residential energy. It operates open innovation at three levels to maximize impact—demo site, consortium and beyond-consortium level—and aims to stimulate stakeholder interaction at these three levels. Its approach to capacity building and promoting social inclusion centers, not only on end-users, but also on involving a diversity of actors, core and peripheral, via an online SPEN community to embark on the energy transition.

Social innovation occurs through both external activities to the projects (i.e., indirectly) and internalized ones embedded in project structures (i.e., directly). This raises awareness about where to locate responsibilities and practices for social innovation according to the project context.

The public sector plays a necessary role in the demo sites of +CityxChange, ZEN Centre and syn.ikia in integrating PEDs into urban development planning, policy and processes on multiple governmental levels. The provisions under the Planning and Building Act can pose significant challenges for private developers. Thereby, we identified that for many of the demo sites for PED deployment, there is a public project owner for the whole development or coordination, though sometimes one or multiple building owners take that role, for example, in Zero Village Bergen or in +CityxChange. The scope and degree of stakeholder engagement and sharing the initiative for PED uptake, nevertheless, varies widely. Looking at the differences between the three projects, we identified variation within the ZEN Centre alone, as multiple demo sites were shown to vary based on the local contexts, shaping different stakeholder constellations and ways of 'getting things done'. The comparison of all projects shows the local adaptation of approaches, even as they follow similar concepts, which is in line with the stated importance of local context for PED development [24,41,51]. Furthermore, we identified the importance of innovative approaches within stakeholder engagement across sectors and stakeholder groups to appropriately address the complexity of PED projects. Additionally, the scope and focus group for capacity building varied between the three projects.

While this study focused on projects in the Norwegian context, there are other projects with Nordic or European sites, building upon the policy framework already presented

in Section 2. Newly published studies do compare PED projects without taking social innovation approaches into consideration but, at the same time, highlight the importance of stakeholder involvement, citizen participation and capacity building as important elements for PED deployment [24,37,40,41]. An international comparison would contribute to a deeper understanding of social innovation's role in PED development, but is outside the scope of this paper.

The variety of social innovation approaches in PED development in the Norwegian projects analyzed in this paper could also be seen under a broader light of a Nordic model, much akin to the developments on the city scale. Further research could analyze the commonalities and differences with other regional PED projects. Here, the insights and experiences of both +CityxChange and syn.ikia, which include other European demo sites, would add richness to the ongoing work in developing a PED database, to which researchers in PED international forums, such as COST Action Positive Energy Districts European Network and IEA EBC Annex 83 Positive Energy Districts, are contributing.

What are the learnings to guide future PED developments in social innovations?

The three types of projects reviewed here show strong similarity in making social innovation issues a priority in their work. Within that, they demonstrate variations which can partly be traced to the calls and funding schemes establishing the scopes of projects, and partly seem to be due to varying approaches, site selections and local contexts. Comparing these projects at an early stage gives us the possibility to reflect on the applied and envisioned approaches towards social innovation as a complementary effort to their technical innovation in the PEDs and derive some learning and practical guidance. As a limitation, given the early stages, we cannot yet draw on actual evaluation and, thus, base this part on the selected and used methods in the projects so far.

Taken together, planning and early implementation of PEDs in our cases demonstrated a plethora of potential social innovation activities that can be realized in specific local contexts and stakeholder configurations, using a variety of methods from living labs, workshops and innovation playgrounds. The analysis has shown that social innovation builds on the three pillars of stakeholder involvement, citizen participation and capacity building in a more dynamic way, as presented in Figure 1. The experiences from Norwegian demo sites identified dynamic interactions between these pillars, that evolves over time.

We have learned that to enable a successful deployment of PEDs, capacity building, education and training should include all relevant stakeholders, professional and citizens/end-users of buildings and infrastructure, and especially key personnel responsible for citizen involvement and capacity building, in the respective demo sites. Stakeholders, and especially key personnel, developing knowledge, skills and experiences with respect to stakeholder engagement, citizen participation and capacity building will enable them to orchestrate social innovation in a more directed and efficient way over time. Raising knowledge about the local context of PED development and its specific needs, drivers and challenges will contribute to better capacities towards social innovation. Through evolving capacities on orchestrating capacity building, stakeholder involvement and citizen participation, social innovation's role will change over time to be an enabler for exploration and deployment of PEDs in alignment with technological innovation (see Figure 3).

With regard to stakeholder involvement, we see a strong interaction with citizen participation, as learnings from the Norwegian demo sites have shown citizen participation to be an integrative part of stakeholder involvement that should be guaranteed and facilitated both in early phases of PED development, and in later deployment and operation phases. Widening the scope of stakeholder interaction and enabling continuous co-creation processes that include citizens will contribute to adaptive cycles of PED exploration and deployment. Additionally, this touches a major challenge in society nowadays, as the integrative PED concept relates to different sectors and stakeholders involved, such as policy makers, PED developers, operators and civil society, whose presence and influence vary over time. The PED concept, therefore, asks for a governance model that steers and

manages social innovation activities over time, from early planning to operation, in a holistic way.

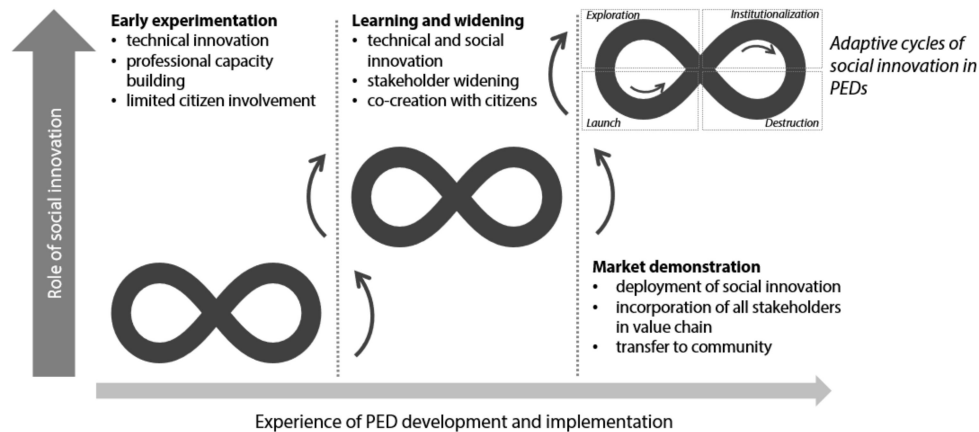


Figure 3. Model of transformative change in PED socio-technical system through social innovation (source: authors' own, based on [62,63]).

The responsibilities for stakeholder interaction towards all relevant stakeholders and the enabling for social innovation should be identified and communicated, especially with regard to the early involvement of citizens as future users. We consider that responsibility can be taken by different groups according to local contexts and legal requirements and can shift throughout the life of the project according to stage of PED development and the evolving needs of stakeholders and citizens, specifically. At the same time, there is a need for a structured process and common understanding of social innovation activities incorporated in a holistic governance model over the lifetime of the PED project.

To elaborate on social innovation, methods including living labs, workshops and innovation playgrounds are used in the three PED projects reaching out to include different stakeholder groups at different phases of PED development. The learnings of which methods and tools are suitable, to foster social innovation for what specific context of PEDs and the respective phase of development, are evolving. Experiences of social innovation activities from diverse PED projects can help to build an understanding of the suitability of methods and tools in specific PED contexts and with regard to goals of social innovation activities.

Building on our findings, we draw the picture of a more dynamic role of social innovation in the socio-technological system of PEDs (Figure 3). Taking inspiration from the theory of transformative agency in socio-ecological systems [62,64], each PED project represents an adaptive cycle [63] of exploring and testing social innovation. Each iteration of an adaptive cycle creates knowledge from successes and failures to be carried to the next. As PED projects and their adaptive cycles progress through early experimentation to learning and widening, and market demonstration phases, the role of social innovation becomes more deeply embedded in project structures and the aspects of social innovation (i.e., citizen involvement, stakeholder interaction and capacity building) mature. Social innovation can thereby be seen as a transformative element in socio-technical systems, "tipping towards sustainability" [64], by supporting energy transition aims indicated in the SET Plan and other policies and programs.

6. Conclusions

This paper has analyzed the prevailing approaches towards social innovation in the planning and early implementation of PEDs in the Norwegian context. We investigated three projects with twelve PED demo sites in Norway in a comparative case study, capturing the variety of approaches for social innovation so far. The results show that each of the

PED projects balanced technological solutions as well as social innovations, but in a varied approach and scope with regard to citizen involvement, stakeholder interaction and capacity building. Due to the early stages of the projects and demo sites, we cannot yet evaluate specific results of these social innovation processes, but the set-up of how the three projects address social innovation allows us to extract an overview of the variety of practical approaches and the way context drives them.

From this broad variety of local contexts and approaches, we derive three open questions that can be helpful in guiding future PED projects towards social innovation:

- Who is responsible for social innovation activities over the lifetime of the PED project?
- How can the responsible persons and organizations for citizen and stakeholder involvement ensure they have the capacity (abilities, knowledge, skills) to facilitate social innovation activities within PED development and to involve, educate and train on the new concept of PED and its practical implications?
- How could the respective stakeholders, including citizens, be appropriately involved in the PED development to enable social innovation processes?

We conclude that within the PED projects studied, no single specific approach served or is used in all, thus there are multiple roads to PEDs. This is in line with reported experiences from the wider European landscape of PED projects [46,47]. Nevertheless, we see value in the variety of approaches towards PEDs in general and, accordingly, in the variety of approaches to social innovation as specifically presented in this paper. To accommodate variety, we developed a dynamic and evolutionary understanding of social innovation in PEDs based on the knowledge gained in each iteration that enables a deepening role of various social innovation aspects in PED projects. From our specific cases, this study guides the reader towards possible approaches and solutions based on project context and the maturity of social innovation in the local system.

To enable a successful energy transition towards climate neutral and socially inclusive cities, the PED concept and its definition, as well as the practical deployment of PED projects, asks for a balanced approach incorporating technical and social innovation simultaneously, in order to enable broad citizen and stakeholder involvement activities through the whole lifetime of the project. Stakeholders involved in future planning of PED projects within Norway and internationally can plan around these three questions to consider a multitude of options for addressing social innovation processes and outcomes when setting up a PED project, drawing inspiration from the reviewed Norwegian projects.

The approaches to social innovation, in part, fulfil programmatic requirements at national and international levels, while being founded in theory to differing degrees. Since the PED projects run as experiments for social and technical innovation, they also allow deeper analysis of the results of these approaches. The theoretical basis for social innovation particular to Norwegian PED development, can be strengthened through continued analysis during each project's progression. Further work should follow the implementation approaches on the demo site level to evaluate the strengths and weaknesses of social innovation approaches. This would offer further comprehensive insights and capture learnings from these PED projects for robust cross-country comparisons and foster further dialogue in the evolution of the PED concept and its European and international development.

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Abbreviations

EU	European Union
FME	Research Centres for Environmentally Friendly Energy [Forskningscenter for Miljøvennlig Energi]
GHG	Greenhouse Gas
GIS	Geographic Information System
H2020	Horizon 2020—the eighth European framework programme for Research and Innovation
JPI UE	Joint Programming Initiative Urban Europe
NTNU	Norwegian University of Science and Technology
PEB	Positive Energy Block
PED	Positive Energy District
RCN	Research Council of Norway
SET	Strategic Energy Transition
SPEN	Sustainable Positive Energy Neighbourhood
ZEN	Zero Emission Neighbourhood

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