Positive energy neighbourhoods as drivers of local energy transitions

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Keywords

Energy Performance of Buildings Directive (EPBD), Renewable Energy Directive (RES), positive energy neighbourhood, energy renovation

Abstract

Positive Energy Neighbourhoods (PENs) are an innovative policy concept to reimaging traditionally supply-side focused local energy initiatives. They integrate sufficiency design principles and deep renovation to reduce demand alongside collective production and storage of renewable energy adjusted to the local context. Municipalities can achieve renovation and climate targets by engaging key stakeholders to adjust technical, social and financial solutions to each neighbourhood. However, demo projects from the oPEN Lab Horizon 2020 project show that PEN projects' potential is limited by regulatory and financial barriers.

This study employed a combination of policy analysis, desk research and focus groups with key enablers of oPEN Living Labs located in Belgium, Spain and Estonia, such as public authorities, business developers, architects and social housing associations. Key regulatory gaps and barriers, as well as best practices, were identified in national, regional and local policies. The lessons learnt from the implementation of the 2018 Energy Performance in Buildings Directive (EPBD), Renewable Energy Directive (RED) II and Electricity Directive (EMD) can inform the upcoming transposition of the 'Fit for 55' package in Member States. The goal is to establish a PEN-friendly policy framework to reap the full potential of neighbourhood and participatory approaches in building renovation policies.

Findings show policy efforts towards energy efficiency and renewable energy at the building scale but fall short in enabling and facilitating neighbours to collectively renovate and harness of benefits of collective energy production and storage of renewable energy. Limited transposition of REDII and EMD disincentivises the monetisation of renewable energy and flexibility services and jeopardises PEN business models. Also, regulations or incentives to adopt a whole life carbon perspective in renovations are currently absent from the established policy landscape. Going forward, these results will inform tailored policy recommendations across Member States, empowering citizens to collectively contribute to the complex but urgent energy transition ahead.

Introduction

With the European Climate Law, the European Union (EU) has set a course to systemically align climate and energy relevant policies to achieve a net greenhouse gas (GHG) emissions reduction of at least 55 % below 1990 levels by 2030 and climate neutrality by 2050[1]. Under the 'Fit for 55 package' the past years have seen a systemic revision and recast of the EU climate and energy directives. While the latest progress report of the European Scientific Advisory Board on Climate Change from January 2024[2] concludes that delivering on the Fit for 55 package will now largely depend on national action, they also

1. Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 ('European Climate Law'), 243 OJ L (2021). http://data.europa.eu/eli/reg/2021/1119/oj/eng

2. European Scientific Advisory Board on Climate Change. (2024). Towards EU climate neutrality: Progress, policy gaps and opportunities [Assessment Report]. https://climate-advisory-board.europa.eu/reports-and-publications/towards-eu-climate-neutrality-progress-policy-gaps-and-opportunities

highlight the importance of facilitating engagement and participation of local communities, local renewable energy production and the need to build the capacity of local and public authorities.

A key intervention point with high leverage for climate mitigation but also social agenda is buildings. Not only are buildings and related material consumption key contributors to the climate crisis, but on the path towards solutions they also pose a vital site, close to local communities' realities, for piloting innovative technological and social concepts. To accelerate action, the Renovation Wave from 2020 has set out to at least double the annual energy renovation rate by 2030 in the EU building stock[3]. The 2024 Energy Performance in Buildings Directive (EPBD) recast version from December 14, 2023[4] for the first time envisions the shift from the individual building to a district and neighbourhood approach in regards to renovation. It specifically recognises the cost effectiveness and integration of urban infrastructure. Furthermore, while the 2024 EPBD recast introduces minimum energy standards (MEPS) for each building[5], also the potential of buildings for the local energy transition starts to be better understood. With MEPS, Member States are required to set up roadmaps with milestones for renovating the worst-performing buildings. In the implementation of MEPS, the neighbourhood can be a useful approach to renovating clusters of worst-performing buildings using industrial renovation. The EPBD recast also mandates the deployment of solar energy installations in buildings. Also, the Renewable Energy Directive (REDIII) recognises the role of buildings in the deployment of renewable energy and has set the share of renewable energy in the building sector to 49 % by the end of the decade[6]. More so, previous REDII has introduced the definitions of 'jointly acting renewables self-consumers' (shortened to collective self-consumption (CSC)) and renewable energy community (REC), and the directive for Electricity Market Design (EMD) from 2019 defined Citizen Energy Communities (CEC)[7]. While these different forms of energy sharing have been transposed to varying degrees across Member States, these developments have been crucial in empowering the local level to mobilise citizens to become a more active part of the energy transition.

Positive Energy Neighbourhoods (PENs) have gradually emerged as an approach and actionable project to structure and amplify the effects of interventions in buildings to reach above targets. By integrating energy efficiency and renovation, renewable energy production, storage and energy management adjusted to local contexts, PENs offer a comprehensive approach to local energy transition. They empower municipalities and local communities to engage, providing practical examples of how energy renovation and climate targets can be implemented effectively at the local level.

Positive Energy Neighbourhoods

BACKGROUND

Currently, there is no consistent terminology and no commonly agreed definition or framework for PENs. Brozoysky et al. find more than 35 terms that define similar concepts like PEN such as Green Building Neighbourhoods, Positive Energy Blocks, or Sustainable Plus Energy Neighbourhoods, which differ in their system boundaries, KPIs and spatial scale[8]. Some of them focus exclusively on the operational phase, while others take into account also embodied emissions, resource efficiency and sustainable material use. Furthermore, some frameworks apply to all the existing buildings within a district, while others include only a selected group of interconnected buildings that are part of a new development or renovation project. However, all of them go beyond achieving a positive energy balance, and include social, economic and environmental aspects. In addition to focusing on energy systems and environmental impacts, PEN also consider life cycle assessments, emphasising the importance of assessing GHG emissions holistically. They also take into account social aspects, studying the impact on humans and interactions between PENs and people, although these areas are less researched compared to the energy system focus. The European Strategic Energy Technology (SET) Plan[9] has set the target of deployment and replication of 100 Positive Energy Neighbourhoods by 2025 through the programme "Positive Energy Districts and Neighbourhoods for Sustainable Urban Development". The recast of the EPBD foresees reporting from the Member States on the progress on 'district and neighbourhood approaches' within the template for the National Building Renovation Plans in Annex II.

Furthermore, also outside of the EU, there has been an interest in the PEN like concept. The Annex 83 initiative by the International Energy Agency (IEA) within the Energy in Buildings and Communities program aims to refine the Positive Energy District (PED) concept, focusing on the synergy between buildings and urban infrastructure. Its objectives include energy efficiency and enhancing on-site renewable energy generation and storage, improving load-matching and self-consumption through smart systems, thereby reducing the need for additional capacity updates of the grid. Sched-

3. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Renovation Wave for Europe – Greening our buildings, creating jobs, improving lives, (2020).

4. Energy performance of buildings (recast) European Parliament legislative resolution of 12 March 2024 on the proposal for a directive of the European Parliament and of the Council on the energy performance of buildings (recast) (COM(2021)0802 – C9-0469/2021 – 2021/0426(COD).

5. ZEB upgrade previous nearly zero-emission buildings (NZEB) from the 2018 EPBD. By 2030, all new buildings should be ZEB, with 'zero on-site carbon emissions from fossil fuels and zero or a very low amount of operational greenhouse gas emissions'. The goal for the existing stock is to become ZEB by 2050.

6. Directive (EU) 2023/2413 of the European Parliament and of the Council of 18 October 2023 amending Directive (EU) 2018/2001, Regulation (EU) 2018/1999 and Directive 98/70/EC as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652, CONSIL, EP (2023).

7. For more information on the difference of these concepts, see Frieden, D., Tuerk, A., Robert, J., d'Herbemont, S., & Gubina, A. (2019). Collective self-consumption and energy communities.

8. 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. https://doi.org/10.1016/j.scs.2021.103013

9. Directorate-General for Research and Innovation (European Commission) & Joint Research Centre (European Commission). (2018). The strategic energy technology (SET) plan. Publications Office of the European Union. https://data.europa.eu/doi/10.2777/04888

uled to conclude in 2024, the project is working on standardising PED definitions, methodologies, tools, and governance frameworks, using case studies for impact analysis. This effort supports integrating the PEN approach into policy frameworks at various levels, with contributions from projects like oPEN Lab.

DEFINITION

Within the oPEN Lab project, a working definition of PEN was developed based on a literature review of previous initiatives and lessons learnt from the three Living Labs located in Spain, Belgium and Estonia. A PEN is characterised by a group of buildings and public areas with connected infrastructure, within a geographical area. It aims for energy-efficient and energy-flexible groups of connected buildings and urban areas that produce net zero greenhouse gas emissions from energy use on an annual basis and actively manage an annual local or regional surplus production of renewable energy. Depending on the municipal strategy and focus within which a PEN is realised, a PEN should focus on several key concepts:

- PENs seek an integrated, participatory, neighbourhood-based approach to maximise the benefits of innovative energy systems.
- The benefits of a PEN extend to providing affordable living, enhancing **indoor environments**, and promoting well-being among its residents.
- A PEN is linked to an urban and regional energy system and it is driven by **renewable energies**, which provide optimized and flexible supply.
- A PEN is based on a high level of **energy efficiency**, in order to keep annual local energy consumption lower than the amount of locally produced renewable energy.
- PEN facilitates increased use of renewable energy within the local and regional energy system by providing **optimal flexibility & managing consumption and storage capacities** according to demand.
- Through the effective utilization of materials, local renewable energy sources, and various low-carbon innovations (such as local storage, smart energy grids, demand-response mechanisms, cutting-edge energy management systems, user interaction, and ICT), a PEN maximizes efficiency.
- A PEN features the **sufficiency principle** of energy, environmental and social strategies
- PEN supports **circular economy** and residual value, by embracing Life Cycle Assessment (LCA) analysis of embodied energy and embodied carbon considerations.

ADDED VALUE

PENs are at the forefront of the local energy transition in urban environments, crucial for the decarbonisation of the building stock. These neighbourhoods enhance residents' well-being and social cohesion by offering a more integrated, holistic approach. PENs extend beyond deep renovation of individual buildings to include shared amenities like heat pumps, renewable energy systems, heat and electricity storage, electric vehicles (EVs), EV charging stations, bicycles, as well as communal spaces, green spaces and water bodies.

PENs represent a paradigm shift from merely focusing on individual positive energy buildings to a comprehensive integration of buildings into neighbourhood and urban infrastructure. This creates a dynamic interplay between energy, mobility, and residential, commercial and public buildings with different use consumption patterns, embodying an integrated, participatory approach.

Finally, PENs can contribute to incorporating the sufficiency principles into energy and environmental policies. Sufficiency is one of the key pillars in building policies in delivering decarbonisation while tackling inequalities in accessing energy services. According to the 6th Assessment Report of Working Group III of the IPCC "Sufficiency policies are a set of measures and daily practices that avoid the demand for energy, materials, land and water while delivering human wellbeing-for-all within planetary boundaries"[10]. The main goal is to meet human needs and services required for human well-being (i.e., housing including thermal comfort, nutrition, and mobility) which implies an economy within planetary boundaries. The PEN approach can untap a series of sufficiency design strategies, with shared spaces, services, renewable energy sources and Heating, Ventilation and Air Conditioning (HVAC) systems which can provide added community well-being while reducing material and land use. For example, having one heat pump for a building or PEN instead of individual heat pumps in each flat. Another example is having shared rental EVs or better access to public transport instead of personal cars which implies additional parking lots and more pollution.

The neighbourhood is the right scale for public authorities to engage local communities to find collectively technical solutions for alternative renewable energy heating systems, depending on the renewable energy production and storage potential. For example, if in the neighbourhood there is a lake there is the potential for seasonal water heat storage. The neighbourhood is also the right scale to find solutions to overcome technical, social, regulatory and financial challenges. For example, a neighbourhood is likely to have similar heritage protection of buildings.

oPEN Lab

The oPEN Lab project focuses on transforming neighbourhoods in three European cities into a PEN – Genk in Belgium, Tartu in Estonia, and Pamplona in Spain. The project is driven by a consortium of local stakeholders within a Living Lab framework. The pilot sites for PEN within these Living Labs encompass a group of buildings, public spaces, and shared amenities. In Genk, the oPEN Living Lab consists of eight privately owned dwellings in Garden City Waterschei and 27 more recent dwellings. In Pamplona, the PEN covers two buildings in the San Pedro district and the IWER building, a previous industrial complex of 30,000 m^2. In Tartu, the PEN pilot covers one 9-storey apartment building and one 5-storey building. They

10. IPCC. (2022). Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. doi: 10.1017/9781009157926.

all incorporate specific technological and financial strategies tailored to the local environment. These Living Labs foster collaborations that excel in community engagement, consultation, and co-creation, while maintaining trustful relationships with local stakeholders and communities. The goal of oPEN Living Labs is to materialise into practice the climate and environmental policies and targets which are defined at the national and municipal levels.

Methodology

PENs require a cross-sectoral approach to renovations, energy provision and urban planning whose value propositions rest on the synergies between these. As a result, PENs are impacted by various policy fields, and there is no one policy initiative that regulates and supports PENs. They can make essential contributions to achieving not only GHG emission and renewable energy targets, but also to reaching renovation targets, creating more social cohesion in neighbourhoods, and addressing energy poverty by reducing long-term energy costs. However, to make PEN a scalable concept it is key to investigate any regulatory barriers in the current policy framework that could hamper its uptake.

To guide the analysis of regulatory barriers, first, a mapping of relevant policies at the EU, as well as their implementation at national, regional and local levels was undertaken with desk research. Four aspects of PEN policy were identified:

- Energy performance
- Collective production, sharing and selling of energy
- Demand-side flexibility (DSF)
- Whole life carbon and circularity

To dive deeper into the regulatory barriers for the regulatory framework, data were collected in a series of focus group sessions with local practitioners and experts of the three demo locations. The quadruple helix model consists of the following stakeholder groups:

1. industry (Small and Medium Enterprises (SMEs), large companies, start-ups and scale-ups in both construction and energy value chains)
2. government (local public administration)
3. academia
4. civil participants (residents, NGOs)

Stakeholders were grouped into four categories according to field of expertise to address the above policy categories given the heterogeneity of roles of stakeholder types across oPEN Living Labs. The focus group sessions were conducted online and followed a semi-structured interview format. The interview insights were completed with desk research using the above four categories as keywords. It was mainly aimed at policy mapping ahead and after the interviews to better place and identify regulatory barriers identified in the interview. This provides a base for tailored policy recommendations to facilitate PEN uptake.

Results

STATUS QUO LIVING LABS

Spain – oPEN Living Lab Pamplona

The oPEN Living Lab Pamplona aims to set up one of the few operational PEN pilots in Spain and demonstrate a new urban energy concept bringing together social, technical and process innovations. Pamplona is a city of 203,418 inhabitants, and the capital of Navarra, a region leader in the renewable energy sector in Spain. Pamplona municipality set up 2030 targets and is monitoring progress on main categories of indicators – climate mitigation, climate adaptation and fuel poverty to which the Pamplona PEN project can contribute. oPEN Lab focuses on two pilot sites within the Living Lab which include the IWER complex, a former industrial building of private ownership, and two social housing blocks from the San Pedro group owned by the Pamplona City Council and the IWER building, a complex for business and offices. The goal for this part of the project is to have Building Integrated PV and Building Applied PV, lithium second-life battery, review of HVAC system with efficient aerothermal heat pumps and low global warming potential (GWP) refrigerants, underground water tank and water mines for thermal accumulation (ATES). In the San Pedro social housing area, the context of oPEN Lab, two buildings will be fully refurbished.

Flanders – Genk Living Lab

The oPEN Living Lab Genk is located in the North-East of Flanders in Belgium. Under the Belgian governance structure, the federal government oversees electricity transmission, large-scale generation, and energy security, while the three regional governments (Flanders, Wallonia and Brussels Region), have competencies on topics such as renewable energy, energy efficiency, the regulation of retail energy markets, and housing. Thus, most PEN related regulations, particularly those aimed at reducing GHG emissions in buildings, fall under Flemish authority due to its regional competence in energy and climate matters.

The city of Genk has a population of around 66,000 inhabitants. The oPEN Living Lab Genk is located in the 'Nieuw Texas' social housing group in a sub-urban neighbourhood called Waterschei with semi-detached residential buildings. The oPEN Living Lab Genk consists of eight privately owned dwellings in Garden City Waterschei and 27 more recent dwellings in Nieuw Texas from the social housing company WiL. oPEN Lab will transform these houses into energy positive buildings through collective and individual measures. The area is envisioned to be a 'technological playground' where the various setups and combinations of different types of heat pumps, batteries, solar panels, and ventilation systems can be compared. They are connected through a central platform and a neighbourhood energy management system to allow for DSF. A bidirectional communication system will be implemented that allows the interaction of real time data from individual building components with climate and weather forecasts, and dynamic tariffs (e.g. day-ahead prices). It automates DSF smoothly and matches the cheapest times for energy consumption for individual buildings while still guaranteeing sufficient comfort. Different dwellings can have different energy

use patterns for HVAC, ending up with the optimal solution of spreading the energy load at the district level.

Estonia – Tartu Living Lab

The city of Tartu is located in the South-East of Estonia. Within the oPEN Lab project, Tartu aims to demonstrate a PEN model interconnecting refurbished public and high-storey apartment blocks with a local multi-vector energy system including large scale heat storage. This will be the first of its kind in Estonia and in the whole Baltic region.

Tartu City has a population of around 95,000 people. Part of the pilot is one 9-storey building and one 5-storey building, which will be used to compare conventional versus more innovative renovation with prefabricated elements. Both of them aim to achieve a nearly-zero energy building (NZEB) level after renovation.

Estonia has been particularly hit by high interest rates and higher renovation costs due to the increase in construction prices. As a result, the project has struggled to secure a pilot building and various rounds of engagement have been conducted. Estonia has a Good Practice of Involvement[11] which sets the minimum key principles for good engagement and consultations; can be used as a good role model and code of conduct while planning engagement processes in PEN development.

REGULATORY BARRIERS TO PEN IMPLEMENTATION

Energy performance

Under the 2018 EPBD it has been mandatory for Member States to transpose minimum energy performance requirements for new construction (NZEB from 2020) and major renovations. The three Living Labs in Pamplona, Genk and Tartu aim to bring their pilot buildings to NZEB standards after renovation. However, none of the countries has put in place incentives to go beyond minimum requirements. Going forward Member States should transpose ZEB requirements of the 2024 EPBD recast and provide public incentives to go beyond minimum requirements to create conditions for positive energy buildings and PEN.

As previously discussed, deep renovation is a key element of PEN. However, it was found, that the multiple benefits of renovation were difficult to communicate (e.g. improved air quality and comfort, increase in real estate value) in the Estonian pilot. Despite recent changes in the Non-Profit Legal Entity Act[12] in Estonia to facilitate decision-making procedures, mostly voluntary organised housing associations were regarded as the bottleneck to PEN, particularly renovation. Challenges of the communication of PEN benefits tie into a wider barrier for PEN financing and business model development; the multiple social and environmental co-benefits of PEN are difficult to monetise and quantify. While current economic trends in fact pose a threat to the success of renovations in the EU and pioneer projects such as PENs, also financial actors mostly do not yet recognise benefits such as improved comfort and public health, social inclusion, climate resilience, value retention, alleviation of energy poverty or contribution to energy security. The public sector, as stated in the 2024 EPBD recast, must set up "an enabling framework including technical assistance and financial measures, in particular for vulnerable households"[13].

The 2024 EPBD recast also gathers that

> Member States should encourage financial institutions to promote targeted financial products, grants and subsidies to improve the energy performance of buildings housing vulnerable households, as well as to owners in worst-performing multi-dwelling buildings and buildings in rural areas, and other groups for whom access to financing is difficult. The Commission should adopt a voluntary framework to help financial institutions to target and increase lending volumes in accordance with the Union's decarbonisation ambition and relevant energy targets.[14]

What is more, practitioners particularly from Spain highlighted long permitting processes and strict technical requirements for installation of renewable energy sources which pose difficulties to PEN planning and investments. To tackle this challenge, there is a need to implement the recent REDIII provisions on accelerating permit-granting procedure for renewable energy sources and implement previous provisions on the obligation of Distribution System Operators (DSOs) to make public the information regarding grid capacity.

Besides building envelope and renewable energy, also decarbonising heating and cooling and encouraging District Heating and Cooling (DHC) is essential. This was recognised in the policy framework of all three countries through recent updates. However, Spain in particular had an issue with existing buildings relying on individual HVAC systems for each apartment and not being equipped with collective systems as households moved to gas boilers in the past. There is a need to promote collective solutions in buildings not only to implement heat pumps and connection to DHC, but also their integration with heat storage and renewable energy sources.

Finally, urban planning regulation can prohibit innovative and potentially new solutions for energy performance improvement. In the oPEN Living Lab Genk, a box with a combination of energy technologies is placed outside the houses and is shared among several buildings. However, flexibility to provide a regulatory sandbox from urban planning regulations is required to permit their placement. This is an example of a regulatory framework not yet adapted to the technological innovation of PEN like projects. Similarly, current regulations and incentives are lagging behind in acknowledging the benefits of innovative prefabricated renovation and incentives to promote it. For the PEN approach, serial prefabricated renovation can help to achieve renovation targets efficiently for certain types of building typologies. They are specifically of interest to social housing companies who can avoid moving their tenants dur-

11. State Chancellery. (2020). Good Practice of Involvement. https://riigikantselei.ee/kaasamise-hea-tava

12. The Law on Non-Profit Organizations, RT I, 23.12.2022, 15. https://www.riigiteataja.ee/akt/123052020006?leiaKehtiv

13. Energy performance of buildings (recast) European Parliament legislative resolution of 12 March 2024 on the proposal for a directive of the European Parliament and of the Council on the energy performance of buildings (recast) (COM(2021)0802 – C9-0469/2021 – 2021/0426(COD). p.19.

14. Energy performance of buildings (recast) European Parliament legislative resolution of 12 March 2024 on the proposal for a directive of the European Parliament and of the Council on the energy performance of buildings (recast) (COM(2021)0802 – C9-0469/2021 – 2021/0426(COD). p. 35.

Table 1. Timeline of minimum energy performance standards (MEPS) in Flanders.

1/1/2028	1/1/2035	1/1/2040	1/1/2045
House: label C	House: label B	House: label A	House: label A
Apartment: label C	Apartment: label C	Apartment: label B	Apartment: label A

ing the renovation phase. Subsidies and public funding should enable a more widespread use applicable for example for social housing public procurement.

Best practice piloting Minimum Energy Performance Standards (MEPS) in Flanders

Flanders has been one of the few Member States to implement MEPS which have been introduced only later at the EU level with the EPBD recast of 2024. In Flanders, renovations are already obligatory since January 2023 for new owners of residential real estate of EPC class E or F to a level of at least D within five years. D is the first step with further tightening of obligation in 2028, 2040 and 2045, as seen in Table 1.

Collective production, sharing and selling of energy

A precondition for PENs to unfold their potential is a regulatory framework that enables collective energy production, storage and sharing. Only then it can offer DSF services to the grid, facilitate true community engagement and implement renewable energy deployment effectively. The three pilot countries have implemented the concept of RECs, CEC, and CSC in different ways with some crucial barriers remaining. In all three countries, it became apparent that the difference between the three concepts is not fully understood (see Table 2). All three countries failed to properly implement CECs. The framework for RECs has been implemented in all three countries, however, Flanders has not set a geographical boundary for RECs yet and in Estonia, the REC concept is legally implemented but not widely applied. For CSC, the implementation differs. Spain has made various adjustments in the past years to improve and facilitate self- and collective energy sharing. In Flanders the legal framework was improved too, however, CSC is only possible within a building – while in PEN buildings might share energy horizontally. In Estonia, the main barriers to virtual energy sharing and the lifting of grid tariffs remain. In Flanders, to address the confusion around the different concepts that seem to prevail across MS, a "Technical Assistant Hub" has been set up in December 2023 to provide better information on energy sharing models.

Even if neighbours decide to not engage in an energy community, CSC and the possibility to virtually share energy at no costs with neighbours and to self-consume are key. Each country has been facing regulatory challenges in creating a favourable environment for this: in Flanders, the key issue is that CSC implementation poses barriers for apartment blocks because they have to pay grid tariffs. Also, virtual sharing between horizontally connected buildings is not yet possible. This means that neighbourhoods with (semi-)detached buildings like in the Genk Living Lab cannot currently easily share energy. CSC should thus be extended to include horizontal virtual energy sharing and remove grid tariffs for apartment blocks. Furthermore, there is no revenue for shared electricity while an injection price is paid to the prosumer if they decide not to share. This disincentivises sharing and makes individuals more likely to sell to the network. There is a need to remove additional billing costs for CSC and allow CSC within a multifamily apartment building, which is discriminatory compared to single family prosumers.

Similar issues are found in Estonia. Tariff and contracting structures mean there is no system to virtually share energy, even within apartment buildings. Energy from roof PV can be used for common areas such as the hallway. However, every apartment owner has their own contract with an energy provider and CSC would require separate meters and changes in the individual contracts. To enable virtual energy sharing, clearer regulation on CSC to facilitate individual billing for collectively produced energy is necessary.

Spain has developed a clever system to allocate shares within a condominium to determine individual tenants' costs. However, it is not possible to sell energy among multiple RECs within a PEN, with only the possibility to feed in energy and sell excess energy directly to the grid at a lower price.

The REDII limits RECs to natural persons, SMEs and municipalities. In Spain and Flanders, the risk of corporate capture of RECs was mentioned due to poor control of registered RECs. There is a need to establish a supervising agency to approve REC registration.

Demand-side flexibility

Smart and automated interaction of technologies such as storage and RES with the building or the heating system are a precondition to establishing a DSF. If coordinated on a neighbourhood level, DSF can be a key selling point for PEN, allowing it to stabilise the grid, absorb peak production and aid peak consumption. Regulation or policy in all three countries has been rare as the concept and its benefits only started to be more understood. In Spain for example the framework is under definition and is expected for 2025. It remains a key question for example in Flanders and in Estonia how to monetarise flexibility services to boost the PEN business case. A crucial actor to take onboard here is the DSOs which overlook the capacity of the distribution grid.

Some key barriers were found for example in Estonia, where the Electricity Market Act needs to be adapted to remove the transfer fees from batteries for small consumers. Transfer fees are the costs associated with moving electricity from one place to another, often included in energy bills. For households, these fees can be significant, sometimes around EUR 118/MWh[15] which can discourage energy sharing. There is a need to avoid double taxation: when purchasing energy from the grid for storage purposes the buyer has to pay all grid fees for the transfer. If they sell it to the grid and someone else purchases that energy, then they pay all the fees once again for the same electricity. While this makes sense for the energy transfer fee as the user in fact uses the grid, it does not make sense for the excise or renewable energy fee. This makes energy sharing and storage and thus flexibility less financially viable for small consumers.

15. This includes Transfer fee, renewable energy fee, excise, VAT: https://www.elektrilevi.ee/-/doc/8644141/kliendile/Elektrilevi_hinnakiri_vorguteenuse_hinnad_alates_01.01.2024.pdf.

Table 2. Transposition of EU directives in the three countries/regions.

		Collective self-consumption (CSC)	Renewable Energy Community (REC)	Citizen Energy Community (CEC)
Spain	Transposition	Royal Decree-Law 15/2018 and Royal Decree 244/2019	Royal Decree 23/2020	Mentioned in Royal Decree 23/2020, no direct transposition
	Key provision	Article 4 … The user needs to be in proximity to 2,000 meters of the renewable energy source.	Article 4 Sets out definitions, requirements and activities. RECs need to be legal entities.	NA
	Fit for PEN	CSC allows PEN residents to invest collectively in RES and benefit from their bills without setting up a legal entity.	No taxes are paid on shared energy, grid fees are set to zero. However, setting up a legal entity may be a barrier.	Since CEC only focuses on electricity and has no geographic limits, it is not ideal for PEN
Flanders	Transposition	Energy Decree	Energy Decree	Energy Decree
	Key provision	Article 4.4.2 version 21/03/2022 Defines the right to become an active prosumer already in the 2009 version, as well as the right to self-consumption. Article 7.2.1 version 08/01/2023 (energy sharing) In an apartment, people can invest together in renewable energy on the building, but grid tariffs apply when it is shared between residents. Article 7.2.2, §2 version 08/01/2023 (peer-to-peer trading) 7.2.3 (Sales in apartment buildings and multi-purpose buildings) Protocol Energy selling: P2P trading between 2 people or many-to-one, or the (communal or private) owner of an apartment building can sell electricity to the inhabitants. grid tariffs and administration costs for energy companies apply.	Article 4.8.2., version 07/06/2021 Definition of a REC and its rights. Article 4.8.4. version 07/06/2021 Definition of REC activities: generating and using their own energy, storing excess energy for later use, participating in energy-saving programs, selling any surplus energy they produce, offering electric vehicle charging services, and sharing energy among members.	Article 4.8.1. version 07/06/2021 Definition of a CEC and its rights. Article 4.8.4. version 07/06/2021 Definition of CEC activities: generate their own energy through local facilities, use the energy they produce, store any extra energy, engage in energy-related services, adapt their energy use to help balance supply and demand, sell extra energy, offer electric vehicle charging, and share energy with other group members.
	Fit for PEN	The existing framework limited to only an apartment building for CSC is not fit for PENs. The grid tariffs do not make a business model for energy sharing in Flanders.	Geographical boundary not defined: Given the low density of Belgium's population a geographical boundary for energy sharing like in Spain (2km) would often not fit the local context. Instead, a boundary could be set for low and medium voltage grids and a number of transformers. Currently, most energy cooperatives are said to be set up in 30 km proximity of their installation.	The sharing model can encourage demand-side flexibility.

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Table 2. Transposition of EU directives in the three countries/regions (continued).

		Collective self-consumption (CSC)	Renewable Energy Community (REC)	Citizen Energy Community (CEC)
Estonia	Transposition	Electricity Market Act RT I, 30.06.2023, 5	Electricity Market Act RT I, 30.06.2021, 3	NA
	Key provision	§32(6) Apartment associations are permitted to divide and sell electricity to apartments for the purpose of supplying electricity. In 2013, the concept of energy associations was introduced into law. Energy can be sold to people in one building without a license.	REC may act as limited liability companies, as well as public limited companies. The only restriction is that the renewable energy community cannot be a general partnership or a limited partnership within the meaning of the Commercial Code, since the members of these two legal entities cannot be local governments.	NA
	Fit for PEN	This arrangement requires a single contract and electrical connection with the Distribution System Operator (DSO) and the use of sub-meters for the internal electricity division. This can pose a major barrier because it means each apartment owner needs to be convinced to give up their private energy contract.	The concept in regulation, however, is not widely used yet.	NA

The national government should remove the renewable energy fee for small producers for charging batteries from the grid when the demand is low (off-peak hours to balance the grid by shifting energy usage to times when there is an excess supply).

Dynamic tariff systems have been introduced in all three countries which incentivise consumption in moments when electricity is cheap. In Flanders for example, there is also a surcharge invoiced via the supplier based on individual consumption which is calculated by the DSO per 15 minutes. It incentivises reducing the peak demand to disincentivise using various appliances at the same time as charging their EV. However, this means a private household electrifying their fossil fuel car and heat will quicker and more often have a higher peak. This disincentivises the electrification of heat and private transport.

In Estonia, as in other MS, the excess renewable energy of prosumers is sold via a retailer and flexibility via an aggregator, which adds middlemen and extra fees. These costs can be saved in a PEN where energy is directly shared at no cost. However, the main financial gain can be achieved if energy is directly shared for self-consumption among buildings of a PEN to reduce the bills if it is exempted by grid tariffs. However, Estonia does not have a framework in place that allows collective self-consumption beyond a building. Furthermore, an issue mentioned several times revolved mostly around aggregated or lack of availability of data for energy optimisation. However, Estonia has already created a digital building registry where users at least can opt-in to share their data with a third party.

Best practice: Estonia 3D digital twin

Estonia is the first country in the world to have a 3D digital twin of its buildings stock. The digital twin allows one to walk through neighbourhoods and visualise data from the building register from planned, erected, existing and demolished buildings.[16] These data are matched with building information models (BIM) allowing to also display of areas related to heritage protection or environment and technical zones. It is therefore used as a tool for decision making and could long-term also serve the development of PEN.

Whole life carbon and circularity

PEN might hold buildings of varying types and use a large variety and combination of technological systems, allowing for some flexibility for materials used in renovation processes or technology choices. Policy on whole life carbon (WLC) is absent from current national policy frameworks in Spain and Estonia.[17] In Flanders, the Flanders Public Waste, Materials & Soil Agency (OVAM) has been developing a methodology for using a WLC perspective in buildings called TOTEM. It is an online tool for architects that calculates the environmental footprint of buildings. The methodology can be used to determine the energy performance of buildings also considering combinations of materials used and technical installations[18].

What was said to be a main issue in Spain is the absence of certification that can ensure a certain quality standard. Spain did not introduce a calculation method and does not have a calen-

16. Ministry of Economic Affairs and Communications. (2023). In the updated Estonian 3D twin, you can see buildings rising in the neighbourhood. https://mkm.ee/uudised/uuendatud-eesti-3d-kaksikus-naeb-naabruskonda-kerkivaid-hooneid

17. The EU is currently developing a WLC Roadmap aimed to be published in April 2024.

18. OVAM. (2020). The Impact of Materials for Renovation and New Housing in the Context of Climate Policy Actions. https://emis.vito.be/sites/emis/files/articles/91/2020/THE%20IMPACT%20OF%20MATERIALS%20NEEDED%20FOR%20RENOVATION%20AND%20NEW%20HOUSING.pdf

dar for introducing minimum thresholds for embodied carbon as other front runner countries. This inhibits the incorporation of re-used elements and sustainable materials. This feeds into a more general issue around the reuse of construction materials. Planning is very tedious as not only second-hand material quality but also availability can be uncertain, making it expensive. Under the 2024 EPBD recast the calculation of embodied emissions will soon be obligatory life cycle Global Warming Potential (GWP)). Another approach is to include LCA as a requirement in Green Public Procurement.

Best Practices Madaster cadastre for materials and products
The Dutch marketplace for construction materials Madaster[19] allows to make available or required inventory from demolition, renovation or construction available online.

Towards a PEN friendly policy framework

Findings have shown policy efforts towards energy efficiency and renewable energy at the building scale but Member States fall short in enabling and facilitating neighbours to collectively renovate and harness of benefits of collective energy production and storage of RE. Limited transposition of REDII and EMD disincentivises the monetisation of renewable energy and flexibility services and jeopardises PEN business models. Also, regulations or incentives to adopt a WLC perspective in renovations are currently absent from the established national policy landscape in the three countries.

An aspect not yet considered is the potential trade-off between local generation and DSF, which require more limited boundaries, versus untapping more opportunities and potential of RES, of big buildings with different energy use patterns, which require extending the boundaries. A strategy would be to define it based on the grid configuration (low and medium voltage, within 1 transformer, the available capacity of the grid). Another strategy is administrative or physical boundaries, based on regulations for energy sharing, e.g. 2 km of CSC in Spain.

In general, there is a need for a unified conceptualisation of the PEN definition and framework. As under the recast EPBD one-stop shops have been getting more prominent, they could also act to combine and centralise information sharing about renovation, RECs, DSF but also sufficiency.[20]

BEST PRACTICE KLIMAAKTIV RATING SYSTEM AUSTRIA

The Klimaaktiv standard for settlements and neighbourhoods in Austria focuses on urban development, infrastructure quality, and planning quality. It is divided into six fields of action: Management, Communication, Urban Development, Building, Supply, and Mobility. This holistic approach aims to have a lasting positive influence on rural and urban areas.

Outlook

Going forward, these results will inform tailored policy recommendations across Member States, empowering citizens to collectively contribute to the complex but urgent energy transition ahead. They can also inform with best practices the implementation of the EPBD recast and REDIII. Pilots such as oPEN Lab are key to experimenting and optimising technology mixes and interactions and raising awareness not only for the benefits of neighbourhood approaches for the local energy transition but also for the regulatory obstacles that hinder their success. While a roll-out of pilots across Europe is needed, national governments need to make sure to transpose the EPBD recast, REDIII and soon to be expected revised EMD, which includes crucial elements for energy sharing, in a manner that can support PEN roll-out. Local governments can support through One Stop Shops and generate more awareness not only for renovation alone and available financial means but also in identifying neighbourhoods that are particularly suited for PEN, and support them through their climate action plan.

PENs rely strongly on public funding and thus require more substantial contributions from private finance. Thanks to the EU taxonomy and slowly growing interest in Environmental Social Governance (ESG) finance, also financial stakeholders need to recognise their role to play for PENs role out to boost the local energy transition more effectively. However, high inflation and high borrowing costs pose a threat to renovation and pioneer PEN projects. The public sector can play a role here to have the multiple benefits of PEN for the local community and society as a whole better understood and quantified, such as improved comfort and public health, social inclusion, climate resilience and value retention, but also alleviation of energy poverty and contribution to energy security. A common approach is needed for measuring, tracking and reporting projects' environmental, social and governance (ESG) impacts, at both the building and the neighbourhood level.

Acknowledgements

This paper received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant agreement No. 101037080.

19. https://madaster.com/

20. The Living Space Agency in Goettingen that operates under the department for planning, and infrastructure provides extensive advice about living space optimisation, among other they advise for communal living. This to an OSS similar institution could easily adopt wider advice on PEN or PEN relevant areas, e.g. advice on renovation could be combined with sufficiency interventions.